WATER QUALITY OF A STREAM-AQUIFER SYSTEM, SOUTHERN FRANKLIN COUNTY, OHIO

By Jeffrey T. de Roche and Allan C. Razem

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ERRATA

p. 5 -- Figure 2; well FR-115 should have collector designation.

p. 28 -- last paragraph, fifth line should read

" . . . calcite, dolomite, and gypsum were reacted . . . "

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ILLUSTRATIONS

TABLES

CONVERSION FACTORS

For the benefit of readers who prefer to use the International System of units (SI), conversion factors for terms used in this report are listed below:

Multiply inch-pound units	By	To obtain SI units
inches (in.)	25.40	millimeters (mm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
cubic feet per second (ft^3/s)	28.32	liters per second (L/s)
million gallons per day (Mgal/d)	43.81	liters per second (L/s)

ABBREVIATIONS AND SYMBOLS

Abbreviation	Description
AC-FT, ac-ft	acre-foot
cols./100 ml	colonies per 100 milliliters
°C, deg. C	degrees Celsius
FET-FLD, fet-fld	fixed-endpoint titration, field determination
FTU	formazin turbidity units
K	estimated count, based on non-ideal colony count
KF-AGAR	a selective plating medium for detecting fecal streptococci
mg/L	milligrams per liter
mmol	millimole
ND	constituent not detected
sq. miles	square miles
ug/L	micrograms per liter
umho/cm	micromhos per centimeter at 25 degrees Celsius
0.7 UM-MF	seven-tenths micron pore size membrane filter
--	constituent not analyzed for

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ABSTRACT

The chemical quality of the water resources in the Scioto River valley south of Columbus, Ohio, was evaluated on the basis of data collected from 74 wells and 4 surface-water sites. A very hard calcium bicarbonate water that is high in dissolved solids is characteristic of the aquifer. Mean pH of the ground water is 7.3, and bicarbonate concentrations range from 238 to 530 milligrams per liter. Concentrations of dissolved iron in water samples (0.01 to 3.9 milligrams per liter) frequently exceed the drinking water standard of 0.3 milligrams per liter established by the Ohio Environmental Protection Agency.

The chemical quality of local streams closely resembles the ground-water quality, except for higher concentrations of sodium, chloride, and sulfate in the surface water. Microbiological testing of ground water for fecal bacteria indicated concentrations ranging from 1 to 2,400 colonies per 100 milliliters. The higher concentrations were observed in one well on the Scioto River flood plain after a flood event.

Mass-balance calculations of the chemical data indicate that pH is buffered primarily by the carbonate system. Data for pH, calculated Eh, and concentrations of ferrous iron and reduced sulfur show that areas of different chemical environments exist within the aquifer. A reaction model of an induced-infiltration radial collector system indicates the amount of mass transfer (chemical reactions that occur as ground water and surface water mix) is small, and that the mixing ratio between ground and surface waters is four to one.

INTRODUCTION

The City of Columbus, Ohio, has been developing an induced-infiltration water supply in the glacial outwash aquifer that underlies the Scioto River and Big Walnut Creek in southern Franklin County. The high sustained yields from the glacial aquifer are a function of the ground-water flow from the aquifer system and the induced flow of surface water from overlying streams. In this two-component mixing situation, the chemical quality of the ground-water and surface-water sources -- and their interaction -- determine the chemical characteristics of the water produced by the well field.

Purpose and Scope

This report presents the results of a study conducted by the U.S. Geological Survey in cooperation with the City of Columbus. The purpose of the study was to investigate the chemical quality of ground water and surface water within the recharge area of the glacial aquifer. Specifically, the report defines (1) the general water quality of the area, with particular attention to compositional differences between ground and surface waters, and (2) the chemical relationships between ground water and surface water. The study is based on 62 water-quality analyses -- 54 from wells and 8 from area streams. The samples were collected from 1975 to 1980 and analyzed for common constituents, trace metals, organic carbon, bacteria, and nitrogenous compounds. This report is part of a series of investigations that evaluate the hydrogeology of the glacial aquifer in southern Franklin County and its suitability for an induced-infiltration water supply.

Previous Studies

Several reports on the hydrogeology and water quality of southern Franklin County have been published. A report by Schmidt and Goldthwait (1958) provides information on the geology and ground-water resources of Franklin County. A report by Stowe (1979) includes detailed information on the hydrogeology of the Scioto River valley. Weiss and Razem (1980) describe the construction of a finite difference two-dimensional ground-water flow model for the southeastern Franklin County area, and a report by de Roche and Razem (1981) describes water quality conditions in the vicinity of several landfills located just north of the study area. Razem (1983) modeled transient flow conditions in the glacial outwash aquifer.

Physical Setting

The study area (fig. 1) is located in the southern part of Franklin County, and includes a small section of the city of Columbus. The major streams in the area are Big Walnut Creek, Walnut Creek, and the Scioto River. Topography is generally flat; the land slopes 40 to 70 feet per mile towards the major streams. The primary land use in the area is agriculture, and the major crops are corn and soybeans. The floodplains of the Scioto River and Big Walnut Creek are both used for agriculture.

Methods of Investigation

The data-collection network (fig. 2, table 1) consisted of 74 wells[1] and 4 surface-water sites. Casing diameter of the wells ranges from 2 inches to 240 inches and depths range from 16 feet to 222 feet. The majority of the wells in the network were domestic wells; however, twenty-three 2-inch diameter observation wells were drilled, cased, and screened to provide additional data. The data were collected and analyzed during a 5-year period that began in 1975.

Periodic water-level measurements were made at the observation wells to determine the potentiometric surface and direction of ground-water flow. Ground-water and surface-water quality were compared by means of Stiff diagrams (Stiff, 1951), statistics, and Piper diagrams (Piper, 1944). Water composition was studied using WATEQF (Plummer and others, 1976), a FORTRAN computer program that models the thermodynamic speciation of inorganic aqueous species in natural waters. The chemical reactions between mixing ground water and surface water were investigated using the FORTRAN computer program BALANCE (Parkhurst and others, 1982).

Acknowledgments

The authors express thanks to the City of Columbus, Division of Water, for its assistance, and to the individual well owners who allowed their wells to be measured and sampled.

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[1] The well numbers FR-101 and FR-115 each apply to two wells with identical locations -- the original test or "pilot" well (PW) and the subsequently installed collector well (CW). The PW wells were used from 1975 until 1978 when they were replaced by the CW wells.

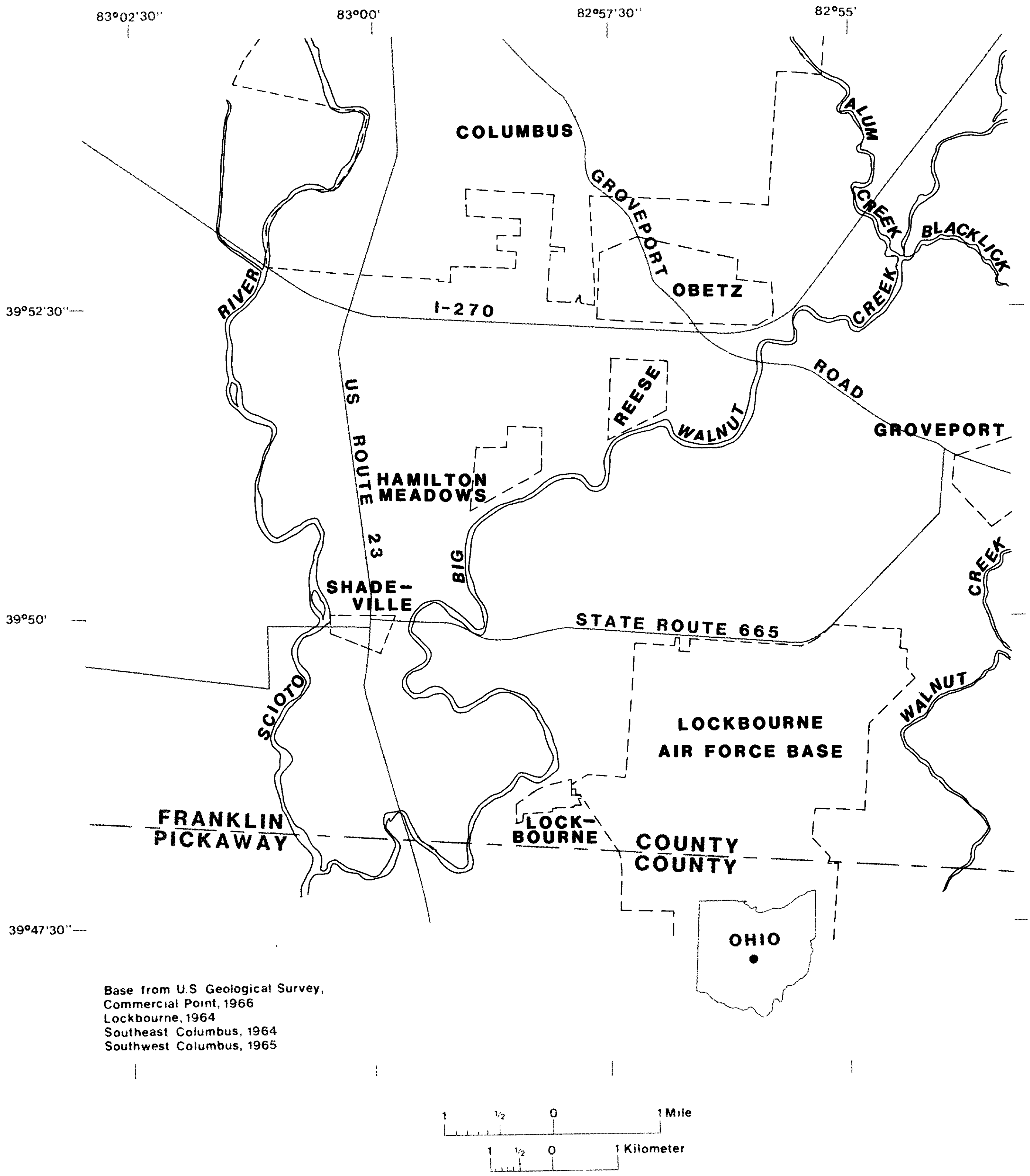
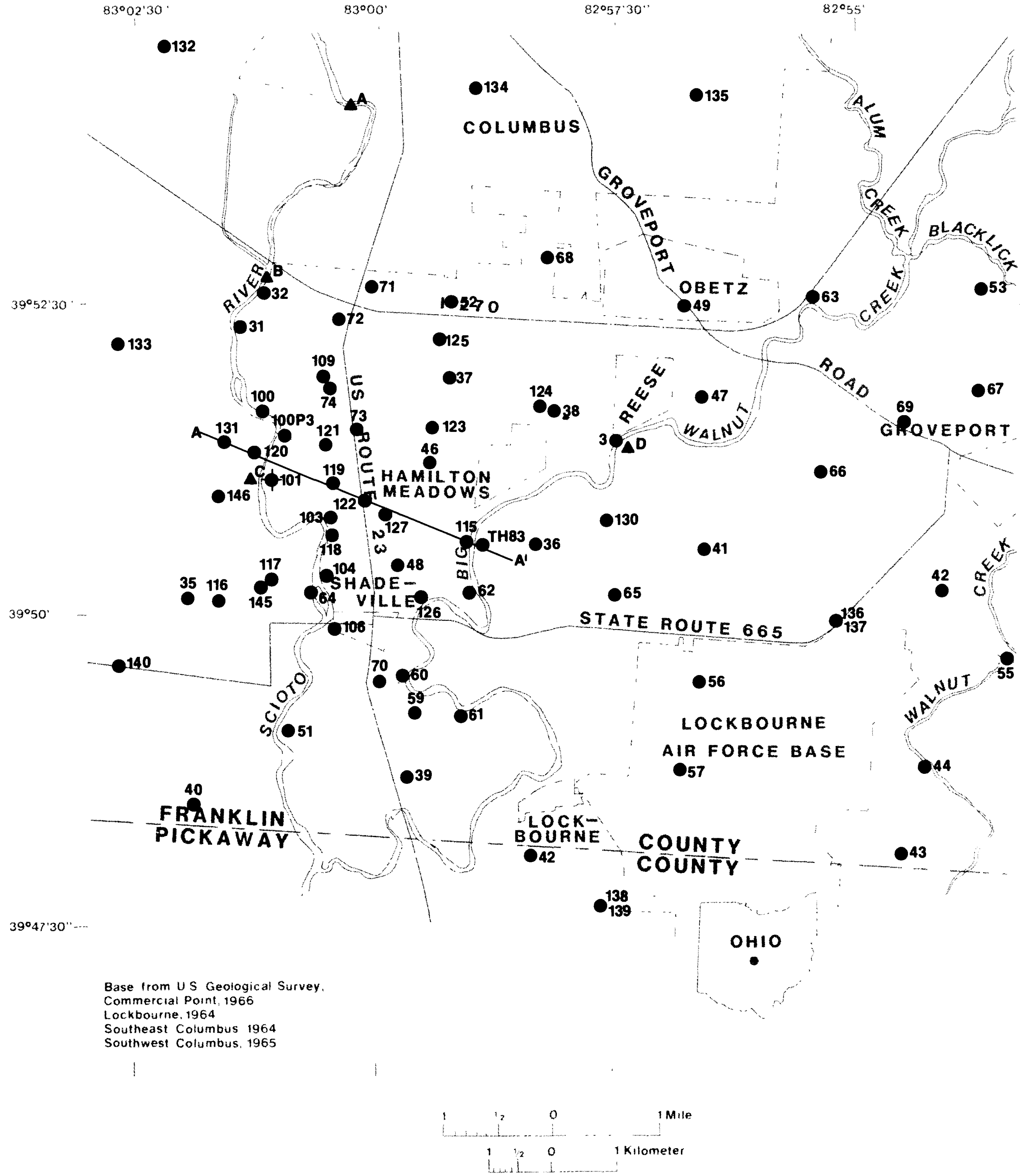


Figure 1.--Location of study area.



