GEOHYDROLOGY AND QUALITY OF WATER IN AQUIFERS IN LUCAS, SANDUSKY, AND WOOD COUNTIES, NORTHWESTERN OHIO

By Kevin J. Breen and Denise H. Dumouchelle

U.S. GEOLOGICAL SURVEY

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MEMORANDUM

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SUBJECT: ADDENDUM--"Geohydrology and Quality of Water in Aquifers in Lucas, Sandusky, and Wood Counties, Northwestern Ohio," by Kevin J. Breen and Denise H. Dumouchelle (WRIR 91-4024)

The following errors are noted for the above-mentioned report:

1. On figure 48, the first line of the note at the top of the figure should read: "Results for well S-231-RL36 are not shown."

2. On figure 10, the shade patterns for sand and glacial till are reversed in the explanation.

Richard P. Frehs

RPF/ldc

cc: Denise H. Dumouchelle, Hydrologist, USGS-WRD, Columbus, OH
Kevin J. Breen, Supervisory Hydrologist, USGS-WRD, Lemoyne, PA

#212

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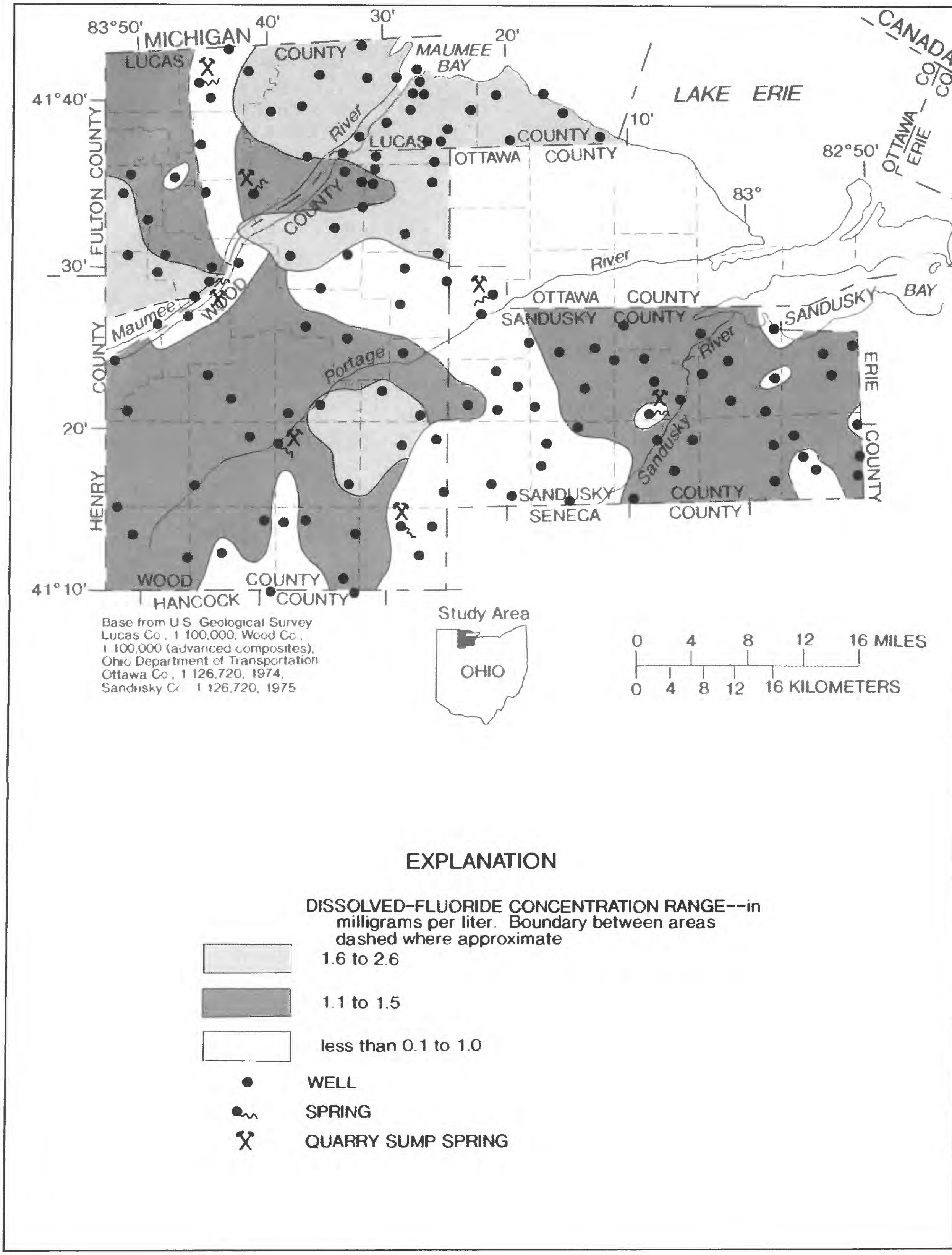

Figure 29.--Distributions of dissolved-fluoride concentrations in water from the carbonate aquifer.

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter
foot per second (ft/s)	0.3048	meter per second
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
foot squared per day (ft^2/d)	0.0929	meter squared per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer
gallon per minute (gal/min)	0.06308	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day
gallon per day per square mile [$(gal/d)/mi^2$]	9.803	liter per day per square kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second

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

$$°C = (°F - 32)/1.8$$

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

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GLOSSARY

The following are definitions of selected technical terms as they are used in this report; they are not necessarily the only valid definitions for these terms. Terms defined in the glossary are in **bold print** where first used in the main body of this report.

Alluvium.--General term for deposits of clay, silt, sand, gravel, or other particulate rock material laid down by a river in a streambed, on a flood plain, or on a delta.

Alpha particles.--The nucleus of a helium atom ejected from a radioactive nucleus when it disintegrates. They can penetrate matter for only a short distance and are usually a health hazard only when radioactive material emitting alpha particles has been ingested or otherwise absorbed into the body.

Anion.--Ion that has a negative electrical charge; for example, nitrate and chloride ions are anions.

Annular space (annulus).--The space between casing or well screen and the wall of a drilled hole.

Anthropogenic.--Related to or originating from human activities.

Aquifer.--A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquifer system.--A heterogeneous layered body of aquifers and confining units that functions regionally as a hydraulic unit; it comprises two or more aquifers separated at least locally by confining unit(s) that impede ground-water movement but do not greatly affect the regional hydraulic continuity of the system.

Aquifer test.--A test to determine hydrologic properties of the aquifer involving the withdrawal of measured quantities of water from or addition of water to a well and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or additions.

Argillaceous.--Geologic materials comprised by a notable proportion of clay.

Artesian.--Synonymous with confined when referring to aquifers.

Artesian spring.--"An artesian spring is one whose water issues under artesian pressure generally through some fissure or other opening in the confining bed that overlies the aquifer. Such springs, by definition, occur only in areas of artesian flow, where the potentiometric surface is above the land surface." (Meinzer, 1923, p. 51)

Artesian well.--Well tapping a confined aquifer in which the static water level is above the top of the aquifer; a flowing artesian well is a well in which the water level is above the land surface.

Bacteria.--Microscopic unicellular organisms, typically spherical, rodlike, or spiral and threadlike in shape, often clumped into colonies. Some bacteria cause disease; others perform an essential role in nature in the recycling of materials, for example, by decomposing organic matter into a form available for reuse by plants.

Baseline monitoring.--The establishment and operation of a designed surveillance system for continuous or periodic measurements and recording of existing and changing conditions that will be compared with future observations.

Bedding plane.--A plane that separates two strata of differing characteristics.

Bedrock.--General term for consolidated (solid) rock that underlies soils or other unconsolidated material.

Beta particles.--Electrons emitted by the nucleus of a radioactive atom when it disintegrates. They may have high or low energies but are generally only moderately penetrative. Although they dissipate their energies relatively quickly, they may represent an external as well as an internal health hazard.

Bimodal.--A frequency distribution that has two maxima.

Brine.--Water that contains more than 35,000 milligrams per liter of dissolved solids. See also Saline water.

Buried valley.--Valley incised into bedrock, filled, and covered with unconsolidated deposits.

Cation.--Ion that has a positive electrical charge; for example, sodium and calcium ions are cations.

Censored data.--A set of data that is comprised, in part, by values shown as less than the level of detection of the measurement.

Coliform group.--Group of several types of bacteria that are found in the alimentary tract of warm-blooded animals. The bacteria are often used as an indicator of animal and human fecal contamination of water.

Confined.--A modifier which describes a condition in which the potentiometric surface is above the top of the aquifer.

Confined aquifer.--Aquifer in which ground water is confined under pressure that is significantly greater than atmospheric pressure. Synonym: Artesian aquifer.

Confining unit.--Layer of rock having very low hydraulic conductivity that hampers the movement of water into and out of an adjoining aquifer.

Contamination.--Degradation of water quality as a result of human activity.

Crop out.--To appear exposed and visible at the Earth's surface. See also Outcrop.

Detection limit.--The minimum concentration of a substance that can be identified, measured, and reported with 99 percent confidence that the concentration is greater than zero.

Dewatering.--Removing or draining water from a streambed, caisson, mine shaft, quarry, or aquifer by pumping.

Discharge area (ground water).--An area in which subsurface water, including water in the unsaturated or saturated zone, is discharged to the land surface, to surface water, or to the atmosphere.

Dissolved solids.--Minerals and organic matter dissolved in water.

Distribution.--A statistical frequency of occurrence of chemical concentration values or other data.

Domestic withdrawals.--Water used for normal household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. Also called residential water use. The water may be obtained from a public supply or may be self-supplied.

Drainage well.--A well installed to drain surface water, storm water, or treated waste water into underground strata.

Evapotranspiration.--Collective term that includes water discharged to the atmosphere as a result of evaporation from the soil and surface-water bodies and by plant transpiration.

Fecal coliform bacteria.--Bacteria that are present in the intestine or feces of warm-blooded animals. They are often used as indicators of the sanitary quality of the water. In the laboratory, they are defined as all organisms that produce blue colonies within 24 hours when incubated at 44.5 °C (degrees Celsius) ± 0.2 °C on M-FC medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL (milliliters) of sample.

Fecal streptococcal bacteria.--Bacteria that are present in the intestine of warm-blooded animals. Their presence in water is considered verification of fecal pollution. They are characterized as gram-positive, cocci bacteria that are capable of growth in brain-heart infusion broth. In the laboratory, they are defined as all the organisms that produce red or pink colonies within 48 hours at 35 °C ± 1.0 °C on KF-streptococcus medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL of sample.

Flow.--As used in this report, movement of water.

Flowing well.--A well tapping an aquifer where the potentiometric surface (water level) is above the land-surface elevation.

Formation.--The fundamental unit in rock-stratigraphic classification, consisting of a distinctive mappable body of rock.

Fracture.--A break in rock units due to structural stresses. Fractures may exist as faults, joints, and planes of fracture cleavage.

Freshwater.--Water that contains less than 1,000 mg/L (milligrams per liter) of dissolved solids; generally more than 500 mg/L is undesirable for drinking and many industrial uses.

Glacial drift.--A general term applied to all materials transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. Includes unstratified material (till) and stratified material.

Ground-water basin.--A general term used to define a ground-water-flow system that has defined boundaries and may include permeable materials that are capable of storing or furnishing a significant water supply; the basin includes both the surface area and the permeable materials beneath it.

Ground-water divide.--Ridge in the water table or other potentiometric surface; ground water moves in both directions normal to the divide. See also Potentiometric surface and Water table.

Gypsum.--A natural hydrated calcium sulfate, $CaSO_4 \cdot 2H_2O$. A common evaporite mineral used in the manufacture of plaster of paris and wallboard.

Hardness (water).--A property of water that causes the formation of an insoluble residue when the water is used with soap and a scale in vessels in which water has been allowed to evaporate. It is due primarily to the presence of ions of calcium and magnesium. Generally expressed as milligrams per liter as calcium carbonate ($CaCO_3$). A general hardness scale (Hem, 1985, p. 159) is:

Description	Hardness concentration in milligrams per liter as $CaCO_3$
Soft	0- 60
Moderately hard	61-120
Hard	121-180
Very hard	More than 180

Health Advisory Level.--Guidance contaminant levels that would not result in adverse health effects over specified short time periods for most people.

Hydraulic gradient.--Slope of the potentiometric surface or water table.

Hydrograph.--A graph relating stage, flow, velocity, or other characteristics of water with respect to time.

Impermeable.--A characteristic of some geologic material that limits its ability to transmit significant quantities of water under the head differences ordinarily found in the subsurface. No geologic material is entirely impermeable, but some are nearly impermeable.

Karst.--Type of topography that results from dissolution of limestone, dolomite, or gypsum beds and characterized by closed depressions or sinkholes, caves, and underground drainage.

Leaky aquifer.--Aquifers, whether artesian or water-table, that lose or gain water through adjacent less permeable layers.

Less-than values.--Analytical concentrations that are smaller than the detection limit for the measurement procedure. Designated in tables with a less-than symbol (<) preceding the detection-limit concentration.

Lithology.--The physical character (composition) of rocks.

MCL.--Maximum contaminant level established nationally by U.S. Environmental Protection Agency; maximum permissible level of a contaminant in water at the tap. Primary MCL's apply to public water supplies, are health-related, and are legally enforceable. The secondary MCL's (SMCL's) apply to contaminants in drinking water that chiefly affect the aesthetic qualities related to public acceptance of drinking water; SMCL's are intended as guidelines and are not enforceable.

Median.--The middle value in a series of ranked data--that is, there are an equal number of values greater than and less than the median. If the number of values is even, the median value is halfway between the two middle values.

Milliequivalent per unit.--Unit that expresses the chemical equivalence of ions or compounds by taking into account their formula weight and ionic charge or valence. The specific units include milligram-equivalents per kilogram if derived from parts per million, or milligram-equivalents per liter if derived from milligrams per liter.

Noncarbonate hardness.--That part of hardness in water in excess of its bicarbonate plus carbonate concentration or alkalinity.

Outcrop.--That part of a geologic unit exposed at the surface of the Earth.

Picocurie (pCi).--A picocurie is one-trillionth (1×10^{-12}) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7×10^{10} radioactive disintegrations per second. A picocurie yields 2.22 dpm (disintegrations per minute).

Potable water.--Water that is safe and palatable for human consumption.

Potentiometric surface.--An imaginary surface representing the static head of ground water in tightly cased wells that tap a water-bearing rock unit (aquifer); or, in the case of unconfined aquifers, the water table.

Public supply.--Water withdrawn by public and private water suppliers and delivered to groups of users. Public suppliers provide water for a variety of uses, such as domestic, commercial, industrial, and public water use.

Radioactivity.--The property of certain nuclides of spontaneously disintegrating, with emission of alpha or beta particles, or gamma radiation, or particulate and gamma radiation simultaneously. The most common types of ionizing radiation include alpha and beta particles, gamma rays, and X rays.

Radionuclide.--Species of atom that emits alpha, beta, or gamma rays for a measurable length of time. Individual radionuclides are distinguished by their atomic weight and atomic number.

Recharge (ground water).--Process of addition of water to the ground-water system by natural or artificial processes.

Recharge area (ground water).--An area over which recharge occurs.

Saline water.--Water that generally is considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids. Salinity is generally expressed as milligrams per liter of dissolved solids, with 35,000 milligrams per liter defined as seawater. A general salinity scale (Swenson and Baldwin, 1965) is:

Description	Dissolved solids concentration, in milligrams per liter
Slightly Saline	1,000- 3,000
Moderately Saline	3,000-10,000
Very Saline	10,000-35,000
Brine	More than 35,000

Sand-point well.--Well point installed by augering, driving, or water jetting to depths usually less than 25 feet in sand. Synonomous with drive-point well.

Semiconfined aquifer.--Aquifer that loses or gains water through an adjacent layer (or layers) of lower-permeability material. Same as leaky artesian aquifer.

Sinkhole.--General term for closed depressions. They may be basin, funnel, or cylindrical-shaped.

Sinking stream.--A small stream that disappears underground.

Solubility.--The total amount of solute species that will remain indefinitely in a solution maintained at constant temperature and pressure in contact with the solid crystals from which the solutes were derived.

Specific conductance.--A measure of the ability of water to conduct an electrical current, this is an index of dissolved mineral content. Generally, it is reported in units of microsiemens per centimeter at 25 °C (μS/cm).

Spring.--A discrete place where ground water flows naturally from a rock or the soil onto the land surface or into a body of surface water.

Stage.--Height of the water surface in a reservoir or a river above a predetermined point (may be on or near the channel floor). Used interchangeably with gage height.

Subcrop.--Areal limits of a buried rock unit at a surface of unconformity.

Surge block.--Device used as a plunger in the development of water wells.

Synoptic.--Displaying ground-water or surface-water conditions as they exist approximately simultaneously over a broad area.

Till.--Dominantly unsorted and unstratified drift, generally unconsolidated, deposited directly by and beneath a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.

Total coliform bacteria.--A particular group of bacteria that are used as indicators of possible sewage pollution. They are characterized as aerobic or facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35 °C. In the laboratory, these bacteria are defined as the organisms that produce colonies with a golden-green metallic sheen within 24 hours when incubated at 35 °C $\pm$ 1.0 °C on M-Endo medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL of sample.

Transmissivity.--The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. Expressed in units of feet squared per day (ft^2/d).

Tritium.--Hydrogen-3, the only known radioactive isotope of hydrogen found in nature. It has a half life of 12.3 years and disintegrates to form the stable isotope of helium-3. The quantity of tritium existing naturally is so small that its presence has no effect on the use of water.

Tritium unit (T.U.).--Concentration of tritium in water where 1 T.U. represents 1 tritium atom per 10^{18} atoms of ordinary hydrogen.

Unconfined aquifer.--Aquifer whose upper surface is a water table free to fluctuate.

Vein.--Term used by well drillers to describe sources of water to wells in carbonate rocks.

Volatile organic compounds (VOC's).--A group of lightweight, synthetic organic compounds, many of which are aromatic; sometimes referred to as "purgeable organic compounds" because of their low solubility in water.

Water table.--Top of the saturated zone in an unconfined aquifer. The water level in wells that penetrate the uppermost part of an unconfined aquifer marks the position of the water table.

Water year.--A continuous 12-month period selected to present data relative to hydrologic or meteorologic phenomena during which a complete annual hydrologic cycle normally takes place. The water year used by the U.S. Geological Survey runs from October 1 through September 30.

GEOHYDROLOGY AND QUALITY OF WATER IN AQUIFERS IN LUCAS, SANDUSKY, AND WOOD COUNTIES, NORTHWESTERN OHIO

by Kevin J. Breen and Denise H. Dumouchelle

ABSTRACT

The hydrology and quality of ground water were evaluated for the surficial sand and carbonate aquifers in northwestern Ohio. A locally important surficial sand aquifer in western Lucas County was evaluated on the basis of data from 10 wells completed in undeveloped and developed areas. The carbonate aquifer in Silurian and Devonian bedrock at its northernmost extent on the Ohio mainland was evaluated on the basis of data from previous studies and data from 466 wells and 11 springs. Most data are for the period 1985-88.

The unconfined surficial sand aquifer is less than 50 ft (feet) thick. Clay-rich drift, which restricts vertical movement of water, underlies the aquifer. Recharge is from precipitation, and discharge is by evapotranspiration and by flow to local streams and drainage ditches. Water levels are generally 2 to 8 ft below land surface and fluctuate a total of about 3.5 ft seasonally in a forested area. Concentrations of iron and manganese in ground water are excessive in some areas. Waters from shallow drive-point wells in residential areas contained larger concentrations of dissolved solids, hardness, sodium, and chloride than did waters from identical wells in undeveloped areas. The presence of nitrate nitrogen and other selected constituents in ground water in residential areas, and the absence of these constituents in ground water in undeveloped areas, indicate that the surficial sand aquifer has been affected by development.

In the carbonate aquifer, fractures, bedding-plane joints, and other secondary openings are the principal water-bearing zones. These zones can be areally and stratigraphically separated by low-permeability rock. Leaky artesian or semiconfined conditions predominate beneath most of the 1,400-mi^2 study area. The aquifer is confined by relatively impermeable underlying shale of Silurian age and overlying clay-rich drift of Quaternary age. Unproductive strata, including evaporites, within the sequence of carbonate rocks also confine some water-bearing zones.

The carbonate aquifer is part of a regional ground-water-flow system; however, subsystems such as the eastern karst and central outcrops are locally important. The potentiometric surface indicates that recharge from areas south and west of the study area flows toward discharge areas along major rivers (Maumee, Portage, and Sandusky), to a buried bedrock valley in central Sandusky County, and to springs and flowing wells. The potentiometric surface flattens markedly near the southern shore of Lake Erie, where ground-water levels approximate those of the

lake, indicating a hydraulic connection between the lake and the aquifer. Hydrogeologic characteristics and water-quality data indicate that Lake Erie is not a major source of recharge to the aquifer. Ground-water ages inferred from tritium concentrations and potentiometric-surface maps indicate that recharge from precipitation enters the aquifer by subsurface drainage in karstified strata in eastern Sandusky County and by infiltration in shallow bedrock areas where drift is less than 20 ft thick.

The quality of water in the carbonate aquifer is described with reference to 52 properties and constituents that characterize chemical, radiochemical, bacteriologic, and physical conditions. Ground-water samples from 135 wells and 11 springs are used in the characterization. On the basis of these data, water from the aquifer is generally suitable for drinking and for most domestic purposes. The most areally widespread aesthetic factors limiting the use of ground water are hardness, concentrations of dissolved solids, sulfate, and iron, and the presence of hydrogen sulfide.

Selected bacteria are commonly present and may compromise the potability of water from the aquifer. Coliform bacteria from surface sources were found in 47 of 143 water samples. Analyses for total coliform bacteria indicate that 36 of the 125 samples from wells maintained for potable supply have bacteria counts of 4 or more colonies per 100 mL--counts that are bacteriologically unsafe.

Concentrations of alpha- and beta-particle radioactivity equaled or exceeded 5 pCi/L in many areas. The largest concentrations of beta-particle radioactivity are in waters with large potassium concentrations.

The trace elements selenium, silver, lead, antimony, cadmium, and copper are rarely detected in the samples analyzed. Concentrations detected are generally less than 5 μg/L and never exceeded the SMCL or MCL's for these elements. Arsenic, chromium, lithium, mercury, barium, nickel, aluminum, and zinc are commonly detected in the samples analyzed. Concentrations of 10 μg/L or greater are commonly reported for zinc, lithium, and barium. Few aluminum and nickel concentrations exceed 10 μg/L. Few arsenic and mercury concentrations exceed 2 μg/L. Chromium concentrations greater than 50 μg/L are reported in 3 of 54 wells sampled.

Volatile-organic compounds in concentrations greater than 3 μg/L were detected in only 1 of the 45 wells sampled. Cyanide in concentrations greater than 10 μg/L was not detected in any of the 48 wells sampled.

Variations in water quality are related to the geochemical makeup of rock units, the thickness of drift overlying the aquifer, and past and current uses of land in areas of shallow bedrock. The presence or absence of calcium sulfate minerals in the rock causes a bimodal distribution of concentrations of dissolved solids, hardness, and sulfate in waters from the Bass Islands Group. Dissolution of calcium sulfate minerals contributes to excessive concentrations of sulfate that approach 2,000 mg/L. Sulfate reduction probably contributes to excessive hydrogen sulfide concentrations in some sulfate-rich waters.

Waters derived solely from the Lockport Dolomite are relatively dilute and are a calcium magnesium bicarbonate type. Strontium concentrations as large as 50 mg/L characterize sulfate-poor waters and are the result of dissolution of strontium-bearing minerals in the aquifer matrix. Shale mineralogies naturally soften water and increase sodium concentrations, most notably in western Lucas County.

Br:Cl ratios were useful in tracing the source of large chloride concentrations. Sources were the dissolution of salt in evaporite-bearing strata and brine produced by oil and gas development.

Ground water in shallow bedrock areas is most likely to indicate effects of past and current uses of the land. Concentrations of nitrogen, phosphorus, chloride, and dissolved-organic carbon generally are elevated only in areas of shallow bedrock.

INTRODUCTION

The County planners and health officials of Lucas, Sandusky, and Wood Counties, in northwestern Ohio, are faced with increasing concerns relating to **contamination** and use of ground-water resources in the three-county area. In response to a need for detailed documentation of ground-water hydrology and water quality in this area, a regional ground-water investigation was made in 1985-88 by the U.S. Geological Survey (USGS), in cooperation with county and municipal agencies.

The carbonate **aquifer** in Silurian and Devonian rocks is the primary source of rural domestic and irrigation water supplies. Ten villages, with about 12,700 inhabitants, obtain **public supply** from the carbonate aquifer. Therefore, the primary objective of this study was to assess the ground-water resources in the carbonate aquifer by (1) describing the hydrogeologic framework of the **aquifer system**, (2) defining the directions of ground-water **flow**, and (3) identifying factors affecting ground-water quality. In addition, limited testing of water from the surficial sand aquifer in Lucas County was done to document water quality in undeveloped areas and in developed areas where septic tanks are used for disposal of domestic sewage.

Purpose and Scope

This report describes the hydrology and water quality of ground waters in Lucas, Sandusky, and Wood Counties, Ohio, with emphasis on the carbonate aquifer in Silurian and Devonian rocks. This report also describes the quality of water from 10 wells in the surficial sand aquifer in Lucas County and relates water quality to land use.

For the carbonate aquifer, hydrogeologic data for 466 domestic, industrial, irrigation, and public water-supply wells and 11 selected springs are used to describe the aquifer framework and levels of ground water in the aquifer (including seasonal fluctuations). Those data are used to determine the flow directions of ground water. The ground-water-quality data base, developed from samples from 135 wells and 11 springs, includes data for 52 properties and constituents.

Results are presented, in part, with reference to five areas that allow delineation of ground-water flow and water quality at a local scale. Maps of each area show (1) hydrogeologic conditions and (2) hydrochemical conditions.

Water-quality data are presented in reference to established water-quality criteria. Graphs and statistical summaries of the data are used to illustrate factors affecting ground-water quality, which includes the geologic unit that yields water to wells and springs, depth to carbonate **bedrock** (drift thickness), and historic land use for oil and gas production. Maps of selected water-quality constituents are used to illustrate features of regional significance.

Acknowledgments

The authors are grateful to the many well owners and quarry owners, managers, and operators who allowed access to wells and springs for water-level and water-quality measurements. Representatives from the cooperating agencies, especially Jim Black, Robert Bowman, Ronald Carmichael, Joseph Cory, Kenneth Kerik, Mary Ann Koebel, Lee Pfouts, Rex Powers, Floyd Schutte, and Larry Sorrells, offered many suggestions and provided data that aided the author with field studies. The author also would like to thank Tom Duvendack, Toledo Metropolitan Parks; Dave Cramer, Boy Scouts of America; Edward Grosswiler and Robert Watkins, City of Sylvania; Huntington Farms, of Sylvania; Ohio Air National Guard at Toledo Express Airport; and Mr. Jack Butcher for permission to install sand-point wells on their properties. Mr. Bruce Mason of the France Stone Company is gratefully acknowledged for granting permission to install a water-level recorder on a well at the Bellevue quarry. Professor Lon Ruedisili, University of Toledo, supplied copies of several of his students' theses on the hydrogeology in northwestern Ohio.

June Brown, Toledo Metropolitan Area Council of Governments, was most supportive of this study and organized numerous meetings with the cooperating agencies. S.R. Reiner and V.J. Steigerwald provided able assistance in the collection and field analysis of water-quality samples. H.B. Eagon, Jr., provided numerous reports on ground-water conditions at well fields in the study area. Stanley E. Norris, a consulting hydrogeologist, is gratefully acknowledged for consultations on the geologic framework of the carbonate aquifer and for providing insightful comments on this report.

DESCRIPTION OF STUDY AREA

Topography and Drainage

Lucas, Sandusky, and Wood Counties (fig. 1) comprise about 1,400 mi^2 of Lake Plains in the Central Lowlands physiographic province (Meinzer, 1923, pl. 28). The topography in most of the area is flat with some local undulating ridges. The land-surface elevation is greatest in southern Wood County and southeastern Sandusky County (about 750 ft above sea level). The land surface slopes toward Lake Erie at gradients that range from approximately 25 ft/mi in southeastern Sandusky County to 5 ft/mi in Wood County. Near the lake, the gradients approach 3 ft/mi.

Lake Erie, whose mean surface elevation is 572 ft above sea level, receives all of the surface drainage from rivers and streams in the study area. Regional surface-water drainage divides are shown in fig. 1. All except the area in southeastern Sandusky County (designated as "karst area") discharge directly into Lake Erie, Maumee Bay, or Sandusky Bay.

Land Use and Climate

Multiple uses of the land characterize this part of northwestern Ohio. Land use is predominantly agricultural in Wood and Sandusky Counties. Residential, commercial, and industrial land uses predominate near Toledo, whereas forested and agricultural lands predominate in extreme eastern and western Lucas County.

The climate is temperate. The 30-year (1951-80) mean-annual temperature and precipitation for four weather stations within the study area averages 50 degrees Fahrenheit (10 degrees Celsius) and 32.4 in., respectively. Pan evaporation data are measured in April through October at one weather station in the study area. Annual evapotranspiration is estimated, as a percentage of pan evaporation, at about 24 in. (Lyford and Cohen, 1988, p. 55).

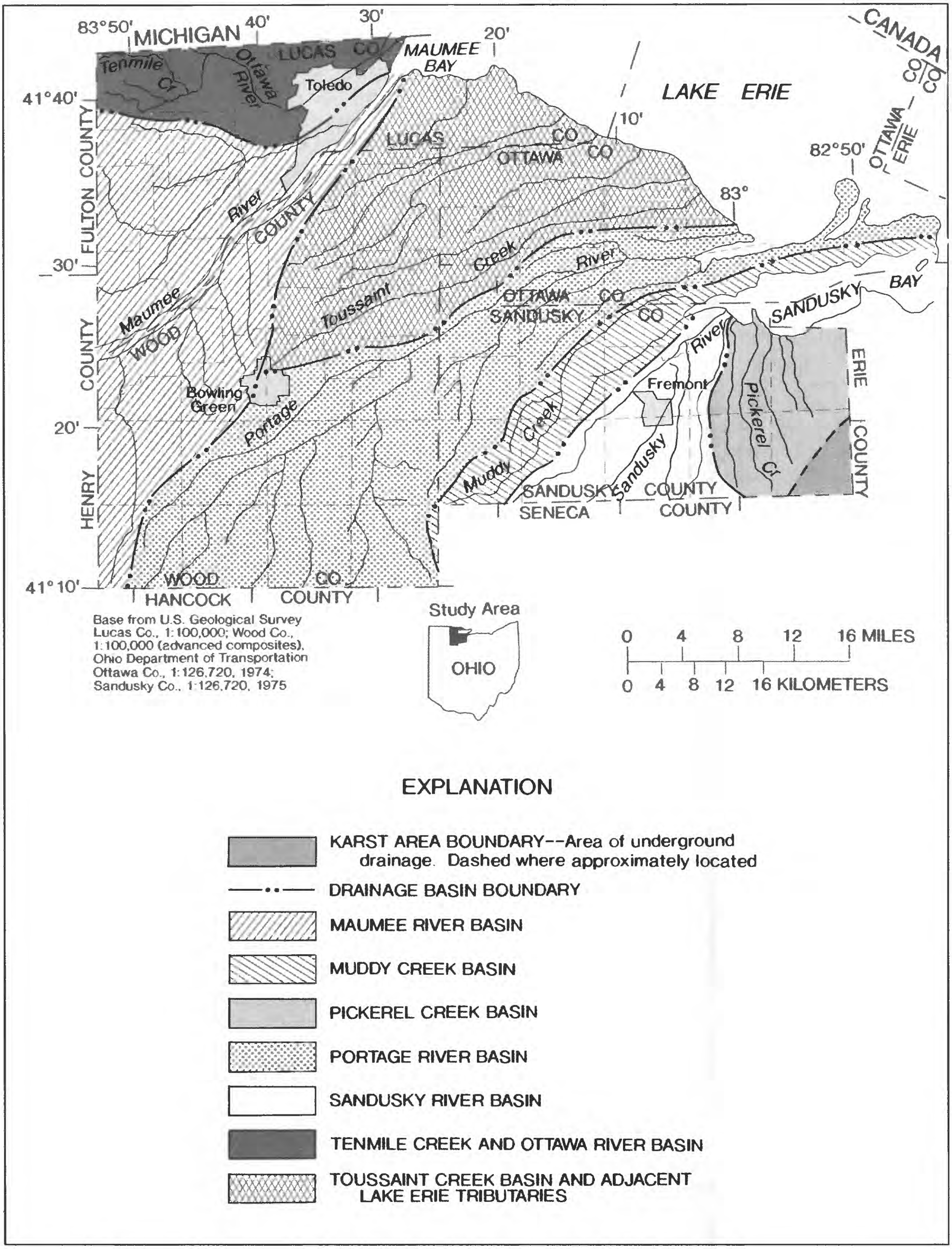


Figure 1.--Location, selected drainage features, and largest cities in each county of the study area.

Population and Water Use

Census figures for 1980 (U.S. Bureau of the Census, 1981) show populations of 107,500 in Wood County, 63,300 in Sandusky County, and 472,000 in Lucas County. The agricultural-based counties have substantially lower populations and population densities than Lucas County. The population of Toledo alone is 355,000, and the population density is 2,200 inhabitants per square mile. The large centers of population, including Toledo, Bowling Green, and Fremont, are supplied by surface water from Lake Erie, the Maumee River, and the Sandusky River, respectively.

In the rural areas of the three counties, water from the carbonate aquifer is the primary source of domestic supply. The carbonate aquifer is a source of public supply for the ten villages (total population 12,700) shown in figure 2.

Estimates of daily mean ground-water withdrawals for several categories of use in the 1985 calendar year are summarized by county in table 1. Ground water accounts for about 1 percent of the combined surface-water and ground-water use in Lucas County. Nearly one third of the combined surface water and ground water use in Sandusky and Wood Counties is ground water from the carbonate aquifer.

METHODS OF STUDY

Data-Collection Networks

The data-collection networks (pl. 1) consist of wells and springs in the carbonate aquifer throughout the study area and wells in the surficial sand aquifer in Lucas County. All network wells are used as water-level measurement sites. Selected wells and springs are also water-quality measurement sites.

Site-Identification System

All wells and springs inventoried by the USGS are identified on the basis of the latitude and longitude of the site in degrees (D), minutes (M), and seconds (S). The 15-digit site-identification number consists of a six-digit latitude (DDMMSS), a seven-digit longitude (DDDMMSS), and a two-digit suffix or sequence number used to differentiate sites at the same coordinates. Thus, a site numbered 414109083265300 is at 41°41'09" north latitude and 83°26'53" west longitude.

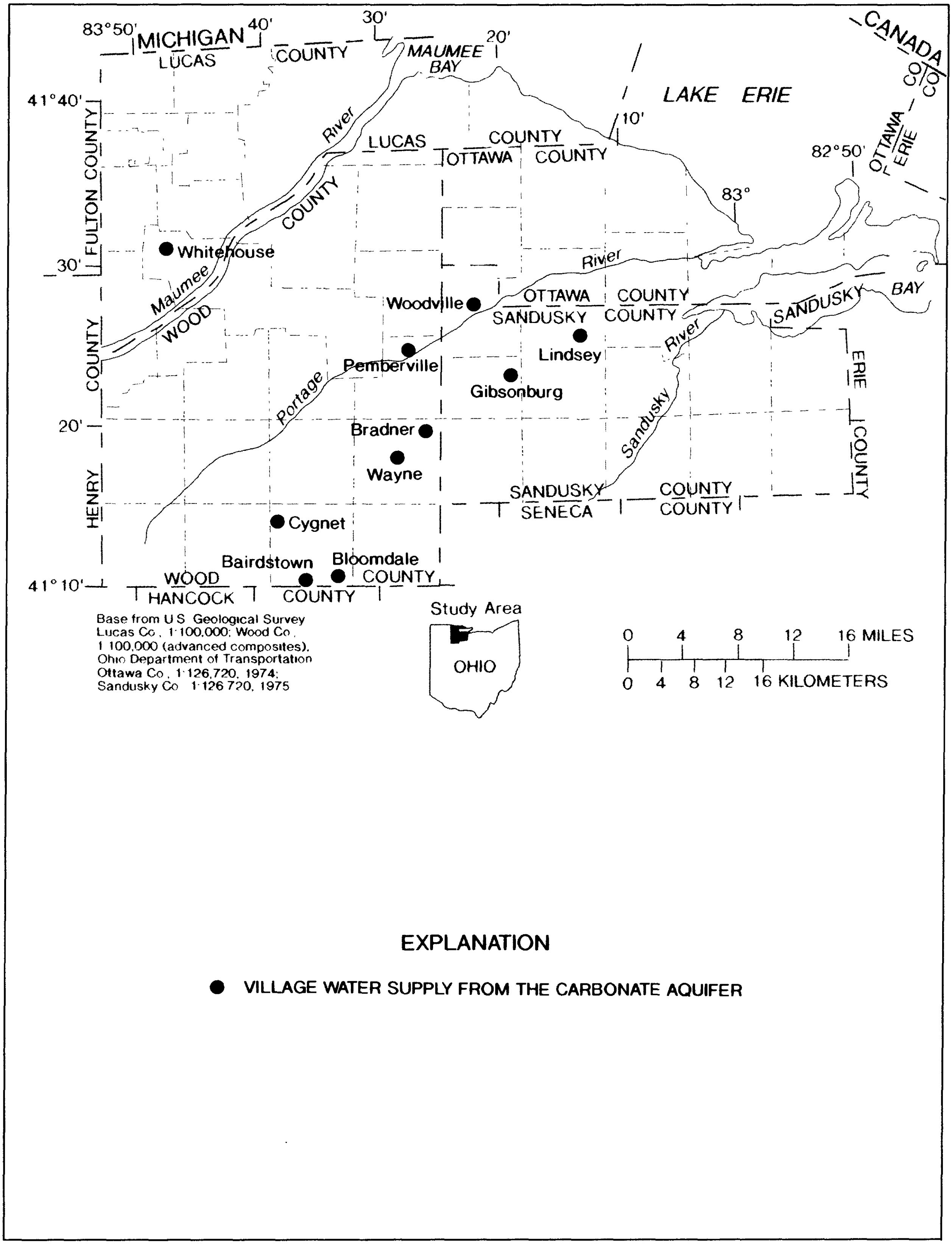


Figure 2.--Location of villages with water supplies from the carbonate aquifer.

Table 1.--Ground-water withdrawals by category of use in Lucas, Sandusky, and Wood Counties, Ohio

[Values are in million gallons per day. Data are compilations for 1985 calendar year on file with U.S. Geological Survey, Water Resources Division, Columbus, Ohio, except where noted.]

Category of use	County		
	Lucas	Sandusky	Wood
Agricultural (nonirrigation)---	0.070	0.31	0.19
Agricultural (irrigation)------	.84	.21	.020
Domestic (rural private wells)----	.90	2.0	3.4
Golf-course irrigation[a]-------	.94	.65	.46
Industrial----------	.28	.47	.21
Public supply-------	.37	.65	.69
total population[b] served------------	(2,900)	(6,500)	(7,600)
Quarry dewatering[c]--	2.0	3.0	3.0

[a] Data from Black, 1983; for days during irrigation season.

[b] Total population includes (1) villages, and (2) non-community supplies such as mobile parks.

[c] Estimates from data submitted to the Ohio Environmental Protection Agency for compliance with National Pollution Discharge Elimination System permits.

A separate site-identification system, hereafter referred to as the local site identifier, is designed so the county, township and section, or city where the site is located can be determined from the identifier. The local site identifier consists of (1) a county prefix (Wood County, WO; Lucas County, LU; and Sandusky County, S), (2) a sequence number assigned in the order that the site was included in the network, and (3) a suffix that identifies the township and section or the city in which the site is located. A complete listing of the township and city abbreviations used in local site-identifier suffixes is given in table 2. Local site identifiers that lack the suffix generally represent sites numbered before this investigation.

Local site identifiers for Lucas County beginning with a sequence number of 301 (for example, LU-301-SW17) correspond to wells completed in the surficial sand aquifer. Wells in Lucas County with 300-series sequence numbers are not, therefore, open to the carbonate aquifer.

Water-Level Sites

Well logs on file with county health departments and with the Ohio Department of Natural Resources (ODNR), Division of Water, were compiled and evaluated. Availability of details regarding well construction and completion was initially a requirement for including a well in the network; however, detailed drilling information was not available for some areas, and wells were inventoried on the basis of owner-reported information and data gathered during site visits. Owner permission and general access to the well site were practical limitations on the inclusion of wells for study.

Records of wells and springs are listed in tables 3 and 4 (Supplemental Data section). Well records include details on construction, use, and historic water levels. The number of wells selected in each county (Lucas, 110; Sandusky, 144; and Wood, 190) was based on the need for adequate areal coverage to map the **potentiometric surface** and to determine other features of hydrogeologic importance. Springs were included in the network to assess ground-water discharge to quarries and streams. The altitude of the water surface in quarry sumps provided an approximation of the potentiometric surface elevation in areas of discharge to quarries.

Water levels in wells, in feet below land surface, were determined by use of chalked-steel tape, air line, or water-**stage** recorder. General descriptions of these measurement techniques are given by Heath (1983, p. 72-73). Garber and Koopman (1968) provide additional details on the air-line technique. The accuracy of the chalked-steel tape and recorder measurements is 0.01 ft. Air-line measurements are recorded to the nearest foot.

Table 2.--Abbreviations of cities and townships for suffix of local site identifier for Lucas, Sandusky, and Wood Counties

Lucas County		Sandusky County		Wood County	
City or township	Abbreviation	City or township	Abbreviation	City or township	Abbreviation
Jerusalem	J	Ballville	B	Bloom	B
City of Maumee	MA	Green Creek	GC	Center	C
Monclova	M	Jackson	J	Freedom	F
City of Oregon	O	Madison	M	Grand Rapids	GR
Providence	P	Rice	R	Henry	H
Richfield	R	Riley	RL	Jackson	J
Spencer	SP	Sandusky	S	Liberty	LI
Springfield	SF	Scott	SC	Lake	LK
Swanton	SW	Townsend	T	Middleton	MD
Sylvania	SY	Washington	W	Milton	ML
City of Toledo	T	Woodville	WO	Montgomery	MO
Washington	WA	York	Y	City of Northwood	N
Waterville	W			Perry	PE
				Perrysburg	PB
				Plain	PL
				Portage	PO
				City of Rossford	R
				Troy	T
				Washington	WA
				Webster	WB
				Weston	WS

Water-level altitudes were computed by subtracting the water level, in feet below land surface, from the land-surface elevation at the well site. The land-surface elevation at each well site was determined either from USGS 7.5-minute topographic quadrangle maps with 5-ft contour intervals or by leveling from USGS or U.S. Coast and Geodetic Survey benchmarks.

Most of the measured water levels represent nonpumping conditions. Water levels were measured in some wells that were being pumped during the mapping period and are denoted by "P" on maps and in tables.

Flowing wells with sufficient casing at land surface to contain the water were measured with a chalked-steel tape. Water levels for overflowing wells are denoted by "F" on maps and in tables.

Water levels were measured by USGS when each well was initially inventoried. **Synoptic** measurements of water levels in all network wells were made during the periods June 30 through July 11, 1986, and January 26 through February 11, 1987. Water levels also were measured when water-quality samples were collected during May through October 1987.

Water levels in the surficial sand aquifer were periodically measured only at the 10 **sand-point wells** installed for this study. A continuous recorder was operated on one well to assess the response of water levels in the surficial sand aquifer to recharge and evapotranspiration.

All data describing well and spring characteristics and ground-water levels are stored in the USGS's Ground Water Site Inventory (GWSI) computer data base. Data from routine measurements of ground-water levels are described in reports by Shindel and others (1986, p. 240-264; 1987, p. 178-340; and 1988, p. 171-194).

Water-Quality Sites

The network of sites for collection of samples of water from the carbonate aquifer was designed to meet four objectives:

1. Adequate areal coverage given a limit of about 50 sites per county. This requirement is based on the need for representative **baseline** data for the region as well as each township in each county. Five analyses from two earlier studies by the USGS were reviewed and included for statistical analysis of water quality. Other data from state and local agencies were used as needed to map water-quality variations for selected areas.

2. Adequate representation of each geologic unit and selected aquifer types. Each geologic unit (table 5) of the carbonate aquifer was represented by wells and springs producing water primarily from that unit. Obtaining the numbers of samples required for a valid statistical comparison was not possible for Devonian carbonate rocks or the Upper Silurian Salina Formation because of their small areal extent. Representative samples of waters were collected from these units, however, for baseline information. A comparison was possible between waters from the Lockport Dolomite (57 samples) and Bass Islands Group (80 samples). These data were used to determine whether waters representing the Lockport Dolomite and Bass Islands Group have the same major-ion constituent concentrations. In addition, three types of aquifer conditions (unconfined, confined, and multiple confined) were identified for the Lockport Dolomite and used to determine whether the three types contain ground waters having the same water-quality characteristics.

3. Adequate range of depths to bedrock within a single geologic unit and the carbonate aquifer as a whole. Five ranges of drift thickness are 0-20 ft, 21-40 ft, 41-60 ft, 61-80 ft, and greater than 80 ft (table 5). This subdivision is designed to help determine whether concentrations of nutrients and other selected constituents in ground water are influenced by the thickness of drift overlying the carbonate aquifer.

4. Adequate number of sites inside and outside of oil- and gasfields. This mixture of locations (table 5) could be used to determine whether ground waters in areas of historic oil and gas land use contain the same concentrations of selected indicator constituents as areas not developed for oil and gas.

These four objectives are discussed in detail in the section on Factors Affecting Water Quality.

Well-construction and access criteria also were considered in the selection of a well for water-quality sampling. The details of well construction, such as casing length, depth of hole, principal geologic unit yielding water to the well, type of completion, pump and plumbing configurations, and the date of drilling were determined for all wells. Wells for which data were inadequate were not considered for sampling. The access for obtaining a raw, untreated sample from the domestic, commercial, and irrigation wells also was a practical consideration in network design.

Table 5.-- Classification of water-quality sampling sites within geologic units of the carbonate aquifer

[Abbreviations for historic oil and gas activity land use: OF, historic and (or) present-day (1974) oilfield; GF, historic and (or) present-day gasfield; NF, area not part of a designated oilfield or gasfield (DeBrosse and Vohwinkle, 1974). Aquifer-type codes: U, unconfined single; C, confined single; M, multiple confined; N, multiple unconfined. County location codes: LU, Lucas; S, Sandusky; WO, Wood. Drift-thickness range codes: D1, 0 to 20 ft; D2, 21 to 40 ft; D3, 41 to 60 ft; D4, 61 to 80 ft; D5, greater than 80 ft. Numbers for totals do not include the "Salina Group" (well site S-231-RL36), which was not used in statistical analysis of water quality.]

Geologic unit	Total number of sites	Total number of sites within indicated category																
		Site type		County location			Aquifer type				Depth to bedrock or Drift-thickness range					Historic oil and gas land use		
							Confined		Unconfined									
		Wells	Springs	LU	S	WO	C	M	U	N	D1	D2	D3	D4	D5	OF	GF	NF
Devonian System																		
Devonian carbonate rocks	5	5	0	5	0	0	4	0	1	0	0	1	2	2	0	0	0	5
Detroit River Group	4	3	1	3	0	1	2	1	0	1	1	1	0	2	0	0	0	4
Silurian System																		
Bass Islands Group																		
Raisin River Dolomite	20	19	1	10	0	10	17	1	1	1	4	5	6	4	1	3	1	16
Undifferentiated (Sandusky Co.)	21	18	3	0	21	0	11	4	3	3	7	1	3	6	4	1	0	20
Tymochtee Dolomite	8	7	1	2	0	6	7	1	0	0	2	4	2	0	0	6	0	2
Greenfield Dolomite	31	28	3	15	0	16	23	4	3	1	5	2	8	10	6	14	2	15
"Salina Group"	1	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1
Lockport Dolomite	57	55	2	9	27	21	25	17	14	1	29	10	6	4	8	35	3	19
Totals	146	135	11	44	48	54	89	28	22	7	48	24	27	28	19	59	6	81

Wells are commonly finished as open holes in the rock. Waters are likely to flow into the well from openings in the rock at several different depths. The deeper the well, the greater is the probability that waters from several depths will enter and mix within the well bore. A water mixture that represents the differing water contributions to the well bore could result. No attempt is made to case to a selected zone in the carbonate aquifer, but some wells are cased through a zone of broken rock commonly found at the interface between the drift and the carbonate rock. The casing is set into the solid rock to provide a hydraulic and sanitary seal between the aquifer and overlying deposits.

Pumps used to deliver water to the land surface are of several types. Wells for rural domestic supply are usually fitted with submersible pumps. Vertical turbine pumps are more common on large-capacity commercial and irrigation wells. In some areas of Sandusky County, flowing **artesian wells** may or may not have a pump, depending on the artesian pressure, water-level fluctuations, and use of the water.

Well construction and pump characteristics for the sites selected for collection of water-quality samples from the carbonate aquifer are summarized in table 6. This summary indicates that, at many of the sites in the network, wells have steel casing, are fitted with submersible pumps, and are used for domestic water supplies.

For the surficial sand aquifer, wells representing: (1) undeveloped areas (wells LU-301, 302, 303, 304, and 307), and (2) developed areas, where septic tanks are present (wells LU-305, 306, 308, 309, and 310) were sampled for water quality to determine whether shallow ground water from the two land-use types have similar concentrations of water-quality constituents. Ten sand-point wells were constructed by the USGS for sampling and testing of water quality. Five wells were installed in each of the two types of land-use areas.

Locations of surficial sand aquifer wells were primarily in the Sylvania and Swanton Township areas of western Lucas County. Wells in undeveloped areas included four sites in the Oak Openings Metropolitan Park in Swanton Township and one site at a Boy Scout reservation in Sylvania. Wells in developed areas with septic tanks included three sites within Sylvania and two sites near Holland (pl. 1).

Wells in the surficial sand aquifer are sand-points installed with a motorized driver. All wells consist of 1.25-in. inside-diameter galvanized steel casing attached by a threaded coupling to a well point 1.5 ft long with 0.007-in. continuous wire slotted well screen. The well points and sections of casing, including couplings, were cleaned of oil and grease with a detergent wash, then were rinsed with distilled water, hexane, and alcohol to allow rapid drying.

Table 6.--Characteristics of wells and pumps at sites in the water-quality network, carbonate aquifer

[Well use codes: C, commercial/industrial; H, domestic; I, irrigation; OT, observation/test; P, public supply. Casing material codes: S, steel; P, polyvinyl chloride. Pump type codes: S, submersible; VT, vertical turbine; F, flowing; J, jet. Total number of wells summarized is 135.]

	Well use					Casing material		Pump type			
	C	H	I	OT	P	S	P	S	VT	F	J
Number of wells	14	98	8	8	7	132	3	114	9	3	9
Percentage of total	10	73	6	6	5	98	2	84	7	2	7

For consistency in construction, the top of the screen section was driven to a depth of about 5 ft below the water table. The total depth of each well is given in table 3 (Supplemental Data section). The screened interval is the section beginning 1.5 ft above the total depth and ending at the total depth of the well. The wells were developed by use of a surge block and rotary pump. A concrete collar was installed at land surface to prevent infiltration of surface water around the casing. Four-in. inside-diameter protective, lockable steel casings were installed over the well casings.

The wells yield about 2 to 3 gal/min of water representing the depth interval of the aquifer in which the well is screened. Wells were purged before sampling by use of a rotary pump. Samples were collected from the wells by a portable peristaltic pump.

Field Methods for Water Quality

Samples were collected, prepared, and preserved according to techniques described by Claassen (1982), Wood (1976), and Federal Interagency Work Groups (1977). Ground water in the surficial sand aquifer was sampled during the first two weeks of June 1987. Ground-water samples from the carbonate aquifer were collected during September 1986 and June through October 1987. Details of field methods specific to this study are given here. Techniques used to prepare and preserve samples for the constituents analyzed for in this study are summarized in table 7.

Before sampling, a minimum of three casing volumes was removed from each well. Onsite determination of the static level of water, the casing diameter, and the depth of each well were used to calculate the volume of water in the well bore. A plastic hose was connected to the pump discharge line nearest the well. All devices for domestic and industrial water treatment were bypassed, and, if possible, samples were collected ahead of the pressure tank.

Specific conductance, pH, temperature, and dissolved-oxygen concentration were continuously monitored in an air-tight chamber attached to the discharge hose. Samples were collected after these characteristics had stabilized. The same procedures were used for the carbonate aquifer and the surficial sand aquifer except that a probe was inserted directly into the sand-aquifer wells to measure dissolved-oxygen concentration and temperature.

Samples from springs were collected after monitoring the stability of water-quality characteristics directly in the free-flowing discharge of the spring. Analyses were done for dissolved oxygen; however, those concentrations in waters from springs may not be representative of conditions in the carbonate aquifer because of the interaction between the waters and the atmosphere before sample collection.

Table 7.-- Number of sample sites and summary of the methods for onsite processing and preservation of samples for analysis of water-quality constituents

[Number of sites represents carbonate aquifer, number in parentheses for Lucas County is surficial sand aquifer. Abbreviations used for preparation/preservation method: bottle type--gl, glass, pl, plastic (high-density polyethylene), br, brown or amber; processing type--F, filtered, FAg, silver membrane filter, hs, headspace; preservation type--A, nitric acid to pH 2, KDN, potassium dicromate and nitric acid, HgCl, mercuric chloride/NaCl, ZnAc, zinc acetate]

Inorganic constituent	No. of sites	No. of sites, by county code LU	S	WO	Method of preservation/ preparation
Calcium, dissolved[1]	145	44(10)	47	54	pl, F, A
Magnesium, dissolved	145	44(10)	47	54	pl, F, A
Sodium, dissolved	146	44(10)	48	54	pl, F, A
Potassium, dissolved	146	44(10)	48	54	pl, F, A
Hydrogen sulfide, total	144	43(10)	48	53	pl, ZnAc
Sulfate, dissolved	146	44(10)	48	54	pl, F
Chloride, dissolved	146	44(10)	48	54	pl, F
Fluoride, dissolved	146	44(10)	48	54	pl, F
Bromide, dissolved	96	43(10)	2	51	pl, F
Silica, dissolved	146	44(10)	48	54	pl, F
Strontium, dissolved	144	43(10)	47	54	pl, F, A
Dissolved solids	146	44(10)	48	54	pl, F
Nutrients and organic constituents					
Carbon, organic, dissolved	143	44(10)	47	52	gl, FAg
Volatile organic compounds	45	21 (5)	0	24	br gl, vial septum, no hs
Nitrite, dissolved	143	43(10)	47	53	br pl, F, HgCl
Nitrite + nitrate, dissolved	143	43(10)	47	53	br pl, F, HgCl
Ammonia, dissolved	143	43(10)	47	53	br pl, F, HgCl
Ammonia + organic N, dissolved	144	43(10)	47	53	br pl, F, HgCl
Orthophosphate, dissolved	142	43(10)	47	53	br pl, F, HgCl
Radiochemical constituents					
Beta-particle radioactivity, dissolved	82	21 (5)	30	31	pl, F, A
Alpha-particle radioactivity, dissolved	82	21 (5)	30	31	pl, F, A
Uranium, dissolved	82	21 (5)	30	31	pl, F, A

Trace element	No. of sites	No. of sites, by county code LU	S	WO	Method of preservation/ preparation
Aluminum, dissolved	141	43(10)	45	53	pl, F, A
Antimony, dissolved	48	21 (5)	1	26	pl, F, A
Arsenic, dissolved	82	27 (5)	5	50	pl, F, A
Barium, dissolved	91	21 (5)	44	26	pl, F, A
Boron, dissolved	98	43(10)	2	53	pl, F, A
Cadmium, dissolved	53	21 (5)	4	28	pl, F, A
Chromium, dissolved	54	21 (5)	4	29	pl, F, A
Copper, dissolved	51	21 (5)	4	26	pl, F, A
Cyanide, dissolved	48	21 (1)	1	26	pl
Iodide, dissolved	8	0 (0)	3	5	pl, F
Iron, dissolved	146	44(10)	48	54	pl, F, A
Lead, dissolved	53	21 (5)	4	28	pl, F, A
Lithium, dissolved	50	21 (5)	1	28	pl, F, A
Manganese, dissolved	145	44(10)	48	53	pl, F, A
Mercury, dissolved	47	21 (5)	4	22	gl, F, KDN
Nickel, dissolved	49	21 (5)	1	27	pl, F, A
Selenium, dissolved	53	21 (5)	4	28	pl, F, A
Silver, dissolved	51	21 (5)	4	26	pl, F, A
Zinc, dissolved	92	21 (5)	45	26	pl, F, A

[1] "Dissolved" is defined for the U.S. Geological Survey by Feltz and others (1985, p1-2) as: "Constituents of a whole water sample which pass through a membrane filter with a pore size of 0.45 µm (micrometer)." The 142-mm (millimeter) filtration apparatus described by Kennedy and others (1976) was used for onsite processing of water samples for determination of concentrations of dissolved constituents.

Several constituents were analyzed at the time of sample collection. Alkalinity was determined onsite by incremental titration of an unfiltered whole water sample. Samples were processed in the field for analysis of **total coliform, fecal coliform,** and **fecal streptococci bacteria.** The membrane-filter method with immediate incubation was used for all bacteria analyses. Total coliform colonies were grown on M-endo broth medium, fecal coliform colonies on M-FC medium, and fecal streptococci colonies on KF Streptococcus agar (Greeson and others, 1977, p. 29-33 and 53-62).

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) procedures were used to ensure that analyses of concentrations of constituents in ground water were within acceptable error limits. The QA/QC procedures included the following:

1. Standard reference water samples submitted to the laboratory;

2. **Cation-to-anion** balances for major-inorganic-ion concentrations in all waters;

3. A two-laboratory, split-sample program for gross alpha-particle radioactivity;

4. Field and laboratory blank samples for dissolved organic carbon; and

5. Duplicate analyses and blank samples for bacteriologic determination.

The QA/QC procedures demonstrate that the analytical results are within acceptable error limits. The characteristics and results of the QA/QC procedures are summarized in Appendix (at back of report).

Statistical Analysis

Summary statistics for the water-quality data describe the general distribution of the data and indicate whether the concentrations of water-quality constituents are normally distributed. The distribution is tabulated by percentiles, which represent the percentage of samples that have concentrations less than or equal to the concentration associated with the percentile.

Constituents or properties that had some number of concentrations less than the **detection limit** are termed **censored data.** Summary statistics for censored sets of data were computed by use of the method developed by Helsel and Gilliom (1986).

Summary statistics for uncensored data sets were computed by use of a univariate statistics procedure (SAS Institute, 1979, p. 427). Box plots and dot plots of the frequency distributions of uncensored data were prepared by use of Minitab statistical software (Ryan and others, 1985).

GEOLOGIC SETTING

Structural Features

The Findlay arch, an anticlinal structure, trends north-northeastward through the approximate center study area, and controls the spatial distribution of the bedrock deposits. There is disagreement in the literature on the location of the axial trace. The Ohio Department of Natural Resources (ODNR) (1970, pl. 3) mapped the axis as shown in figure 3; however, Janssens (1977, pl. 1) shows a more northerly trending axis about 20 mi to the west. The older carbonate rocks (Lockport Dolomite) are located along the axis of the arch, and younger rocks overlie the Lockport to the east and west. On the eastern flank of the arch in central and eastern Sandusky County, the rocks dip about 35 ft/mi (<.5 degrees) to the southeast. On the western flank of the arch in Wood and Lucas Counties, they dip more steeply to the west-northwest.

The Bowling Green fault zone (Van Wagner, 1988) and Lucas County monocline (Norris, 1975) are structural features on the western flank of the arch. The normal fault, with younger down-thrown rocks on the western side, has a reported displacement of 200 ft in central Wood County (Ohio Department of Natural Resources, 1970, p. 9). The monocline, with a west-dipping limb, exists north of the trend of the fault zone in Lucas County.

Bedrock Stratigraphy

Stratigraphic nomenclature of both the U.S. Geological Survey and the Ohio Department of Natural Resources, Division of Geological Survey (Janssens, 1970b, 1977) is used for Silurian and Devonian strata discussed in this report. The stratigraphy of the principal near-surface rocks (table 8) is discussed first for the western flank, and then for the eastern flank. The sequence of rock formations in Silurian and Devonian strata of northwestern Ohio has been described by Carman (1946, 1948), Forsyth (1968), Janssens (1970a, 1970b, 1977), ODNR (1970), and Sparling (1988). These investigators have shown that the stratigraphy and areal extent of the carbonate rock formations are not yet defined in detail. Facies changes and gradational lithologic boundaries preclude exact placement of formation contacts on geologic maps and geologic sections. Facies changes complicate the process of differentiating formations in the

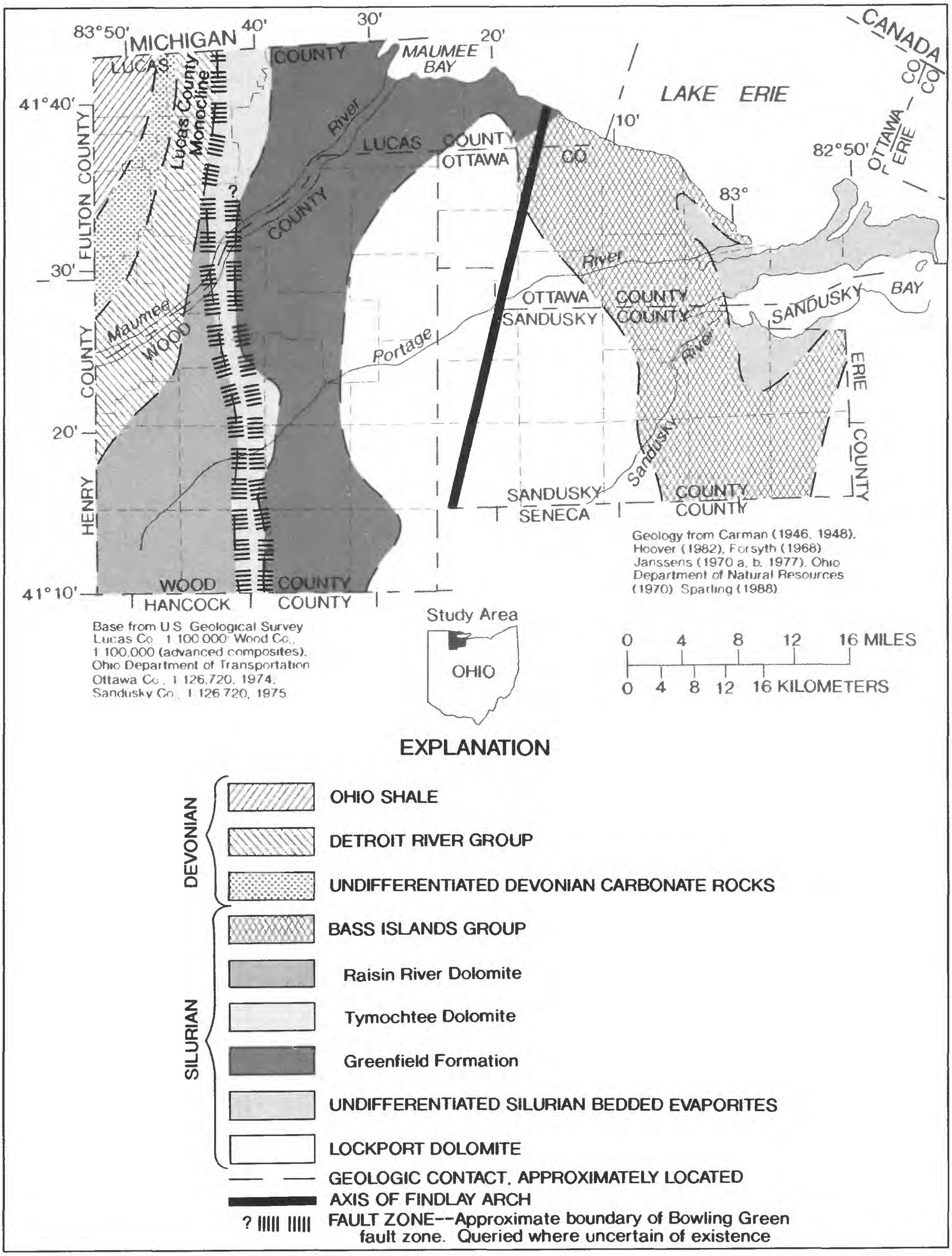


Figure 3.--Generalized geology of the study area.

Table 8.--Generalized stratigraphic chart for near-surface rocks on the western and eastern flanks of the Findlay arch in Lucas, Sandusky, and Wood Counties, Ohio

[Modified from Janssens, 1970b and 1977, fig. 1]

SYSTEM	SERIES	GROUP	FORMATION OR PRINCIPAL LITHOLOGY AS DESIGNATED BY THE OHIO GEOLOGICAL SURVEY: WESTERN FLANK OF FINDLAY ARCH, LUCAS AND WOOD COUNTIES	FORMATION OR PRINCIPAL LITHOLOGY AS DESIGNATED BY THE OHIO GEOLOGICAL SURVEY: EASTERN FLANK OF FINDLAY ARCH, SANDUSKY COUNTY
QUATERNARY	Holocene and Pleistocene		Glacial and alluvial deposits	Glacial and alluvial deposits
DEVONIAN	Upper		Ohio Shale	Undifferentiated Devonian rocks
	Middle	Traverse [1]	Tenmile Creek Dolomite [1]	
			Silica Formation [1]	
			Dundee Limestone	Columbus Limestone
		Detroit River	Undivided Detroit River Group	Undivided Detroit River Group
			Sylvania Sandstone [1]	
SILURIAN	Upper	Bass Islands	Raisin River Dolomite	Undivided Bass Islands Dolomite
			Tymochtee Dolomite [1]	
			Greenfield Dolomite	
				"Salina Group": F unit
				"Salina Group": E unit
				"Salina Group": C unit
				"Salina Group": B unit
				"Salina Group": A unit
	Middle		Lockport Dolomite	Lockport Dolomite
			Rochester Shale	Rochester Shale

[1] Unit follows usage of Ohio Department of Natural Resources, Division of Geological Survey.

subsurface. Thus, formations that overlie the Lockport Dolomite may not exist or may not be correlative on both the eastern and western flanks of the Findlay arch.

Western Flank of the Findlay Arch

Middle Silurian through Upper Devonian strata are the principal near-surface rocks on the western flank of the arch in Lucas and Wood Counties. The Middle Silurian Rochester Shale is a green-colored unit about 15 ft thick that does not subcrop beneath glacial deposits and **alluvium** or crop out anywhere in the study area. Greenish-gray dolomite is interbedded with the shale.

The Lockport Dolomite is gray to white, fine to coarse crystalline dolomite that is about 125 to 475 ft thick. The Lockport is massively bedded; lithology ranges from fossiliferous and porous to biostromal or biohermal. Outcrops or subcrops beneath glacial deposits exist only near the axial trace of the arch in western Sandusky County and eastern Wood County.

The Bass Islands Group of Late Silurian age overlies the Lockport Dolomite. On the western flank, the Bass Islands Group is divided into the Greenfield, Tymochtee, and Raisin River Dolomites. The Greenfield is brown, mostly microcrystalline, medium bedded dolomite that is about 50 ft thick. Biohermal and biostromal facies of the Greenfield with minor black-shale interbeds underlie northernmost Wood County and parts of Lucas County (Janssens, 1977, p. 35). The Greenfield contains inclusions of small anhydrite crystals. The Tymochtee is grayish-brown, microcrystalline dolomite that is thinly bedded, **argillaceous,** and contains black shaly partings. The Tymochtee has traces of anhydrite, and layered gypsum nodules are present near the base of the unit. The Raisin River Dolomite (Ohio Department of Natural Resources, 1970, p. 12) is gray to brown microcrystalline dolomite that is medium- to thick-bedded, with a reported thickness of about 250 ft. Janssens (1977, p. 26) uses "undifferentiated Salina dolomite" to describe these rocks. Two shale marker beds and anhydritic beds are recognized by Janssens. A thin green shale is present at the top of the Raisin River Dolomite. This dolomite is the uppermost Silurian unit and is overlain unconformably by Middle Devonian strata of the Detroit River Group.

The Detroit River Group only is present in westernmost Lucas and Wood Counties (Janssens, 1970b, p. 11-12) and includes at the base the Sylvania Sandstone--a white, friable unit less than 50 ft thick, and undifferentiated, gray and brown microcrystalline dolomites that thicken westward from zero to greater than 140 ft in the Lucas County monocline. The dolomite contains nodular anhydrite and gypsum.

The Dundee Limestone unconformably overlies the Detroit River Group. The lower Dundee consists of less than 40 ft of grayish-brown, fine to medium crystalline, sandy limestone, with white and tan chert. The upper part of the Dundee is yellow-gray to brown, medium- to coarse-grained fossiliferous limestone less than 20 ft thick.

The Traverse Group, restricted to northwestern Lucas County, includes the Silica Formation and the Tenmile Creek Dolomite. The Silica Formation is a grayish-brown to green, fossiliferous and shaly limestone interbedded with calcareous shale less than 55 ft thick. The Tenmile Creek Dolomite is a buff-colored shaly unit less than 35 ft thick that contains nodular white chert.

The Upper Devonian Ohio Shale unconformably overlies the Traverse Group. The Ohio Shale is the youngest consolidated rock and is present only in northwestern Lucas County (figure 3). The unit consists of about 100 ft of black and dark-brown shale, the basal 30 ft of which is interbedded with dark-brown dolomite.

Eastern Flank of the Findlay Arch

Middle Silurian through Middle Devonian strata are the principal near-surface rocks on the eastern flank of the arch in Sandusky County. The Rochester Shale and the Lockport Dolomite are present on the eastern flank, where the Lockport has a minimum thickness of about 200 ft, and the contact between the Lockport and overlying rocks is considered anomalous compared to other parts of northwestern Ohio.

Stratigraphic nomenclature defined by ODNR (1970) for the rocks overlying the Lockport Dolomite on the eastern flank of the arch was completely revised by Janssens (1977). The latter work advances the concept of a "Salina Group," comprised by five units (A, B, C, E, and F), overlain by a "Bass Islands Dolomite" (table 8). The earlier work assigned rocks above the Lockport to the Bass Islands Group. The nomenclature is conflicting. For the purposes of this report, it is sufficient to describe the lithologies and thicknesses of units in Janssens' "Salina Group" and overlying rocks of Devonian age in eastern Sandusky County; however, for continuity in nomenclature within this report, the Silurian rocks overlying the Lockport Dolomite will be grouped together and subsequently referred to as the Bass Islands Group.

The rocks overlying the Lockport Dolomite are evaporite-bearing. The A unit is about 160 ft thick and consists mostly of dolomite of the Lockport-like lithology; however, a 25-ft-thick basal bed of anhydrite is recognized locally, and another anhydrite bed about 10 ft thick is present near the middle of the A unit. The B unit consists of about 100 ft of interbedded anhydrite, dark-brown dolomite, and dark-gray shaly dolomite. The C unit consists of 75 ft of greenish-gray, argillaceous dolomite that contains anhydrite and grades into shale.

About 10 ft of bedded anhydrite is in the middle of the unit. The E unit is anhydrite-bearing, argillaceous, microcrystalline dolomite about 85 ft thick. The upper 10 to 20 ft of the unit is very argillaceous and is considered a marker bed. The F unit, in easternmost Sandusky County, is characterized by interbedded anhydrite, anhydritic brown dolomite, and argillaceous and shaly dark gray dolomite. Anhydrite has been altered to gypsum, and evidence of gypsum removal by leaching increases toward the west. The thickness of the F unit in Sandusky County is uncertain but is probably less than 30 ft on the basis of data for neighboring Seneca County.

North of Sandusky County the undifferentiated Bass Islands Dolomite is about 55 ft thick but is probably thinner locally because of erosion of its upper surface prior to deposition of Middle Devonian Detroit River Group rocks. The dolomite contains inclusions of small anhydrite crystals similar to those noted in the Greenfield Dolomite.

Detroit River Group rocks in Sandusky County are undivided dolomites about 100 ft thick that are thick- to massive-bedded in the lower part and thin- to thick-bedded in the upper part (Sparling, 1988, p. 4). The dolomites grade into the Columbus Limestone.

The Columbus Limestone is a gray or brownish-gray fossiliferous, thinly bedded unit about 60 ft thick; cherty zones are recognized (Hatfield, 1988, p. 18-20). This unit is the youngest consolidated rock in the eastern flank of the arch in the study area.

Unconsolidated Deposits

The thickness and texture of the unconsolidated deposits, hereafter termed drift, overlying the bedrock is widely variable across the three-county area. The thickness ranges from more than 120 ft in preglacial bedrock valleys to 10 ft or less in many parts of eastern Wood County, western Sandusky County, and other parts of the study area. Maps showing the thickness of drift have been published for Lucas County (Leow, 1985), Sandusky County (Larsen, 1984), and Wood County (Peterson, 1985).

The texture of the deposits is variable areally and with depth below land surface. The deposits commonly are stratified. The drift is mostly clay-rich lacustrine or till deposits of Quaternary age. The contact between bedrock and drift material is commonly described as a broken-rock zone or a detrital zone. The detrital zone can include sand and gravel deposits. The sands and gravels are typically found in bedrock valleys formed by preglacial drainage (Forsyth, 1968, p. 77). Surficial sand deposits also are present. The types of sand deposits found in Lucas and Wood County are described by Forsyth (1968, p. 66), and the extent of sand deposits in Sandusky County is described by Angle (1987). The thickest and most areally extensive sand deposits are the surficial sands in Lucas County. This belt of sand, with thicknesses generally less than 50 ft, is west of the Maumee River (fig. 4) and is known informally as the Oak Openings sands.

GEOHYDROLOGY

Unconsolidated Deposits

The geohydrology of the surficial sand deposits has been studied only in local areas (Trexler and Ruedisili, 1976; Hallfrisch, 1987). Sand deposits in Lucas County (fig. 4) yield enough water to be used for rural domestic water supplies. These deposits of sand, hereafter termed surficial sand aquifer, represent the only regionally extensive aquifer other than the underlying carbonate aquifer, in the three-county study area.

As shown in geologic section A-A' (fig. 5; line of section appears on pl. 1), the sand overlies till and forms a belt of hummocky and undulating topography. The surficial sand aquifer is recharged by precipitation; there are no natural impermeable barriers between the land surface and the **water table**. Water levels are generally between 2 and 8 ft below land surface, and figure 6 shows the magnitude and seasonal characteristics of water-table fluctuations at well LU-303-SW20, located in a wooded area of the Oak Openings Preserve Metropolitan Park in Swanton Township. (See pl. 1 for well location.) During the period October 1986 through April 1987, the water table rose rapidly and declined gradually as the water moved to discharge points at local streams. In May 1987, evapotranspiration increased, and the water table began a seasonal decline. The decline was interrupted by occasional rainstorms through July. In August and September, precipitation had only small effects on the seasonal decline until the end of the growing season. Precipitation during the fall recharged the aquifer, causing water levels to rise to levels of the previous winter and spring. At well LU-303-SW20, the fluctuation of the water table during the 1987 water year was a total of about 3.5 ft. Fluctuations in other areas are likely to be similar.

Measurements of **tritium** concentration in ground water can indicate the age of water in an aquifer: pre-1952 water is old, and water with a post-1952 component is young. The absence of tritium in ground water indicates that the water is precipitation that occurred before 1952, when atomic-bomb tests increased tritium levels in the atmosphere. Old water is sometimes termed dead because of the absence of radioactive tritium (Michel, 1989).

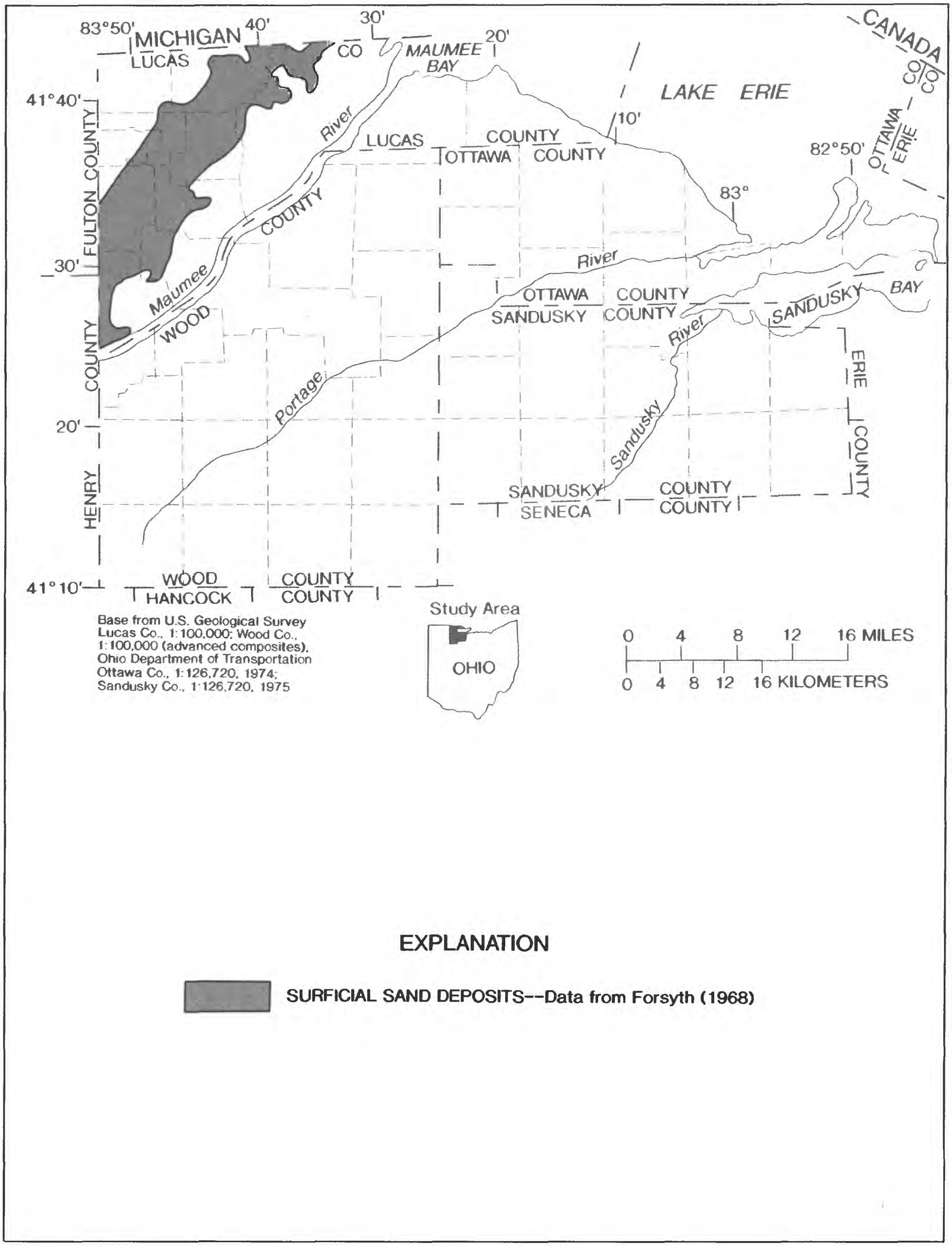


Figure 4.--Extent of surficial sand deposits in Lucas County.

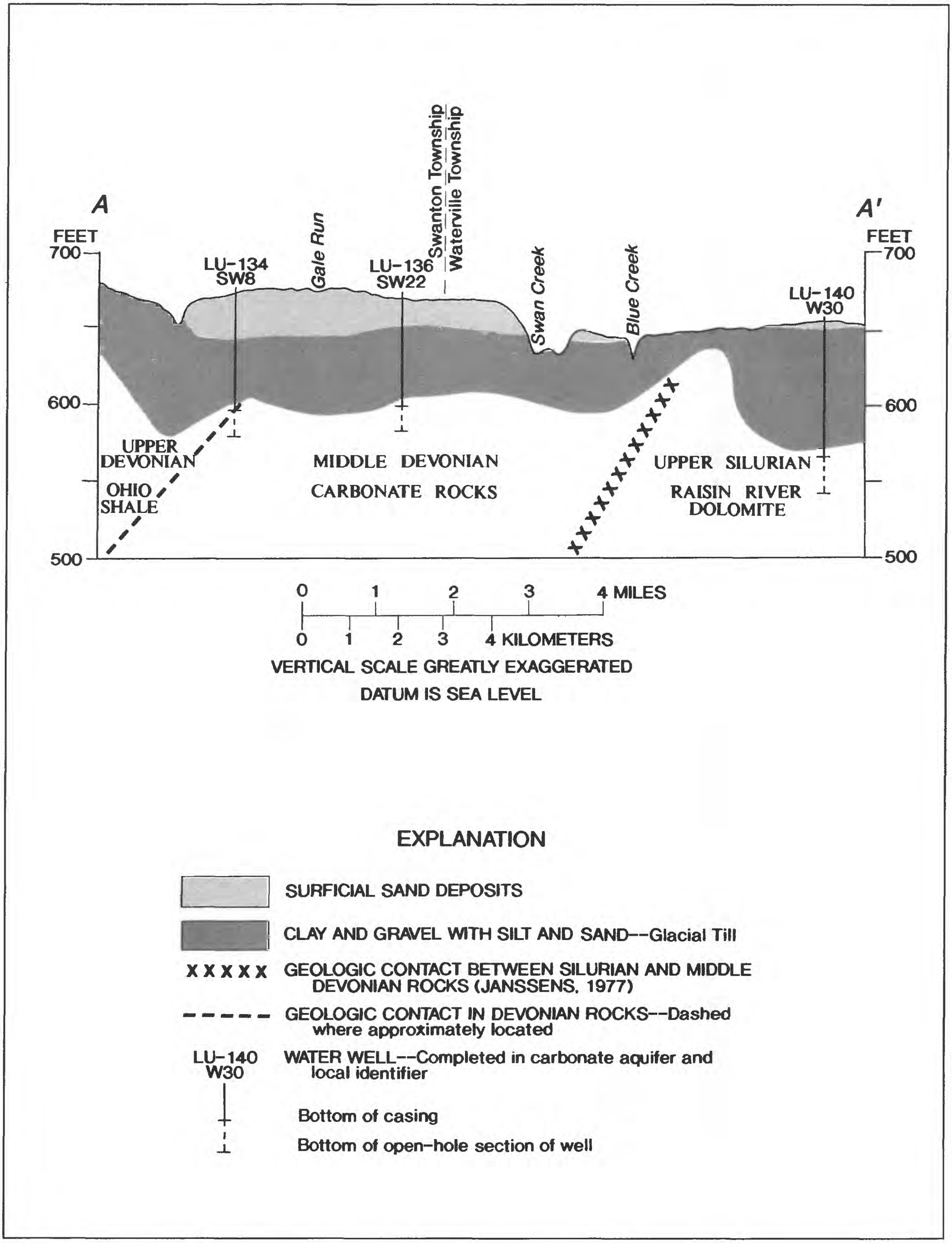


Figure 5.--Geologic section *A-A'*. (Trace of section shown on plate 1.)

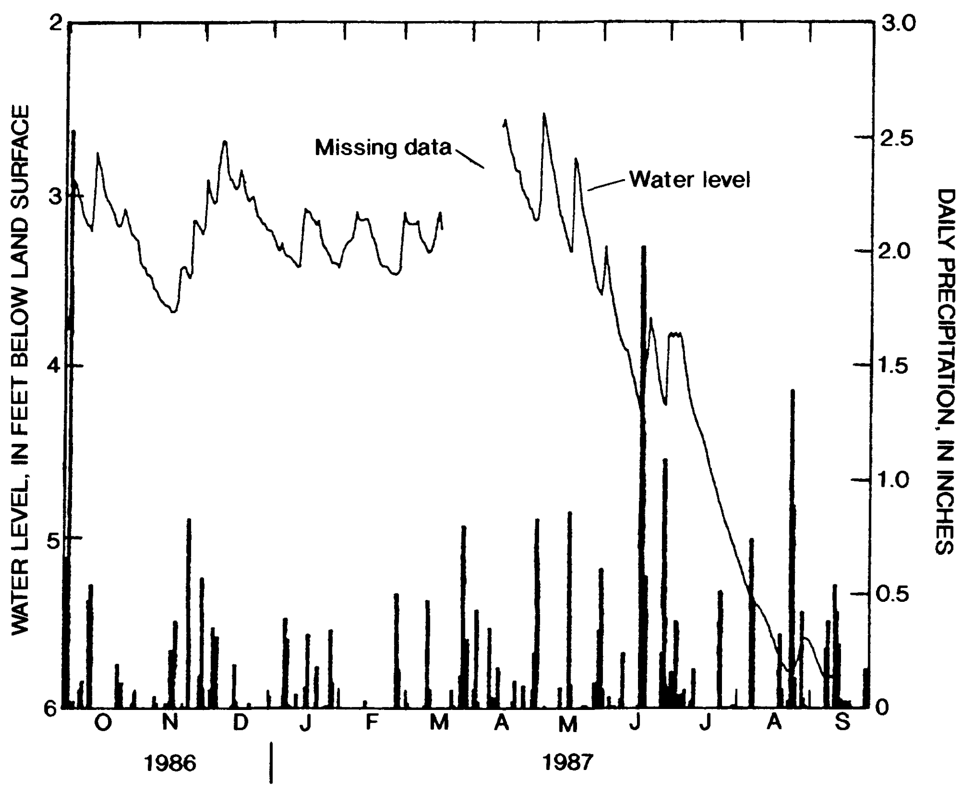


Figure 6.--Water levels in the surficial sand aquifer at well LU-303-SW20 and daily precipitation at Toledo Express Airport, 1987 water year.

The presence of tritium indicates the presence of post-1952 water; however, exact water age cannot be determined because of complications arising from the mixing of waters and radioactive decay. The results for selected samples of ground water from the sand aquifer are listed in table 9 (Supplemental Data section). The tritium concentrations range from 62 to 92 pCi/L (picocuries per liter) or 19 to 29 **tritium units**. These results indicate that the sand aquifer contains post-1952 water from precipitation. In fact, the rapid response of water levels in the sand aquifer to precipitation indicates that the water in the aquifer is very recent.

The sand is separated from the bedrock by about 50 ft or less of drift. The clay-rich drift, chiefly till, inhibits the vertical movement of water downward from the surficial sand aquifer. Thus, the top of the drift or till is considered the bottom of the sand aquifer.

Although the surficial sand aquifer is only in parts of Lucas County, the drift deposits are found throughout most of the study area. The drift seldom yields enough water to be considered an aquifer; however, the deposits are often saturated, and a seasonal water table is present (Kunkle, 1971). The drift is thinnest in the central part of the study area (western Sandusky County) and thickest in **buried valleys** incised in the carbonate bedrock. The two largest buried valleys, containing drift at least 100 ft in thickness (fig. 7), are (1) near the Maumee River, and (2) in east-central Sandusky County.

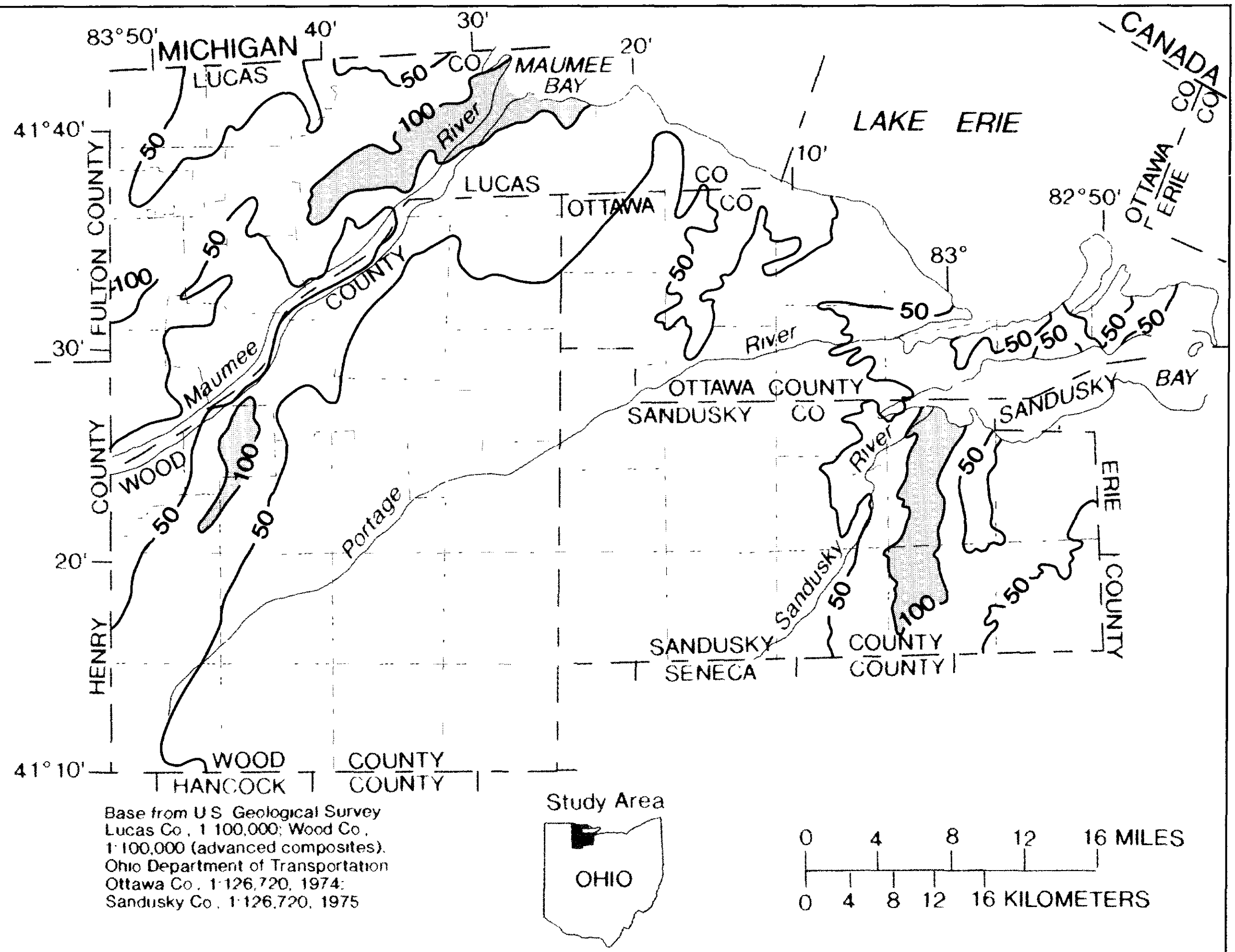
Sand and gravel deposits above the bedrock contact have been reported, but little information about the water-yielding capacity of these deposits is available. The sand and gravel deposits are developed as a water supply only in buried valleys in Lucas and Sandusky Counties (Hallfrisch, 1986a and Schmidt, 1980). A detrital zone or broken-rock zone is sometimes just above the bedrock. The broken-rock zone is generally saturated with ground water and commonly is a good source of water for domestic supplies (Forsyth, 1968, p. 85).

Bedrock

The hydrology of the bedrock aquifer was evaluated by use of the following:

1. Reviews of previous investigations;
2. Well-log inventories;
3. Mapping of the potentiometric surface; and
4. Analyses of ground-water geochemistry.

This information is used in combination with information on the geologic setting to define and describe the geohydrology, sources of recharge to the aquifer, directions of ground-water flow indicated by the potentiometric surface, and aquifer discharge.



EXPLANATION

—— 50 —— LINE OF EQUAL THICKNESS OF DRIFT DEPOSITS--Shaded areas indicate thickest deposits in buried bedrock valleys

Figure 7.--Thickness of drift in the study area (from Soller, 1986).

The Upper Devonian Ohio Shale is the youngest bedrock in the study area, and its presence is restricted to the northwestern corner of Lucas County (fig. 3 and table 8). The shale is a poor aquifer; yields of 3 to 10 gal/min to wells are characteristic (Hallfrisch, 1986a). In some places, the aquifer does not yield usable quantities of water.

Carbonate rocks of Middle Devonian through Middle Silurian age are generally good to excellent aquifers; well yields of 25 to 500 gal/min or more are characteristic (Schmidt, 1980; Hallfrisch, 1986a; Hallfrisch, 1986b). These dolomites and limestones, when considered together, are termed the carbonate aquifer. The carbonate aquifer is conceptualized for study as a regionally interconnected network of fractures, joints, and **bedding planes** in the rock. Rock-weathering processes before and after glaciation have contributed to the formation of these secondary openings in the rocks. Before glaciation, the aquifer is believed similar to that conceptualized by White (1969, p. 16) and illustrated schematically in figure 8A. Periodically, the rocks were structurally perturbed along the Findlay arch, jointing and fracturing the rock and leaving it open to surface recharge waters (Norris and Fidler, 1971a); percolating recharging waters dissolved the carbonate and dissolved and altered the minerals above bedding-plane separations, fractures, and joints to produce void spaces. Glacial processes contributed to additional chemical and physical weathering of the rocks, and, because of glaciation, the fractured and jointed rocks in the aquifer are covered with drift (fig. 8B). The rocks that comprise the aquifer are exposed at the land surface only in areas where the drift is thin or absent (shallow bedrock areas) and in quarries.

Fractures are regional and local features. Fracture lineaments that could be traced across counties were identified from satellite imagery of a large area of northwestern Ohio (Van Wagner, 1988). Fracture traces, or the expressions at land surface of subsurface fractures (Lattman and Parizek, 1964), have been mapped in Ottawa County by use of aerial photographs (Kessler, 1986, p. 31). Most fractures in Ottawa County appear in map-plan view to be less than 1 mi long and widely variable in distribution within individual townships. Some traces are areally extensive and are nearly 3 mi long. The longest and most areally extensive fracture traces trend northeast. Bearings of N.50°- 70°E. are identified as the dominant trend for all fracture traces mapped in Ottawa County. Similar trends are mapped for small-scale fractures and joint sets in a quarry within the study area (Kihn, 1988, p. 79). Fracture-trace analysis, which is often used in locating potential high-yield areas for the drilling of production water wells (Sharpe and Parizek, 1979), has been used successfully to site wells at Cygnet, Pemberville, and Gibsonburg (Eagon, 1980, 1983a, and 1984).

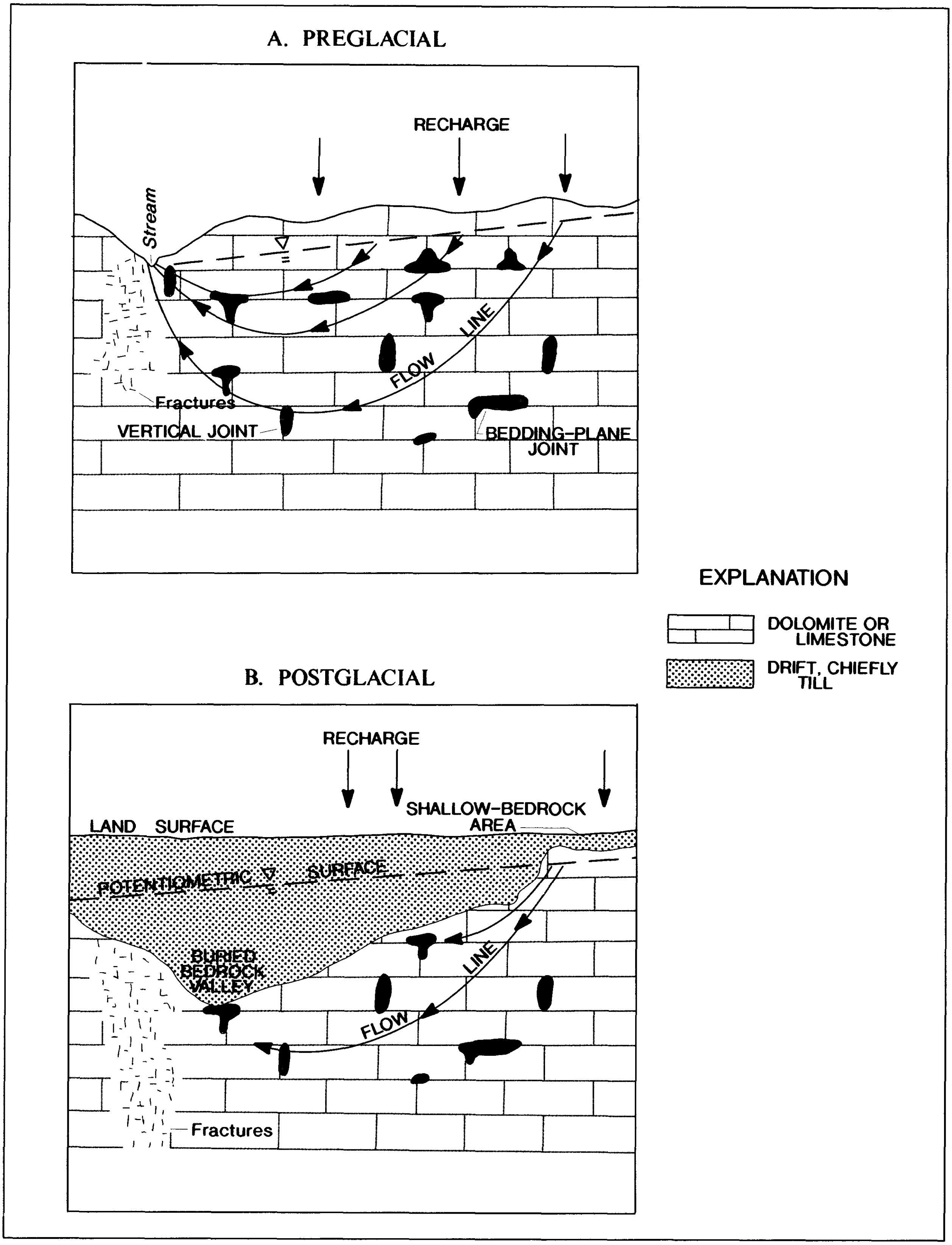


Figure 8.--Preglacial and postglacial conceptualization of the carbonate aquifer (part A. from White, 1969, with minor modifications; reproduced with permission).

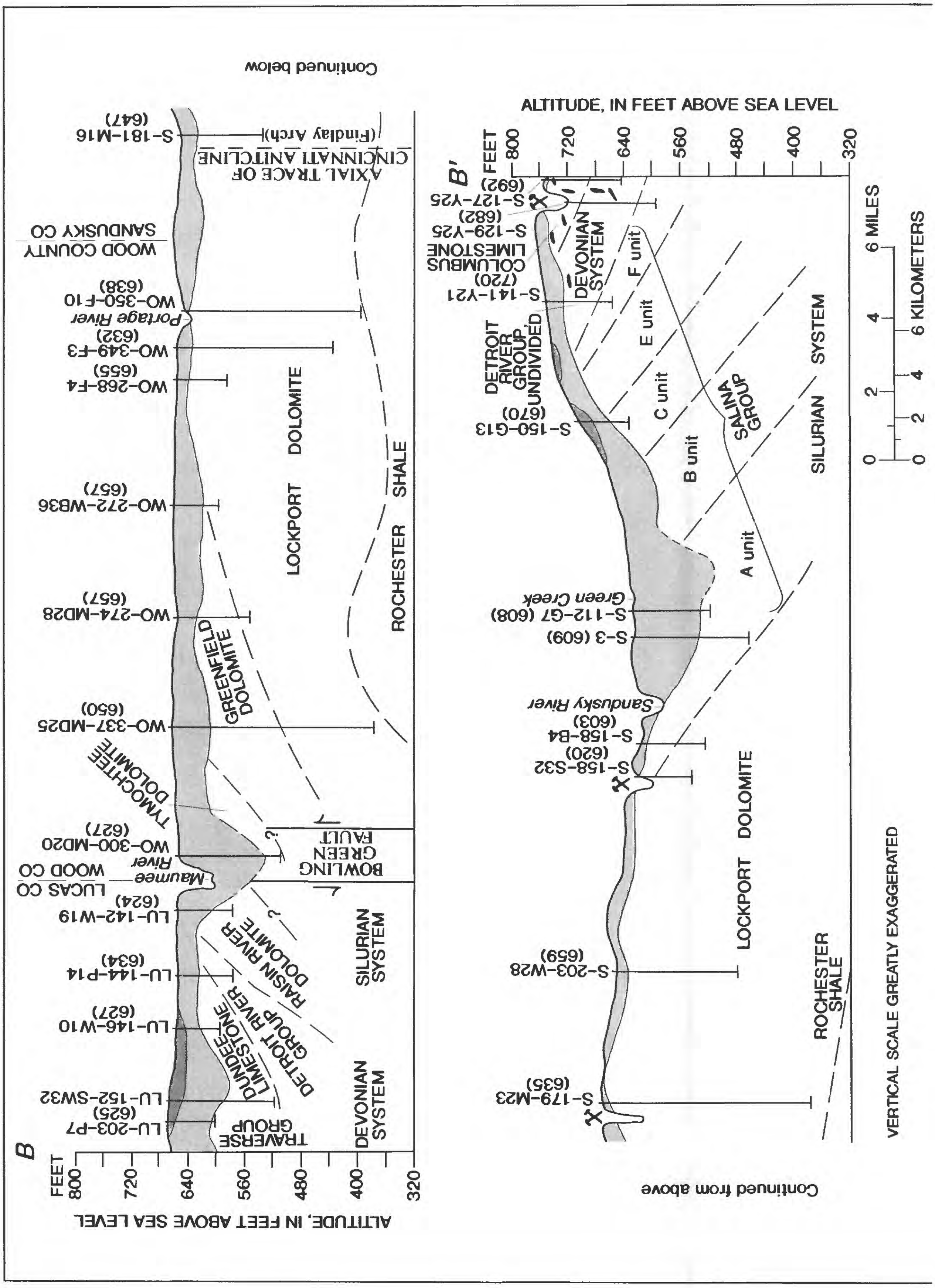
Ground water enters drilled wells through horizontal bedding planes, joints, and sub-vertical fractures that are described as water-producing zones (Ohio Department of Natural Resources, 1970). Water-producing zones can be separated from one another by relatively impermeable unproductive rocks. Ground water within these zones commonly is under artesian pressure where the potentiometric surface is above the top of the water-producing zone (and usually above the top of the aquifer or base of the drift), as illustrated in fig. 8B. The drift that overlies the carbonate aquifer is a confining layer for the aquifer over much of the area. The drift is not impermeable, and leakage from the drift to the carbonate aquifer does occur, as does upward leakage. The carbonate aquifer can, therefore, be termed a **leaky artesian** or **semiconfined aquifer**.

The existence of water-producing zones is supported by observations of ground-water discharges along bedding planes and fractures into local quarries. For example, ground-water discharge from a bedding-plane joint in dolomite of the Detroit River Group at the Silica quarry in northwestern Lucas County is shown in figure 9. The discharge of ground water from this single opening in the rock was estimated to be about 2 ft^3/s or 1.3 Mgal/d. Thus, a single water-producing zone or **vein** (drillers' term) such as that observed in the quarry, if tapped by a drilled well, potentially could yield 200 to 400 gal/min and would constitute an excellent source of water for an industrial or commercial well. Drilling reports for wells attest to the fact that water is from one zone or a small number of zones in the uncased well bore of industrial or commercial wells (at North Baltimore and Gibsonburg, for example).

The Ohio Department of Natural Resources (1970, p. 30) showed that hydraulic characteristics of water-producing zones depend on the stratigraphic or geologic units penetrated by a drilled well. Attempts to generalize the presence of water-producing zones in the various geologic units within the framework of the carbonate aquifer are summarized by ODNR (1970, p. 11, table 2), and shown in hydrogeologic section B-B', figure 10. (Location of section line is shown on pl. 1.) Figure 10 shows the variability in water-producing characteristics and how the variability is related to the geologic units.

To obtain maximum yields for public supply or industrial uses, wells are commonly completed to the bottom of the carbonate aquifer to intersect as many water-producing zones as possible. Wells WO-337-MD25, WO-350-F10, and S-179-M23 (fig. 10) represent completions of this type. The wells bottom just above a virtually **impermeable** basal shale. The Rochester Shale does not yield usable quantities of water and underlies the carbonate aquifer throughout the study area, although at considerable depth on the flanks of the Findlay arch.

Figure 9.--Photograph showing discharge of ground water from a bedding-plane joint in carbonate rocks in a quarry near Silica, Lucas County, Ohio.


B
B'
ALTITUDE, IN FEET ABOVE SEA LEVEL
FEET
800
720
640
560
480
400
320
Continued below
Continued from above
LU-203-P7 (625)
LU-152-SW32 (625)
LU-146-W10 (627)
LU-144-P14 (634)
LU-142-W19 (624)
Maumee River
LUCAS CO
WOOD CO
WO-300-MD20 (627)
BOWLING GREEN FAULT
WO-337-MD25 (650)
WO-274-MD28 (657)
WO-272-WB36 (657)
WO-268-F4 (655)
WO-349-F3 (632)
Portage River
WO-350-F10 (638)
WOOD COUNTY
SANDUSKY CO
AXIAL TRACE OF CINCINNATI ANTICLINE (Findlay Arch)
S-181-M16 (647)
TRAVERSE GROUP
DUNDEE LIMESTONE
DETROIT RIVER GROUP
RAISIN RIVER DOLOMITE
TYMOCHTEE DOLOMITE
GREENFIELD DOLOMITE
LOCKPORT DOLOMITE
ROCHESTER SHALE
DEVONIAN SYSTEM
SILURIAN SYSTEM
S-179-M23 (635)
S-203-W28 (659)
S-158-S32 (620)
S-158-B4 (603)
Sandusky River
S-3 (609)
S-112-G7 (608)
Green Creek
S-150-G13 (670)
S-141-Y21 (720)
S-129-Y25 (682)
S-127-Y25 (692)
COLUMBUS LIMESTONE
DETROIT RIVER GROUP, UNDIVIDED
SALINA GROUP
A unit
B unit
C unit
E unit
F unit
0 2 4 6 MILES
0 2 4 6 KILOMETERS
VERTICAL SCALE GREATLY EXAGGERATED

EXPLANATION

SAND DEPOSITS

GLACIAL CLAY TILL--Includes local occurences of sand, gravel, and silt

SOLUTION CAVITIES AND CAVERNOUS CONDITIONS EXIST IN CARBONATE ROCKS

HYDROGEOLOGIC CONTACT--Dashed where approximate. Queried where uncertain

S-158-B4
(603)

WELL--Upper number is local well number. Number in parentheses is altitude of water level from Breen (1989), in feet above sea level

QUARRY

TRAVERSE GROUP (UNDIVIDED)--Poor aquifer, often not water bearing, yields of less than 5 gallons per minute are common

DUNDEE LIMESTONE--Good aquifer, primary water-bearing zones 20-40 feet below top of unit

DETROIT RIVER GROUP--Good aquifer, most wells yield from water-bearing zones 40-60 feet below top of unit

RAISIN RIVER DOLOMITE--Poor aquifer, however yields to wells increase in the vicinity of Bowling Green Fault. Highly variable yields and variable depths of water-bearing zones

TYMOCHTEE DOLOMITE--Good to excellent aquifer, primary water-bearing zones are in the upper 70 feet of the unit. Yields of 250 gallons per minute or more are common

GREENFIELD DOLOMITE--Poor to marginal aquifer, often not water bearing. Wells generally penetrate into underlying Lockport Dolomite for yields greater than 50 gallons per minute

LOCKPORT DOLOMITE--locally may contain Bass Islands Group. Excellent aquifer, however yields are consistently poor and range from 25-300 gallons per minute with a median of 100 gallons per minute. Most wells yield from distinct water-bearing zones whose depth varies widely across the study area, but are generally 50-80 feet below the top of the formation

SALINA GROUP (OF JANSSENS, 1977)/BASS ISLANDS GROUP--Excellent aquifer with potential yields as high as 750-1,000 gallons per minute. Most water at the weathered bedrock surface and in zone of broken rock at top of bedrock beneath buried valley fill. Evaporite beds may be non-water bearing. Cavernous conditions occur locally in uppermost unit

DETROIT RIVER GROUP, UNDIVIDED--Good aquifer, yields to domestic wells are typically about 25 gallons per minute. Cavernous conditions occur locally, near Bellevue, drainage wells are completed into this unit

COLUMBUS LIMESTONE--Limestone Karst; sinkholes in shallow bedrock areas; highly variable water-bearing characteristics

Figure 10.--Hydrogeologic section *B-B'*. (Trace of section shown on plate 1. Aquifer descriptions from Ohio Dept. of Natural Resources, 1970).

Regional Geohydrologic Conditions

Semiconfined conditions are manifest in the carbonate aquifer by the response of ground-water levels to changes in atmospheric pressure. As atmospheric pressure decreases, water levels rise in wells that tap a confined aquifer. A measure of the response of an aquifer to changes in barometric pressure is called the barometric efficiency (BE) of the aquifer (Walton, 1970, p. 208).

Water-level response to atmospheric-pressure change was measured at selected wells where water levels are above the top of the aquifer. The results for July 8, 1986 (fig. 11), indicated that the degree of confinement of the aquifer varies with well location. At well LU-1 in Toledo, the aquifer is characterized by a BE of about 90 percent. Wells LU-110-T and WO-200-MO24 have BE's of 40 and 50 percent, respectively. Water levels in well S-3 fluctuate in response to nearby pumpage; thus, BE was not computed. For a different time period, a BE of about 80 percent was computed for well WO-121-N at Northwood (de Roche and Breen, 1989, p. 22).

In wells S-129-Y25 and S-170-W12, water levels are below the top of the aquifer, and water level does not change in response to changes in atmospheric pressure. Thus, unconfined or water-table conditions prevail. Water levels below the top of the aquifer are most prevalent in shallow bedrock areas.

Recharge areas

Recharge to the carbonate aquifer is by three primary processes:

1. Leakage of water from precipitation through the semi-confining layer of drift overlying the carbonate rocks.

2. Infiltration of the carbonate rock by surface water and precipitation in areas where drift is thin or absent.

3. Induced infiltration of surface water through riverbeds and streambeds as a result of ground-water withdrawals.

Areas where the carbonate aquifer is receiving recharge were delineated by interpretation of potentiometric-surface maps (Breen, 1989 and pls. 2-6), geologic data, and geochemical data for ground water, including specific conductance and tritium concentration.

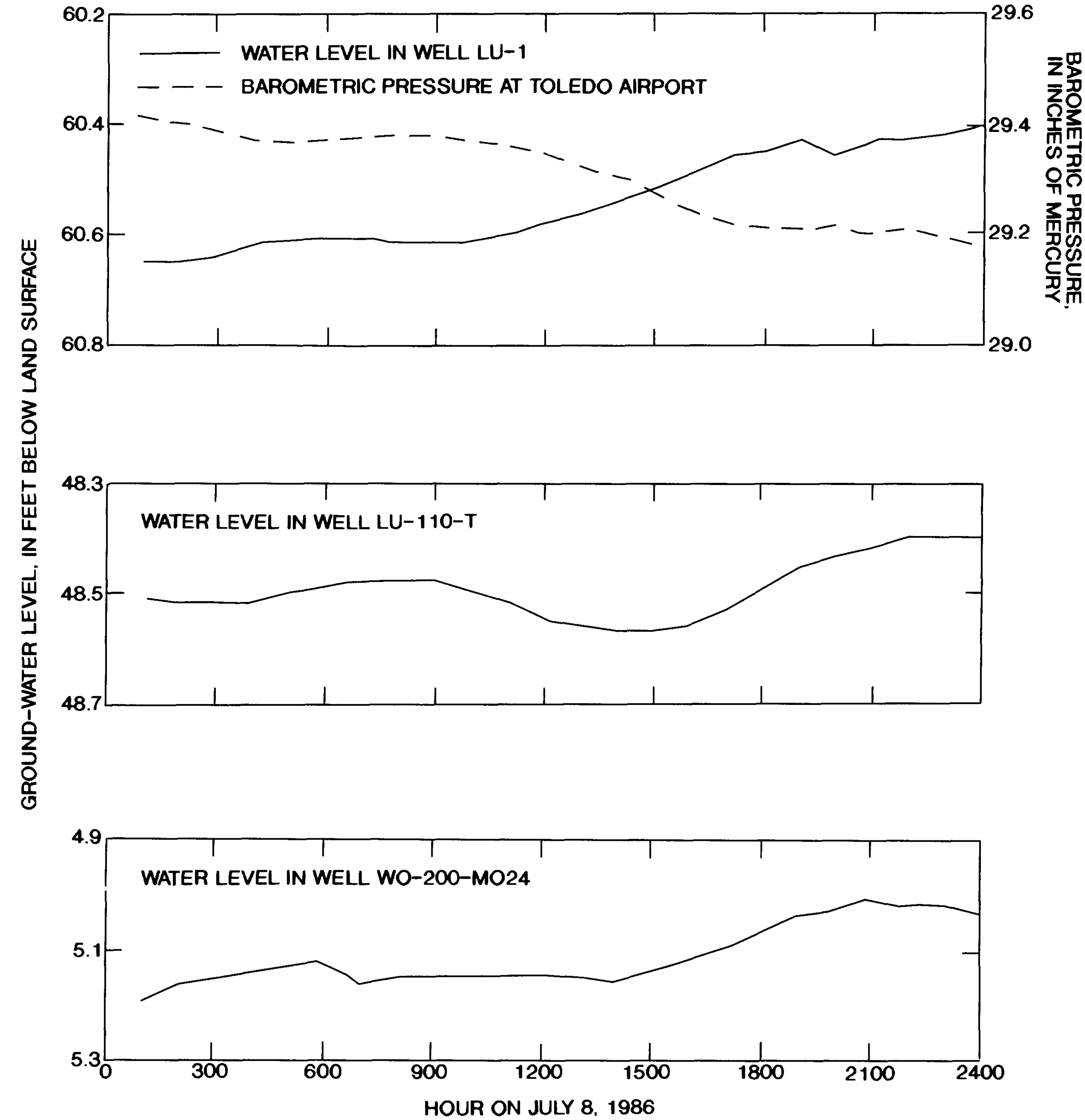


Figure 11.--Effect of atmospheric pressure fluctuation on water levels in wells LU-1, LU-110-T, and WO-200-MO24.

The aquifer contains younger (more recently recharged) water in some areas than in others. The relative age of water in an aquifer is an important indication of recent recharge--thus the susceptibility of an aquifer to contamination from sources at the land surface. Detectable concentrations of recently manufactured agricultural pesticides, for example, would not be expected in pre-1952 waters. Evidence of chemical infiltration from surface activities might be more likely, however, in areas where waters are young.

To determine the relative ages of ground water, tritium concentrations were analyzed in water from 59 sites to identify which waters in the aquifer are old (pre-1952) or are younger (have some post-1952 component). Data are tabulated with the water-quality data in table 9. Dot plots of tritium concentrations in ground water are shown in figure 12. Two concentration units are presented--tritium units (T.U.) and picocuries per liter (pCi/L). The units can be converted as follows: 1 T.U. equals 3.2 pCi/L. The distribution of data is highly right-skewed, and values in the 15- to 22-pCi/L range are distinctly absent. The tritium concentrations greater than 25 pCi/L (8 T.U.) indicate the presence of post-1952 (post-atomic-bomb tests) waters. Tritium concentrations less than 10 pCi/L indicate that waters are older than 1952 and that, in places, the aquifer is not open to recharge by, or mixing with, recently recharged surface waters or precipitation. For subsequent discussions, recent recharge is evident if the ground water has a tritium concentration of 25 pCi/L or more. This level of tritium indicates some component of the water produced by the well or spring is post-1952.

To examine the importance of leakage or infiltration of recent precipitation as a source of recharge to the carbonate aquifer, an attempt was made to correlate tritium concentrations in ground water with the thickness of the drift at each sampling site (fig. 13). On the basis of this correlation, shallow bedrock areas are defined as areas where drift is less than 20 ft thick. A vertical dashed line at 20 ft separates the data for shallow bedrock areas from data collected in areas where the drift is thicker. Data symbols serve to differentiate geologic units and aquifer types (semiconfined and unconfined). Most young (tritiated) waters are in shallow bedrock areas where the aquifer is generally unconfined (open data symbols).

The tritium data, combined with potentiometric mapping (Breen, 1989 and pl. 2-6), were used to produce the regional map of areas where the aquifer is receiving recent recharge (fig. 14). The shaded areas generally delineate where the carbonate aquifer is recharged by direct infiltration of surface water or precipitation into carbonate rock outcrops at land surface or infiltration through relatively thin drift. Tritiated waters (concentration >25 pCi/L) are in areas of thick drift only

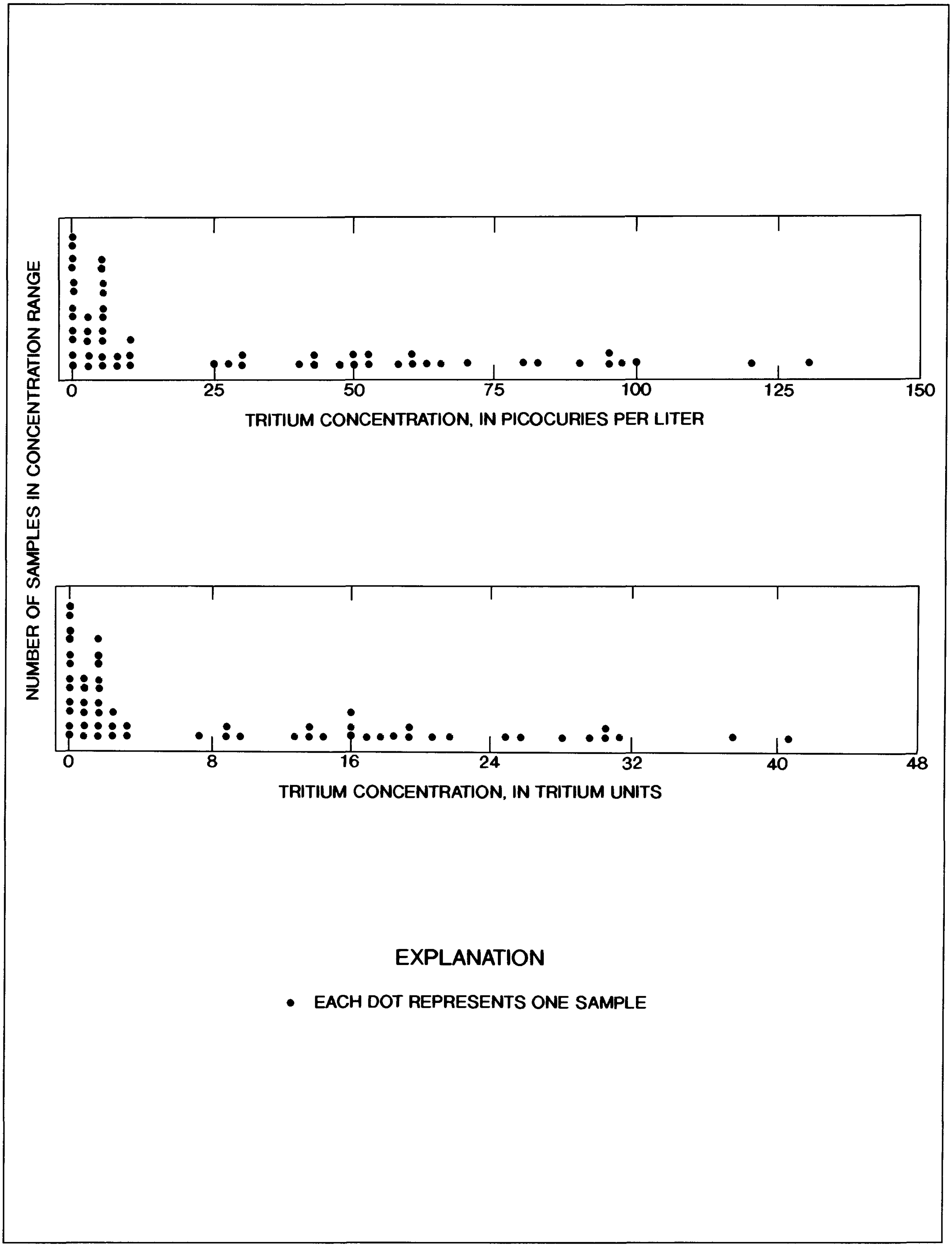
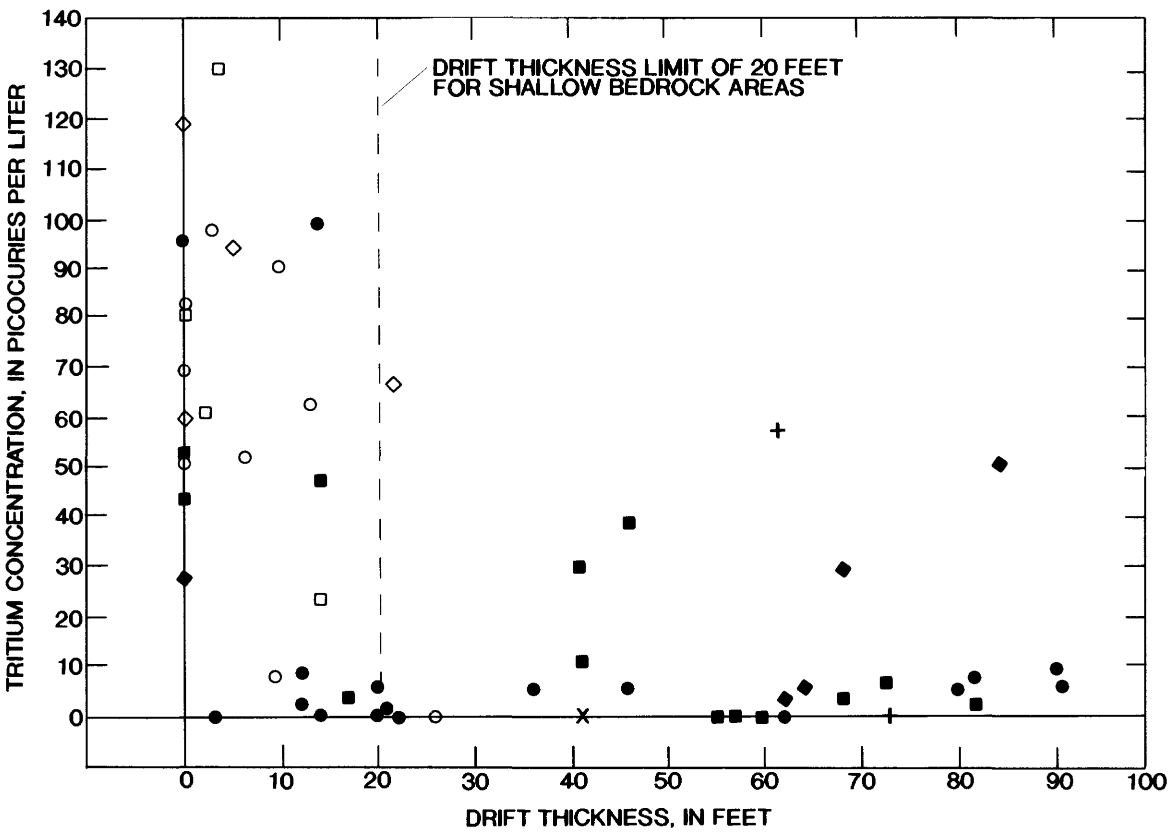


Figure 12.--Dot plots of the distribution of tritium concentration in water from the carbonate aquifer. (Note: Tritium concentrations reported as less than a detection limit are set equal to that limit for the purpose of this illustration.)



EXPLANATION

GEOLOGIC UNIT-AQUIFER TYPE

- + Devonian rocks-confined
- ■ Bass Islands Group-confined
- □ Bass Islands Group-unconfined
- ● Lockport Dolomite-confined
- ○ Lockport Dolomite-unconfined
- ◆ Sandusky County Bass Islands Group-confined
- ◇ Sandusky County Bass Islands Group-unconfined
- X 'Salina Group' well S-231-RL36-confined

Figure 13.--Tritium concentration in water from the carbonate aquifer as a function of drift thickness.

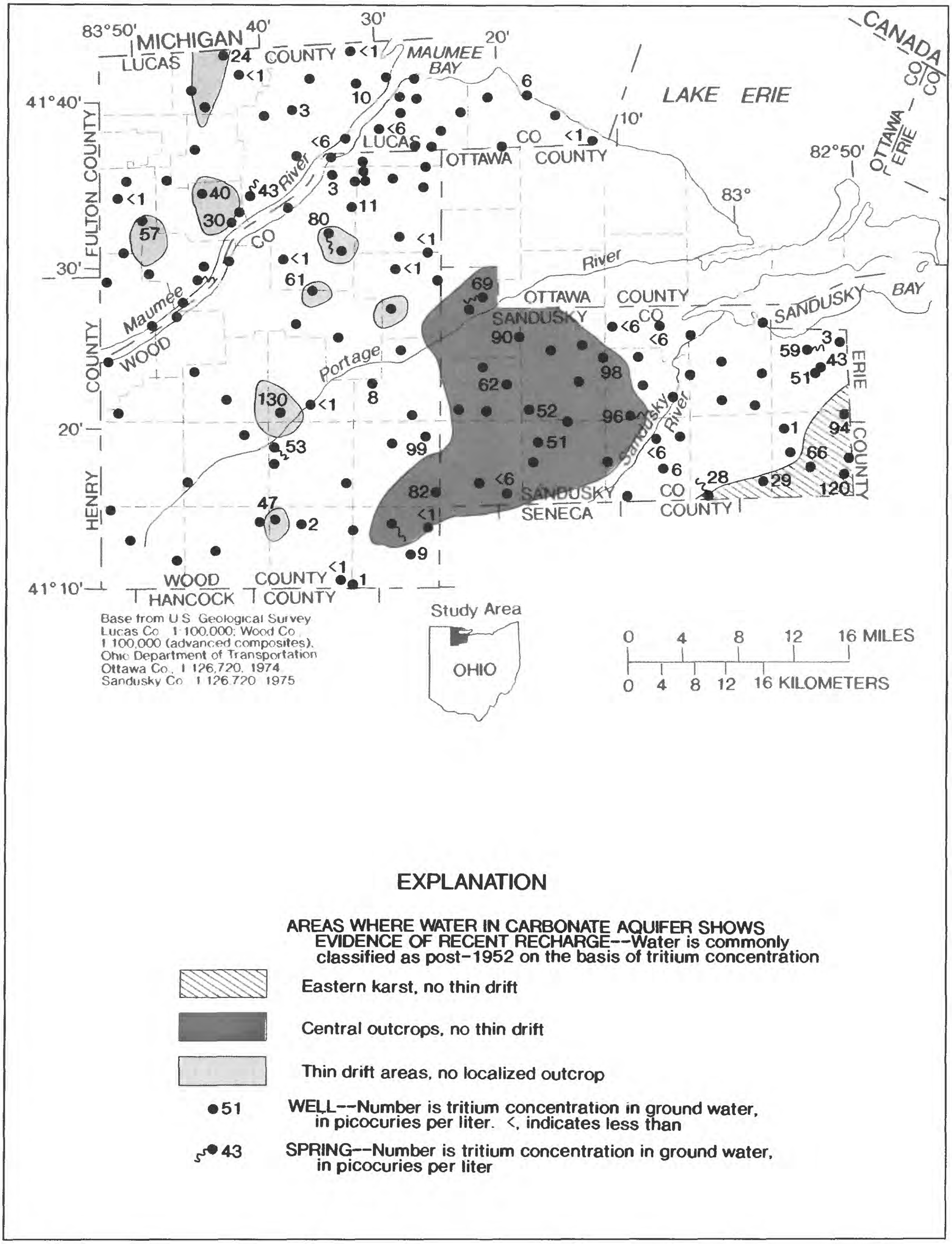


Figure 14.--Generalized areas where carbonate aquifer has recent recharge.

north of the karst terrain of easternmost Sandusky County (at wells S-141-Y21, S-147-G25, S-218-T15, and S-218A-T22) and in westernmost Lucas County near the Lucas County monocline (LU-113-M10, LU-116-M32, and LU-136-SW22). The geohydrology of each of these areas is discussed in detail in the section on Local Geohydrologic Conditions.

In other areas, leakage through thick drift is probably the dominant process by which the aquifer is recharged. The leakage is such a small fraction of the water produced by drilled wells that the waters appear to be pre-1952 on the basis of tritium concentration. Where recharge is otherwise considered to occur only as leakage through thick drift, direct pathways of recharge, such as abandoned and leaking well casings, may contribute to tritium concentrations in ground waters locally.

Dissolved-oxygen concentration, pH, and temperature indicate that the carbonate aquifer contains waters that are not in direct contact with air, even in the recharge areas. Dissolved oxygen, for example, is seldom detected; if present, it is usually at concentrations less than 0.3 mg/L. This supports the concept that much of the aquifer is confined by drift and that water flow is slow enough in recharge areas to allow for chemical changes in the water as it recharges the aquifer.

Discharge areas

Discharge of ground water from the carbonate aquifer is by three primary processes:

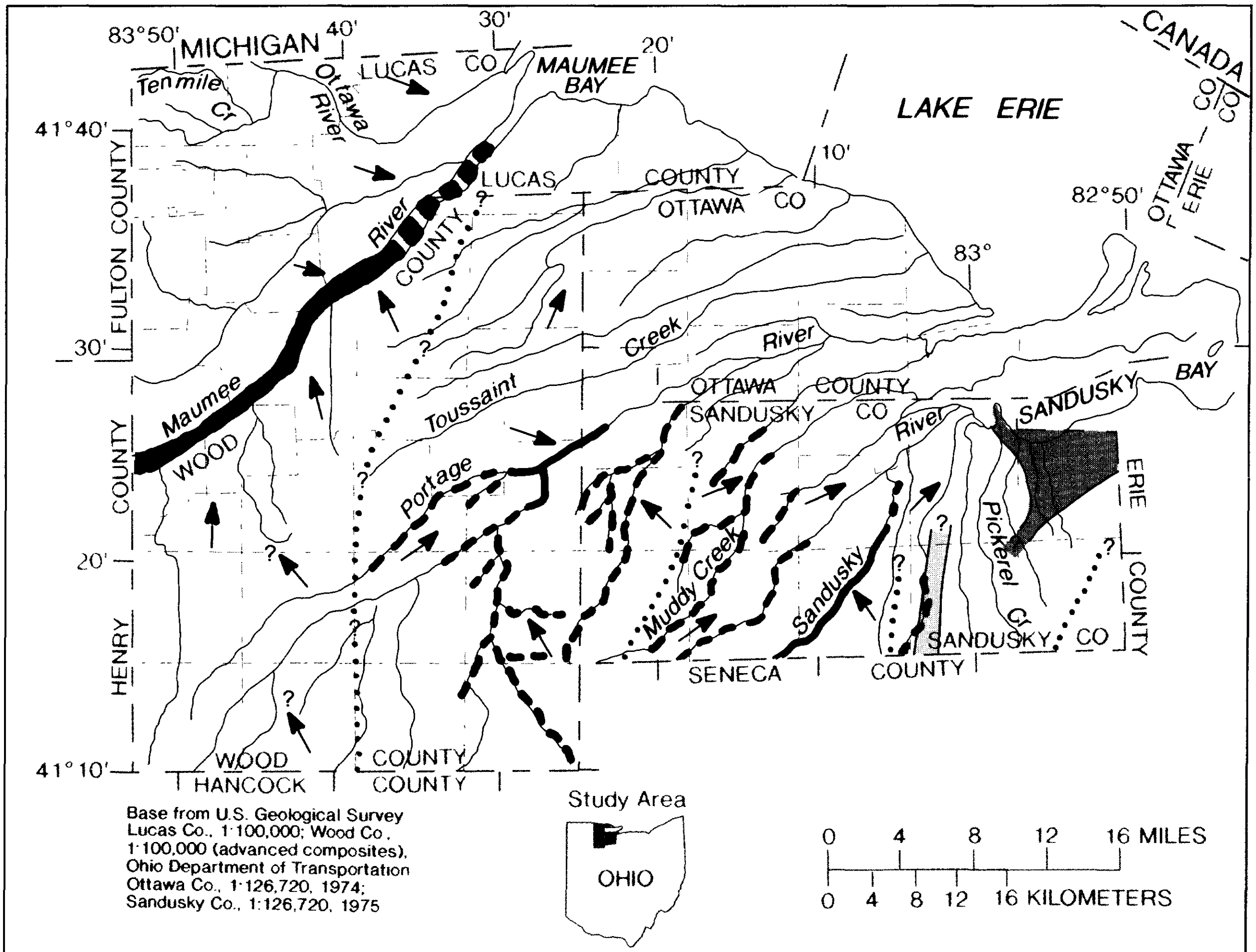
1. Flow from springs and flowing wells;

2. Flow into rivers, streams, lakes, and quarries; and

3. Pumpage from wells and quarries.

Areas of discharge from the carbonate aquifer were delineated by interpreting ground-water-flow directions and the positions of **ground-water divides** as indicated by potentiometric-surface maps (Breen, 1989 and pls. 2-6). A ground-water divide is similar to a surface-drainage divide in that it is a boundary along a high surface or ridge from which ground water moves away in both directions normal to the ridge line; it differs in that the ridge is in the potentiometric surface, not the land surface. Some ground-water-flow directions in the carbonate aquifer are different from those indicated by the gradients on potentiometric-surface maps. Secondary porosity along bedding planes, fractures and joints creates flow-direction anisotropy.

The ground-water discharge areas, divides, and indicated flow directions are shown in figure 15. Subsurface flow from recharge areas to the south and west enters the study area and moves toward discharge areas along major rivers and at springs.



EXPLANATION

- AREA OF DISCHARGE TO SPRINGS AND FLOWING WELLS--Queried where uncertain
- AREA OF DISHCARGE TO BURIED VALLEY--Queried where uncertain
- RIVER REACH RECEIVING GROUND-WATER--Dashed where approximate
- ? • • • • • GROUND-WATER DIVIDE--Queried where uncertain
- ? ◄—— DIRECTION OF GROUND-WATER FLOW ON THE BASIS OF POTENTIOMETRIC-SURFACE MAPPING--plate 2-6. Queried where uncertain

Figure 15.--Discharge areas, ground-water divides, and generalized ground-water flow directions indicated by potentiometric-surface mapping of the carbonate aquifer.

Several types of discharge areas are apparent. The Maumee, Portage, and Sandusky rivers are discharge areas for ground water from the carbonate aquifer. Tributary streams can also be receiving ground-water discharge, especially in the shallow bedrock areas of western Sandusky County and eastern Wood County. In areas of thicker drift, ground-water discharge into tributaries to Lake Erie is likely only where the stream channels are in contact with bedrock. Discharge also is to an area of springs and flowing wells along the southern shore of Sandusky Bay in northeastern Sandusky County and to the buried valley in east-central Sandusky County. The geohydrology of each of these areas is discussed in detail in the section on Local Geohydrologic Conditions.

Local Geohydrologic Conditions

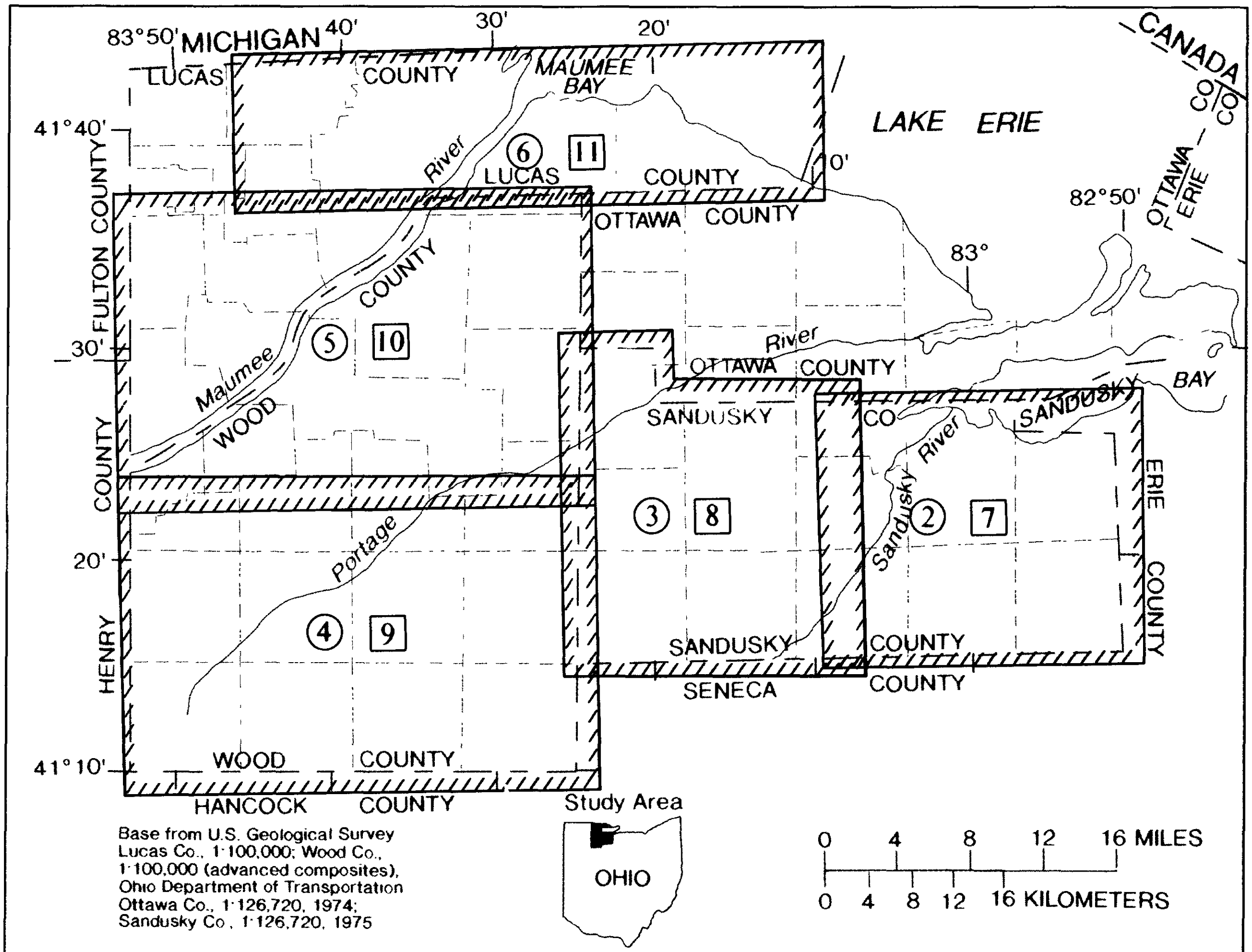
In five mapped areas (fig. 16), geohydrologic conditions, including aquifer transmissivity, seasonal water-level fluctuations, recharge, and discharge, are described with reference to local geographic and political features. The conditions and features are given on plates 2 to 6 (at back of report). The following discussions refer extensively to the plates.

Eastern Sandusky County

A complex ground-water-flow system in eastern Sandusky County is indicated by the altitude and configuration of the potentiometric surface on plate 2. The contours are irregularly spaced and convoluted in several areas. Aquifer transmissivity, recharge areas, and discharge areas influence the potentiometric surface and indicated patterns of ground-water flow.

Transmissivities from aquifer tests (Ohio Department of Natural Resources, 1970) near Green Springs and at well S-3 are 8,700 ft^2/d and greater than 13,000 ft^2/d, respectively. (Locations are shown with diamonds in pl. 2.) Further north, a transmissivity of about 3,500 ft^2/d was determined at well S-18. Transmissivity values of this magnitude are representative of the high-yield well zone reported by Ohio Department of Natural Resources (1970) and Norris and Fidler (1971a, p. B233). The high-yield well zone includes the north-trending buried valley about 4 mi east of Fremont (see pl. 2) and extends eastward from the buried valley. This zone, which can yield 500 to 1,000 gal/min to wells, is present in the Salina Group and Bass Islands Group rocks that overlie the Lockport Dolomite.

Recharge areas are associated with the shallow bedrock (the shaded pattern on pl. 2) near Bellevue where karst features, such



EXPLANATION

HYDROGEOLOGIC PLATE NUMBER	HYDROCHEMICAL PLATE NUMBER	LOCAL MAP AREA
②	[7]	Eastern Sandusky County
③	[8]	Western Sandusky County
④	[9]	Southern Wood County
⑤	[10]	Northern Wood/Southern Lucas County
⑥	[11]	Northern Lucas County

Figure 16.--Mapping area selected to illustrate local hydrogeologic and hydrochemical conditions in the study area.

as caverns and sinkholes, are present. The karst in southeastern Sandusky County is described in detail by Kihn (1988). Some cavernous features appear to be related to fractures rather than to weathering (dissolution) of the carbonate rock (Kihn, 1988, p. 88). The configuration of the potentiometric contours indicates a recharge area south of the 700-ft contour that is part of the karst system. A localized recharge area is indicated by the mounding of the potentiometric surface near well S-131-Y11.

In the Bellevue area, recharge enters the aquifer directly through **drainage wells**, sinkholes, and **sinking streams** (Ohio Division of Water, 1961; Pettyjohn, 1972; and Kihn, 1988, p. 41). The potentiometric surface near Bellevue indicates flow of ground water toward the quarry just northwest of Bellevue. Drainage wells drilled into the quarry floor allow water from a shallow zone in the carbonate aquifer (Columbus Limestone) to drain into a deeper part of the carbonate aquifer (in Detroit River and older units) (Bruce Mason, France Stone Co., oral commun., 1985).

The highly convoluted patterns of the potentiometric surface in the Bellevue area clearly indicate a different flow system from the one farther west. Near Bellevue, flow is through fractures, caverns, and other dissolution openings in the karst terrain. North of Bellevue, the contours indicate flow toward Sandusky Bay. Chemical studies at springs north of Bellevue led Kihn (1988, p. 73) to conclude that flow in the aquifer is diffuse flow rather than conduit flow common in karst areas.

Regional discharge from the carbonate aquifer in eastern Sandusky County is by flow to springs and flowing wells. Miller's Spring (S-30-T9) is capable of discharging more than 3,000 gal/min (Ohio Division of Water, 1968). Reports that some parts of the surface of Sandusky Bay remain unfrozen in winter (Dale Liebenthal, Ohio Geological Survey, oral commun., 1989) indicate that the bay also could receive subsurface ground-water discharge. Similar water-level altitudes in the carbonate aquifer and Sandusky Bay indicate a hydraulic connection between the bay and the aquifer. A small discharge area where wells flow seasonally is west of the Village of Clyde.

Subsurface discharge from the carbonate aquifer to the buried valley east of Fremont is indicated by the potentiometric surface. The contours point upvalley, indicating that ground water from the carbonate aquifer is discharging into the valley from the southeast and southwest. Discharge of about 5,500 gal/min from the spring at Green Springs[1] is possibly a surficial expression of the subsurface discharge from the carbonate aquifer into the

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[1] The village was named Green Spring in 1839 because of the emerald-green color of water that issues from the spring at St. Francis Hospital. The name of the village was later changed to Green Springs.

buried valley north of Green Springs. The carbonate aquifer also discharges into the Sandusky River channel south of Fremont.

Pumping for industrial and irrigation supplies is another source of discharge seasonally in local areas. Water levels in industrial wells at Fremont when the wells are pumped (P) and not pumped (NP) indicate extreme seasonal fluctuations in water levels. Ground water is used seasonally for irrigation in the areas surrounding Fremont. Well S-3 is located in an area where seasonal pumping affects water levels in the carbonate aquifer.

The hydrograph for well S-3 (fig. 17) indicates that seasonal fluctuations in water levels occur and are generally less than 10 ft. During the first three months of the year, the water level is relatively constant. Seasonal declines begin in May and continue till September. The declines are often interrupted by abrupt rises of about 2 to 3 ft immediately after rainstorms. The cause of the abrupt rise is either a response to recharge or a response to decreased irrigation pumpage during and after rainstorms. Water levels rise steadily during the winter, and the cycle is repeated the following year. The hydrograph indicates a seasonal balance between recharge and discharge.

In other areas, seasonal water-level changes of less than 5 ft are common (table 3), except near pumping or dewatering operations and near Bellevue, where changes of 10 to 40 ft were measured in several wells not affected by pumping. Graphs of intermittent water levels in three wells (fig. 18) illustrate the water-level fluctuations in the eastern karst area near Bellevue. In contrast to conditions at well S-3, natural seasonal changes can exceed 40 ft at well S-129-Y25, and commonly are 10 to 30 ft near Bellevue.

A summary of the characteristics of three ground-water-flow systems in eastern Sandusky County is given in table 10. Recharge and discharge characteristics are different in each system. The diversity of geohydrologic conditions in eastern Sandusky County is in contrast to the more uniform conditions in western Sandusky County.

Western Sandusky County

Throughout most of western Sandusky County, potentiometric contours are uniformly spaced (pl. 3), indicating that the transmissivity of the aquifer, recharge characteristics, and discharge characteristics are also relatively uniform.

Uniform transmissivity in western Sandusky County was noted by the Ohio Department of Natural Resources (1970, p. 34). Transmissivities computed from aquifer-test data (S-11, S-12) were generally in the range of 200 to 700 ft^2/d and approached a

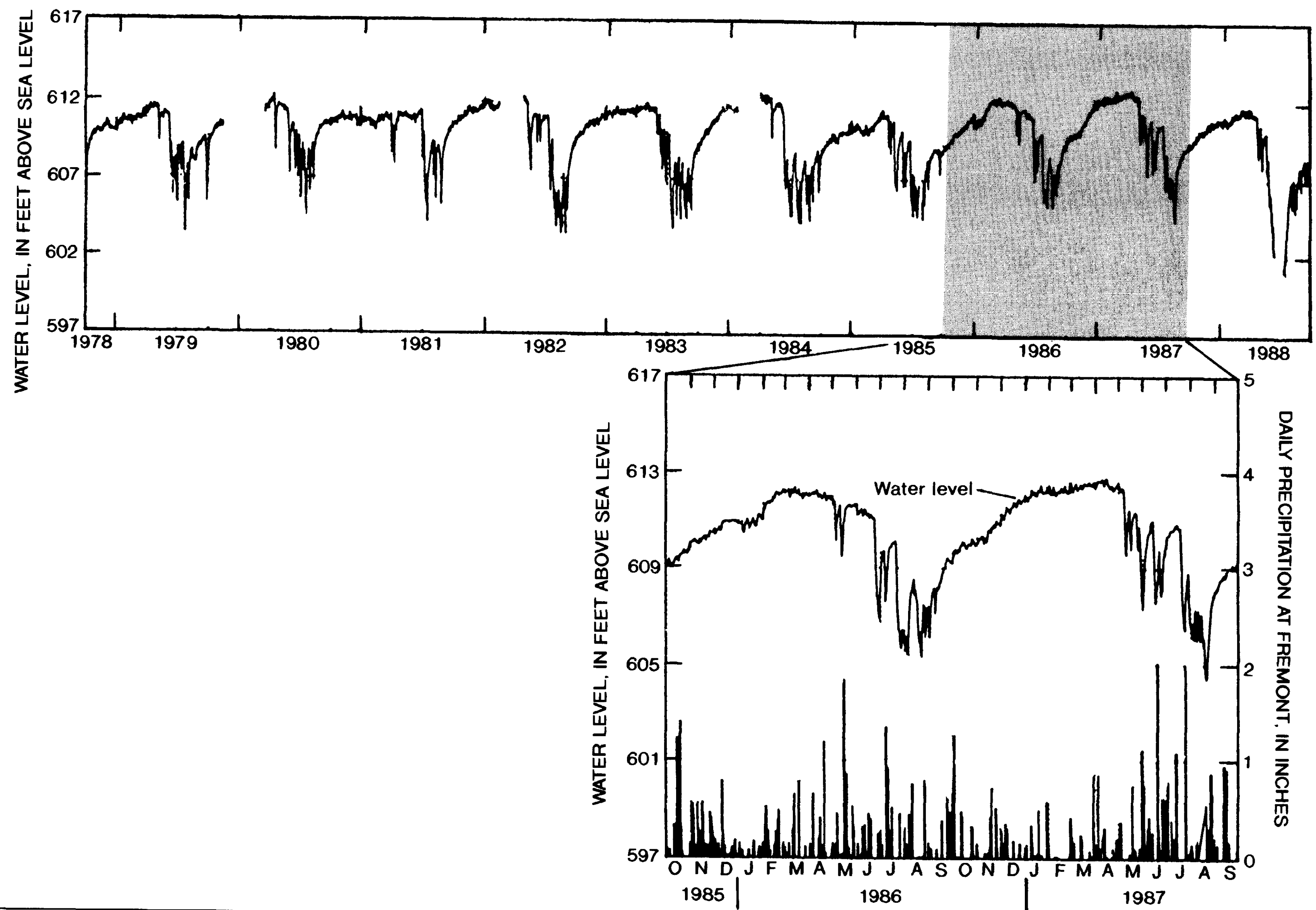
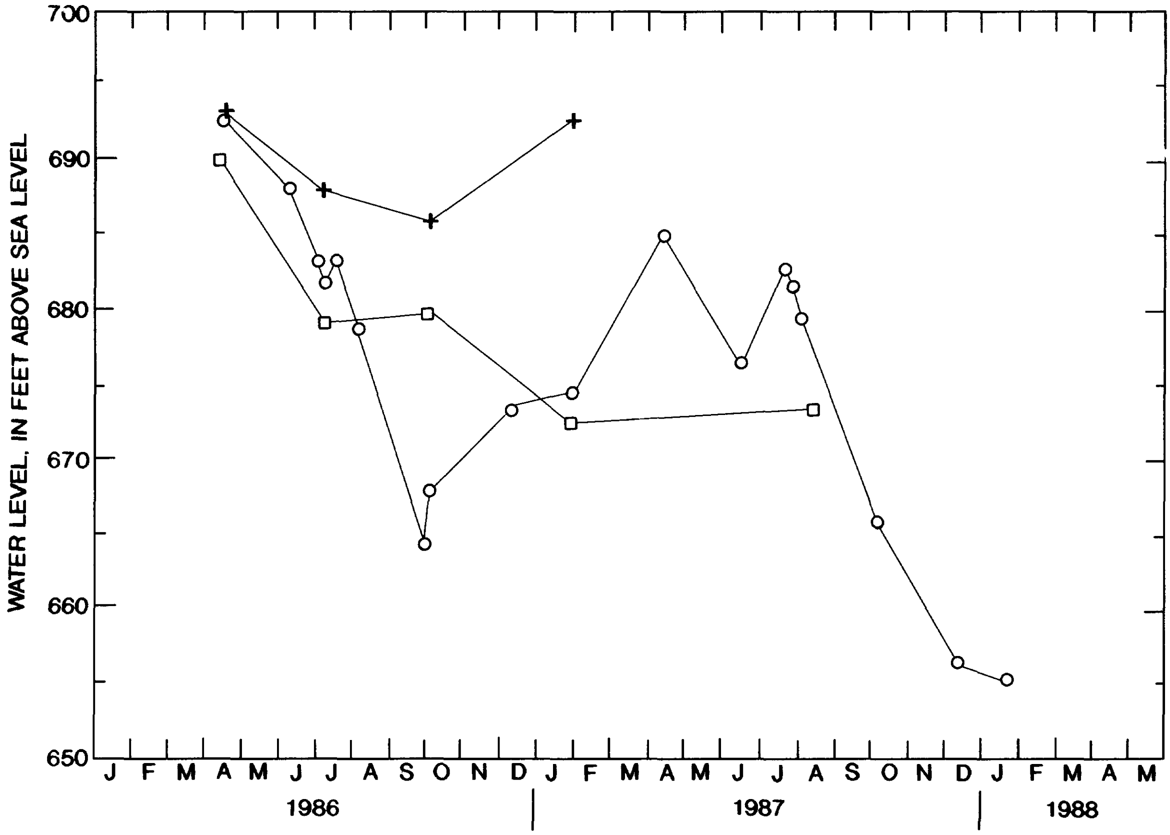


Figure 17.--Hydrograph for the carbonate aquifer at well S-3, southeast of Fremont, Ohio.