EXPLANATION

- ●3 Observation-well and site number
- ▲B Surface water site
- ◆-101 Radial collector well and site number
- A—A' Location of cross section

- ▲A Scioto River below sewage treatment plant
- ▲B Scioto River at I-270
- ▲C Scioto River at site 101
- ▲D Big Walnut Creek at Reese

Figure 2.--Data collection network and location of geologic cross section. (The county code prefix, Fr- or Pk-, has been deleted from well numbers.)

Table 1.--Records of selected wells in southern Franklin County, Ohio

[All water-level measurements were made October 15-17, 1979]

Well number	Latitude	Longitude	Year com-pleted	Casing diameter (inches)	Altitude of land surface (feet)	Depth of well (feet)	Altitude of water (feet)
FR-3	39°51'14"	82°57'32"	1946	12	713	60	702.3
FR-31	39°52'15"	83°01'24"	1969	6	680	80	--
FR-32	39°52'34"	83°01'13"	1968	6	700	80	660.6
FR-35	39°50'08"	83°01'57"	1940	36	715	24	--
FR-36	39°50'37"	82°58'19"	1970	4	720	31	706.4
FR-37	39°51'53"	82°59'16"	1950	4	726	38	712.6
FR-38	39°51'38"	82°58'08"	1950	6	742	23	710.1
FR-39	39°48'44"	82°59'38"	1940	36	690	18	682.6
FR-40	39°48'32"	83°01'55"	1940	4	710	40	704.6
FR-41	39°50'32"	82°56'38"	1965	4	740	45	722.6
FR-42	39°50'09"	82°54'09"	1965	4	733	39	714.0
FR-43	39°48'05"	82°54'37"	1940	36	737	--	731.8
FR-44	39°48'47"	82°54'20"	1940	30	736	16	--
FR-46	39°51'14"	82°59'26"	1960	6	718	38	702.4
FR-47	39°51'43"	82°56'38"	1960	36	731	26	701.6
FR-48	39°50'20"	82°59'47"	1965	12	732	--	690.9
FR-49	39°52'29"	82°56'46"	1970	4	754	42	710.5
FR-51	39°49'09"	83°00'57"	1972	6	682	62	--
FR-52	39°52'30"	82°59'13"	1940	6	735	84	711.2
FR-53	39°52'41"	82°53'39"	1950	--	733	16	--
FR-55	39°49'39"	82°53'28"	1965	6	719	188	719.0
FR-56	39°49'30"	82°56'38"	1950	12	745	200	--
FR-57	39°48'47"	82°56'53"	1950	8	740	--	709.9
FR-59	39°49'12"	82°59'37"	1965	4	732	63	690.5
FR-60	39°49'29"	82°59'42"	1972	12	689	100	--
FR-61	39°49'11"	82°59'09"	1950	4	735	73	690.1
FR-62	39°50'12"	82°58'57"	1972	12	706	--	687.3
FR-63	39°52'29"	82°55'25"	1969	12	720	140	710.6
FR-64	39°50'08"	83°00'42"	1969	6	680	94	677.5
FR-65	39°50'08"	82°57'34"	1950	4	742	57	714.3
FR-66	39°51'05"	82°55'22"	1950	--	745	--	729.3
FR-67	39°51'45"	82°53'45"	1960	4	743	23	727.3
FR-68	39°52'52"	82°58'09"	1955	4	743	--	--
FR-69	39°51'30"	82°54'33"	1974	4	760	--	728.1
FR-70	39°49'27"	82°59'58"	1950	4	705	59	689.0
FR-71	39°52'38"	83°00'05"	1950	4	700	40	688.4
FR-72	39°52'17"	83°00'23"	1950	4	715	48	687.8
FR-73	39°51'32"	83°00'12"	1960	--	735	--	691.3
FR-74	39°51'53"	83°00'29"	--	8	730	80	--
FR-100	39°51'34"	83°01'02"	1975	12	688	60	682.8
FR-100P3	39°51'34"	83°01'00"	1975	6	686	57	--

Table 1.--Records of selected wells in southern Franklin County, Ohio--Continued

Well number	Latitude	Longitude	Year com- pleted	Casing diameter (inches)	Altitude of land surface (feet)	Depth of well (feet)	Altitude of water (feet)
FR-101[a]	39°51'14"	83°01'04"	1975	12	688	80	681.5
FR-101[b]	39°51'15"	83°01'06"	1979	240	685	74	--
FR-103	39°50'46"	83°00'31"	1974	12	699	101	685.1
FR-104	39°50'20"	83°00'31"	1975	12	691	80	684.6
FR-106	39°49'54"	83°00'28"	1975	12	687	75	676.5
FR-109	39°51'57"	83°00'35"	1975	6	702	92	687.6
FR-115[a]	39°50'31"	82°59'03"	1975	12	710	68	690.6
FR-115[b]	39°50'30"	82°59'02"	1979	240	708	68	--
FR-116	39°50'06"	83°01'36"	1977	2	725	62	--
FR-117	39°50'16"	83°01'03"	1977	2	700	45	685.9
FR-118	39°50'39"	83°00'26"	1977	2	690	98	--
FR-119	39°51'11"	83°00'26"	1977	2	700	85	685.2
FR-120	39°51'17"	83°01'16"	1977	2	690	72	682.5
FR-121	39°51'23"	83°00'33"	1977	2	710	45	686.9
FR-122	39°50'59"	83°00'09"	1977	2	730	104	695.5
FR-123	39°51'31"	82°59'24"	1977	2	710	36	703.1
FR-124	39°51'41"	82°58'14"	1977	2	750	44	710.1
FR-125	39°52'13"	82°59'19"	1977	2	720	51	710.3
FR-126	39°50'08"	82°59'31"	1977	--	700	122	691.5
FR-127	39°50'48"	82°59'54"	1977	2	730	54	701.3
FR-130	39°50'46"	82°57'34"	1977	2	740	48	708.3
FR-131	39°51'26"	83°01'40"	1977	2	727	53	685.9
FR-132	39°54'37"	83°02'13"	1977	2	730	34	--
FR-133	39°52'18"	83°02'39"	1977	2	765	82	715.4
FR-134	39°54'21"	82°58'54"	1977	2	728	50	715.7
FR-135	39°54'16"	83°56'43"	1977	2	770	42	--
FR-136	39°49'55"	82°55'11"	1977	2	741	--	734.8
FR-137	39°49'54"	82°55'13"	1977	2	741	176	734.7
FR-140	39°49'35"	83°02'40"	1977	2	745	61	741.4
FR-145	39°50'17"	83°01'07"	--	--	720	--	--
FR-146	39°51'53"	83°00'29"	1979	4	720	222	--
TH-83	39°50'27"	82°58'56"	1977	8	707	64	691.4
PK-42	39°48'08"	82°58'25"	1940	36	722	18	714.0
PK-138	39°47'39"	82°57'37"	1977	2	715	28	712.8
PK-139	39°47'39"	82°57'37"	1977	2	715	175	701.7

[a]PW series
[b]CW series

HYDROGEOLOGIC SETTING

Glacial deposits consisting of sand and gravel interspersed with till are the major source of water in the study area. These deposits are underlain by the Delaware and Columbus Limestones of Devonian age, which contribute water to the overlying glacial aquifer by upward leakage. The glacial deposits range from 10 to 200 feet in thickness, have a high degree of heterogeneity, and are overlain by 10 to 15 feet of Holocene alluvium (Weiss and Razem, 1980).

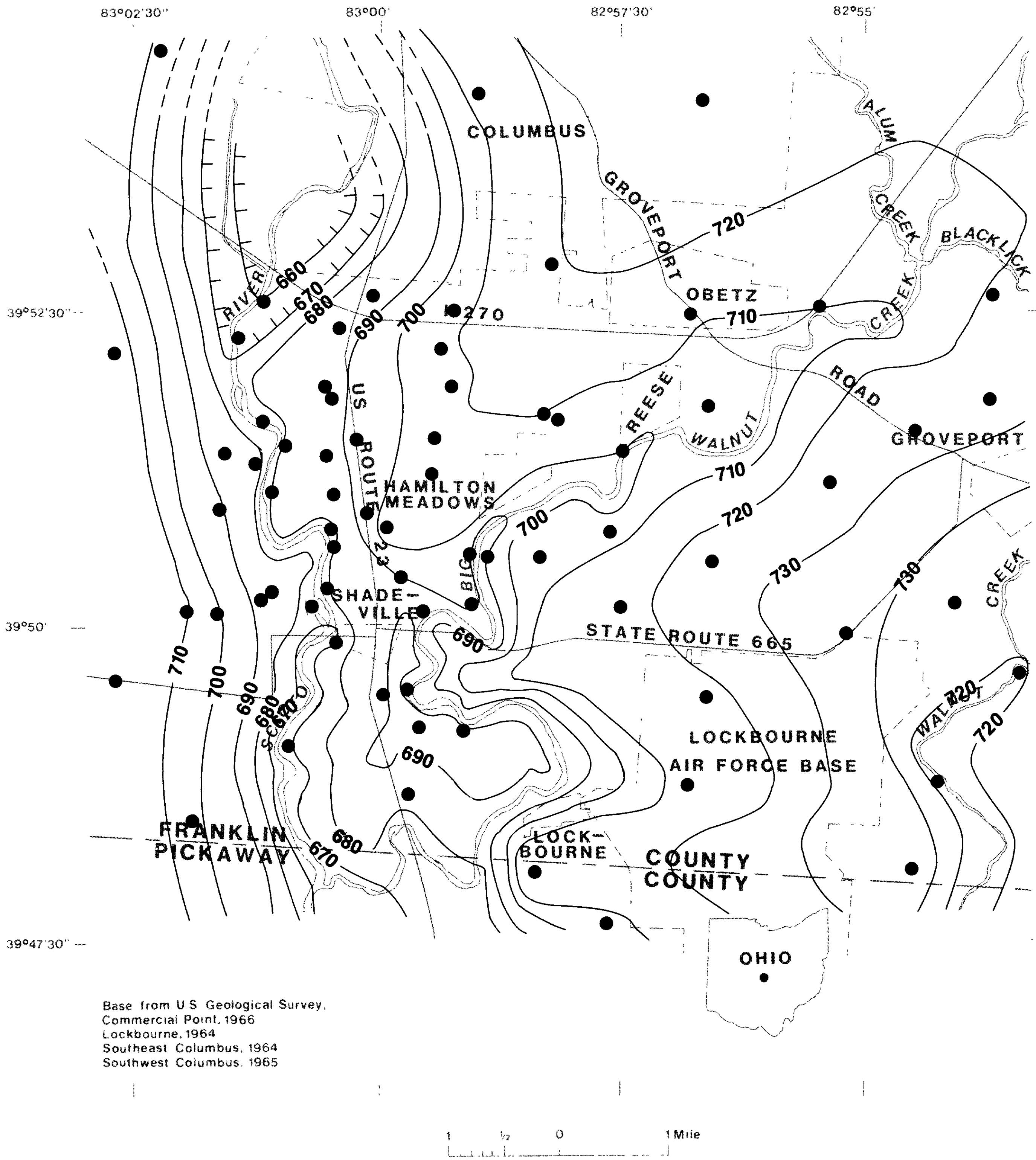
The glacial deposits contain a wide variety of rock types from igneous, metamorphic, and sedimentary environments. Granitic rocks containing sodium and potassium feldspars, mica, quartz, and hornblende are fairly common. Also common are limestone, chert, pyrite, globular marcasite, and silica-cemented quartz sandstones. Of the metamorphic rocks, mica schists are predominant, although other types have been noted.

The ground-water potentiometric map shown in figure 3 is based on water-level data obtained in October 1979. The map indicates that most ground water discharges into Big Walnut Creek and the Scioto River. Recharge areas are located to the east and west of the streams and between the two streams. Recharge to the western edge of the study area by ground-water movement has been estimated at 25 Mgal/d (million gallons per day), whereas recharge from precipitation was calculated to be 12 inches per year (Weiss and Razem, 1980).

During periods of low flow in the late summer months, effluent from the Jackson Pike sewage-treatment plant and ground-water discharge to streams accounts for most of the streamflow. The mean low flow for water years 1976-80 for Big Walnut Creek was 47.2 ft^3/s (cubic feet per second) or 30.4 Mgal/d, whereas the Scioto River had a mean low flow of 148.4 ft^3/s or 95.9 Mgal/d. The geologic section (fig. 4), which was constructed from driller's and geologist's logs of project wells, shows the relationship between the aquifer, the Scioto River, Big Walnut Creek, and the water-supply wells.

WATER QUALITY

The chemical quality of ground water and surface water was investigated by sampling 30 wells and 4 stream sites (fig. 5; tables 2 and 3, at back of report). Between April 10, 1975 and May 29, 1980, a total of 62 chemical-quality samples were taken -- 54 from wells and 8 from local streams. Several of the samples were taken from the collector-type supply wells during aquifer tests.



EXPLANATION

● Water-level-measurement site

—690— Water level contour showing altitude of potentiometric surface, in feet. National Geodetic Vertical Datum of 1929.

Figure 3.--Potentiometric surface in the study area, October 15-17, 1979.