EXPLANATION

WATER IDENTIFIER--Measurements are connected with straight lines to show general trends. Actual levels between measurements may have been different than indicated by these lines

- ○ S-129-Y25
- □ S-130-Y13
- + S-131-Y11

Figure 18.--Ground-water levels in selected wells near Bellevue, Sandusky County, Ohio, 1986-88.

Table 10.--Characteristics of ground-water-flow systems in eastern Sandusky County

[ft, feet]

Flow system	Characteristics
1. Eastern karst	Occurrence--York and Townsend Townships and part of western Erie County. Recharge--Through drainage wells, sinkholes, and sinking streams in York Township and south of York Township; also as regional flow from the southwest and southeast. Discharge--To springs and flowing wells along southern shore of Sandusky Bay in Townsend Township and Erie County (confined conditions). Upward leakage to drift in areas of flowing wells and springs. Geologic units--Middle Devonian strata of Detroit River Group and younger units (including the Columbus Limestone). Age of water--Generally post-1952 in recharge and discharge areas. Water-level fluctuations--10-40 ft seasonally in recharge area; less than 5 ft in discharge area.
2. Central buried valley region of Sandusky River area	Occurrence--East of Fremont in Ballville, Green Creek, and Riley Townships. Recharge--From Western York Township, from shallow bedrock south of Sandusky County (Norris, 1974, p. 530), and from leakage through unconsolidated deposits. Discharge--To spring at Green Springs, to sand and gravel deposits in buried valley north of Green Springs, and to flowing wells and springs in Green Creek and Riley Townships. Upward leakage to drift in areas of flowing wells and springs. Geologic units--Undifferentiated "Salina Group" and Bass Islands Group of Silurian age. Age of water--Pre-1952. Water-level fluctuations--About 5-8 ft seasonally at well S-3 due to pumpage for irrigation supplies. Larger fluctuations occur near industrial pumping near Fremont.
3. Lockport subcrop region of Sandusky River area	Occurrence--West of Sandusky River in Ballville Township, Sandusky Township, and Fremont. Locally, east of Sandusky River in Ballville Township. Recharge--From south of Sandusky County (Norris, 1974, p. 530) and from shallow bedrock areas west of Fremont. Discharge--To Sandusky River channel south of Fremont, toward Sandusky Bay north of Fremont; seasonal pumpage and quarry dewatering influences discharge. Geologic units--Transitional zone between Lockport Dolomite to west and overlying "Salina Group" and Bass Islands Group to east. Age of water--Pre-1952 except where younger waters recharge the shallow bedrock areas west of Fremont. Water-level fluctuations--Generally less than 10 ft of fluctuation seasonally, except where local pumpage affects water levels.

maximum of about 1,300 ft^2/d (WO-12). These uniform properties are attributed to the homogeneity of the Lockport Dolomite. Local presence of Bass Islands Group rocks is documented, however, and the Ohio Department of Natural Resources (1970) reports that these rocks yield little water in this area.

Variations in the uniform spacing of contours are apparent at several locations. For example, south of the 690-ft contour line, contour spacing increases. The distance between contours becomes abruptly narrow east of Lindsey near well S-170-W12, then widens between the 580- and 570-ft contours. The narrow contour spacing is believed to represent a zone of low-transmissivity rock, probably similar to thinly laminated dolomite exposed in the western side of the quarry just west of Fremont. Drillers identify this unit as gray- and brown-streaked dolomite or limestone. The gradational contact between the Lockport and younger overlying strata to the east is also exposed in the quarry. The overlying strata are more transmissive than the Lockport, which results in the change to widely spaced contours north of Fremont. The chemistry of water in the carbonate aquifer (discussed later in the report) also indicates that this area is a transition zone between two different types of carbonate rocks.

Recharge to the aquifer in western Sandusky County is from areas south of Sandusky County and from local recharge areas. The thin drift and numerous areas where the carbonate rocks are exposed at land surface provide the rationale for classifying most of western Sandusky County as central outcrops. Drift is less than 20 ft thick over much of this area (pl. 3). The central outcrops contain relatively young waters compared with water in other parts of the carbonate aquifer, showing that recharge is taking place. Ages of ground water, as estimated from tritium concentrations, are commonly post-1952.

Recharge is indicated by an area of high hydraulic heads in the potentiometric surface in southwestern Sandusky County. The 700- and 710-ft contours define a ground-water divide that influences directions of ground-water flow. The potentiometric-surface contours indicate the divergence of flow away from the divide. This divide corresponds generally with the boundary between the Sandusky River and Portage-Toussaint River **ground-water basins** described by Hoover (1982, p. 64). The divide is in an area of thin drift cover and is within the central outcrops.

Seasonal recharge in western Sandusky County is indicated by water-level changes from recording gages with 1-hour recording intervals at wells WO-200-MO24 and S-170-W12 (pl. 3). The hydrographs are shown in figure 19; precipitation records for two nearby weather stations also are plotted. Details on well construction at these sites are listed in table 3.

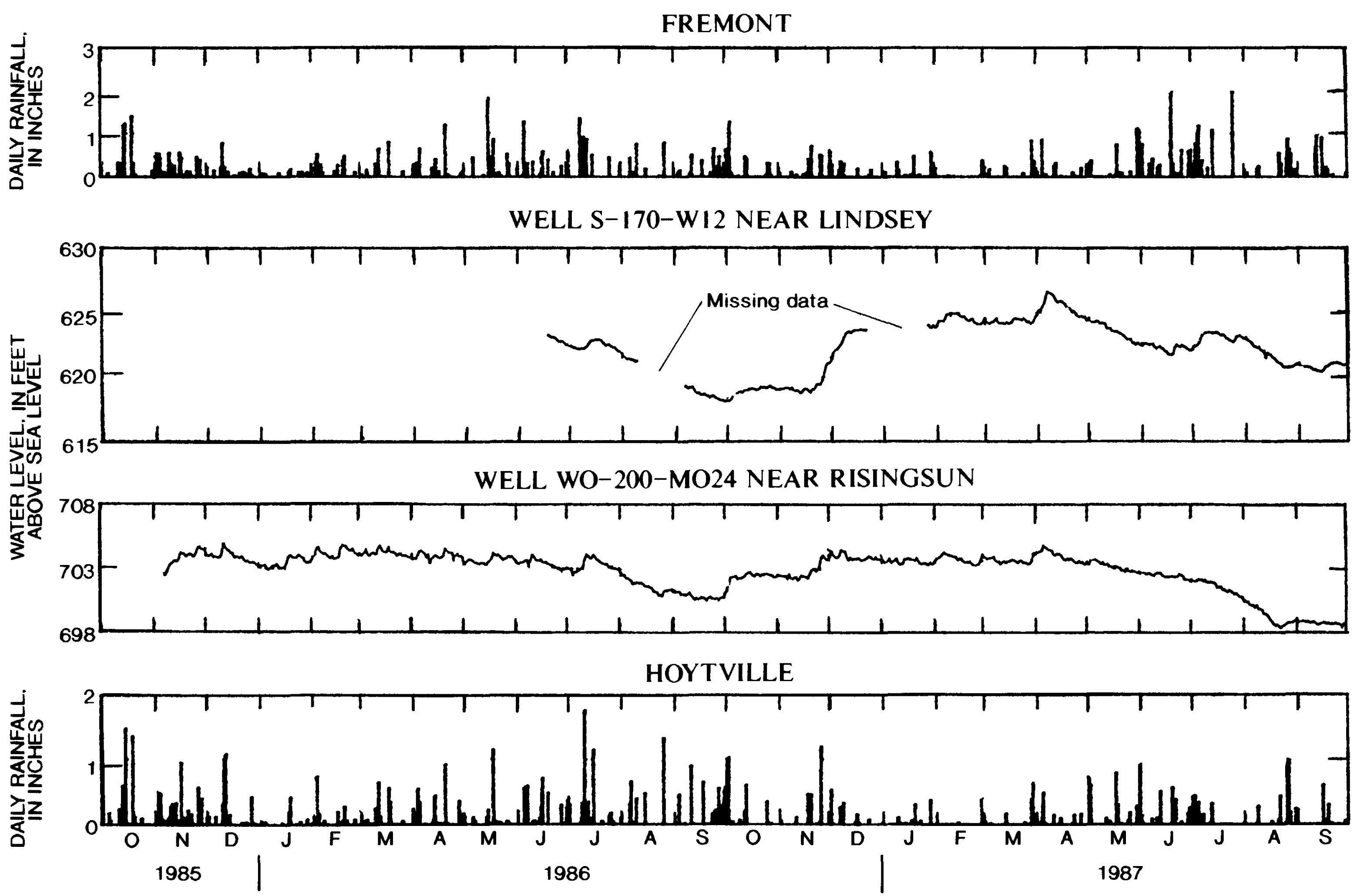


Figure 19.--Water levels for selected wells and precipitation for selected gages in the western Sandusky County area, 1986-87 water years.

Well S-170-W12 is located in an area of thin drift cover (3 ft to bedrock) where the water level is below the top of the aquifer. Maximum water-level fluctuations are less than 10 ft, with seasonal lows in September and seasonal highs in April that reflect spring recharge. The hydrograph shows that water levels rise rapidly during the spring in response to precipitation. During May through October, when evapotranspiration is occurring, water-level increases resulting from precipitation are less pronounced than those that occur in the spring. Water levels in well WO-200-MO24, where about 30 ft of clay overlies the bedrock, show similar seasonal patterns; however, total water-level fluctuations are usually 5 ft or less. Conditions at other wells (table 3) are generally similar except near pumping.

Regional discharge from the carbonate aquifer in western Sandusky County is to the Sandusky River and Portage River, both underlain by bedrock channels. Localized discharge to smaller streams also takes place. The potentiometric contours near the Sandusky River south of Fremont indicate that ground water discharges to the river. Pettyjohn and Henning (1979, p. 106) have shown that this reach of the Sandusky River receives ground-water discharge ranging from 200,000 to 300,000 $(gal/d)/mi^2$ or 0.3 to 0.45 $(ft^3/s)/mi^2$ from its watershed.

Ground-water/surface-water interactions along the Portage River near Woodville are complicated by quarry dewatering. Ground water discharges to the Portage River system at the rate of 100,000 to 200,000 $(gal/d)/mi^2$ (0.15 to 0.3 $(ft^3/s)/mi^2$) of drainage area in the Portage River basin (Pettyjohn and Henning, 1979, p. 106), on the basis of data from a streamflow-gaging station at Woodville; however, the cone of influence from quarry dewatering extends to the river channel and induces recharge to the aquifer from the river. Water from well S-188-WO28 between the river and the quarry contains large amounts of silt- and clay-sized particles believed to represent the sediment in river water that is drawn into fractures in the aquifer during high streamflow.

Discharge as pumpage from wells at Woodville, Lindsey, and Gibsonburg is estimated at 0.864, 0.140, and 0.900 Mgal/d, respectively (J.A. McClure, U.S. Geological Survey, written commun., 1986). Quarry dewatering at Woodville and Millersville also represents discharge from the aquifer system of 1 and 0.1 Mgal/d, respectively.

Southern Wood County

The potentiometric surface in southern Wood County, shown on plate 4, indicates that geohydrologic conditions, including transmissivity, recharge, and discharge, differ in the eastern and western parts of the area. The uniform characteristics described for western Sandusky County extend into easternmost southern Wood County.

The uniform spacing of potentiometric contours in southeastern Wood County changes markedly to widely spaced and convoluted contours to the north and also to the west of the Bowling Green fault zone. The change in contour spacing is probably due, in part, to the variation in the water-bearing properties of the carbonate rocks, which are summarized in terms of transmissivity in table 11. The wells east of the fault zone produce water in part from the Lockport Dolomite, and transmissivities are consistent with those for the Lockport in western Sandusky County.

Potentiometric contours are tentative, and, therefore, are dashed in the area designated as the Bowling Green fault zone because of a lack of water-level data. Van Wagner (1988) reviewed data available on the fault and interpreted geophysical and water-well data to indicate that the fault is actually a zone of disturbed or fractured rock about 2 mi wide. The dashed contour lines across the fault zone indicate that different ground-water-flow systems may be present on the two sides of the fault zone; however, because of the fracturing associated with the fault, the flow systems may be hydraulically connected.

Regional recharge originates mostly in areas south of Wood County. Ground water flows northward into Wood County, and additional recharge occurs locally in the shallow bedrock areas of southeastern Wood County (note shaded pattern on pl. 4). Localized recharge is indicated by the closed 680-ft contour south of Bowling Green and the closed 670-ft contour in southern Freedom Township. In both areas, shallow bedrock is overlain by permeable sand deposits.

Estimates of ground-water age can be made only for the eastern half of southern Wood County because no samples were analyzed for tritium concentrations in the western half. Water ages appear to be variable in the eastern half, probably because recharge is affected by the variable thickness of drift overlying the carbonate aquifers. In wells sampled near the Hancock-Wood County line, waters contain no tritium and are probably pre-1952. Evidence for young waters is restricted to five samples from wells north of West Millgrove and Cygnet. The highest concentrations of tritium were in waters from wells at Bradner and Bowling Green.

Ground water discharges from the carbonate aquifer into quarries near Custar, Portage, West Millgrove, and near North Baltimore. The quarries are dewatered at rates estimated at 0.6, 0.5, 0.3, and 1.5 Mgal/d, respectively. Estimates of pumpage from public-supply wells at Cygnet, Bloomdale-Bairdstown, Bradner, and Wayne are 0.06, 0.05, 0.09, and 0.07 Mgal/d, respectively. Drawdown from these pumped wells is localized and is not known to influence the regional pattern of ground-water flow. Potentiometric contours on the northeastern corner of plate 4 indicate a convergence of flow to the Portage River and could indicate the effects of pumpage at Pemberville.

Table 11.--Carbonate-aquifer transmissivities at selected locations in southern Wood County, Ohio

[Data from Eagon (1980, 1983a, 1983c) and Ohio Department of Natural Resources (1970)]

Well identifier on Plates 1 and 5	Location	Transmissivity (feet squared per day)
WO-10------------	Weston Water Works	1,350
WO-11------------	North Baltimore	670[a]
WO-23-C27--------	Center Township	1,500
WO-12 and WO-200-MO24----	Risingsun	1,300-1,500
WO-350-F10-------	Pemberville south well field No. 10	660
WO-351-B6--------	Cygnet well field No. 9	1,300
WO-352-B36-------	Bloomdale well field	160-240

[a] Driller reports most water originates above depth of 85 feet in well.

The potentiometric surface in the shallow bedrock areas of the southeastern parts of Wood County indicates that ground water probably is discharging from the carbonate aquifer to the rivers and streams that cross shallow bedrock. The ground-water-level measurements could not be used to confirm connection of the aquifer and river systems. Such a connection is likely only in areas where streams flow directly in bedrock channels.

Seasonal water-level fluctuations are commonly less than 5 ft except in areas affected by pumping (table 3). The hydrograph of well WO-200-MO24 in Montgomery Township (fig. 19), discussed previously, represents typical seasonal fluctuations of water levels in the carbonate aquifer.

Northern Wood County and Southern Lucas County

The geohydrology of northern Wood County and southern Lucas County is complex because of local structural features, the presence of the Maumee River, and the variable thickness of drift above the carbonate aquifer. These features affect the patterns of ground-water flow indicated by the potentiometric surface on plate 5.

The primary structural feature, the Bowling Green fault zone, is depicted on plate 5 in Wood County and in Lucas County, where it is exposed in the quarry at Waterville. North of the quarry, the fault zone is not reported in Carman's (1948) maps; instead, the eastern edge of the Lucas County monocline is shown. The bedrock formations closest to the surface are carbonate rocks, except to the west of the subcrop line of the Ohio Shale (pl. 5).

The potentiometric contours on plate 5 are perturbed notably near the Bowling Green fault zone and Lucas County monocline. In Lucas County, the fairly uniform contour spacing east of the monocline changes abruptly to a more widely spaced, less uniform configuration to the west. The abrupt change indicates a change in the ability of the rock to transmit water. In Wood County, contours are dashed and are refracted or bent across the fault zone. This perturbation in the contours also is indicative of a change in the ability of the carbonate rocks to transmit water.

The widely spaced contours west of the Lucas County monocline could be due, in part, to high transmissivities. Transmissivities of about 8,000 and 14,000 ft^2/d, respectively, were determined from aquifer tests at Whitehouse (Eagon, 1979) and at LU-10 (Ohio Department of Natural Resources, 1970, table 7A). A transmissivity of about 2,000 ft^2/d was determined from aquifer tests at the Plaskon site in Toledo. In contrast, transmissivities in the range of 200 to 700 ft^2/d were determined from aquifer tests at WO-13 and at Pemberville.

According to the Ohio Department of Natural Resources (1970, pl. 7), the Lockport Dolomite is the primary aquifer in the southeastern part of the area. Younger strata of the Greenfield Dolomite contribute water to wells north and northwest of Pemberville that could affect the potentiometric surface in those areas. Water chemistry also indicates that the mineralogy and lithology of the rock formations differ locally.

The contours in the southeastern part of the area from north of Bowling Green to Pemberville are widely spaced and appear to be affected by recharge into shallow bedrock areas. The shaded pattern on plate 5 shows that the thickness of drift is less than 20 ft in many areas. Shallow bedrock is most prevalent in the eastern parts of Wood County.

Where drift is thin and (or) consists of permeable sand, the carbonate aquifer is recharged locally, as indicated by the orientation of the contours near Dowling, New Rochester, Luckey, east of Lemoyne, and north of Lime City in Wood County. In Lucas County, shallow bedrock areas along the Lucas County monocline are possible recharge areas also. High hydraulic heads in wells west of the monocline are indicative of additional recharge; however, data are not sufficient to determine if recharge to the carbonate aquifer originates in the overlying Ohio Shale.

The age of ground water is variable areally and dependent on the location of wells in relation to areas of shallow bedrock. Tritium concentrations at selected well locations are summarized in table 9. The recharge area at Dowling, in Wood County, is characterized by relatively young water (post-1952). Near Lemoyne, waters contain little tritium and are old (pre-1952). Because of the shallow bedrock that characterizes quarry locations at Lime City and Maumee, waters from quarry-sump springs are relatively young and are probably mixtures of ground water with recent recharge. The absence of tritiated waters in samples from areas where thick drift overlies the aquifer supports the concept that recharge is a small component of the water in the carbonate aquifer.

The Maumee River is a regional discharge area for water in the carbonate aquifer. Potentiometric contours indicate that flow is towards the Maumee River in the western two-thirds of the area. Thin drift is characteristic of the Maumee River channel as far downstream as Ewing Island. The channel is in carbonate bedrock between Grand Rapids and Indian Island. Thus, interchange of water in the aquifer and river is possible. Pettyjohn and Henning (1979, p. 106) estimate a baseflow discharge of 100,000 to 200,000 $(gal/d)/mi^2$ from the Maumee River drainage area (0.15 to 0.3 $(ft^3/s)/mi^2$). The response of the carbonate aquifer at well LU-3-W39 and river-stage fluctuations of the Maumee River is shown in figure 20. Ground-water levels rise slightly as river stage rises.

A buried valley cuts across the Maumee River just upstream from Waterville and parallels the river as it flows toward Toledo (pl. 6). Discharge from the carbonate aquifer to the buried bedrock valley cannot be determined from available data.

Ground-water discharge in quarries at Lime City, Waterville, and Maumee is estimated to be 0.5, 0.6, and 1.5 Mgal/d, respectively. Pumpage for industrial supply at Rossford is estimated to be 0.2 Mgal/d. Pumpage at Pemberville and Whitehouse, which consists primarily of municipal supply, is estimated to be 0.085 and 0.5 Mgal/d, respectively.

Ground-water-level rises in 1978-88 indicate that recharge exceeds discharge in the Toledo area. The 10-year hydrograph of well LU-1 (fig. 21) illustrates the rising trend of ground-water levels. The trend of rising water levels near Toledo is also apparent in the 5-year period of intermittent measurements of levels in selected wells in the Northwood area (fig. 22). At well WO-100, for example, the net change in water level from 1983 to 1987 is about 2 ft. Wells WO-102, 103, and 104 also have rising trends, with changes of 4 ft or more. This probably represents a response of the aquifer to several factors: (1) decreased numbers of active wells in Toledo, Rossford, and Oregon as use of municipally supplied water from Lake Erie increased; (2) rising levels of Lake Erie during 1981-86; and (3) increased recharge from the generally wet years of 1968-86, as inferred from above-average streamflows for the Maumee, Portage, and Sandusky rivers (J.M. Sherwood, U.S. Geological Survey, written commun., 1989).

The hydrograph of well WO-121-N is compared with LU-1 in figure 23. Although well WO-121-N is less than 5 mi east of LU-1, the carbonate aquifer appears to respond differently at the two locations. Rainstorms, such as those of November 1985 and October 1986, cause greater water-level rises at WO-121-N than at LU-1, even though the aquifer is confined at both locations.

Northern Lucas County

In northern Lucas County, the altitude and configuration of the potentiometric surface, shown on plate 6, demonstrate the effects of isolated local recharge areas and local discharge areas. The Maumee River, Maumee Bay, and Lake Erie also contribute to the local geohydrologic conditions.

Transmissive properties of the carbonate aquifer are highly variable in westernmost Lucas County. The complex geology associated with the westward change from Silurian to Devonian strata across the Lucas County monocline (Carman, 1948; see location on pl. 6) may contribute to the variable properties.

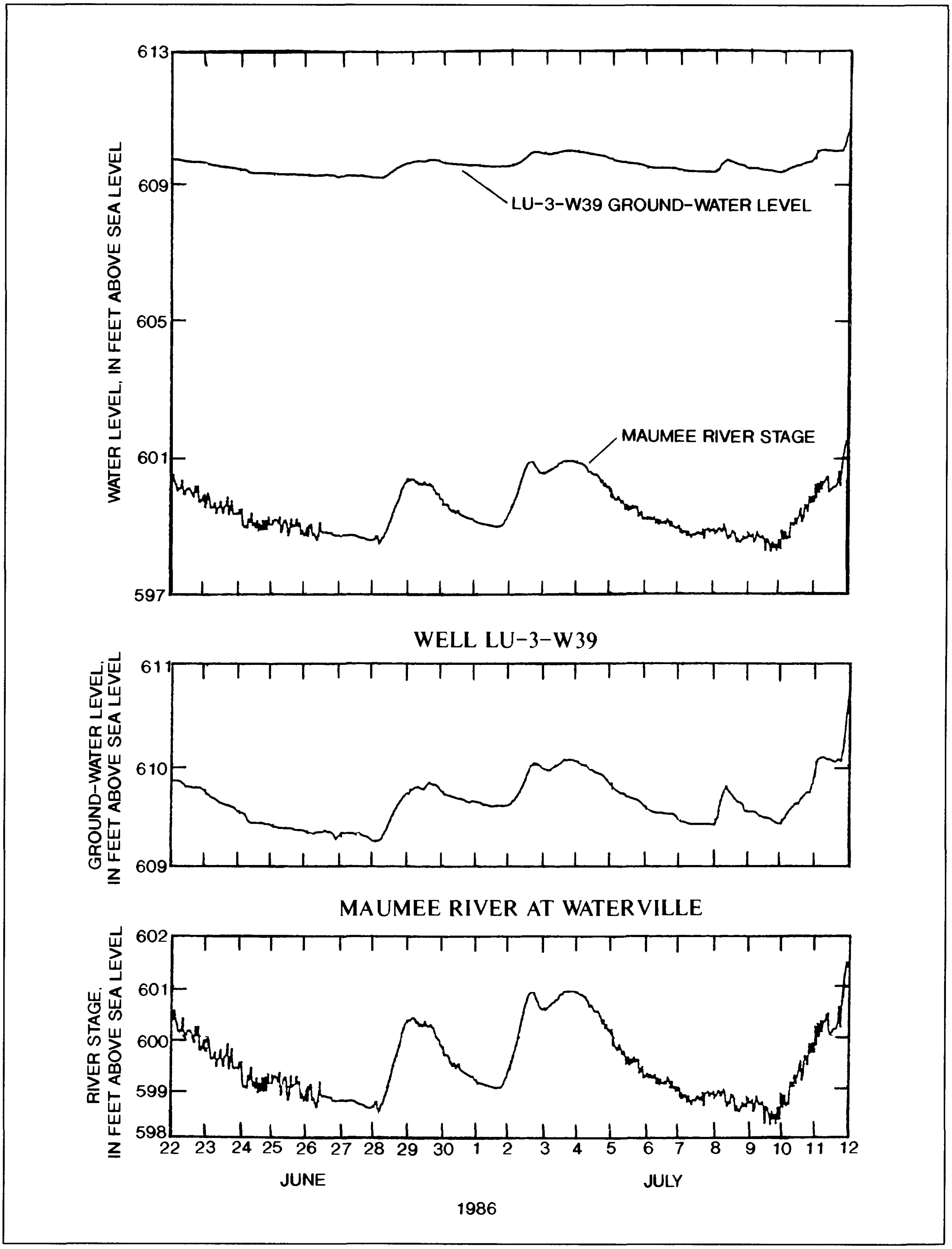


Figure 20.--Water levels at well Lu-3-W39 and Maumee River stage at Waterville, Ohio, June-July, 1986.

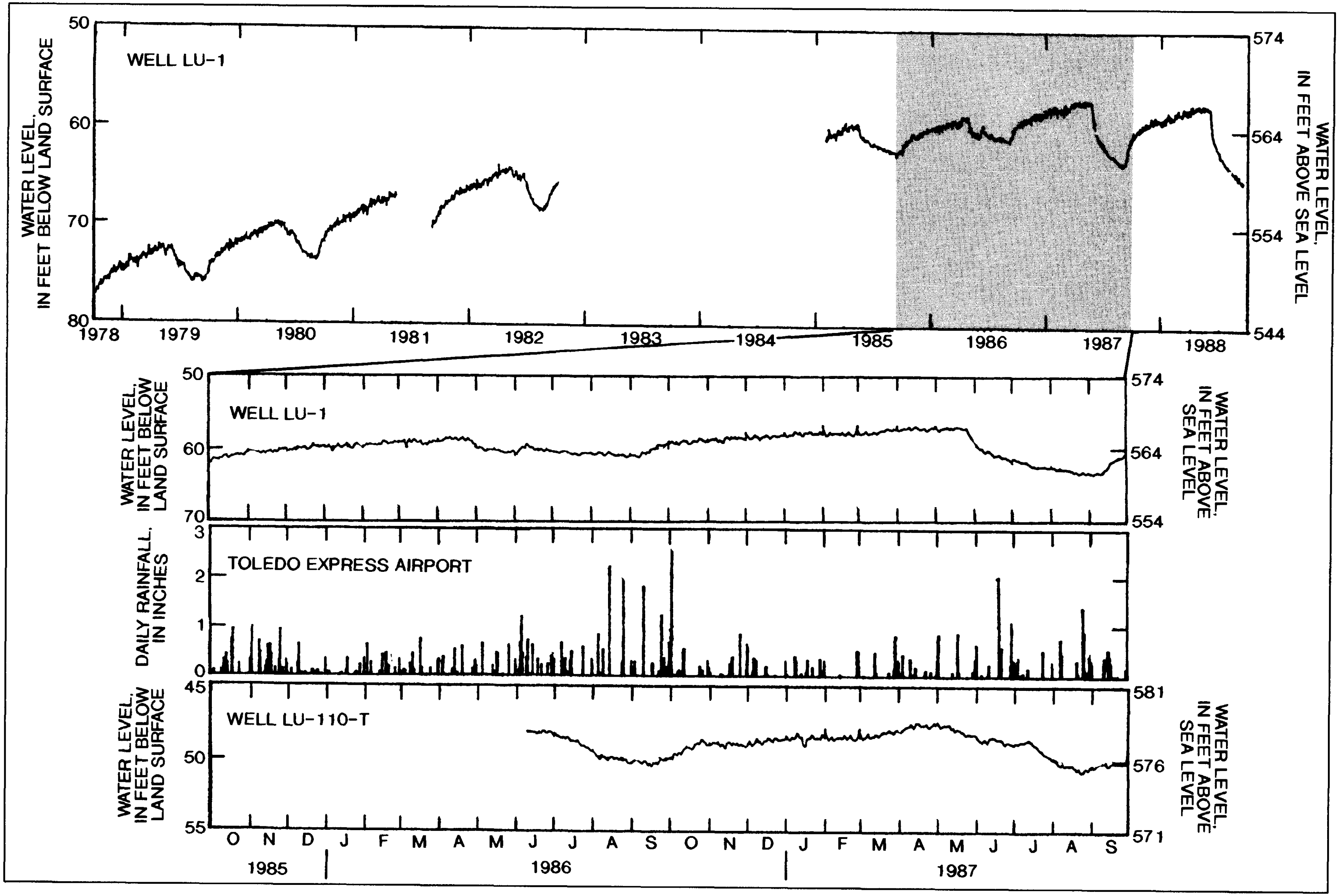


Figure 21.--Hydrographs at wells LU-1 and LU-110-T and precipitation for selected periods of record.

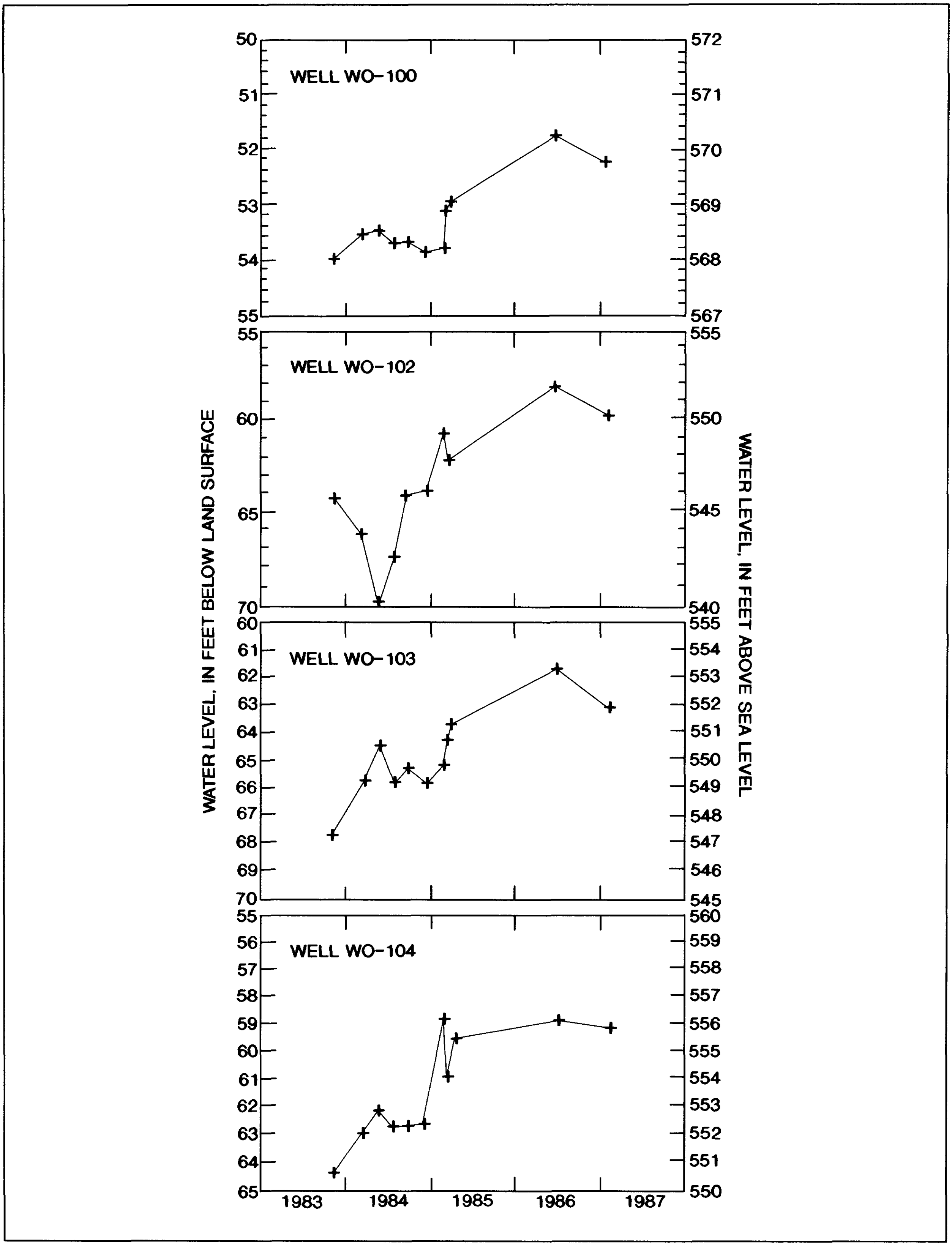


Figure 22.--Water-level changes in selected wells in the Northwood, Ohio, area, 1983-88. (Measurements are connected with straight lines to show general trends. Actual levels between measurements may have been different than indicated by these lines).

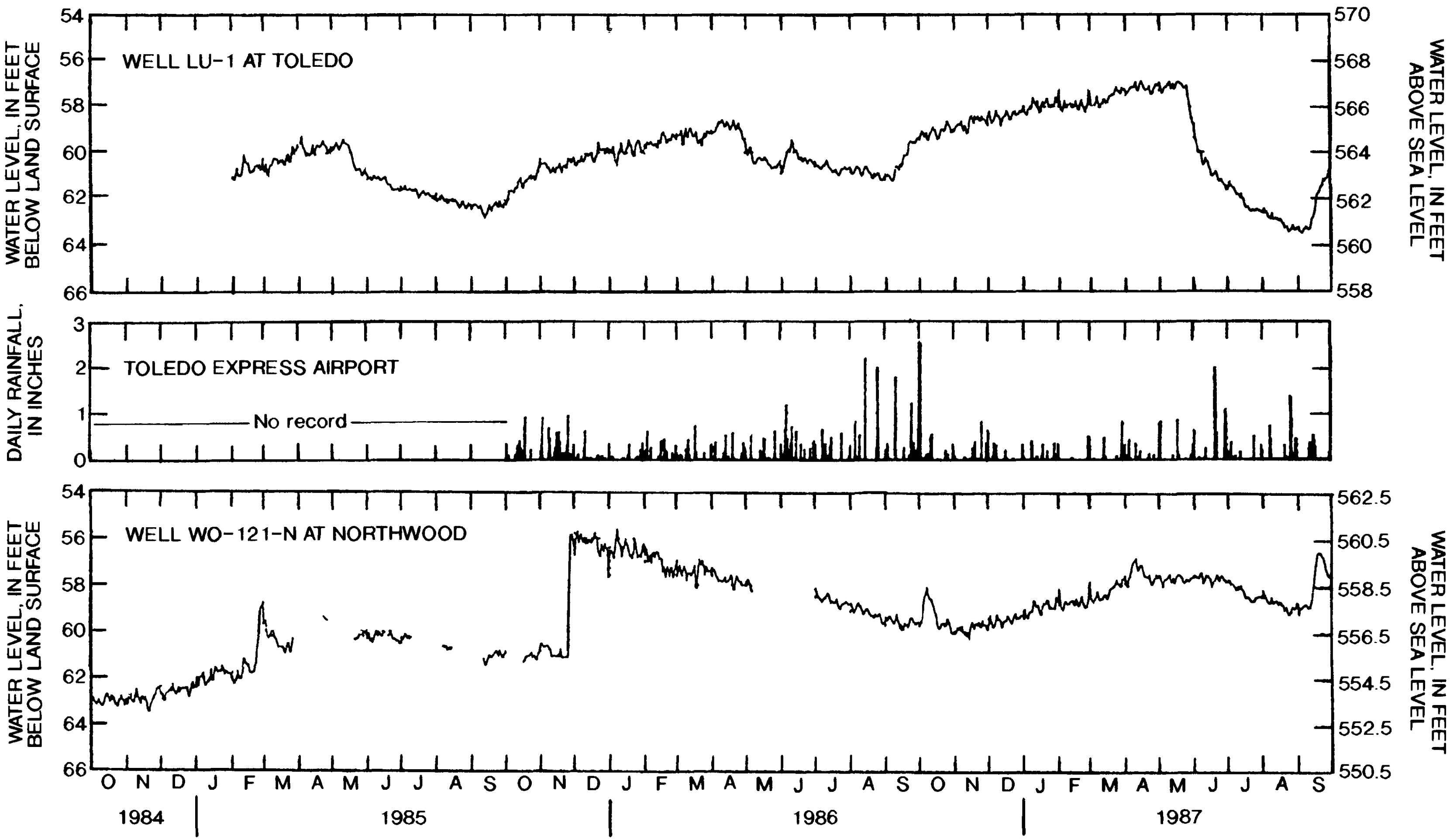


Figure 23.--Water levels at wells LU-1 and WO-121-N and precipitation at Toledo Express Airport, 1984-87.

The Ohio Department of Natural Resources (1970, p. 39) characterized the area west of the monocline as an area of relatively high-yield wells. Maximum yields from wells of 800 to 1,000 gal/min were described as representative. Aquifer-test data are sparse for the western parts of northern Lucas County. A transmissivity of about 25,000 ft^2/d was determined from an aquifer test at well LU-11 (location on pl. 1), which is completed in both shale and carbonate rocks. This transmissivity is quite large compared with transmissivities calculated from aquifer tests east of the monocline. The transmissivity of 2,000 ft^2/d from a test in the Toledo area (Plaskon test location) is characteristic of areas east of the monocline.

Recharge areas in the shallow bedrock areas of westernmost Lucas County (pl. 6) and recharge from areas in adjacent counties is indicated by the west-to-east gradients of the potentiometric surface. The presence of young (post-1952) water from selected wells near the Lucas County monocline supports the idea that recharge is entering the carbonate aquifer locally. It is not known if permeable surficial sand deposits affect recharge to the carbonate aquifer. The potentiometric surface does not indicate that recharge is localized in areas with sand at the surface. The drift that separates the sand and the carbonate aquifer probably restricts recharge. Small concentrations of tritium and large concentrations of dissolved solids in most other parts of the area are evidence of old waters that contain little recent recharge.

Recharge to the aquifer from Lake Erie is unlikely even though the similar hydraulic head in the lake and the aquifer in easternmost Lucas County indicates that a hydraulic connection exists. Wells in Jerusalem Township adjacent to the lake have water-level altitudes of about 570 ft above sea level. The lake stage at Reno Beach in Lucas County during the 1986 and 1987 water years ranged from 570.5 to 576 ft above sea level (USGS datum). The lower hydraulic heads inland (note the 560- and 550-ft contours) in Jerusalem Township and Oregon indicate that flow is inland from the lake. This condition may be natural, but pumpage in the Oregon, Rossford, and Toledo areas is believed to influence the head distribution near the lake. The age of ground water in wells adjacent to Lake Erie, as inferred from tritium concentration, indicates little or no lake water in the carbonate aquifer. The highly mineralized character of water in shallow (100-ft deep) wells adjacent to the lake also indicates that little or no lake water is produced from drilled wells. Lake water is very dilute (dissolved-solids concentration of about 130 mg/L). If well waters were being derived from Lake Erie, some dilution of water would be expected.

Recharge to the aquifer from the Maumee River as the river nears Maumee Bay is not readily discernible from the potentiometric surface. Near the bay, the potential exists for flow from the river to the aquifer because pumping has lowered the potentiometric surface below the river surface. The physical characteristics of the river channel change from the bedrock that characterizes the upstream reaches to **alluvium** (Herdendorf, 1970, p. 6). The absence of exposed carbonate rock in the downstream river channel is likely to decrease interchange of water between the river and the carbonate aquifer. Dilute river water with elevated tritium concentrations is not observed in wells near the river.

Delineation of discharge areas in northern Lucas County is complicated by a lowering of the potentiometric surface by pumping in the Toledo, Rossford, and Oregon areas. The pumping is a form of ground-water discharge. The pumping of the aquifer in these areas could serve to intercept water that naturally would discharge to the river if pumping did not occur.

The 10-year record of water-level fluctuations in well LU-1 (fig. 21) shows the seasonal cycles of water-level declines and water-level rises that are characteristic of the Toledo area. Three industrial locations are known pumping centers. Industrial pumpage from these wells is estimated to be about 0.8 Mgal/d (Lee Pfouts, City of Toledo, Department of Public Utilities, written commun., 1985); however, detailed records of water use were not available. Seasonal pumpage is locally significant during the summer when golf courses and industries use water from wells for irrigation and cooling, respectively. Seasonal pumpage lowers water levels by about 5 ft at LU-1. Some lowering of water levels in wells farther from the pumping centers (such as well LU-110-T, fig. 21) occurs seasonally because of pumping.

Ground-water discharge in the western parts of northern Lucas County includes withdrawals from rural domestic and small community wells (mobile home parks, see public-supply well-designation on pl. 1); however, the largest single withdrawal, about 1 to 1.5 Mgal/d, is dewatering for quarry operations at Silica.

Ground-water discharge to Lake Erie cannot be discounted or proved on the basis of available data. As previously noted, evidence for recharge from the lake to the aquifer is equivocal. Thus, the possibility exists ground water discharges to the lake. Potentiometric-surface gradients are relatively flat near the lake; the resulting flow directions are uncertain and are affected by seasonal pumping in Toledo and Oregon. The absence of hydraulic heads for the aquifer beneath Lake Erie precludes determining whether or not the ground water is discharging to the lake.

QUALITY OF WATER IN AQUIFERS

Surficial Sand Aquifer in Lucas County

Ground-water quality is compared between two groups of five wells representing two land-use areas: (1) undeveloped, and (2) developed with septic tanks. The sampling of ground-water quality was conducted during the first 2 weeks of June 1987, when the water table had begun a seasonal decline. The hydrograph for well LU-303-SW20 is expanded in figure 24 for the period June 1 through June 10, 1987, to show that little precipitation was recorded during the period of sample collection and that no major recharge events were recorded. Thus, any bias caused by dilution of samples from precipitation is believed to have been minimized.

The locations of sites for the collection of water-quality samples are shown on plate 1. The results of the analyses of water quality are listed with the data for Lucas County in table 9. Local well numbers in the 300 series represent samples from the surficial sand aquifer. Each sample is from a different well. Concentrations listed as less than (<) were smaller than the detection limits for the analytical techniques used. Concentration data that are comprised, in part, by less-than values are termed censored data.

Table 12 provides summary statistics for the data from the two land-use categories. The number of detections indicates the degree to which the data are censored for the 48 constituents determined.

Waters from undeveloped areas are very dilute calcium bicarbonate types (fig. 25). The median dissolved-solids concentration is 89 mg/L. Sulfate concentrations range from approximately 10 to about 50 mg/L. Chloride concentrations are less than 5 mg/L. Waters are soft to moderately hard, and the median hardness is 74 mg/L as $CaCO_3$ (moderately hard).

Waters in developed areas (where septic tanks are used for disposal of domestic sewage) have a median dissolved-solids concentration of 385 mg/L. Water in developed areas has a greater tendency to be a calcium-sodium type with bicarbonate and chloride as dominant anions (fig. 25). Sulfate concentrations range from 35 to 120 mg/L. The median chloride concentration is 54 mg/L. Waters in the developed areas are hard to very hard, and the median hardness is 260 mg/L as $CaCO_3$ (very hard).

A comparison of median concentrations of constituents in developed and undeveloped areas (table 12) shows that waters in the undeveloped areas are commonly more dilute and have lower median concentrations of many major and minor constituents. Minor and trace constituents are detected less commonly in samples from undeveloped areas.

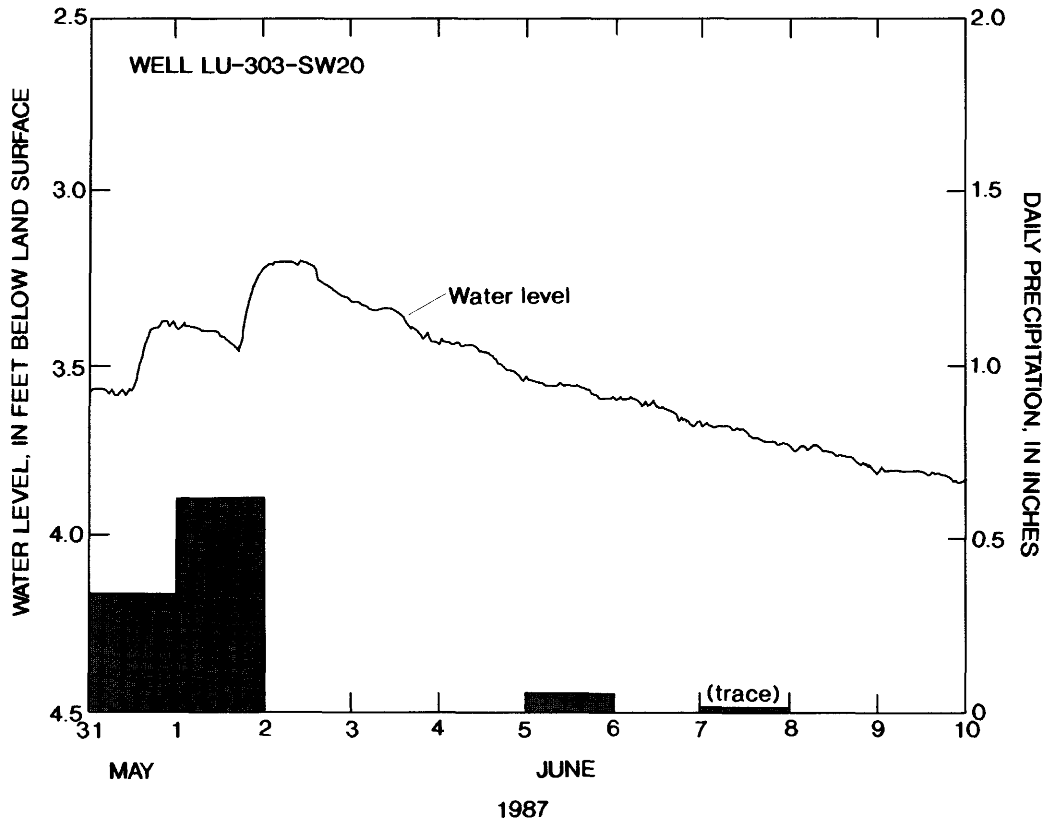


Figure 24.--Water levels in the surficial sand aquifer at well LU-303-SW20 during the sample-collection period, June 1-10, 1987.

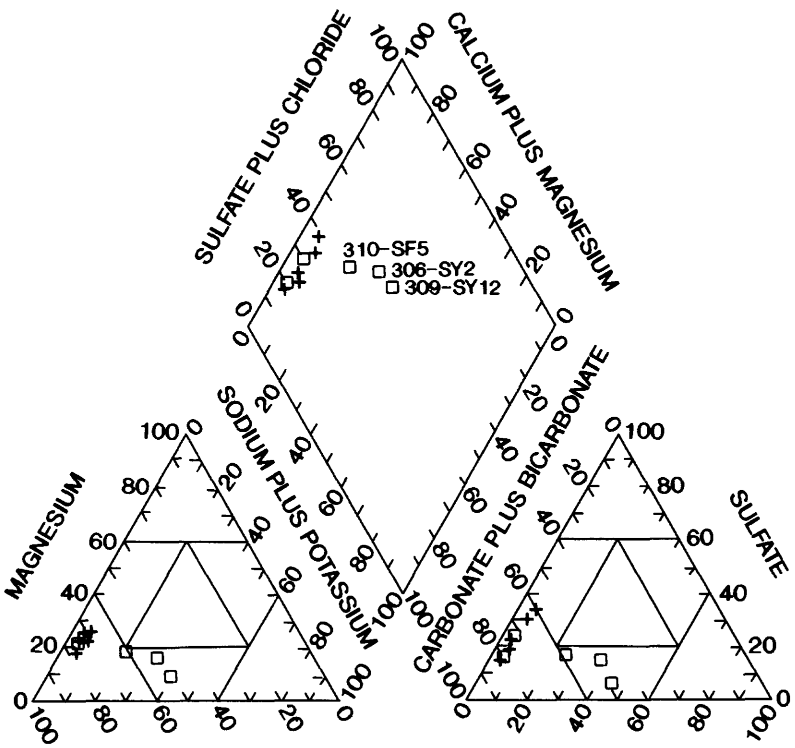
Table 12.-- Selected water-quality statistics for two land-use areas, surficial sand aquifer

[µS/cm, microsiemens per centimeter at 25 degrees Celsius (°C); mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picoCuries per liter; asterisk indicates that statistic was estimated by use of the method developed by Helsel and Gilliom (1986); dashes indicate that data are insufficient to calculate statistic]

Property or constituent and unit of measurement	Undeveloped areas: Number of wells	Number of detections	Mean	Median	Minimum	Maximum	Developed areas: Number of wells	Number of detections	Mean	Median	Minimum	Maximum
Inorganic Constituents or Physical Properties												
Specific conductance (µS/cm)	5	5	169	170	91	298	5	5	727	590	270	1,450
pH (standard units)	5	5	8.4	8.3	7.3	9.3	5	5	7.5	7.4	7.2	7.9
Temperature, water (°C)	5	5	10.0	10.0	9.0	10.0	5	5	10.3	10.0	9.0	12.0
Oxygen, dissolved (mg/L)	5	5	3.1	2.6	1.6	4.5	5	5	1.4	1.3	.4	3.2
Hardness (mg/L as $CaCO_3$)	5	5	75	74	39	140	5	5	268	260	140	420
Hardness, noncarbonate (mg/L as $CaCO_3$)	5	5	16	9	5	48	5	5	52	63	19	80
Calcium (mg/L)	5	5	23	22	12	45	5	5	85	79	44	140
Magnesium (mg/L)	5	5	4.0	3.8	2.2	6.5	5	5	14	14	7.4	17
Sodium (mg/L)	5	5	1.9	1.6	1.1	3.6	5	5	43	29	2.5	120
Potassium (mg/L)	5	4	.4*	.4*	.2	.6	5	5	1.1	.6	.2	.2
Bicarbonate (mg/L)	5	5	69	78	31	111	5	5	264	249	148	434
Alkalinity (mg/L as $CaCO_3$)	5	5	60	66	35	94	5	5	215	203	118	354
Carbon dioxide (mg/L)	5	5	1.1	.7	0	3.4	5	5	16	10	4.4	41
Hydrogen sulfide (mg/L as S)	5	0	--	--	--	--	5	0	--	--	--	--
Sulfate (mg/L)	5	5	22	16	9.7	51	5	5	60	49	35	120
Chloride (mg/L)	5	5	1.8	1.0	.4	4.8	5	5	72	54	2.8	170
Fluoride (mg/L)	5	1	--	--	--	--	5	3	.1	.1	.1	.1
Bromide (mg/L)	5	1	--	--	--	--	5	2	.046	--	.030	.062
Silica (mg/L)	5	5	10.8	9.7	8.8	15	5	5	11.5	11	6.6	18
Dissolved solids (mg/L)	5	5	99	89	51	186	5	5	452	385	196	869
Nutrients and Organic Constituents												
Carbon, organic dissolved (mg/L as C)	5	5	1.0	.8	.6	1.6	5	5	7.4	8.2	2.5	11
Nitrite (mg/L as N)	5	0	--	--	--	--	5	1	--	--	--	--
Nitrite + nitrate (mg/l as N)	5	0	--	--	--	--	5	2	5.7	--	.34	11
Ammonia (mg/L as N)	5	4	.03*	.03*	.02	.03	5	5	.10	.08	.02	.22
Ammonia + organic N (mg/L)	5	4	.3*	.2*	.2	.6	5	5	1.36	1.20	.8	2.2
Orthophosphate (mg/L as P)	5	5	.01	.01	.004	.012	5	5	.01	.01	.001	.027
Radiochemical Constituents												
Beta-particle radioactivity (pCi/L as Sr/Yt-90)	2	1	--	--	--	--	3	3	2.8	1.1	.9	6.3
Beta-particle radioactivity (pCi/L as Cs-137)	2	1	--	--	--	--	3	3	3.8	1.4	1.1	8.9
Alpha-particle radioactivity (µg/L as uranium-natural)	2	0	--	--	--	--	3	2	3.6	--	2.1	5.2
Uranium (µg/L)	2	0	--	--	--	--	3	3	2.6	.99	.09	6.7

Table 12.-- Selected water-quality statistics for two land-use areas, surficial sand aquifer--Continued

Property or constituent and unit of measurement	Undeveloped areas: Number of wells	Number of detections	Mean	Median	Minimum	Maximum	Developed areas: Number of wells	Number of detections	Mean	Median	Minimum	Maximum
Trace Constituents												
Aluminum (µg/L)	5	5	20	16	20	30	5	5	30	24	15	62
Antimony (µg/L)	2	0	--	--	--	--	3	0	--	--	--	--
Arsenic (µg/L)	2	1	--	--	--	--	3	1	--	--	--	--
Barium (µg/L)	2	2	20	--	20	20	3	3	51	62	21	71
Boron (µg/L)	5	4	29*	20*	10	70	5	5	294	50	30	1,100
Cadmium (µg/L)	2	0	--	--	--	--	3	0	--	--	--	--
Chromium (µg/L)	2	1	--	--	--	--	3	2	20	--	20	20
Copper (µg/L)	2	2	1.5	--	1	2	3	3	1.7	1	1	3
Cyanide (mg/L)	2	1	--	--	--	--	0	0	--	--	--	--
Iron (mg/L)	5	3	136*	51*	51	550	5	5	1,550	680	12	5,500
Lead (µg/L)	2	1	--	--	--	--	3	1	--	--	--	--
Lithium (µg/L)	2	1	--	--	--	--	3	3	10.7	11	7	14
Manganese (µg/L)	5	5	33	47	2	59	5	5	150	180	8	290
Mercury (µg/L)	2	0	--	--	--	--	3	0	--	--	--	--
Nickel (µg/L)	2	1	--	--	--	--	3	2	1	--	1	1
Selenium (µg/L)	2	0	--	--	--	--	3	0	--	--	--	--
Silver (µg/L)	2	0	--	--	--	--	3	1	--	--	--	--
Strontium (µg/L)	5	5	46	44	24	82	5	5	275	170	63	620
Zinc (µg/L)	2	2	80	--	40	120	3	3	470	210	100	1,100

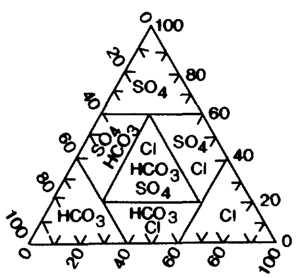


EXPLANATION

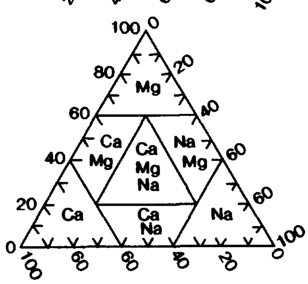
LAND-USE TYPE--Number is local well identifier

□ Developed, with septic tanks

+ Undeveloped



ANION WATER TYPE



CATION WATER TYPE

Figure 25.--Trilinear diagram of percentages of cation and anion milliequivalents for water in the surficial sand aquifer, two land-use areas, Lucas County, Ohio.

The trilinear diagram (fig. 25) indicates waters from wells LU-310-SF5, LU-306-SY2, and LU-309-SY12 from the developed areas can be distinguished chemically from the other seven samples. Elevated concentrations of nitrate and chloride in two of these three waters indicate possible effects of domestic sewage on water quality. Water from well LU-309-SY12 has elevated concentrations of organic nitrogen and zinc. In addition, the largest concentration of bromide in waters sampled from the sand aquifer was detected at well LU-309-SY12.

Bromide concentrations equal to or greater than the 0.010-mg/L quantitation level were measured in three samples (see table 9). Ratios of concentration of bromide to chloride are a useful means of identifying and tracing sources of saline waters and oilfield brines (Whittemore, 1988, p. 342). The ratio is multiplied by 10,000 so that whole numbers, instead of small fractions, result from the calculations. Whole numbers are more readily comparable between different samples. Values of the Br:Cl concentration ratio x 10,000 equal to 63, 75, and 3.6 were calculated for water from wells LU-304-SW21, LU-308-M11, and LU-309-SY12, respectively. The small value is likely an indicator of a salt-solution source for the elevated concentration of chloride (170 mg/L) observed. Possible sources of salt near well LU-309-SY12 are road-deicing salts entering the aquifer as infiltration of runoff from the paved surface, or water-softener salt entering the aquifer through a septic-tank leach field. The ratios of 63 to 75 in the sand aquifer are likely caused by the mixing of large Br:Cl-concentration-ratio rainwaters (values of 100 to 250 for Br:Cl x 10,000) into waters with dissolved constituents from sources other than rainwater.

Additional general observations about the quality of water in the sand aquifer (table 9) are as follows:

- At five sample sites, no volatile organic compounds were detected that equaled or exceeded the 3-μg/L (microgram per liter) detection limit.

- There is little evidence of radiochemical activity in water from the sand aquifer, except at well LU-306-SY2, where the gross alpha-particle radioactivity, the gross beta-particle radioactivity, and the uranium concentration were measurable and larger than values in the carbonate aquifer (discussed in subsequent sections of this report).

- Colored waters generally indicate large concentrations of dissolved-organic carbon with associated large concentrations of dissolved iron and dissolved manganese.

Carbonate Aquifer

A data base of ground-water quality has been established by the USGS for this study for the carbonate aquifer. Data are available for 52 water-quality properties and constituents that describe the chemical, radiological, and bacterial quality and the physical characteristics of ground water. Samples from 135 wells and 11 springs were used to develop the data base. Each sample is from a different site.

The quality of water is first described in terms of general characteristics, and then the quality of water for drinking and other uses is addressed. Finally, factors affecting water quality in the carbonate aquifer are discussed.

The locations of sites for the collection of water-quality samples are shown on plate 1. The local numbers of the sites are used to cross-reference site locations with the water-quality data listed in table 9. The data are tabulated by county and are presented in numerical order by local number. For the five mapping areas described in the section "Geohydrology," plates 7 to 11 show sites where samples were collected for this study and the sites where other miscellaneous analyses of water quality are available.

General Water Characteristics

The data for about half of the 52 properties and constituents listed in table 9 are highly censored--that is, for many of the analyses, concentrations of certain constituents (especially trace metals, nitrogen and phosphorus compounds, and bacterial concentrations) were commonly below detection limits for the analytical techniques used.

Summary water-quality statistics for the carbonate aquifer are listed in table 13. The summary statistics describe the aquifer as a single hydrologic unit and provide information for making generalizations about the overall ranges and distributions of concentrations for water-quality constituents. If the number of detections listed is smaller than the total number of samples analyzed, then the data set for that constituent is censored, and modified procedures are used to compute summary statistics (Helsel and Gilliom, 1986). The general distribution in concentration is shown in the table by the quartile percentages. The quartile percentages simply indicate the percentages of samples that are less than or equal to the concentration shown.

Details of the concentration distributions are difficult to discern from table 13. Thus, figure 26 (Supplemental-Data section) is included to show the distributions of concentrations for 22 major and minor constituents that are not highly censored.

Table 13.--Water-quality statistics for the carbonate aquifer

[μS/cm, microsiemens per centimeter at 25 degrees Celsius (°C); mg/L, milligrams per liter; μg/L, micrograms per liter; cols./100mL, colonies per 100 milliliters; pCi/L, picocuries per liter. Asterisk indicates statistic estimated by the method developed by Helsel and Gilliom (1986). Dashes indicate no limit established or insufficient data to calculate statistic. Less-than symbol (<) indicates value is less than the laboratory limit of detection. Numbers in parentheses are Maximum Contaminant Levels (MCL) or Secondary Maximum Contaminant Levels (SMCL) for public water supplies. Letter codes associated with MCL and SMCL indicate: a, Health Advisory Concentration; b, see a detailed description in table 15; c, proposed MCL (U.S. Environmental Protection Agency, 1989); d, proposed SMCL (U.S. Environmental Protection Agency, 1989)]

Property or constituent and unit	Number of sites	Number of detections	Mean	Standard Deviation	MCL or SMCL	Percentage of samples in which values were less than or equal to those shown: 10%	25%	Median (50%)	75%	90%
Inorganic Constituents and Physical Properties										
Specific conductance (μS/cm)	146	146	1,340	780	(--)	620	760	1,100	1,940	2,520
pH (standard units)	146	146	7.3	.3	(6.5-8.5)	7.0	7.1	7.3	7.4	7.8
Temperature, water (°C)	146	146	13.0	1.7	(--)	11.5	12.0	12.5	13.5	15.5
Oxygen, dissolved (mg/L)	140	47	.7*	2.2*	(--)	<.1*	<.1*	<.1*	.3*	1.4*
Hardness (mg/L as $CaCO_3$)	145	145	720	490	(--)	290	380	540	1,000	1,600
Hardness, noncarbonate	145	145	490	520	(--)	40	100	250	810	1,400
(mg/L as $CaCO_3$)	145	145	490	520	(--)	40	100	250	810	1,400
Calcium (mg/L)	145	145	180	140	(--)	67	84	120	240	420
Magnesium (mg/L)	145	145	63	42	(--)	26	33	50	77	130
Sodium (mg/L)	146	146	37	33	(20a)	6.2	12	28	52	72
Strontium (μg/L)	144	144	17,000	12,000	(--)	2,400	8,800	15,000	22,000	34,000
Potassium (mg/L)	146	146	3.7	5.3	(--)	1.4	1.9	2.5	3.5	6.0
Bicarbonate (mg/L)	146	146	290	110	(--)	130	190	300	360	430
Alkalinity (mg/L as $CaCO_3$)	146	146	230	90	(--)	110	160	250	300	360
Carbon dioxide (mg/L)	146	146	29	24	(--)	4.1	10	24	41	64
Hydrogen sulfide (mg/L as S)	144	31	7*	35*	(--)	<.5*	<.5*	<.5*	1.9*	15*
Sulfate (mg/L)	146	146	550	560	(250)	48	100	290	980	1,600
Chloride (mg/L)	146	146	32	51	(250)	2.8	8.0	16	36	66
Fluoride (mg/L)	146	146	1.3	.5	(2.4)	.5	1.0	1.4	1.6	2.0
Boron (μg/L)	98	97	380*	290*	(--)	60*	200*	320*	530*	740*
Bromide (mg/L)	96	89	0.4*	1.1*	(--)	0.02*	0.06*	0.1*	0.3*	0.5*
Silica (mg/L)	146	146	13	16	(--)	6.8	9.2	11	14	17
Dissolved solid (mg/L)	146	146	1,100	826	(500)	381	498	738	1,700	2,400
Iron (μg/L)	146	141	420*	630*	(300)	11*	41*	190*	570*	1,100*
Manganese (μg/L)	145	130	18*	33*	(50)	1*	4*	9*	20*	40*
Nutrients and Organic Constituents										
Carbon, organic dissolved (mg/L as C)	143	143	2.1	1.2	(--)	1.2	1.4	1.8	2.4	3.6
Nitrite (mg/L as N)	143	74	.005*	.02*	(1c)	.0003*	.0006*	.002*	.004*	.009*
Nitrite + nitrate (mg/l as N)	143	63	.34*	1.5*	(10)	.0003*	.002*	.01*	.07*	.53*
Ammonia (mg/L as N)	143	142	.43*	.45*	(--)	.05*	.18*	.31*	.58*	.82*
Ammonia + organic N (mg/L)	144	140	.95*	1.1*	(--)	.30*	.50*	.70*	1.0*	1.6*
Orthophosphate (mg/L as P)	142	75	.07*	.67*	(--)	<.001*	<.001*	.001*	.005*	.01*

Table 13.--Water-quality statistics for the carbonate aquifer--Continued

Property or constituent and unit	Number of sites	Number of detections	Mean	Standard Deviation	MCL or SMCL	Percentage of samples in which values were less than or equal to those shown: 10%	25%	Median (50%)	75%	90%
Radiochemical Constituents										
Beta-particle radioactivity (pCi/L as Sr/Yt-90)	82	82	9.2	36	(b)	2.2	3.1	3.9	5.2	8.6
Beta-particle radioactivity (pCi/L as Cs-137)	82	82	13	55	(b)	3.1	4.4	5.4	8.0	13
Alpha-particle radioactivity (μg/L as uranium-natural)	82	71	15*	67*	(b)	.5*	1.9*	5.4*	8.6*	21*
Alpha-particle radioactivity (pCi/L as uranium-natural)	82	71	10*	46*	(b)	.3*	1.3*	3.6*	5.8*	14*
Uranium (μg/L)	82	80	1.1*	3.3*	(--)	.04*	.11*	.23*	.58*	3.1*
Bacteriological Constituents										
Coliform, total (cols./100mL)	141	74	10*	21*	(4)	<1*	<1*	1*	10*	30*
Coliform, fecal (cols./100mL)	143	23	1.5*	7*	(0)	<1*	<1*	<1*	<1*	2*
Streptococci, fecal (cols./100 mL)	141	56	7*	20*	(0)	<1*	<1*	<1*	5*	16*
Trace Constituents										
Aluminum (μg/L)	141	70	10*	9*	(50d)	<10*	<10*	<10*	20*	20*
Antimony (μg/L)	48	10	.6*	.4*	(--)	<1*	<1*	<1*	<1*	1*
Arsenic (μg/L)	82	22	1*	2.3*	(50)	<1*	<1*	<1*	1*	3*
Barium (μg/L)	91	76	87*	90*	(1,000)	15*	28*	56*	118*	214*
Cadmium (μg/L)	53	4	--	--	(10)	--	--	--	--	--
Chromium (μg/L)	54	30	28*	95*	(50)	<10*	<10*	10*	20*	34*
Copper (μg/L)	51	13	.8*	1.2*	(1,000)	<1*	<1*	<1*	1*	2*
Cyanide (mg/L)	48	0	--	--	(--)	--	--	--	--	--
Iodide (mg/L)	8	8	.01	.01	(--)	.002	.003	.006	.01	.04
Lead (μg/L)	53	3	--	--	(50)	--	--	--	--	--
Lithium (μg/L)	50	49	36*	23*	(--)	10*	21*	30*	48*	69*
Mercury (μg/L)	47	25	.5*	.9*	(2)	<.1*	<.1*	.1*	.4*	1.5*
Nickel (μg/L)	49	22	2*	2.6*	(--)	<1*	<1*	<1*	3*	5*
Selenium (μg/L)	53	4	--	--	(10)	--	--	--	--	--
Silver (μg/L)	51	3	--	--	(50)	--	--	--	--	--
Zinc (μg/L)	92	86	86*	280*	(5,000)	4*	10*	21*	64*	130*

For each constituent illustrated by a dot plot in figure 26, the uppermost graph shows the distribution for all samples of ground water from the carbonate aquifer in Silurian and Devonian rocks. This overall-distribution dot plot is further subdivided into results for waters from four geologic units. Dot plots are given for samples from Devonian carbonate rocks above the Detroit River Group and for samples from the Detroit River Group. Data for the Lockport Dolomite and the Bass Islands Group, the two primary sample sets, are summarized with dot plots and box plots. The box plots aid in identifying those data in the concentration distributions that are anomalous and considered outliers. The number of samples that are outliers can be determined precisely by combining the dot plot and box plot.

Samples from Devonian rocks are sparse. The four samples from the Detroit River Group and the five samples collected from Devonian limestones and dolomites above the Detroit River Group are not large enough sample sizes to warrant a box-plot summary. Nevertheless, the figure allows the concentrations of constituents in waters from Devonian strata to be compared directly with the results from the Lockport Dolomite and Bass Islands Group.

Seventeen of the 22 constituents shown in figure 26 have right-skewed overall distributions. Only fluoride concentration has a left-skewed distribution. Concentrations of silica, alkalinity, and bicarbonate and values of pH are normally distributed.

Many of the dot plots, including those of dissolved solids, sulfate, bicarbonate, alkalinity, specific conductance, and magnesium, show a characteristic bimodal distribution. Because of the relation of hardness to calcium, magnesium, sulfate, and bicarbonate concentrations, distributions for total hardness and noncarbonate hardness also are bimodal. Calculation of Pearson correlation coefficients between constituents indicates that sulfate has a large positive linear correlation ($R=0.94$ or greater) with calcium, dissolved solids, specific conductance, hardness, and noncarbonate hardness. Sulfate is also correlated ($R=0.84$) with magnesium. These correlations indicate that much of the bimodality could be related to the presence of sulfate in ground water.

The dot plots for individual geologic units show that the pronounced bimodality is produced by data from the Bass Islands Group, whereas bimodality of the data from the Lockport Dolomite is less well-defined and the data include smaller constituent concentrations.

The distributions and magnitudes of concentrations, when expressed in milliequivalents per liter, show that the major cations in ground water are calcium, magnesium, sodium, and strontium. The major anions are bicarbonate, sulfate, and chloride. Major-ion composition and dissolved-solids concentration indicate that the carbonate aquifer contains waters with widely variable characteristics. The dominant ions in a water sample, regardless of the concentration, are used to classify water types.

The 15 water types recognized in the carbonate aquifer are shown in table 14. Most waters (61 percent) are calcium magnesium types; bicarbonate and sulfate are the dominant anions. Sodium-dominated water types are comparatively rare. The percentages of cations and anions in ground waters, in milliequivalents, are shown as a trilinear diagram in figure 27. Strontium is a major ion but is not included in either table 14 or figure 27. The median strontium concentration contributes five times more milliequivalents than does the median potassium concentration in these waters.

Water type and dissolved-solids concentration are related. The summary percentiles in table 13 show that 25 percent of all water samples from the carbonate aquifer have dissolved-solids concentrations less than 500 mg/L. The 500-mg/L concentration is the secondary maximum contaminant level (SMCL); this level is an aesthetic limit established by the U.S. Environmental Protection Agency (USEPA) (1986a) for public drinking-water supplies. The concentrations of dissolved solids can be divided into three general categories and are related in the following manner to water type:

1. Dissolved-solids concentration less than or equal to 500 mg/L (SMCL).--Waters are commonly (75 percent of group) a calcium-bicarbonate or calcium magnesium-bicarbonate type; all sodium bicarbonate-type waters also are in this category.

2. Dissolved-solids concentration between 500 and 1,000 mg/L.--50 percent of waters in this group are a calcium-magnesium-bicarbonate type, and 43 percent are a calcium-magnesium-sulfate type.

3. Dissolved-solids concentration greater than 1,000 mg/L.--94 percent of waters in this group are calcium-sulfate or calcium-magnesium sulfate types.

The relations between large dissolved-solids concentrations and the predominance of sulfate-type waters support the earlier observations of a strong positive linear correlation between dissolved-solids concentration and sulfate concentration. Thus, dissolved-solids bimodality reflects, to a degree, the sulfate bimodality. This is especially true of the waters from the Bass Islands Group.

Table 14.--Major-ion water types in the carbonate aquifer in Silurian and Devonian rocks, Lucas, Sandusky, and Wood Counties, northwestern Ohio

[N = 145 sites; Anion abbreviations: HCO_3, bicarbonate; SO_4, sulfate; Cl, chloride. Cation abbreviations: Ca, calcium; Mg, magnesium; Na, sodium]

Anion group	Cation group					Anion total	Percentage of anion total
	Ca	Ca - Mg	Ca - Mg - Na	Na - Ca	Na		
HCO_3	7	28	5	2	3	45	31
HCO_3 - SO_4	1	26	0	0	0	27	19
HCO_3 - SO_4 - Cl	0	3	1	0	0	4	3
HCO_3 - Cl	0	0	2	0	0	2	1
SO_4	21	32	11	2	0	66	45
Cl	0	0	0	0	1	1	1
Cation total	29	89	19	4	4	145	
Percentage of cation total	20	61	13	3	3		100

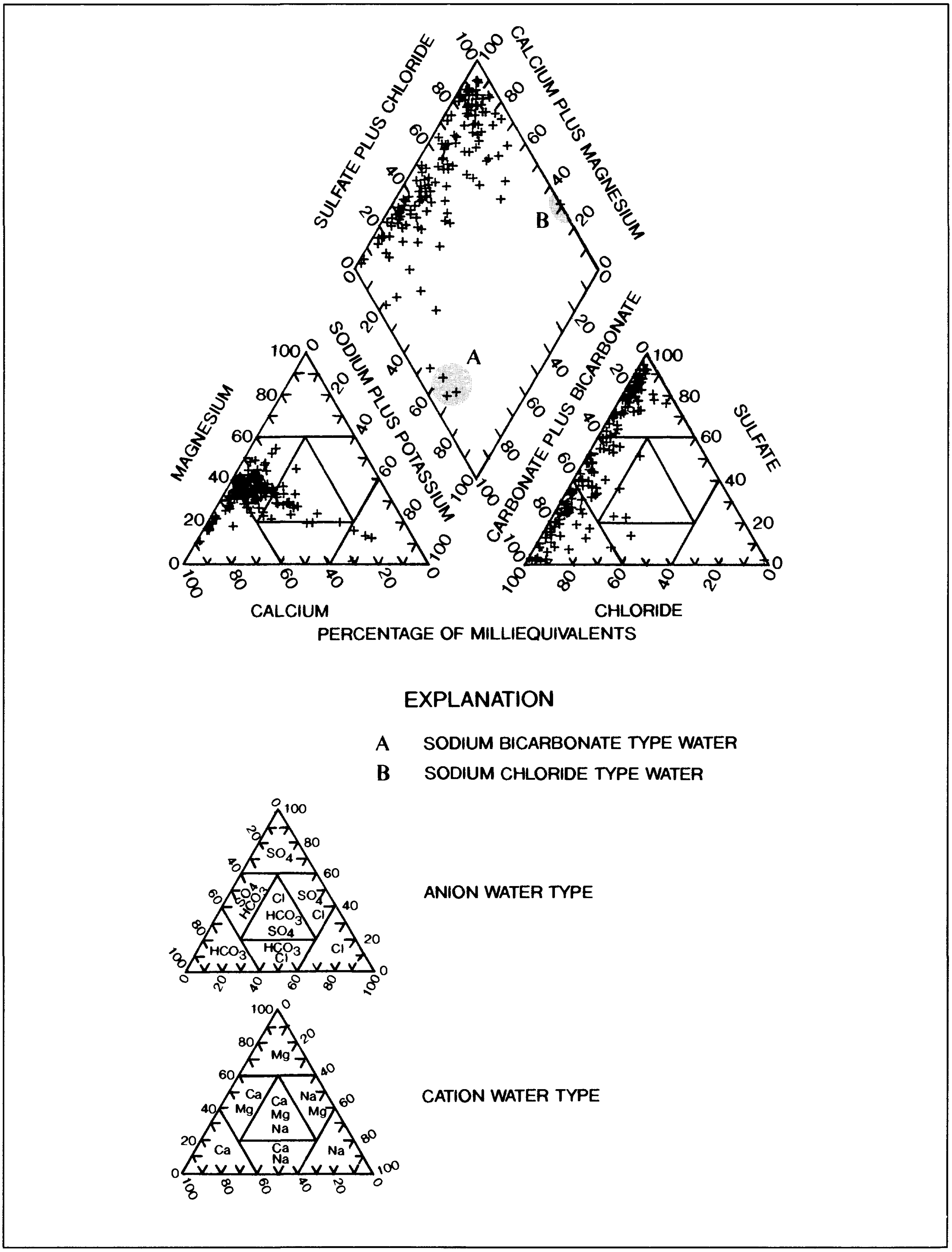


Figure 27.--Trilinear diagram of percentages of cation and anion milliequivalents for waters in the carbonate aquifer.

Areal distributions of sulfate concentrations and dissolved-solids concentration are shown in detail on plates 7 to 11. These maps also contain additional hydrochemical information for the five mapping areas. This information is discussed in the section on Local Hydrochemical Conditions.

Specific conductance of ground water can be used as an estimate of the overall ground-water quality in terms of dissolved solids and water type. Specific conductances were separated into two distributions, each one representing one mode of the bimodal distribution.[2] Regression analysis resulted in the following equations, which should be used within the specified specific conductance range:

For waters having a specific conductance ranging from 284 to less than 1,400 μS/cm (microsiemens per centimeter at 25 degrees Celsius)--

$$DS = 0.781\ S.C. - 75.5, \qquad (1)$$

where DS is dissolved-solids concentration, residue on evaporation at 180 °C in mg/L, and S.C. is specific conductance in μS/cm at 25 °C.

For waters having a specific conductance ranging from 1,400 to 4,000 μS/cm--

$$DS = 1.81\ SpC - 1.45 \times 10^{-4}(S.C.)^2 - 1220. \qquad (2)$$

Equations (1) and (2) have R-squared values of 0.78 and 0.93, respectively.

Dissolved solids is one of many constituents for which regulations have been established by the USEPA for health-related or aesthetic reasons. The USEPA maximum contaminant levels (MCL's) and secondary maximum contaminant levels (SMCL's) listed in table 13 are health-related and aesthetic standards, respectively. The relation between concentrations of dissolved constituents in ground water and these limits can be used to evaluate the quality of ground water for drinking and other domestic uses. Nondomestic uses of ground water, such as irrigation, also are affected by the quality of water; therefore, it is important to relate observed water chemistry to the quality of water for selected uses.

[2] Analysis of residuals plots from least-squares regression indicated that a single equation to estimate dissolved-solids concentration from the observed range of specific-conductance values was not appropriate.

Quality of Water for Drinking and other Domestic Uses

Quality of water in the carbonate aquifer has a considerable influence on its use for drinking and other domestic uses. The most persistent and areally widespread factors contributing to poor water quality are hardness, sulfate concentration, the presence of hydrogen sulfide, iron concentration, the presence of bacteria, and elevated background concentrations of alpha- and beta-particle radioactivity. Trace elements and volatile organic compounds are not present in concentrations that would affect domestic use of ground water.

Water quality generally is discussed in terms of public drinking-water regulations; however, no regulations have been established for certain constituents or some properties, such as hardness, that can affect the domestic use of water.

Table 15 (Supplemental Data section) highlights the MCL's and SMCL's of the USEPA and offers a brief explanation of the rationale for the various limits. Primary regulations are established on the basis of health considerations. Secondary regulations are established on the basis of aesthetic considerations. Various references of the USEPA (1976, 1982a, 1982b, 1986a, 1986b, 1986c, 1986d, 1988a, 1988b, 1988c, 1989a, and 1989b) are used to compile information for the table.

Concentrations of constituents for individual samples (table 9) and concentrations for percentiles in the frequency distribution for all samples analyzed (table 13) are compared with the concentrations in the primary and secondary regulations. MCL and SMCL concentrations also are listed in table 13 to aid in such comparisons. Thus, the overall suitability of ground water for domestic use or specific judgments about waters from selected areas are considered.

Detailed discussions on the presence and areal distribution of selected constituents that are important for determining suitability of water for drinking and domestic use are also provided in this section. The properties and constituents discussed are bacteria, fluoride, nitrate, selected trace elements, radionuclides, volatile organic compounds, hardness, hydrogen sulfide, and iron.

Bacteria

The presence of viable bacteria in ground water indicates relatively recent inflows of bacteria-containing waters into the aquifer. The length of time that bacteria can remain viable in ground-water systems is not well established. Romero (1970, p. 212) noted survival periods of up to 5 years under favorable conditions in sand and gravel aquifers. Randall (1970, p. 719) showed that bacteria can move a distance of 180 ft from a river to a well in sand and gravel deposits. Bitton and others (1983, p. 408) showed attrition rates for selected bacteria and found that fecal streptococci lived longer than total or fecal coliforms in shallow wells.

The results of bacterial testing indicate that bacteria are commonly present in ground water of the carbonate aquifer. Three separate tests were done to determine the presence of bacteria in ground waters.

Total coliforms.-- USEPA drinking-water regulations include tests for total coliform bacteria. Primary drinking-water regulations (U.S. Environmental Protection Agency, 1989a) are based on the presence of total coliforms rather than on an estimate of coliform density. If a sample is positive for total coliforms, the culture is analyzed for fecal coliforms or *E. coli*. If fecal coliform or *E. coli* are detected, the regulation has been violated. The Ohio Department of Health considers a private water supply to be unsafe if four or more total coliform colonies are detected per 100 mL (milliliters) of water. Total coliform bacteria were detected in about half of the samples collected (table 13). More specific confirmatory tests for fecal coliform and fecal streptococci bacteria were done in order to estimate whether the source of bacteria contained organisms originating in the intestines of warm-blooded animals.

Fecal coliforms.--About one third of the waters that contained total coliform bacteria also contained fecal coliform bacteria. About one-half of the 23 samples found to contain fecal coliform bacteria were from observation wells, unused wells, or unimproved springs. These sites were not maintained for potable supply. Thus, the presence of the fecal coliform organisms may not reflect conditions in the carbonate aquifer, but rather individual site contamination. The presence of these organisms at certain well sites, however, indicates that the wells are receiving waters containing viable bacteria and that the wells may be unsanitary.

Fecal streptococci.--The presence of these organisms in water is considered verification of fecal pollution. Fecal streptococci were present in about two-thirds of the waters testing unsafe for total coliforms and in 70 percent of waters with fecal coliforms.

The source of the bacteria present in water can, under some circumstances, be identified by calculating ratios of colonies of fecal coliform (FC) and fecal streptococci (FS); however, the ratio of FC colony counts to FS colony counts is not likely to provide information on sources of the bacteria found in waters from the carbonate aquifer (American Public Health Association, 1985, p. 818). Fecal streptococcus counts are usually less than 100 colonies per 100 mL; in samples in which fecal streptococci are found, fecal coliform organisms are seldom detected. Under these conditions, the American Public Health Association recommends that ratio methods not be used to determine bacteria sources.

The presence of fecal streptococci and fecal coliforms are indicative of fecal pollution of the carbonate aquifer; however, the source and distribution of bacteria in ground water on a regional basis remains uncertain.

Possible causes for the presence of fecal streptococci and fecal coliform bacteria in ground water are (1) faulty well construction; (2) an unsanitary (leaking) surface well seal; (3) deterioration of the casing; and (4) geologic conditions, such as a shallow depth to bedrock.

The presence of bacteria in ground waters in the representative five drift-thickness categories was not dependent on drift thickness. On the basis of statistical analysis by means of 2 x 5 contingency tables (Iman and Conover, 1983, p. 304), the presence of total coliforms, fecal coliforms, and fecal streptococci are independent (at the 95-percent confidence level) of drift thickness.

The presence of tritium in ground water was compared with the presence of bacteria. Statistical tests, by 2 x 2 contingency tables (Conover, 1971, p. 140), of the number of detections and nondetections for the three bacterial tests for tritiated and nontritiated waters indicated that there is no difference in the proportion of detections at the 95-percent confidence level.

The effects of possible well deterioration on the presence of bacteria in ground water were evaluated by determining the percentages of detections of fecal coliform and fecal streptococci for wells representing four periods of well completions (figure 28). Fecal-streptococci percentages are similar (average of 36 percent) for all four periods; thus, the fecal streptococci may be characteristic of the waters in the carbonate aquifer and not the result of well deterioration. Fecal-coliform percentages are nearly equal during the first three periods. The latest period (1980-1987) of wells has a notably lower incidence of fecal-coliform detections. This may reflect well-grouting procedures and extensions of casing above land surface in recent years. Well grouting and extension of casing help ensure a sanitary seal between the land surface and the aquifer.

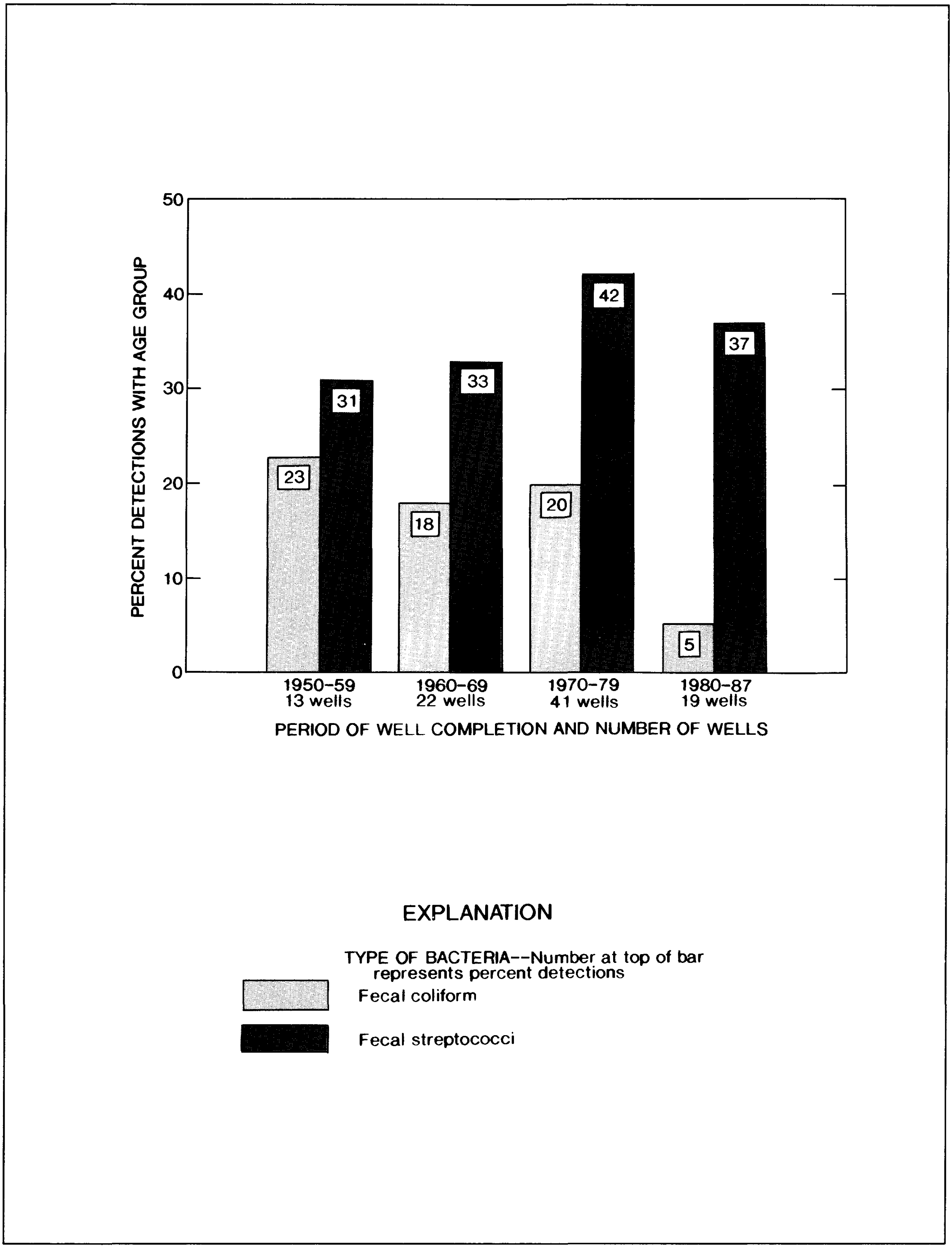


Figure 28.--Histogram of percentages of detections for fecal coliform and fecal streptococci related to decade of well completion, carbonate aquifer (wells of uncertain age are grouped with those from 1950–59)

Fluoride

The median fluoride concentration for 146 samples of ground water from the carbonate aquifer is 1.4 mg/L (table 13). Fluoride concentrations in 90 percent of the samples are less than or equal to 2.0 mg/L. The generalized areal distribution of fluoride in ground water is shown in figure 29, where concentrations have been divided into three ranges. The figure indicates regions of the carbonate aquifer that have characteristically large (greater than 1.5 mg/L) concentrations of fluoride. These include northern Wood County, southwestern Lucas County, the Toledo area, and eastern Lucas County. As table 13 indicates, concentrations are equal to or greater than the SMCL of 2.0 mg/L in 10 percent of all samples. The maximum concentration of 2.6 mg/L is less than the MCL of 4.0 mg/L.

Fluoride concentrations were compared with data from two other studies in the area (Jones and Parker, 1985; Sypniewski, 1982). In central Wood County (Eastwood School District), Jones and Parker found concentrations as large as 3.8 mg/L and a median concentration of 2.1 mg/L for 92 samples. In Woodville Township, Sandusky County, Sypniewski (1982) reports complete water analyses (table 16, Supplemental Data section) that include fluoride concentrations for 46 wells. Considerable local variation was noted, but concentrations in this area ranged from 0.1 to 1.7 mg/L, with a median concentration of 0.4 mg/L. Data from these two studies are uncommon in that few studies are available with such detail over a relatively small area. The work indicates that concentrations can be quite variable within two small geographic areas.

Results of analyses by the USGS of water from eight wells in the Eastwood School District are in poor agreement with those of Jones and Parker (1985) except at the Pemberville north well field. Concentrations reported by Jones and Parker are generally 0.5 to 1.0 mg/L larger than concentrations in waters from nearby wells sampled for this study. The four samples from Woodville Township, Sandusky County, collected for this study range in concentration from 0.3 to 0.6 mg/L and are comparable to the results of Sypniewski's (1982) analyses.

Nitrate

The nitrogen compounds, nitrite and nitrate, are present at very small concentrations in water from the carbonate aquifer. Nitrite plus nitrate nitrogen was detected at a concentration of 0.1 mg/L in less than half the waters tested. The median concentration of 0.01 mg/L (table 13) is three orders of magnitude less than the MCL of 10 mg/L (as N) of nitrate.

Baker and others (1989) examined nitrate concentrations in water from private wells, many of which were not completed in the carbonate aquifer. The difference in the quality of water from wells in general and quality of water from the carbonate aquifer appears to be significant. Baker and others found a mean nitrate concentration in well water of 0.65 mg/L, 0.71 mg/L, and 1 mg/L (as N) in Lucas, Sandusky, and Wood Counties, respectively. Results of USGS analyses indicate that less than 10 percent of the waters in the carbonate aquifer have nitrate concentrations greater than 0.53 mg/L (as N) (table 13). This result is considerably different from that of Baker and others (1989). The distinction between "well waters" evaluated by Baker and others and "waters from the carbonate aquifer" evaluated in this study could account for much of the difference. In Lucas County, for instance, results of Baker and others show that all nitrate concentrations in the 3- to 10-mg/L range are from shallow wells (mean depth of 17 ft, probably in the surficial sand aquifer).

Barium, lead, and zinc

Sources of trace elements in ground water may be (1) **anthropogenic** (related to human activities), or (2) natural (from minerals within the carbonate rocks). In general, USEPA primary drinking-water regulations for trace elements are established at concentrations that relate to effects on human health. (See tables 13 and 15.)

Barium, lead, and zinc from minerals in the carbonate rocks are present in ground water in northwestern Ohio. Deering (1981), Sypniewski (1982), and Deering and others (1983) have focused regional studies and a detailed study of Woodville Township in Sandusky County on barium, lead, and zinc in ground water as indicators of lead-zinc mineralization in the carbonate rocks. Barium was commonly found in ground water, but lead and zinc were detected less frequently in the regional studies. Sypniewski (1982) showed that in Woodville Township, barium and zinc were commonly present in ground water, but that lead was seldom detected at concentrations greater than 5 µg/L.

The results of the analyses for barium, lead, and zinc from this study (table 13) are consistent with results of Deering and Sypniewski, mentioned above. Lead rarely is detected, and barium and zinc are commonly present but at concentrations well below the 5,000-µg/L SMCL for zinc and the 1,000-µg/L MCL for barium. Waters from individual wells, such as LU-187-023 in Oregon and S-236-RL23 east of Fremont, contain uncommonly large concentrations of zinc.

Arsenic, chromium, and mercury

A statistical summary of the concentrations of arsenic, chromium, and mercury in ground water is in table 13. The summary shows that the number of sites sampled (of the 146 total sites) ranged from 82 sites for arsenic to 54 sites and 47 sites for chromium and mercury, respectively. The number of sites sampled in each county for these constituents is shown in table 7.

To define and highlight the magnitude of anomalous concentrations of arsenic, chromium, and mercury in ground water, box plots that account for the censored nature of the data are shown in figure 30. The local well numbers of sites where anomalous concentrations were found are shown along with the MCL's.

Arsenic was detected in water at 22 of the 82 sample sites. The 13 samples with concentrations greater than 1 µg/L are anomalous; however, they are less than the 50-µg/L MCL. Several anomalous concentrations are from samples in an area within the cities of Northwood and Oregon in Wood and Lucas Counties, respectively.

Chromium was detected in water at 30 of the 54 sample sites. Four samples have concentrations considered anomalous, as indicated by the box plot in figure 30. Three samples had concentrations greater than the 50 µg/L MCL. The largest concentration of chromium (710 µg/L) was from a private well at Bradner in Wood County. A chromium concentration of 110 µg/L was in a water sample from a well in the city of Sylvania in Lucas County near the border between Michigan and Ohio. Chromium in ground waters at sites north of the border between Michigan and Ohio is described elsewhere (Deutsch, 1972, p. 26; Toledo Blade, February 11, 1984).

Mercury was detected in 25 of the 47 water samples tested. Mercury has the lowest MCL of any trace metal, 2 µg/L. Figure 30 shows concentrations greater than 1 µg/L can be considered anomalous. Water samples from only three wells had concentrations of mercury greater than its MCL. Mercury is widespread geographically, and the largest concentration (3.9 µg/L) was from a well in the Oregon area in Lucas County.

Radionuclides and radiochemicals

Radioactivity in ground water can affect the suitability of water for drinking. The radioactivity commonly is caused by the natural radioactive decay of specific **radionuclides** dissolved in the water. Radiological quality of public drinking water is based on a 5-pCi/L MCL for the sum of concentrations of radium-226 and radium-228. As they decay,

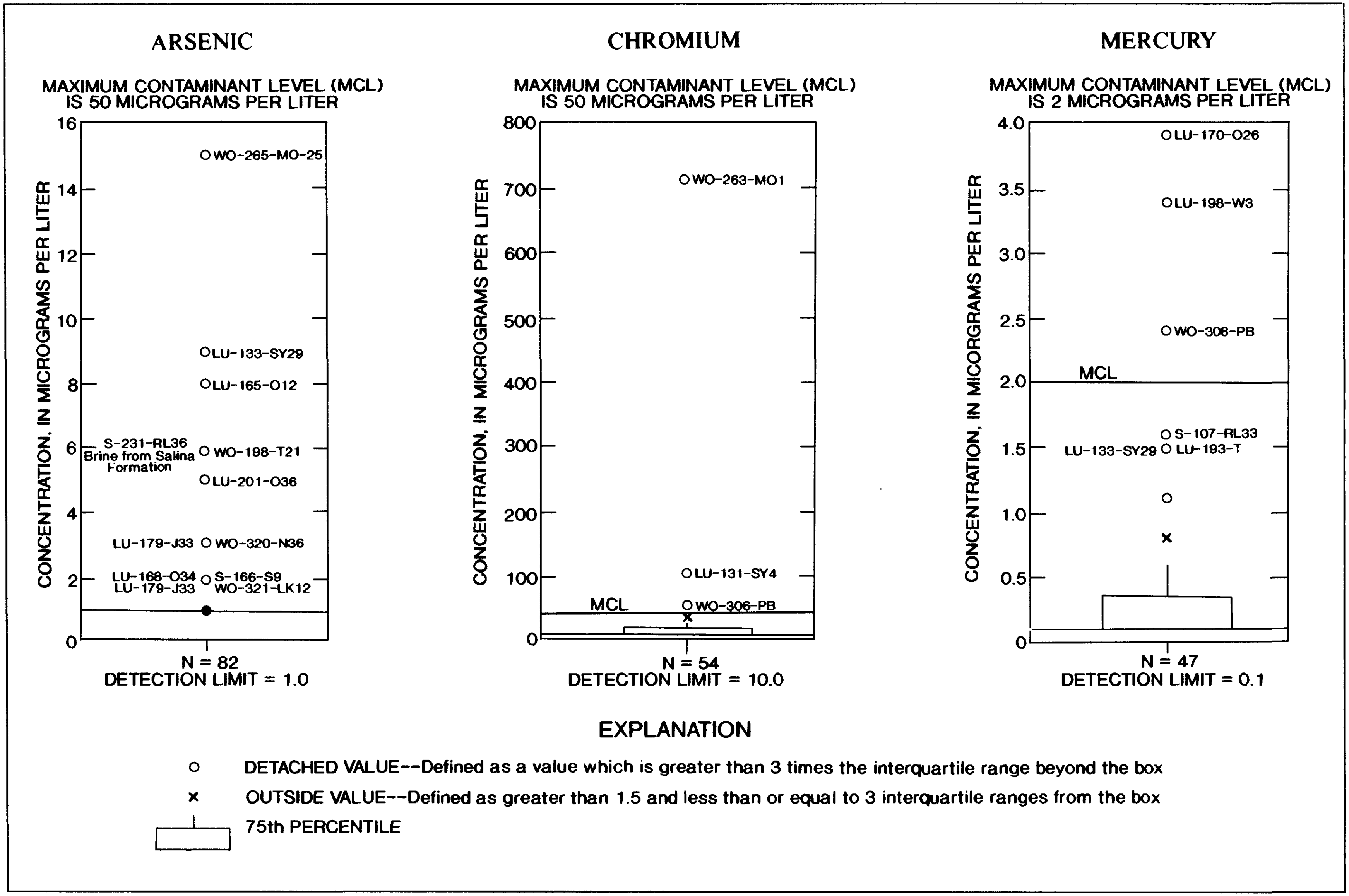


Figure 30.--Box plots of arsenic, chromium and mercury concentrations in water from carbonate aquifer.

radium-226 emits alpha particles, and radium-228 emits beta particles. Radium is chemically similar to calcium; thus, if waters containing radium are ingested, the radium could be incorporated in the bones. The radioactive decay of radium within the human body has potentially adverse health effects.

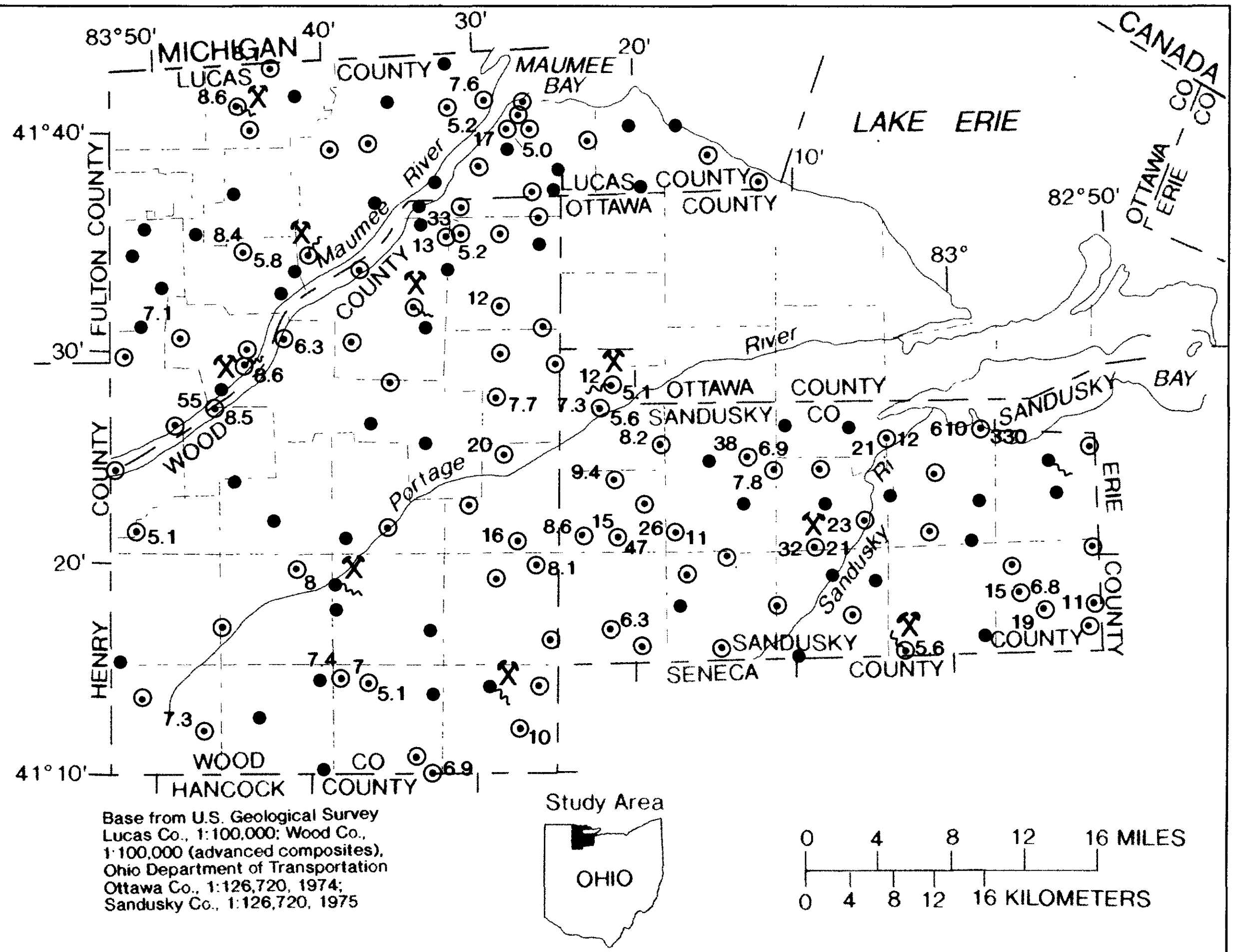
Measurement of the gross alpha-particle radioactivity is used to determine if more detailed and expensive analyses are needed for specific radionuclides. The procedure is termed gross alpha-particle screening. In the screening process, when gross alpha activity exceeds 5 pCi/L, an equivalent sample is analyzed for radium-226. If the concentration of radium-226 exceeds 3 pCi/L, an equivalent sample is analyzed for radium-228. For investigations of baseline conditions, Cecil and others (1987) warn that gross alpha screening should be used with caution because many waters may have radium-228 concentrations in excess of radium-226 concentrations. Thus, with gross alpha screening alone, beta-particle and radium-228 anomalies can be missed because radium-228 does not emit alpha particles.

For this study of natural radiological quality of ground water, a broadly based screening was used that included measurements of gross alpha-particle radioactivity, gross beta-particle radioactivity, and uranium. Summary statistics for the radiochemical constituents are listed in table 13. The alpha-particle radioactivity is converted from microgram per liter to picocuries per liter by use of the factor 0.68 pCi/μg (picocuries per microgram) (Thatcher and others, 1977, p. 88).

Alpha- and beta-particle radioactivity have nearly equal median concentrations of 3.6 pCi/L (as uranium) and 3.9 pCi/L (as Sr-/Yt-90), respectively. About 25 percent of the samples have concentrations which exceed the gross alpha screening criterion (5 pCi/L or about 7 μg/L as uranium). About 25 percent of the waters have beta-particle activities greater than 5 pCi/L (as Sr-/Yt-90). The map in figure 31 shows sites with alpha- and beta-particle activities greater than 7 μg/L and 5 pCi/L, respectively. The sites are widespread geographically. Large concentrations of alpha-particle radioactivity do not always indicate that large concentrations of beta-particle radioactivity are present and vice versa.

A specific radionuclide responsible for the alpha-particle radioactivity has not been identified. Alpha-particle radioactivity is caused by alpha decay of radionuclide parents to form daughters (table 17). Uranium-234 and -238, radium-226, radon-222, and thorium-228 are potential sources of alpha-particle radioactivity.

Uranium as a potential source of alpha-particle radioactivity was assessed by examining the relation between concentrations of alpha-particle radioactivity and concentrations of uranium in ground water. Dissolved uranium



EXPLANATION

RADIOCHEMICAL SAMPLE SITE--Number to left is gross alpha-particle radioactivity in micrograms per liter as U. Number to right is beta-particle radioactivity in picocuries per liter. Alpha-particle radioactivities greater than 7 micrograms per liter are shown. Beta-particle radioactivities greater than 5 picocuries per liter are shown

21⊙12 **Well**

8.6⊙25 **Spring**

⊙ **Well sampled for radiochemical but samples did not exceed the analysis threshold**

● **WELL NOT SAMPLED**

●~ **SPRING NOT SAMPLED**

⚒ **QUARRY SUMP SPRING**

Figure 31.--Distribution of alpha-and beta-particle radioacitivity in water from the carbonate aquifer.

Table 17.--Selected decay patterns for beta- and alpha-particle radioactivity

Alpha-particle decay			Beta-particle decay		
Parent		Daughter	Parent		Daughter
^{234}U	--->	^{226}Ra	^{27}Mg	--->	^{27}Al
^{226}Ra	--->	^{222}Rn	^{38}Cl	--->	^{38}Ar
^{222}Rn	--->	^{218}Po	^{40}K	--->	^{40}Ca
^{228}Th	--->	^{224}Ra	^{87}Rb	--->	^{87}Sr
^{238}U	--->	^{234}Th	^{228}Ra	--->	^{228}Th
			^{234}Th	--->	^{234}U

concentrations were measured and represent the sum of all uranium isotopes (^{234}U and ^{238}U).

Two general types of alpha-particle radioactivity are associated with water from the carbonate aquifer (figure 32). Alpha-particle radioactivity independent of uranium concentration is characterized by concentrations greater than the screening limit (7 μg/L of alpha-particle radioactivity) that have corresponding uranium concentrations less than 1 μg/L. The second type of alpha-particle radioactivity, greater than the screening limit, increases with increasing uranium concentration greater than 1 μg/L. Thus, the second type depends on uranium concentration.

Waters from wells in western Sandusky County (S-202-W31, S-188-WO28) and a spring in central Sandusky County (S-32-S32) are characterized by the second type of alpha-particle radioactivity and contain the largest concentrations of dissolved uranium in the study area.

Examination of the data in figure 32 in relation to other knowledge about the aquifer system indicates that the following factors affect alpha-particle radioactivity:

1. Gross alpha-particle radioactivity depends on uranium concentrations in waters that either contain dissolved oxygen, are tritiated, or are from near-surface zones of the aquifer in areas of thin drift. These factors are characteristic of an oxygenated geochemical environment where uranium is mobile (Zapecza and Szabo, 1987, p. 53-54). Uranium concentrations greater than approximately 2.5 μg/L characterize these waters.

2. Gross alpha-particle radioactivity is independent of uranium concentrations in waters that are from a reducing geochemical environment. This environment is most likely where the aquifer is overlain by thick drift, waters are relatively old (contains little or no tritium), hydrogen-sulfide is present, and the concentration of dissolved oxygen is less than 0.1 mg/L.

Radon-222, which is a decay product of radium-226, was not measured and could be a source of some of the alpha-particle radioactivity.

Radium-226 is a probable source of the alpha-particle radioactivity; however, few data are available (October 1989) to describe the presence of radium-226 in the carbonate aquifer.

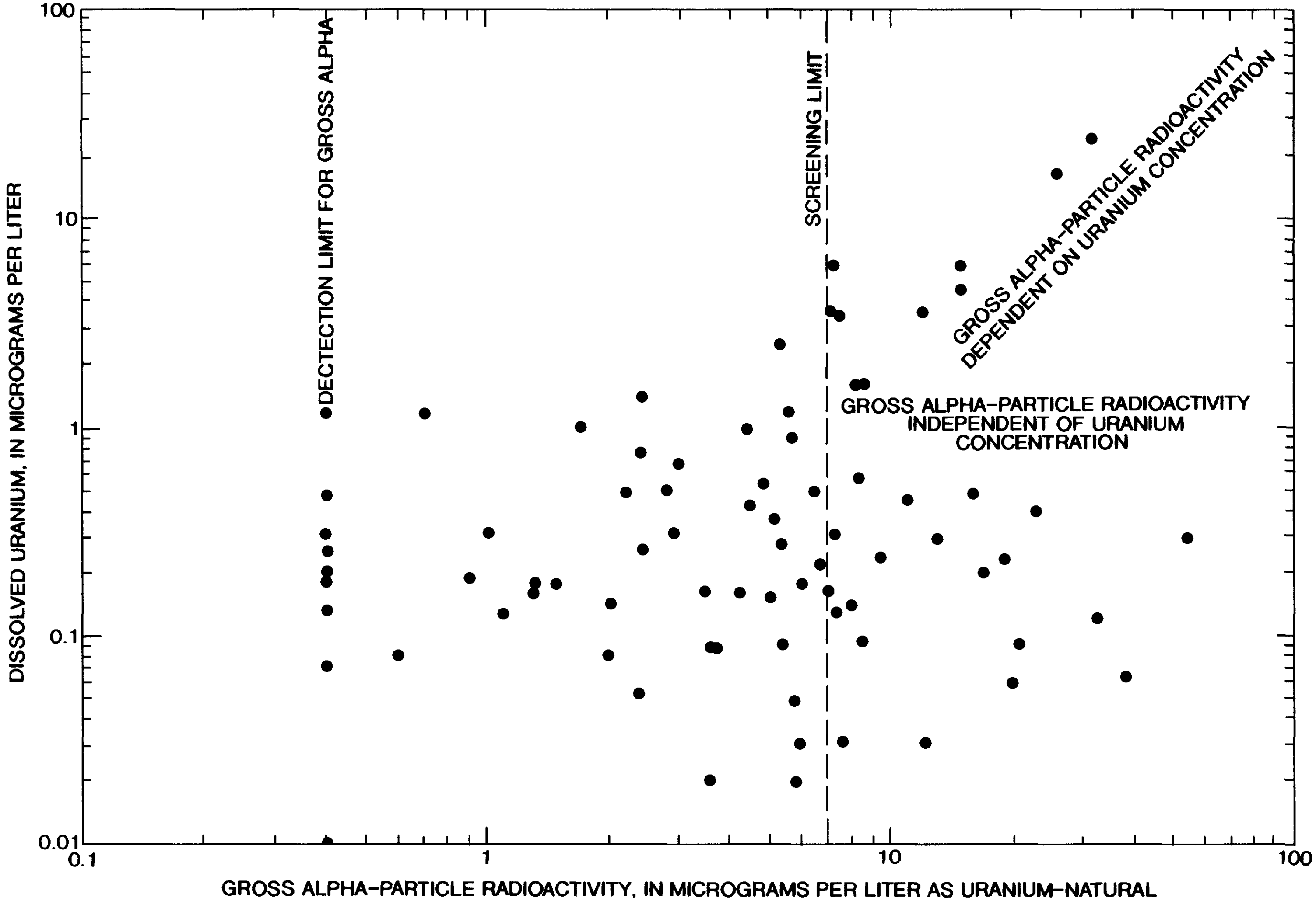


Figure 32.--Relation between alpha-particle radioactivity and uranium concentrations in water from the carbonate aquifer.

Local and State health department and Ohio Environmental Protection Agency (OEPA) records show one documented case of an elevated concentration of 11.3 pCi/L radium-226 in a single well water from Woodville Township in western Sandusky County (Ohio Environmental Protection Agency, 1983). Alpha-particle radioactivity of about 50 pCi/L has been reported by OEPA for water from this well.

Potential sources of beta-particle radioactivity were examined by comparing parent common-element (table 17) concentrations in ground water with corresponding beta-particle radioactivity. Comparisons were limited because no data for rubidium-87 or radium-228 were collected. Radium-228 and beta-particle activity are possibly associated, but few data are available for radium-228. Local and State health department and OEPA records show one documented case of an elevated concentration of 5.3 pCi/L radium-228 in the same well water from Woodville Township found to contain radium-226. Samples from this well were not analyzed for beta-particle radioactivity.

Plots of beta-particle radioactivity as a function of magnesium, chloride, strontium, and potassium concentrations indicate that potassium has a positive correlation with beta-particle radioactivity (fig. 33; Pearson coefficient, R=0.92). Thus, radioactive decay of potassium could be, in part, a source of the beta-particle radioactivity in ground water. This needs to be tested by further study of the existence of beta-particle radioactivity in potassium-rich waters.

Potassium concentrations are largest in waters from wells completed in the Silurian rocks of eastern Sandusky County where evaporite-bearing strata sometimes contain the mineral sylvite (KCl). If gross beta-particle radioactivity were due to potassium instead of radium-228, then, water treatment for radium removal would not be required, unless radium-226 were present.

Additional testing is needed to determine whether radium is the source of the radioactivity in other areas where screening analyses show alpha- and beta-particle radioactivities greater than 5 pCi/L. This testing would assist in determining whether any health precautions are warranted.

Volatile-organic compounds

Waters from selected wells in Lucas and Wood Counties and a spring in Lucas County were examined for volatile-organic compounds (VOC's), which are analyzed as total recoverable purgeable organic compounds by gas chromatography/mass spectrometry. No samples were collected in Sandusky County. The results of the analyses for the 45 sites sampled are listed in table 9. Concentrations of VOC's were less than the detection limit for the analyses in waters from all but one well. The organic

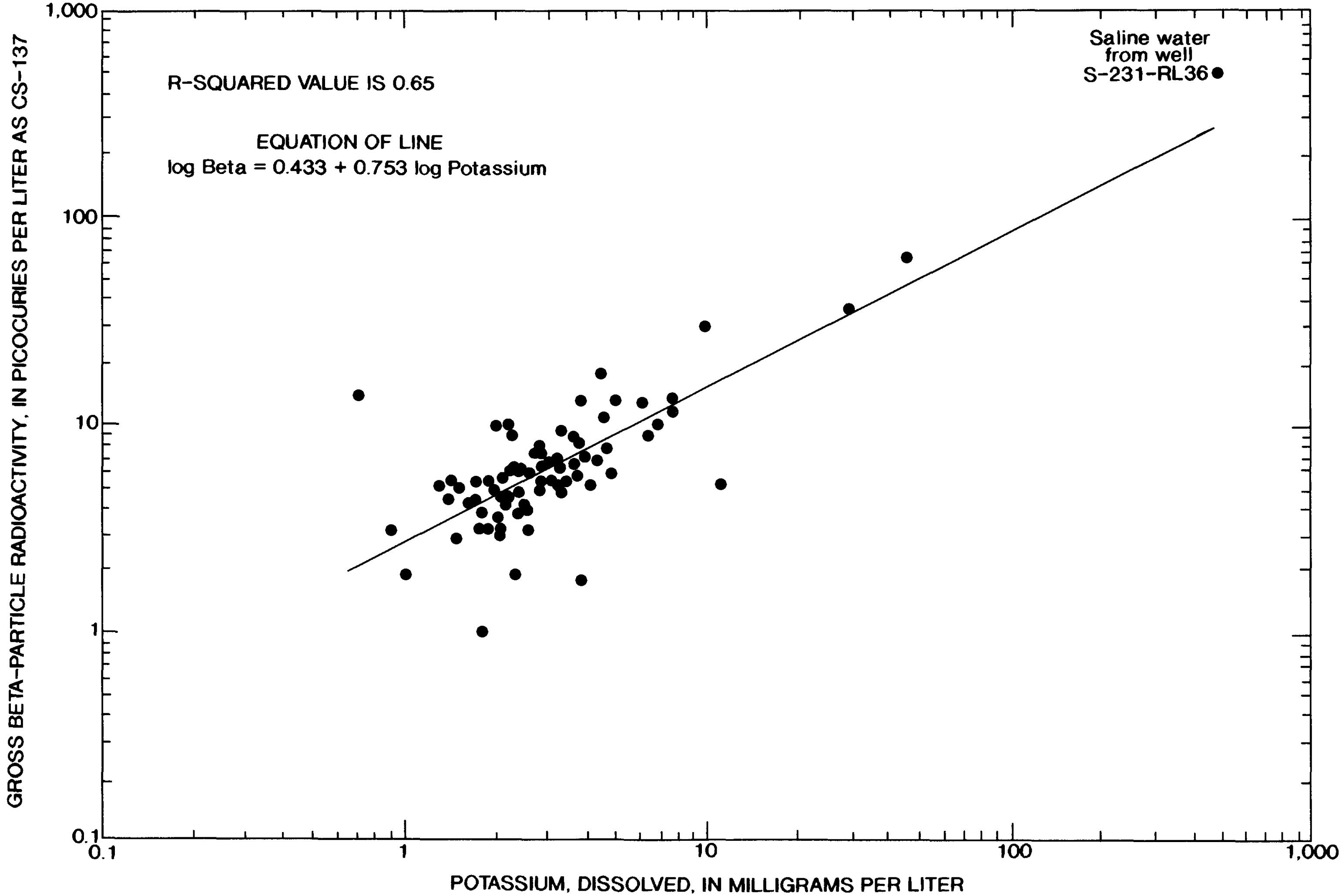


Figure 33.--Relation between beta-particle radioactivity and potassium concentration in water from the carbonate aquifer.

compounds 1, 1, 1-trichloroethane and tetrachloroethylene are present in water from well WO-326-WS32, located along Beaver Creek in Weston Township, Wood County (see plate 1). The presence of organics was first noted in August 1987 and was confirmed by a second sample in 1989.

The concentrations detected are summarized in the following table:

Date	Time	Tetra-chloro-ethylene (µg/L)	1, 1, 1-Tri-chloro-ethane (µg/L)
August 4, 1987------	1455	310	220
January 31, 1989----	1600	120	4.7
Maximum contaminant level for drinking water--		5*	200

*MCL proposed by USEPA (1989b).

No other samples were collected in the vicinity of well WO-326-WS32 to evaluate the areal extent or source of the organics in the aquifer. The presence of coliform bacteria in water from this well also indicates that additional contaminants could be present and that, possibly, a surface leakage contributed to the observed VOC concentrations.

Hardness

Waters from the carbonate aquifer are very hard. Hardness in water is due to the presence of calcium, magnesium, and other constituents such as strontium and barium. Very hard waters are classified (Hem, 1985, p. 159) as waters with hardness concentrations greater than 180 mg/L as calcium carbonate ($CaCO_3$). Hardness concentrations greater than 300 mg/L are common (table 13).

Noncarbonate hardness is the hardness in excess of the alkalinity in water. For waters from carbonate aquifers, noncarbonate hardness usually indicates that calcium and magnesium originate from minerals other than carbonates, such as calcium sulfate (anhydrite). If hardness exceeds the alkalinity, which is true of more than 75 percent of the waters sampled, then the excess is the noncarbonate hardness. The largest concentration of hardness and noncarbonate hardness is characteristic of the calcium sulfate and calcium magnesium sulfate-type waters. Hardness concentrations of 1,000 mg/L or greater are common in sulfate-type waters. These waters occur in many areas of Lucas, Wood, and eastern Sandusky Counties. The frequency distributions of hardness and noncarbonate hardness shown in figure 26 indicate that the largest concentrations are in waters from the Bass Islands Group.

Samples from Devonian strata above the Detroit River Group have relatively little hardness (fig. 26). These waters are sodium-bicarbonate types that are naturally soft to moderately hard and commonly have no noncarbonate hardness. These naturally soft waters are limited to western Lucas County and are most common in Springfield, Swanton, and Providence Townships. Drillers' logs in these areas indicate a mixture of shale and limestone bedrock that is characteristic of the Traverse Group.

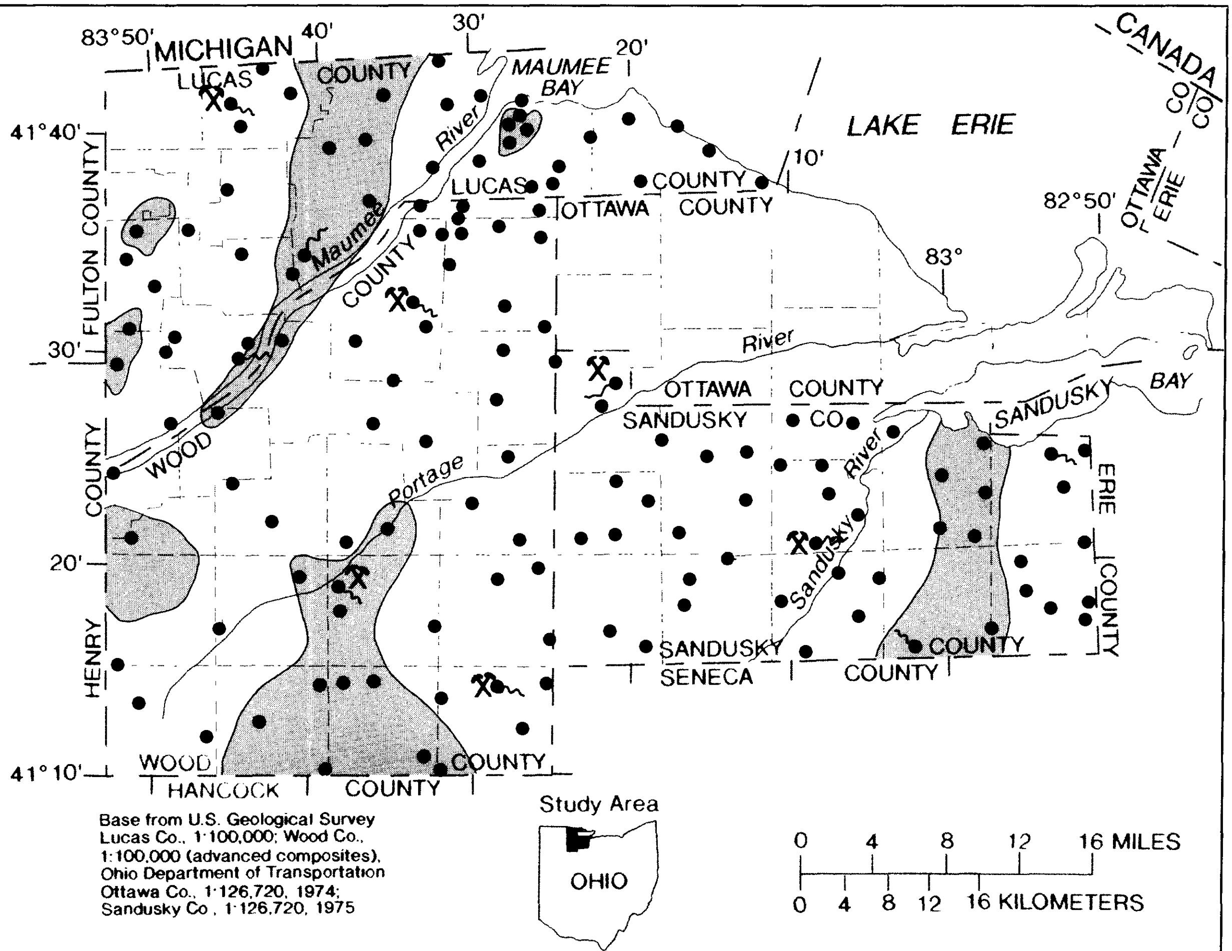
Hydrogen sulfide

Hydrogen sulfide is a gas that imparts an objectionable odor (often described as that of rotten eggs) to water and is corrosive to pipe and plumbing fixtures. The sulfur odor is noticeable at concentrations less than 0.25 µg/L. There are no drinking-water regulations specifically for hydrogen sulfide; however, the aesthetic degradation of water quality commonly depends on individual sensitivities. The titration technique for laboratory determination of hydrogen sulfide (Fishman and Friedman, 1985, p. 622-624) has a quantitation concentration of 0.5 mg/L.

Parts of the study area where concentrations of hydrogen sulfide in ground water exceeded 0.5 mg/L are shown in figure 34. These concentrations may change with depth in the aquifer. The Ohio Department of Natural Resources (1970, p. 53) states that concentrations of hydrogen sulfide generally increase with depth. The hachured areas in the figure represent areas where hydrogen-sulfide concentrations are independent of the depth of wells, according to drillers' reports and chemical data. Thus, hydrogen sulfide would be expected in ground water from the carbonate aquifer in these areas regardless of the depth of the well. Detailed maps showing the areal distribution of hydrogen sulfide are presented on plates 7 to 11.

Iron

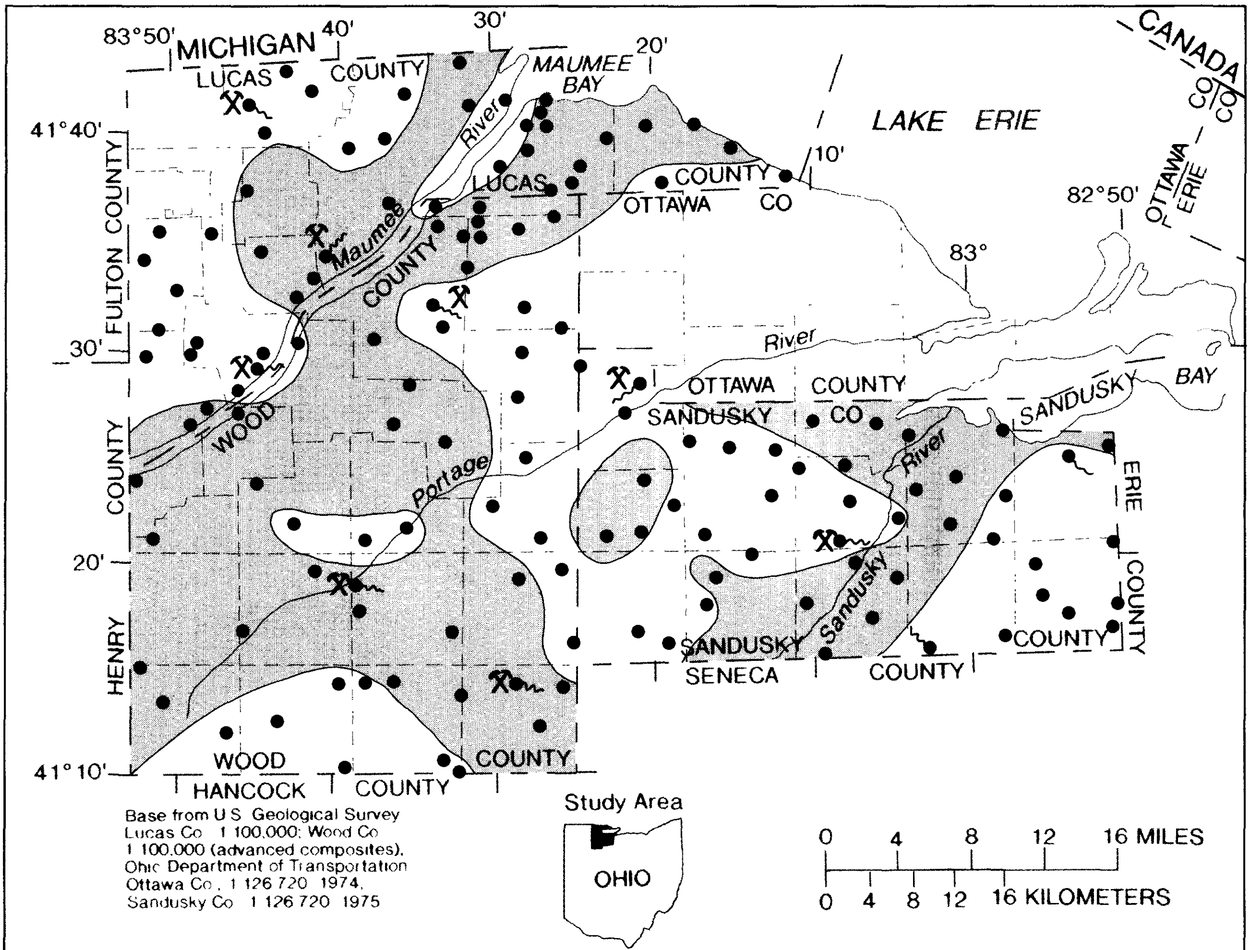
Excessive iron affects the aesthetic quality of water by causing staining of plumbing fixtures and a metallic taste. Concentrations of 300 µg/L or more exceed the USEPA SMCL for iron. Areas that have iron concentrations less than, equal to, and in excess of 300 µg/L in ground water are shown in figure 35. The presence of iron may vary seasonally or with the depth to which a well is completed. These results are representative of typical well completions and offer a perspective on areal variability of iron concentration, not variability with depth of well completion or season.



EXPLANATION

- AREA WHERE HYDROGEN SULFIDE CONCENTRATION IN GROUND WATER IS MEASURED AND IS GREATER THAN 0.5 MILLIGRAMS PER LITER AS S
- ● WELL
- SPRING
- QUARRY SUMP SPRING

Figure 34.--Areas where concentrations of hydrogen sulfide area greater than 0.5 milligrams per liter and are independent of depth in the carbonate aquifer.



EXPLANATION

AREA WHERE DISSOLVED-IRON CONCENTRATIONS IN GROUND WATER ARE EQUAL TO OR GREATER THAN 300 MICROGRAMS PER LITER

AREA WHERE DISSOLVED-IRON CONCENTRATIONS IN GROUND WATER ARE LESS THAN 300 MICROGRAMS PER LITER

● WELL

SPRING

QUARRY SUMP SPRING

Figure 35.--Distribution of iron concentration in water from the carbonate aquifer.

Suitability of Water for Irrigation

Water from the carbonate aquifer has salinity that can limit its use for irrigation. A method developed by the U.S. Salinity Laboratory Staff (1954) classifies sodium and salinity hazards for irrigation waters in arid areas of the western United States. In the nonarid study area, the sodium and salinity hazard classification for arid areas can only be applied in a general way because of the dilution of water in, and flushing of water from, the root zone during recharge events. The specific conductance of the water is a measure of the salinity hazard, and the sodium adsorption ratio (SAR) is used to evaluate the sodium hazard. Descriptions of the classes of sodium and salinity hazards are given in table 18.

The sodium adsorption ratio (SAR) is an indication of the sodium hazard in terms of the relative concentrations of calcium ($Ca^{2}+$), magnesium ($Mg^{2}+$), and sodium (Na+) in a water; the ratio is calculated from concentrations of these elements in milliequivalents per liter, by the equation

$$SAR = Na^{+}/((Ca^{2+} + Mg^{2+})/2)^{1/2}. \qquad (3)$$

The sodium- and salinity-hazard classifications are shown in graphical form in figure 36. Water in the carbonate aquifer has a low sodium hazard because the SAR is generally less than 4. The salinity hazard, however, may be a problem where waters have specific conductances exceeding 2,250 µS/cm. Most ground waters studied have specific conductances greater than 750 µS/cm.

Saline water originating in the Salina Group has a very high alkali hazard (SAR value of 56, not shown) and salinity hazard (specific-conductance value of 80,000 µS/cm) and is probably not suitable for irrigation. Waters of this saline type are found within a limited area of Riley and Townsend Townships in Sandusky County.

Boron is an element that is essential as a plant nutrient; however, concentrations of boron greater than 750 µg/L may cause toxicity symptoms in some sensitive plants (Severson and Shacklette, 1988, p. 21). At 9 of the 98 sites where boron concentrations in water were determined, boron concentrations were greater than 750 µg/L. Most waters are rated permissible to excellent for irrigation on the basis of boron concentration (Hem, 1985, p. 216).

Large boron concentrations correlate with elevated sodium concentrations (figure 37). Waters having boron concentrations exceeding 750 µg/L also have the largest SAR values observed, but the sodium hazard for these waters is still considered low (Class S1 in fig. 36).

Table 18.--Selected appraisal factors and hazard classification for irrigation waters

[Summarized from U.S. Salinity Laboratory, 1954. µS/cm, microsiemens per centimeter at 25 degrees Celsius]

USABILITY APPRAISAL

Three important factors relating to dissolved solids are involved in appraising the usability of water for irrigation:

1. The minerals in the soil and the drainage properties of the soil,
2. The tolerance of the irrigated crop to the major constituents in the water, and
3. The concentration of major constituents in the water.

SALINITY HAZARD CLASSIFICATION

Class	Description
C1	Low-salinity water can be used on most crops and soils. Some leaching is necessary, thus soils with low permeability may be affected (specific conductance range, 100-250 µS/cm).
C2	Medium-salinity water can be used if soil permeability and drainage are sufficiently high (specific conductance range, 250-750 µS/cm).
C3	High-salinity water should not be used on soils with low permeability. Crops with low salt tolerance, even with adequate drainage, may be affected (specific conductance range, 750-2,250 µS/cm).
C4	Very high-salinity water is not suitable for irrigation under most conditions (specific conductance range, 2,250-5,000 µS/cm.)

SODIUM HAZARD CLASSIFICATION

Class	Description
S1	Low-sodium water can be used on most soils with little danger of developing hazardous levels of exchangeable sodium.
S2	Medium-sodium water may present problems in fine-textured soils with high cation-exchange capacity.
S3	High-sodium water may produce harmful levels of sodium in most soils.
S4	Very high-sodium water is generally unsatisfactory for irrigation purposes. Solution of calcium from the soil, use of soil additives, and a low-salinity water may make irrigation with this water possible.

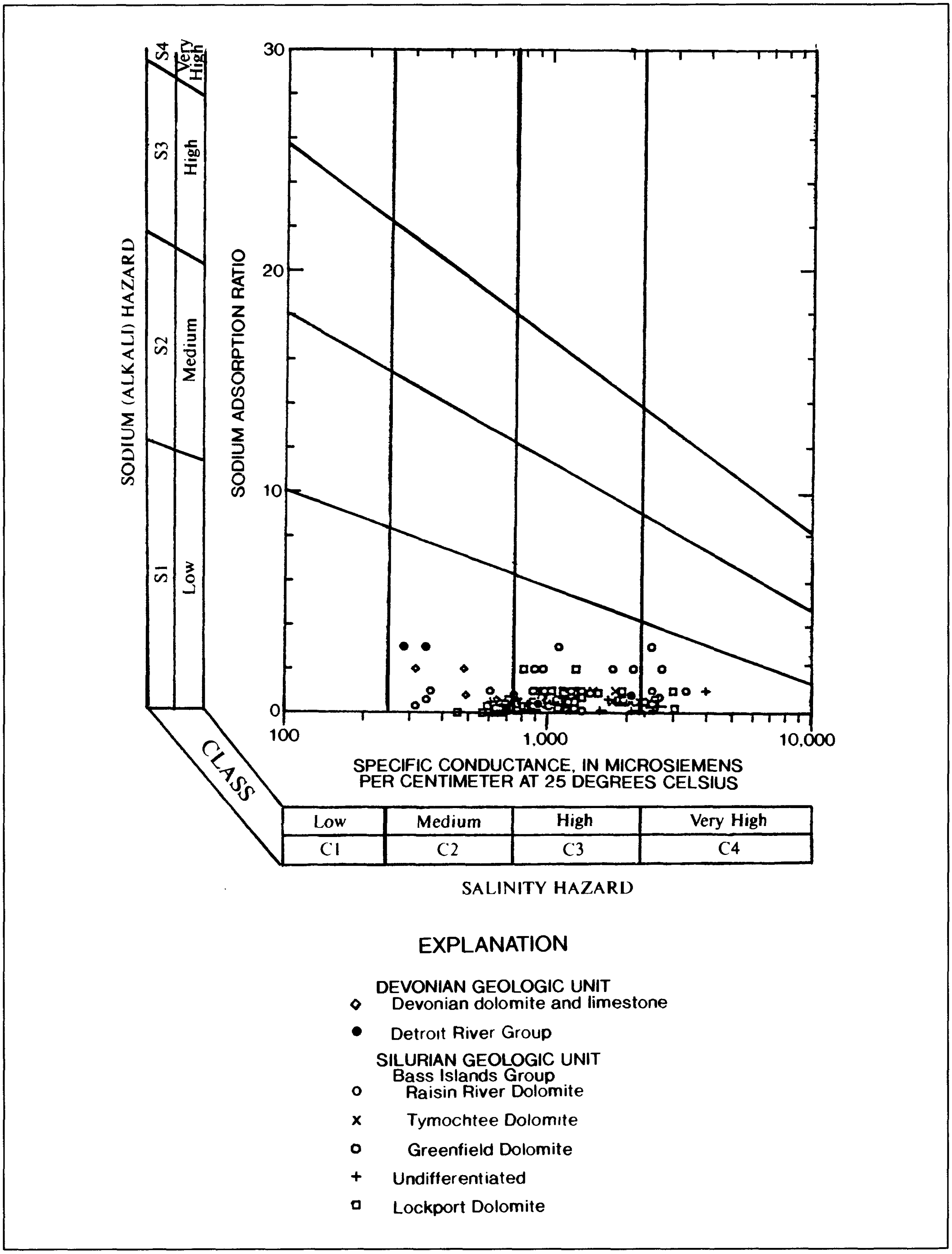


Figure 36.--Classification of water in the carbonate aquifer for irrigation (modified from Burkhardt, 1984, fig. 4).

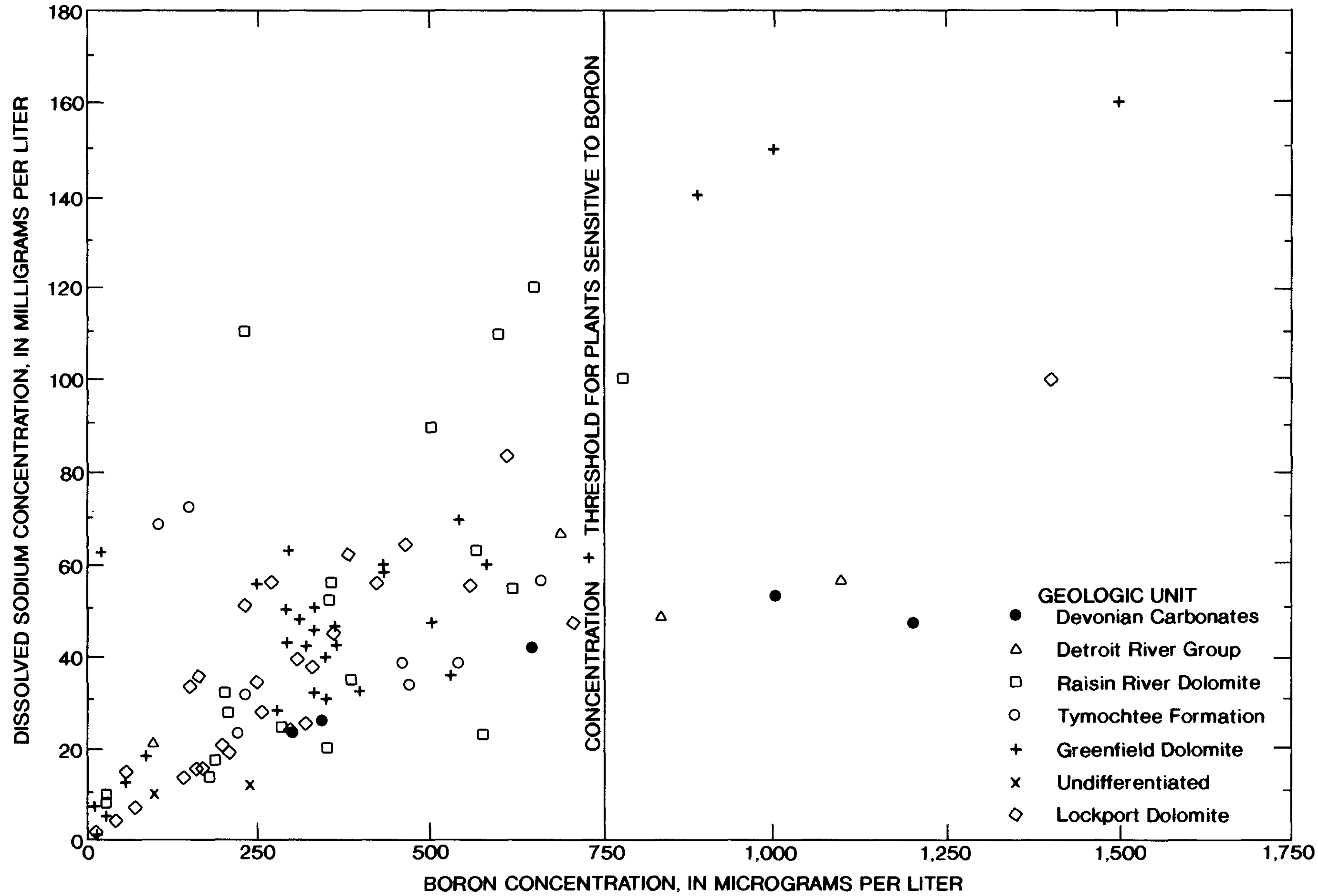


Figure 37.--Relation between sodium and boron concentrations in water from the carbonate aquifer.

Factors Affecting Water Quality

This section addresses three factors that affect the quality of water and its usability. An understanding of the factors affecting ground-water quality in the carbonate aquifer is needed for appropriate management and development of the aquifer's water resource.

Geochemical controls on major-ion chemistry

Major-ion chemistry of water in the carbonate aquifer is controlled, to a large extent, by interactions between the water and minerals that comprise the aquifer matrix. Minerals that are in a water-bearing zone of the aquifer can affect water quality. Water-mineral interactions affect the chemistry of ground water by providing mechanisms, whereby chemical constituents can be added to or removed from water in the aquifer. Residence times and flow rates of water can affect the degree to which waters equilibrate (that is, become saturated with minerals). Geochemical controls on the concentrations of calcium, magnesium, strontium, sulfate, and fluoride are discussed below.

Gypsum (hydrous calcium sulfate) and anhydrite (anhydrous calcium sulfate) are common in some parts of the aquifer. The major-ion chemistry of ground water reflects the effects of dissolution of these minerals. Calcium-sulfate-type waters result from dissolution of these minerals; water from wells that tap the Bass Islands Group are affected most notably.

The chemical characteristics of ground water in carbonate-rock aquifers commonly are controlled by chemical processes far more complicated than mineral solubility and equilibration. Back and others (1983) explain that, as ground water flows in a carbonate-rock aquifer, the water initially dissolves calcite, dolomite, and gypsum or anhydrite at variable rates. Chemical equilibrium (saturation) is first established with respect to calcite and dolomite, which contribute calcium, magnesium, and bicarbonate to water. The chemistry of the ground-water system is altered by the continued dissolution of gypsum, which increases calcium and sulfate concentrations. Increased calcium and sulfate concentrations lead to the incongruent dissolution of additional dolomite and the accompanying formation of calcite. Calcite precipitation removes calcium ions from the ground water and effectively keeps the water undersaturated with respect to gypsum. The net result of this process is to alter the calcium:magnesium concentration ratio and to increase the concentration of sulfate.

The degree of mineral saturation was computed for ground waters by use of the USGS computer program WATEQF (Plummer and others, 1976). WATEQF calculations yield a saturation index (SI), which quantifies the tendency for a mineral to be dissolving in or precipitating from the water analyzed, as follows:

$$SI = \log(IAP/KT), \qquad (4)$$

where IAP is the ion-activity product of the mineral-water reaction, and KT is the equilibrium constant or solubility product of a mineral (K) at the temperature (T) of the ground-water system in degrees Kelvin (Drever, 1988, p. 22). Minerals with positive SI values indicate that the water is oversaturated with respect to the mineral and that the mineral would tend to precipitate; minerals with negative SI values indicate that the water is undersaturated with respect to the mineral and that the mineral would tend to dissolve in the water. Plots of the SI for the predominant minerals in the carbonate aquifer are shown in figure 38. All are plotted in terms of sulfate concentration--an important anion in understanding ground-water geochemistry in carbonate aquifers (Back and others, 1983).

The saturation indices for calcite and dolomite indicate that the aquifer matrix in contact with the waters sampled is generally near equilibrium (not dissolving); however, gypsum or anhydrite in water-bearing zones would tend to dissolve in the waters undersaturated with respect to gypsum. Gypsum undersaturation depends on sulfate concentration. Dolomite and calcite saturation appear to be independent of sulfate concentration and geologic unit.

Geochemical controls affect the concentration of strontium in ground water. Maximum strontium concentrations are affected by sulfate concentration and the solubility constraints imposed by the mineral celestite ($SrSO_4$). The largest strontium concentration is about 50,000 µg/L, which agrees with measured celestite solubility in pure water at 10 °C (Reardon and Armstrong, 1987, p. 66). The smallest strontium concentrations are generally less than 7,000 µg/L, which approximates the measured solubility (5,000 µg/L) of strontianite ($SrCO_3$) in pure water (Busenburg and others, 1984, p. 2021). The smallest and largest strontium concentrations are in water with small sulfate concentrations (less than 250 mg/L, fig. 39).

Saturation indices for strontium-bearing minerals are plotted in figure 40 and indicate that waters with sulfate concentrations less than 250 mg/L are generally saturated with respect to strontianite and undersaturated with respect to celestite. In waters having a sulfate concentration greater than 250 mg/L, celestite saturation is common. Waters become increasingly undersaturated with respect to strontianite as sulfate concentration increases. Some waters are undersaturated with respect to both celestite and strontianite. This condition indicates that neither mineral is present in some water-bearing zones.