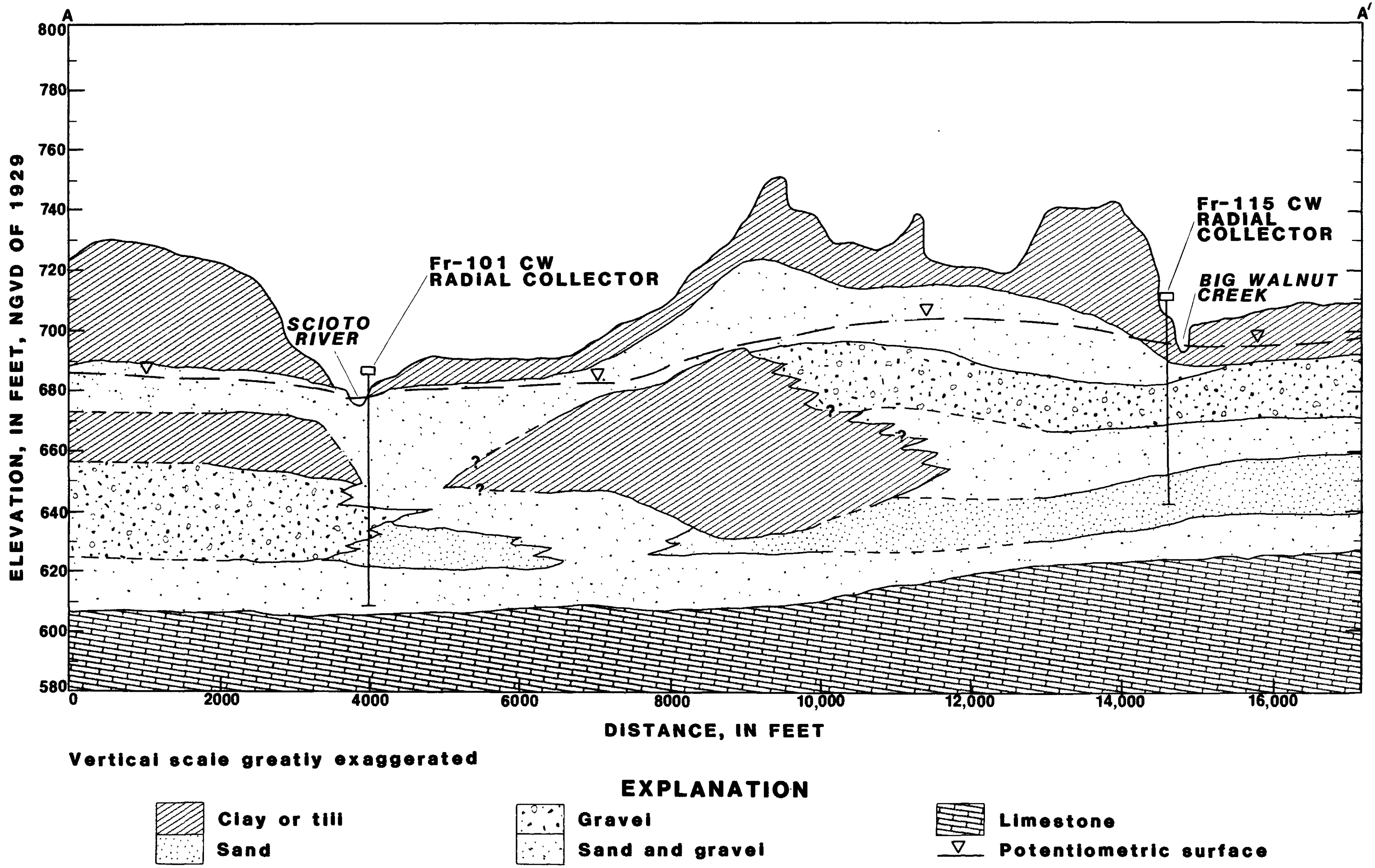
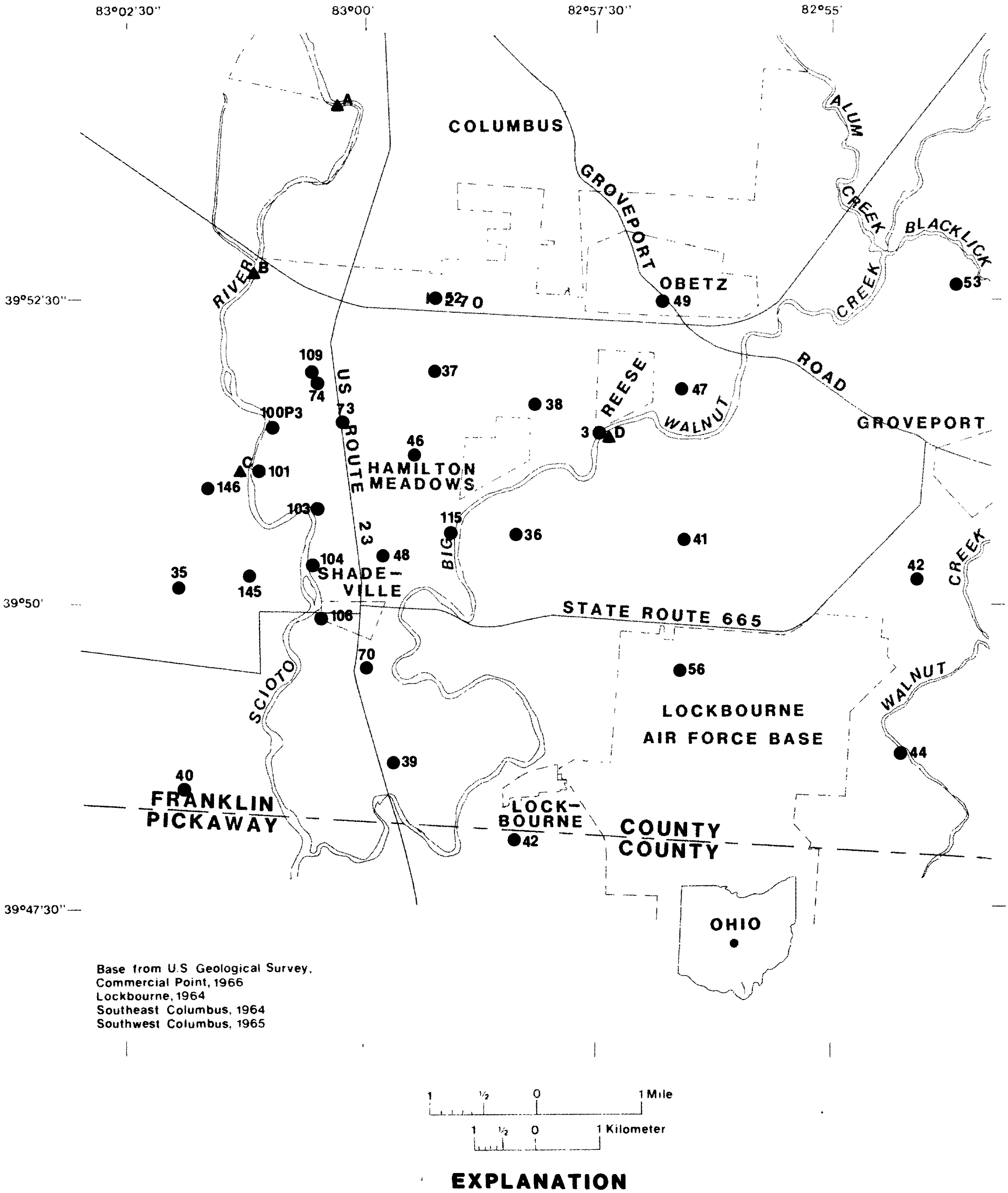


Figure 4.--Geologic section A-A′.



EXPLANATION

●3 Ground-water chemical-quality site and number
▲A Surface-water chemical-quality site

Figure 5.--Water quality sampling network. (The county code prefix, Fr- or or Pk-, has been deleted from well numbers.)

Ohio Drinking-Water Standards

Primary contaminant standards regulate toxic substances in water that singularly or collectively can produce harmful effects on organisms that either live in or use the water. Secondary contaminant standards regulate undesirable substances that are not normally toxic except at high concentrations, but that may restrict the usability of the water or reduce its esthetic quality. The Ohio Environmental Protection Agency (1978, 1980), in chapters 3745-81 and 3745-82 of the Ohio Administrative Code, has established the following standards on selected constituents in water. For public-water supplies, the contaminants in the following tables are not to exceed the specified concentrations at any time:

Primary contaminants	Concentration, in milligrams per liter
Arsenic	0.05
Barium	1
Cadmium	.01
Chromium	.05
Lead	.05
Mercury	.002
Nitrate (as N)	10
Selenium	.01
Silver	.05

The standard for coliform bacteria is one colony per 100 milliliters.

The contaminant levels for fluoride are based upon the annual average of the maximum daily air temperatures for the location in which the community water system is situated. The maximum primary contaminant levels for fluoride are:

Temperature		Concentration, in milligrams per liter
Degrees Fahrenheit	Degrees Celsius	
53.7 and below-------	12.0 and below-------	2.4
53.8 to 58.3---------	12.1 to 14.6---------	2.2
58.4 to 63.8---------	14.7 to 17.6---------	2.0
63.9 to 70.6---------	17.7 to 21.4---------	1.8
70.7 to 79.2---------	21.5 to 26.2---------	1.6
79.3 to 90.5---------	26.3 to 32.5---------	1.4

Secondary contaminants	Concentration or value
Chloride----------------------	250 mg/L (milligrams per liter)
Color-------------------------	15 color units
Copper------------------------	1 mg/L
Corrosivity-------------------	noncorrosive
Foaming agents----------------	0.5 mg/L
Iron--------------------------	0.3 mg/L
Manganese---------------------	0.05 mg/L
Odor--------------------------	3 (threshold odor number)
pH----------------------------	7.0 - 10.5
Sulfate-----------------------	250 mg/L
Total dissolved solids--------	500 mg/L
Zinc--------------------------	5 mg/L

Ground Water

A very hard calcium bicarbonate water that is high in dissolved solids is characteristic of the ground-water quality of southern Franklin County. The composition of the water is similar throughout the study area, as illustrated by the Stiff diagrams (Stiff, 1951) in figure 6.

Calcium and magnesium are the most abundant of the major cations; mean concentrations are 100 mg/L (milligrams per liter) for calcium and 33 mg/L for magnesium (table 4). Bicarbonate, the most abundant of the anions, ranges in concentration from 238 to 530 mg/L and has a mean concentration of 389 mg/L.

Mean pH of the ground water is 7.3. Dissolved carbon dioxide has an average concentration of 35.6 mg/L. Both reduced (sulfide) and oxidized (sulfate) sulfur species are present in the study area; concentrations range from 0 to 22 mg/L for hydrogen sulfide and 11 to 240 mg/L for sulfate. Concentrations of dissolved iron range from 0.01 to 3.9 mg/L; 35 of the 54 analyses exceed the Ohio Environmental Protection Agency (OEPA) water-quality standard of 0.3 mg/L for iron. Concentrations of manganese range from 5.0 to 230.0 µg/L, and 27 of the analyses exceed the OEPA standard of 50.0 µg/L for manganese.

Fecal streptococci bacteria are being used increasingly as a microbiological indicator of significant contamination of water because the normal habitat of these organisms is the intestines of humans and animals. The term "fecal streptococci" encompasses several varieties and groups of bacteria, some of which may not be of sanitary significance (Pagel and Hardy, 1980).

Bacteriological analyses were done according to Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1980); KF streptococcus agar was used for the enumeration of fecal streptococci. Brodsky and Schiemann (1976) investigated the recovery of fecal streptococci by KF agar and confirmed that 83 percent of the typical red-to-pink colonies recovered at 35°C were fecal streptococci. A similar study (Pagel and Hardy, 1980) confirmed 81 percent of typical colonies recovered were fecal streptococci, the remaining 19 percent being non-fecal streptococci.

Microbiological testing for fecal coliform and fecal streptococci bacteria was done on water from 15 wells within the study area. Water from 11 of the 15 wells tested (table 2) contained either fecal coliform or fecal streptococci bacteria or both. Concentrations of fecal bacteria ranged from 1 to 2,400 cols./100 ml (colonies per 100 milliliters).

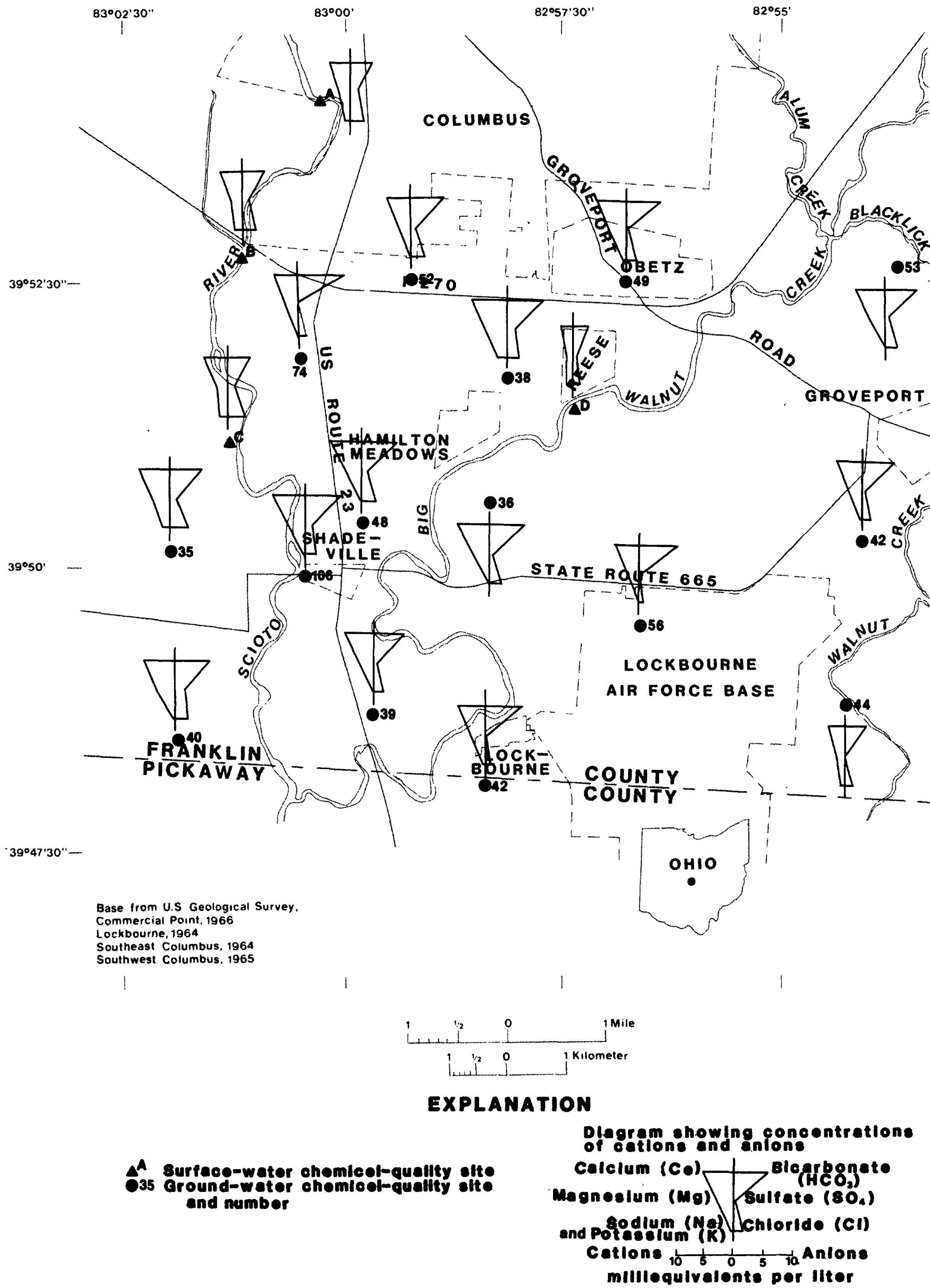


Figure 6.--Stiff diagrams showing the similarity of dissolved anions and cations in the study area. (The county code prefix, Fr- or Pk-, has been deleted from well numbers.)