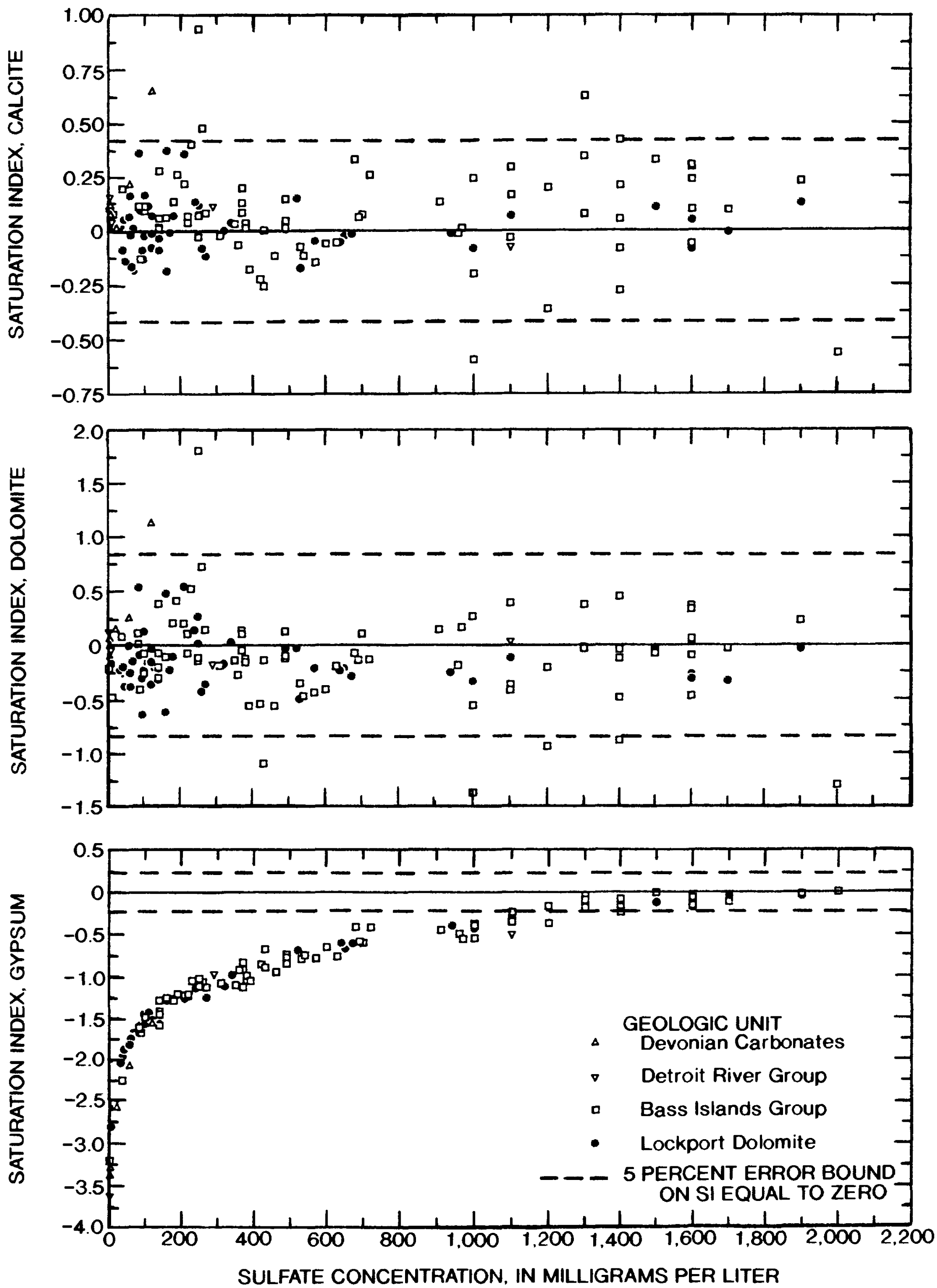


Figure 38.--Saturation indices for calcite, dolomite, and gypsum in waters of the carbonate aquifer.

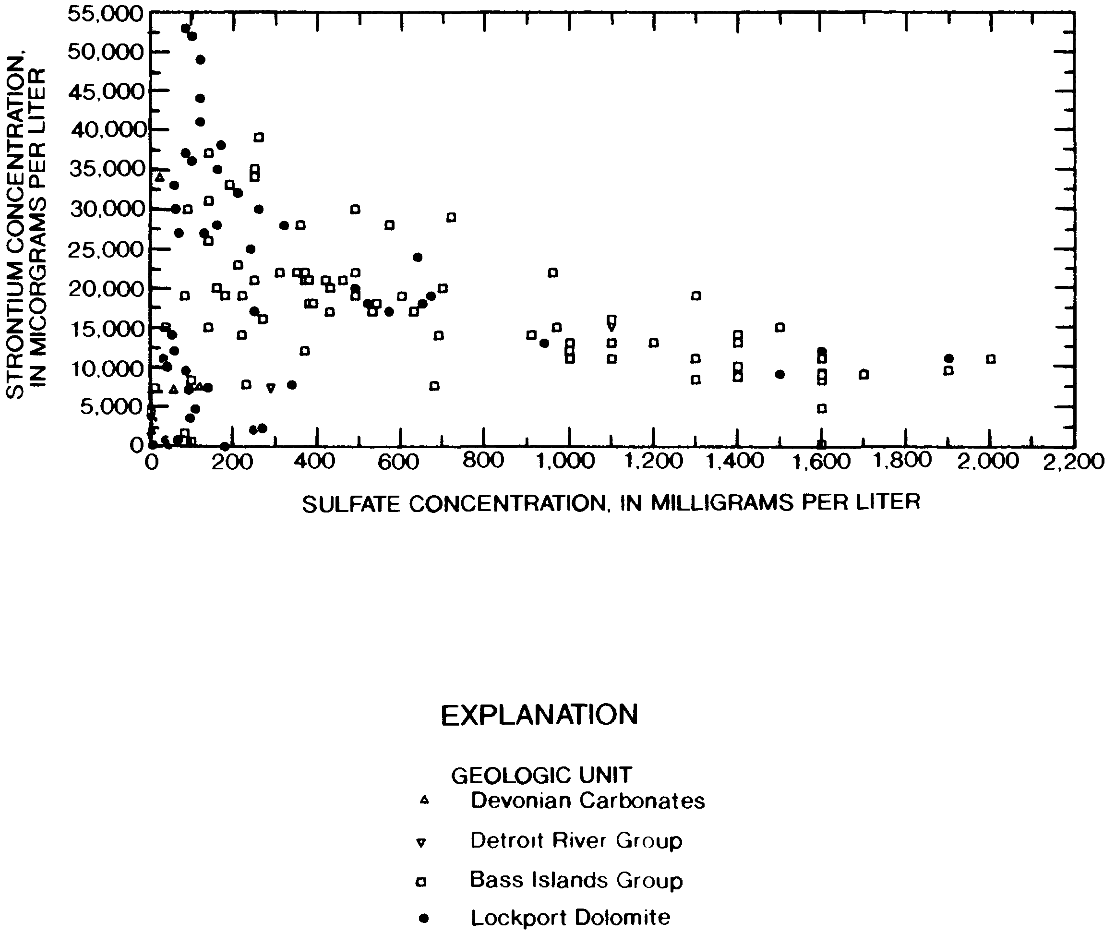


Figure 39.--Relation between strontium and sulfate concentrations in waters from the carbonate aquifer.

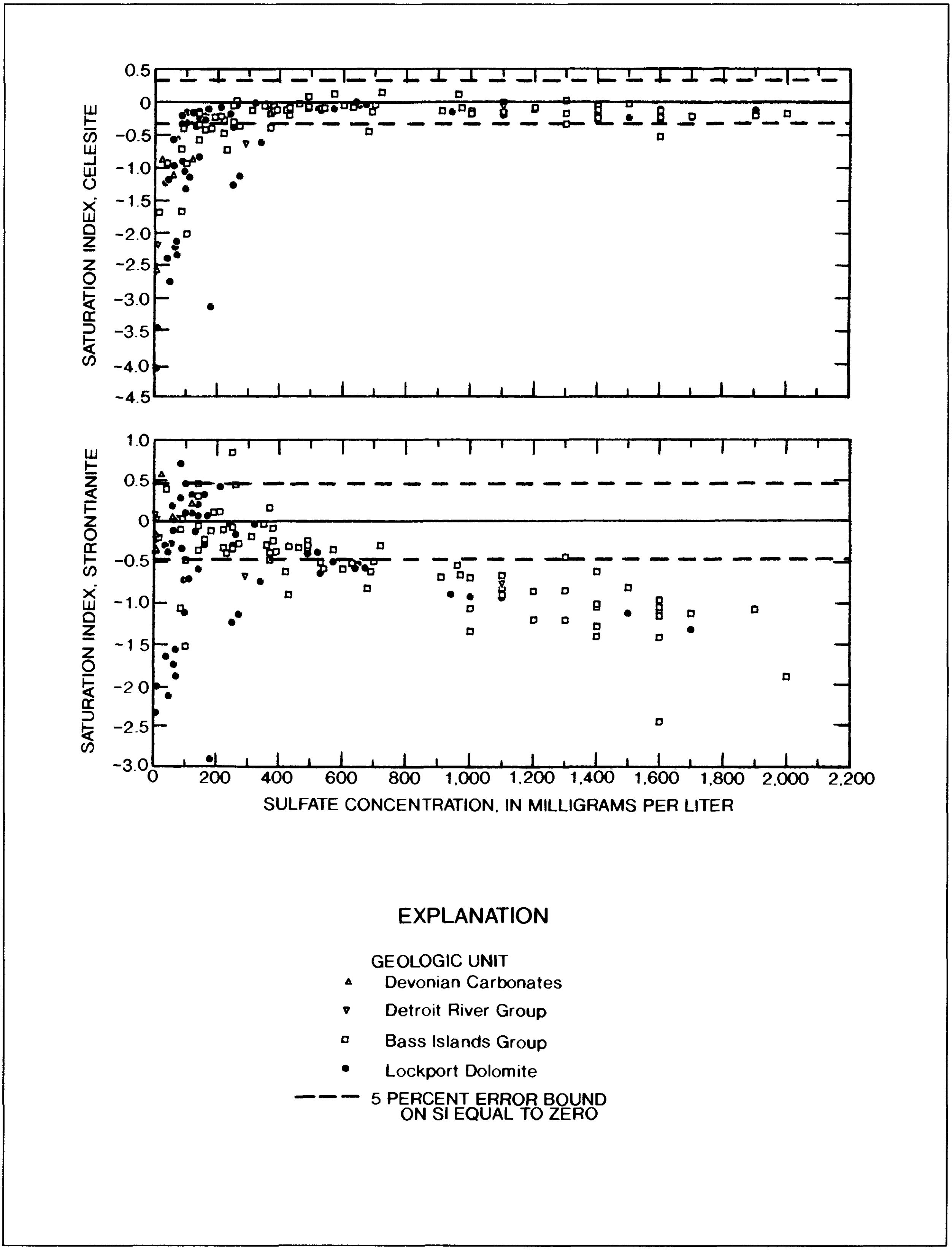


Figure 40.--Saturation indices for celestite and strontianite in waters from the carbonate aquifer.

Fluoride is a major ion in ground water; it is believed to originate from the mineral fluorite (CaF_2) in the carbonate rocks (Ohio Department of Natural Resources, 1970, p. 51). Possible geochemical controls on fluoride concentration are shown in figure 41. Two minerals that could affect fluoride concentration are fluorite and fluorapatite ($Ca_5(PO_4)F$)--a mineral that is present in some fossils but has not been described in literature on carbonate rocks of northwestern Ohio. The figure is constructed for a pH of 7 and a temperature of 12 °C, as described by Cravotta (1986, p. 155-159). The figure shows--

1. Maximum fluoride concentrations of about 2 mg/L are independent of calcium concentrations;

2. Many waters plot near the fluorite saturation line, but the slope of the line does not match the data; and

3. Small concentrations of fluoride correspond with the saturation line for fluorapatite only if the orthophosphate concentration is less than the 0.001-mg/L detection limit.

Oilfield and gasfield brines

The oilfields of northwestern Ohio (DeBrosse and Vohwinkle, 1974) were tapped by numerous wells during the late 1800's. As of 1989, most wells and production fields have been abandoned. The oil and gas wells that were active in 1989 also produced brine as a by-product.

Brines are waters containing extremely elevated concentrations of many dissolved constituents. The chemistry of brine from the oilfields of northwestern Ohio is poorly understood. Brines in eastern Ohio have been studied in detail (Stith, 1979; Breen and others, 1985). The brines in northwestern Ohio are part of the oil and gas reservoirs of the Trenton Limestone of Ordovician age. Analyses of brines from the Trenton Limestone in Allen County, Indiana (Keller, 1983, p. 27) and in Wood County, Ohio (Henry Township) (David A. Stith, Ohio Geological Survey, oral commun., 1989) contain a range of dissolved-solids concentrations of 33,400 to 84,300 mg/L (table 19, Supplemental Data section). The brines are sodium-calcium-chloride-type waters with chloride concentrations in the range of 19,000 to 52,400 mg/L. These elevated concentrations are of concern if the brine is not properly disposed of when brought to the land surface during oil and gas production.

To determine if brines from past or current oil and gas activities are affecting water quality in the carbonate aquifer, bromide-to-chloride (Br:Cl) ratios of ground waters and Trenton

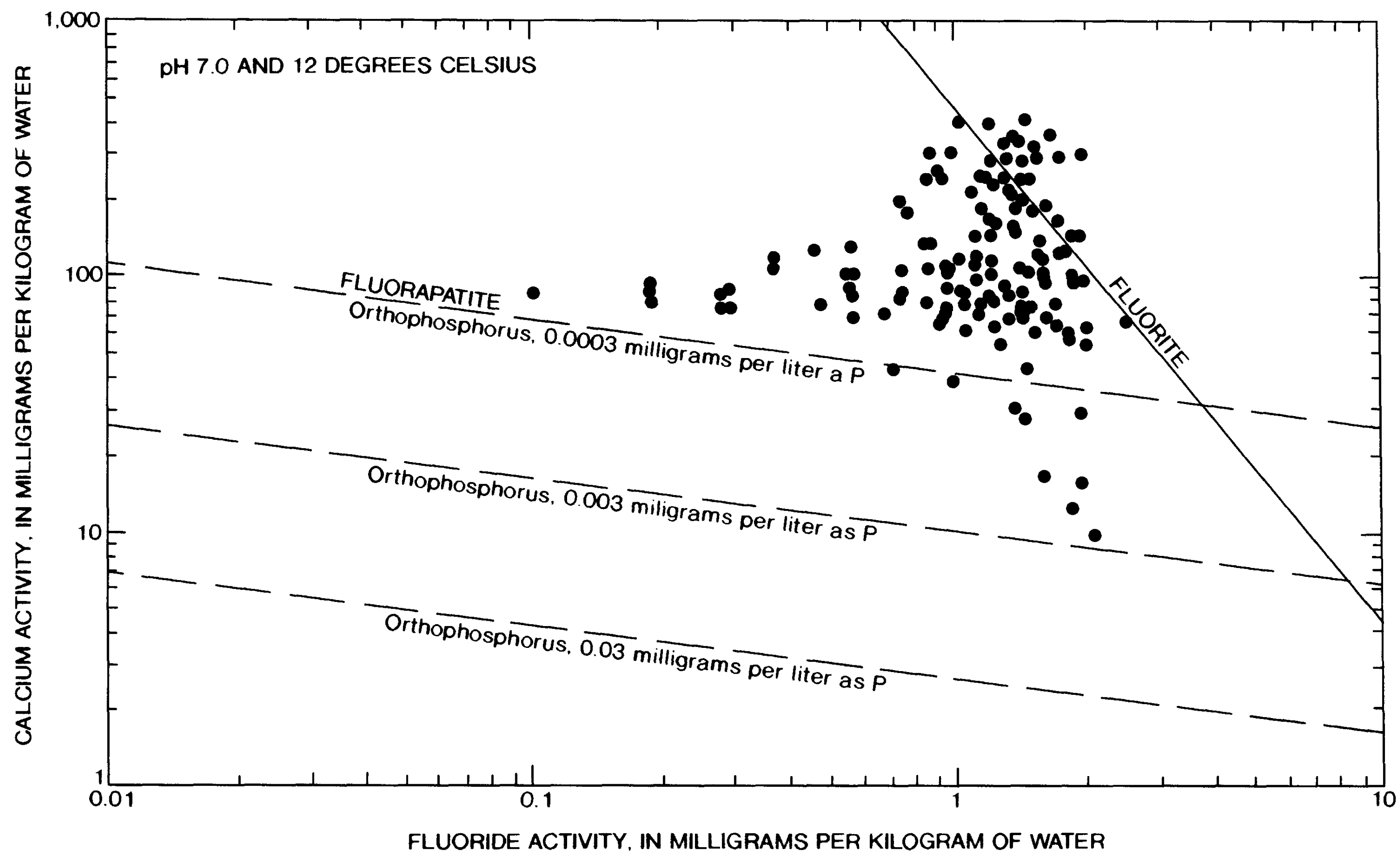


Figure 41.--Activities (from WATEQF) of calcium ion and fluoride ion in waters from the carbonate aquifer showing fluorite and fluorapatite stability relations

brines were compared (fig. 42). Brines from the Trenton Limestone are noted to have Br:Cl ratios x 10,000 between 20 and 60, whereas a saline water from the Salina Group has a ratio x 10,000 less than 1. These differences characterize and differentiate brines of oilfield origin from those derived from salt deposits such as those in the Salina. Small Br:Cl ratios also are indicated for brines formed from highway-deicing salts.

Ground-water samples generally had Br:Cl ratios x 10,000 near 100. Smaller ratios are apparent where evidence is strong that the aquifer is being recharged by recent precipitation or by infiltration of surface waters (including domestic wastewaters).

The two dashed lines in figure 42 represent hypothetical mixing lines for end-member freshwaters whose Br:Cl ratios x 10,000 are 100 and 500. For the upper line, freshwater (chloride concentration, 1 mg/L and bromide concentration 0.05 mg/L) is mixed with Trenton oilfield brine whose Br:Cl ratio x 10,000 is about 40 (chloride concentration, 30,000 mg/L, and bromide concentration, 130 mg/L). For the lower line, freshwater (chloride concentration, 1 mg/L, and bromide concentration, 0.01 mg/L) is mixed with a salt solution brine whose Br:Cl ratio x 10,000 is 1 (chloride concentration, 180,000 mg/L, and bromide concentration, 36 mg/L). The upper line closely matches the observed data.

Br:Cl ratios are generally consistent for most waters. A slight decrease in the ratios when chloride concentration increases results in values that follow the mixing line for the freshwater-Trenton oilfield brine and project to large chloride concentration near the Trenton composition. The measured values and the calculated values for the mixing line correspond and indicate the presence of a very dilute amount of oilfield brine in many of the waters in the aquifer; however, the chloride concentrations are less than the USEPA SMCL of 250 mg/L and do not represent an adverse water-quality condition.

The Br:Cl ratio technique appears useful for determining the plausible source of elevated chloride concentrations. For example, the elevated chloride concentration of 190 mg/L in water from well WO-351-B6 at Cygnet, Wood County, is noted on figure 42. The Br:Cl ratio for this water is 58. This ratio plots very near the oilfield-brine mixing line and indicates that the source of elevated chloride is oilfield brine. The volume of brine needed to elevate the chloride concentration would be only about 0.6 percent of the volume of the freshwater. The photograph of the Cygnet area (from Ohio Geological Survey files) in figure 43 illustrates the conditions that existed in the 1880's and provides evidence that an abandoned oil well or historic oil-producing activities may be contributing or may have contributed brine to the aquifer in this area.

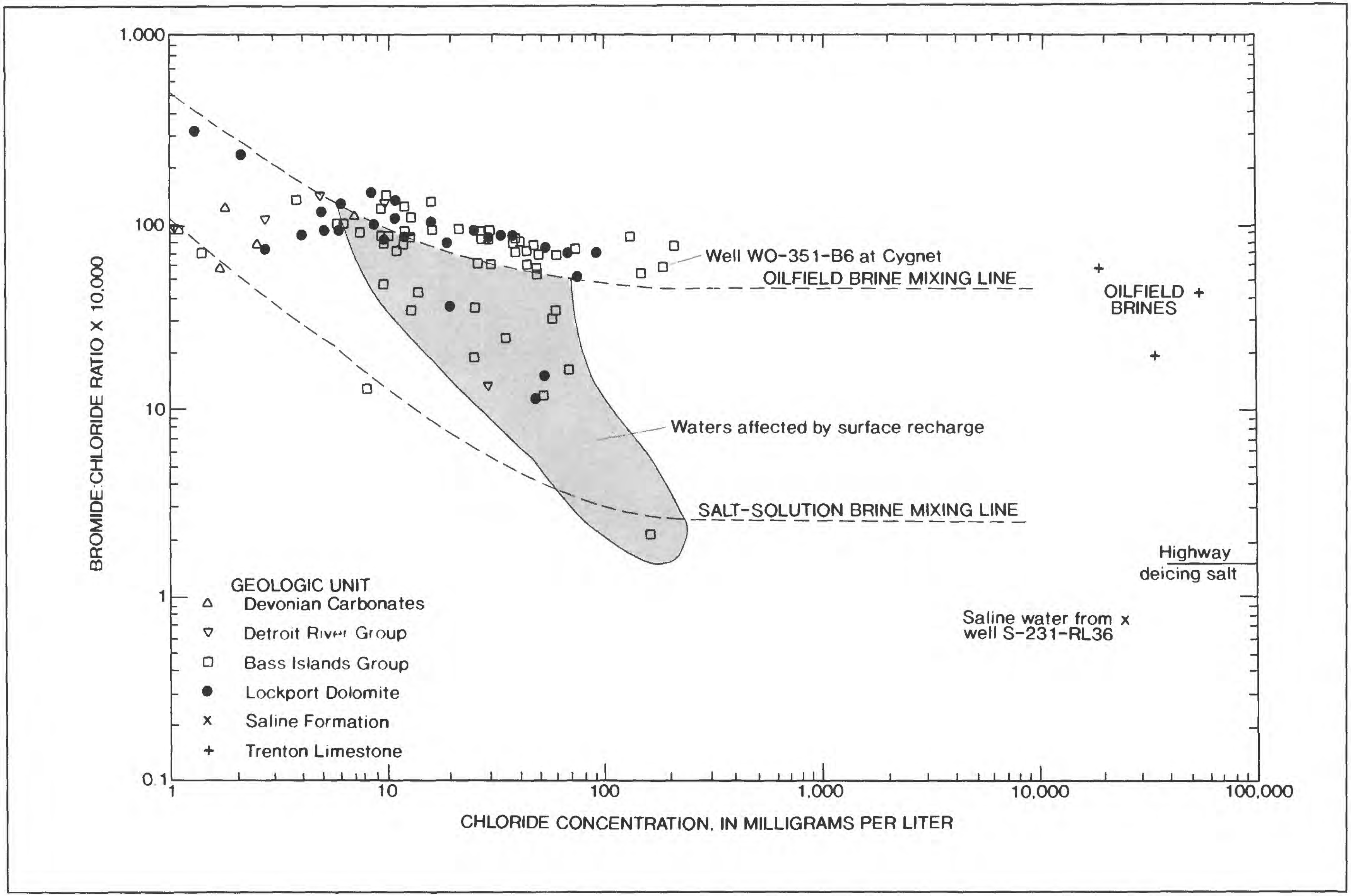


Figure 42.--Bromide:chloride ratios as a function of chloride concentrations in waters from the carbonate aquifer

Figure 43.--Photograph of the Cygnet area, Wood County, Ohio (about 1890), showing historic land-use activities (photo from Ohio Geological Survey file).

Shallow bedrock areas

Shallow bedrock is in areas where the thickness of drift overlying the bedrock (carbonate aquifer) is 20 ft or less. Some recharge to the aquifer occurs in localized areas of shallow bedrock. The concentrations of dissolved-organic carbon, and the chemistry of nitrogen and phosphorus in ground water from these areas indicates that shallow bedrock affects water quality.

Dissolved organic carbon.--Dissolved organic carbon (DOC) is common in ground water. The median concentration of DOC is 1.8 mg/L. Large concentrations of 3.5 mg/L or greater are in water from 16 of the 143 sample sites (table 13).

Of the samples with large DOC concentrations, 10 of the 16 are from wells in areas of shallow bedrock. The prevalance of large concentrations of DOC in shallow bedrock areas is illustrated in figure 44, where DOC concentration is plotted against the drift thickness at the sample site. The 1.0-mg/L reporting level is shown as a dashed line. Samples that plot below the 1.0-mg/L line have large dissolved-solids concentrations that are believed to interfere with the DOC analysis.

Three groupings of points are identified for the 18 samples that have DOC concentrations greater than about 3.5 mg/L. The first grouping represents shallow bedrock areas and the central oilfields. Many shallow bedrock areas coincide with oilfields in the central part of the study area. In these areas, specifically at Cygnet in central Wood County and at Risingsun and along Stein Road in eastern Wood County, oil has been reported in drilled wells in the carbonate aquifer. The largest DOC concentration of 9.7 mg/L, from well S-205-J8, is in a water with a distinct hydrocarbon odor.

A characteristic of waters from two wells in shallow bedrock areas (WO-253-PO18 and WO-198-T21) with large DOC concentrations is the pale yellow color of the water. The color is an indication that dissolved organic acids are present (Oliver and others, 1983, p. 2031).

The second grouping represents wells in western Lucas County. These waters are from wells with relatively thick drift cover (40-80 ft) compared with the shallow bedrock areas. The western Lucas County wells are all completed in or are open hole through Devonian limestones and dolomites and the Detroit River Group rocks. Shale lithologies and naturally soft waters are present in several of these wells, and the DOC concentrations could reflect a contribution from the shale that also affects major inorganic ion water chemistry in these areas.

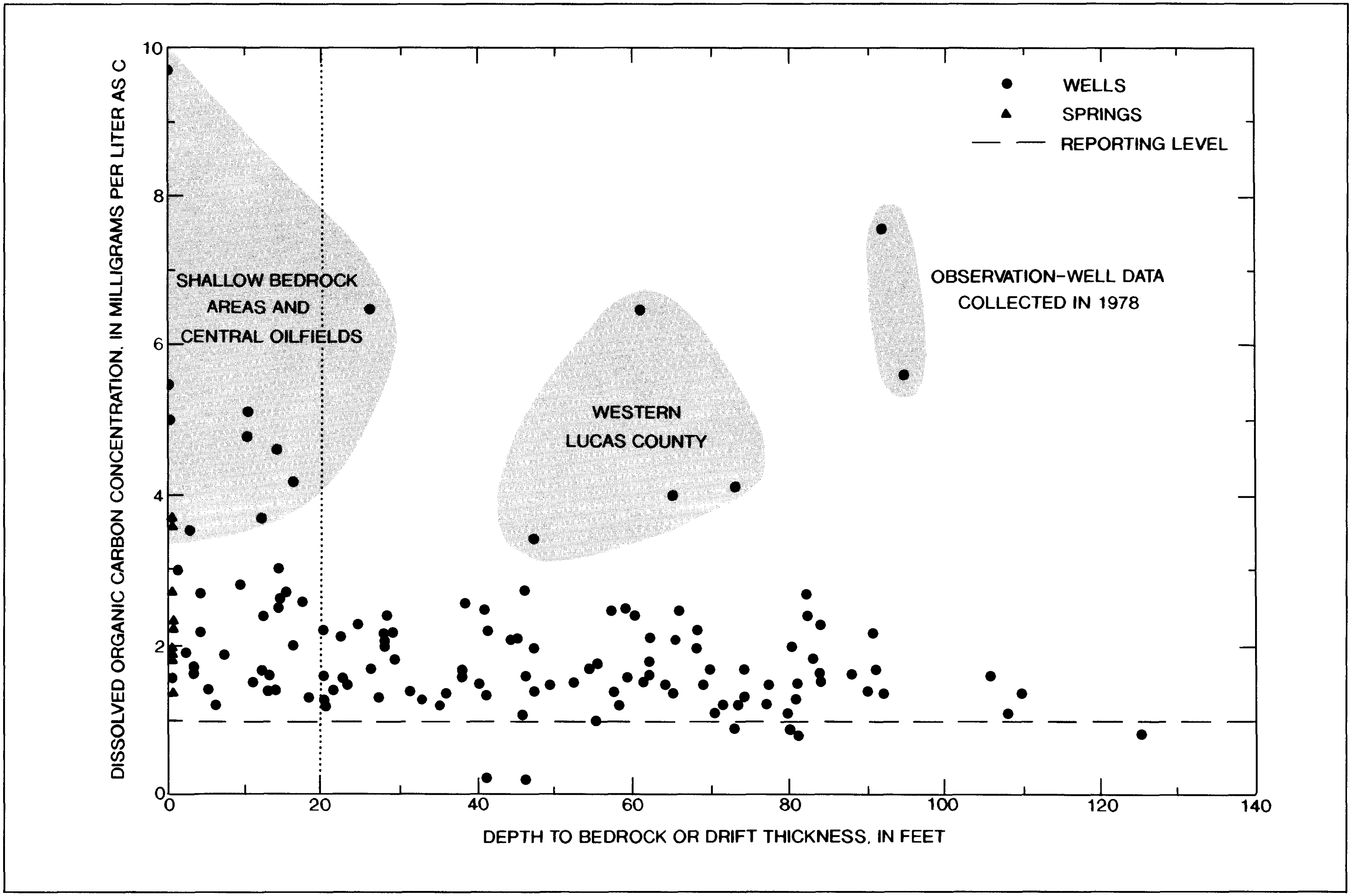


Figure 44.--Relation of dissolved organic carbon concentrations to the thickness of drift above the carbonate aquifer.

The third group consists of only two data points. These are samples collected in 1978 from State of Ohio observation wells (LU-1, S-3) where drift cover at the well sites is thick. The source of the elevated DOC concentration in these samples has not been identified.

The areal distribution of elevated DOC concentrations is shown in figure 45. The patterns of elevated DOC in the central oilfields and shallow bedrock areas and in western Lucas County are identified on this map.

Phosphorus and nitrogen.--The chemistry of phosphorus and nitrogen is affected by shallow bedrock conditions. Orthophosphate concentrations are detected at the 0.001-mg/L (as P) concentration in 75 of the 142 water samples analyzed (table 13). Less than 10 percent of the 142 water samples have concentrations greater than 0.01 mg/L. The largest concentrations of 7.9 mg/L and 1.4 mg/L were found in wells completed in the carbonate aquifer in areas where the aquifer is exposed at land surface (fig. 46A). Domestic sewage from septic-tank leachate is a plausible source of these elevated concentrations, which are present in water samples that previously were noted to have elevated DOC concentrations. Orthophosphate was present at small concentrations in well S-205-J8, indicating that the DOC found in that water probably is not from a domestic sewage source.

Dissolved total phosphorus was determined in a 56-sample subset of the 142 samples analyzed for orthophosphate. Only those concentrations equal to or greater than the 0.005-mg/L (as P) reporting level are plotted in figure 46B. Aside from the 10-mg/L concentration in well WO-198-T21, most concentrations plot near 0.01 mg/L.

No known source minerals for phosphorus are present in the carbonate rocks. Because of the lack of phosphorus-bearing minerals, and because the water in many parts of the aquifer system is pre-1952, it would be unusual to find large concentrations of phosphorus or orthophosphate.

Similarly, nitrogen compounds are unlikely to be derived from the carbonate rocks. Large concentrations of nitrogen compounds in ground water probably are derived from surface sources.

The oxygenated nitrogen species nitrite and nitrate were detected in 68 of the 142 water samples tested (table 13). Reduced nitrogen species and organic nitrogen are more commonly detected. Median concentrations (mg/L as N) for nitrite, nitrate plus nitrite, ammonia nitrogen, and dissolved total kjeldahl nitrogen (ammonia plus organic) are 0.002, 0.01, 0.3, and 0.7 mg/L as N, respectively.

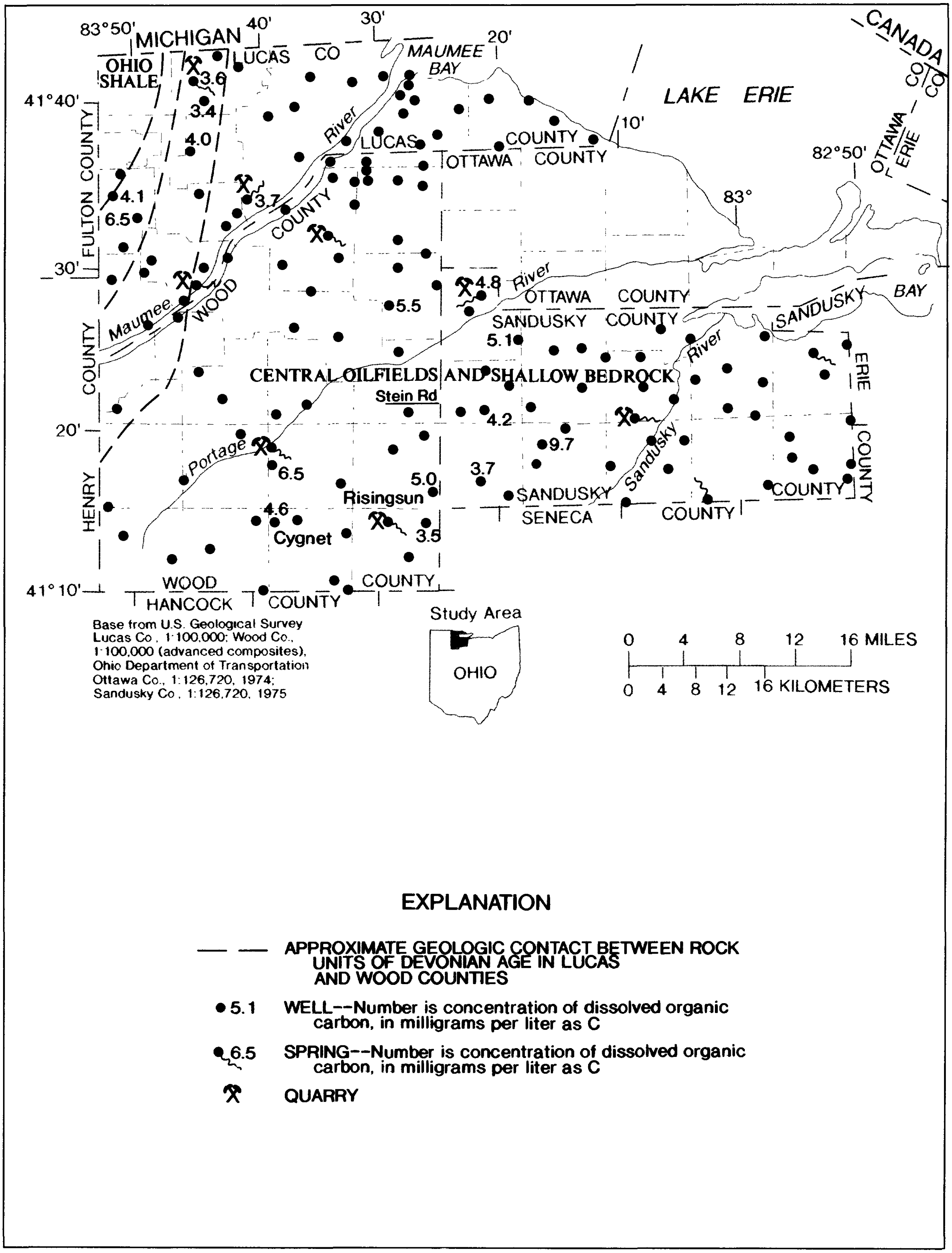


Figure 45.--Elevated dissolved organic carbon concentrations in Lucas, Sandusky, and Wood Counties, Ohio.

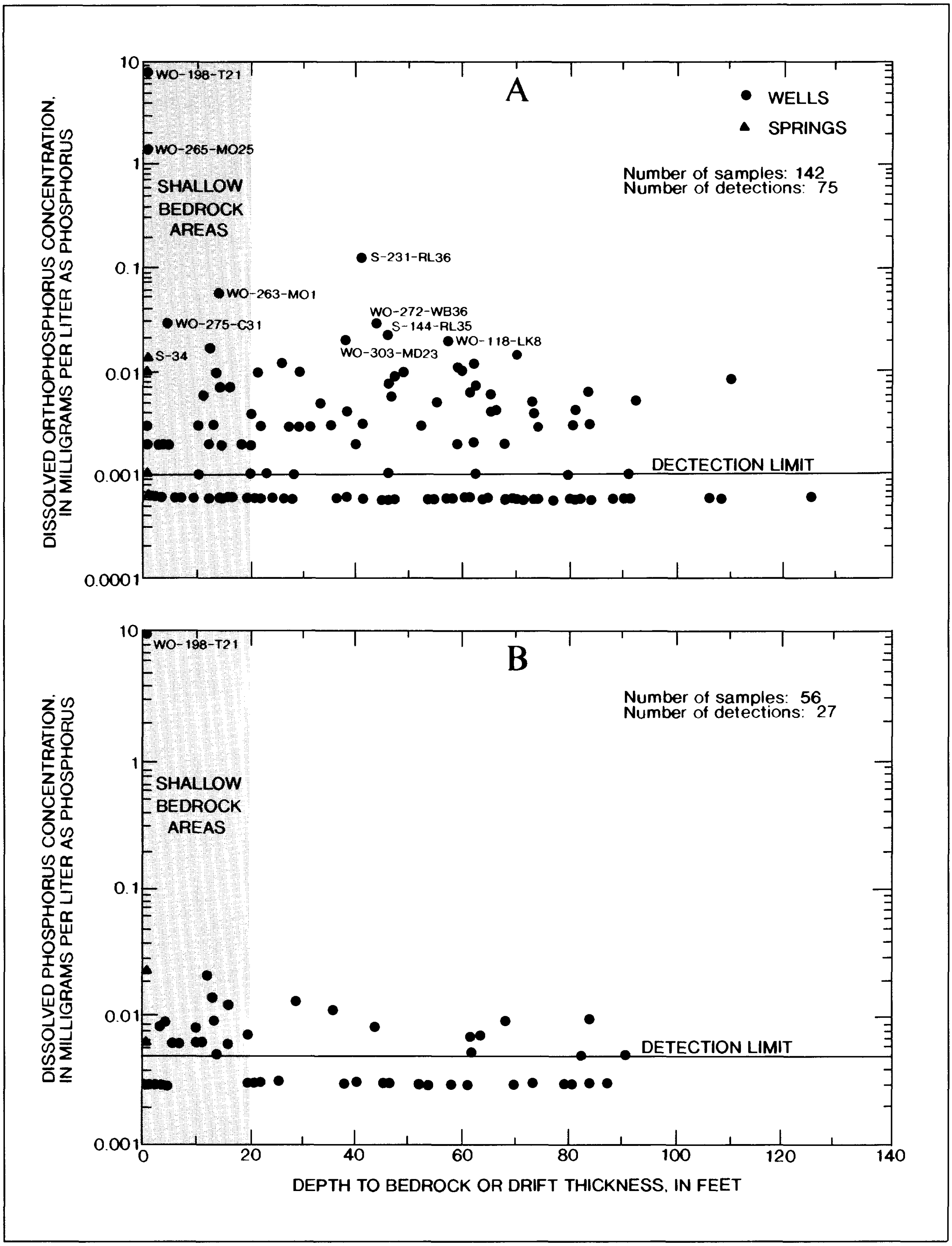


Figure 46.--Relations of phosphorus concentrations to the thickness of drift above the carbonate aquifer; (A) orthophosphorus and (B) dissolved total phosphorus

The type of nitrogen compounds in ground water is related to depth to bedrock. The concentrations of nitrogen compounds are plotted in figure 47 against drift thickness. Nitrate nitrogen is most prevalent in shallow bedrock areas (fig. 47A) and is at concentrations greater than 1 mg/L only in areas of shallow bedrock.

The concentration of ammonia nitrogen in ground water increases with increasing drift thickness. The smallest concentrations of ammonia are in shallow bedrock areas. As figure 47B shows, ammonia nitrogen has a median concentration of about 0.5 mg/L outside of areas of shallow bedrock.

The concentration of organic nitrogen also is related inversely to drift thickness (fig. 47C); thus, the concentration of organic nitrogen (as a difference) in shallow bedrock areas is seldom less than 0.1 mg/L. The difference is calculated by subtracting ammonia nitrogen from the concentration of ammonia plus organic nitrogen (dissolved total kjeldahl nitrogen). If the concentration of ammonia nitrogen is greater than that of ammonia plus organic nitrogen, a negative difference results, and the absolute value is indicated by a special data symbol in the figure.

The results (1) indicate that nitrogen chemistry is dominated by nitrate in shallow bedrock areas, and (2) support the conclusions of the Ohio Department of Health (ODH) (1982). The ODH found that nitrate concentrations of 5.2 to 16.8 mg/L as N in water from the carbonate aquifer in an area of shallow bedrock was affected by domestic sewage (Perry Township, southeastern Wood County).

The data for the carbonate aquifer indicate that domestic sewage commonly affects ground water in areas of shallow bedrock; however, because as much as 20 ft of drift covers bedrock, the concentration of nitrate, although elevated above background concentrations, was found to exceed or approach the 10-mg/L MCL only rarely in this regional investigation. Detailed study of areas of shallow bedrock would likely reveal the magnitude and the local extent of elevated concentrations of nitrate, phosphorus, and DOC concentrations in water from the carbonate aquifer.

Local Hydrochemical Conditions

The areal distribution of the concentrations of sulfate, chloride, and dissolved solids in ground water at the sampling sites in five mapping areas (fig. 16) are given on plates 7 to 11 (at back of report). Local variations in water quality are noted on the plates and are described in the following discussions, which refer extensively to the plates.

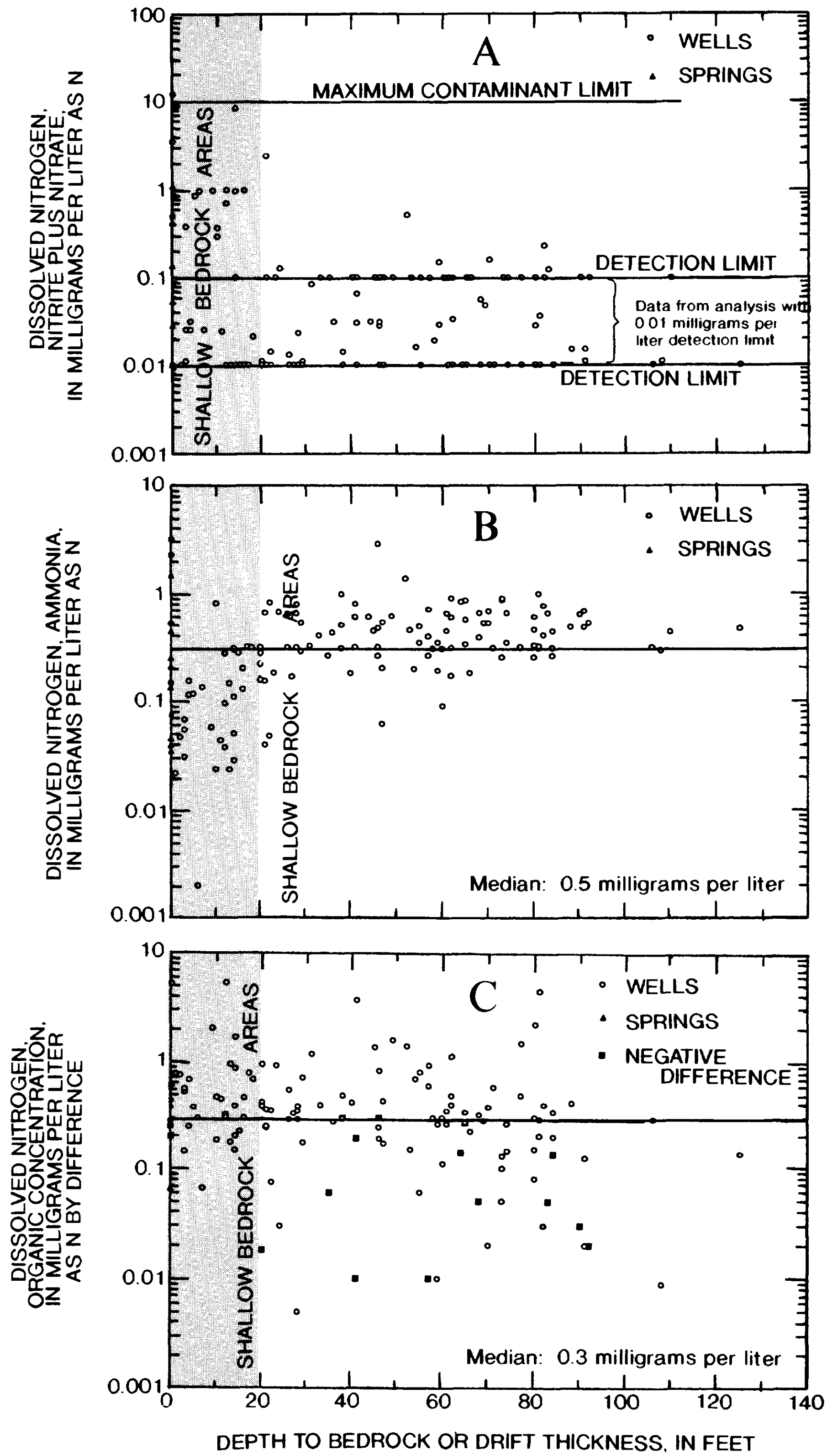


Figure 47.--Relation of concentrations of nitrogen compounds in ground water to the thickness of drift above the carbonate aquifer; (A) nitrite plus nitrate, (B) ammonia, and (C) organic nitrogen.

Eastern Sandusky County

The variable geology of eastern Sandusky County is reflected by the variable water quality in the carbonate aquifer (pl. 7). Areas where concentration of dissolved-solids and sulfate in water from the Lockport Dolomite are small are shown on the westernmost part of plate 7. To the east, an area of transitional water quality characterized by increased concentrations of dissolved solids and sulfate forms an approximately 2-mi-wide north-trending band through Fremont. In this area, water is produced from wells that are completed in Upper Silurian dolomites and the Lockport Dolomite.

The central part of eastern Sandusky County is an area where elevated concentrations of sulfate in wells and springs are derived from gypsum and anhydrite in the rocks. In the north-central part, utility of water is especially limited because the water is locally saline and is a sodium chloride type. The areal extent of the waters with large sodium and chloride concentrations is indicated on plate 7. It is not known whether the sodium and chloride originate from the dissolution of salt in the evaporite-bearing strata of this area or if they originate from some other source. The association of salt with gypsum in the evaporites of Silurian age of eastern Ohio (Ulteig, 1964) has not been described in literature on evaporite-bearing strata of Sandusky County.

The most elevated chloride concentration, 37,000 mg/L, is in water from well S-231-RL36 at the Tippit Marsh along Sandusky Bay. Water flows from the well at a rate of about 5 gal/min. The water is effervescent and releases hydrogen sulfide and probably other gases at the wellhead. The complete chemical analysis of this saline water is listed in table 9. The water has a density of 1.050 g/mL (grams per milliliter) and elevated alpha-particle and beta-particle radioactivity. The Br:Cl ratio technique discussed previously (see fig. 42) was used to determine the source of the chloride-rich water. The Br:Cl ratio is less than 1 for this water; thus, the source of the large concentration of chloride is dissolution of salt (NaCl).

A synoptic survey (sites are shown as triangle symbols on pl. 7) of the specific conductance of selected surface waters that drain into Sandusky Bay showed that surface waters have specific conductances similar to those of ground water. Streamflow is comprised, in part, by ground water that has discharged at the land surface from flowing wells and springs.

The southeastern part of Sandusky County is characterized as an area of transitional water quality. The gypsiferous rocks of Silurian age are overlain by karstified limestones of Devonian age. The karstic nature of the flow system, and the fact that some wells are completed in more than one geologic unit, are responsible for the highly variable quality of water locally.

Waters with small sulfate concentrations (less than 100 mg/L) can be found in several locations. Extreme variability is present at Bellevue, where sulfate concentrations of 100 to 1,100 mg/L were detected in water from nearby wells[3] completed to the same depth and altitude in the aquifer.

Hydrogen sulfide is present at objectionable concentrations (concentrations of about 2 mg/L or greater) in a north-south-trending area in the central part of eastern Sandusky County. Hydrogen sulfide is associated with wells completed in carbonate rocks containing gypsum and anhydrite. This association could indicate that sulfate from gypsum and anhydrite is being reduced to form hydrogen sulfide.

Western Sandusky County

Most ground water is withdrawn from the Lockport Dolomite in this area. As a result, water quality is consistent throughout most of western Sandusky County (pl. 8). Sulfate and dissolved-solids concentrations are small compared with those in eastern Sandusky County. Concentrations of sulfate and dissolved solids are slightly elevated only in a local area around Woodville.

Water quality is affected by the large areas of shallow bedrock (pl. 3). Drilling activity for oil was extensive in western Sandusky County during the late 1800's. The numerous oil wells tap the Gibsonburg oil pool (Debrosse and Vohwinkle, 1974).

Chloride concentrations are generally less than 25 mg/L; chloride concentrations are elevated locally, however. Bromide-concentration data for Sandusky County are lacking, and the Br:Cl ratio technique, discussed previously, can not be used to determine sources of salts.

As an example of how the ratio technique might be used to help identify the source of chloride, Br:Cl ratios in well waters at Risingsun (WO-265-MO25) and Bradner (WO-263-MO1) in Wood County were determined in an attempt to explain the slightly elevated chloride concentrations of about 50 mg/L. The Br:Cl ratios are 11 and 15 for Risingsun and Bradner, respectively. These ratios indicate that the source of chlorides is, in part, from salt. This source is believed to be septic-tank leachate because (1) these wells are in areas of shallow bedrock, and (2) the waters contain elevated concentrations of other indicators of septic-tank leachate, such as elevated concentrations of nitrate and dissolved organic carbon.

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[3] Wells S-130-Y13 and S-129-Y25, which are 1.5 mi apart.

The numbered symbols on plate 8 in Woodville Township represent the sites used by Sypniewski (1982) in an areally detailed water-chemistry study that included some trace-element analyses. The numbers can be cross referenced to analysis numbers from Sypniewski (1982, Appendixes A and B) that are provided in table 16. These data, which represent some of the most dense coverage available on general water quality in northwestern Ohio, are useful for describing chemical variability on a local scale.

Radiochemical quality of water is an issue in western Sandusky County. Selected wells in the Woodville-Gibsonburg area have waters with elevated potassium concentrations. Potassium concentrations greater than 40 mg/L (see tables 9 and 16, Supplemental Data section) were found in water at three locations. An association between potassium occurrence and beta-particle radioactivity is suspected but remains unverified.

Southern Wood County

In contrast to western Sandusky County, southern Wood County (pl. 9) has carbonate rocks representing most of the entire Silurian and Devonian stratigraphic sequence. Considerable variability in water quality occurs because wells are completed in several geologic units.

In the eastern half of the area, ground water has the small sulfate concentrations and small dissolved-solids concentrations characteristic of the Lockport Dolomite; however, younger carbonate rocks of the Greenfield Dolomite introduce calcium and sulfate into well waters. The sulfate concentration contributes to elevated dissolved-solids concentrations locally.

In the central part of the area, the elevated sulfate and dissolved-solids concentrations are present except where the aquifer is overlain by thin unconsolidated deposits and is being recharged (as noted for the vicinity of Bowling Green).

In the central and western parts of the area, variable recharge conditions and complex geology contribute to water quality that is extremely variable on a local scale. The Bowling Green fault zone (pl. 4) is a major factor contributing to the complex geology.

The ground waters in wells completed west of the fault zone generally have a larger proportion of sodium ions compared with waters east of the fault zone. Sodium is the dominant cation in waters from western Jackson Township. This area of sodium-calcium-sulfate-type waters is indicated on plate 9.

A common characteristic of all the wells with sodium-dominated water is that most water is pumped from the Raisin River Dolomite (Ohio Department of Natural Resources, 1970). The dominance of sodium in waters with small chloride concentrations indicates that the waters have been naturally softened to some extent. Natural softening occurs when calcium and magnesium ions are exchanged for sodium ions as the waters interact with the host rocks. Commonly, a shale or argillaceous (clay-rich) stratum is involved, and the Raisin River Dolomite is argillaceous. The softening has only minor effects on total hardness because calcium from gypsum still contributes noncarbonate hardness; therefore, the resulting water can still be very hard.

Oilfields and gasfields are widespread throughout the central and southeastern parts of the area. The status of many oil and gas wells is uncertain, and some have been buried by agricultural row cropping in former production fields. Documented reports of hydrocarbons in water from wells are more numerous for southern Wood County than for other parts of the study area. Areas where hydrocarbons are found in water from wells are shown on plate 9.

Hydrogen sulfide is in well water throughout a large part of southern Wood County. Reports of black sulfur (drillers' term) are prevalent in many wells. The analyses of hydrogen sulfide in water samples (table 9) were combined with observations in drilling reports and from well inventories for this study to delineate boundaries of the area where potentially objectionable hydrogen sulfide concentrations generally are found (pl. 9). Reports of objectionable hydrogen sulfide concentrations are less prevalent only in the eastern and southwestern parts of southern Wood County.

Extreme problems with corrosion of household fixtures, plumbing, and electronic equipment are caused by hydrogen sulfide in water from individual domestic-supply wells at Bairdstown (Eagon, 1983b). Consequently, water for Bairdstown is supplied by pipeline from the Bloomdale well field.

A definite source of the hydrogen sulfide is unknown; however, plausible sources are (1) bacterial reduction of sulfate in ground water to form hydrogen sulfide, (2) reaction of mineral deposits with ground water to produce hydrogen sulfide, and (3) migration of hydrogen sulfide gases from oil- and natural gas-producing strata into wells and water systems.

Northern Wood County and Southern Lucas County

In northern Wood County (pl. 10), the Lockport Dolomite, the Bass Islands Group, and the Detroit River Group strata yield water of variable quality. In Lucas County, only the deepest (250 to 500 ft) wells in Toledo penetrate the Lockport.

The Bass Islands Group yields waters to most wells east of the Lucas County monocline (pl. 5). West of the monocline, most of the wells are completed in strata of Middle Devonian age.

On plate 10, a boundary has been drawn in the eastern part of northern Wood County to separate waters in the Lockport Dolomite containing small sulfate concentrations and small dissolved-solids concentrations from waters containing elevated sulfate and dissolved-solids concentrations in the Bass Islands Group dolomites to the west and north. The boundary is irregular because of the complexity of the geology and the variability of the mineralogic composition of the carbonate rocks.

The area of large sulfate and dissolved-solids concentrations extends westward into Lucas County, and sulfate concentrations greater than 1,000 mg/L are common. The area is bounded on the west by the Lucas County monocline (fig. 2). Sulfate concentrations greater than 1,000 mg/L also characterize the water in wells near the Maumee River at Waterville and upstream from Waterville. Kahle and Floyd (1972, p. 2076) describe the bedrock that crops out in the Maumee River channel as Tymochtee Dolomite. This formation contains gypsum and celestite that can contribute to the large sulfate concentrations in ground water.

The shallow bedrock areas at Bowling Green contribute small sulfate and dissolved-solids concentrations in an area in which large sulfate and dissolved-solids concentrations would be expected on the basis of geologic considerations. The shallow bedrock that occurs beneath a thin veneer of sand at Dowling is another area of relatively dilute water in the carbonate aquifer.

West of the Lucas County monocline, an abrupt change to waters with small concentrations of sulfate is apparent, and sodium bicarbonate becomes the dominant water type in wells tapping Middle Devonian rocks and in wells near the subcrop boundary of the Ohio Shale. Concentrations of hardness in ground water in these areas of northern Providence, Swanton, northern Monclova, and Spencer Townships are satisfactory for domestic use.

The western half of northern Wood County is an area where objectionable concentrations of hydrogen sulfide (greater than 2 mg/L) are commonly found in ground-water supplies. This area, where ground water contains hydrogen sulfide, extends northward into Lucas County through the Waterville and Maumee areas and into the western suburbs of Toledo. Hydrogen sulfide is not prevalent in west-central Lucas County, but it is in water from wells completed through the Ohio Shale in westernmost Lucas County.

Depth of a well also can affect sulfide concentration. A geologist's report for test well LU-10, northwest of Whitehouse (pl. 5), indicates that water-bearing zones at 75 to 80 ft and

110 to 115 ft yielded about 40 gal/min of water free of hydrogen sulfide. At 130 ft, however, hydrogen sulfide was present with a well yield of 125 gal/min.

Chloride concentrations are generally less than 20 mg/L in northern Wood and southern Lucas Counties. The smallest concentrations (less than 10 mg/L) are common in the sodium bicarbonate waters of western Lucas County and in waters from the Lockport Dolomite in eastern Wood County. Chloride concentration ranges from 30 to 210 mg/L in the area east of and adjacent to the Lucas County monocline and near Waterville. Another area of elevated chloride concentrations is at Pemberville in eastern Wood County. Chloride concentrations are quite variable near the Pemberville wellfield.

Northern Lucas County

Water quality in northern Lucas County (pl. 11) is affected primarily by (1) the gypsiferous strata of the Bass Islands Group that yield highly mineralized waters, and (2) the shallow bedrock area in the western part of the area where younger carbonate rocks associated with the Lucas County monocline yield waters that are less mineralized than waters to the east of the monocline.

General water quality is affected by the northernmost subcrops of the Lockport Dolomite near the Lucas-Ottawa County line in Jerusalem Township. Water in wells in this area is similar to that described for northwestern Sandusky County, where the Lockport Dolomite yields water with sulfate concentrations of about 250 mg/L. Sulfate concentrations ranging from 500 to 1,000 mg/L are characteristic of the rest of Lucas County east of the Maumee River. Increased sulfate and dissolved-solids concentrations are related to the effect of rocks of the Bass Islands Group.

The dilute water of Lake Erie, which has a dissolved-solids concentration of about 130 mg/L, appears to have little effect on water quality in wells adjacent to the lake. If lake water is entering the carbonate aquifer, it becomes mineralized even in shallow (100-ft-deep) wells.

The isolated presence of small sulfate concentrations in ground water at wells LU-169-05 (adjacent to Interstate 280 in Oregon), WO-313-R along the Maumee River at Rossford, and LU-1 at Toledo (2.5 mi west of WO-313-R), are the result of contributions of sulfate-bearing waters to wells completed in multiple geologic units. These wells are 250 to 550 ft deep and produce water from both the Lockport and Bass Islands Group dolomites. The resulting water quality reflects the water quality of both sequences of strata; the water is a mixture of water with a sulfate concentration of about 100 mg/L from the Lockport Dolomite and a water with a sulfate concentration of 500 to 1,000 mg/L or greater from the Bass Islands Group. In the early 1900's, attempts were made to case off the poor-quality sulfate-rich water in the Bass Islands Group at the old Perrysburg well-field (Ohio Water Supply Board, 1945, p. 63) to obtain only the fresh water from the Lockport Dolomite. Similar casing strategies have not been used in wells drilled since that time.

An area of extremely large sulfate concentrations that commonly equal or exceed 1,400 mg/L is in the northern part of Oregon and the northern and western parts of Toledo. Rocks of the Bass Islands Group contain gypsum and anhydrite minerals that contribute the sulfate in ground water. The elevated sulfate concentrations and the presence of hydrogen sulfide limit the use of ground water in these areas.

In the westernmost parts of northern Lucas County, sulfate concentrations are less than the extreme concentrations near Toledo and Oregon because water is produced from younger carbonate strata above the Bass Islands Group. Near the Lucas County monocline (fig. 2), sulfate concentrations are much smaller in water from wells drilled to depths of 100 ft or less. The naturally soft sodium-bicarbonate water described for southern Lucas County is not widespread in this area; however, shale strata can contribute water of mixed sodium and calcium bicarbonate character that results in smaller hardness concentrations at selected wells (LU-105-SY14, for example).

Chloride concentrations are highly variable. Concentrations of less than 10 mg/L are common in the western areas between Sylvania and Holland and also in the southern part of Jerusalem Township. Water in wells completed in the Bass Islands Group commonly contains 20 to 60 mg/L of chloride. A concentration of 130 mg/L was determined in water from a well located in Oregon (LU-202-011).

Hydrogen sulfide is present at objectionable concentrations and is a problem in much of the area. A general boundary for the presence of hydrogen sulfide is shown on plate 11. The only areas where the odor of hydrogen sulfide and corrosiveness of waters are not generally objectionable are in parts of Oregon, in Jerusalem Township, and in a small area west of Holland.

Drilling records from a well completed in the sand and gravel of the southwest-northeast-trending bedrock valley (LU-109-T) indicate that the odor of hydrogen sulfide is not objectionable in water from the sand and gravel deposits. The sand and gravel, thus, provide an alternative source of ground water locally; however, the data are sparse on the availability of water and variability of water quality in these sand and gravel deposits.

SUMMARY

A regional ground-water investigation of two aquifers was made in 1985-88 by the USGS, in cooperation with county and municipal agencies in Lucas, Sandusky, and Wood Counties. The carbonate aquifer in Silurian and Devonian rocks is the primary source of rural domestic and irrigation water supplies. Ten villages, with about 12,700 inhabitants, obtain water for public supply from the carbonate aquifer. The surficial sand aquifer in western Lucas County is a source of drinking water in rural areas and is widely used as a source of water for lawns and gardens.

The unconfined surficial sand aquifer in western Lucas County extends from near Sylvania on the Ohio-Michigan border southwestward to Swanton and Providence Townships. Clay-rich drift, which restricts vertical movement of water, underlies the aquifer. The aquifer is recharged by precipitation; there are no natural impermeable barriers between the land surface and the water table. Water levels are generally 2 to 8 ft below land surface and fluctuate a total of about 3.5 ft seasonally in a forested area of Swanton Township. Discharge is by evapotranspiration and by flow to local streams and ditches. Aesthetic factors limit use of ground water from the aquifer in areas where iron concentrations greater than 0.5 mg/L and manganese concentrations greater than 0.2 mg/L cause staining and are associated with red-brown to yellow coloration of water from dissolved organic matter. Concentrations of dissolved organic carbon are greater than 8 mg/L in these organic-rich waters.

Surficial aquifer water from shallow drive-point wells in residential areas has median concentrations of dissolved solids and hardness that are about four times larger than in water from identical wells in undeveloped areas. Median concentrations of sodium and chloride are 15 and 50 times larger, respectively, in residential areas compared to undeveloped areas. In three of five samples from residential areas, concentrations of chloride and sodium indicated a salt source not present in undeveloped areas. The presence of nitrate nitrogen in residential areas, combined with the observed differences in constituent concentrations between residential and undeveloped areas, indicate that the surficial sand aquifer is affected by local development.

In the carbonate aquifer, fractures, bedding-plane joints, and other secondary openings are the principal water-bearing zones. These zones can be areally and stratigraphically separated by relatively unproductive rock. Leaky artesian or semiconfined conditions predominate beneath most of the 1,400-mi^2 study area. The aquifer is confined by relatively impermeable underlying shale of Silurian age and overlying clay-rich drift of Quaternary age. Unproductive strata, including evaporites, within the sequence of carbonate rocks also confine some water-bearing zones. Unconfined or water-table conditions

may prevail in shallow bedrock areas where the drift is less than 20 ft thick.

The carbonate aquifer is part of a regional ground-water-flow system; however, subsystems in Sandusky County include an eastern karstic area, a central buried valley, and outcrops and shallow bedrock in the central and western parts of the county. Shallow bedrock extends into eastern and central Wood County and also characterizes some parts of western Lucas County. The subsystems have water-bearing zones with transmissive properties and water-quality characteristics that are highly variable. Thus, a complex framework of water-bearing zones is indicated, but is not yet fully understood.

On the basis of the potentiometric surface, recharge areas are south and west of the study area; ground water flows toward discharge areas along major rivers (Maumee, Portage, and Sandusky), to a buried bedrock valley in central Sandusky County, and to springs and flowing wells. The potentiometric surface flattens markedly near the southern shore of Lake Erie, where ground-water levels approximate those of the lake, indicating a hydraulic connection between the lake and the aquifer. Geohydrologic characteristics and water-quality data indicate that Lake Erie is not a major source of recharge to the aquifer. Ground-water ages inferred from tritium concentrations and potentiometric maps indicate that recharge from precipitation enters the aquifer by subsurface drainage in karstified strata in eastern Sandusky County and by infiltration in shallow bedrock areas.

Water-level fluctuations are caused by the response of the confined aquifer to changes in atmospheric pressure and to seasonal patterns of recharge and discharge. Total fluctuations for a water year are about 5 to 10 ft, except where pumping causes greater changes of water levels. Total fluctuations for a water year of 10 to 40 ft in the karst of southeastern Sandusky County are an indication that the aquifer responds differently to recharge and discharge.

The quality of water in the carbonate aquifer is described with reference to 52 water-quality properties and constituents that characterize the chemical, radiochemical, bacteriologic, and physical conditions. Ground-water samples from 135 wells and 11 springs are used in the characterization. On the basis of these data, water from the aquifer is generally suitable for drinking and most domestic purposes. The most areally widespread aesthetic factors limiting the use of ground water are hardness; concentrations of dissolved solids, sulfate, and iron; and the presence of hydrogen sulfide.

Bacterial occurrences are widespread areally. Fecal streptococci bacteria, an indicator of fecal contamination, were detected in 39 percent, or 56 of the 143 total wells and spring waters tested. Of the wells maintained for potable supplies, 38 percent, or 48 of the 125 samples tested contained fecal streptococci. Analyses for total coliform bacteria indicate that 33 percent, or 47 of the 143 total wells and spring waters tested and 29 percent, or 36 of the 125 samples of water from wells maintained for potable supply have bacteria counts of 4 or more colonies per 100 mL; counts that are considered bacteriologically unsafe. Fecal coliform bacteria are less prevalent than total coliform or fecal streptococci bacteria and are reported for 23 of the 143 samples. In wells maintained for potable supply, 15 of the 125 waters contained fecal coliform bacteria.

Concentrations of alpha- and beta-particle radioactivity equaled or exceeded 5 pCi/L in about 25 percent of the 82 samples. Alpha-particle radioactivity and beta-particle radioactivity greater than 5 pCi/L exist independently of one another in some areas, and, in other areas, concentrations of both constituents are elevated. Radioactivity in ground water is widespread geographically. Specific radionuclides responsible for the radioactivity have not been identified. The largest concentrations of beta-particle radioactivity are in waters with large potassium concentrations; therefore, potassium-40 could be a source of some beta-particle radioactivity.

The trace elements selenium, silver, lead, antimony, cadmium, and copper were rarely detected in the samples analyzed. Concentrations detected are generally less than 5 µg/L and never exceed the SMCL's or MCL's for these elements. Arsenic, chromium, lithium, mercury, barium, nickel, aluminum, and zinc were commonly detected in the samples analyzed. Concentrations of 10 µg/L or greater are commonly reported for zinc, lithium, and barium. Few aluminum and nickel concentrations exceed 10 µg/L. Few arsenic and mercury concentrations exceed 2 µg/L. Chromium concentrations greater than 50 µg/L were detected in 3 of 54 wells sampled.

Volatile-organic compounds in concentrations greater than 3 µg/L were detected in only 1 of 45 wells sampled. Cyanide in concentrations greater than 10 µg/L was not detected in any of the 48 wells sampled.

Ground water is generally suitable for irrigation; however, boron concentrations greater than 750 µg/L were present in 9 of the 98 waters tested.

Variations in water quality are related to the geochemical makeup of the aquifer matrix, the thickness of drift overlying the aquifer, and past and current uses of land in areas of shallow bedrock. The presence or absence of calcium sulfate minerals in the rock causes a bimodal distribution of concentrations of dissolved solids, hardness, and sulfate in waters from the Bass Islands Group. Dissolution of calcium sulfate minerals contributes to excessive concentrations of sulfate of up to 2,000 mg/L. Some sulfate-rich waters contain excessive concentrations of hydrogen sulfide.

Waters derived solely from the Lockport Dolomite are relatively dilute and are a calcium-magnesium-bicarbonate type. Strontium concentrations as large as 50 mg/L characterize sulfate-poor waters and are the result of dissolution of strontium-bearing minerals in the aquifer matrix. Shale mineralogies naturally soften water and incease sodium concentrations, most notably in western Lucas County.

Br:Cl ratios were useful in tracing the source of large chloride concentrations. Sources were the dissolution of salt in evaporite-bearing strata and brine produced by oil and gas development.

Ground water in shallow bedrock areas is most likely to indicate effects of past and current uses of the land. Concentrations of nitrogen, phosphorus, chloride, and dissolved-organic carbon generally are greater than background concentrations only in areas of shallow bedrock.

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S U P P L E M E N T A L   D A T A

FIGURE 26 BELONGS HERE

TABLES 3, 4, 9, 15, 16, AND 19 BELONG HERE.

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties

EXPLANATION OF COLUMN HEADINGS

All columns — A double dash indicates no information was obtained; ft, feet.

Number in plate 1 — Local well number shown on index map. County prefix is omitted in plate 1. Parentheses indicate an identification number used by Ohio Department of Natural Resources (1970).

Year completed — Year of well completion as reported on driller's log or other record of well completion.

Aquifer — CARB, carbonate rocks
S+G , sand and gravel in glacial drift overlying carbonate rocks
SAND, surficial sand in Lucas County

Casing material — S, Steel; P, PVC plastic; G, galvanized steel.

Casing length — Feet of casing used to complete well, as reported on driller's log.

Use of well —

C, commercial	P, public supply	O, observation (see note below)
D, drainage	T, test well	R, recreation
H, rural domestic	I, irrigation	J, industrial cooling
N, industrial	U, unused	S, stock
Z, destroyed		

Note: Observation well asterisk notation--
* , Ohio Department of Natural Resources ground-water-level recording gage (60-minute punch cycle) for long-term monitoring;

** , Ground-water-level recording gage operated by University of Toledo (paper chart);

***, U.S. Geological Survey ground-water-level gage operated for short-term project requirements (60-minute punch cycle).

Elevation of land surface — Land-surface datum; general surface at well site, in feet above sea level.

Drift thickness — Feet of glacial drift; includes sand, gravel, clay, and hardpan overlying carbonate rocks at well site.

Depth of well — Total depth of well.

Range of WL change during study — General range code representing the difference, in feet, between the maximum and minimum Water Levels measured during intermittent site visits by U.S. Geological Survey personnel during the period October 1985 through October 1987.

Range codes are: A--less than 5 feet; B--from 5 to 10 feet; C--from 11 to 20 feet; D--from 21 to 30 feet; E--greater than 30 feet.

If another letter is present, its meaning is as follows: P, pumping influences measured water levels; F, well overflowing and water levels not measured

WL change between date of original completion and 07/86 — The difference, in feet, between the water level as reported on the well completion date and that measured in July 1986. Positive numbers indicate a rise in water level, negative numbers indicate a decline in water level.