Table 4.--Water-quality statistics for ground water in southern Franklin County, Ohio

Constituent or property	Number of observations	Mean	Median	Minimum value	Maximum value
Turbidity (FTU)	23	13.68	10	0.00	75
Specific conductance (μmho/cm)	54	746.9	736	435	1000
pH (units)	54	7.3	7.35	6.7	8.2
Carbon dioxide, dissolved (mg/L as CO_2)	54	35.6	30.6	2.1	113
Alkalinity, field (mg/L as $CaCO_3$)	54	319	323	195	435
Bicarbonate, fet-fld (mg/L as HCO_3)	54	389	394	238	530
Nitrogen, dissolved (mg/L as N)	23	6.76	.21	.01	110
Nitrogen, ammonia, dissolved (mg/L as N)	24	.41	.05	.00	7.1
Nitrogen, nitrite and nitrate, dissolved (mg/L as N)	24	1.9	.04	.0	21
Phosphorus, total (mg/L as P)	47	.06	.01	.00	.58
Carbon, organic, total (mg/L as C)	50	18.3	2.8	.0	720
Hardness (mg/L as $CaCO_3$)	54	384	383	200	580
Hardness, noncarbonate (mg/L $CaCO_3$)	54	85	67	0	220
Calcium, dissolved (mg/L as Ca)	54	99.7	100	24.0	140
Magnesium, dissolved (mg/L as Mg)	54	33.0	33	19.0	56
Sodium, dissolved (mg/L as Na)	53	8.2	5.7	1.0	52
Potassium, dissolved (mg/L as K)	53	2.5	1.3	.6	20
Chloride, dissolved (mg/L as Cl)	54	19.8	15.5	2.4	66
Sulfate, dissolved (mg/L as SO_4)	54	74	74	11	240
Fluoride, dissolved (mg/L as F)	54	.3	.3	.1	1.4
Silica, dissolved (mg/L as SiO_2)	53	11.8	12	.0	20
Iron, dissolved (μg/L as Fe)	53	1284	1200	10	3900
Manganese, dissolved (μg/L as Mn)	53	64	60	5	230
Solids, residue at 180°C, dissolved	24	456	458	297	619
Solids, sum of constituents, dissolved	53	437	437	238	721

High concentrations of fecal coliform (190 cols./100 ml) and fecal streptococci (2,400 cols./100 ml) in water from well FR-104 might have been the result of flooding of the Scioto River. Subsequent retesting of the well water revealed greatly reduced fecal coliform and fecal streptococci concentrations of 2 and 40 cols./100 ml, respectively.

Surface Water

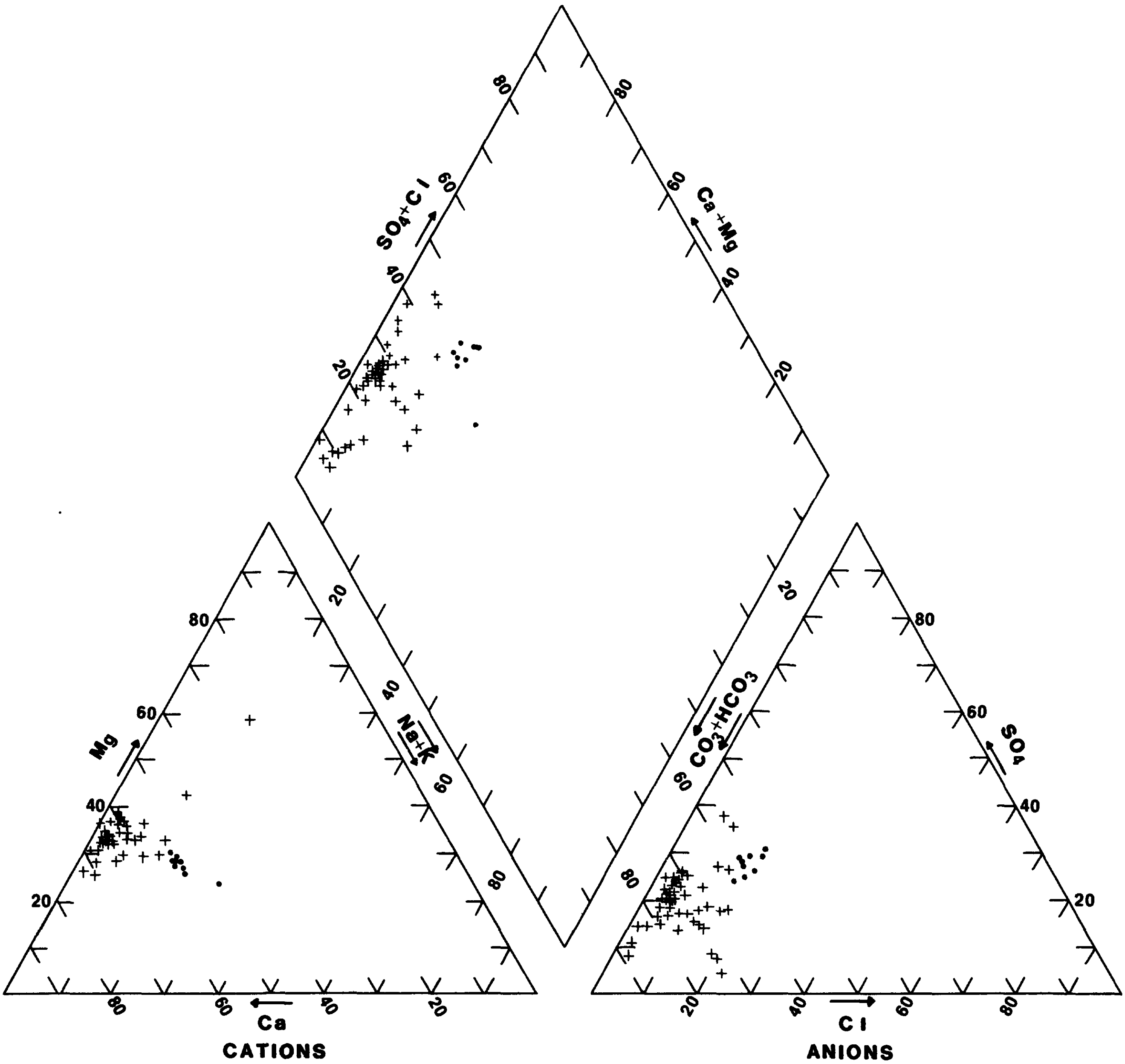
Water-quality samples were collected from the Scioto River on November 20, 1979, and May 19, 1980 at flows of 788 and 1,240 ft^3/s, respectively. Samples were collected from Big Walnut Creek on November 13, 1979, at a flow of 637 ft^3/s and on May 20, 1980, at a flow of 1,090 ft^3/s. Three sites were sampled on the Scioto River; one site was sampled on Big Walnut Creek (fig. 5).

Water from the two streams, although slightly less mineralized, is very similar to the underlying ground water in chemical quality (fig. 6, table 3). The principal cations in the surface waters are calcium and magnesium, whose concentrations range from 50 to 85 mg/L and 14 to 26 mg/L, respectively. Bicarbonate and sulfate are the most abundant anions, their respective concentrations ranging from 150 to 260 mg/L and 51 to 110 mg/L.

Differences among the composition of the ground water and surface waters are slight, as illustrated by the water-analysis diagram in figure 7 (Piper, 1944). Concentrations of calcium, magnesium, and bicarbonate are higher in ground water, owing in part to long residence time in aquifer materials that contain significant amounts of these ions, and in part to increased solubility of carbonate minerals caused by solution of carbon dioxide from the soil/root zone.

Microbiological samples (table 3) were collected from three sites on the Scioto River on November 11, 1979 and May 19, 1980. The 1979 samples show relatively small concentrations of fecal coliform and fecal streptococci at all three sites, whereas 1980 samples contained 21,000 cols./100 ml of fecal coliform and 80,000 cols./100 ml of fecal streptococci at one site. Samples collected from Big Walnut Creek on November 13, 1979, and May 20, 1980, show relatively small concentrations of both types of bacteria.

Coliform organisms do not necessarily constitute a threat to water supplies using induced infiltration systems; however, microbial contamination of induced infiltration systems has been known to occur. In 1964, coliform bacteria were shown to have traveled 180 feet from the Susquehanna River through highly permeable coarse sand and gravel to a municipal supply well in Endicott,



EXPLANATION

+ Ground-water analysis

• Surface-water analysis

Figure 7.--Water -quality diagrams showing the distribution of constituents in ground water and surface water within the study area.

New York (Randall, 1970). Normally, the aquifer would have filtered out bacteria as stream water moved through the base of the river. The influx of bacteria was traced to several excavations in the stream channel that disturbed the natural stratification of the sediments and allowed the bacteria to pass.

The glacial outwash aquifer in southeastern Franklin County is very similar to the aquifer at Endicott. The streambeds of the Scioto River and Big Walnut Creek are composed of gravel and fine-to-medium sand and silt that can provide adequate filtration. Barring disturbance of the bed material, the water-supply wells should be adequately protected from bacterial contamination.

From October 1971 through November 1972, a monthly pesticide sampling program (U.S. Geological Survey, 1973) was conducted by the U.S. Geological Survey on the Scioto River above Big Walnut Creek near Shadeville, Ohio. At this location, just downstream of the water-supply wells, water samples were analyzed for a total of 19 pesticides from organophosphorus, phosphorus, chlorophenoxy, and other groups. None of these 19 pesticides was detected in any of the analyses.

GEOCHEMISTRY AND INTERACTION OF GROUND AND SURFACE WATER

Water-quality samples from 7 wells and 2 surface-water sites were chosen to study the chemical relationships between ground water and surface water. The FORTRAN computer programs WATEQF (Plummer and others, 1976) and BALANCE (Parkhurst and others, 1982) were used to interpret the chemical data. WATEQF models the thermodynamic speciation of inorganic aqueous species in natural waters, and provides information on the processes that control water composition in ground- and surface-water systems. BALANCE calculates the mass transfer that takes place when two "initial" waters combine to form a third, "final" water. BALANCE also calculates the relative contribution, in percent, of each initial water.

Mass-Balance Analysis

The saturation values calculated by WATEQF (table 5) indicate that water from the outwash aquifer is approximately in equilibrium with calcite, dolomite, and silica. The water is supersaturated with respect to pyrite and undersaturated with respect to $Fe(OH)_3$ amorphous. Redox potentials at selected wells were calculated using the concentrations of H_2S and SO_4^{2-}:

FR-101 (August 27, 1975)	millivolts	-170
FR-101 (May 6, 1975)	do	-210
FR-104 (April 2, 1975)	do	-200
FR-109 (June 13, 1978)	do	-210

Table 5.--Saturation indices of various minerals for selected wells and streams in southern Franklin County, Ohio

[Calculated from analytical data by WATEQF (Plummer and others, 1976) for wells in Table 2. Saturation index = log (IAP/K_{eq}).]

Well or stream site	Sampling date (mo.-day-year)	Saturation index									
		Calcite	Dolomite	Gypsum	Anhydrite	Siderite*	Pyrite*	Hematite*	Goethite*	$Fe(OH)_3$*	Silica
FR-36------	04-16-75	0.09	-0.21	-1.42	-1.78	--	--	--	--	--	0.59
	05-28-80	.207	.85	-1.39	-1.73	--	--	--	--	--	.47
FR-38------	04-16-75	.22	.14	-1.27	-1.63	--	--	--	--	--	.49
FR-74------	05-27-80	.159	-0.033	-1.99	-2.34	--	--	--	--	--	.589
FR-100-----	06-12-75	.363	.209	-1.28	-1.63	--	--	--	--	--	.49
FR-101-----	08-27-75	-2.16	-0.689	-0.906	-1.25	-1.32	13.09	-0.77	-0.154	-6.73	.159
	05-06-75	.25	.163	-1.04	-1.39	.04	13.14	3.26	1.86	-4.72	.523
	05-28-80	.36	.45	-1.35	-1.63	--	--	--	--	--	.407
FR-104-----	04-02-75	.278	.229	-1.46	-1.81	.244	10.17	3.73	2.09	-4.49	.557
FR-115-----	07-08-76	.102	-0.147	-1.33	-1.68	--	--	--	--	--	.589
	05-28-80	.202	.059	-1.39	-1.75	--	--	--	--	--	.522
Scioto River at Site 101---	05-19-80	-0.186	-0.694	-1.60	-1.91	--	--	--	--	--	.074
Big Walnut Creek at Rees-------	05-20-80	-0.825	-0.950	-1.81	-2.10	--	--	--	--	--	.201

*For calculations involving redox equilibria, redox potential was computed from analytical data for SO_4 and H_2S, assuming equilibrium between the two.

Redox potentials calculated on selected samples indicate a reducing environment; however, this chemical state is not representative of the entire aquifer. The presence of dissolved oxygen ranging from 0.2 to 2.1 mg/L in certain areas of the aquifer (U.S. Geological Survey, 1982) indicate an oxidizing environment.