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com- pleted	Aqui- fer	Casing Mate- rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick- ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
LU-1	41°37'04"	83°36'22"	--	CARB	--	93	O*	620	95	525	B	--
LU-3-W39	41°29'18"	83°43'54"	1950	CARB	S	--	O**	625	--	39	--	--
LU-10 (M-39)	41°31'43"	83°51'16"	1969	CARB	S	68.5	T	665	66	250	--	--
LU-11 (M-40)	41°42'57"	83°47'42"	1969	CARB	S	51.5	T	680	47	335	--	--
LU-12	41°41'02"	83°44'39"	1969	CARB	--	--	U	670	--	323	--	--
LU-13-T	41°40'07"	83°40'31"	1979	CARB	S	31	U	631	27	391	A	20
LU-100-SY16	41°41'27"	83°42'48"	--	CARB	S	--	C	675	--	--	A	--
LU-101-SY16	41°41'25"	83°42'35"	1966	CARB	S	68	R	673	60	83	A	0
LU-102-SY16	41°41'32"	83°42'33"	1968	CARB	S	71	R	673	63	104	A	0
LU-103-SY9	41°42'13"	83°43'20"	1979	CARB	P	35	H	660	30	50	A	- 6
LU-104-SY11	41°42'38"	83°39'57"	1976	CARB	P	68	H	667	64	100	A	10
LU-105-SY14	41°42'09"	83°40'58"	1982	CARB	S	61	C	655	60	71	B	-10
LU-106-SF5	41°38'24"	83°43'51"	1980	CARB	S	23	H	660	20	60	A	- 5
LU-107-SY11	41°42'42"	83°40'57"	1963	CARB	--	28	I	630	26	90	--	--
LU-108-SF32	41°39'14"	83°44'10"	1979	CARB	P	30	H	664	16	75	C	17
LU-109-T	41°37'47"	83°38'09"	1957	S+G	S	116	C	625	116	116	A	17
LU-110-T	41°37'28"	83°39'39"	1968	CARB	S	121.5	O***	626	114	251	A	20
LU-111-MA36	41°34'47"	83°38'25"	1965	CARB	S	78	I	632	74	410	C	9
LU-112-MA3	41°33'28"	83°41'05"	1974	CARB	S	73	C	638	73	305	A	- 7
LU-113-M10	41°32'46"	83°41'54"	1976	CARB	S	47	H	636	41	57	A	0
LU-114-M7	41°32'13"	83°44'50"	1977	CARB	S	43	H	641	41	63	A	2
LU-115-M5	41°33'32"	83°44'05"	1978	CARB	S	18.5	H	634.7	17	44	B	2
LU-116-M32	41°34'36"	83°44'13"	1977	CARB	S	46	H	639	46	55	A	- 6
LU-117-SF19	41°36'14"	83°44'16"	1980	CARB	S	55	H	639	54	61	A	- 1
LU-118-SF18	41°36'38"	83°45'32"	1981	CARB	S	19	H	645	18	61	A	--
LU-119-SF18	41°37'28"	83°44'56"	1982	CARB	S	68	H	654	65	80	A	5
LU-120-SF1	41°35'34"	83°47'09"	1980	CARB	S	67.5	H	670	66	90	A	-19
LU-121-M33	41°34'24"	83°42'14"	1980	CARB	S	70	H	634	65	73	A	11
LU-122-SF15	41°36'43"	83°42'11"	1966	S+G	S	98	U	631	98	98	A	30
LU-123-SY23	41°41'26"	83°39'53"	1971	CARB	S	62	H	637	56	73	A	8
LU-124-SY27	41°39'39"	83°42'07"	1977	CARB	P	74	H	645	70	97	A	- 5
LU-125-T	41°39'22"	83°38'48"	1972	CARB	S	79	I	626	60	143	A	--
LU-126-T	41°39'05"	83°38'53"	1957	CARB	S	101.5	I	625	84	155	--	24
LU-127-T	41°39'42"	83°36'44"	1979	CARB	S	87	I	600	82	200	B	10
LU-128-T	41°38'19"	83°37'02"	1965	CARB	S	124	U	620	116	143	A	50

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
LU-129-T	41°37'48"	83°32'16"	1971	CARB	S	82	N	605.7	82	550	C P	70
LU-130-T	41°43'21"	83°30'33"	1982	CARB	S	73	C	587	70	93	D P	--
LU-131-SY4	41°43'17"	83°42'41"	1967	CARB	S	17	H	662	14	52	A	7
LU-132-SY6	41°43'15"	83°44'54"	1976	CARB	S	24	H	676	12	56	D	- 3
LU-133-SY29	41°40'24"	83°43'55"	1979	CARB	P	52	H	678	47	100	A	10
LU-134-SW8	41°34'29"	83°51'12"	1976	CARB	S	73	H	674	73	95	A	- 1
LU-135-SW4	41°35'35"	83°50'28"	1983	CARB	S	50	H	665	47	80	A	0
LU-136-SW22	41°33'03"	83°49'28"	1980	CARB	S	71	H	665	61	83	A	- 2
LU-137-W26	41°32'17"	83°47'53"	1977	CARB	S	54	H	652.7	54	83	A	- 2
LU-138-M24	41°33'27"	83°47'08"	1976	CARB	S	51	H	655	51	75	A	-14
LU-139-M14	41°34'26"	83°47'48"	1972	CARB	S	73	H	665	73	100	A	-10
LU-140-W30	41°29'52"	83°44'42"	1984	CARB	S	92	H	655	84	113	C	23
LU-141-W29	41°30'03"	83°44'13"	1977	CARB	S	33	H	652	33	77	A	0
LU-142-W19	41°28'D3"	83°45'45"	1974	CARB	S	63	H	662	63	85	A	-15
LU-143-W24	41°27'36"	83°47'15"	1983	CARB	S	50	H	667	48	60	A	-14
LU-144-P14	41°28'43"	83°47'48"	1975	CARB	S	34	H	660	34	82	A	- 4
LU-145-W12	41°29'29"	83°46'03"	1981	CARB	S	19	H	655	18	100	A	- 5
LU-146-W10	41°29'45"	83°48'57"	1982	CARB	S	24.5	H	656	23	74.5	A	- 7
LU-147-P27	41°27'31"	83°49'21"	1979	CARB	S	54	H	667	53	65	A	-14
LU-148-P34	41°26'33"	83°48'24"	1983	CARB	S	58	H	667	57	61	A	-22
LU-149-P33	41°25'39"	83°50'38"	1978	CARB	S	39	H	662.6	39	77	A	5
LU-150-P29	41°27'04"	83°51'12"	1973	CARB	S	51	H	668.5	51	67	A	- 8
LU-151-P17	41°29'06"	83°51'22"	1982	CARB	--	73	H	665	71	78	A	-14
LU-152-SW32	41°31'02"	83°50'46"	1982	CARB	S	64	H	667	62	143.5	A	-23
LU-153-W36	41°31'21"	83°46'23"	1979	CARB	S	38	H	647	33	78	A	--
LU-154-J33	41°39'27"	83°22'13"	1977	CARB	S	66	H	584	57	82	B	5
LU-155-J28	41°40'29"	83°21'41"	1973	CARB	S	91	H	578	85	96	A	10
LU-156-J2	41°39'09"	83°19'53"	1982	CARB	S	64	H	580	57	101	A	10
LU-157-J32	41°39'39"	83°15'42"	1976	CARB	S	64	I	572	59	80	A	4
LU-158-J1	41°38'20"	83°18'14"	1982	CARB	S	47	H	576	44	68	A	4
LU-159-J6	41°38'30"	83°16'28"	1972	CARB	S	59	H	575	52	69	A	4
LU-160-J11	41°37'27"	83°19'05"	1970	CARB	S	40	H	506	35	83	A	5
LU-161-J30	41°40'22"	83°17'18"	1982	CARB	S	76	C	578	73	100	A	2
LU-162-J10	41°37'34"	83°21'03"	1979	CARB	S	73	H	590	69	116	A	13
LU-163-J12	41°37'28"	83°17'35"	1979	CARB	S	57	H	581	54	82	A	7

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com- pleted	Aqui- fer	Casing Mate- rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick- ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
LU-164-J17	41°37'19"	83°22'13"	1966	CARB	S	72	U	590	68	150	A	16
LU-165-012	41°37'30"	83°25'02"	1979	CARB	S	81	H	602	77	102	B	24
LU-166-07	41°37'49"	83°23'43"	1967	CARB	S	76	H	596	73	112	B	9
LU-167-032	41°39'37"	83°22'37"	1961	CARB	S	76	H	581	74	100	B	7
LU-168-034	41°39'31"	83°27'42"	1963	CARB	S	96	H	594	92	110	B	20
LU-169-05	41°38'30"	83°29'38"	--	CARB	S	85	C	600	80	256	--	--
LU-170-026	41°40'19"	83°26'14"	1967	CARB	S	84	H	587	80	110	B	25
LU-171-09	41°37'23"	83°28'03"	1960	CARB	S	78	U	612	75	105	B	14
LU-172-T	41°38'30"	83°33'52"	--	CARB	S	--	N	601.6	--	500	B	--
LU-173-T	41°43'14"	83°35'10"	1961	CARB	S	58	C	610	58	82.5	A	20
LU-174-T	41°41'51"	83°35'22"	--	CARB	S	--	N	615	--	180	A	--
LU-175-T	41°41'42"	83°29'04"	1970	CARB	S	108	I	575	108	522	B	14
LU-176-J3	41°38'19"	83°19'56"	1981	CARB	S	59	H	585	53	83	A	2
LU-177-J27	41°40'29"	83°20'10"	1983	CARB	S	67	H	575	59	83	A	7
LU-178-J31	41°39'26"	83°17'33"	1978	CARB	S	60	H	575	56	69	A	3
LU-179-J33	41°39'15"	83°14'42"	1963	CARB	S	61	H	575	55	91	A	1
LU-180-J12	41°37'43"	83°11'23"	1955	CARB	S	61	H	575	55	105	A	- 1
LU-181-J12	41°37'42"	83°11'16"	1955	CARB	S	70	H	575	65	130	A	3
LU-182-J8	41°37'30"	83°15'35"	1970	CARB	S	52	H	577	50	66	A	11
LU-183-010	41°37'47"	83°26'52"	1955	CARB	S	65	H	600	60	182	B	0
LU-184-06	41°38'17"	83°24'27"	1979	CARB	S	85	H	595	80	112	B	--
LU-185-J33	41°39'12"	83°22'14"	1971	CARB	S	66	H	585	61	82	A	17
LU-186-033	41°39'50"	83°28'13"	1964	CARB	--	72	U	588.93	67	101	--	16
LU-187-023	41°41'09"	83°26'53"	1974	CARB	S	116	N	585.62	106	130	C	15
LU-188-027	41°40'39"	83°27'24"	1962	CARB	S	103	N	589.26	98	204	--	- 9
LU-189-027	41°40'15"	83°28'00"	1982	CARB	--	88	O	586.43	84	125	--	9
LU-190-027	41°40'13"	83°27'37"	1983	CARB	--	91	O	592.18	87	100	--	- 9
LU-191-028	41°39'59"	83°28'08"	1983	CARB	--	82	O	587.27	75	112	--	- 6
LU-192-027	41°39'59"	83°27'42"	1983	CARB	--	91	O	593.55	82	118	--	3
LU-193-T	41°41'28"	83°31'48"	1940	CARB	S	--	J	595	--	518	A P	--
LU-194-T	41°43'30"	83°31'57"	1965	CARB	S	62	C	595	57	135	A	30
LU-195-WA4	41°43'44"	83°29'20"	1964	CARB	S	73	H	580	66	89	A	--
LU-196-T	41°43'28"	83°28'13"	1961	S+G	S	95	H	575	95	95	A	--
LU-197-027	41°40'32"	83°27'46"	1964	CARB	S	121	N	589	110	215	-- P	--
LU-198-W3	41°30'49"	83°48'38"	1981	CARB	S	42	P	655	40	170	-- P	--

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
LU-199-024	41°41′01″	83°24′46″	1959	CARB	S	91	U	580	90	242	--	0
LU-200-029	41°40′10″	83°23′23″	1973	CARB	S	109	H	583	104	117	--	5
LU-201-036	41°41′38″	83°26′50″	1985	CARB	S	127	U	582	125	131	A	6
LU-202-011	41°37′25″	83°26′16″	1987	CARB	S	88	H	603	81	129	--	--
LU-203-P7	41°29′28″	83°52′20″	1980	CARB	S	60	H	665	59	63	--	--
LU-301-SW17	41°34′08″	83°51′24″	1986	SAND	G	13.3	O	675	--	14.95	A	--
LU-302-SW29	41°32′12″	83°51′43″	1986	SAND	G	9.6	O	675	--	11.27	A	--
LU-303-SW20	41°33′00″	83°51′05″	1986	SAND	G	9.6	O***	675	--	11.80	A	--
LU-304-SW21	41°33′28″	83°50′11″	1986	SAND	G	10.6	O	675	--	12.70	A	--
LU-305-SY16	41°41′33″	83°42′48″	1986	SAND	G	13.5	O	675	--	15.10	A	--
LU-306-SY2	41°43′14″	83°40′31″	1986	SAND	G	11.1	O	670	--	13.25	A	--
LU-307-SY15	41°42′03″	83°41′17″	1986	SAND	G	13.0	O	670	--	14.65	A	--
LU-308-M11	41°35′03″	83°47′39″	1986	SAND	G	5.9	O	665	--	8.00	A	--
LU-309-SY12	41°42′42″	83°39′51″	1986	SAND	G	13.4	O	669	--	15.55	A	--
LU-310-SF5	41°38′23″	83°43′52″	1986	SAND	G	10.2	O	660	--	12.30	A	--
LU-311-SY1	41°43′27″	83°39′51″	--	SAND	G	--	I	673	--	14.12	--	--
LU-312-SY11	41°42′58″	83°40′31″	--	SAND	G	--	I	668	--	9.40	A	--
LU-313-SY10	41°42′35″	83°42′04″	--	SAND	G	--	I	661	--	8.50	--	--
LU-314-SY9	41°42′28″	83°42′28″	--	SAND	G	--	I	666	--	10.60	--	--
LU-315-SY16	41°42′03″	83°42′55″	--	SAND	G	--	I	668	--	10.80	A	--
LU-316-SY16	41°42′02″	83°42′24″	--	SAND	G	--	I	668	--	12.35	--	--
LU-317-SY16	41°41′22″	83°42′57″	--	SAND	G	--	I	673	--	12.10	--	--
LU-318-SF5	41°38′58″	83°43′26″	--	SAND	G	--	I	660	--	16.10	--	--
LU-319-SF9	41°38′15″	83°42′46″	--	SAND	G	--	U	652	--	8.53	--	--
S-1	41°27′07″	83°21′41″	--	CARB	S	--	U	635	--	210	--	--
S-2	41°27′03″	83°21′36″	1946	CARB	--	--	O*	635	--	198	E P	--
S-3-B12(S-24)	41°19′14″	83°04′53″	1969	CARB	S	93	O*	627	92	163	B	0
S-10	41°20′42″	83°08′54″	1968	CARB	--	--	T,Z	640	--	38	--	--
S-11-M15(P-11)	41°23′56″	83°21′26″	1969	CARB	S	27	O,T	648	27	250	A	- 2
S-12 (P-13)	41°19′48″	83°15′15″	1969	CARB	S	30	T,Z	670	19	280	--	--
S-18-R1(S-18)	41°25′37″	83°04′01″	1969	CARB	S	180	H,T	575	70	340	A	0
S-22 (P-13A)	41°19′53″	83°15′16″	1969	CARB	--	--	U	671	16	285	--	--
S-23 (S-23)	41°15′31″	83°04′46″	1969	CARB	S	95	O,T	675	95	108	A	2
S-99-Y35	41°15′20″	82°51′42″	1987	CARB	P	80	H	770	8	145	--	--

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com- pleted	Aqui- fer	Casing Mate- rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick- ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
S-100-S15	41°23'16"	83°07'13"	1969	CARB	S	63	H	600	59	68	--	--
S-101-S10	41°24'35"	83°07'18"	1979	CARB	S	57	H	594	48	72	A	- 3
S-102-R35	41°26'04"	83°06'21"	1967	CARB	S	52	H	580	46	55	A	24
S-103-R1	41°25'27"	83°04'23"	1974	CARB	S	71	H	581	60	76	A	23
S-104-R12	41°24'50"	83°05'10"	1973	CARB	S	57	C	580	48	100	A	9
S-105-RL18	41°23'14"	83°04'06"	1972	CARB	S	--	H	595	81	86	A	- 1
S-106-RL8	41°24'27"	83°02'28"	1971	CARB	S	75	H	580	75	90	A	3
S-107-RL33	41°21'23"	83°01'20"	1972	CARB	S	96.5	H	615	88	100	A	- 1
S-108-RL29	41°22'14"	83°02'57"	1973	CARB	S	96	I	605	96	101	A	8
S-109-S36	41°20'32"	83°04'12"	1963	CARB	S	100	H	620	96	102	A	15
S-110-S26	41°21'43"	83°05'35"	1968	CARB	S	88	N	619.9	83	315	E P	--
S-111-S26	41°21'28"	83°05'40"	1942	CARB	S	--	N	621	--	300	E P	--
S-112-G7	41°19'18"	83°04'00"	1973	CARB	S	96	H	635	96	106	A	11
S-113-G9	41°19'27"	83°01'07"	1977	CARB	S	67.5	H	640	64	80	A	- 2
S-114-G22	41°17'31"	83°00'12"	1971	CARB	S	70	H	695	68	93	A	12
S-115-G27	41°16'15"	83°00'19"	1971	CARB	S	51	H	715	50	60	A	21
S-116-G30	41°16'52"	83°03'10"	1976	CARB	S	94	H	670	92	125	A	- 1
S-117-B24	41°17'51"	83°04'18"	1975	CARB	S	103	H	653	100	105	A	- 3
S-118-B10	41°19'20"	83°07'16"	1978	CARB	S	64	H	643	64	66	B	- 8
S-119-B23	41°17'29"	83°06'17"	1974	CARB	S	94	I	660	91	355	C	--
S-120-B35	41°15'49"	83°06'43"	1968	CARB	S	84	H	675	84	102	A	1
S-121-B21	41°17'11"	83°07'50"	1974	CARB	S	58.5	H	665	57	75	A	5
S-122-B19	41°17'55"	83°11'10"	1972	CARB	S	24	H	660	4	61	A	8
S-123-B32	41°15'47"	83°09'39"	1969	CARB	S	87	H	670	47	92	A	6
S-124-J35	41°15'36"	83°12'41"	1964	CARB	S	21	H	685	17	75	A	0
S-125-J26	41°16'56"	83°13'01"	1961	CARB	S	26	H	682	18	50	A	2
S-126-J33	41°16'02"	83°14'54"	1977	CARB	S	26	H	707	7	83	A	3
S-127-Y25	41°16'22"	82°50'29"	--	CARB	S	--	D	751.4	--	180	C	17
S-128-Y25	41°16'15"	82°50'51"	--	CARB	S	--	D	755	23	155	C	- 2
S-129-Y25	41°16'44"	82°51'16"	1974	CARB	S	9	O***	730	0	130	E	24
S-130-Y13	41°17'57"	82°50'43"	1977	CARB	P	31	H	736	13	140	C	20
S-131-Y11	41°18'51"	82°52'18"	1972	CARB	S	45.5	H	735	29	145	B	23
S-132-Y1	41°20'26"	82°50'50"	1976	CARB	S	32	H	735	5	150	C	- 6
S-133-T26	41°21'53"	82°51'41"	1977	CARB	S	29	H	675	23	70	A	-30
S-134-T34	41°20'52"	82°53'19"	1974	CARB	S	82.5	H	680	62	115	A	- 6

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
S-135-Y8	41°19'35"	82°56'03"	1979	CARB	S	65	H	680	62	70	B	10
S-136-Y19	41°17'44"	82°56'16"	--	CARB	--	--	I	740	--	--	--	--
S-136A-Y17	41°18'06"	82°55'48"	--	CARB	S	--	I	730	11	250	-- P	--
S-137-Y16	41°18'35"	82°55'00"	1963	CARB	S	40	U	730	19	93	C	25
S-138-Y29	41°16'27"	82°55'42"	1971	CARB	S	38	H	780	33	100	A	10
S-139-Y31	41°15'26"	82°56'45"	1973	CARB	S	26.5	H	782	19	85	A	11
S-140-Y33	41°15'21"	82°53'57"	1974	CARB	S	27.5	H	778	6	110	D	- 1
S-141-Y21	41°17'22"	82°54'02"	1980	CARB	S	28	H	757	22	100	B	13
S-142-Y16	41°18'15"	82°54'59"	--	CARB	S	--	U	745	--	55	B	--
S-143-T32	41°21'15"	82°56'08"	1960	CARB	S	68	H	635	65	72	A	3
S-144-RL35	41°21'02"	82°58'50"	1968	CARB	S	48	H	625	46	48	A	1
S-145-G11	41°19'38"	82°59'20"	1974	CARB	S	74	H	642	68	75	A	- 2
S-146-G23	41°17'29"	82°58'53"	--	CARB	S	--	U	685	--	--	A	--
S-147-G25	41°16'32"	82°58'03"	1967	CARB	S	76	I	725	68	138	B	- 6
S-147A	41°16'34"	82°58'13"	--	CARB	--	--	P	720	--	90	--	--
S-148-G26	41°16'27"	82°58'40"	--	CARB	S	--	I	736	--	--	A	--
S-149-G35	41°15'34"	82°58'59"	1964	CARB	S	49	H	760	48	63	A	3
S-150-G13	41°18'31"	82°57'52"	--	CARB	S	--	U	698	--	85	A	6
S-151-G13	41°18'31"	82°57'54"	1971	CARB	S	62	U	698	57	65	A	8
S-152-S33	41°20'55"	83°07'32"	1976	CARB	S	54	N	625	54	325	A	9
S-153-S33	41°20'55"	83°07'32"	1960	CARB	S	48	N	625	48	180	A	23
S-154-S28	41°21'50"	83°08'30"	1966	CARB	S	25	U	630	18	295	C	4
S-155-S28	41°21'50"	83°08'36"	1966	CARB	S	26	U	630	18	250	--	--
S-156-S32	41°20'50"	83°09'14"	1973	CARB	S	21	H	640	9	92	B	14
S-157-S19	41°22'26"	83°10'29"	1967	CARB	S	21	H	630	15	90	A	33
S-158-B4	41°20'03"	83°08'18"	1964	CARB	S	30	H	615	6	92	A	23
S-159-B9	41°18'55"	83°08'56"	1972	CARB	S	21	H	650	12	60	A	3
S-160-J16	41°18'06"	83°14'54"	1954	CARB	S	30.5	H	700	20	98	A	7
S-161-J3	41°20'13"	83°14'24"	1978	CARB	S	21	H	680	1	81	B	10
S-162-W26	41°21'46"	83°12'49"	1970	CARB	S	23	H	648	17	72	B	- 6
S-163-W23	41°22'41"	83°13'16"	1963	CARB	S	20	H	665	3	66	B	- 7
S-164-W9	41°24'04"	83°14'31"	1970	CARB	S	27	H	631.1	27	102	A	12
S-165-S21	41°22'41"	83°08'04"	1972	CARB	S	--	H	615	54	150	B	11
S-166-S9	41°24'20"	83°08'16"	1969	CARB	S	58	H	600	58	98	A	9
S-167-R28	41°26'36"	83°08'09"	1971	CARB	S	53	H	587	46	65	A	- 2

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
S-168-R5	41°24'55"	83°09'43"	1962	CARB	S	37	H	603	32	85	A	3
S-169-W12	41°24'10"	83°11'00"	1949	CARB	P	26.5	H	630	4	70	A	15
S-170-W12	41°24'09"	83°11'02"	1972	CARB	S	21	O***	630	3	61	B	1
S-171-W11	41°24'49"	83°13'04"	1971	CARB	S	22	H	620	20	87	A	4
S-172-W35	41°26'20"	83°13'17"	1964	CARB	S	32	H	610	28	98	A	13
S-173-R31	41°26'21"	83°10'24"	1972	CARB	S	36	H	590	36	80	A	0
S-174-W33	41°26'19"	83°15'04"	1959	CARB	S	31	H	618	25	110	B	0
S-175-W5	41°24'51"	83°15'36"	1975	CARB	S	25	H	627	21	91	A	- 1
S-176-W21	41°22'40"	83°15'14"	1957	CARB	S	25	H	650	6	120	A	3
S-177-W8	41°23'59"	83°16'28"	1977	CARB	S	21	H	643	9	95	A	--
S-178-M24	41°23'03"	83°18'05"	1967	CARB	S	21	H	675	8	118	A	9
S-179-M23	41°22'49"	83°19'14"	1961	CARB	S	28	P	685	13	301	D P	-20
S-180-M11	41°23'59"	83°19'13"	1955	CARB	S	40	H	659	10	110	A	- 2
S-181-M16	41°23'29"	83°21'32"	1969	CARB	S	29	H	650	22	120	A	- 1
S-182-W05	41°24'51"	83°23'25"	1971	CARB	S	21.5	H	660	5	82	A	0
S-183-M18	41°23'18"	83°24'46"	1950	CARB	S	30	H	695	9	92	A	- 6
S-184-M21	41°22'41"	83°22'40"	1967	CARB	S	31	H	660	26	67	A	0
S-185-W032	41°26'27"	83°23'08"	1965	CARB	S	41.5	H	640.2	28	112	A	1
S-186-W01	41°25'37"	83°18'11"	1976	CARB	S	25	H	640	2	105	B	1
S-187-W02	41°25'39"	83°19'37"	1976	CARB	S	26	H	645	3	100	B	0
S-188-W028	41°27'22"	83°22'12"	1964	CARB	S	36	I	638	21	142	A	0
S-189-W09	41°29'09"	83°21'45"	1963	CARB	S	20	H	620	17	72	A	14
S-190-W07	41°29'09"	83°24'51"	1967	CARB	S	31	H	635	10	71	A	- 3
S-191-W019	41°27'45"	83°24'53"	1969	CARB	S	30	H	636	22	97	A	- 3
S-192-W034	41°26'19"	83°21'19"	1963	CARB	S	25	N	650	6	250	B	-17
S-193-W034	41°26'23"	83°21'26"	1964	CARB	S	55	N	650	7	252	A	33
S-194-SC32	41°16'02"	83°22'49"	1961	CARB	S	35	H	725	29	51	A	0
S-195-SC18	41°17'54"	83°24'16"	1955	CARB	S	33	H	700	24	106	A	- 1
S-196-SC6	41°20'01"	83°24'45"	1968	CARB	S	25	H	697	19	61	A	- 2
S-197-SC4	41°19'51"	83°22'40"	1979	CARB	S	--	H	693	3	43	A	1
S-198-M32	41°21'18"	83°23'14"	1975	CARB	S	--	H	675	16	52	B	2
S-199-M19	41°22'14"	83°24'56"	1957	CARB	S	25	H	675	9	102	A	0
S-200-M34	41°21'19"	83°20'58"	1976	CARB	S	24	H	692	16	85	A	5
S-201-M26	41°21'58"	83°19'17"	1955	CARB	S	25	H	690	2	95	A	0
S-202-W31	41°21'20"	83°17'24"	1976	CARB	S	25	H	687	6	80	B	- 6

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
S-203-W28	41°21'22"	83°15'26"	1955	CARB	S	32	H	663	18	179	A	1
S-204-J8	41°19'14"	83°16'42"	--	CARB	S	--	C	640	--	--	A	--
S-205-J8	41°19'11"	83°16'51"	1974	CARB	S	25	N	700	0	300	A	2
S-206-J18	41°17'57"	83°17'11"	1978	CARB	S	25	H	700	14	50	A	- 1
S-207-J21	41°17'15"	83°15'32"	1976	CARB	S	26	S	700	22	125	A	--
S-208-SC26	41°16'13"	83°19'33"	1960	CARB	S	32	P	706	20	230	A	0
S-209-SC34	41°15'19"	83°21'18"	1974	CARB	S	23	H	710	20	65	A	0
S-210-SC27	41°16'54"	83°21'34"	1979	CARB	S	21	C	726	12	102	B	18
S-211-SC2	41°20'23"	83°19'49"	1970	CARB	S	22	H	710	2	105	B	15
S-212-SC10	41°19'21"	83°20'25"	1970	CARB	S	21.5	H	710	3	126	A	6
S-213-SC1	41°19'59"	83°18'19"	1978	CARB	S	25	H	695	5	100	A	2
S-214-SC9	41°19'35"	83°21'39"	1971	CARB	S	25	H	703	2	50	A	0
S-215-SC13	41°17'54"	83°18'55"	1955	CARB	S	26	H	710	9	162	A	5
S-216-T24	41°23'11"	82°51'08"	1984	CARB	S	60	H	625	58	100	-- F	- 2
S-217-T1	41°25'05"	82°51'24"	1978	CARB	--	64	H	595	62	76	-- F	--
S-218-T15	41°23'14"	82°53'30"	1964	CARB	S	111	H	609	84	109	-- F	--
S-218A-T22	41°23'10"	82°53'30"	1987	S+G	S	81.5	R	609	80	80	-- F	--
S-219-R12	41°24'31"	82°58'02"	1971	CARB	S	62	H	583	57	108	-- F	--
S-220-Y22	41°17'51"	82°53'10"	1972	CARB	S	32	U	730	8	110	C	7
S-221-RL23	41°22'19"	82°58'55"	1979	CARB	P	56.5	O	609.17	45	200	--	--
S-222-RL23	41°22'19"	82°59'27"	1981	CARB	P	47	O	608.38	43.5	65	--	--
S-223-RL23	41°22'22"	82°58'38"	1979	CARB	P	48	O	608.84	45	50	--	--
S-224-RL26	41°22'06"	82°59'09"	1979	CARB	P	46	O	610.65	42	50	--	--
S-225-RL26	41°22'04"	82°58'44"	1979	CARB	G	47	O	612.88	47	50	--	--
S-227-T9	41°24'05"	82°54'57"	1956	CARB	--	51	H	593	49	57	-- F	--
S-228-T4	41°25'46"	82°54'04"	--	CARB	--	--	H	580	--	--	-- F	--
S-229-T19	41°23'10"	82°56'09"	1966	CARB	S	61.5	H	595	56	61.5	A	1
S-230-T19	41°23'12"	82°57'05"	--	CARB	S	--	S	595	--	--	-- F	--
S-231-RL36	41°26'05"	82°57'49"	1959	CARB	--	45	U	575	41	300	-- F	--
S-232-RL10	41°24'17"	82°59'33"	--	CARB	--	--	U	585	--	--	-- F	--
S-233-RL10	41°24'53"	82°59'55"	--	CARB	S	--	U	580	--	39	-- F	--
S-234-RL16	41°23'40"	83°01'14"	--	CARB	S	--	H	590	--	--	-- F	--
S-235-RL13	41°23'13"	82°57'35"	--	CARB	S	--	U	590	--	57.5	-- F	--
S-236-RL23	41°22'52"	82°58'26"	1962	CARB	P	58	H	598	52	62	B	12

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year completed	Aquifer	Casing Material	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thickness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
WO-10 (M-38)	41°20'31"	83°48'02"	1969	CARB	S	410	O,T	679.1	15	500	A	0
WO-11 (P-18)	41°10'07"	83°40'16"	1969	CARB	S	26	O,T	725	25	300	A	17
WO-12 (P-8)	41°17'05"	83°25'41"	1969	CARB	S	32	O,T	705	28	260	A	2
WO-13 (P-14)	41°26'45"	83°31'58"	1969	CARB	S	51	O,T	650	48	250	A	0
WO-22 (P-3)	41°10'12"	83°33'09"	1969	CARB	S	23.5	O,T	745	20	230	--	9
WO-23-C27(P-9)	41°21'40"	83°35'27"	1969	CARB	S	22	O,T	670	22	235	A	- 2
WO-100-PB25	41°35'12"	83°32'09"	1977	CARB	S	58	H	622	52	139	A	10
WO-101	41°36'31"	83°31'42"	--	CARB	S	--	H	615	70	250	A	--
WO-102	41°36'35"	83°29'34"	1977	CARB	S	76	H	610	70	149	A	16
WO-103	41°35'51"	83°29'39"	1972	CARB	S	74	H	615	71	250	A	3
WO-104	41°36'20"	83°30'41"	1983	CARB	S	74	C	615	73	155	A	6
WO-105	41°35'32"	83°29'58"	1983	CARB	P,S	67	O	618	63.5	100	--	--
WO-106	41°36'04"	83°30'01"	1983	CARB	P,S	75	O	616	70	94	--	--
WO-107	41°36'26"	83°30'29"	1983	CARB	P,S	85	O	619	78.5	123	--	--
WO-108	41°36'25"	83°30'35"	1983	CARB	P,S	74	O	610	72	100	--	--
WO-109	41°36'16"	83°30'23"	1983	CARB	P,S	76	O	619	74	109	--	--
WO-110	41°36'08"	83°30'34"	1983	CARB	P,S	87	O	618	69	120	--	--
WO-111	41°36'14"	83°30'23"	1983	CARB	P,S	77	O	617	70	110	--	--
WO-112	41°36'18"	83°30'23"	1983	CARB	P,S	76	O	613	70	109	--	--
WO-114	41°36'05"	83°30'23"	1974	CARB	S	80	O	615	72	200	--	--
WO-115	41°36'29"	83°30'23"	1983	CARB	P,S	77.5	O	614	74	83	--	--
WO-116	41°36'30"	83°30'12"	1983	CARB	P,S	85	O	615	77.5	90	--	--
WO-117	41°36'35"	83°31'39"	1946	CARB	S	45	H	620	60	102	--	--
WO-118-LK8	41°35'15"	83°30'43"	1974	CARB	S	66	H	619	57	160	A	15
WO-119-LK7	41°35'15"	83°31'37"	1958	CARB	S	55	H	620	53	132	A	1
WO-120	41°35'57"	83°30'48"	--	CARB	--	--	C	619	60	84	--	--
WO-121	41°36'29"	83°30'44"	--	CARB	S	--	O***	616	65	188	B	--
WO-122	41°36'31"	83°31'58"	--	CARB	S	--	C	619	--	330	--	--
WO-124	41°36'55"	83°30'58"	--	CARB	--	--	H	620	--	--	B	--
WO-129-PB23	41°35'57"	83°33'23"	1976	CARB	S	74	I	615	68	149	B	21
WO-131-PB24	41°35'40"	83°32'22"	--	CARB	--	--	U	620	--	620	A	--
WO-141-LK4	41°35'46"	83°29'20"	--	CARB	--	--	P	615	--	--	C	--
WO-198-T21	41°27'26"	83°28'31"	1978	CARB	S	25	H	665	0	55	--	--
WO-199-F34	41°21'03"	83°27'22"	1950	CARB	S	28	H	665	18	72	--	--
WO-200-MO24	41°17'21"	83°25'09"	--	CARB	--	--	O***	707.7	--	265	B	--

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
WO-201-PE24	41°11'52"	83°25'39"	1964	CARB	S	40	H	767	3	76	A	11
WO-202-PE25	41°11'30"	83°25'33"	--	CARB	S	--	H	754	--	--	A	--
WO-203-PE12	41°14'11"	83°26'06"	1960	CARB	S	27	H	721	3	70	A	5
WO-204-PE22	41°12'09"	83°27'35"	1981	CARB	S	25	H	745	12	65	A	5
WO-205-PE34	41°10'37"	83°27'53"	1973	CARB	S	32	H	753	27	74	A	6
WO-206-PE4	41°14'43"	83°29'15"	1971	CARB	S	25	C	713	5	99	B	3
WO-207-B24	41°12'35"	83°32'40"	1956	CARB	S	25	H	720	16	33	A	--
WO-208-PE31	41°10'36"	83°32'05"	1978	CARB	S	26	H	740	17	36	A	10
WO-209-B36	41°10'12"	83°33'09"	--	CARB	S	--	C	745	--	187	A	--
WO-210-B35	41°10'50"	83°33'34"	1975	CARB	S	25	H	742	14	80	A	--
WO-211-B23	41°11'50"	83°33'20"	1982	CARB	P	25	H	737	16	50	A	3
WO-212-B4	41°14'29"	83°36'22"	1979	CARB	S	21	H	695	12	30	A	4
WO-213-B16	41°13'31"	83°36'06"	1969	CARB	S	27	H	705	27	75	A	10
WO-214-B32	41°10'31"	83°36'44"	1974	CARB	S	36	C	735.2	34	60	A	5
WO-215-B8	41°13'52"	83°37'18"	1976	CARB	S	24	H	710.5	8	50	A	4
WO-216-H1	41°14'28"	83°39'54"	--	CARB	S	28	H	695	28	48	A	6
WO-218-H36	41°10'22"	83°39'40"	1963	CARB	S	22	H	734	20	62	A	15
WO-219-H11	41°13'36"	83°41'12"	1978	CARB	S	20	H	704	12	58	A	4
WO-220-H10	41°13'54"	83°42'27"	1977	CARB	S	25	H	698	19	36	A	3
WO-221-H9	41°13'39"	83°43'02"	1981	CARB	S	21	H	706	12	54	A	- 3
WO-222-H17	41°12'53"	83°43'40"	1973	CARB	S	30	H	703	30	89	A	1
WO-223-H17	41°12'50"	83°43'40"	1973	CARB	S	29	H	703	29	40	A	1
WO-224-H29	41°11'01"	83°44'29"	--	CARB	S	--	H	709	--	115	A	--
WO-225-H8	41°14'25"	83°44'16"	1973	CARB	S	28	H	694	23	60	A	- 1
WO-226-H5	41°14'29"	83°44'08"	1980	CARB	S	34	H	697.1	33	93	A	1
WO-227-H18	41°13'01"	83°45'55"	1954	CARB	S	62	H	699	61	63	--	--
WO-228-H18	41°12'56"	83°45'31"	1959	CARB	S	61	C	700	61	65	A	--
WO-229-H18	41°12'57"	83°45'53"	1954	S+G	S	74	C	699	74	74	--	--
WO-230-J24	41°12'16"	83°47'03"	1980	CARB	S	62	H	705	61	89	A	- 3
WO-231-J22	41°12'07"	83°48'16"	1985	CARB	P	62.5	H	706	63.5	120	A	1
WO-232-J27	41°10'59"	83°48'49"	1977	CARB	S	66	H	714	60	74	A	3
WO-233-J31	41°10'25"	83°51'43"	1971	CARB	S	46	H	717	44	65	A	- 8
WO-234-J20	41°12'17"	83°51'09"	1983	CARB	S	80	H	707	78	100	A	1
WO-235-J19	41°12'17"	83°51'53"	1977	CARB	S	69.5	H	707	67	89	A	2
WO-236-J8	41°13'37"	83°50'38"	1980	CARB	S	66	H	704	65	100	A	1

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
WO-237-ML31	41°15'20"	83°52'09"	1975	CARB	S	68.5	H	699.8	69	93	A	1
WO-238-ML18	41°18'46"	83°52'53"	1977	CARB	S	39	H	684	39	97	A	4
WO-239-ML6	41°19'44"	83°52'57"	--	CARB	--	--	H	682	--	--	B	--
WO-240-ML8	41°19'40"	83°51'16"	1977	CARB	P	35	H	680	35	38	A	0
WO-241-ML21	41°17'06"	83°50'32"	1978	CARB	S	65	C	692.5	64	120	A	--
WO-242-ML4	41°19'43"	83°49'32"	1979	CARB	S	53	H	681	52	133	A	6
WO-243-PB57	41°31'23"	83°41'58"	1974	CARB	S	40	H	635	37	47	--	--
WO-244-ML22	41°16'52"	83°49'57"	1971	CARB	S	68	H	695	68	--	A	8
WO-245-ML1	41°19'45"	83°46'57"	1976	CARB	S	50	H	684	50	72	A	6
WO-246-LI19	41°17'06"	83°45'56"	1977	CARB	S	46	H	689	46	57	A	2
WO-247-ML36	41°15'21"	83°46'25"	1975	CARB	S	53	H	694	51	80	A	3
WO-248-LI32	41°16'09"	83°44'13"	1953	CARB	S	32	H	695	28	50	A	10
WO-249-LI16	41°18'00"	83°43'39"	1960	CARB	S	22.5	C	689	21	80	A	1
WO-250-LI2	41°19'45"	83°41'06"	1974	CARB	S	25	H	686	24	31	A	4
WO-251-LI23	41°17'49"	83°40'19"	1952	CARB	S	21	H	690	14	37	A	- 1
WO-252-LI35	41°16'03"	83°40'12"	1977	CARB	S	25	H	686	19	50	A	1
WO-253-PO18	41°17'52"	83°38'47"	1982	CARB	S	32	H	685	26	50	A	--
WO-254-PO9	41°18'41"	83°36'39"	1973	CARB	S	25	H	678	25	46	A	5
WO-255-PO16	41°17'49"	83°36'10"	--	CARB	S	--	H	680	--	30	A	--
WO-256-PO33	41°15'35"	83°36'12"	1963	CARB	S	26.5	H	690	25	46	A	--
WO-257-PO33	41°15'16"	83°36'09"	1953	CARB	S	27	H	694	27	99	A	--
WO-258-PO15	41°18'28"	83°34'52"	1977	CARB	S	25	H	677	22	52	A	2
WO-259-PO24	41°16'58"	83°32'35"	1961	CARB	S	29	H	684	28	33	A	4
WO-260-MO9	41°19'11"	83°28'53"	1973	CARB	--	--	H	675	28	40	C	2
WO-261-MO15	41°17'56"	83°28'25"	1969	CARB	--	35	P	695	28	98	A	14
WO-262-MO33	41°15'33"	83°28'42"	1976	CARB	S	25	H	705	17	90	A	7
WO-263-MO1	41°19'43"	83°26'13"	1977	CARB	S	21	H	685	14	75	A	--
WO-264-MO24	41°17'00"	83°26'11"	--	CARB	S	--	U	705	--	55	A	--
WO-265-MO25	41°16'16"	83°25'19"	1962	CARB	S	42	H	718	0	74	A	0
WO-266-F26	41°22'04"	83°27'18"	1954	CARB	S	48	H	669	18	148	A	6
WO-267-F1	41°25'24"	83°25'28"	1980	CARB	S	36	H	646	22	54	A	3
WO-268-F4	41°24'53"	83°29'17"	1980	CARB	S	33	H	660	33	68	A	11
WO-269-F20	41°22'37"	83°30'18"	1982	CARB	S	19	H	685.7	9	82	A	8
WO-270-F29	41°21'36"	83°30'03"	1972	CARB	S	28	H	667	20	49	A	4
WO-271-WB14	41°23'16"	83°33'48"	1976	CARB	S	24	H	664	17	54	A	4

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
WO-272-WB36	41°25'42"	83°33'07"	1972	CARB	S	51	H	663	44	69	A	0
WO-273-WB26	41°27'21"	83°33'39"	1983	CARB	S	29	H	657	26	90	C	0
WO-274-MD28	41°26'35"	83°36'27"	1978	CARB	S	47	H	664	41	75	A	0
WO-275-C31	41°21'14"	83°38'04"	1975	CARB	S	22	H	694	4	42	C	4
WO-276-C20	41°22'53"	83°37'24"	1964	CARB	S	21	I	674	16	236	A	3
WO-277-C17	41°23'57"	83°37'14"	--	CARB	S	--	C	673	--	--	A	--
WO-278-C8	41°24'31"	83°37'45"	1966	CARB	S	26	H	670	26	54	A	3
WO-279-C7	41°24'38"	83°37'50"	1974	CARB	S	45	S	670	45	60	A	2
WO-280-PL24	41°23'05"	83°39'09"	--	CARB	S	--	H	678	--	--	A	--
WO-281-PL24	41°22'21"	83°40'23"	1961	CARB	S	20	H	695	9	26	A	7
WO-282-PL35	41°21'17"	83°41'05"	1977	CARB	S	36	H	694	36	77	A	4
WO-283-PL20	41°22'35"	83°44'12"	1972	CARB	S	60	C	675	53	100	A	0
WO-284-PL20	41°22'36"	83°43'53"	--	CARB	S	--	C	675	--	--	A	--
WO-285-PL20	41°22'44"	83°44'14"	--	CARB	S	--	U	675	--	--	A	--
WO-286-PL17	41°23'50"	83°44'49"	1979	CARB	S	81	H	672	81	88	A	30
WO-287-WA5	41°25'41"	83°44'30"	1984	CARB	--	105	H	664	92	213	A	19
WO-288-WS25	41°21'31"	83°46'05"	1976	CARB	S	59	H	682	59	77	A	19
WO-289-WS25	41°22'18"	83°46'34"	1977	CARB	S	67	H	675.2	67	74	A	5
WO-290-WS22	41°22'25"	83°49'27"	1972	CARB	S	39	H	674	39	61	A	- 2
WO-291-GR3	41°24'57"	83°48'29"	1975	CARB	S	55	H	666	47	75	A	- 4
WO-292-WA36	41°26'30"	83°46'50"	1978	CARB	S	56	H	660	55	102	A	- 1
WO-293-WA3	41°25'54"	83°48'32"	1974	CARB	S	56	H	661.0	56	91	A	- 5
WO-294-GR9	41°24'53"	83°50'46"	1982	CARB	S	27	H	665	17	51	A	--
WO-295-GR7	41°24'38"	83°52'10"	1976	CARB	S	28	H	662.4	28	50	A	- 9
WO-296-GR29	41°22'00"	83°51'48"	1976	CARB	S	42	H	677	31	52	A	0
WO-297-GR30	41°21'44"	83°51'52"	1977	CARB	P	40	H	676	40	52	--	--
WO-298-WS32	41°21'24"	83°51'30"	1973	CARB	S	40.5	H	676	39	57	A	- 1
WO-299-WA24	41°27'35"	83°46'08"	1975	CARB	S	29	H	638	17	36	A	3
WO-300-MD20	41°28'02"	83°43'57"	1973	CARB	S	133	H	660	133	155	A	- 2
WO-301-MD20	41°28'04"	83°43'52"	1974	CARB	S	122.5	H	660	120	135	A	- 2
WO-302-MD51	41°30'25"	83°42'30"	--	CARB	--	--	H	647	--	66	A	--
WO-303-MD23	41°30'26"	83°42'08"	1972	CARB	S	38	H	650	38	48	B	-19
WO-304-ML21	41°17'07"	83°50'32"	--	CARB	--	--	C	692.9	--	65	A	--
WO-305-PB18	41°32'10"	83°38'06"	1975	CARB	S	73	H	635	69	189	B	14
WO-306-PB	41°33'45"	83°37'15"	1965	CARB	S	72	H	628	70	192	A	10

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com-pleted	Aqui-fer	Casing Mate-rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick-ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
WO-307-WB15	41°28'39"	83°35'20"	1972	CARB	S	21.5	H	675	2	82	A	2
WO-308-LK32	41°31'17"	83°30'39"	1960	CARB	S	28	H	638	22	82	A	3
WO-309-LK27	41°31'47"	83°27'58"	1978	CARB	S	62	H	628	38	149	B	- 4
WO-310-LK23	41°33'02"	83°26'06"	--	CARB	S	--	I	617	--	118	A	--
WO-311-PB27	41°35'35"	83°34'38"	1956	CARB	S	67	H	621	65	132	A	- 1
WO-313-R	41°36'58"	83°33'29"	1956	CARB	S	93	N	615	91	541	E P	82
WO-314-R	41°36'56"	83°33'30"	--	CARB	--	--	N	615	--	--	C	--
WO-315-N28	41°37'00"	83°29'10"	1958	CARB	S	72	Z	614	70	175	A	22
WO-316-LK4	41°35'42"	83°28'27"	1977	CARB	S	78	H	615	71	149	A	6
WO-317-LK10	41°35'15"	83°27'18"	1972	CARB	S	75.5	H	609	70	100	A	8
WO-318-N35	41°36'57"	83°26'30"	1976	CARB	S	88	H	604	72	112	A	11
WO-319-N35	41°36'28"	83°26'08"	1952	CARB	S	74.5	H	604	72	105	A	- 5
WO-320-N36	41°36'08"	83°25'55"	1976	CARB	S	84	H	606	77	110	A	13
WO-321-LK12	41°34'55"	83°26'04"	1973	CARB	S	74	H	611	74	115	A	12
WO-322-WA12	41°24'11"	83°46'41"	--	CARB	S	--	U	670	--	73	A	--
WO-323-PB57	41°31'23"	83°42'02"	--	CARB	S	--	H	635	--	100	A	--
WO-324-H18	41°13'09"	83°45'35"	1967	CARB	S	95	I	699	45	260	A	- 1
WO-325-H18	41°12'50"	83°45'28"	1971	CARB	S	83	I	700	52	166	A	- 1
WO-326-WS32	41°21'23"	83°51'29"	1974	CARB	S	38	H	676	38	55	A	0
WO-327-PL20	41°22'20"	83°44'14"	1971	CARB	S	--	C	676	--	53	A	--
WO-328-PB10	41°32'26"	83°34'52"	1962	CARB	S	44	H	641	42	144	A	-15
WO-329-PB34	41°33'55"	83°34'41"	1982	CARB	S	55	H	628	48	145	A	0
WO-330-PB1	41°33'45"	83°31'42"	1967	CARB	S	45	H	624	41	130	A	3
WO-331-PB23	41°31'01"	83°32'53"	1976	CARB	S	35	H	640	29	85	A	10
WO-332-PB21	41°30'27"	83°35'33"	1976	CARB	S	38	H	649	38	56	A	0
WO-333-PB19	41°30'25"	83°37'40"	1969	CARB	S	64	H	650	62	112	A	- 1
WO-334-PB11	41°32'39"	83°40'15"	1962	CARB	S	21	H	590	16	40	A	- 3
WO-335-MD25	41°29'35"	83°39'25"	1978	CARB	S	56	H	659	52	169	A	- 3
WO-336-PL10	41°24'30"	83°41'52"	1984	CARB	S	35.5	H	673	34	246	A	3
WO-337-MD25	41°27'28"	83°39'55"	1965	CARB	S	63	C	664	58	293	A	4
WO-338-T18	41°28'47"	83°31'32"	1961	CARB	S	28	H	649	24	57	A	6
WO-339-T28	41°27'13"	83°28'40"	1982	CARB	P	25	H	666	6	70	A	10
WO-340-LK16	41°33'31"	83°28'36"	1980	CARB	S	42	C	623	34	140	A	0
WO-341-LK36	41°30'55"	83°25'43"	1960	CARB	S	35	H	630	20	80	A	- 2
WO-342-T9	41°29'50"	83°28'25"	1960	CARB	S	40	C	645	26	135	A	- 4

Table 3.-- Records of selected wells in Lucas, Sandusky, and Wood Counties--Continued

Number in plate 1	Latitude	Longitude	Year com- pleted	Aqui- fer	Casing Mate- rial	Casing Length (ft)	Use of well	Elevation of land surface (ft)	Drift thick- ness (ft)	Depth of well (ft)	Range of WL change during study (ft)	WL change between date of original completion and 07/86 (ft)
WO-343-T25	41°26'57"	83°26'02"	1976	CARB	S	27	H	657	3	95	A	4
WO-344-PL27	41°22'02"	83°42'30"	1974	CARB	S	31	H	680	31	38	A	2
WO-345-PL32	41°20'50"	83°43'57"	1976	CARB	S	41	H	685	40	100	A	8
WO-346-LI7	41°19'13"	83°44'52"	1976	CARB	S	34	H	680	34	50	A	2
WO-347-B12	41°13'54"	83°32'20"	1976	CARB	S	20	H	705	15	41	A	2
WO-348-B15	41°12'42"	83°35'32"	1973	CARB	S	20	H	715	12	25	A	1
WO-349-F3	41°24'51"	83°28'02"	1945	CARB	S	--	P	655	25	227	D P	-11
WO-350-F10	41°24'06"	83°27'24"	1952	CARB	S	27	P	651	8	260	B P	- 4
WO-351-B6	41°14'32"	83°38'51"	1982	CARB	S	25	U,P	697	14	100	A	--
WO-352-B36	41°10'03"	83°33'02"	--	CARB	S	30	P	745	21	185	--	--
WO-353-GR30	41°21'44"	83°51'51"	1986	CARB	S	42.5	H	676	40	60	A	1

Table 4.--Records of selected springs in Lucas, Sandusky, and Wood Counties

[Type of spring: F, fracture; A, artesian. Sphere of discharge: W, subaqueous (discharges beneath pool of water); A, subaerial; discharges are in gallons per minute. Discharge-measurement method: E, estimated from time required to fill 5-gallon container; C, current meter; Z, owner reported. Use of water: D, dewatering; U, unused.]

Number on Plate 1	Location		Name of spring	Type of spring	Sphere of dis-charge	Dis-charge	Discharge measure-ment method	Use of water
	Latitude	Longitude						
Lucas County								
LU-14-MA35	41°34'31"	83°40'34"	Maumee Quarry Sump Spring	F	W	300	E	D
LU-15-SY18	41°41'35"	83°44'51"	Silica Quarry Spring	F	A	800	E	D
LU-16-W40	41°29'30"	83°44'06"	Waterville Quarry West Wall Spring	F	A	200	E	D
Sandusky County								
S-30-T9	41°24'17"	82°54'30"	Millers Spring near Vickery	A	W	900	C	U
S-31-S32	41°20'45"	83°09'06"	Gottron Quarry Bench Spring at Fremont	F	A	25	E	D
S-32-S32	41°20'48"	83°08'55"	Gottron Quarry Floor Spring at Fremont	F	A	3	E	D
S-33-WO22	41°28'05"	83°21'14"	Martin-Marietta Quarry East Sump at Woodville	F	A	225	E	D
S-34-G31	41°15'51"	83°03'09"	St. Francis Spring at Green Springs	A	W	5,500	Z	U
Wood County								
WO-150-PE4	41°14'26"	83°29'07"	West Millgrove Quarry Bench Spring	F	A	5	E	D
WO-151-PB11	41°32'19"	83°33'43"	Lime City Quarry Spring	F	A	10	E	D
WO-152-PO7	41°19'12"	83°38'48"	Portage Quarry Spring	F	A	10	E	D

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio

Explanation of Column Headings

All columns	A double dash indicates information not available or not applicable; <, actual value is less than the value given; >, actual value is greater than the value given.
Number in plate 1	Local well number shown on index map. County prefix is omitted on Plate 1 .
Station number	15-digit unique identifier based on site latitude (first six digits), longitude (digits seven through thirteen), and a 2-digit sequence-number suffix.
Name	Property owner's name and geographic location descriptor. NR, near.
Type of site	GW, ground water from well; SP, spring water.
Type of aquifer	C, confined single geologic unit; M, confined multiple geologic units; U, unconfined single geologic unit; N, unconfined multiple geologic units.
Geologic-unit Code	Code abbreviation of geologic unit or units that are primary water-bearing strata where well is completed or where spring occurs. Codes: **LAKE**--Lake sand of Quaternary age. **OTSH**--Outwash deposits of Quaternary age; includes sand, gravel, and rock fragments. **DVNN**--Devonian age carbonate rocks above the Detroit River Group. **DRVR**--Detroit River Group dolomites, undivided. Bass Islands Group--differentiated **RRVR**--Raisin River Dolomite of Late Silurian age. **TMCT**--Tymochtee Dolomite, dolomite and shale **GFLD**--Greenfield Dolomite Bass Islands Group-- Undifferentiated **BILD**--undifferentiated strata of Sandusky County **SLRN**--bedded evaporites of "Salina Group" in Sandusky County. **LCKP**--Lockport Dolomite
Major-ion Water Type	Cation: C, calcium; M, magnesium; N, sodium. Anion : H, bicarbonate; S, sulfate; C, chloride.
Remarks	Observations and notes during the collection of water sample.

Abbreviations

deg C, degrees Celsius;
cols., colonies;
ND, not detected;
mL, milliliter;
µS/cm, microsiemens per centimeter at 25 degrees Celsius.
mg/L, milligrams per liter;
µg/L, micrograms per liter;
pCi/L, picocuries per liter;

IT-FLD, onsite incremental titration for alkalinity;
t.u., tritium units (1 t.u. equals 3.2 pCi/L),
O.D.H., Ohio Department of Health Laboratory, Columbus, Ohio.
K, number of colonies based on a non-ideal count of less than 20 colonies per 100 milliliters.
u nat, uranium natural

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Station number	Name	Type of site	Type of aquifer	Geologic-unit code
LU-1	413704083362200	State of Ohio Hospital at Toledo	GW	M	GFLD,LCKP
LU-14-MA35	413431083403400	Stoneco Spring at Maumee	SP	M	GFLD
LU-15-SY18	414135083445100	France Stone Spring nr Silica	SP	N	DRVR
LU-16-W40	412930083440600	France Stone Spring at Waterville	SP	N	RRVR
LU-105-SY14	414209083405800	Sylvania C.C. at Sylvania	GW	C	RRVR
LU-112-MA3	413328083410500	St. Lukes Hospital at Maumee	GW	M	GFLD,LCKP
LU-113-M10	413246083415400	Graham SW. of Maumee	GW	C	TMCT
LU-116-M32	413436083441300	Wildarger N. of Monclova	GW	M	RRVR
LU-119-SF18	413728083445600	Nowowiejski nr Crissey	GW	C	RRVR
LU-120-SF1	413534083470900	Wagner nr Crissey	GW	C	DRVR
LU-126-T	413905083385300	Inverness G.C. No. 3 at Toledo	GW	M	TMCT,GFLD
LU-127-T	413942083364400	University of Toledo at Toledo	GW	C	TMCT,GFLD
LU-129-T	413748083321600	Kuhlman Builders at Toledo	GW	M	GFLD,LCKP
LU-131-SY4	414317083424100	Westgate at Sylvania	GW	U	RRVR
LU-133-SY29	414024083435500	Coventry Furniture nr Sylvania	GW	C	RRVR
LU-134-SW8	413429083511200	Lambdin E. of Swanton	GW	C	DVNN
LU-135-SW4	413535083502800	Pietraszak nr Swanton	GW	C	DVNN
LU-136-SW22	413303083492800	Webber nr Whitehouse	GW	C	DVNN
LU-141-W29	413003083441300	Craddock at Waterville	GW	C	RRVR
LU-142-W19	412803083454500	Seeman SW. of Waterville	GW	C	RRVR
LU-146-W10	412945083485700	Senancik nr Whitehouse	GW	U	DVNN
LU-148-P34	412633083482400	Kunkle nr Providence	GW	C	RRVR
LU-152-SW32	413102083504600	Bittersweet Farms nr Whitehouse	GW	M	DVNN,DRVR
LU-160-J11	413727083190500	Courtay E. of Curtice	GW	M	GFLD,LCKP
LU-161-J30	414022083171800	City of Oregon nr Reno Beach	GW	C	GFLD
LU-165-O12	413730083250200	Schroeder at Oregon	GW	C	GFLD
LU-167-O32	413937083223700	Dusseau at Oregon	GW	C	GFLD
LU-168-O34	413931083274200	Frigmanski at Oregon	GW	C	GFLD
LU-169-O5	413830083293800	Fun-Spot Skate at Oregon	GW	M	GFLD,LCKP
LU-170-O26	414019083261400	Fox at Oregon	GW	C	GFLD
LU-174-T	414151083352200	Dupont at Toledo	GW	M	TMCT
LU-175-T	414142083290400	Detwiler Golf at Toledo	GW	M	GFLD,LCKP
LU-177-J27	414029083201000	Lewis E. of Oregon	GW	C	GFLD
LU-179-J33	413915083144200	Davis at Reno Beach	GW	M	GFLD,LCKP
LU-180-J12	413743083112300	Crane Cr Park nr Reno Beach	GW	M	TMCT,GFLD
LU-184-O6	413817083242700	Iman at Oregon	GW	C	GFLD
LU-187-O23	414109083265300	Union Oil at Oregon	GW	C	GFLD
LU-193-T	414128083314800	Diversitech Corp at Toledo	GW	M	TMCT,LCKP
LU-194-T	414330083315700	Lucas Asphalt at Toledo	GW	C	TMCT,GFLD
LU-197-O27	414032083274600	Sohio, Toledo Refinery at Oregon	GW	M	GFLD,LCKP
LU-198-W3	413049083483800	Whitehouse No. 3 at Whitehouse	GW	C	RRVR
LU-201-O36	414138083265000	Harting at Oregon	GW	C	GFLD
LU-202-O11	413725083261600	Nappenbach at Oregon	GW	C	GFLD
LU-203-P7	412928083522000	Neapolis Fire Dept. at Neapolis	GW	C	DVNN
LU-301-SW17	413408083512400	USGS-Toledo Metroparks nr Swanton	GW	U	LAKE
LU-302-SW29	413212083514300	USGS-Toledo Metroparks nr Swanton	GW	U	LAKE
LU-303-SW20	413300083510500	USGS-Toledo Metroparks nr Swanton	GW	U	LAKE
LU-304-SW21	413328083501100	USGS-Toledo Metroparks nr Swanton	GW	U	LAKE
LU-305-SY16	414133083424800	USGS-City of Sylvania at Sylvania	GW	U	LAKE
LU-306-SY2	414314083403100	USGS-Huntington Farms, Inc. at Sylvania	GW	U	LAKE
LU-307-SY15	414203083411700	USGS-Camp Miakonda at Sylvania	GW	U	LAKE
LU-308-M11	413503083473900	USGS-Ohio Air Guard nr Swanton	GW	U	LAKE
LU-309-SY12	414242083395100	USGS-Arbor Jr. High School at Sylvania	GW	U	LAKE
LU-310-SF5	413823083435200	USGS-Sewing Machine Sales nr Holland	GW	U	LAKE

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Specific conductance (µS/cm)	pH (standard units)	Temperature, water (deg C)	Oxygen, dissolved (mg/L)	Coliform, total (cols. per 100 mL)	Coliform, fecal, (cols. per 100 mL)	Streptococci, fecal, (cols. per 100 mL)
LU-1	06-22-78	1,150	7.8	11.5	--	--	--	--
LU-14-MA35	08-05-87	1,350	8.1	19.0	7.8	K16	K11	K16
LU-15-SY18	10-07-87	920	7.4	13.5	1.0	K4	<1	K2
LU-16-W40	10-08-87	3,350	7.3	11.5	<.1	<1	<1	<1
LU-105-SY14	06-17-87	360	8.0	13.0	<.1	<1	<1	<1
LU-112-MA3	07-07-87	3,000	7.3	12.5	<.1	<1	<1	<1
LU-113-M10	06-17-87	1,760	7.0	12.5	<.1	K12	K1	K17
LU-116-M32	06-25-87	2,040	7.3	13.5	.2	K14	K6	<1
LU-119-SF18	06-24-87	347	7.8	13.0	.1	<1	<1	<1
LU-120-SF1	06-23-87	284	8.4	15.5	<.1	<1	K1	K2
LU-126-T	10-07-87	2,500	7.0	11.5	<.1	K2	<1	<1
LU-127-T	06-17-87	1,990	7.3	14.0	<.1	K2	<1	<1
LU-129-T	06-17-87	1,560	7.3	13.0	4.0	<1	<1	<1
LU-131-SY4	06-10-87	830	7.2	13.0	<.1	<1	<1	<1
LU-133-SY29	06-16-87	315	7.8	12.5	<.1	<1	<1	<1
LU-134-SW8	06-16-87	315	8.1	13.0	<.1	>80	<1	<1
LU-135-SW4	06-24-87	480	7.9	12.5	9.5	K2	<1	K2
LU-136-SW22	06-23-87	490	7.7	13.5	<.1	<1	<1	<1
LU-141-W29	07-07-87	950	7.2	12.5	<.1	K16	K1	K6
LU-142-W19	06-26-87	2,060	7.2	17.5	<.1	K7	K1	K11
LU-146-W10	07-08-87	640	8.1	12.5	.1	<1	<1	<1
LU-148-P34	06-25-87	1,120	7.4	12.0	<.1	K1	<1	<1
LU-152-SW32	06-24-87	344	8.3	12.5	.6	<1	<1	<1
LU-160-J11	07-14-87	870	7.3	14.5	<.1	K3	<1	<1
LU-161-J30	07-09-87	1,150	7.7	12.5	.1	<1	<1	<1
LU-165-O12	07-06-87	1,270	7.3	12.5	.1	K13	<1	K1
LU-167-O32	07-13-87	890	7.8	13.5	<.1	21	<1	>100
LU-168-O34	07-14-87	2,110	7.3	13.0	.7	K5	<1	K7
LU-169-O5	07-23-87	810	7.6	17.5	<.1	K12	K3	K12
LU-170-O26	07-07-87	2,710	7.3	12.5	<.1	K1	<1	K1
LU-174-T	06-23-87	2,540	7.4	12.5	3.0	<1	<1	<1
LU-175-T	10-06-87	2,450	7.4	11.5	<.1	>80	K1	<1
LU-177-J27	07-15-87	1,150	7.7	12.5	<.1	K1	<1	K1
LU-179-J33	07-14-87	1,350	7.6	12.5	<.1	K4	<1	<1
LU-180-J12	07-23-87	1,940	7.1	13.0	.8	K3	<1	<1
LU-184-O6	07-08-87	1,450	7.3	12.0	.1	K1	<1	K1
LU-187-O23	10-14-87	2,130	6.8	12.5	<.1	K1	K1	K15
LU-193-T	06-22-87	2,560	7.1	14.0	.1	<1	<1	<1
LU-194-T	06-23-87	2,340	7.0	18.0	<.1	<1	<1	K1
LU-197-O27	07-15-87	2,520	7.4	12.0	14.0	<1	<1	<1
LU-198-W3	07-08-87	750	7.6	12.5	<.1	K7	<1	K1
LU-201-O36	10-13-87	2,150	7.6	12.0	<.1	<1	<1	K10
LU-202-O11	10-14-87	2,480	7.0	11.5	<.1	<1	<1	<1
LU-203-P7	10-08-87	342	8.2	13.5	<.1	K1	<1	<1
LU-301-SW17	06-02-87	117	7.3	10.0	2.6	<1	<1	<1
LU-302-SW29	06-02-87	170	8.3	10.0	2.3	<1	<1	K1
LU-303-SW20	06-03-87	91	9.3	10.0	4.5	<1	<1	<1
LU-304-SW21	06-03-87	170	8.7	9.0	4.3	<1	<1	<1
LU-305-SY16	06-03-87	270	7.4	9.5	1.5	<1	<1	K4
LU-306-SY2	06-03-87	820	7.6	10.0	1.3	<1	<1	<1
LU-307-SY15	06-10-87	298	8.3	10.0	1.6	<1	<1	K1
LU-308-M11	06-09-87	503	7.4	12.0	.7	K1	<1	K3
LU-309-SY12	06-04-87	1,450	7.2	9.0	3.2	<1	<1	<1
LU-310-SF5	06-09-87	590	7.9	11.0	.4	<1	<1	<1

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate (mg/L as HCO_3)	Alkalinity, total (mg/L as $CaCO_3$)
LU-1	06-22-78	450	250	110	41	60	2.7	236	194
LU-14-MA35	08-05-87	560	300	120	53	5.4	1.0	318	261
LU-15-SY18	10-07-87	460	270	130	32	21	29	237	191
LU-16-W40	10-08-87	2,100	1,900	520	190	120	7.8	216	178
LU-105-SY14	06-17-87	140	0	31	10	25	1.0	214	173
LU-112-MA3	07-07-87	1,700	1,600	460	140	100	7.4	184	153
LU-113-M10	06-17-87	1,000	620	210	120	38	3.6	510	407
LU-116-M32	06-25-87	1,100	920	280	100	52	3.6	244	199
LU-119-SF18	06-24-87	150	0	40	10	17	.9	228	185
LU-120-SF1	06-23-87	47	0	10	4.5	48	.9	162	135
LU-126-T	10-07-87	1,700	1,500	500	110	35	3.2	316	259
LU-127-T	06-17-87	1,100	910	250	110	40	3.2	221	178
LU-129-T	06-17-87	770	610	190	66	56	4.0	188	154
LU-131-SY4	06-10-87	440	150	120	30	8.5	1.7	356	291
LU-133-SY29	06-16-87	150	16	46	7.2	7.8	1.0	167	137
LU-134-SW8	06-16-87	82	0	18	8.4	42	2.0	210	170
LU-135-SW4	06-24-87	150	0	34	15	47	5.4	282	230
LU-136-SW22	06-23-87	220	0	30	26	25	1.4	314	255
LU-141-W29	07-07-87	520	210	120	47	19	3.9	379	314
LU-142-W19	06-26-87	1,200	910	300	98	55	3.6	309	251
LU-146-W10	07-08-87	290	45	65	29	23	1.6	299	245
LU-148-P34	06-25-87	600	260	150	52	27	2.0	415	347
LU-152-SW32	06-24-87	64	0	14	6.1	57	1.8	217	193
LU-160-J11	07-14-87	510	240	110	49	15	2.4	325	266
LU-161-J30	07-09-87	520	420	120	49	43	2.2	121	99
LU-165-O12	07-06-87	620	470	150	55	50	2.4	182	150
LU-167-O32	07-13-87	350	280	80	31	69	1.6	87	71
LU-168-O34	07-14-87	960	840	260	70	60	2.5	146	120
LU-169-O5	07-23-87	280	150	66	27	56	1.3	154	125
LU-170-O26	07-07-87	1,300	1200	360	98	150	4.1	122	100
LU-174-T	06-23-87	1,500	1,200	410	100	33	2.7	259	212
LU-175-T	10-06-87	1,700	1,600	420	150	35	2.5	122	97
LU-177-J27	07-15-87	560	490	130	52	42	1.8	82	66
LU-179-J33	07-14-87	700	620	160	69	38	2.6	109	90
LU-180-J12	07-23-87	1,100	990	260	110	47	2.4	150	123
LU-184-O6	07-08-87	720	570	180	60	50	2.5	182	148
LU-187-O23	10-14-87	1,100	950	310	88	59	2.8	245	201
LU-193-T	06-22-87	1,500	1,400	360	150	48	3.8	182	149
LU-194-T	06-23-87	1,500	1,300	400	120	46	3.3	215	175
LU-197-O27	07-15-87	1,800	1,700	490	130	40	2.7	107	87
LU-198-W3	07-08-87	390	170	90	34	14	1.9	268	222
LU-201-O36	10-13-87	1,600	1,500	470	110	45	2.4	112	92
LU-202-O11	10-14-87	730	620	170	71	160	4.8	135	109
LU-203-P7	10-08-87	76	0	17	7.4	53	2.3	218	179
LU-301-SW17	06-02-87	44	9	13	2.9	1.4	.6	43	35
LU-302-SW29	06-02-87	74	7	22	4.6	1.6	.2	82	67
LU-303-SW20	06-03-87	39	5	12	2.2	1.1	.4	31	36
LU-304-SW21	06-03-87	76	10	24	3.8	1.9	<.1	78	66
LU-305-SY16	06-03-87	140	19	44	7.4	2.5	.2	148	118
LU-306-SY2	06-03-87	280	80	87	16	60	2.1	249	203
LU-307-SY15	06-10-87	140	48	45	6.5	3.6	.4	111	94
LU-308-M11	06-09-87	260	33	79	14	2.5	.4	271	223
LU-309-SY12	06-04-87	420	64	140	17	120	2.2	434	354
LU-310-SF5	06-09-87	240	63	74	14	29	.6	220	179

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Carbon dioxide, dis-solved (mg/L as CO_2)	Car-bonate (mg/L as CO_3)	Sulfide, total (mg/L as S)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Bromide, dis-solved (mg/L as Br)	Silica, dis-solved (mg/L as SiO_2)
LU-1	06-22-78	5.9	0	4.0	360	24	1.4	--	7.7
LU-14-MA35	08-05-87	4.5	0	ND	250	9.7	1.3	.075	7.7
LU-15-SY18	10-07-87	16	0	ND	290	29	.9	.039	7.2
LU-16-W40	10-08-87	19	0	11	1,900	210	1.9	1.6	8.0
LU-105-SY14	06-17-87	3.4	0	--	38	1.4	2.0	<.010	10
LU-112-MA3	07-07-87	16	0	29	1,900	8.6	2.2	.13	10
LU-113-M10	06-17-87	91	0	ND	700	14	1.4	.059	15
LU-116-M32	06-25-87	18	0	<.5	1,000	73	.8	.54	11
LU-119-SF18	06-24-87	6.4	0	ND	3.1	1.0	1.0	<.010	16
LU-120-SF1	06-23-87	1.1	0	<.5	8.6	2.8	2.1	.030	11
LU-126-T	10-07-87	47	0	.9	1,400	30	1.5	.18	15
LU-127-T	06-17-87	18	0	.6	910	44	1.7	.27	13
LU-129-T	06-17-87	15	0	ND	670	70	2.1	.50	9.2
LU-131-SY4	06-10-87	40	0	<.5	140	25	1.0	.048	12
LU-133-SY29	06-16-87	4.2	0	<.5	13	8.0	.7	<.010	15
LU-134-SW8	06-16-87	2.7	0	<.5	5.4	1.7	1.6	<.010	9.8
LU-135-SW4	06-24-87	5.6	0	9.3	58	2.5	1.4	.020	7.7
LU-136-SW22	06-23-87	10	0	<.5	22	1.0	1.5	<.010	22
LU-141-W29	07-07-87	43	0	.8	160	7.4	.4	.067	13
LU-142-W19	06-26-87	30	0	7.2	1,100	39	1.2	.27	12
LU-146-W10	07-08-87	4.0	0	ND	120	1.8	1.9	.022	11
LU-148-P34	06-25-87	26	0	ND	230	51	.6	.060	15
LU-152-SW32	06-24-87	1.8	0	<.5	3.0	4.9	1.9	.071	9.4
LU-160-J11	07-14-87	25	0	<.5	240	2.1	2.0	.050	17
LU-161-J30	07-09-87	3.7	0	ND	490	30	2.1	.28	8.7
LU-165-O12	07-06-87	15	0	<.5	540	44	1.7	.31	11
LU-167-O32	07-13-87	2.5	0	ND	390	12	1.3	.15	10
LU-168-O34	07-14-87	11	0	ND	1,100	27	1.5	.22	12
LU-169-O5	07-23-87	6.9	0	ND	270	11	2.1	.15	9.7
LU-170-O26	07-07-87	9.3	0	5.4	1,600	36	1.6	.31	12
LU-174-T	06-23-87	16	0	2.2	1,400	59	1.7	.20	13
LU-175-T	10-06-87	7.2	0	<.5	1,500	47	2.0	.37	9.1
LU-177-J27	07-15-87	2.4	0	<.5	530	16	1.7	.15	9.7
LU-179-J33	07-14-87	4.4	0	<.5	650	34	1.7	.30	10
LU-180-J12	07-23-87	17	0	ND	1,000	29	1.8	.26	9.4
LU-184-O6	07-08-87	15	0	<.5	600	58	1.7	.18	11
LU-187-O23	10-14-87	56	0	ND	1,400	48	1.5	.26	14
LU-193-T	06-22-87	23	0	ND	1,600	55	1.6	.41	12
LU-194-T	06-23-87	31	0	<.5	1,400	30	1.6	.25	11
LU-197-O27	07-15-87	7.4	0	<.5	1,600	35	1.6	.31	8.7
LU-198-W3	07-08-87	11	0	<.5	210	9.7	1.2	.045	8.5
LU-201-O36	10-13-87	5.0	0	<.5	1,600	27	1.7	.24	10
LU-202-O11	10-14-87	21	0	ND	1,000	130	1.2	1.1	14
LU-203-P7	10-08-87	2.5	0	1.1	4.7	6.9	2.0	.076	10
LU-301-SW17	06-02-87	3.4	0	ND	16	1.0	<.1	<.010	11
LU-302-SW29	06-02-87	.7	0	ND	13	1.0	<.1	<.010	8.8
LU-303-SW20	06-03-87	.0	5.0	ND	9.7	.40	.2	<.010	9.3
LU-304-SW21	06-03-87	.3	1.0	ND	19	1.6	<.1	.010	15
LU-305-SY16	06-03-87	8.7	0	ND	42	2.8	<.1	<.010	18
LU-306-SY2	06-03-87	10	0	ND	35	130	.1	<.010	6.6
LU-307-SY15	06-10-87	.9	0	ND	51	4.8	<.1	<.010	9.7
LU-308-M11	06-09-87	17	0	ND	49	4.0	.1	.030	14
LU-309-SY12	06-04-87	41	0	ND	120	170	<.1	.062	11
LU-310-SF5	06-09-87	4.4	0	<.5	56	54	.1	<.010	8.1

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Solids, residue at 180 deg C, dis-solved (mg/L)	Solids, sum of constit-uents, dis-solved (mg/L)	Nitro-gen, nitrite, dis-solved (mg/L as N)	Nitro-gen, NO2+NO3, dis-solved (mg/L as N)	Nitro-gen, ammonia, dis-solved (mg/L as N)	Nitro-gen, am-monia + organic, dis-solved (mg/L as N)	Phos-phorous, ortho, dis-solved (mg/L as P)
LU-1	06-22-78	765	725	--	--	--	--	--
LU-14-MA35	08-05-87	674	640	.011	.537	.207	.60	.001
LU-15-SY18	10-07-87	628	664	.005	.136	.134	.20	<.001
LU-16-W40	10-08-87	3,240	3,080	<.001	<.010	1.50	.80	<.001
LU-105-SY14	06-17-87	216	239	<.010	<.100	.090	.20	<.001
LU-112-MA3	07-07-87	2,910	2,730	.010	<.100	.900	1.0	.004
LU-113-M10	06-17-87	1,430	1,370	<.010	<.100	.310	.30	<.001
LU-116-M32	06-25-87	1,870	1,650	<.010	<.100	.470	1.3	.008
LU-119-SF18	06-24-87	203	207	<.010	<.100	.330	.60	.006
LU-120-SF1	06-23-87	173	172	<.010	<.100	.180	.40	.004
LU-126-T	10-07-87	2,290	2,260	<.001	<.010	.435	.30	<.001
LU-127-T	06-17-87	1,790	1,500	<.010	<.100	.400	.80	<.001
LU-129-T	06-17-87	1,210	1,180	.030	.230	.770	.80	<.001
LU-131-SY4	06-10-87	555	529	<.010	<.100	.110	1.8	.002
LU-133-SY29	06-16-87	190	189	<.010	<.100	.200	<.20	.009
LU-134-SW8	06-16-87	193	195	<.010	<.100	.250	.30	.005
LU-135-SW4	06-24-87	285	319	<.010	<.100	.530	.70	<.001
LU-136-SW22	06-23-87	320	318	<.010	<.100	.440	.70	.006
LU-141-W29	07-07-87	646	578	<.010	<.100	.400	.80	.005
LU-142-W19	06-26-87	1,950	1,780	<.010	<.100	.610	2.2	.010
LU-146-W10	07-08-87	390	409	<.010	<.100	.180	1.1	.001
LU-148-P34	06-25-87	782	741	<.010	<.100	.260	1.2	<.001
LU-152-SW32	06-24-87	212	210	<.010	<.100	.170	1.3	.001
LU-160-J11	07-14-87	624	623	<.010	<.100	.260	.20	.003
LU-161-J30	07-09-87	858	826	<.010	<.100	.870	1.0	<.001
LU-165-O12	07-06-87	992	963	<.010	<.100	.310	1.8	<.001
LU-167-O32	07-13-87	675	657	<.010	<.100	.340	.60	.003
LU-168-O34	07-14-87	1,900	1,620	<.010	<.100	.520	.50	.005
LU-169-O5	07-23-87	652	523	.003	.028	.450	.60	<.001
LU-170-O26	07-07-87	2,500	2,330	<.010	<.100	.320	.40	.001
LU-174-T	06-23-87	2,400	2,160	<.010	<.100	.440	1.8	<.001
LU-175-T	10-06-87	2,380	2,240	<.001	.011	.291	.30	<.001
LU-177-J27	07-15-87	875	842	<.010	.150	.340	.60	.011
LU-179-J33	07-14-87	1,080	1,040	<.010	<.100	.340	.40	.005
LU-180-J12	07-23-87	1,710	1,550	.002	.010	.490	1.3	<.001
LU-184-O6	07-08-87	1,110	1,070	<.010	<.100	.250	2.5	<.001
LU-187-O23	10-14-87	2,350	2,060	.001	<.010	.310	.60	<.001
LU-193-T	06-22-87	2,580	2,340	<.010	<.100	.630	.60	<.001
LU-194-T	06-23-87	2,340	2,130	<.010	<.100	.710	.70	<.001
LU-197-O27	07-15-87	2,520	2,370	<.050	<.100	.430	5.8	.008
LU-198-W3	07-08-87	499	525	<.010	<.100	.180	.60	.002
LU-201-O36	10-13-87	2,480	2,330	<.001	<.010	.463	.60	<.001
LU-202-O11	10-14-87	1,740	1,630	<.001	<.010	.314	.60	<.001
LU-203-P7	10-08-87	208	215	<.001	.029	.190	.20	.002
LU-301-SW17	06-02-87	66	68	<.010	<.100	.030	.40	.004
LU-302-SW29	06-02-87	89	92	<.010	<.100	.030	.60	.012
LU-303-SW20	06-03-87	51	61	<.010	<.100	.020	.20	.012
LU-304-SW21	06-03-87	105	110	<.010	<.100	<.010	<.20	.009
LU-305-SY16	06-03-87	196	191	<.010	<.100	.080	1.2	.010
LU-306-SY2	06-03-87	473	461	<.010	.340	.020	1.0	.001
LU-307-SY15	06-10-87	186	176	<.010	<.100	.030	.20	.011
LU-308-M11	06-09-87	335	302	<.010	<.100	.120	1.6	.010
LU-309-SY12	06-04-87	869	796	.020	11.0	.060	2.2	.002
LU-310-SF5	06-09-87	385	347	<.010	<.100	.220	.80	.027