Concentration of bicarbonate and values of pH are fairly constant throughout the study area. The pH is buffered primarily by the dissolution of carbonate rocks:

$$CO_2(aq) + CaCO_3(s) + H_2O(l) \rightleftharpoons Ca^{2+}(aq) + 2HCO_3^-(aq)$$

Carbonate dissolution alone cannot account for the amount of bicarbonate, because the analyzed concentration of calcium is deficient by approximately 1.0 to 1.5 mmol/L (millimoles per liter) (40 to 60 mg/L) in most of the samples.

Removal of calcium by cation-exchange reactions with sodium was considered as a possible cause for the calcium deficit; however, sodium concentrations in the study area's ground water are too low. The balance of the bicarbonate may result from weathering of silicate minerals. The evidence for silicate weathering as a bicarbonate-producing reaction is (1) the abundance of silica-containing rocks in the aquifer, (2) the presence of many silica-cemented rocks, and (3) the approximate equilibrium condition of silica with respect to the system.

Sulfate concentrations differ throughout the aquifer system. The combination of low redox potential, the presence of reduced sulfur species, and relatively low sulfate concentrations indicates sulfate reduction is occurring to some extent in the aquifer.

The ground water also contains fairly large concentrations of dissolved iron. Ferrous iron (Fe^{2+}) and reduced sulfur (H_2S) are rarely found together in natural waters that have attained equilibrium (Hem, 1970). A possible explanation for this unlikely combination of chemical species may be the configuration of the collector-type wells.

A collector-type well system produces water from several levels and directions within the aquifer. Chemical quality of ground water varies with depth and location in an aquifer. The presence of both Fe^{2+} and H_2S probably results from the mixture of two waters from environments that vary in reducing strength. As these two chemically different waters are pumped from the well, there is not sufficient time for them to mix and attain equilibrium; therefore, a nonequilibrium condition is attained in which both ferrous iron and reduced sulfur are present.

In certain areas of the glacial aquifer, oxidation of pyrite and formation of sulfate occurs:

$$FeS_2(s) + 8H_2O(l) \rightleftharpoons Fe^{2+}(aq) + 2SO_4{}^{2-}(aq) + 2H^+(aq) + 7H_2(g)$$

The high concentrations of sulfate in water from well FR-101 in June (180 mg/L) and August (240 mg/L) 1975 support this equation; however, the concentrations of ferrous iron are less than expected. The equation (Barnes and others, 1964) also indicates oxygen is supplied through the reduction of water, however, there is uncertainty over the fate of the hydrogen that would be generated. The reduction of hematite (Barnes and others, 1964) has been suggested as a sink for the hydrogen through the reaction:

$$Fe_2O_3(s) + H_2(g) + 4H^+(aq) \rightleftharpoons 2Fe^{2+}(aq) + 3H_2O(aq)$$

Analysis of a sample collected from FR-101 on August 27, 1975 (table 5), seems to support this hypothesis. In this sample, which has a redox potential of -170 millivolts, hematite is approximately in equilibrium, whereas the other samples indicate supersaturation with respect to hematite.

In other areas within the reach of the collector system, conditions are favorable for sulfate reduction:

$$SO_4{}^{2-}(aq) + 2CH_2O(aq) + 2H^+(aq) \rightleftharpoons 2CO_2(g) + H_2S(aq) + 2H_2O(l)$$

Pyrite oxidation and sulfate reduction occur in different chemical environments; concentrations of various chemical species in this sample (FR-101) represent a composite of different waters and have characteristics of both. Values of pH and Eh, which would aid in identifying these different chemical environments, must be viewed carefully because they represent an unstable nonequilibrium chemical system. Evidence that different chemical environments are present in the aquifer is based on field observation and chemical analyses of multiple samples of the products of these reactions.

Because the equation for sulfate reduction indicates that the process is endothermic, a source of energy (such as hydrocarbons) must be available. Concentrations of total organic carbon (TOC) in the water are much too low in most cases to encourage sulfate reduction. Nevertheless, there are other sources of carbon that were not quantitatively measured. A well located 200 feet east of collector FR-101 produces water from just below the limestone-outwash contact; the water is highly charged with hydrogen sulfide and is black from precipitation of iron sulfide (FeS). In addition, stringers of highly carbonaceous material have been observed in the Columbus Limestone, which underlies the glacial aquifer. The silt and mud bed of the Scioto River adjacent to collector 101 also is a source of carbon and bacteria -- a source that might support a reducing environment because of its proximity to the sewage-treatment plant upstream.

Reaction Model of the Stream-Aquifer System

BALANCE is a computer program that models the chemical reactions that take place between minerals and water in a natural system. For the mixing-type simulation, the following information is required: (1) Chemical compositions of three waters, two initial (or end-member) waters, and a third (or final) water that results from mixing of the two end-member waters; and (2) a set of mineral phases for the chemical species that are presumed to react in the system. The reaction models defined by BALANCE are limited only by mass balance between the elements, thus, the model may produce a reaction that is thermodynamically impossible.

The main objectives in modeling the collector system were to determine the interaction of surface water and ground water, and to arrive at a general idea of the chemical reactions that occur. Reaction simulations were limited to the carbonate chemistry, as the carbonate system is the major control on the aquifer. Because of insufficient data, oxidation-reduction reactions were ignored and no attempt was made to define a unique model for the system.

Three chemical analyses (table 6) were chosen to model the mass transfer that takes place when surface water and ground water mix to form the final water that flows from the collector well. Well FR-74 represents water from the recharge area of the glacial aquifer; Scioto River at site 101 represents surface water, and well FR-101 is the collector or final water (fig. 8). Mineral phases (table 7) chosen for the model were based upon the observed mineralogy of the aquifer and saturation data calculated previously.

Results of simulation 1 (table 7) indicate that the final water is composed of 80 percent ground water and 20 percent surface water. The collector sample was taken at a pumping rate of 15.9 ft^3/s.

The purpose of simulation (table 7) was to include all mineral phases that might have a significant effect on aquifer chemistry. To achieve the final water in simulation 1, 0.51 mmol/L (millimoles per liter) of calcite was precipitated, 0.67 mmol/L of gypsum was dissolved, and 0.30 mmol/L of carbon dioxide was lost to the atmosphere. None of the other chemical phases included in the simulation contributed significantly to the production of the final water.

As noted earlier in the report, the model confirms that calcium/sodium exchange has very little effect on the aquifer chemistry. The results of simulation 1 (table 7) indicate 0.16 mmol/L (6.4 mg/L) of calcium were removed by the ion exchange reaction. The simulation confirms that removal of

Table 6.--Concentrations of chemical species used in reaction model

[All concentrations in millimoles per kilogram of water]

Element	[a]Initial water, Fr-74	[b]Initial water, Scioto River at site 101	[c]Final water, Fr-101
Calcium------------------	2.02	1.45	2.50
Magnesium----------------	1.11	0.74	1.32
Sodium-------------------	0.20	.87	0.31
Potassium----------------	.02	.07	.03
Chloride-----------------	.08	.79	.51
Sulfur-------------------	.24	.76	1.01
Carbon-------------------	8.10	3.40	6.92

[a] Sampled May 27, 1980
[b] Sampled May 19, 1980
[c] Sampled May 28, 1980

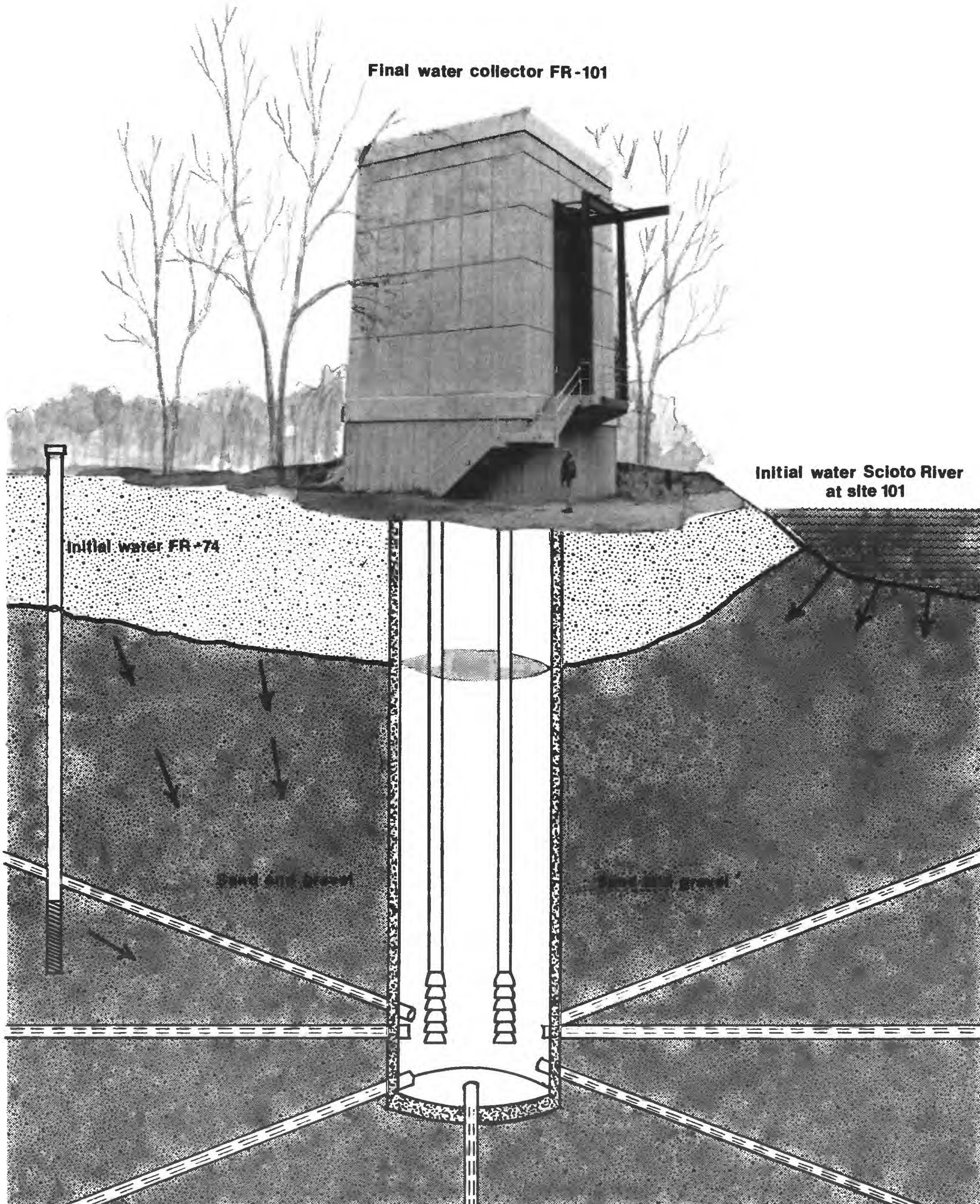


Figure 8.--Conceptual diagram showing radial collector and mixing of ground water and surface water.

Table 7.--Results of reaction modeling simulations of selected well and stream sites in southern Franklin County, Ohio

[All concentrations in millimoles per kilogram of water]

Mineral phases	Simulation 1*		Simulation 2*	
	Dissolved	Precipitated	Dissolved	Precipitated
Calcite------------		0.51		0.36
Dolomite-----------	0.28		0.28	
Carbon dioxide----		.30		.45
Ion exchange (Ca-Na)----------		.16		
Gypsum-------------	.67		.66	
Halite-------------	.29			

*Contribution of initial waters in both simulations: ground water, 80 percent; surface water, 20 percent.

calcium by ion exchange may occur, however, it does not happen in quantities sufficient to overcome the calcium deficit (40 to 60 mg/L) with respect to production of bicarbonate. Weathering of silicate minerals may indeed account for the balance of bicarbonate in the system.

In simulation 2, the mineral phases (table 7) "ion exchange" (Ca-Na) and "halite" were excluded. Results of simulation 2 (table 7) show that 0.36 mmol of calcite was precipitated and 0.45 mmol of carbon dioxide was lost to the atmosphere. Small amounts of dolomite and gypsum were dissolved. The calcium removed by exchange in simulation 1 is precipitated as calcium carbonate in simulation 2. Either pathway for removal of calcium is equally possible. Exchange reactions may occur on silts and clays as river water is induced to flow downward through the base of the river. Chemical precipitation may occur as the two waters mix before discharging from the well. The small scale of the chemical reactions and the amount of mass transfer indicates the close chemical resemblance between the carbonate chemistry of the ground- and surface-water systems.

The relative percentages of ground-water and surface-water contribution, as calculated by chemical modeling, agree favorably with results obtained by digital ground-water flow modeling. Both reaction-modeling simulations indicate that the final water was composed of 80 percent ground water and 20 percent surface water. Simulation of pumping collectors in a digital ground-water flow model designed for this study area (Razem, 1983) indicates that the water from four collectors pumping at a combined rate of 60 ft^3/s is composed of 32 percent surface water and 68 percent ground water.

SUMMARY AND CONCLUSIONS

Topography in the Scioto River valley near Columbus, Ohio, generally is flat and the predominant land use is agriculture. Glacial deposits up to 200 feet thick that consist of sand and gravel interspersed with till are the major source of ground water; however, the Columbus Limestone contributes some water by upward leakage. A potentiometric map indicates that ground-water flow enters the Scioto River and Big Walnut Creek from recharge areas adjacent to and between the two streams. Ground-water recharge to the western edge of the study area has been estimated at 25 Mgal/d.

A very hard calcium bicarbonate ground water high in dissolved solids is characteristic of the area. Mean pH is 7.3 and calcium, magnesium, and bicarbonate are the dominant dissolved ions. Concentrations of dissolved iron and manganese routinely exceed OEPA Public Water Supply criteria for iron and manganese. Thirty-five of 54 water analyses exceeded the OEPA standards for iron, and 27 analyses exceeded the standard for manganese.

Microbiological testing of ground water indicated that 11 of 15 well waters contained fecal coliform or fecal streptococci bacteria. The highest concentration of fecal streptococci (2,400 cols./100 ml) was found in well FR-104, located on the flood plain of the Scioto River. Abandoned and unsealed wells within the flood plain area may allow the river waters to flow directly into the glacial aquifer and thereby lose the beneficial effect of normal infiltration in reducing bacteria concentration. The maximum analyzed concentrations of bacteria in the Scioto River were 24,000 cols./100 ml fecal coliform, and 80,000 cols./100 ml fecal streptococci.

Differences between the chemical composition of the ground water and surface water are slight. Stiff diagrams show that the streams have the same general chemical characteristics as the ground water, but are a more dilute solution.

Saturation indices calculated with the computer program WATEQF indicate that water from the glacial aquifer is approximately in equilibrium with calcite, dolomite, and silica, and supersaturated with respect to pyrite. Buffering of pH is accomplished primarily by the carbonate system; however, weathering of silicate minerals may also influence pH by production of bicarbonate. Sulfur species and their concentrations differ throughout the aquifer, which suggests the existence of different chemical environments.

Redox potentials and the presence of hydrogen sulfide indicate that certain areas of the aquifer are under reducing conditions. Dissolved-oxygen concentrations of 0.2 to 2.1 mg/L indicate other areas of the aquifer that are under oxidizing conditions. The aquifer in the vicinity of the Scioto River is considered to be an unstable, nonequilibrium system. The eventual sustained use of the collector-pumping system will further modify the chemistry of the glacial aquifer and, although change is certain, it is difficult to predict what types of chemical reactions will occur.

Three chemical analyses were chosen to model the mass transfer that takes place when surface water and ground water combine to form the final water that flows from the collector well. The model simulations of the carbonate system show that small amounts of calcite, dolomite, and gypsum were precipitated in achieving the final water, which was composed of 80 percent ground water and 20 percent surface water. The relative contributions from stream and aquifer sources, calculated by chemical mass balance, compare favorably with results calculated by a digital ground-water flow model.

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Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio

Well number	Date of sample	Time	Temperature (deg. C)	Temperature, air (deg. C)	Turbidity (FTU)	Specific conductance (µmho/cm)	Oxygen demand biochemical, 5 day (mg/L)
FR-3-------	04-14-78	1015	12.5	--	--	648	--
	05-28-80	1240	12.0	27.5	12	660	0.1
FR-35------	04-22-75	1400	16.0	--	--	917	--
FR-36------	04-16-75	1130	12.5	--	--	695	--
	11-20-79	1445	12.5	20.0	20	1,000	--
	05-28-80	1035	12.0	26.0	2.5	800	.6
FR-37------	11-13-79	1130	11.0	5.0	1.0	860	--
	05-23-80	0910	13.5	21.0	0.50	880	.4
FR-38------	05-29-80	1120	12.5	24.0	2.5	540	.2
FR-39------	04-24-75	0945	12.5	--	--	814	--
FR-40------	04-17-75	1415	10.0	--	--	980	--
FR-41------	04-24-75	1430	14.0	--	--	701	--
	05-20-80	1210	15.0	22.0	--	720	.1
FR-42------	04-14-75	1000	10.5	--	--	673	--
FR-44------	04-18-75	1030	10.0	--	--	463	--
FR-46------	05-20-80	1405	15.0	23.0	.70	930	.1
FR-47------	04-15-75	1530	11.0	--	--	679	--
FR-48------	11-14-79	1300	11.0	4.5	6.0	850	--
	05-23-80	1140	15.0	24.5	2.0	780	.6
FR-49------	04-14-75	1130	11.5	--	--	717	--
FR-52------	04-24-75	0915	11.0	--	--	728	--
	05-23-80	1400	15.5	27.0	1.3	732	.4
FR-53------	04-17-75	0930	9.0	--	--	615	--
FR-56------	04-28-75	1415	13.0	--	--	665	--
FR-70------	04-10-75	1430	13.0	--	--	435	--
FR-73------	05-29-80	0940	12.5	28.0	15	658	.1
FR-74------	11-21-79	0930	11.5	15.5	30	940	--
	05-27-80	1015	11.5	21.0	30	645	.1
FR-100P3---	06-04-75	1430	11.0	26.0	--	750	--
	06-12-75	1015	11.0	18.0	--	723	--
	11-19-79	1230	11.5	--	2.0	723	--
	05-27-80	1305	11.5	22.0	75	745	.1
FR-101-----	05-06-75	1400	11.5	--	--	858	--
	08-27-75	1200	11.5	--	--	975	--
	11-15-79	1100	12.0	--	20	760	--
	05-28-80	1405	15.0	27.0	6.2	750	1.0
FR-103-----	12-11-74	1530	10.5	--	--	810	--
	12-20-74	1000	11.0	4.0	--	849	--
FR-104-----	04-02-75	1400	11.5	25.5	--	746	--
	08-26-75	1230	11.0	--	--	714	--
	08-29-75	1200	11.5	--	--	755	--
	11-19-79	1430	12.0	18.5	.00	696	--
	05-27-80	1500	11.0	25.5	10	500	.6
FR-106-----	02-07-75	1500	11.0	.0	--	845	--
	02-12-75	1400	11.0	--	--	804	--
FR-109-----	08-28-75	1009	11.5	--	--	675	--
	06-13-78	1700	11.5	--	--	710	--
FR-115-----	07-06-76	1530	11.5	31.5	--	712	--
	07-08-76	1045	11.5	22.5	--	740	--
	11-20-79	1330	12.0	23.5	20	830	--
	05-28-80	0855	11.5	22.5	30	750	.0
FR-145-----	05-29-80	1315	12.0	28.0	13	680	.0
FR-146-----	05-29-80	1455	12.5	29.5	15	790	.1
PK-42------	04-23-75	1345	9.5	--	--	720	--

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Oxygen demand, chemical, high level (mg/L)	Coliform, fecal, 0.7 UM-MF (cols./ 100 ml)	Streptococci, fecal, KF agar (cols./ 100 ml)	Hydrogen sulfide, total (mg/L as H_2S)	Carbon, organic, total (mg/L as C)
FR-3-------	04-14-78	--	--	--	ND	--
	05-28-80	6	K16	<2	ND	2.0
FR-35------	04-22-75	--	--	--	ND	4.5
FR-36------	04-16-75	--	--	--	ND	4.5
	11-20-79	--	<1	K3	--	3.0
	05-28-80	8	K20	K10	--	2.4
FR-37------	11-13-79	--	<1	<1	--	1.2
	05-23-80	--	--	--	--	0.2
FR-38------	05-29-80	7	K8	K8	--	1.4
FR-39------	04-24-75	--	--	--	ND	5.0
FR-40------	04-17-75	--	--	--	ND	3.1
FR-41------	04-24-75	--	--	--	ND	2.5
	05-20-80	--	<2	<2	ND	--
FR-42------	04-14-75	--	--	--	ND	3.0
FR-44------	04-18-75	--	--	--	ND	5.0
FR-46------	05-20-80	24	<2	K6	--	2.3
FR-47------	04-15-75	--	--	--	0.2	4.8
FR-48------	11-14-79	--	<1	K1	--	.6
	05-23-80	--	--	--	--	ND
FR-49------	04-14-75	--	--	--	.7	6.8
FR-52------	04-24-75	--	--	--	ND	3.2
	05-23-80	--	--	--	ND	ND
FR-53------	04-17-75	--	--	--	ND	4.0
FR-56------	04-28-75	--	--	--	ND	6.9
FR-70------	04-10-75	--	--	--	ND	2.6
FR-73------	05-29-80	1	<2	K20	ND	4.9
FR-74------	11-21-79	--	<1	K10	--	2.8
	05-27-80	7	K20	30	--	6.6
FR-100P3---	06-04-75	--	--	--	ND	11
	06-12-75	--	--	--	ND	11
	11-19-79	--	K5	K60	--	720
	05-27-80	23	<2	K4	--	4.7
FR-101-----	05-06-75	--	--	--	4.8	4.0
	08-27-75	--	--	--	22	--
	11-15-79	--	K6	15	--	2.8
	05-28-80	8	K10	<2	--	2.4
FR-103-----	12-11-74	--	--	--	2.0	.5
	12-20-74	--	--	--	1.1	.9
FR-104-----	04-02-75	--	--	--	.1	.8
	08-26-75	--	--	--	ND	1.4
	08-29-75	--	--	--	ND	5.6
	11-19-79	--	190	K2400	--	8.6
	05-27-80	12	<2	40	ND	3.7
FR-106-----	02-07-75	--	--	--	ND	1.5
	02-12-75	--	--	--	ND	.7
FR-109-----	08-28-75	--	--	--	ND	38
	06-13-78	--	--	--	ND	--
FR-115-----	07-06-76	--	--	--	ND	1.0
	07-08-76	--	--	--	ND	1.7
	11-20-79	--	<1	K1	--	2.3
	05-28-80	6	<2	K10	--	2.4
FR-145-----	05-29-80	4	<2	<2	--	.7
FR-146-----	05-29-80	6	<2	K4	--	1.2
PK-42------	04-23-75	--	--	--	ND	8.1

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	pH (units)	Carbon dioxide, dis- solved (mg/L as CO_3)	Alka- linity (mg/L as $CaCO_3$)	Bicar- bonate (mg/L as HCO_3)
FR-3-------	04-14-78	7.4	22	279	340
	05-28-80	7.5	7.4	290	350
FR-35------	04-22-75	7.6	16	328	400
FR-36------	04-16-75	7.2	39	315	384
	11-20-79	7.0	69	353	430
	05-28-80	7.3	32	350	430
FR-37------	11-13-79	7.1	48	312	380
	05-23-80	7.2	34	300	370
FR-38------	05-29-80	7.5	12	290	350
FR-39------	04-24-75	7.4	23	292	356
FR-40------	04-17-75	7.4	28	359	438
FR-41------	04-24-75	7.4	30	390	476
	05-20-80	7.1	62	400	490
FR-42------	04-14-75	7.4	24	312	380
FR-44------	04-18-75	7.5	12	195	238
FR-46------	05-20-80	7.3	26	330	400
FR-47------	04-15-75	7.4	24	315	384
FR-48------	11-14-79	6.8	101	328	400
	05-23-80	7.2	41	350	430
FR-49------	04-14-75	7.2	40	328	400
FR-52------	04-24-75	7.4	24	308	376
	05-23-80	7.4	21	310	380
FR-53------	04-17-75	7.4	18	231	282
FR-56------	04-28-75	7.5	23	376	458
FR-70------	04-10-75	7.8	7.1	228	278
FR-73------	05-29-80	7.4	19	340	410
FR-74------	11-21-79	7.0	85	435	530
	05-27-80	7.3	25	360	440
FR-100P3---	06-04-75	7.2	37	299	364
	06-12-75	7.5	18	295	360
	11-19-79	7.1	58	377	460
	05-27-80	7.1	29	310	380
FR-101-----	05-06-75	7.4	22	287	350
	08-27-75	6.8	113	364	444
	11-15-79	7.8	8.4	271	330
	05-28-80	7.4	17	320	390
FR-103-----	12-11-74	7.0	71	366	446
	12-20-74	7.2	42	340	414
FR-104-----	04-02-75	7.4	25	328	400
	08-26-75	7.2	40	328	400
	08-29-75	6.8	97	315	384
	11-19-79	7.6	9.6	197	240
	05-27-80	8.2	2.1	200	240
FR-106-----	02-07-75	7.3	31	322	392
	02-12-75	7.2	40	325	396
FR-109-----	08-28-75	6.8	106	341	416
	06-13-78	7.4	27	349	425
FR-115-----	07-06-76	7.3	31	320	390
	07-08-76	7.2	39	320	390
	11-20-79	7.0	67	344	420
	05-28-80	7.3	24	350	430
FR-145-----	05-29-80	7.5	15	280	340
FR-146-----	05-29-80	7.4	17	330	400
PK-42------	04-23-75	7.4	29	369	450

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Nitrogen, dissolved (mg/L as N)	Nitrogen, organic, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)
FR-3-------	04-14-78	--	0.11	0.020
	05-28-80	3.9	ND	.010
FR-35------	04-22-75	--	--	--
FR-36------	04-16-75	--	--	--
	11-20-79	0.35	.26	.050
	05-28-80	.07	ND	.040
FR-37------	11-13-79	16	.15	.050
	05-23-80	21	.07	.040
FR-38------	05-29-80	.04	ND	.020
FR-39------	04-24-75	--	--	--
FR-40------	04-17-75	--	--	--
FR-41------	04-24-75	--	--	--
	05-20-80	--	--	--
FR-42------	04-14-75	--	--	--
FR-44------	04-18-75	--	--	--
FR-46------	05-20-80	.35	ND	.120
FR-47------	04-15-75	--	--	--
FR-48------	11-14-79	.12	.07	.030
	05-23-80	.19	.01	.050
FR-49------	04-14-75	--	--	--
FR-52------	04-24-75	--	--	--
	05-23-80	.12	.06	.040
FR-53------	04-17-75	--	--	--
FR-56------	04-28-75	--	--	--
FR-70------	04-10-75	--	--	--
FR-73------	05-29-80	.13	ND	.120
FR-74------	11-21-79	.30	.06	.220
	05-27-80	.34	ND	.250
FR-100P3---	06-04-75	--	--	--
	06-12-75	--	--	--
	11-19-79	.77	.47	.050
	05-27-80	.04	ND	.040
FR-101-----	05-06-75	--	--	--
	08-27-75	--	--	--
	11-15-79	.49	.15	.300
	05-28-80	.21	ND	.090
FR-103-----	12-11-74	--	--	--
	12-20-74	--	--	--
FR-104-----	04-02-75	--	--	--
	08-26-75	--	--	--
	08-29-75	--	--	--
	11-19-79	110	100	7.10
	05-27-80	.98	ND	1.10
FR-106-----	02-07-75	--	--	--
	02-12-75	--	--	--
FR-109-----	08-28-75	--	--	--
	06-13-78	--	--	--
FR-115-----	07-06-76	--	--	--
	07-08-76	--	--	--
	11-20-79	.13	.05	.030
	05-28-80	.05	ND	.040
FR-145-----	05-29-80	.01	ND	<.01
FR-146-----	05-29-80	.07	ND	.060
PK-42------	04-23-75	--	--	--