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)
LU-1	06-22-78	--	--	--	--	--	--	--	--
LU-14-MA35	08-05-87	20	--	<1	--	30	--	--	--
LU-15-SY18	10-07-87	8	1	1	190	100	<1	10	<1
LU-16-W40	10-08-87	<10	1	<1	<100	650	<1	20	<1
LU-105-SY14	06-17-87	10	--	--	--	290	--	--	--
LU-112-MA3	07-07-87	10	--	--	--	1,400	--	--	--
LU-113-M10	06-17-87	20	--	--	--	460	--	--	--
LU-116-M32	06-25-87	10	<1	<1	<100	350	<1	<10	7
LU-119-SF18	06-24-87	<10	--	--	--	190	--	--	--
LU-120-SF1	06-23-87	<10	--	--	--	840	--	--	--
LU-126-T	10-07-87	<10	<1	<1	<100	530	<1	<10	<1
LU-127-T	06-17-87	10	<1	<1	100	350	<1	20	<1
LU-129-T	06-17-87	10	--	--	--	270	--	--	--
LU-131-SY4	06-10-87	20	<1	<1	230	30	<1	110	1
LU-133-SY29	06-16-87	20	<1	9	320	30	<1	<10	<1
LU-134-SW8	06-16-87	<10	--	--	--	650	--	--	--
LU-135-SW4	06-24-87	<10	--	--	--	1,200	--	--	--
LU-136-SW22	06-23-87	20	--	--	--	340	--	--	--
LU-141-W29	07-07-87	<10	<1	<1	42	350	<1	<10	<1
LU-142-W19	06-26-87	30	--	--	--	630	--	--	--
LU-146-W10	07-08-87	<10	--	--	--	300	--	--	--
LU-148-P34	06-25-87	<10	<1	<1	110	210	1	<10	2
LU-152-SW32	06-24-87	10	--	--	--	1,100	--	--	--
LU-160-J11	07-14-87	<10	--	<1	--	170	--	--	--
LU-161-J30	07-09-87	<10	--	--	--	360	--	--	--
LU-165-O12	07-06-87	<10	--	8	--	330	--	--	--
LU-167-O32	07-13-87	<10	--	<1	--	540	--	--	--
LU-168-O34	07-14-87	<10	--	2	--	580	--	--	--
LU-169-O5	07-23-87	<10	<1	<1	19	560	<1	10	<1
LU-170-O26	07-07-87	10	<1	<1	<100	1,000	<1	<10	<1
LU-174-T	06-23-87	10	--	--	--	470	--	--	--
LU-175-T	10-06-87	<10	1	<1	<100	250	<1	20	1
LU-177-J27	07-15-87	<10	--	1	--	320	--	--	--
LU-179-J33	07-14-87	10	<1	3	12	330	<1	<10	<1
LU-180-J12	07-23-87	<10	<1	<1	10	500	<1	10	<1
LU-184-O6	07-08-87	<10	--	--	--	290	--	--	--
LU-187-O23	10-14-87	10	<1	<1	100	430	<1	20	<1
LU-193-T	06-22-87	20	<1	<1	<100	710	<1	<10	<1
LU-194-T	06-23-87	20	--	--	--	360	--	--	--
LU-197-O27	07-15-87	10	<1	<1	<100	310	<1	<10	<1
LU-198-W3	07-08-87	<10	<1	<1	57	180	<1	<10	<1
LU-201-O36	10-13-87	<10	1	5	<100	330	1	20	<1
LU-202-O11	10-14-87	<10	<1	<1	<100	1,500	<1	10	<1
LU-203-P7	10-08-87	4	1	<1	84	1,000	<1	20	<1
LU-301-SW17	06-02-87	20	<1	2	20	20	<1	20	2
LU-302-SW29	06-02-87	20	<1	<1	20	<10	<1	<10	1
LU-303-SW20	06-03-87	30	--	--	--	10	--	--	--
LU-304-SW21	06-03-87	20	--	--	--	40	--	--	--
LU-305-SY16	06-03-87	60	<1	1	21	50	<1	20	1
LU-306-SY2	06-03-87	20	<1	<1	71	30	<1	20	1
LU-307-SY15	06-10-87	20	--	--	--	70	--	--	--
LU-308-M11	06-09-87	30	--	--	--	40	--	--	--
LU-309-SY12	06-04-87	20	<1	<1	62	250	<1	<10	3
LU-310-SF5	06-09-87	20	--	--	--	1,100	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Nickel, dis-solved (µg/L as Ni)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)
LU-1	06-22-78	210	--	--	80	--	--	--	--
LU-14-MA35	08-05-87	260	--	--	25	--	--	--	--
LU-15-SY18	10-07-87	19	5	22	37	<.1	10	<1	<1.0
LU-16-W40	10-08-87	30	<5	90	20	.3	4	<1	<1.0
LU-105-SY14	06-17-87	4	--	--	<1	--	--	--	--
LU-112-MA3	07-07-87	100	--	--	20	--	--	--	--
LU-113-M10	06-17-87	860	--	--	35	--	--	--	--
LU-116-M32	06-25-87	460	<5	50	50	.2	4	<1	1.0
LU-119-SF18	06-24-87	610	--	--	6	--	--	--	--
LU-120-SF1	06-23-87	77	--	--	3	--	--	--	--
LU-126-T	10-07-87	180	12	60	20	<.1	<1	<1	<1.0
LU-127-T	06-17-87	30	<5	60	20	<.1	<1	<1	<1.0
LU-129-T	06-17-87	70	--	--	14	--	--	--	--
LU-131-SY4	06-10-87	300	<5	22	8	<.1	<1	<1	<1.0
LU-133-SY29	06-16-87	190	<5	7	7	1.5	<1	<1	<1.0
LU-134-SW8	06-16-87	8	--	--	10	--	--	--	--
LU-135-SW4	06-24-87	43	--	--	3	--	--	--	--
LU-136-SW22	06-23-87	130	--	--	4	--	--	--	--
LU-141-W29	07-07-87	39	<5	40	7	.4	2	<1	<1.0
LU-142-W19	06-26-87	80	--	--	20	--	--	--	--
LU-146-W10	07-08-87	25	--	--	<1	--	--	--	--
LU-148-P34	06-25-87	1,200	<5	29	<1	.8	3	<1	7.0
LU-152-SW32	06-24-87	18	--	--	<1	--	--	--	--
LU-160-J11	07-14-87	130	--	--	6	--	--	--	--
LU-161-J30	07-09-87	300	--	--	5	--	--	--	--
LU-165-O12	07-06-87	450	--	--	2	--	--	--	--
LU-167-O32	07-13-87	360	--	--	10	--	--	--	--
LU-168-O34	07-14-87	860	--	--	50	--	--	--	--
LU-169-O5	07-23-87	100	<5	24	4	.6	<1	4	<1.0
LU-170-O26	07-07-87	360	<5	40	50	3.9	4	<1	<1.0
LU-174-T	06-23-87	220	--	--	20	--	--	--	--
LU-175-T	10-06-87	80	<5	40	10	<.1	5	<1	<1.0
LU-177-J27	07-15-87	350	--	--	11	--	--	--	--
LU-179-J33	07-14-87	1,100	<5	39	21	1.1	5	<1	<1.0
LU-180-J12	07-23-87	220	<5	63	6	<.1	<1	<1	<1.0
LU-184-O6	07-08-87	320	--	--	5	--	--	--	--
LU-187-O23	10-14-87	680	<5	30	30	<.1	<1	<1	<1.0
LU-193-T	06-22-87	1,800	<5	70	40	1.5	<1	<1	1.0
LU-194-T	06-23-87	1,500	--	--	90	--	--	--	--
LU-197-O27	07-15-87	260	<5	30	20	.2	<1	<1	<1.0
LU-198-W3	07-08-87	110	<5	12	5	3.4	2	<1	<1.0
LU-201-O36	10-13-87	910	<5	30	20	<.1	3	<1	<1.0
LU-202-O11	10-14-87	650	<5	50	40	<.1	<1	4	<1.0
LU-203-P7	10-08-87	5	<5	17	4	<.1	4	<1	<1.0
LU-301-SW17	06-02-87	550	<5	5	47	<.1	1	<1	<1.0
LU-302-SW29	06-02-87	51	9	<4	55	<.1	<1	<1	<1.0
LU-303-SW20	06-03-87	<3	--	--	3	--	--	--	--
LU-304-SW21	06-03-87	<3	--	--	2	--	--	--	--
LU-305-SY16	06-03-87	680	<5	7	40	<.1	1	<1	1.0
LU-306-SY2	06-03-87	240	<5	11	290	<.1	1	<1	<1.0
LU-307-SY15	06-10-87	65	--	--	59	--	--	--	--
LU-308-M11	06-09-87	5,500	--	--	180	--	--	--	--
LU-309-SY12	06-04-87	12	10	14	8	<.1	<1	<1	<1.0
LU-310-SF5	06-09-87	1,300	--	--	230	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Strontium, dissolved (µg/L as Sr)	Zinc, dissolved (µg/L as Zn)	Carbon, organic, dissolved (mg/L as C)	Cyanide, total (mg/L as Cn)	Sodium adsorption ratio	Cation-anion imbalance (percent)	Major-ion water type (cation : anion)
LU-1	06-22-78	--	--	5.6	--	1	+ 2.0	C M N : S
LU-14-MA35	08-05-87	35,000	--	3.7	--	.1	+ 2.8	C M : H S
LU-15-SY18	10-07-87	7,300	8	3.6	<.010	.4	+ 0.7	C : S H
LU-16-W40	10-08-87	9,500	10	1.4	<.010	1	- 2.0	C M : S
LU-105-SY14	06-17-87	15,000	--	2.4	--	1	- 7.4	C N M : H
LU-112-MA3	07-07-87	11,000	--	1.2	--	1	- 4.5	C M : S
LU-113-M10	06-17-87	20,000	--	2.5	--	.5	- 1.8	C M : S
LU-116-M32	06-25-87	12,000	40	1.6	<.010	.7	- 4.0	C M : S
LU-119-SF18	06-24-87	4,200	--	4.0	--	.6	- 2.4	C M N : H
LU-120-SF1	06-23-87	3,000	--	2.5	--	3	- 0.3	N : H
LU-126-T	10-07-87	10,000	<10	2.3	<.010	.4	+ 0.8	C : S
LU-127-T	06-17-87	14,000	10	2.7	<.010	.5	- 0.5	C M : S
LU-129-T	06-17-87	19,000	--	2.4	--	.9	- 3.8	C M : S
LU-131-SY4	06-10-87	15,000	47	2.6	<.010	.2	- 1.5	C : H
LU-133-SY29	06-16-87	7,300	7	3.4	<.010	.3	+ 2.3	C : H
LU-134-SW8	06-16-87	2,100	--	4.1	--	2	- 2.4	N C : H
LU-135-SW4	06-24-87	7,200	--	2.0	--	2	- 6.2	N C M : H
LU-136-SW22	06-23-87	34,000	--	6.5	--	.8	- 1.5	M C N : H
LU-141-W29	07-07-87	20,000	3	1.3	<.010	.4	+ 4.7	C M : H
LU-142-W19	06-26-87	13,000	--	1.5	--	.7	- 6.0	C M : S
LU-146-W10	07-08-87	7,600	--	1.5	--	.6	- 4.9	C M : H
LU-148-P34	06-25-87	7,800	75	2.5	<.010	.5	+ 0.7	C M : H S
LU-152-SW32	06-24-87	3,500	--	2.1	--	3	- 0.7	N : H
LU-160-J11	07-14-87	25,000	--	1.2	--	.3	+ 1.5	C M : H S
LU-161-J30	07-09-87	19,000	--	.9	--	.9	- 2.9	C M : S
LU-165-O12	07-06-87	18,000	--	1.5	--	.9	- 2.9	C M : S
LU-167-O32	07-13-87	18,000	--	1.3	--	2	+ 0.3	C N M : S
LU-168-O34	07-14-87	16,000	--	1.4	--	.9	- 9.0	C : S
LU-169-O5	07-23-87	2,300	170	2.0	<.010	2	- 3.1	C N M : S
LU-170-O26	07-07-87	11,000	20	0.9	<.010	2	- 5.0	C M N : S
LU-174-T	06-23-87	14,000	--	2.1	--	.4	- 7.0	C : S
LU-175-T	10-06-87	9,100	10	1.1	<.010	.4	+ 0.6	C : S
LU-177-J27	07-15-87	17,000	--	1.6	--	.8	+ 0.5	C M : S
LU-179-J33	07-14-87	18,000	10	1.0	<.010	.7	- 1.6	C M : S
LU-180-J12	07-23-87	13,000	150	1.8	<.010	.6	+ 0.5	C M : S
LU-184-O6	07-08-87	19,000	--	1.1	--	.9	- 1.8	C M : S
LU-187-O23	10-14-87	8,700	2,000	1.6	<.010	.8	-14.7	C : S
LU-193-T	06-22-87	12,000	100	1.4	<.010	.6	- 7.2	C M : S
LU-194-T	06-23-87	13,000	--	1.4	--	.5	- 2.8	C : S
LU-197-O27	07-15-87	12,000	20	1.4	<.010	.4	+ 1.5	C : S
LU-198-W3	07-08-87	23,000	4	1.5	<.010	.3	- 3.6	C M : H S
LU-201-O36	10-13-87	9,000	110	.8	<.010	.5	- 1.7	C : S
LU-202-O11	10-14-87	11,000	30	.8	<.010	3	-10.5	C N M : S
LU-203-P7	10-08-87	2,700	<3	2.5	<.010	3	- 1.2	N : H
LU-301-SW17	06-02-87	47	120	1.1	--	.1	- 3.8	C : H
LU-302-SW29	06-02-87	32	40	.8	.300	.1	- 2.9	C : H
LU-303-SW20	06-03-87	24	--	.6	--	.1	- 4.1	C : H
LU-304-SW21	06-03-87	44	--	.8	--	.1	- 5.2	C : H
LU-305-SY16	06-03-87	63	210	11	--	.1	- 6.7	C : H
LU-306-SY2	06-03-87	620	100	4.4	--	2	- 0.8	C N : H C
LU-307-SY15	06-10-87	82	--	1.6	--	.1	- 1.2	C : H
LU-308-M11	06-09-87	110	--	11	--	.1	- 0.6	C : H
LU-309-SY12	06-04-87	410	1,100	2.5	--	3	- 5.3	C N : H C
LU-310-SF5	06-09-87	170	--	8.2	--	.8	- 0.8	C : H C

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Di-chloro-bromo-methane, total (µg/L)	Carbon-tetra-chlo-ride, total (µg/L)	1,2-Di-chloro-ethane, total (µg/L)	Bromo-form, total (µg/L)	Chloro-di-bromo-methane, total (µg/L)	Chloro-form, total (µg/L)	Toluene, total (µg/L)
LU-1	06-22-78	--	--	--	--	--	--	--
LU-14-MA35	08-05-87	--	--	--	--	--	--	--
LU-15-SY18	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-16-W40	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-105-SY14	06-17-87	--	--	--	--	--	--	--
LU-112-MA3	07-07-87	--	--	--	--	--	--	--
LU-113-M10	06-17-87	--	--	--	--	--	--	--
LU-116-M32	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-119-SF18	06-24-87	--	--	--	--	--	--	--
LU-120-SF1	06-23-87	--	--	--	--	--	--	--
LU-126-T	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-127-T	06-17-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-129-T	06-17-87	--	--	--	--	--	--	--
LU-131-SY4	06-10-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-133-SY29	06-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-134-SW8	06-16-87	--	--	--	--	--	--	--
LU-135-SW4	06-24-87	--	--	--	--	--	--	--
LU-136-SW22	06-23-87	--	--	--	--	--	--	--
LU-141-W29	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-142-W19	06-26-87	--	--	--	--	--	--	--
LU-146-W10	07-08-87	--	--	--	--	--	--	--
LU-148-P34	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-152-SW32	06-24-87	--	--	--	--	--	--	--
LU-160-J11	07-14-87	--	--	--	--	--	--	--
LU-161-J30	07-09-87	--	--	--	--	--	--	--
LU-165-O12	07-06-87	--	--	--	--	--	--	--
LU-167-O32	07-13-87	--	--	--	--	--	--	--
LU-168-O34	07-14-87	--	--	--	--	--	--	--
LU-169-O5	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-170-O26	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-174-T	06-23-87	--	--	--	--	--	--	--
LU-175-T	10-06-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-177-J27	07-15-87	--	--	--	--	--	--	--
LU-179-J33	07-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-180-J12	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-184-O6	07-08-87	--	--	--	--	--	--	--
LU-187-O23	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-193-T	06-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-194-T	06-23-87	--	--	--	--	--	--	--
LU-197-O27	07-15-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-198-W3	07-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-201-O36	10-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-202-O11	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-203-P7	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-301-SW17	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-302-SW29	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-303-SW20	06-03-87	--	--	--	--	--	--	--
LU-304-SW21	06-03-87	--	--	--	--	--	--	--
LU-305-SY16	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-306-SY2	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-307-SY15	06-10-87	--	--	--	--	--	--	--
LU-308-M11	06-09-87	--	--	--	--	--	--	--
LU-309-SY12	06-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-310-SF5	06-09-87	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Benzene, total (µg/L)	Chloro-benzene, total (µg/L)	Chloro-ethane, total (µg/L)	Ethyl-benzene, total (µg/L)	Methyl-bromide, total (µg/L)	Methyl-chlo-ride, total (µg/L)	Methyl-ene chlo-ride, total (µg/L)
LU-1	06-22-78	--	--	--	--	--	--	--
LU-14-MA35	08-05-87	--	--	--	--	--	--	--
LU-15-SY18	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-16-W40	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-105-SY14	06-17-87	--	--	--	--	--	--	--
LU-112-MA3	07-07-87	--	--	--	--	--	--	--
LU-113-M10	06-17-87	--	--	--	--	--	--	--
LU-116-M32	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-119-SF18	06-24-87	--	--	--	--	--	--	--
LU-120-SF1	06-23-87	--	--	--	--	--	--	--
LU-126-T	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-127-T	06-17-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-129-T	06-17-87	--	--	--	--	--	--	--
LU-131-SY4	06-10-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-133-SY29	06-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-134-SW8	06-16-87	--	--	--	--	--	--	--
LU-135-SW4	06-24-87	--	--	--	--	--	--	--
LU-136-SW22	06-23-87	--	--	--	--	--	--	--
LU-141-W29	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-142-W19	06-26-87	--	--	--	--	--	--	--
LU-146-W10	07-08-87	--	--	--	--	--	--	--
LU-148-P34	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-152-SW32	06-24-87	--	--	--	--	--	--	--
LU-160-J11	07-14-87	--	--	--	--	--	--	--
LU-161-J30	07-09-87	--	--	--	--	--	--	--
LU-165-O12	07-06-87	--	--	--	--	--	--	--
LU-167-O32	07-13-87	--	--	--	--	--	--	--
LU-168-O34	07-14-87	--	--	--	--	--	--	--
LU-169-O5	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-170-O26	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-174-T	06-23-87	--	--	--	--	--	--	--
LU-175-T	10-06-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-177-J27	07-15-87	--	--	--	--	--	--	--
LU-179-J33	07-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-180-J12	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-184-O6	07-08-87	--	--	--	--	--	--	--
LU-187-O23	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-193-T	06-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-194-T	06-23-87	--	--	--	--	--	--	--
LU-197-O27	07-15-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-198-W3	07-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-201-O36	10-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-202-O11	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-203-P7	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-301-SW17	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-302-SW29	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-303-SW20	06-03-87	--	--	--	--	--	--	--
LU-304-SW21	06-03-87	--	--	--	--	--	--	--
LU-305-SY16	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-306-SY2	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-307-SY15	06-10-87	--	--	--	--	--	--	--
LU-308-M11	06-09-87	--	--	--	--	--	--	--
LU-309-SY12	06-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-310-SF5	06-09-87	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Tetra-chloro-ethyl-ene, total (µg/L)	Tri-chloro-fluoro-methane, total (µg/L)	1,1-Di-chloro-ethane, total (µg/L)	1,1-Di-chloro-ethyl-ene, total (µg/L)	1,1,1-Tri-chloro-ethane, total (µg/L)	1,1,2-Tri-chloro-ethane, total (µg/L)	1,1,2,2 Tetra-chloro-ethane, total (µg/L)	1,2-Di-Chloro-benzene, total (µg/L)
LU-1	06-22-78	--	--	--	--	--	--	--	--
LU-14-MA35	08-05-87	--	--	--	--	--	--	--	--
LU-15-SY18	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-16-W40	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-105-SY14	06-17-87	--	--	--	--	--	--	--	--
LU-112-MA3	07-07-87	--	--	--	--	--	--	--	--
LU-113-M10	06-17-87	--	--	--	--	--	--	--	--
LU-116-M32	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-119-SF18	06-24-87	--	--	--	--	--	--	--	--
LU-120-SF1	06-23-87	--	--	--	--	--	--	--	--
LU-126-T	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-127-T	06-17-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-129-T	06-17-87	--	--	--	--	--	--	--	--
LU-131-SY4	06-10-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-133-SY29	06-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-134-SW8	06-16-87	--	--	--	--	--	--	--	--
LU-135-SW4	06-24-87	--	--	--	--	--	--	--	--
LU-136-SW22	06-23-87	--	--	--	--	--	--	--	--
LU-141-W29	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-142-W19	06-26-87	--	--	--	--	--	--	--	--
LU-146-W10	07-08-87	--	--	--	--	--	--	--	--
LU-148-P34	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-152-SW32	06-24-87	--	--	--	--	--	--	--	--
LU-160-J11	07-14-87	--	--	--	--	--	--	--	--
LU-161-J30	07-09-87	--	--	--	--	--	--	--	--
LU-165-O12	07-06-87	--	--	--	--	--	--	--	--
LU-167-O32	07-13-87	--	--	--	--	--	--	--	--
LU-168-O34	07-14-87	--	--	--	--	--	--	--	--
LU-169-O5	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-170-O26	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-174-T	06-23-87	--	--	--	--	--	--	--	--
LU-175-T	10-06-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-177-J27	07-15-87	--	--	--	--	--	--	--	--
LU-179-J33	07-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-180-J12	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-184-O6	07-08-87	--	--	--	--	--	--	--	--
LU-187-O23	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-193-T	06-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-194-T	06-23-87	--	--	--	--	--	--	--	--
LU-197-O27	07-15-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-198-W3	07-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-201-O36	10-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-202-O11	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-203-P7	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-301-SW17	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-302-SW29	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-303-SW20	06-03-87	--	--	--	--	--	--	--	--
LU-304-SW21	06-03-87	--	--	--	--	--	--	--	--
LU-305-SY16	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-306-SY2	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-307-SY15	06-10-87	--	--	--	--	--	--	--	--
LU-308-M11	06-09-87	--	--	--	--	--	--	--	--
LU-309-SY12	06-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-310-SF5	06-09-87	--	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	1,2-Di-chloro-propane, total (µg/L)	1,2-Transdi-chloro-ethene, total (µg/L)	1,3-Di-chloro-propene, total (µg/L)	1,3-Di-chloro-benzene, total (µg/L)	1,4-Di-chloro-benzene, total (µg/L)	2-Chloro-ethyl-vinyl-ether, total (µg/L)	Di-chloro-Di-fluoro-methane, total (µg/L)
LU-1	06-22-78	--	--	--	--	--	--	--
LU-14-MA35	08-05-87	--	--	--	--	--	--	--
LU-15-SY18	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-16-W40	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-105-SY14	06-17-87	--	--	--	--	--	--	--
LU-112-MA3	07-07-87	--	--	--	--	--	--	--
LU-113-M10	06-17-87	--	--	--	--	--	--	--
LU-116-M32	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-119-SF18	06-24-87	--	--	--	--	--	--	--
LU-120-SF1	06-23-87	--	--	--	--	--	--	--
LU-126-T	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-127-T	06-17-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-129-T	06-17-87	--	--	--	--	--	--	--
LU-131-SY4	06-10-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-133-SY29	06-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-134-SW8	06-16-87	--	--	--	--	--	--	--
LU-135-SW4	06-24-87	--	--	--	--	--	--	--
LU-136-SW22	06-23-87	--	--	--	--	--	--	--
LU-141-W29	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-142-W19	06-26-87	--	--	--	--	--	--	--
LU-146-W10	07-08-87	--	--	--	--	--	--	--
LU-148-P34	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-152-SW32	06-24-87	--	--	--	--	--	--	--
LU-160-J11	07-14-87	--	--	--	--	--	--	--
LU-161-J30	07-09-87	--	--	--	--	--	--	--
LU-165-O12	07-06-87	--	--	--	--	--	--	--
LU-167-O32	07-13-87	--	--	--	--	--	--	--
LU-168-O34	07-14-87	--	--	--	--	--	--	--
LU-169-O5	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-170-O26	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-174-T	06-23-87	--	--	--	--	--	--	--
LU-175-T	10-06-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-177-J27	07-15-87	--	--	--	--	--	--	--
LU-179-J33	07-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-180-J12	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-184-O6	07-08-87	--	--	--	--	--	--	--
LU-187-O23	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-193-T	06-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-194-T	06-23-87	--	--	--	--	--	--	--
LU-197-O27	07-15-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-198-W3	07-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-201-O36	10-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-202-O11	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-203-P7	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-301-SW17	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-302-SW29	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-303-SW20	06-03-87	--	--	--	--	--	--	--
LU-304-SW21	06-03-87	--	--	--	--	--	--	--
LU-305-SY16	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-306-SY2	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-307-SY15	06-10-87	--	--	--	--	--	--	--
LU-308-M11	06-09-87	--	--	--	--	--	--	--
LU-309-SY12	06-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-310-SF5	06-09-87	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Trans-1,3-Dichloropropene, total (µg/L)	Cis 1,3-Dichloropropene, total (µg/L)	1,2-Dibromoethylene, total (µg/L)	Vinyl chloride, total (µg/L)	Trichloroethylene, total (µg/L)	Styrene, total (µg/L)	Xylene, total water whole tot rec (µg/L)
LU-1	06-22-78	--	--	--	--	--	--	--
LU-14-MA35	08-05-87	--	--	--	--	--	--	--
LU-15-SY18	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-16-W40	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-105-SY14	06-17-87	--	--	--	--	--	--	--
LU-112-MA3	07-07-87	--	--	--	--	--	--	--
LU-113-M10	06-17-87	--	--	--	--	--	--	--
LU-116-M32	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-119-SF18	06-24-87	--	--	--	--	--	--	--
LU-120-SF1	06-23-87	--	--	--	--	--	--	--
LU-126-T	10-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-127-T	06-17-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-129-T	06-17-87	--	--	--	--	--	--	--
LU-131-SY4	06-10-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-133-SY29	06-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-134-SW8	06-16-87	--	--	--	--	--	--	--
LU-135-SW4	06-24-87	--	--	--	--	--	--	--
LU-136-SW22	06-23-87	--	--	--	--	--	--	--
LU-141-W29	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-142-W19	06-26-87	--	--	--	--	--	--	--
LU-146-W10	07-08-87	--	--	--	--	--	--	--
LU-148-P34	06-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-152-SW32	06-24-87	--	--	--	--	--	--	--
LU-160-J11	07-14-87	--	--	--	--	--	--	--
LU-161-J30	07-09-87	--	--	--	--	--	--	--
LU-165-O12	07-06-87	--	--	--	--	--	--	--
LU-167-O32	07-13-87	--	--	--	--	--	--	--
LU-168-O34	07-14-87	--	--	--	--	--	--	--
LU-169-O5	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-170-O26	07-07-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-174-T	06-23-87	--	--	--	--	--	--	--
LU-175-T	10-06-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-177-J27	07-15-87	--	--	--	--	--	--	--
LU-179-J33	07-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-180-J12	07-23-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-184-O6	07-08-87	--	--	--	--	--	--	--
LU-187-O23	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-193-T	06-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-194-T	06-23-87	--	--	--	--	--	--	--
LU-197-O27	07-15-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-198-W3	07-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-201-O36	10-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-202-O11	10-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-203-P7	10-08-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-301-SW17	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-302-SW29	06-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-303-SW20	06-03-87	--	--	--	--	--	--	--
LU-304-SW21	06-03-87	--	--	--	--	--	--	--
LU-305-SY16	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-306-SY2	06-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-307-SY15	06-10-87	--	--	--	--	--	--	--
LU-308-M11	06-09-87	--	--	--	--	--	--	--
LU-309-SY12	06-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
LU-310-SF5	06-09-87	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Tritium, total (pCi/L)	Tritium, total (t.u.)	Gross alpha, dis-solved (μg/L as u-nat)	Gross alpha, dis-solved (pCi/L) O.D.H. labs	Gross beta, dis-solved (pCi/L as Sr/Yt-90)	Gross beta, dis-solved (pCi/L as Cs-137)	Uranium, dis-solved, extrac-tion (μg/L)	Uranium, natural, dis-solved (μg/L as U)
LU-1	06-22-78	--	--	--	--	--	--	--	--
LU-14-MA35	08-05-87	43	13	--	--	--	--	--	--
LU-15-SY18	10-07-87	--	--	8.6	<3	25	36	--	1.6
LU-16-W40	10-08-87	--	--	3.6	<3	8.6	13	--	.09
LU-105-SY14	06-17-87	<.3	<.1	--	--	--	--	--	--
LU-112-MA3	07-07-87	--	--	--	--	--	--	--	--
LU-113-M10	06-17-87	30	9	--	--	--	--	--	--
LU-116-M32	06-25-87	40	12	8.4	--	5.8	8.9	.56	--
LU-119-SF18	06-24-87	--	--	--	--	--	--	--	--
LU-120-SF1	06-23-87	--	--	--	--	--	--	--	--
LU-126-T	10-07-87	--	--	<.4	<3	3.9	6.3	--	.01
LU-127-T	06-17-87	2.5	1	3.6	--	3.4	5.1	.02	--
LU-129-T	06-17-87	8.0	3	--	--	--	--	--	--
LU-131-SY4	06-10-87	24	8	8.1	--	3.9	5.3	.14	--
LU-133-SY29	06-16-87	--	--	3.7	--	1.5	1.9	.09	--
LU-134-SW8	06-16-87	<.3	<.1	--	--	--	--	--	--
LU-135-SW4	06-24-87	--	--	--	--	--	--	--	--
LU-136-SW22	06-23-87	57	18	--	--	--	--	--	--
LU-141-W29	07-07-87	--	--	1.5	--	4.7	7.0	.18	--
LU-142-W19	06-26-87	--	--	--	--	--	--	--	--
LU-146-W10	07-08-87	--	--	--	--	--	--	--	--
LU-148-P34	06-25-87	--	--	5.6	--	3.2	4.7	1.2	--
LU-152-SW32	06-24-87	--	--	--	--	--	--	--	--
LU-160-J11	07-14-87	--	--	--	--	--	--	--	--
LU-161-J30	07-09-87	6.0	2	--	--	--	--	--	--
LU-165-O12	07-06-87	--	--	--	--	--	--	--	--
LU-167-O32	07-13-87	--	--	--	<3	--	--	--	--
LU-168-O34	07-14-87	--	--	--	--	--	--	--	--
LU-169-O5	07-23-87	<5.7	<2	5.4	--	4.0	5.2	.09	--
LU-170-O26	07-07-87	--	--	1.1	--	3.4	5.1	.13	--
LU-174-T	06-23-87	--	--	--	--	--	--	--	--
LU-175-T	10-06-87	--	--	7.6	<3	2.8	4.2	--	.03
LU-177-J27	07-15-87	--	--	--	--	--	--	--	--
LU-179-J33	07-14-87	--	--	<.4	<3	2.5	3.9	.07	--
LU-180-J12	07-23-87	<1.0	<.3	<.4	--	3.2	4.8	.13	--
LU-184-O6	07-08-87	--	--	--	--	--	--	--	--
LU-187-O23	10-14-87	--	--	<.4	<3	4.2	6.2	--	.47
LU-193-T	06-22-87	9.6	3	<.4	--	5.2	8.1	.18	--
LU-194-T	06-23-87	.9	.3	--	--	--	--	--	--
LU-197-O27	07-15-87	--	--	17	6.3	5.0	7.4	.20	--
LU-198-W3	07-08-87	--	--	7.1	<3	3.8	5.3	3.6	--
LU-201-O36	10-13-87	--	--	<.4	9.4	4.2	6.2	--	.25
LU-202-O11	10-14-87	--	--	2.2	<3	3.9	5.7	--	.48
LU-203-P7	10-08-87	--	--	<.4	--	1.4	1.9	--	.01
LU-301-SW17	06-02-87	--	--	<.4	--	1.1	1.2	<.01	--
LU-302-SW29	06-02-87	--	--	<.4	--	<.4	<.4	<.01	--
LU-303-SW20	06-03-87	76	24	--	--	--	--	--	--
LU-304-SW21	06-03-87	--	--	--	--	--	--	--	--
LU-305-SY16	06-03-87	92	29	2.1	--	.9	1.1	.09	--
LU-306-SY2	06-03-87	86	27	5.2	--	6.3	8.9	6.7	--
LU-307-SY15	06-10-87	--	--	--	--	--	--	--	--
LU-308-M11	06-09-87	62	19	--	--	--	--	--	--
LU-309-SY12	06-04-87	--	--	<.4	--	1.1	1.4	.99	--
LU-310-SF5	06-09-87	--	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Remarks
LU-1	06-22-78	--
LU-14-MA35	08-05-87	--
LU-15-SY18	10-07-87	High coliform background count
LU-16-W40	10-08-87	Sulfur odor
LU-105-SY14	06-17-87	--
LU-112-MA3	07-07-87	Turbid water, sulfur odor
LU-113-M10	06-17-87	High coliform background count
LU-116-M32	06-25-87	Jet pump
LU-119-SF18	06-24-87	High coliform background count
LU-120-SF1	06-23-87	--
LU-126-T	10-07-87	Sulfur odor
LU-127-T	06-17-87	Sulfur odor
LU-129-T	06-17-87	--
LU-131-SY4	06-10-87	--
LU-133-SY29	06-16-87	--
LU-134-SW8	06-16-87	Sulfur odor, high coliform background count
LU-135-SW4	06-24-87	Turbid water, sulfur odor
LU-136-SW22	06-23-87	--
LU-141-W29	07-07-87	Sulfur odor
LU-142-W19	06-26-87	Sulfur odor
LU-146-W10	07-08-87	--
LU-148-P34	06-25-87	High coliform background count
LU-152-SW32	06-24-87	--
LU-160-J11	07-14-87	--
LU-161-J30	07-09-87	--
LU-165-O12	07-06-87	--
LU-167-O32	07-13-87	--
LU-168-O34	07-14-87	--
LU-169-O5	07-23-87	--
LU-170-O26	07-07-87	Sulfur odor
LU-174-T	06-23-87	Sulfur odor
LU-175-T	10-06-87	Sulfur odor
LU-177-J27	07-15-87	High coliform background count
LU-179-J33	07-14-87	Jet pump
LU-180-J12	07-23-87	--
LU-184-O6	07-08-87	--
LU-187-O23	10-14-87	High coliform background count, hydrocarbon odor
LU-193-T	06-22-87	--
LU-194-T	06-23-87	Sulfur odor
LU-197-O27	07-15-87	Sulfur odor
LU-198-W3	07-08-87	Sulfur odor
LU-201-O36	10-13-87	High coliform background count, hydrocarbon odor and film on water surface
LU-202-O11	10-14-87	--
LU-203-P7	10-08-87	High coliform background count
LU-301-SW17	06-02-87	--
LU-302-SW29	06-02-87	--
LU-303-SW20	06-03-87	--
LU-304-SW21	06-03-87	--
LU-305-SY16	06-03-87	--
LU-306-SY2	06-03-87	--
LU-307-SY15	06-10-87	--
LU-308-M11	06-09-87	High coliform background count, water is yellow-brown color
LU-309-SY12	06-04-87	--
LU-310-SF5	06-09-87	Water is yellow-green color

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Station number	Name	Type of site	Type of aqui-fer	Geologic-unit Code
S-3-B12	411914083045300	Keiser SE. of Fremont	GW	C	BILD
S-11-M15	412356083212600	NWOH Test-Ackerman nr Gibsonburg	GW	M	GFLD,LCKP
S-18-R1	412537083040100	NWOH Test-Lamalie nr Wightmans Grove	GW	M	BILD
S-30-T9	412417082543000	Millers Blue Hole Spring nr Vickery	SP	M	BILD
S-31-S32	412045083090600	Gottron Quarry Bench Spring at Fremont	SP	U	BILD
S-32-S32	412048083085500	Gottron Quarry Floor Spring at Fremont	SP	M	BILD,LCKP
S-33-WO22	412805083211400	Martin-Marietta Quarry Spring at Woodville	SP	U	LCKP
S-34-G31	411551083030900	St. Francis Spring at Green Springs	SP	C	BILD
S-102-R35	412604083062100	Thrun W. of Wightmans Grove	GW	C	LCKP
S-105-RL18	412314083040600	Overmyer NE. of Fremont	GW	C	BILD
S-107-RL33	412123083012000	Diedrich nr Erlin	GW	C	BILD
S-110-S26	412143083053500	Heinz No. 1 at Fremont	GW	M	BILD,LCKP
S-118-B10	411920083071600	Loew S. of Fremont	GW	C	BILD
S-119-B23	411729083061700	Sacks S. of Fremont	GW	M	BILD,LCKP
S-122-B19	411755083111000	Roth nr Havens	GW	N	BILD,LCKP
S-123-B32	411547083093900	Guth nr Green Springs	GW	C	LCKP
S-126-J33	411602083145400	Mutchler nr Burgoon	GW	C	LCKP
S-129-Y25	411644082511600	France Stone at Bellevue	GW	N	DVNN,BILD
S-130-Y13	411757082504300	Gardner N. of Bellevue	GW	N	DVNN,BILD
S-132-Y1	412026082505000	Groves N. of Bellevue	GW	N	DVNN,BILD
S-135-Y8	411935082560300	Snyder NE. of Clyde	GW	C	BILD
S-136A-Y17	411806082554800	Steinbauer Farms nr Clyde	GW	U	BILD
S-141-Y21	411722082540200	Gore S. of Wales Corners	GW	U	BILD
S-144-RL35	412102082585000	Hoffman N. of Clyde	GW	C	BILD
S-147-G25	411632082580300	Green Hills G.C. S. of Clyde	GW	C	BILD
S-161-J3	412013083142400	Hallbert NW. of Gabels Corners	GW	U	LCKP
S-163-W23	412241083131600	Zimmerman SE. of Hessville	GW	U	LCKP
S-165-S21	412241083080400	Dick N. of Fremont	GW	C	LCKP
S-166-S9	412420083081600	Schneider S. of Kingsway	GW	C	BILD
S-170-W12	412409083110200	Wonderly nr Lindsey	GW	U	LCKP
S-171-W11	412449083130400	Roepke nr Lindsey	GW	M	GFLD,LCKP
S-173-R31	412621083102400	Lagrou NE. of Lindsey	GW	C	LCKP
S-175-W5	412451083153600	Fahle NW. of Hessville	GW	C	LCKP
S-179-M23	412249083191400	Village Well 4 at Gibsonburg	GW	U	LCKP
S-186-WO1	412537083181100	James nr Busy Corners	GW	U	LCKP
S-188-WO28	412722083221200	Woodmore Schools at Woodville	GW	U	LCKP
S-190-WO7	412909083245100	Minke NW. of Woodville	GW	C	LCKP
S-198-M32	412118083231400	Holcomb NE. of Bradner	GW	C	LCKP
S-200-M34	412119083205800	Underwood nr Rollersville	GW	C	LCKP
S-202-W31	412120083172400	Wasserman N. of Helena	GW	U	LCKP
S-205-J8	411911083165100	Ohio Lime Co. nr Millersville	GW	U	LCKP
S-206-J18	411757083171100	Bender S. of Millersville	GW	C	LCKP
S-208-SC26	411613083193300	Lakota High School SE. of Girton	GW	C	LCKP
S-210-SC27	411654083213400	Deiter at Girton	GW	U	LCKP
S-217-T1	412505082512400	Hall nr Castalia	GW	C	BILD
S-218-T15	412314082533000	Warner SW. of Vickery	GW	C	BILD
S-218A-T22	412310082533000	Warner SW. of Vickery	GW	C	OTSH
S-231-RL36	412605082574900	ODNR Wildlife at Bayview	GW	M	SLRN
S-234-RL16	412340083011400	Pearson nr Wightmans Grove	GW	M	BILD
S-236-RL23	412252082582600	Griffaw nr Vickery	GW	M	BILD

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Specific conductance (µS/cm)	pH (standard units)	Temperature water (deg C)	Oxygen, dissolved (mg/L)	Coliform, total, (cols. per 100 mL)	Coli-, form, fecal, (cols./ 100 mL)	Streptococci, fecal, (cols./ 100 mL)
S-3-B12	06-06-78	1,700	7.4	11.0	--	--	--	--
S-11-M15	09-02-87	651	7.4	11.5	<.1	>80	K4	<1
S-18-R1	08-13-87	2,680	7.2	13.0	<.1	K10	<1	K9
S-30-T9	08-13-87	2,250	7.3	14.5	5.5	>80	56	>100
S-31-S32	08-06-87	840	7.3	18.0	--	25	K5	23
S-32-S32	08-06-87	950	7.0	12.0	<.1	<1	<1	<1
S-33-WO22	08-12-87	1,100	7.1	20.5	.6	80	<1	K9
S-34-G31	08-14-87	2,520	7.1	11.0	<.1	<1	<1	<1
S-102-R35	08-18-87	759	7.7	12.0	.2	<1	<1	<1
S-105-RL18	08-19-87	2,240	7.1	12.0	<.1	K10	<1	K1
S-107-RL33	08-18-87	2,630	7.3	13.0	<.1	<1	<1	K1
S-110-S26	08-20-87	2,150	7.1	13.0	15.0	K10	K2	K6
S-118-B10	08-26-87	607	7.2	12.5	<.1	<1	<1	K7
S-119-B23	08-27-87	1,270	7.4	11.0	<.1	K10	<1	K2
S-122-B19	08-17-87	899	7.4	14.0	<.1	<1	<1	<1
S-123-B32	08-20-87	633	7.2	15.0	<.1	K3	<1	<1
S-126-J33	08-27-87	630	7.3	12.0	<.1	K2	<1	65
S-129-Y25	08-05-87	2,080	7.1	12.0	<.1	K3	<1	<1
S-130-Y13	08-18-87	648	7.4	12.0	<.1	K16	<1	>100
S-132-Y1	08-19-87	1,620	7.3	11.5	<.1	<1	<1	<1
S-135-Y8	08-20-87	1,020	7.1	12.5	<.1	<1	<1	<1
S-136A-Y17	08-20-87	1,220	6.8	11.5	<.1	K5	K3	K1
S-141-Y21	08-18-87	910	7.4	12.0	<.1	K2	<1	<1
S-144-RL35	08-11-87	4,000	7.3	12.5	<.1	K7	K2	<1
S-147-G25	08-14-87	1,580	7.2	11.5	<.1	<1	<1	<1
S-161-J3	09-03-87	880	7.0	12.0	1.4	K4	<1	<1
S-163-W23	08-26-87	682	7.2	14.0	<.1	K1	<1	K1
S-165-S21	08-19-87	666	7.6	13.0	.2	<1	<1	<1
S-166-S9	08-18-87	727	7.6	12.5	.4	<1	<1	<1
S-170-W12	08-13-87	670	7.2	12.0	<.1	52	K1	<1
S-171-W11	08-25-87	801	7.1	12.5	<.1	<1	<1	<1
S-173-R31	08-24-87	755	7.2	12.0	<.1	<1	<1	<1
S-175-W5	08-19-87	700	7.4	13.0	<.1	<1	<1	<1
S-179-M23	08-26-87	722	7.1	11.5	<.1	<1	<1	<1
S-186-WO1	08-25-87	697	7.0	12.5	<.1	<1	<1	K7
S-188-WO28	09-04-86	1,120	7.1	12.0	--	--	<1	--
S-190-WO7	08-25-87	799	7.1	12.0	<.1	<1	<1	<1
S-198-M32	08-26-87	665	7.4	11.0	<.1	<1	<1	K2
S-200-M34	08-26-87	885	7.3	11.0	.8	<1	<1	<1
S-202-W31	08-27-87	675	7.3	11.0	2.8	<1	<1	K6
S-205-J8	08-12-87	910	7.0	12.0	<.1	<1	<1	<1
S-206-J18	08-27-87	765	7.0	12.0	<.1	21	<1	40
S-208-SC26	08-27-87	590	7.3	14.0	.3	K5	<1	K10
S-210-SC27	08-26-87	1,280	7.0	12.5	3.0	<1	<1	<1
S-217-T1	08-19-87	2,340	7.2	11.0	<.1	<1	<1	<1
S-218-T15	08-20-87	2,230	7.1	11.5	<.1	<1	<1	<1
S-218A-T22	08-19-87	2,300	7.2	11.5	<.1	<1	<1	<1
S-231-RL36	08-11-87	100,000	6.3	12.0	<.1	K3	<1	<1
S-234-RL16	08-13-87	2,730	7.1	11.5	<.1	<1	<1	<1
S-236-RL23	08-20-87	3,980	6.6	16.5	<.1	K2	<1	<1

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number i plate 1	Date of sample	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate (mg/L as HCO_3)	Alkalinity, total (mg/L as $CaCO_3$)
S-3-B12	06-06-78	960	770	250	82	39	2.8	230	189
S-11-M15	09-02-87	350	77	77	27	8.8	1.9	328	269
S-18-R1	08-13-87	1,700	1,500	430	150	26	4.4	286	235
S-30-T9	08-13-87	1,700	1,400	590	44	9.0	2.2	316	259
S-31-S32	08-06-87	410	170	89	38	17	8.3	289	241
S-32-S32	08-06-87	480	180	110	43	19	10	366	296
S-33-WO22	08-12-87	580	280	120	63	9.7	2.8	366	299
S-34-G31	08-14-87	1,700	1,400	570	67	12	2.8	364	299
S-102-R35	08-18-87	410	150	85	38	22	2.5	306	250
S-105-RL18	08-19-87	1,400	1,200	370	110	33	3.4	201	164
S-107-RL33	08-18-87	1,700	1,500	450	140	27	3.6	236	192
S-110-S26	08-20-87	1,200	970	300	100	38	3.7	253	206
S-118-B10	08-26-87	330	49	67	32	19	1.9	347	285
S-119-B23	08-27-87	700	490	180	57	29	1.7	257	211
S-122-B19	08-17-87	500	160	120	40	10	2.1	421	347
S-123-B32	08-20-87	380	57	78	35	3.0	1.4	390	319
S-126-J33	08-27-87	350	60	87	30	4.9	1.3	358	293
S-129-Y25	08-05-87	1,100	810	350	44	10	2.1	311	255
S-130-Y13	08-18-87	360	110	92	31	4.2	1.8	301	246
S-132-Y1	08-19-87	940	700	310	37	10	2.3	288	236
S-135-Y8	08-20-87	590	240	120	60	19	2.8	416	339
S-136A-Y17	08-20-87	730	470	220	38	7.9	2.2	308	254
S-141-Y21	08-18-87	350	120	98	24	52	2.2	290	237
S-144-RL35	08-11-87	--	--	--	--	160	15	192	155
S-147-G25	08-14-87	960	680	300	44	9.1	2.3	345	282
S-161-J3	09-03-87	450	97	96	50	22	2.8	436	356
S-163-W23	08-26-87	400	110	84	35	8.6	3.2	354	289
S-165-S21	08-19-87	380	67	76	32	6.1	1.8	384	308
S-166-S9	08-18-87	370	100	77	34	21	2.4	329	269
S-170-W12	08-13-87	370	42	82	36	5.3	1.4	399	321
S-171-W11	08-25-87	460	140	100	41	7.7	2.0	392	321
S-173-R31	08-24-87	410	77	79	40	16	2.3	409	335
S-175-W5	08-19-87	410	97	84	34	4.3	1.4	381	312
S-179-M23	08-26-87	420	110	87	38	8.2	1.5	378	310
S-186-WO1	08-25-87	410	64	83	50	5.2	1.8	427	349
S-188-WO28	09-04-86	600	240	140	61	10	2.3	445	358
S-190-WO7	08-25-87	420	47	90	38	11	1.4	450	368
S-198-M32	08-26-87	350	90	83	31	5.4	.9	312	254
S-200-M34	08-26-87	370	95	100	29	9.5	45	342	279
S-202-W31	08-27-87	370	90	80	34	3.0	.7	343	280
S-205-J8	08-12-87	510	150	93	60	9.6	2.8	445	360
S-206-J18	08-27-87	410	140	110	32	5.3	1.1	326	268
S-208-SC26	08-27-87	300	23	73	25	12	1.5	336	274
S-210-SC27	08-26-87	430	70	92	49	77	6.3	442	362
S-217-T1	08-19-87	1,500	1,200	480	60	6.5	3.2	312	255
S-218-T15	08-20-87	1,300	1,100	410	64	8.0	2.5	305	247
S-218A-T22	08-19-87	1,100	870	340	62	7.3	2.4	306	251
S-231-RL36	08-11-87	15,000	15,000	5,800	150	15,000	480	328	269
S-234-RL16	08-13-87	1,600	1,400	400	150	25	3.8	273	225
S-236-RL23	08-20-87	2,400	2,200	590	210	140	34	133	109

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Carbon dioxide, dis- solved (mg/L as CO_2)	Sulfide, total (mg/L as S)	Sulfate, dis- solved (mg/L as SO_4)	Chlo- ride, dis- solved (mg/L as Cl)	Fluo- ride, dis- solved (mg/L as F)	Bromide, dis- solved (mg/L as Br)	Iodide, dis- solved (mg/L as I)	Silica, dis- solved (mg/L as SiO_2)
S-3-B12	06-06-78	15	<0.5	840	13	1.5	--	--	14
S-11-M15	09-02-87	21	ND	84	11	.7	--	--	13
S-18-R1	08-13-87	27	ND	1,600	40	1.4	--	--	10
S-30-T9	08-13-87	24	ND	1,300	21	1.1	--	--	9.8
S-31-S32	08-06-87	26	ND	140	34	1.3	--	--	5.6
S-32-S32	08-06-87	64	ND	160	38	1.7	--	--	4.5
S-33-WO22	08-12-87	42	ND	250	26	.6	--	--	5.3
S-34-G31	08-14-87	52	2.6	1,500	11	1.3	.080	--	12
S-102-R35	08-18-87	9.7	ND	210	11	1.5	--	--	15
S-105-RL18	08-19-87	28	ND	1,400	12	1.0	--	--	12
S-107-RL33	08-18-87	19	ND	1,600	16	1.1	--	.004	13
S-110-S26	08-20-87	29	ND	1,100	30	1.5	--	--	14
S-118-B10	08-26-87	35	ND	89	2.0	1.1	--	--	18
S-119-B23	08-27-87	18	ND	520	6.5	1.3	--	--	15
S-122-B19	08-17-87	27	<.5	160	12	1.0	--	.004	12
S-123-B32	08-20-87	36	ND	57	1.3	1.2	--	--	10
S-126-J33	08-27-87	32	ND	42	4.8	.6	--	--	11
S-129-Y25	08-05-87	40	<.5	1,100	26	1.2	.098	--	8.9
S-130-Y13	08-18-87	20	ND	100	5.5	1.4	--	--	9.1
S-132-Y1	08-19-87	24	<.5	680	22	.9	--	--	8.6
S-135-Y8	08-20-87	56	ND	250	2.8	1.6	--	--	18
S-136A-Y17	08-20-87	87	ND	430	23	.8	--	--	9.1
S-141-Y21	08-18-87	20	ND	100	80	.3	--	--	11
S-144-RL35	08-11-87	16	26	2,100	310	1.4	--	--	16
S-147-G25	08-14-87	39	.6	720	8.7	1.3	--	--	13
S-161-J3	09-03-87	66	ND	94	19	1.1	--	--	6.0
S-163-W23	08-26-87	36	<.5	99	14	1.5	--	--	5.6
S-165-S21	08-19-87	15	ND	84	7.0	1.4	--	--	11
S-166-S9	08-18-87	13	ND	140	5.5	1.4	--	.010	13
S-170-W12	08-13-87	43	ND	53	8.3	1.6	--	--	5.7
S-171-W11	08-25-87	45	ND	170	1.4	1.5	--	--	16
S-173-R31	08-24-87	40	ND	120	3.4	1.5	--	--	17
S-175-W5	08-19-87	26	ND	100	4.7	1.5	--	--	11
S-179-M23	08-26-87	44	ND	120	17	.9	--	--	7.4
S-186-WO1	08-25-87	69	ND	63	7.9	.3	--	--	3.8
S-188-WO28	09-04-86	56	.3	250	23	.4	--	--	6.6
S-190-WO7	08-25-87	58	<.5	61	25	.3	--	--	8.7
S-198-M32	08-26-87	20	ND	87	8.4	1.1	--	--	10
S-200-M34	08-26-87	26	ND	110	28	.1	--	--	10
S-202-W31	08-27-87	29	ND	68	8.1	1.0	--	--	6.7
S-205-J8	08-12-87	64	ND	130	18	.8	--	--	9.5
S-206-J18	08-27-87	48	ND	97	31	.6	--	--	8.8
S-208-SC26	08-27-87	28	ND	33	12	.6	--	--	16
S-210-SC27	08-26-87	74	ND	47	130	.1	--	--	4.8
S-217-T1	08-19-87	33	ND	1,300	12	1.4	--	--	19
S-218-T15	08-20-87	39	<.5	1,200	17	1.4	--	--	12
S-218A-T22	08-19-87	32	ND	1,200	15	1.0	--	--	7.5
S-231-RL36	08-11-87	244	300	1,200	37,000	.6	--	2.2	8.8
	05-26-89	--	--	--	25,000	--	1.9	--	--
S-234-RL16	08-13-87	34	.6	1,700	33	1.3	--	--	14
S-236-RL23	08-20-87	58	1.1	2,000	380	1.7	--	--	11

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Solids, residue at 180 deg C, dis- solved (mg/L)	Solids, sum of constit- uents, dis- solved (mg/L)	Nitro- gen, nitrite, dis- solved (mg/L as N)	Nitro- gen, NO2+NO3, dis- solved (mg/L as N)	Nitro- gen, ammonia, dis- solved (mg/L as N)	Nitro- gen, am- monia + organic, dis- solved (mg/L as N)	Phos- phorous, dis- solved (mg/L as P)	Phos- phorous, ortho, dis- solved (mg/L as P)
S-3-B12	06-06-78	1,460	1,360	--	--	--	--	--	--
S-11-M15	09-02-87	419	423	<.005	<.010	.167	.50	--	.003
S-18-R1	08-13-87	2,610	2,410	.001	<.010	.520	.90	<.005	<.001
S-30-T9	08-13-87	2,250	2,150	.001	<.010	.250	.50	<.005	<.001
S-31-S32	08-06-87	528	502	.002	1.10	.035	.70	.006	<.001
S-32-S32	08-06-87	619	594	.004	.495	.046	.70	<.005	<.001
S-33-WO22	08-12-87	703	675	<.003	.417	.040	.50	<.005	<.001
S-34-G31	08-14-87	2,530	2,370	.002	<.010	.440	1.1	.022	.014
S-102-R35	08-18-87	551	569	.001	.031	.260	.50	<.005	<.001
S-105-RL18	08-19-87	2,250	2,050	.004	<.010	.302	4.8	<.005	.003
S-107-RL33	08-18-87	2,260	2,380	.001	.015	.480	.90	<.005	<.001
S-110-S26	08-20-87	2,000	1,720	.010	.125	.650	.60	.005	.006
S-118-B10	08-26-87	419	432	<.001	<.010	.840	.70	.007	<.001
S-119-B23	08-27-87	986	957	.004	.015	.475	.60	.005	<.001
S-122-B19	08-17-87	603	601	<.001	.025	.153	.40	.009	.002
S-123-B32	08-20-87	411	413	.002	<.010	.062	.50	<.005	.006
S-126-J33	08-27-87	373	370	.003	.025	.134	<.20	.006	<.001
S-129-Y25	08-05-87	1,890	1,710	.002	<.010	.520	.80	--	.002
S-130-Y13	08-18-87	401	394	<.001	<.010	.146	1.1	.014	.010
S-132-Y1	08-19-87	1,340	1,220	.003	.856	.117	.50	<.005	.002
S-135-Y8	08-20-87	738	714	.002	<.010	.590	1.0	.005	.007
S-136A-Y17	08-20-87	950	900	.003	.024	.044	.50	.006	.006
S-141-Y21	08-18-87	540	519	.001	.014	.048	.40	<.005	.003
S-144-RL35	08-11-87	3,830	--	<.001	.028	2.90	2.6	<.005	.023
S-147-G25	08-14-87	1,390	1,300	.001	<.010	.380	.70	.009	.002
S-161-J3	09-03-87	536	513	.039	8.90	.022	.80	<.005	<.001
S-163-W23	08-26-87	468	461	.004	.381	.055	.20	.008	.002
S-165-S21	08-19-87	463	462	.001	.016	.196	.90	<.005	<.001
S-166-S9	08-18-87	496	494	.001	.019	.300	.60	<.005	<.001
S-170-W12	08-13-87	405	404	.004	.025	.031	.60	<.005	<.001
S-171-W11	08-25-87	562	571	<.002	<.010	.157	1.1	.007	.002
S-173-R31	08-24-87	518	526	<.001	.031	.425	.70	.011	<.001
S-175-W5	08-19-87	490	481	.001	<.010	.153	.40	<.005	<.001
S-179-M23	08-26-87	502	507	<.001	<.010	.024	.20	.009	.003
S-186-WO1	08-25-87	429	426	.002	.369	.024	.50	.008	.003
S-188-WO28	09-04-86	860	714	<.010	2.40	.040	.40	--	<.010
S-190-WO7	08-25-87	496	489	.002	.294	.815	1.0	.006	.001
S-198-M32	08-26-87	381	390	<.001	<.010	.129	.60	.012	.007
S-200-M34	08-26-87	532	506	.182	.988	.200	.50	.006	<.001
S-202-W31	08-27-87	411	397	.004	.971	<.002	.30	.006	<.001
S-205-J8	08-12-87	590	571	<.001	<.010	.147	.40	<.005	.003
S-206-J18	08-27-87	474	450	.017	.962	.051	<.20	.005	<.001
S-208-SC26	08-27-87	349	350	.002	<.010	.218	<.20	.007	.001
S-210-SC27	08-26-87	647	624	.005	1.00	.038	5.4	.020	.016
S-217-T1	08-19-87	2,230	2,220	.001	<.010	.304	.80	<.005	.002
S-218-T15	08-20-87	2,190	1,880	<.001	<.010	.259	.60	.010	<.001
S-218A-T22	08-19-87	2,170	1,800	.002	<.010	.304	.50	<.005	.003
S-231-RL36	08-11-87	72,400	59,900	.005	.030	.800	4.5	<.005	.133
S-234-RL16	08-13-87	2,720	2,470	.001	<.010	.600	.90	<.005	<.001
S-236-RL23	08-20-87	3,570	3,450	.041	.516	1.40	2.8	<.005	.003

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)
S-3-B12	06-06-78	--	--	--	--	--	--	--	--
S-11-M15	09-02-87	<10	--	--	55	--	--	--	--
S-18-R1	08-13-87	20	--	--	100	--	--	--	--
S-30-T9	08-13-87	20	--	--	100	--	--	--	--
S-31-S32	08-06-87	20	--	--	150	--	--	--	--
S-32-S32	08-06-87	<10	--	--	190	--	--	--	--
S-33-WO22	08-12-87	20	--	--	77	--	--	--	--
S-34-G31	08-14-87	20	<1	<1	100	240	<1	10	<1
S-102-R35	08-18-87	<10	--	--	20	--	--	--	--
S-105-RL18	08-19-87	10	--	--	--	--	--	--	--
S-107-RL33	08-18-87	20	--	<1	<100	--	<1	40	<1
S-110-S26	08-20-87	--	--	--	<100	--	--	--	--
S-118-B10	08-26-87	<10	--	--	150	--	--	--	--
S-119-B23	08-27-87	20	--	--	40	--	--	--	--
S-122-B19	08-17-87	<10	--	1	120	--	<1	20	1
S-123-B32	08-20-87	<10	--	--	120	--	--	--	--
S-126-J33	08-27-87	<10	--	--	570	--	--	--	--
S-129-Y25	08-05-87	<10	--	<1	--	100	--	--	--
S-130-Y13	08-18-87	10	--	--	160	--	--	--	--
S-132-Y1	08-19-87	10	--	--	36	--	--	--	--
S-135-Y8	08-20-87	10	--	--	30	--	--	--	--
S-136A-Y17	08-20-87	20	--	--	140	--	--	--	--
S-141-Y21	08-18-87	10	--	--	220	--	--	--	--
S-144-RL35	08-11-87	--	--	--	100	--	--	--	--
S-147-G25	08-14-87	20	--	--	35	--	--	--	--
S-161-J3	09-03-87	<10	--	--	220	--	--	--	--
S-163-W23	08-26-87	<10	--	--	70	--	--	--	--
S-165-S21	08-19-87	<10	--	--	84	--	--	--	--
S-166-S9	08-18-87	<10	--	2	42	--	<1	30	<1
S-170-W12	08-13-87	20	--	--	100	--	--	--	--
S-171-W11	08-25-87	<10	--	--	23	--	--	--	--
S-173-R31	08-24-87	20	--	--	77	--	--	--	--
S-175-W5	08-19-87	<10	--	--	34	--	--	--	--
S-179-M23	08-26-87	<10	--	--	28	--	--	--	--
S-186-WO1	08-25-87	<10	--	--	80	--	--	--	--
S-188-WO28	09-04-86	<10	--	--	--	--	--	--	--
S-190-WO7	08-25-87	<10	--	--	220	--	--	--	--
S-198-M32	08-26-87	<10	--	--	150	--	--	--	--
S-200-M34	08-26-87	<10	--	--	150	--	--	--	--
S-202-W31	08-27-87	20	--	--	160	--	--	--	--
S-205-J8	08-12-87	10	--	--	97	--	--	--	--
S-206-J18	08-27-87	<10	--	--	47	--	--	--	--
S-208-SC26	08-27-87	<10	--	--	170	--	--	--	--
S-210-SC27	08-26-87	10	--	--	30	--	--	--	--
S-217-T1	08-19-87	20	--	--	<100	--	--	--	--
S-218-T15	08-20-87	10	--	--	200	--	--	--	--
S-218A-T22	08-19-87	20	--	--	<100	--	--	--	--
S-231-RL36	08-11-87	40	--	6	300	--	<1	<10	<1
S-234-RL16	08-13-87	20	--	--	100	--	--	--	--
S-236-RL23	08-20-87	20	--	--	14	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Iron, dis- solved (µg/L as Fe)	Lead, dis- solved (µg/L as Pb)	Lithium, dis- solved (µg/L as Li)	Manga- nese, dis- solved (µg/L as Mn)	Mercury, dis- solved (µg/L as Hg)	Nickel, dis- solved (µg/L as Ni)	Sele- nium, dis- solved (µg/L as Se)	Silver, dis- solved (µg/L as Ag)
S-3-B12	06-06-78	<10	--	--	20	--	--	--	--
S-11-M15	09-02-87	650	--	--	<1	--	--	--	--
S-18-R1	08-13-87	4,800	--	--	80	--	--	--	--
S-30-T9	08-13-87	40	--	--	5	--	--	--	--
S-31-S32	08-06-87	<3	--	--	<1	--	--	--	--
S-32-S32	08-06-87	17	--	--	19	--	--	--	--
S-33-WO22	08-12-87	3	--	--	7	--	--	--	--
S-34-G31	08-14-87	30	<5	40	10	<.1	1	<1	<1.0
S-102-R35	08-18-87	1,000	--	--	7	--	--	--	--
S-105-RL18	08-19-87	3,100	--	--	20	--	--	--	--
S-107-RL33	08-18-87	2,100	<5	--	40	1.6	--	<1	<1.0
S-110-S26	08-20-87	290	--	--	20	--	--	--	--
S-118-B10	08-26-87	610	--	--	8	--	--	--	--
S-119-B23	08-27-87	1,300	--	--	18	--	--	--	--
S-122-B19	08-17-87	1,400	<5	--	18	<.1	--	<1	<1.0
S-123-B32	08-20-87	620	--	--	6	--	--	--	--
S-126-J33	08-27-87	1,100	--	--	16	--	--	--	--
S-129-Y25	08-05-87	80	--	--	10	--	--	--	--
S-130-Y13	08-18-87	11	--	--	6	--	--	--	--
S-132-Y1	08-19-87	21	--	--	<1	--	--	--	--
S-135-Y8	08-20-87	160	--	--	6	--	--	--	--
S-136A-Y17	08-20-87	77	--	--	27	--	--	--	--
S-141-Y21	08-18-87	180	--	--	13	--	--	--	--
S-144-RL35	08-11-87	20	--	--	--	--	--	--	--
S-147-G25	08-14-87	68	--	--	7	--	--	--	--
S-161-J3	09-03-87	5	--	--	<1	--	--	--	--
S-163-W23	08-26-87	25	--	--	3	--	--	--	--
S-165-S21	08-19-87	180	--	--	2	--	--	--	--
S-166-S9	08-18-87	670	<5	--	19	.4	--	<1	<1.0
S-170-W12	08-13-87	21	--	--	2	--	--	--	--
S-171-W11	08-25-87	120	--	--	2	--	--	--	--
S-173-R31	08-24-87	1,100	--	--	7	--	--	--	--
S-175-W5	08-19-87	77	--	--	2	--	--	--	--
S-179-M23	08-26-87	160	--	--	3	--	--	--	--
S-186-WO1	08-25-87	220	--	--	9	--	--	--	--
S-188-WO28	09-04-86	22	--	--	<1	--	--	--	--
S-190-WO7	08-25-87	1,500	--	--	10	--	--	--	--
S-198-M32	08-26-87	400	--	--	6	--	--	--	--
S-200-M34	08-26-87	200	--	--	140	--	--	--	--
S-202-W31	08-27-87	15	--	--	1	--	--	--	--
S-205-J8	08-12-87	690	--	--	11	--	--	--	--
S-206-J18	08-27-87	15	--	--	11	--	--	--	--
S-208-SC26	08-27-87	240	--	--	5	--	--	--	--
S-210-SC27	08-26-87	<3	--	--	<1	--	--	--	--
S-217-T1	08-19-87	570	--	--	20	--	--	--	--
S-218-T15	08-20-87	150	--	--	20	--	--	--	--
S-218A-T22	08-19-87	80	--	--	20	--	--	--	--
S-231-RL36	08-11-87	500	<5	--	190	--	--	<1	<1.0
S-234-RL16	08-13-87	350	--	--	20	--	--	--	--
S-236-RL23	08-20-87	100	--	--	7	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Strontium, dissolved (µg/L as Sr)	Zinc, dissolved (µg/L as Zn)	Carbon, organic, dissolved (mg/L as C)	Cyanide, total (mg/L as Cn)	Sodium adsorption ratio	Cation-anion imbalance (percent)	Major-ion water type cation : anion
S-3-B12	06-06-78	--	--	7.6	--	0 .6	- 1.7	C M : S
S-11-M15	09-02-87	37,000	34	1.3	--	.2	- .6	C M : H
S-18-R1	08-13-87	290	<10	1.1	--	.3	- 5.2	C : S
S-30-T9	08-13-87	19,000	10	1.8	--	.1	+ 1.6	C : S
S-31-S32	08-06-87	26,000	17	2.7	--	.4	+ 2.0	C M : H S
S-32-S32	08-06-87	28,000	37	2.7	--	.4	+ 1.1	C M : H S
S-33-WO22	08-12-87	17,000	27	1.4	--	.2	+ .3	C M : H S
S-34-G31	08-14-87	15,000	<10	2.0	<.010	.1	- 3.7	C : S
S-102-R35	08-18-87	32,000	25	1.1	--	.5	- 3.2	C M : H S
S-105-RL18	08-19-87	8,700	20	1.5	--	.4	- 5.5	C : S
S-107-RL33	08-18-87	9,200	60	1.6	--	.3	- 2.9	C : S
S-110-S26	08-20-87	11,000	20	1.8	--	.5	- 5.2	C : S
S-118-B10	08-26-87	30,000	17	1.5	--	.5	- .5	C M : H
S-119-B23	08-27-87	18,000	<3	1.7	--	.5	+ .5	C M : S
S-122-B19	08-17-87	35,000	10	2.2	--	.2	+ .1	C : H
S-123-B32	08-20-87	33,000	65	1.4	--	.1	+ .3	C M : H
S-126-J33	08-27-87	10,000	110	1.9	--	.1	+ 3.1	C : H
S-129-Y25	08-05-87	11,000	--	1.6	--	.1	-13.8	C : S
S-130-Y13	08-18-87	660	3	1.6	--	.1	+ 1.0	C : H
S-132-Y1	08-19-87	7,600	460	1.4	--	.1	- 1.0	C : S
S-135-Y8	08-20-87	34,000	69	1.8	--	.4	+ 1.7	C M : H S
S-136A-Y17	08-20-87	17,000	12	1.5	--	.1	+ .7	C : S
S-141-Y21	08-18-87	8,300	6	2.1	--	1	+ 1.5	C N M : H C S
S-144-RL35	08-11-87	9,500	20	0.2	--	--	--	-- : --
S-147-G25	08-14-87	29,000	4	2.0	--	.1	- 3.1	C : S
S-161-J3	09-03-87	7,100	32	3.0	--	.5	- 1.1	C M : H
S-163-W23	08-26-87	36,000	64	1.7	--	.2	- .0	C M : H
S-165-S21	08-19-87	53,000	76	1.7	--	.2	- 2.2	C M : H
S-166-S9	08-18-87	37,000	21	1.2	--	.5	+ .1	C M : H
S-170-W12	08-13-87	14,000	190	1.6	--	.1	- 2.0	C M : H
S-171-W11	08-25-87	38,000	12	1.3	--	.2	- 2.3	C M : H
S-173-R31	08-24-87	44,000	15	1.4	--	.4	- 1.7	C M : H
S-175-W5	08-19-87	52,000	21	1.4	--	.1	- .7	C M : H
S-179-M23	08-26-87	41,000	<3	1.4	--	.2	- 2.3	C M : H
S-186-WO1	08-25-87	680	35	5.1	--	.1	- .1	C M : H
S-188-WO28	09-04-86	2,100	--	--	--	.2	- 3.1	C M : H S
S-190-WO7	08-25-87	30,000	34	4.8	--	.3	- 2.7	C M : H
S-198-M32	08-26-87	9,500	21	2.0	--	.1	- .2	C M : H
S-200-M34	08-26-87	4,700	320	4.2	--	.2	+ 1.8	C M : H
S-202-W31	08-27-87	27,000	39	1.2	--	.1	+ 1.2	C M : H
S-205-J8	08-12-87	27,000	23	9.7	--	.2	+ .8	C M : H
S-206-J18	08-27-87	3,600	38	1.4	--	.1	+ .8	C : H
S-208-SC26	08-27-87	11,000	24	1.2	--	.3	- .2	C M : H
S-210-SC27	08-26-87	290	77	3.7	--	2	+ .9	C M N : H
S-217-T1	08-19-87	11,000	80	1.6	--	.1	- 4.9	C : S
S-218-T15	08-20-87	13,000	10	1.6	--	.1	- 7.2	C : S
S-218A-T22	08-19-87	13,000	30	1.5	--	.1	-14.5	C : S
S-231-RL36	08-11-87	84,000	100	0.2	--	56	- 5.3	N : C
S-234-RL16	08-13-87	9,000	<10	2.0	--	.3	- 9.6	C M : S
S-236-RL23	08-20-87	11,000	1,900	1.5	--	1	- .7	C M : S