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, nitrate, total (mg/L as N)	Nitrogen $NO_2 + NO_3$, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)
FR-3-------	04-14-78	--	--	3.7	--
	05-28-80	--	--	3.9	0.020
FR-35------	04-22-75	0.010	2.0	--	.080
FR-36------	04-16-75	<.010	0.04	--	.060
	11-20-79	--	--	0.04	--
	05-28-80	--	--	.03	<.01
FR-37------	11-13-79	--	--	16	.010
	05-23-80	--	--	21	<.01
FR-38------	05-29-80	--	--	.02	.010
FR-39------	04-24-75	.010	16	--	<.010
FR-40------	04-17-75	.010	3.4	--	.110
FR-41------	04-24-75	<.010	.01	--	.200
	05-20-80	--	.00	--	--
FR-42------	04-14-75	<.010	.09	--	<.010
FR-44------	04-18-75	<.010	.01	--	.010
FR-46------	05-20-80	--	--	.23	.030
FR-47------	04-15-75	<.010	8.6	--	.040
FR-48------	11-14-79	--	--	.02	.010
	05-23-80	--	--	.13	.010
FR-49------	04-14-75	.010	.01	--	.050
FR-52------	04-24-75	.010	<.01	--	<.010
	05-23-80	--	--	.02	.010
FR-53------	04-17-75	<.010	9.8	--	.010
FR-56------	04-28-75	.020	.23	--	.010
FR-70------	04-10-75	.010	.73	--	.030
FR-73------	05-29-80	--	--	.01	.010
FR-74------	11-21-79	--	--	.02	--
	05-27-80	--	--	.09	.010
FR-100P3---	06-04-75	.010	.09	--	.070
	06-12-75	.020	.30	--	.030
	11-19-79	--	--	.25	--
	05-27-80	--	--	<.01	.170
FR-101-----	05-26-75	.010	<.01	--	.010
	08-27-75	<.010	.01	--	.010
	11-15-79	--	--	.04	.050
	05-28-80	--	--	.12	.010
FR-103-----	12-11-74	<.010	.02	--	.010
	12-20-74	.010	.17	--	.010
FR-104-----	04-02-75	.010	<.01	--	.330
	08-26-75	.010	.04	--	.030
	08-29-75	.020	.35	--	.010
	11-19-79	--	--	.02	--
	05-27-80	--	--	.01	.040
FR-106-----	02-07-75	.030	1.3	--	.100
	02-12-75	<.010	.03	--	.010
FR-109-----	08-28-75	<.010	.01	--	.010
	06-13-78	--	--	--	<.010
FR-115-----	07-06-76	.010	.02	--	.580
	07-08-76	.020	.02	--	.080
	11-20-79	--	--	.05	--
	05-28-80	--	--	.01	.030
FR-145-----	05-29-80	--	--	.00	.010
FR-146-----	05-29-80	--	--	.01	.010
PK-42------	04-23-75	.080	2.1	--	.530

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
FR-3-------	04-14-78	340	65	90	29	2.0
	05-28-80	380	94	100	32	2.1
FR-35------	04-22-75	460	130	120	38	22
FR-36------	04-16-75	410	96	110	33	3.7
	11-20-79	440	87	120	34	5.5
	05-28-80	390	60	100	34	4.4
FR-37------	11-13-79	420	110	110	36	3.8
	05-23-80	450	170	120	37	5.0
FR-38------	05-29-80	300	100	79	26	2.7
FR-39------	04-24-75	410	120	110	34	6.6
FR-40------	04-17-75	440	76	110	39	52
FR-41------	04-24-75	400	8	100	36	5.0
	05-20-80	430	25	110	37	--
FR-42------	04-14-75	370	62	100	30	3.7
FR-44------	04-18-75	230	38	62	19	13
FR-46------	05-20-80	470	200	120	41	4.7
FR-47------	04-15-75	370	50	100	28	6.8
FR-48------	11-14-79	380	55	99	33	7.4
	05-23-80	460	130	120	38	6.9
FR-49------	04-14-75	430	99	110	37	4.7
FR-52------	04-24-75	420	110	110	35	5.9
	05-23-80	360	88	94	30	5.0
FR-53------	04-17-75	280	47	75	22	17
FR-56------	04-28-75	370	ND	98	31	8.0
FR-70------	04-10-75	250	22	64	22	3.1
FR-73------	05-29-80	370	130	95	33	14
FR-74------	11-21-79	340	0	88	28	4.8
	05-27-80	310	53	81	27	4.6
FR-100P3---	06-04-75	390	87	110	27	5.4
	06-12-75	380	82	110	25	5.9
	11-19-79	350	ND	94	28	5.7
	05-27-80	360	170	96	30	6.1
FR-101-----	05-06-75	460	180	120	40	14
	08-27-75	580	220	140	56	21
	11-15-79	350	79	97	26	9.4
	05-28-80	380	160	100	32	7.2
FR-103-----	12-11-74	470	100	120	41	18
	12-20-74	440	100	110	40	10
FR-104-----	04-02-75	390	66	100	35	10
	08-26-75	400	74	100	37	7.2
	08-29-75	380	68	104	30	6.9
	11-19-79	270	75	56	32	17
	05-27-80	200	34	24	35	19
FR-106-----	02-07-75	450	130	110	42	5.7
	02-12-75	450	130	120	37	6.0
FR-109-----	08-28-75	380	37	92	36	3.9
	06-13-78	350	5	92	30	4.1
FR-115-----	07-06-76	360	36	93	30	2.0
	07-08-76	420	100	110	36	1.0
	11-20-79	420	74	110	35	2.5
	05-28-80	380	130	99	33	2.4
FR-145-----	05-29-80	360	110	91	31	3.4
FR-146-----	05-29-80	360	140	92	32	14
PK-42------	04-23-75	380	12	100	32	3.0

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Sodium adsorption ratio	Percent sodium	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)
FR-3-------	04-14-78	.0	1	2.1	8.3	63
	05-28-80	.0	1	1.7	11	58
FR-35------	04-22-75	.4	9	20	42	140
FR-36------	04-16-75	.1	2	1.1	12	73
	11-20-79	.1	4	1.4	18	95
	05-28-80	.1	2	1.3	15	88
FR-37------	11-13-79	.1	2	1.7	38	66
	05-23-80	.1	2	1.5	41	62
FR-38------	05-29-80	.1	2	1.2	5.8	49
FR-39------	04-24-75	.1	3	6.7	30	64
FR-40------	04-17-75	1.1	20	4.2	66	97
FR-41------	04-24-75	.1	3	0.9	4.7	28
	05-20-80	--	--	--	4.0	34
FR-42------	04-14-75	.1	2	1.2	18	66
FR-44------	04-18-75	.4	11	.6	7.6	58
FR-46------	05-20-80	.1	2	1.5	50	140
FR-47------	04-15-75	.2	4	8.6	4.9	38
FR-48------	11-14-79	.2	4	1.1	11	92
	05-23-80	.1	3	1.0	11	90
FR-49------	04-14-75	.1	2	1.4	11	94
FR-52------	04-24-75	.1	3	1.3	13	98
	05-23-80	.1	3	1.1	10	95
FR-53------	04-17-75	.4	11	16	22	37
FR-56------	04-28-75	.2	4	1.6	5.9	21
FR-70------	04-10-75	.1	3	3.8	5.1	17
FR-73------	05-29-80	.3	7	2.7	4.2	56
FR-74------	11-21-79	.1	5	1.0	5.2	27
	05-27-80	.1	3	1.0	3.0	23
FR-100P3---	06-04-75	.1	3	1.1	16	88
	06-12-75	.1	3	1.2	17	99
	11-19-79	.1	5	1.0	17	100
	05-27-80	.1	4	.9	16	100
FR-101-----	05-06-75	.3	6	1.7	32	180
	08-27-75	.4	7	2.8	27	240
	11-15-79	.2	5	3.3	17	91
	05-28-80	.2	4	1.2	18	97
FR-103-----	12-11-74	.4	8	1.3	40	120
	12-20-74	.2	5	1.2	25	98
FR-104-----	04-02-75	.2	5	1.4	25	72
	08-26-75	.2	4	1.2	16	63
	08-29-75	.2	4	1.2	19	72
	11-19-79	.4	20	3.4	36	22
	05-27-80	.6	17	1.4	43	11
FR-106-----	02-07-75	.1	3	1.8	57	81
	02-12-75	.1	3	2.0	40	76
FR-109-----	08-28-75	.1	2	1.2	2.6	29
	06-13-78	.1	2	1.3	2.4	31
FR-115-----	07-06-76	.0	1	1.1	8.7	84
	07-08-76	.0	1	1.1	9.1	91
	11-20-79	.1	2	.9	14	82
	05-28-80	.1	1	.9	13	85
FR-145-----	05-29-80	.1	2	1.1	14	100
FR-146-----	05-29-80	.3	8	.9	64	33
PK-42------	04-23-75	.1	2	12	7.6	34

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Arsenic, dissolved (µg/L as As)	Arsenic, total (µg/L as As)	Cadmium, dissolved (µg/L as Cd)
FR-3-------	04-14-78	0.1	12	--	--	--
	05-28-80	.2	12	--	--	--
FR-35------	04-22-75	.4	12	--	1	--
FR-36------	04-16-75	.3	14	--	13	--
	11-20-79	.3	14	--	--	--
	05-28-80	.3	11	14	--	4
FR-37------	11-13-79	.2	11	--	--	--
	05-23-80	.2	12	--	--	--
FR-38------	05-29-80	.2	13	--	--	--
FR-39------	04-24-75	.2	11	--	4	--
FR-40------	04-17-75	.4	11	--	<1	--
FR-41------	04-24-75	.4	20	--	30	--
	05-20-80	.4	--	--	--	--
FR-42------	04-14-75	.1	14	--	3	--
FR-44------	04-18-75	.1	7.7	--	1	--
FR-46------	05-20-80	.3	12	4	--	1
FR-47------	04-15-75	.3	10	--	1	--
FR-48------	11-14-79	.3	12	--	--	--
	05-23-80	.3	--	--	--	--
FR-49------	04-14-75	.2	12	--	13	--
FR-52------	04-24-75	.4	13	--	1	--
	05-23-80	.4	13	--	--	--
FR-53------	04-17-75	.2	8.6	--	<1	--
FR-56------	04-28-75	.3	18	--	21	--
FR-70------	04-10-75	.2	9.3	--	3	--
FR-73------	05-29-80	.4	11	--	--	--
FR-74------	11-21-79	.4	16	--	--	--
	05-27-80	.4	14	13	--	8
FR-100P3---	06-04-75	.2	12	--	9	--
	06-12-75	.2	11	--	1	--
	11-19-79	.3	11	--	--	--
	05-27-80	.3	12	4	--	3
FR-101-----	05-06-75	.6	12	--	--	--
	08-27-75	1.4	14	--	<1	--
	11-15-79	.3	8.6	--	--	--
	05-28-80	.5	12	5	--	2
FR-103-----	12-11-74	.7	14	--	--	--
	12-20-74	.6	14	--	--	--
FR-104-----	04-02-75	.6	13	--	--	--
	08-26-75	.5	13	--	3	--
	08-29-75	.5	13	--	2	--
	11-19-79	.3	6.9	--	--	--
	05-27-80	.3	1.8	3	--	3
FR-106-----	02-07-75	.2	12	--	--	--
	02-12-75	.2	12	--	--	--
FR-109-----	08-28-75	.4	15	--	6	--
	06-13-78	.3	15	--	--	--
FR-115-----	07-06-76	.4	14	--	3	--
	07-08-76	.3	14	--	2	--
	11-20-79	.3	14	--	--	--
	05-28-80	.3	12	6	--	<1
FR-145-----	05-29-80	.2	10	--	--	--
FR-146-----	05-29-80	.3	11	4	--	2
PK-42------	04-23-75	.3	8.6	--	3	--

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Chromium, dissolved (µg/L as Cr)	Chromium, total recoverable (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Copper, total recoverable (µg/L as Cu)	Iron, dissolved (µg/L as Fe)
FR-3-------	04-14-78	--	--	--	--	170
	05-28-80	--	--	--	--	430
FR-35------	04-22-75	--	ND	--	ND	40
FR-36------	04-16-75	--	<20	--	ND	2,200
	11-20-79	--	--	--	--	2,900
	05-28-80	<10	--	ND	--	2,200
FR-37------	11-13-79	--	--	--	--	20
	05-23-80	--	--	--	--	80
FR-38------	05-29-80	--	--	--	--	710
FR-39------	04-24-75	--	<20	--	<20	30
FR-40------	04-17-75	--	<20	--	<20	20
FR-41------	04-24-75	--	ND	--	ND	3,200
	05-20-80	--	--	--	--	--
FR-42------	04-14-75	--	ND	--	ND	230
FR-44------	04-18-75	--	<20	--	ND	40
FR-46------	05-20-80	<10	--	1	--	1,600
FR-47------	04-15-75	--	ND	--	ND	40
FR-48------	11-14-79	--	--	--	--	20
	05-23-80	--	--	--	--	50
FR-49------	04-14-75	--	ND	--	ND	2,000
FR-52------	04-24-75	--	<20	--	ND	2,300
	05-23-80	--	--	--	--	1,700
FR-53------	04-17-75	--	ND	--	ND	30
FR-56------	04-28-75	--	ND	--	<20	1,400
FR-70------	04-10-75	--	ND	--	ND	<10
FR-73------	05-29-80	--	--	--	--	1,600
FR-74------	11-21-79	--	--	--	--	3,800
	05-27-80	10	--	ND	--	3,900
FR-100P3---	06-04-75	--	20	--	40	1,200
	06-12-75	--	20	--	30	990
	11-19-79	--	--	--	--	1,100
	05-27-80	10	--	ND	--	1,600
FR-101-----	05-06-75	--	--	--	--	1,100
	08-27-75	--	<20	--	<20	160
	11-15-79	--	--	--	--	2,500
	05-28-80	10	--	ND	--	960
FR-103-----	12-11-74	--	--	--	--	240
	12-20-74	--	--	--	--	470
FR-104-----	04-02-75	--	--	--	--	1,200
	08-26-75	--	<20	--	<20	1,500
	08-29-75	--	<20	--	<20	1,300
	11-19-79	--	--	--	--	710
	05-27-80	10	--	ND	--	250
FR-106-----	02-07-75	--	--	--	--	2,100
	02-12-75	--	--	--	--	1,400
FR-109-----	08-28-75	--	<20	--	<20	3,400
	06-13-78	--	--	--	--	<10
FR-115-----	07-06-76	--	<20	--	ND	2,400
	07-08-76	--	<20	--	ND	2,500
	11-20-79	--	--	--	--	3,500
	05-28-80	10	--	ND	--	3,400
FR-145-----	05-29-80	--	--	--	--	1,500
FR-146-----	05-29-80	<10	--	ND	--	1,600
PK-42------	04-23-75	--	<20	--	ND	270

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Lead, dissolved (µg/L as Pb)	Lead, total recoverable (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Zinc, dissolved (µg/L as Zn)	Zinc, total recoverable (µg/L as Zn)	Selenium, dissolved (µg/L as Se)
FR-3-------	04-14-78	--	--	<10	--	--	--
	05-28-80	--	--	5	--	--	--
FR-35------	04-22-75	--	9	30	--	610	--
FR-36------	04-16-75	--	8	50	--	320	--
	11-20-79	--	--	80	--	--	--
	05-28-80	<1	--	80	580	--	ND
FR-37------	11-13-79	--	--	6	--	--	--
	05-23-80	--	--	5	--	--	--
FR-38------	05-29-80	--	--	50	--	--	--
FR-39------	04-24-75	--	3	<10	--	210	--
FR-40------	04-17-75	--	10	<10	--	960	--
FR-41------	04-24-75	--	10	60	--	290	--
	05-20-80	--	--	--	--	--	--
FR-42------	04-14-75	--	<2	140	--	250	--
FR-44------	04-18-75	--	<2	20	--	460	--
FR-46------	05-20-80	<1	--	230	20	--	ND
FR-47------	04-15-75	--	9	20	--	120	--
FR-48------	11-14-79	--	--	50	--	--	--
	05-23-80	--	--	10	--	--	--
FR-49------	04-14-75	--	28	140	--	1,900	--
FR-52------	04-24-75	--	<2	80	--	130	--
	05-23-80	--	--	50	--	--	--
FR-53------	04-17-75	--	<2	<10	--	80	--
FR-56------	04-28-75	--	<2	150	--	90	--
FR-70------	04-10-75	--	<2	20	--	130	--
FR-73------	05-29-80	--	--	150	--	--	--
FR-74------	11-21-79	--	--	30	--	--	--
	05-27-80	<1	--	30	20	--	ND
FR-100P3---	06-04-75	--	4	80	--	60	--
	06-12-75	--	3	80	--	20	--
	11-19-79	--	--	80	--	--	--
	05-27-80	<1	--	70	6	--	ND
FR-101-----	05-06-75	--	--	60	--	--	--
	08-27-75	--	4	30	--	20	--
	11-15-79	--	--	190	--	--	--
	05-28-80	<1	--	60	10	--	ND
FR-103-----	12-11-74	--	--	50	--	--	--
	12-20-74	--	--	50	--	--	--
FR-104-----	04-02-75	--	--	70	--	--	--
	08-26-75	--	<2	50	--	2,200	--
	08-29-75	--	5	50	--	60	--
	11-19-79	--	--	170	--	--	--
	05-27-80	<1	--	70	ND	--	ND
FR-106-----	02-07-75	--	--	80	--	--	--
	02-12-75	--	--	80	--	--	--
FR-109-----	08-28-75	--	5	30	--	20	--
	06-13-78	--	--	30	--	--	--
FR-115-----	07-06-76	--	<2	60	--	80	--
	07-08-76	--	2	60	--	20	--
	11-20-79	--	--	70	--	--	--
	05-28-80	<1	--	70	ND	--	ND
FR-145-----	05-29-80	--	--	40	--	--	--
FR-146-----	05-29-80	<1	--	140	70	--	ND
PK-42------	04-23-75	--	8	70	--	140	--

Table 2.--Water-quality analyses of ground water from sites in southern Franklin County, Ohio--Continued

Well number	Date of sample	Mercury, dis-solved (µg/L as Hg)	Phenols (µg/L)	Solids, residue at 180 deg. C, dis-solved (mg/L)	Solids, sum of consti-tuents, dis-solved (mg/L)	Solids, dis-solved (tons per ac-ft)
FR-3-------	04-14-78	--	<1	--	391	0.53
	05-28-80	--	1	413	407	.56
FR-35------	04-22-75	--	--	--	592	.81
FR-36------	04-16-75	--	--	--	439	.60
	11-20-79	--	--	505	503	.69
	05-28-80	<0.1	1	531	455	.72
FR-37------	11-13-79	--	--	423	525	.58
	05-23-80	--	--	619	540	.84
FR-38------	05-29-80	--	1	375	298	.51
FR-39------	04-24-75	--	--	--	438	.60
FR-40------	04-17-75	--	--	--	596	.81
FR-41------	04-24-75	--	--	--	433	.59
	05-20-80	--	--	--	--	--
FR-42------	04-14-75	--	--	--	421	.57
FR-44------	04-18-75	--	--	--	285	.39
FR-46------	05-20-80	<.1	<1	553	535	.75
FR-47------	04-15-75	--	--	--	386	.53
FR-48------	11-14-79	--	--	575	453	.78
	05-23-80	--	--	458	466	.62
FR-49------	04-14-75	--	--	--	470	.64
FR-52------	04-24-75	--	--	--	464	.63
	05-23-80	--	--	538	413	.73
FR-53------	04-17-75	--	--	--	337	.46
FR-56------	04-28-75	--	--	--	411	.56
FR-70------	04-10-75	--	--	--	262	.36
FR-73------	05-29-80	--	1	469	362	.64
FR-74------	11-21-79	--	--	370	436	.50
	05-27-80	<.1	1	337	315	.46
FR-100P3---	06-04-75	--	--	--	440	.60
	06-12-75	--	--	--	448	.60
	11-19-79	--	--	419	486	.57
	05-27-80	.1	1	513	377	.70
FR-101-----	05-06-75	--	--	--	574	.78
	08-27-75	--	--	--	721	.98
	11-15-79	--	--	459	418	.62
	05-28-80	.2	1	455	402	.62
FR-103-----	12-11-74	--	--	--	575	.78
	12-20-74	--	--	--	503	.68
FR-104-----	04-02-75	--	--	--	455	.62
	08-26-75	--	--	--	437	.59
	08-29-75	--	--	--	437	.61
	11-19-79	--	--	306	293	.42
	05-27-80	.1	<1	297	238	.40
FR-106-----	02-07-75	--	--	--	505	.69
	02-12-75	--	--	--	490	.67
FR-109-----	08-28-75	--	--	--	389	.53
	06-13-78	--	--	372	386	.51
FR-115-----	07-06-76	--	--	--	428	.58
	07-08-76	--	--	--	457	.62
	11-20-79	--	--	421	469	.57
	05-28-80	<.1	2	479	399	.65
FR-145-----	05-29-80	--	<1	527	403	.72
FR-146-----	05-29-80	<.1	<1	533	381	.72
PK-42------	04-23-75	--	--	--	420	.57

Table 3.--Water-quality analyses of water from streams in southern Franklin County, Ohio

Constituent or property	Scioto River: At site 101 near Columbus		Scioto River: At I-270 at Columbus		Scioto River: Below sewage treatment plant		Big Walnut Creek at Reese	
	11/20/79	05/19/80	11/20/79	05/19/80	11/20/79	05/19/80	11/13/79	05/20/80
Time	1200	1625	1030	1310	0900	1010	1330	1015
Temperature, water (°C)	12.5	18.5	11.0	18.0	10.0	17.5	7.0	17.5
Temperature, air (°C)	22.0	24.0	19.5	22.5	18.0	24.0	4.5	23.0
Turbidity (FTU)	0.00	1.6	1.0	0.50	1.0	0.50	6.0	2.8
Specific conductance (µmho/cm)	895	550	850	550	830	550	470	400
Oxygen demand, biochemical, 5-day (mg/L)	--	6.6	--	7.9	--	5.9	--	3.4
Oxygen demand, chemical (high level) (mg/L)	--	27	--	20	--	19	--	34
Coliform, fecal, 0.7 UM-MF (cols./100 ml)	K7	K20000	K10	K21000	K17	K24000	340	3300
Streptococci, fecal, KF agar (cols./100 ml)	K7	K8600	83	K80000	K30	K12000	E1	2700
Carbon, organic, total (mg/L as C)	6.9	4.6	8.0	4.3	7.8	3.7	6.3	8.1
pH (units)	7.5	8.0	7.4	7.9	7.3	8.0	7.4	7.4
Carbon dioxide, dissolved (mg/L as CO_2)	13	2.7	16	3.4	21	2.9	10	8.5
Alkalinity (mg/L as $CaCO_3$)	213	160	205	160	213	160	131	120
Bicarbonate, FET-FLD (mg/L as HCO_3)	260	190	250	190	260	200	160	150
Nitrogen, dissolved (mg/L as N)	5.1	4.1	5.1	3.8	4.6	3.2	2.0	6.9
Nitrogen, organic, dissolved (mg/L as N)	.70	0.71	0.80	.64	0.81	.48	0.69	0.84
Nitrogen, ammonia, dissolved (mg/L as N)	1.10	.210	1.40	.250	.890	.260	.020	.160
Nitrogen, ammonia + organic, dissolved (mg/L as N)	1.8	.92	2.2	.89	1.7	.74	.71	1.0
Nitrogen, ammmonia + organic, suspended total (mg/L as N)	--	.06	--	.00	--	.03	.00	.20
Nitrogen, nitrite + nitrate, dissolved (mg/L as N)	3.3	3.2	2.9	2.9	2.9	2.5	1.3	5.9

Table 3.--Water-quality analyses of water from streams in southern Franklin County, Ohio--Continued

Constituent or property	Scioto River: At site 101 near Columbus 11/20/79	Scioto River: At site 101 near Columbus 05/19/80	Scioto River: At I-270 at Columbus 11/20/79	Scioto River: At I-270 at Columbus 05/19/80	Scioto River: Below sewage treatment plant 11/20/79	Scioto River: Below sewage treatment plant 05/19/80	Big Walnut Creek at Reese 11/13/79	Big Walnut Creek at Reese 05/20/80
Phosphorus, dissolved (mg/L as P)	0.750	0.220	0.810	0.240	0.690	0.160	0.060	0.100
Phosphorus, total (mg/L as P)	--	.320	--	.360	--	.240	.100	.200
Phosphorus, total (mg/L as PO_4)	--	.98	--	1.1	--	.74	.31	.61
Hardness (mg/L as $CaCO_3$)	310	220	320	240	300	230	190	170
Hardness, noncarbonate (mg/L as $CaCO_3$)	94	79	110	97	87	82	55	63
Calcium, dissolved (mg/L as Ca)	82	58	85	62	79	60	50	46
Magnesium, dissolved (mg/L as Mg)	25	18	26	20	25	20	15	14
Sodium, dissolved (mg/L as Na)	33	20	33	20	30	19	14	16
Sodium adsorption ratio	.8	.6	.8	.6	.8	.5	.4	.5
Percent sodium	25	16	18	15	24	15	14	17
Potassium, dissolved (mg/L as K)	4.5	2.8	4.6	2.7	4.2	2.4	3.3	2.6
Chloride, dissolved (mg/L as Cl)	49	28	48	30	47	28	23	25
Sulfate, dissolved (mg/L as SO_4)	100	73	110	80	97	78	50	51
Fluoride, dissolved (mg/L as F)	.5	.3	.6	.3	.5	.3	.2	.2
Silica, dissolved (mg/L as SiO_2)	5.6	4.9	5.8	4.0	4.7	5.1	5.3	7.2
Arsenic, dissolved (µg/L as As)	--	--	--	4	--	--	--	4
Cadmium, dissolved (µg/L as Cd)	--	--	--	4	--	--	--	2
Chromium, dissolved (µg/L as Cr)	--	--	--	10	--	--	--	10
Copper, dissolved (µg/L as Cu)	--	--	--	6	--	--	--	5
Iron, dissolved (µg/L as Fe)	30	320	30	210	30	240	50	160
Lead, dissolved (µg/L as Pb)	--	--	--	2	--	--	--	ND

Table 3.--Water-quality analyses of water from streams in southern Franklin County, Ohio--Continued

Constituent or property	Scioto River						Big Walnut Creek at Reese	
	At site 101 near Columbus		At I-270 at Columbus		Below sewage treatment plant			
	11/20/79	05/19/80	11/20/79	05/19/80	11/20/79	05/19/80	11/13/79	05/20/80
Manganese, dissolved (µg/L as Mn)--------------	20	30	30	30	20	20	40	30
Zinc, dissolved (µg/L as Zn) -------------	--	--	--	10	--	--	--	10
Selenium, dissolved (µg/L as Se)--------------	--	--	--	ND	--	--	--	ND
Mercury, dissolved (µg/L as Hg)--------------	--	--	--	0.1	--	--	--	0.1
Phenols (µg/L)--------------	--	1	--	3	--	2	--	ND
Solids, residue at 180°C, dissolved (mg/L)----------	475	374	480	368	454	358	266	284
Solids, sum of constituents, dissolved (mg/L)----------	444	304	449	316	429	314	246	254
Solids, dissolved (tons per ac-ft)--------------------	0.65	0.51	0.65	.50	0.62	0.49	0.36	.39
Drainage area (sq. miles)---	--	--	--	--	--	--	544	544

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