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date OF sample	Tritium, total (pCi/L)	Tritium, total (t.u.)	Gross alpha, dis-solved (µg/L as u-nat)	Gross alpha, dis-solved (pCi/L) O.D.H. labs	Gross beta, dis-solved (pCi/L as Sr/Yt-90)	Gross beta, dis-solved (pCi/L as Cs-137)	Uranium, dis-solved, extrac-tion (µg/L)	Uranium, natural, dis-solved (µg/L as U)
S-3-B12	06-06-78	--	--	--	--	--	--	--	--
S-11-M15	09-02-87	--	--	9.4	3.4	2.4	3.2	--	.23
S-18-R1	08-13-87	--	--	21	17.8	12	18	--	.09
S-30-T9	08-13-87	59	18--	--	--	--	--	--	--
S-31-S32	08-06-87	--	--	--	--	--	--	--	--
S-32-S32	08-06-87	96	30	32	8.8	21	30	--	24
S-33-WO22	08-12-87	69	22	12	<3	5.1	7.4	--	3.5
S-34-G31	08-14-87	28	9	4.3	49.9	5.6	8.0	--	.16
S-102-R35	08-18-87	<5.7	<2	--	--	--	--	--	--
S-105-RL18	08-19-87	--	--	--	--	--	--	--	--
S-107-RL33	08-18-87	--	--	2.0	6.2	4.1	6.3	--	.14
S-110-S26	08-20-87	--	--	23	13	3.8	5.7	--	.39
S-118-B10	08-26-87	<5.7	<2	--	--	--	--	--	--
S-119-B23	08-27-87	6.0	2	3.5	4.4	3.0	4.4	--	.16
S-122-B19	08-17-87	--	--	2.9	<3	2.1	2.9	--	.30
S-123-B32	08-20-87	--	--	--	--	--	--	--	--
S-126-J33	08-27-87	--	--	--	5.3	--	--	--	--
S-129-Y25	08-05-87	120	38	<.4	7.8	3.1	4.6	--	1.2
S-130-Y13	08-18-87	--	--	11	15.4	.8	1.0	--	.44
S-132-Y1	08-19-87	94	29	5.3	4.2	4.1	6.3	--	2.4
S-135-Y8	08-20-87	<1.0	<.3	5.1	<3	3.2	4.7	--	.15
S-136A-Y17	08-20-87	--	--	15	<3	6.8	10	--	5.8
S-141-Y21	08-18-87	66	21	19	3.4	4.3	6.0	--	.23
S-144-RL35	08-11-87	--	--	--	--	--	--	--	--
S-147-G25	08-14-87	29	9	5.8	<3	4.1	6.2	--	.05
S-161-J3	09-03-87	--	--	--	3.6	--	--	--	--
S-163-W23	08-26-87	--	--	--	--	--	--	--	--
S-165-S21	08-19-87	--	--	--	--	--	--	--	--
S-166-S9	08-18-87	--	--	4.5	<3	2.7	3.7	--	.42
S-170-W12	08-13-87	98	31	7.5	4.8	4.0	5.4	--	3.4
S-171-W11	08-25-87	--	--	38	14.3	6.9	9.8	--	.06
S-173-R31	08-24-87	<5.7	<2	--	--	--	--	--	--
S-175-W5	08-19-87	--	--	--	--	--	--	--	--
S-179-M23	08-26-87	62	19	4.4	3.2	2.1	2.9	--	1.0
S-186-WO1	08-25-87	90	28	8.2	7.3	2.8	3.8	--	1.6
S-188-WO28	09-04-86	--	--	7.3	--	5.6	8.6	5.8	--
S-190-WO7	08-25-87	--	--	--	--	--	--	--	--
S-198-M32	08-26-87	--	--	8.6	4	2.3	3.1	--	.09
S-200-M34	08-26-87	--	--	15	5.4	47	65	--	4.5
S-202-W31	08-27-87	52	16	26	18.8	11	14	--	16
S-205-J8	08-12-87	51	16	2.8	<3	3.7	5.3	--	.50
S-206-J18	08-27-87	--	--	--	--	--	--	--	--
S-208-SC26	08-27-87	<5.7	<2	6.1	4.7	3.7	5.0	--	.18
S-210-SC27	08-26-87	--	--	2.4	4.3	6.3	9.0	--	.74
S-217-T1	08-19-87	3.0	1	5.2	<3	4.2	6.8	--	.35
S-218-T15	08-20-87	51	16	--	--	--	--	--	--
S-218A-T22	08-19-87	43	13	--	--	--	--	--	--
S-231-RL36	08-11-87	<1.0	<.3	610	62	330	500	--	.20
S-234-RL16	08-13-87	<5.7	<2	<0.4	9	1.2	1.8	--	.20
S-236-RL23	08-20-87	--	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Remarks
S-3-B12	06-06-78	--
S-11-M15	09-02-87	--
S-18-R1	08-13-87	High coliform background count
S-30-T9	08-13-87	--
S-31-S32	08-06-87	--
S-32-S32	08-06-87	--
S-33-WO22	08-12-87	--
S-34-G31	08-14-87	Sulfur odor
S-102-R35	08-18-87	Jet pump
S-105-RL18	08-19-87	High coliform background count
S-107-RL33	08-18-87	--
S-110-S26	08-20-87	High coliform background count
S-118-B10	08-26-87	--
S-119-B23	08-27-87	--
S-122-B19	08-17-87	--
S-123-B32	08-20-87	High coliform background count
S-126-J33	08-27-87	High coliform background count
S-129-Y25	08-05-87	--
S-130-Y13	08-18-87	Sulfur odor
S-132-Y1	08-19-87	High coliform background count
S-135-Y8	08-20-87	High coliform background count
S-136A-Y17	08-20-87	--
S-141-Y21	08-18-87	High coliform background count
S-144-RL35	08-11-87	Hydrocarbon film on surface of water sample, sulfur odor
S-147-G25	08-14-87	Sulfur odor
S-161-J3	09-03-87	--
S-163-W23	08-26-87	--
S-165-S21	08-19-87	High coliform background count
S-166-S9	08-18-87	--
S-170-W12	08-13-87	--
S-171-W11	08-25-87	--
S-173-R31	08-24-87	--
S-175-W5	08-19-87	--
S-179-M23	08-26-87	--
S-186-WO1	08-25-87	--
S-188-WO28	09-04-86	Turbid water, much fine silt in well bore
S-190-WO7	08-25-87	Owner report hydrocarbons in water, sulfur odor
S-198-M32	08-26-87	--
S-200-M34	08-26-87	High coliform background count
S-202-W31	08-27-87	--
S-205-J8	08-12-87	Hydrocarbon and natural gas odor in water
S-206-J18	08-27-87	High coliform background count
S-208-SC26	08-27-87	--
S-210-SC27	08-26-87	--
S-217-T1	08-19-87	--
S-218-T15	08-20-87	--
S-218A-T22	08-19-87	Hydrocarbon film on surface of water sample
S-231-RL36	08-11-87	Sulfur odor, water effervescent and degassing
S-234-RL16	08-13-87	--
S-236-RL23	08-20-87	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Station number	Name	Type of site	Type of aquifer	Geologic-unit code
WO-23-C27	412140083352700	NWOH Test-Stewart nr Bowling Green	GW	M	GFLD,LCKP
WO-118-LK8	413515083304300	Elvy nr Walbridge	GW	C	GFLD
WO-119-LK7	413515083313700	Siewert nr Walbridge	GW	C	GFLD
WO-120-N	413557083304800	Hirzel Farm at Northwood	GW	C	GFLD
WO-121-N	413629083304400	Waste Mgt at Northwood	GW	C	GFLD
WO-129-PB23	413557083332300	Bruns at Northwood	GW	C	GFLD
WO-150-PE4	411426083290700	Macritchie Spring at W. Millgrove	SP	U	GFLD
WO-151-PB11	413219083334300	Stoneco Spring at Lime City	SP	U	GFLD
WO-152-PO7	411912083384800	Stoneco Spring at Portage	SP	C	TMCT
WO-198-T21	412726083283100	Vestal at Luckey	GW	U	LCKP
WO-199-F34	412103083272200	Libbe nr Bradner	GW	C	LCKP
WO-203-PE12	411411083260600	Mauholland nr W. Millgrove	GW	C	LCKP
WO-204-PE22	411209083273500	Dibling nr Fostoria	GW	C	LCKP
WO-210-B35	411050083333400	Baird nr Bloomdale	GW	C	LCKP
WO-212-B4	411429083362200	Roberts at Jerry City	GW	C	LCKP
WO-216-H1	411428083395400	Wagner at Cygnet	GW	C	TMCT
WO-218-H36	411022083394000	Lens Implement at North Baltimore	GW	C	LCKP
WO-223-H17	411250083434000	Smith nr Hammansburg	GW	C	RRVR
WO-230-J24	411216083470300	Smith at Hoytville	GW	C	RRVR
WO-236-J8	411337083503800	Moses nr Deshler	GW	C	RRVR
WO-237-ML31	411520083520900	Feehan nr Custar	GW	C	RRVR
WO-246-LI19	411706083455600	Wensink nr Custar	GW	C	RRVR
WO-250-LI2	411945083410600	Maidment nr Portage	GW	C	TMCT
WO-253-PO18	411752083384700	Copus at Mermill	GW	C	GFLD
WO-259-PO24	411658083323500	Aurand nr Jerry City	GW	C	GFLD
WO-260-MO9	411911083285300	Firsdon Jr nr Wayne	GW	C	LCKP
WO-263-MO1	411943083261300	Beckford at Bradner	GW	C	LCKP
WO-265-MO25	411616083251900	Bowen at Risingsun	GW	U	LCKP
WO-269-F20	412237083301800	Contries at New Rochester	GW	U	LCKP
WO-272-WB36	412542083330700	Webster Methodist nr Scotch Ridge	GW	C	LCKP
WO-274-MD28	412635083362700	Schaller at Dunbridge	GW	C	GFLD
WO-275-C31	412114083380400	Mlinarik at Bowling Green	GW	U	GFLD
WO-286-PL17	412350083444900	Spangler nr Tontogany	GW	C	RRVR
WO-295-GR7	412438083521000	Scott at Grand Rapids	GW	C	DRVR
WO-299-WA24	412735083460800	Seeger nr Grand Rapids	GW	C	RRVR
WO-303-MD23	413026083420800	Ferris nr Waterville	GW	C	TMCT
WO-306-PB	413345083371500	Mizer at Perrysburg	GW	M	TMCT,GFLD
WO-307-WB15	412839083352000	Roth at Dowling	GW	N	GFLD
WO-309-LK27	413147083275800	Sibberson nr Millbury	GW	C	LCKP
WO-313-R	413658083332900	Libbey Owens Ford No. 2 at Rossford	GW	M	GFLD,LCKP
WO-316-LK4	413542083282700	Billings at Walbridge	GW	C	GFLD
WO-320-N36	413608083255500	Draper nr Woodville	GW	C	GFLD
WO-321-LK12	413455083260400	Traver at East Lawn	GW	C	LCKP
WO-326-WS32	412123083512900	Weaver nr Weston	GW	C	RRVR
WO-330-PB1	413345083314200	Snyder nr Moline	GW	C	GFLD
WO-331-PB23	413101083325300	Gurtzweiler nr Lime City	GW	C	TMCT
WO-333-PB19	413025083374000	Voland nr Five Points	GW	M	GFLD,LCKP
WO-341-LK36	413055083254300	Baker nr Forest Park	GW	C	LCKP
WO-342-T9	412950083282500	Luckey Farmers at Lemoyne	GW	U	LCKP
WO-344-PL27	412202083423000	Howard nr Bowling Green	GW	C	RRVR
WO-347-B12	411354083322000	Frederic nr Eagleville	GW	C	RRVR
WO-349-F3	412451083280200	Pemberville North No. 1 at Pemberville	GW	C	LCKP
WO-351-B6	411432083385100	Cygnet No. 9 at Cygnet	GW	C	TMCT
WO-352-B36	411003083330200	Bloomdale 5 at Bloomdale	GW	C	LCKP

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Specific conductance (µS/cm)	pH (standard units)	Temperature water (deg C)	Oxygen, dissolved (mg/L)	Coliform, total cols. per 100 mL)	Coliform, fecal, cols. per 100 mL)	Streptococci, fecal cols. per 100 mL)
WO-23-C27	08-03-87	3,040	6.9	12.0	<0.1	K12	K4	<1
WO-118-LK8	04-02-85	1,230	7.4	11.0	<.1	--	--	--
WO-119-LK7	07-10-85	1,080	7.4	13.0	.2	--	--	--
WO-120-N	03-27-85	975	7.7	11.0	.8	--	--	--
WO-121-N	09-02-87	880	7.9	12.0	<.1	>80	52	K3
WO-129-PB23	07-21-87	1,350	7.5	15.5	1.3	<1	<1	<1
WO-150-PE4	08-03-87	880	7.3	16.0	<.1	33	K13	K13
WO-151-PB11	08-04-87	1,010	7.1	11.0	--	<1	<1	<1
WO-152-PO7	08-04-87	1,810	7.2	13.5	<.1	<1	<1	<1
WO-198-T21	08-13-87	765	7.1	12.5	1.0	<1	<1	<1
WO-199-F34	08-06-87	695	7.3	12.5	.3	<1	<1	<1
WO-203-PE12	07-30-87	566	7.2	14.5	<.1	<1	K1	K18
WO-204-PE22	07-22-87	655	7.4	12.5	.4	K2	<1	K2
WO-210-B35	07-30-87	1,320	7.1	13.0	<.1	K1	<1	51
WO-212-B4	07-22-87	1,890	6.8	12.5	1.5	K2	<1	K3
WO-216-H1	08-04-87	1,230	7.1	13.0	<.1	22	<1	<1
WO-218-H36	07-28-87	1,170	7.0	15.5	<.1	K1	<1	<1
WO-223-H17	08-05-87	1,140	7.6	12.0	<.1	<1	<1	<1
WO-230-J24	08-04-87	1,770	7.5	13.0	<.1	20	<1	<1
WO-236-J8	08-03-87	1,100	7.6	13.0	<.1	<1	<1	K9
WO-237-ML31	08-04-87	944	7.9	13.0	<.1	K7	<1	K9
WO-246-LI19	07-31-87	605	7.7	12.0	<.1	>80	<1	K14
WO-250-LI2	08-05-87	1,220	7.3	13.5	<.1	K11	<1	<1
WO-253-PO18	07-29-87	1,230	6.9	14.0	.5	<1	<1	K1
WO-259-PO24	07-29-87	1,200	6.9	13.5	<.1	K2	<1	>100
WO-260-MO9	07-28-87	711	7.4	12.0	<.1	<1	<1	<1
WO-263-MO1	07-29-87	966	7.1	13.5	1.0	K8	<1	K13
WO-265-MO25	07-22-87	1,040	6.9	13.5	<.1	>80	<1	38
WO-269-F20	08-07-87	455	7.4	12.5	.5	<1	<1	<1
WO-272-WB36	08-13-87	1,210	7.2	15.5	1.1	<1	<1	K14
WO-274-MD28	08-06-87	950	7.4	12.0	<.1	<1	<1	<1
WO-275-C31	08-13-87	1,160	7.3	14.5	.5	K3	<1	<1
WO-286-PL17	08-05-87	2,500	7.6	12.5	<.1	<1	<1	<1
WO-295-GR7	07-24-87	2,080	7.0	12.5	.6	30	<1	K8
WO-299-WA24	07-27-87	2,560	6.9	14.5	<.1	K1	<1	<1
WO-303-MD23	07-28-87	1,910	7.1	13.0	<.1	K1	<1	<1
WO-306-PB	07-16-87	2,110	7.4	12.5	3.2	>80	<1	>100
WO-307-WB15	08-11-87	634	7.4	12.5	<.1	<1	<1	<1
WO-309-LK27	08-12-87	892	7.2	12.0	.5	30	<1	K1
WO-313-R	07-21-87	960	7.5	16.5	6.1	<1	<1	<1
WO-316-LK4	09-02-87	960	7.9	11.5	<.1	<1	<1	<1
WO-320-N36	09-03-87	1,450	7.5	11.5	<.1	K18	<1	<1
WO-321-LK12	08-10-87	1,860	7.2	12.5	.1	<1	<1	<1
WO-326-WS32	08-04-87	2,660	7.2	17.0	<.1	70	K7	28
WO-330-PB1	08-12-87	1,200	7.1	12.5	1.1	<1	<1	<1
WO-331-PB23	08-11-87	772	7.6	11.5	<.1	32	27	K4
WO-333-PB19	08-14-87	1,250	7.4	15.0	<.1	K14	K2	<1
WO-341-LK36	08-11-87	763	7.3	12.5	<.1	<1	<1	<1
WO-342-T9	08-12-87	687	7.3	16.5	.4	<1	<1	<1
WO-344-PL27	08-06-87	930	7.2	13.5	<.1	<1	<1	<1
WO-347-B12	07-30-87	1,260	7.0	13.5	<.1	K1	<1	K8
WO-349-F3	09-03-86	965	7.4	11.5	--	--	<1	--
WO-351-B6	08-05-87	1,490	7.2	16.0	<.1	K12	<1	<1
WO-352-B36	09-03-86	1,920	7.4	11.5	--	--	<1	--
	08-05-87	1,990	7.4	12.5	<.1	<1	<1	<1

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Hard-ness, total (mg/L as $CaCO_3$)	Hard-ness, noncarb-onate total (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate (mg/L as HCO_3)	Alka-linity, total (mg/L as $CaCO_3$)
WO-23-C27	08-03-87	1,900	1,600	500	150	19	3.3	301	245
WO-118-LK8	04-02-85	620	480	130	63	58	2.4	162	133
WO-119-LK7	07-10-85	570	380	120	60	30	2.6	227	186
WO-120-N	03-27-85	440	330	97	43	48	3.4	139	114
WO-121-N	09-02-87	340	240	76	31	56	1.6	122	100
WO-129-PB23	07-21-87	600	470	130	61	61	2.3	150	123
WO-150-PE4	08-03-87	480	210	100	50	14	3.1	332	272
WO-151-PB11	08-04-87	750	460	160	78	18	2.6	358	294
WO-152-PO7	08-04-87	830	560	190	80	73	3.8	332	272
WO-198-T21	08-13-87	390	120	75	49	15	6.7	333	271
WO-199-F34	08-06-87	330	81	72	35	14	2.1	306	250
WO-203-PE12	07-30-87	340	18	81	33	1.8	.6	390	320
WO-204-PE22	07-22-87	350	57	87	29	4.4	3.8	358	293
WO-210-B35	07-30-87	620	430	140	62	63	2.9	243	198
WO-212-B4	07-22-87	1,100	650	230	110	34	4.3	489	400
WO-216-H1	08-04-87	570	150	110	67	32	3.8	515	421
WO-218-H36	07-28-87	610	240	130	68	28	3.4	455	372
WO-223-H17	08-05-87	580	260	130	51	32	2.9	390	317
WO-230-J24	08-04-87	870	770	200	84	110	2.6	123	102
WO-236-J8	08-03-87	380	270	95	28	110	2.3	129	106
WO-237-ML31	08-04-87	290	160	69	22	90	1.9	159	129
WO-246-LI19	07-31-87	240	72	49	20	35	2.1	205	168
WO-250-LI2	08-05-87	630	360	140	65	38	6.1	333	272
WO-253-PO18	07-29-87	650	240	160	55	43	14	505	413
WO-259-PO24	07-29-87	710	420	150	75	31	3.3	348	285
WO-260-MO9	07-28-87	350	120	67	33	24	2.2	275	225
WO-263-MO1	07-29-87	430	48	100	44	42	7.6	469	381
WO-265-MO25	07-22-87	440	0	92	50	51	11	533	435
WO-269-F20	08-07-87	260	4	62	25	1.4	.7	310	253
WO-272-WB36	08-13-87	670	420	140	73	25	2.8	304	247
WO-274-MD28	08-06-87	450	250	96	46	32	1.9	250	207
WO-275-C31	08-13-87	450	150	97	46	63	1.2	375	307
WO-286-PL17	08-05-87	1,400	1,300	360	110	100	2.6	89	73
WO-295-GR7	07-24-87	1,300	990	200	190	67	3.4	379	311
WO-299-WA24	07-27-87	1,700	1,500	430	160	56	5.0	325	266
WO-303-MD23	07-28-87	1,200	810	190	160	56	3.3	411	381
WO-306-PB	07-16-87	980	930	240	89	140	2.2	67	56
WO-307-WB15	08-11-87	340	86	81	33	8.7	3.0	310	254
WO-309-LK27	08-12-87	470	270	110	40	20	1.8	254	207
WO-313-R	07-21-87	380	220	85	32	56	2.7	193	157
WO-316-LK4	09-02-87	380	280	83	35	63	2.2	118	98
WO-320-N36	09-03-87	770	650	190	68	48	2.4	150	123
WO-321-LK12	08-10-87	1,100	950	270	100	45	2.4	184	149
WO-326-WS32	08-04-87	1,600	1,400	390	140	63	4.6	196	161
WO-330-PB1	08-12-87	650	380	140	66	28	2.8	329	268
WO-331-PB23	08-11-87	390	230	88	37	23	2.0	204	169
WO-333-PB19	08-14-87	580	440	130	58	64	2.8	173	141
WO-341-LK36	08-11-87	430	130	87	39	7.5	1.4	366	299
WO-342-T9	08-12-87	350	130	77	29	15	2.0	267	215
WO-344-PL27	08-06-87	530	200	97	66	23	3.6	403	322
WO-347-B12	07-30-87	750	400	180	68	15	3.4	433	354
WO-349-F3	09-03-86	390	160	95	37	36	3.4	281	225
WO-351-B6	08-05-87	640	220	140	62	69	3.2	516	420
WO-352-B36	09-03-86	1,000	890	230	100	84	4.5	129	109
	08-05-87	--	--	--	--	--	--	148	121

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Carbon dioxide, dis- solved (mg/L as CO_2)	Sulfide, total (mg/L as S)	Sulfate, dis- solved (mg/L as SO_4)	Chlo- ride, dis- solved (mg/L as Cl)	Fluo- ride, dis- solved (mg/L as F)	Bromide, dis- solved (mg/L as Br)	Iodide, dis- solved (mg/L as I)	Silica, dis- solved (mg/L as SiO_2)
WO-23-C27	08-03-87	66	1.0	1,700	25	1.6	0.23	--	16
WO-118-LK8	04-02-85	10	<.5	570	9.6	1.8	--	--	8.3
WO-119-LK7	07-10-85	14	.2	430	4.3	1.6	--	--	11
WO-120-N	03-27-85	4.4	<.5	380	11	1.8	--	--	7.4
WO-121-N	09-02-87	2.7	<.5	350	14	2.1	5.2	--	7.5
WO-129-PB23	07-21-87	8.1	ND	630	6.4	1.2	.065	--	12
WO-150-PE4	08-03-87	26	ND	180	30	.8	.18	--	9.2
WO-151-PB11	08-04-87	43	ND	490	26	2.0	.16	--	6.7
WO-152-PO7	08-04-87	34	3.2	490	150	1.5	.81	--	10
WO-198-T21	08-13-87	40	ND	69	23	.1	<.010	--	6.3
WO-199-F34	08-06-87	26	ND	140	6.2	1.8	.059	--	13
WO-203-PE12	07-30-87	44	<0.5	9.1	1.3	.2	.042	.002	12
WO-204-PE22	07-22-87	25	ND	59	2.7	.5	.020	--	14
WO-210-B35	07-30-87	29	14	530	19	1.5	.069	.009	15
WO-212-B4	07-22-87	126	<0.5	640	93	1.3	.65	--	21
WO-216-H1	08-04-87	62	47	270	50	1.4	.34	--	15
WO-218-H36	07-28-87	67	22	340	6.1	.8	.079	--	26
WO-223-H17	08-05-87	17	2.7	260	60	1.0	.41	--	14
WO-230-J24	08-04-87	5.9	ND	960	13	1.2	.14	--	9.2
WO-236-J8	08-03-87	5.1	ND	460	10	1.5	.14	--	10
WO-237-ML31	08-04-87	2.9	<0.5	370	16	1.3	.21	--	8.9
WO-246-LI19	07-31-87	6.4	<0.5	140	10	1.5	.089	.011	14
WO-250-LI2	08-05-87	29	0.8	370	48	1.1	.28	--	18
WO-253-PO18	07-29-87	92	ND	250	68	.9	.11	--	21
WO-259-PO24	07-29-87	75	<0.5	420	21	1.9	.20	--	20
WO-260-MO9	07-28-87	17	ND	140	11	1.9	.12	--	15
WO-263-MO1	07-29-87	66	ND	68	53	.2	.079	--	9.4
WO-265-MO25	07-22-87	100	ND	39	48	.2	.054	--	11
WO-269-F20	08-07-87	19	ND	6.0	1.0	1.6	<.010	--	8.4
WO-272-WB36	08-13-87	33	<0.5	490	5.0	1.2	.059	--	19
WO-274-MD28	08-06-87	17	ND	310	6.0	1.0	.061	--	13
WO-275-C31	08-13-87	33	<0.5	83	160	.6	.034	--	6.7
WO-286-PL17	08-05-87	3.4	ND	1,600	47	1.3	.37	--	17
WO-295-GR7	07-24-87	59	ND	1,100	10	1.4	.13	--	19
WO-299-WA24	07-27-87	65	1.9	1,300	38	1.0	.30	--	16
WO-303-MD23	07-28-87	57	17	970	9.2	1.0	.080	--	16
WO-306-PB	07-16-87	4.2	ND	1,200	9.7	1.3	.12	--	11
WO-307-WB15	08-11-87	19	ND	84	13	.3	.045	--	9.7
WO-309-LK27	08-12-87	23	ND	260	8.8	1.7	.091	--	11
WO-313-R	07-21-87	9.7	<0.5	320	19	1.7	.15	--	8.9
WO-316-LK4	09-02-87	2.6	<0.5	380	12 (14)*	2.6	.75 (.13)*	--	6.4
WO-320-N36	09-03-87	7.5	<0.5	690	16 (17)*	2.0	10 (.16)*	--	9.5
WO-321-LK12	08-10-87	18	ND	940	16	1.6	.16	--	11
WO-326-WS32	08-04-87	21	8.2	1,600	41	1.5	.33	--	11
WO-330-PB1	08-12-87	43	<0.5	360	35	1.3	.083	--	16
WO-331-PB23	08-11-87	8.7	<0.5	220	13	1.0	.11	--	10
WO-333-PB19	08-14-87	11	<0.5	570	10	2.0	.088	--	8.4
WO-341-LK36	08-11-87	30	<0.5	120	5.1	1.8	.047	--	11
WO-342-T9	08-12-87	20	<0.5	140	3.9	1.5	.034	--	11
WO-344-PL27	08-06-87	40	<0.5	220	12	1.3	.093	--	30
WO-347-B12	07-30-87	69	<0.5	370	3.8	1.5	.052	.003	23
WO-349-F3	09-03-86	18	--	180	75	1.1	.39	--	12
WO-351-B6	08-05-87	58	19	190	190	.5	1.1	.039	12
WO-352-B36	09-03-86	8.2	0.2	1,000	37	1.9	.31	--	11
	08-05-87	8.5	ND	--	--	--	--	--	--

* Values in parentheses from resample of 01-31-89.

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Solids, residue at 180 deg C, dis- solved (mg/L)	Solids, sum of constit- uents, dis- solved (mg/L)	Nitro- gen, nitrite, dis- solved (mg/L as N)	Nitro- gen, NO2+NO3, dis- solved (mg/L as N)	Nitro- gen, ammonia, dis- solved (mg/L as N)	Nitro- gen, am- monia,+ organic, dis- solved (mg/L as N)	Phos- phorous dis- solved (mg/L as P)	Phos- phorous, ortho, dis- solved (mg/L as P)
WO-23-C27	08-03-87	2,830	2,570	0.002	<0.010	0.825	0.90	--	<0.001
WO-118-LK8	04-02-85	961	952	<.010	<.100	.390	1.0	--	.020
WO-119-LK7	07-10-85	834	792	<.010	<.100	.450	.60	--	--
WO-120-N	03-27-85	709	679	.040	<.100	.300	.60	--	<.010
WO-121-N	09-02-87	619	627	.003	<.010	.866	.60	--	.004
WO-129-PB23	07-21-87	1,050	997	.001	.056	.650	.60	--	<.001
WO-150-PE4	08-03-87	555	570	.002	.433	.036	.50	--	.002
WO-151-PB11	08-04-87	1,020	990	.003	.028	.077	.50	--	.010
WO-152-PO7	08-04-87	1,220	1,190	.044	.053	1.60	1.4	--	<.001
WO-198-T21	08-13-87	482	436	.010	12.0	2.30	2.9	10.0	7.90
WO-199-F34	08-06-87	468	443	<.001	.021	.310	1.0	--	.002
WO-203-PE12	07-30-87	314	333	.004	.011	.068	.60	--	<.001
WO-204-PE22	07-22-87	396	390	.002	.708	.096	.40	--	.002
WO-210-B35	07-30-87	996	971	.001	<.010	.305	.70	--	<.001
WO-212-B4	07-22-87	1,510	1,400	.001	.010	.274	.60	--	<.001
WO-216-H1	08-04-87	738	820	.002	<.010	.650	1.0	--	<.001
WO-218-H36	07-28-87	818	835	.003	<.010	.310	.70	--	.004
WO-223-H17	08-05-87	776	783	.002	<.010	.286	1.0	--	.003
WO-230-J24	08-04-87	1,580	1,460	.003	<.010	.650	1.0	--	<.001
WO-236-J8	08-03-87	811	803	<.001	<.010	.560	.90	--	<.001
WO-237-ML31	08-04-87	695	681	.003	.048	.520	.80	--	<.001
WO-246-LI19	07-31-87	395	405	<.001	<.010	.311	.50	--	.001
WO-250-LI2	08-05-87	889	864	.033	.127	.670	.70	--	<.001
WO-253-PO18	07-29-87	918	883	<.001	<.010	.310	.60	--	.012
WO-259-PO24	07-29-87	977	916	<.001	<.010	.310	.60	--	<.001
WO-260-MO9	07-28-87	487	468	<.001	<.010	.310	.70	--	.001
WO-263-MO1	07-29-87	563	557	<.001	8.30	.029	.90	--	.058
WO-265-MO25	07-22-87	589	574	.004	3.50	3.20	8.4	--	1.40
WO-269-F20	08-07-87	240	259	.006	.982	.058	2.1	--	<.001
WO-272-WB36	08-13-87	967	927	.002	.031	.600	.60	.008	.029
WO-274-MD28	08-06-87	643	652	.003	.065	.600	.60	--	.003
WO-275-C31	08-13-87	696	661	.001	.031	.114	.80	<.005	.030
WO-286-PL17	08-05-87	2,400	2,290	<.002	.036	1.00	1.2	--	.004
WO-295-GR7	07-24-87	1,890	1,800	.001	.023	.795	.80	--	.001
WO-299-WA24	07-27-87	2,240	2,180	<.001	<.010	.315	1.1	--	<.001
WO-303-MD23	07-28-87	1,670	1,620	.003	<.010	.305	.60	--	.020
WO-306-PB	07-16-87	1,850	1,740	.020	.160	.680	.70	--	.014
WO-307-WB15	08-11-87	382	388	.001	<.010	.047	.80	<.005	<.001
WO-309-LK27	08-12-87	638	609	<.001	. 014	.505	1.0	<.005	<.001
WO-313-R	07-21-87	673	650	.001	.011	.680	.70	--	.001
WO-316-LK4	09-02-87	699	665	<.001	<.010	.305	.90	--	<.001
WO-320-N36	09-03-87	1,180	1,130	<.001	<.010	.305	.80	--	<.001
WO-321-LK12	08-10-87	1,690	1,490	<.001	<.010	.655	.80	<.005	<.001
WO-326-WS32	08-04-87	2,640	2,350	.003	<.010	1.00	.70	--	.004
WO-330-PB1	08-12-87	890	841	<.001	<.010	.590	.40	<.005	<.001
WO-331-PB23	08-11-87	534	514	<.001	.011	.525	.70	.013	.010
WO-333-PB19	08-14-87	977	949	.001	.033	.900	1.3	.007	.012
WO-341-LK36	08-11-87	511	502	<.001	.011	.276	.70	<.005	<.001
WO-342-T9	08-12-87	461	443	<.001	.013	.645	1.2	<.005	<.001
WO-344-PL27	08-06-87	681	666	.003	.084	.320	1.5	--	.003
WO-347-B12	07-30-87	945	901	<.001	<.010	.277	.50	--	<.001
WO-349-F3	09-03-86	610	578	--	--	--	.60	--	--
WO-351-B6	08-05-87	981	955	.006	<.010	.298	.50	--	.007
WO-352-B36	09-03-86	1,620	1,550	<.010	<.100	.660	.90	--	.010
	08-05-87	--	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)
WO-23-C27	08-03-87	20	2	<1	<100	210	<1	40	<1
WO-118-LK8	04-02-85	10	--	<1	--	430	<1	<10	--
WO-119-LK7	07-10-85	--	--	--	--	--	--	--	--
WO-120-N	03-27-85	30	--	1	--	310	<1	10	--
WO-121-N	09-02-87	50	<1	1	5	250	<1	20	<1
WO-129-PB23	07-21-87	<10	--	<1	--	730	--	--	--
WO-150-PE4	08-03-87	<10	--	<1	--	60	--	--	--
WO-151-PB11	08-04-87	10	--	<1	--	90	--	--	--
WO-152-PO7	08-04-87	50	--	<1	--	150	--	--	--
WO-198-T21	08-13-87	<10	1	6	20	60	<1	<10	2
WO-199-F34	08-06-87	<10	--	1	--	140	--	--	--
WO-203-PE12	07-30-87	<10	--	--	--	10	--	--	--
WO-204-PE22	07-22-87	<10	<1	<1	92	40	<1	<10	<1
WO-210-B35	07-30-87	20	<1	<1	23	380	<1	<10	1
WO-212-B4	07-22-87	<10	<1	--	--	150	--	30	--
WO-216-H1	08-04-87	40	--	2	--	230	--	--	--
WO-218-H36	07-28-87	<10	--	<1	--	260	--	--	--
WO-223-H17	08-05-87	<10	--	<1	--	200	--	--	--
WO-230-J24	08-04-87	<10	<1	<1	13	230	<1	20	<1
WO-236-J8	08-03-87	<10	1	1	13	600	<1	<10	<1
WO-237-ML31	08-04-87	<10	--	<1	--	500	--	--	--
WO-246-LI19	07-31-87	20	<1	<1	37	390	<1	<10	1
WO-250-LI2	08-05-87	10	<1	<1	32	540	<1	20	<1
WO-253-PO18	07-29-87	<10	--	<1	--	290	--	--	--
WO-259-PO24	07-29-87	<10	--	<1	--	350	--	--	--
WO-260-MO9	07-28-87	20	<1	1	46	300	<1	30	<1
WO-263-MO1	07-29-87	30	<1	<1	58	320	<1	710	3
WO-265-MO25	07-22-87	<10	2	15	28	230	<1	10	3
WO-269-F20	08-07-87	<10	--	<1	--	<10	--	--	--
WO-272-WB36	08-13-87	<10	--	<1	--	320	--	--	--
WO-274-MD28	08-06-87	<10	--	<1	--	330	--	--	--
WO-275-C31	08-13-87	<10	--	<1	--	20	--	--	--
WO-286-PL17	08-05-87	10	--	1	<100	780	1	<10	<1
WO-295-GR7	07-24-87	10	--	1	--	690	--	--	--
WO-299-WA24	07-27-87	<10	<1	<1	<100	360	<1	20	<1
WO-303-MD23	07-28-87	10	<1	<1	53	660	<1	<10	<1
WO-306-PB	07-16-87	<10	<1	<1	200	890	<1	60	<1
WO-307-WB15	08-11-87	<10	<1	<1	240	10	<1	<10	<1
WO-309-LK27	08-12-87	20	<1	<1	16	200	<1	<10	2
WO-313-R	07-21-87	20	--	<1	--	420	--	--	--
WO-316-LK4	09-02-87	<10	--	<1	--	300	--	--	--
WO-320-N36	09-03-87	<10	1	3	6	310	<1	20	<1
WO-321-LK12	08-10-87	<10	--	2	--	360	--	--	--
WO-326-WS32	08-04-87	10	<1	<1	<100	570	<1	20	<1
WO-330-PB1	08-12-87	10	--	<1	--	280	--	--	--
WO-331-PB23	08-11-87	<10	--	<1	--	220	--	--	--
WO-333-PB19	08-14-87	20	<1	<1	9	460	<1	30	<1
WO-341-LK36	08-11-87	10	<1	<1	36	70	<1	<10	<1
WO-342-T9	08-12-87	<10	<1	<1	30	160	<1	<10	<1
WO-344-PL27	08-06-87	<10	--	<1	--	580	--	--	--
WO-347-B12	07-30-87	10	--	--	--	190	--	--	--
WO-349-F3	09-03-86	<10	<1	<1	31	160	<1	<10	4
WO-351-B6	08-05-87	20	<1	<1	280	110	<1	30	<1
WO-352-B36	09-03-86	20	<1	<1	9	610	2	<10	2
	08-05-87	--	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Iron, dis- solved (µg/L as Fe)	Lead, dis- solved (µg/L as Pb)	Lithium, dis- solved (µg/L as Li)	Manga- nese, dis- solved (µg/L as Mn)	Mercury, dis- solved (µg/L as Hg)	Nickel, dis- solved (µg/L as Ni)	Sele- nium, dis- solved (µg/L as Se)	Silver, dis- solved (µg/L as Ag)
WO-23-C27	08-03-87	180	<5	30	20	<0.1	<1	1	<1.0
WO-118-LK8	04-02-85	110	<1	34	4	--	--	<1	--
WO-119-LK7	07-10-85	90	--	--	2	--	--	--	--
WO-120-N	03-27-85	460	<1	21	--	--	--	<1	--
WO-121-N	09-02-87	56	<5	17	9	--	<1	<1	<1.0
WO-129-PB23	07-21-87	460	--	--	22	--	--	--	--
WO-150-PE4	08-03-87	41	--	--	<3	--	--	--	--
WO-151-PB11	08-04-87	53	--	--	24	--	--	--	--
WO-152-PO7	08-04-87	200	--	--	18	--	--	--	--
WO-198-T21	08-13-87	6	<5	--	11	<.1	5	<1	<1.0
WO-199-F34	08-06-87	290	--	--	6	--	--	--	--
WO-203-PE12	07-30-87	1,900	--	--	11	--	--	--	--
WO-204-PE22	07-22-87	700	<5	26	7	<.1	3	<1	<1.0
WO-210-B35	07-30-87	10	<5	47	<1	.1	2	<1	<1.0
WO-212-B4	07-22-87	1,000	--	100	26	--	1	--	--
WO-216-H1	08-04-87	36	--	--	6	--	--	--	--
WO-218-H36	07-28-87	18	--	--	2	--	--	--	--
WO-223-H17	08-05-87	27	--	--	4	--	--	--	--
WO-230-J24	08-04-87	120	<5	32	7	.1	<1	<1	<1.0
WO-236-J8	08-03-87	310	<5	34	4	<.1	<1	<1	<1.0
WO-237-ML31	08-04-87	200	--	--	5	--	--	--	--
WO-246-LI19	07-31-87	320	<5	27	4	<.1	2	<1	<1.0
WO-250-LI2	08-05-87	470	<5	31	21	.1	<1	<1	<1.0
WO-253-PO18	07-29-87	980	--	--	63	--	--	--	--
WO-259-PO24	07-29-87	700	--	--	10	--	--	--	--
WO-260-MO9	07-28-87	720	<5	33	6	.3	1	<1	<1.0
WO-263-MO1	07-29-87	<3	5	13	1	<.1	<1	1	<1.0
WO-265-MO25	07-22-87	280	<5	10	130	.2	14	<1	<1.0
WO-269-F20	08-07-87	<3	--	--	<1	--	--	--	--
WO-272-WB36	08-13-87	470	--	--	4	--	--	--	--
WO-274-MD28	08-06-87	360	--	--	6	--	--	--	--
WO-275-C31	08-13-87	98	--	--	8	--	--	--	--
WO-286-PL17	08-05-87	1,500	<5	30	40	--	<1	<1	<1.0
WO-295-GR7	07-24-87	2,500	--	--	21	--	--	--	--
WO-299-WA24	07-27-87	660	<5	80	40	.3	<1	<1	<1.0
WO-303-MD23	07-28-87	85	<5	95	260	<.1	<1	<1	<1.0
WO-306-PB	07-16-87	420	<5	20	40	2.4	<1	<1	<1.0
WO-307-WB15	08-11-87	350	<5	<4	15	.2	<1	<1	<1.0
WO-309-LK27	08-12-87	47	<5	11	2	.2	<1	<1	<1.0
WO-313-R	07-21-87	180	--	--	14	--	--	--	--
WO-316-LK4	09-02-87	<3	--	--	<1	--	--	--	--
WO-320-N36	09-03-87	480	<5	23	3	<.1	<1	<1	<1.0
WO-321-LK12	08-10-87	890	--	--	9	--	--	--	--
WO-326-WS32	08-04-87	70	<5	60	10	<.1	<1	<1	<1.0
WO-330-PB1	08-12-87	750	--	--	10	--	--	--	--
WO-331-PB23	08-11-87	46	--	--	2	--	--	--	--
WO-333-PB19	08-14-87	260	<5	12	3	.6	3	<1	<1.0
mgO-341-LK36	08-11-87	93	<5	10	<3	.2	<1	<1	<1.0
WO-342-T9	08-12-87	210	<5	10	2	<.1	<1	<1	<1.0
WO-344-PL27	08-06-87	160	--	--	14	--	--	--	--
WO-347-B12	07-30-87	1,400	--	--	13	--	--	--	--
WO-349-F3	09-03-86	15	<5	40	<1	--	3	<1	<1.0
WO-351-B6	08-05-87	19	<5	25	9	.1	<1	<1	<1.0
WO-352-B36	09-03-86	6	<5	57	2	--	2	<1	<1.0
	08-05-87	--	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Strontium, dissolved (µg/L as Sr)	Zinc, dissolved (µg/L as Zn)	Carbon, organic dissolved (mg/L as C)	Cyanide, total (mg/L as Cn)	Sodium adsorption ratio	Cation-anion imbalance (percent)	Major-ion water type cation : anion
WO-23-C27	08-03-87	9,100	10	1.6	<0.010	0.2	- 3.4	C : S
WO-118-LK8	04-02-85	28,000	--	--	--	1	+ .0	C M : S
WO-119-LK7	07-10-85	20,000	--	--	<.010	.6	- 1.0	C M : S
WO-120-N	03-27-85	18,000	--	--	--	1	+ 3.5	C M N : S
WO-121-N	09-02-87	22,000	13	1.4	--	1	- 2.4	C M N : S
WO-129-PB23	07-21-87	17,000	--	2.2	--	1	- 3.9	C M : S
WO-150-PE4	08-03-87	19,000	--	1.9	--	.3	+ .6	C M : H S
WO-151-PB11	08-04-87	30,000	--	2.2	--	.3	- 2.9	C M : S
WO-152-PO7	08-04-87	22,000	--	2.3	--	1	- .3	C M : S H C
WO-198-T21	08-13-87	460	100	5.5	<.010	.3	+ 1.2	M C : H
WO-199-F34	08-06-87	7,400	--	1.3	--	.3	- 5.7	C M : H
WO-203-PE12	07-30-87	240	--	3.5	--	.0	+ 2.4	C M : H
WO-204-PE22	07-22-87	12,000	84	1.7	<.010	.1	+ .6	C : H
WO-210-B35	07-30-87	17,000	9	2.5	<.010	1	- 1.1	C M : S
WO-212-B4	07-22-87	24,000	--	2.4	<.010	.5	- 2.8	C M : S H
WO-216-H1	08-04-87	16,000	--	2.0	--	.6	- 9.4	M C : H S
WO-218-H36	07-28-87	7,800	--	2.2	--	.5	- 4.2	C M : H S
WO-223-H17	08-05-87	39,000	--	2.2	--	.6	- 1.9	C M : H S
WO-230-J24	08-04-87	22,000	110	1.5	<.010	2	- .4	C M N : S
WO-236-J8	08-03-87	21,000	46	2.1	<.010	3	+ 1.2	N C : S
WO-237-ML31	08-04-87	22,000	--	1.5	--	2	- 5.3	N C : S
WO-246-LI19	07-31-87	31,000	14	2.7	<.010	1	- 1.9	C M N : H C
WO-250-LI2	08-05-87	12,000	14	2.3	<.010	.7	- .5	C M : S H
WO-253-PO18	07-29-87	21,000	--	6.5	--	.8	- .6	C M : H S
WO-259-PO24	07-29-87	21,000	--	2.2	--	.5	+ 1.5	C M : S H
WO-260-MO9	07-28-87	37,000	14	2.4	<.010	.6	+ 1.4	C M : H S
WO-263-MO1	07-29-87	840	170	3.0	<.010	.9	- 2.4	C M : H
WO-265-MO25	07-22-87	790	24	5.0	<.010	1	+ .4	C M N : H
WO-269-F20	08-07-87	77	--	2.8	--	.0	- 1.4	C M : H
WO-272-WB36	08-13-87	20,000	--	2.1	--	.4	- 2.5	C M : S
WO-274-MD28	08-06-87	22,000	--	1.3	--	.7	- 1.1	C M : S H
WO-275-C31	08-13-87	19,000	--	2.7	--	1	- 2.4	C M N : H C
WO-286-PL17	08-05-87	8,300	50	1.3	--	1	- 6.6	C M : S
WO-295-GR7	07-24-87	15,000	--	2.1	--	.8	- .6	M C : S
WO-299-WA24	07-27-87	8,400	10	2.6	<.010	.6	+ 5.5	C M : S
WO-303-MD23	07-28-87	15,000	10	2.6	<.010	.7	- 3.3	M C : S
WO-306-PB	07-16-87	13,000	30	1.7	<.010	2	- 1.3	C M N : S
WO-307-WB15	08-11-87	1,700	94	1.9	<.010	.2	+ .4	C M : H
WO-309-LK27	08-12-87	30,000	31	1.6	<.010	.4	+ 2.4	C M : S H
WO-313-R	07-21-87	28,000	--	2.2	--	1	- 2.0	C M N : S
WO-316-LK4	09-02-87	21,000	--	1.2	--	2	- .1	C M N : S
WO-320-N36	09-03-87	14,000	150	1.2	.010	.8	+ .5	C M : S
WO-321-LK12	08-10-87	13,000	--	1.7	--	.6	+ 2.0	C M : S
WO-326-WS32	08-04-87	4,800	<10	1.7	<.010	.7	- 5.3	C M : S
WO-330-PB1	08-12-87	28,000	--	2.2	--	.5	+ 1.6	C M : S H
WO-331-PB23	08-11-87	19,000	--	1.8	--	.5	+ 3.4	C M : S H
WO-333-PB19	08-14-87	17,000	14	2.1	.010	1	- 1.9	C M N : S
WO-341-LK36	08-11-87	49,000	44	1.6	<.010	.2	+ 1.7	C M : H
WO-342-T9	08-12-87	31,000	16	1.7	<.010	.4	+ 1.1	C M : H S
WO-344-PL27	08-06-87	14,000	--	1.4	--	.5	+ .5	M C : H S
WO-347-B12	07-30-87	21,000	--	2.7	--	.2	+ 2.9	C M : S H
WO-349-F3	09-03-86	32	10	--	<.010	.8	- 5.4	C M : H S C
WO-351-B6	08-05-87	33,000	12	4.6	<.010	1	- 5.5	C M N : H C S
WO-352-B36	09-03-86	12,000	18	--	<.010	1	- .9	C M : S
	08-05-87	--	--	--	--	--		

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Di-chloro-bromo-methane, total (µg/L)	Carbon-tetra-chlo-ride, total (µg/L)	1,2-Di-chloro-ethane, total (µg/L)	Bromo-form, total (µg/L)	Chloro-di-bromo-methane, total (µg/L)	Chloro-form, total (µg/L)	Toluene, total (µg/L)
WO-23-C27	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-118-LK8	04-02-85	--	--	--	--	--	--	--
WO-119-LK7	07-10-85	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-120-N	03-27-85	--	--	--	--	--	--	--
WO-121-N	09-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-129-PB23	07-21-87	--	--	--	--	--	--	--
WO-150-PE4	08-03-87	--	--	--	--	--	--	--
WO-151-PB11	08-04-87	--	--	--	--	--	--	--
WO-152-PO7	08-04-87	--	--	--	--	--	--	--
WO-198-T21	08-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-199-F34	08-06-87	--	--	--	--	--	--	--
WO-203-PE12	07-30-87	--	--	--	--	--	--	--
WO-204-PE22	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-210-B35	07-30-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-212-B4	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-216-H1	08-04-87	--	--	--	--	--	--	--
WO-218-H36	07-28-87	--	--	--	--	--	--	--
WO-223-H17	08-05-87	--	--	--	--	--	--	--
WO-230-J24	08-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-236-J8	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-237-ML31	08-04-87	--	--	--	--	--	--	--
WO-246-LI19	07-31-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-250-LI2	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-253-PO18	07-29-87	--	--	--	--	--	--	--
WO-259-PO24	07-29-87	--	--	--	--	--	--	--
WO-260-MO9	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-263-MO1	07-29-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-265-MO25	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-269-F20	08-07-87	--	--	--	--	--	--	--
WO-272-WB36	08-13-87	--	--	--	--	--	--	--
WO-274-MD28	08-06-87	--	--	--	--	--	--	--
WO-275-C31	08-13-87	--	--	--	--	--	--	--
WO-286-PL17	08-05-87	--	--	--	--	--	--	--
WO-295-GR7	07-24-87	--	--	--	--	--	--	--
WO-299-WA24	07-27-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-303-MD23	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-306-PB	07-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-307-WB15	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-309-LK27	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-313-R	07-21-87	--	--	--	--	--	--	--
WO-316-LK4	09-02-87	--	--	--	--	--	--	--
WO-320-N36	09-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-321-LK12	08-10-87	--	--	--	--	--	--	--
WO-326-WS32	08-04-87	<15	<15	<15	<15	<15	<15	<15
WO-330-PB1	08-12-87	--	--	--	--	--	--	--
WO-331-PB23	08-11-87	--	--	--	--	--	--	--
WO-333-PB19	08-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-341-LK36	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-342-T9	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-344-PL27	08-06-87	--	--	--	--	--	--	--
WO-347-B12	07-30-87	--	--	--	--	--	--	--
WO-349-F3	09-03-86	--	--	--	--	--	--	--
WO-351-B6	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-352-B36	09-03-86	--	--	--	--	--	--	--
	08-05-87	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Benzene, total (µg/L)	Chloro-benzene, total (µg/L)	Chloro-ethane, total (µg/L)	Ethyl-benzene, total (µg/L)	Methyl-bromide, total (µg/L)	Methyl-chlo-ride, total (µg/L)	Methyl-ene chlo-ride, total (µg/L)
WO-23-C27	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<6.0
WO-118-LK8	04-02-85	--	--	--	--	--	--	--
WO-119-LK7	07-10-85	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0
WO-120-N	03-27-85	--	--	--	--	--	--	--
WO-121-N	09-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-129-PB23	07-21-87	--	--	--	--	--	--	--
WO-150-PE4	08-03-87	--	--	--	--	--	--	--
WO-151-PB11	08-04-87	--	--	--	--	--	--	--
WO-152-PO7	08-04-87	--	--	--	--	--	--	--
WO-198-T21	08-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-199-F34	08-06-87	--	--	--	--	--	--	--
WO-203-PE12	07-30-87	--	--	--	--	--	--	--
WO-204-PE22	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-210-B35	07-30-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-212-B4	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-216-H1	08-04-87	--	--	--	--	--	--	--
WO-218-H36	07-28-87	--	--	--	--	--	--	--
WO-223-H17	08-05-87	--	--	--	--	--	--	--
WO-230-J24	08-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<6.0
WO-236-J8	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-237-ML31	08-04-87	--	--	--	--	--	--	--
WO-246-LI19	07-31-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-250-LI2	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<5.0
WO-253-PO18	07-29-87	--	--	--	--	--	--	--
WO-259-PO24	07-29-87	--	--	--	--	--	--	--
WO-260-MO9	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-263-MO1	07-29-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<13
WO-265-MO25	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-269-F20	08-07-87	--	--	--	--	--	--	--
WO-272-WB36	08-13-87	--	--	--	--	--	--	--
WO-274-MD28	08-06-87	--	--	--	--	--	--	--
WO-275-C31	08-13-87	--	--	--	--	--	--	--
WO-286-PL17	08-05-87	--	--	--	--	--	--	--
WO-295-GR7	07-24-87	--	--	--	--	--	--	--
WO-299-WA24	07-27-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-303-MD23	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<5.0
WO-306-PB	07-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-307-WB15	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<24
WO-309-LK27	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<7.4
WO-313-R	07-21-87	--	--	--	--	--	--	--
WO-316-LK4	09-02-87	--	--	--	--	--	--	--
WO-320-N36	09-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-321-LK12	08-10-87	--	--	--	--	--	--	--
WO-326-WS32	08-04-87	<15	<15	<15	<15	<15	<15.0	29
WO-330-PB1	08-12-87	--	--	--	--	--	--	--
WO-331-PB23	08-11-87	--	--	--	--	--	--	--
WO-333-PB19	08-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-341-LK36	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<22
WO-342-T9	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<24
WO-344-PL27	08-06-87	--	--	--	--	--	--	--
WO-347-B12	07-30-87	--	--	--	--	--	--	--
WO-349-F3	09-03-86	--	--	--	--	--	--	--
WO-351-B6	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<6.0
WO-352-B36	09-03-86	--	--	--	--	--	--	--
	08-05-87	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Tetra-chloro-ethyl-ene, total (µg/L)	Tri-chloro-fluoro-methane, total (µg/L)	1,1-Di-chloro-ethane, total (µg/L)	1,1-Di-chloro-ethyl-ene, total (µg/L)	1,1,1-Tri-chloro-ethane, total (µg/L)	1,1,2-Tri-chloro-ethane, total (µg/L)	1,1,2,2 Tetra-chloro-ethane, total (µg/L)	1,2-Di-chloro-benzene, total (µg/L)
WO-23-C27	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-118-LK8	04-02-85	--	--	--	--	--	--	--	--
WO-119-LK7	07-10-85	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
WO-120-N	03-27-85	--	--	--	--	--	--	--	--
WO-121-N	09-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-129-PB23	07-21-87	--	--	--	--	--	--	--	--
WO-150-PE4	08-03-87	--	--	--	--	--	--	--	--
WO-151-PB11	08-04-87	--	--	--	--	--	--	--	--
WO-152-PO7	08-04-87	--	--	--	--	--	--	--	--
WO-198-T21	08-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-199-F34	08-06-87	--	--	--	--	--	--	--	--
WO-203-PE12	07-30-87	--	--	--	--	--	--	--	--
WO-204-PE22	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-210-B35	07-30-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-212-B4	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-216-H1	08-04-87	--	--	--	--	--	--	--	--
WO-218-H36	07-28-87	--	--	--	--	--	--	--	--
WO-223-H17	08-05-87	--	--	--	--	--	--	--	--
WO-230-J24	08-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-236-J8	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-237-ML31	08-04-87	--	--	--	--	--	--	--	--
WO-246-LI19	07-31-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-250-LI2	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-253-PO18	07-29-87	--	--	--	--	--	--	--	--
WO-259-PO24	07-29-87	--	--	--	--	--	--	--	--
WO-260-MO9	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-263-MO1	07-29-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-265-MO25	07-22-87	<3.0	<3.0	3.9	<3.0	<3.0	<3.0	<3.0	<3.0
WO-269-F20	08-07-87	--	--	--	--	--	--	--	--
WO-272-WB36	08-13-87	--	--	--	--	--	--	--	--
WO-274-MD28	08-06-87	--	--	--	--	--	--	--	--
WO-275-C31	08-13-87	--	--	--	--	--	--	--	--
WO-286-PL17	08-05-87	--	--	--	--	--	--	--	--
WO-295-GR7	07-24-87	--	--	--	--	--	--	--	--
WO-299-WA24	07-27-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-303-MD23	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-306-PB	07-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-307-WB15	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-309-LK27	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-313-R	07-21-87	--	--	--	--	--	--	--	--
WO-316-LK4	09-02-87	--	--	--	--	--	--	--	--
WO-320-N36	09-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-321-LK12	08-10-87	--	--	--	--	--	--	--	--
WO-326-WS32	08-04-87	310	<15	<15	<15	220	<15	<15	<15.0
WO-330-PB1	08-12-87	--	--	--	--	--	--	--	--
WO-331-PB23	08-11-87	--	--	--	--	--	--	--	--
WO-333-PB19	08-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-341-LK36	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-342-T9	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-344-PL27	08-06-87	--	--	--	--	--	--	--	--
WO-347-B12	07-30-87	--	--	--	--	--	--	--	--
WO-349-F3	09-03-86	--	--	--	--	--	--	--	--
WO-351-B6	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-352-B36	09-03-86	--	--	--	--	--	--	--	--
	08-05-87	--	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	1,2-Dichloropropane, total (µg/L)	1,2-Transdichloroethene, total (µg/L)	1,3-Dichloropropene, total (µg/L)	1,3-Dichlorobenzene, total (µg/L)	1,4-Dichlorobenzene, total (µg/L)	2-chloroethylvinylether, total (µg/L)	Dichlorodifluoromethane, total (µg/L)
WO-23-C27	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-118-LK8	04-02-85	--	--	--	--	--	--	--
WO-119-LK7	07-10-85	<3.0	<3.0	<3.0	--	--	<3.0	--
WO-120-N	03-27-85	--	--	--	--	--	--	--
WO-121-N	09-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-129-PB23	07-21-87	--	--	--	--	--	--	--
WO-150-PE4	08-03-87	--	--	--	--	--	--	--
WO-151-PB11	08-04-87	--	--	--	--	--	--	--
WO-152-PO7	08-04-87	--	--	--	--	--	--	--
WO-198-T21	08-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-199-F34	08-06-87	--	--	--	--	--	--	--
WO-203-PE12	07-30-87	--	--	--	--	--	--	--
WO-204-PE22	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-210-B35	07-30-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-212-B4	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-216-H1	08-04-87	--	--	--	--	--	--	--
WO-218-H36	07-28-87	--	--	--	--	--	--	--
WO-223-H17	08-05-87	--	--	--	--	--	--	--
WO-230-J24	08-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-236-J8	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-237-ML31	08-04-87	--	--	--	--	--	--	--
WO-246-LI19	07-31-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-250-LI2	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-253-PO18	07-29-87	--	--	--	--	--	--	--
WO-259-PO24	07-29-87	--	--	--	--	--	--	--
WO-260-MO9	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-263-MO1	07-29-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-265-MO25	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-269-F20	08-07-87	--	--	--	--	--	--	--
WO-272-WB36	08-13-87	--	--	--	--	--	--	--
WO-274-MD28	08-06-87	--	--	--	--	--	--	--
WO-275-C31	08-13-87	--	--	--	--	--	--	--
WO-286-PL17	08-05-87	--	--	--	--	--	--	--
WO-295-GR7	07-24-87	--	--	--	--	--	--	--
WO-299-WA24	07-27-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-303-MD23	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-306-PB	07-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-307-WB15	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-309-LK27	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-313-R	07-21-87	--	--	--	--	--	--	--
WO-316-LK4	09-02-87	--	--	--	--	--	--	--
WO-320-N36	09-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-321-LK12	08-10-87	--	--	--	--	--	--	--
WO-326-WS32	08-04-87	<15	<15	<15	<15.0	<15.0	<15	<15
WO-330-PB1	08-12-87	--	--	--	--	--	--	--
WO-331-PB23	08-11-87	--	--	--	--	--	--	--
WO-333-PB19	08-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-341-LK36	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-342-T9	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-344-PL27	08-06-87	--	--	--	--	--	--	--
WO-347-B12	07-30-87	--	--	--	--	--	--	--
WO-349-F3	09-03-86	--	--	--	--	--	--	--
WO-351-B6	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-352-B36	09-03-86	--	--	--	--	--	--	--
	08-05-87	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Trans-1,3-di-chloro-propene total (µg/L)	Cis 1,3-di-chloro-propene total (µg/L)	1,2-Dibromo-ethyl-ene, total (µg/L)	Vinyl chlo-ride, total (µg/L)	Tri-chloro-ethyl-ene, total (µg/L)	Styrene, total (µg/L)	Xylene, total, water whole tot rec (µg/L)
WO-23-C27	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-118-LK8	04-02-85	--	--	--	--	--	--	--
WO-119-LK7	07-10-85	--	--	--	<3.0	<3.0	--	--
WO-120-N	03-27-85	--	--	--	--	--	--	--
WO-121-N	09-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-129-PB23	07-21-87	--	--	--	--	--	--	--
WO-150-PE4	08-03-87	--	--	--	--	--	--	--
WO-151-PB11	08-04-87	--	--	--	--	--	--	--
WO-152-PO7	08-04-87	--	--	--	--	--	--	--
WO-198-T21	08-13-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-199-F34	08-06-87	--	--	--	--	--	--	--
WO-203-PE12	07-30-87	--	--	--	--	--	--	--
WO-204-PE22	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-210-B35	07-30-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-212-B4	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-216-H1	08-04-87	--	--	--	--	--	--	--
WO-218-H36	07-28-87	--	--	--	--	--	--	--
WO-223-H17	08-05-87	--	--	--	--	--	--	--
WO-230-J24	08-04-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-236-J8	08-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-237-ML31	08-04-87	--	--	--	--	--	--	--
WO-246-LI19	07-31-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-250-LI2	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-253-PO18	07-29-87	--	--	--	--	--	--	--
WO-259-PO24	07-29-87	--	--	--	--	--	--	--
WO-260-MO9	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-263-MO1	07-29-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-265-MO25	07-22-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-269-F20	08-07-87	--	--	--	--	--	--	--
WO-272-WB36	08-13-87	--	--	--	--	--	--	--
WO-274-MD28	08-06-87	--	--	--	--	--	--	--
WO-275-C31	08-13-87	--	--	--	--	--	--	--
WO-286-PL17	08-05-87	--	--	--	--	--	--	--
WO-295-GR7	07-24-87	--	--	--	--	--	--	--
WO-299-WA24	07-27-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-303-MD23	07-28-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-306-PB	07-16-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-307-WB15	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-309-LK27	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-313-R	07-21-87	--	--	--	--	--	--	--
WO-316-LK4	09-02-87	--	--	--	--	--	--	--
WO-320-N36	09-03-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-321-LK12	08-10-87	--	--	--	--	--	--	--
WO-326-WS32	08-04-87	<15.0	<15.0	<15	<15	<15.0	<15	<15
WO-330-PB1	08-12-87	--	--	--	--	--	--	--
WO-331-PB23	08-11-87	--	--	--	--	--	--	--
WO-333-PB19	08-14-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	4.2
WO-341-LK36	08-11-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-342-T9	08-12-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-344-PL27	08-06-87	--	--	--	--	--	--	--
WO-347-B12	07-30-87	--	--	--	--	--	--	--
WO-349-F3	09-03-86	--	--	--	--	--	--	--
WO-351-B6	08-05-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
WO-352-B36	09-03-86	--	--	--	--	--	--	--
	08-05-87	--	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Tritium, total (pCi/L)	Tritium, total (t.u.)	Gross alpha, dis-solved (µg/L as u-nat)	Gross alpha, dis-solved (pCi/L) O.D.H. labs	Gross beta, dis-solved (pCi/L as Sr/ Yt-90)	Gross beta, dis-solved (pCi/L as Cs-137)	Uranium, dis-solved, extrac-tion (µg/L)	Uranium, natural, dis-solved (µg/L as U)
WO-23-C27	08-03-87	<0.3	<0.1	<0.4	<3	3.1	4.5	--	0.30
WO-118-LK8	09-01-87	--	--	13	18	2.9	4.0	--	.29
WO-119-LK7	09-01-87	--	--	33	19.1	5.2	7.7	--	.12
WO-120-N	03-27-85	--	--	--	--	--	--	--	--
WO-121-N	09-02-87	--	--	6.5	4	3.1	4.3	--	.49
WO-129-PB23	07-21-87	3.2	1	--	--	--	--	--	--
WO-150-PE4	08-03-87	--	--	--	--	--	--	--	--
WO-151-PB11	08-04-87	80	25	2.4	<3	2.1	3.1	--	1.4
WO-152-PO7	08-04-87	53	17	--	--	--	--	--	--
WO-198-T21	08-13-87	--	--	1.0	<3	7.7	10	--	.31
WO-199-F34	08-06-87	--	--	16	10.5	4.1	5.4	--	.48
WO-203-PE12	07-30-87	.6	.2	--	<3	--	--	--	--
WO-204-PE22	07-22-87	8.8	3	5.7	--	10	13	.90	--
WO-210-B35	07-30-87	<.3	<.1	<.4	9.9	4.4	6.5	<.01	--
WO-212-B4	07-22-87	2.2	.7	7.0	--	5.1	6.9	.16	--
WO-216-H1	08-04-87	--	--	--	--	--	--	--	--
WO-218-H36	07-28-87	--	--	--	--	--	--	--	--
WO-223-H17	08-05-87	--	--	--	--	--	--	--	--
WO-230-J24	08-04-87	--	--	7.3	<3	3.8	5.8	--	.30
WO-236-J8	08-03-87	--	--	3.0	4.6	4.2	6.2	--	.66
WO-237-ML31	08-04-87	--	--	--	--	--	--	--	--
WO-246-LI19	07-31-87	--	--	1.3	4.5	2.3	3.1	.18	--
WO-250-LI2	08-05-87	--	--	.9	5.9	8.0	13	--	.19
WO-253-PO18	07-29-87	--	--	--	--	--	--	--	--
WO-259-PO24	07-29-87	--	--	--	--	--	--	--	--
WO-260-MO9	07-28-87	--	--	2.4	<3	3.1	4.1	.25	--
WO-263-MO1	07-29-87	99	31	.7	4	8.1	12	1.2	--
WO-265-MO25	07-22-87	82	26	.6	--	4.1	5.2	.08	--
WO-269-F20	08-07-87	8.0	3	--	--	--	--	--	--
WO-272-WB36	08-13-87	--	--	--	--	--	--	--	--
WO-274-MD28	08-06-87	--	--	--	--	--	--	--	--
WO-275-C31	08-13-87	130	41	--	--	--	--	--	--
WO-286-PL17	08-05-87	--	--	--	--	--	--	--	--
WO-295-GR7	07-24-87	--	--	--	--	--	--	--	--
WO-299-WA24	07-27-87	3.8	1	55	4.8	8.5	13	.29	--
WO-303-MD23	07-28-87	--	--	5.4	5.6	6.3	9.4	.28	--
WO-306-PB	07-16-87	--	--	1.3	--	3.1	4.6	.16	--
WO-307-WB15	08-11-87	61	19	1.7	3.5	4.1	5.4	--	1.0
WO-309-LK27	08-12-87	--	--	12	5.8	2.3	3.2	--	.03
WO-313-R	07-21-87	<5.7	<2	--	--	--	--	--	--
WO-316-LK4	09-02-87	--	--	6.8	9.2	3.2	4.5	--	.22
WO-320-N36	09-03-87	--	--	4.9	3.7	3.8	6.0	--	.54
WO-321-LK12	08-10-87	--	--	--	--	--	--	--	--
WO-326-WS32	08-04-87	--	--	2.0	4.3	5.1	7.7	--	.08
WO-330-PB1	08-12-87	11	3	--	--	--	--	--	--
WO-331-PB23	08-11-87	--	--	--	--	--	--	--	--
WO-333-PB19	08-14-87	.5	.2	2.4	5.8	3.5	5.3	--	.05
WO-341-LK36	08-11-87	<.3	<.1	6.0	6.5	3.3	4.5	--	.03
WO-342-T9	08-12-87	<.3	<.1	5.9	5.7	2.7	3.6	--	.02
WO-344-PL27	08-06-87	--	--	--	--	--	--	--	--
WO-347-B12	07-30-87	--	--	--	--	--	--	--	--
WO-349-F3	09-03-86	--	--	20	--	3.6	5.2	.06	--
WO-351-B6	08-05-87	47	15--	7.4	<3	3.8	5.7	--	.13
WO-352-B36	09-03-86	--	--	<.4	--	6.9	11	<.01	--
	08-05-87	1.3	.4	--	--	--	--	--	--

Table 9.-- Selected water-quality data for wells and springs in the carbonate aquifer, Lucas, Sandusky, and Wood Counties, and for wells in the surficial sand aquifer, Lucas County, northwestern Ohio--Continued

Number in plate 1	Date of sample	Remarks
WO-23-C27	08-03-87	Sulfur odor
WO-118-LK8	04-02-85	--
WO-119-LK7	07-10-85	Sulfur odor
WO-120-N	03-27-85	--
WO-121-N	09-02-87	--
WO-129-PB23	07-21-87	--
WO-150-PE4	08-03-87	--
WO-151-PB11	08-04-87	High coliform background count
WO-152-PO7	08-04-87	Sulfur odor
WO-198-T21	08-13-87	Water is yellow color
WO-199-F34	08-06-87	--
WO-203-PE12	07-30-87	--
WO-204-PE22	07-22-87	--
WO-210-B35	07-30-87	Sulfur odor
WO-212-B4	07-22-87	--
WO-216-H1	08-04-87	Sulfur odor
WO-218-H36	07-28-87	Hydrocarbons in well, hydrocarbon odor, sulfur odor
WO-223-H17	08-05-87	Sulfur odor
WO-230-J24	08-04-87	--
WO-236-J8	08-03-87	--
WO-237-ML31	08-04-87	Sulfur odor
WO-246-LI19	07-31-87	--
WO-250-LI2	08-05-87	Sulfur odor
WO-253-PO18	07-29-87	Water is yellow color
WO-259-PO24	07-29-87	--
WO-260-MO9	07-28-87	--
WO-263-MO1	07-29-87	--
WO-265-MO25	07-22-87	Owner reports occasional oil occurrence in water
WO-269-F20	08-07-87	--
WO-272-WB36	08-13-87	Jet pump
WO-274-MD28	08-06-87	--
WO-275-C31	08-13-87	Turbid water
WO-286-PL17	08-05-87	--
WO-295-GR7	07-24-87	--
WO-299-WA24	07-27-87	Sulfur odor
WO-303-MD23	07-28-87	Sulfur odor
WO-306-PB	07-16-87	--
WO-307-WB15	08-11-87	--
WO-309-LK27	08-12-87	--
WO-313-R	07-21-87	--
WO-316-LK4	09-02-87	Sulfur odor
WO-320-N36	09-03-87	--
WO-321-LK12	08-10-87	--
WO-326-WS32	08-04-87	Sulfur odor
WO-330-PB1	08-12-87	--
WO-331-PB23	08-11-87	--
WO-333-PB19	08-14-87	--
WO-341-LK36	08-11-87	--
WO-342-T9	08-12-87	--
WO-344-PL27	08-06-87	Sulfur odor, jet pump
WO-347-B12	07-30-87	--
WO-349-F3	09-03-86	--
WO-351-B6	08-05-87	Sulfur odor
WO-352-B36	09-03-86	--
	08-05-87	--

Table 15.--Concentration limits defined by National Primary and Secondary Public Drinking-Water Regulations and implications for domestic water use of selected properties and chemical, bacteriological, and radiological constituents in water

[USEPA, U.S. Environmental Protection Agency; MCL, Maximum Contaminant Level of national primary public drinking-water regulations; SMCL, Secondary Maximum Contaminant Level of national public drinking-water regulations; μg/L, micrograms per liter; mg/L, milligrams per liter; pCi/L, picoCuries per liter; $CaCO_3$, calcium carbonate; mL, milliliters. Primary regulations (MCL's) are established on the basis of health effects; secondary regulations (SMCL's) are established on the basis of aesthetic effects]

Property or constituent and unit of measurement	Concentration limits and implications for domestic water use[1]
pH, standard units	AESTHETIC--Values in the range 6.5 to to 8.5 meet SMCL. Values outside this range may contribute to corrosive water and corrosion of pipes.
Coliform, total, number of colonies per 100 mL	HEALTH-- Water is considered unsafe to drink if 4 or more colonies are detected per 100 mL of water. This criterion is established for private water systems by the State of Ohio.
Coliform, fecal, number of colonies per 100 mL	HEALTH-- Presence of fecal coliform in water is considered indicative of fecal pollution. More than 1 colony indicates that water may be vulnerable to contamination.
Streptococci, fecal, number of colonies per 100 mL	HEALTH--Presence of fecal streptococci in water is considered verification of fecal pollution. More than 1 colony indicates that water supply may be vulnerable to contamination.
Hardness, mg/L as $CaCO_3$ (65 mg hardness is about 1 grain of hardness)	AESTHETIC--Hard water causes mineral deposits, incrustations, or scale to form when water is heated or evaporated and causes increased soap consumption. Hardness is primarily caused by calcium, magnesium and strontium. Hardness generally becomes a concern for domestic use at concentrations greater than 100 mg/L.
Calcium, dissolved, mg/L	AESTHETIC--Contributes to hard water and scale on cooking utensils and water heaters.
Magnesium, dissolved, mg/L	AESTHETIC--Contributes to hard water and contributes to scale formation. High concentrations (greater than 125 mg/L) may cause laxative effects, especially to incidental and transient users.
Sodium, dissolved, mg/L	HEALTH--Health advisory level is 20 mg/L for persons with medical reasons for moderating dietary intake of sodium. Otherwise, sodium in water is not dangerous to human health.
Potassium, dissolved, mg/L	No health or aesthetic implications for the range of concentrations determined in this study; however, concentrations greater than 5 mg/L may indicate a need for testing water from the carbonate aquifer for beta-particle radioactivity.
Alkalinity, mg/L as $CaCO_3$	No health or aesthetic implications for the range of concentrations determined in this study. A measure of the capacity of a water to neutralize acid.

Table 15.--Concentration limits defined by National Primary and Secondary Public Drinking-Water Regulations and implications for domestic water use of selected properties and chemical, bacteriological, and radiological constituents in water--Continued

Property or constituent and unit of measurement	Concentration limits and implications for domestic water use[1]
Hydrogen sulfide, total, mg/L as S	AESTHETIC--No SMCL is established; however, imparts rotten-egg odor and unpleasant taste to water at concentrations less than 0.1 mg/L. Also can cause corrosion of plumbing fixtures and pipes.
Sulfate, dissolved, mg/L	AESTHETIC--SMCL is 250 mg/L. Combined with calcium, forms scale in water heaters. Imparts bitter taste and causes laxative effects at concentrations greater than 500 to 600 mg/L, especially to incidental or transient users, depending on individual's tolerance and other dissolved constituents in the supply.
Chloride, dissolved, mg/L	AESTHETIC--SMCL is 250 mg/L. Causes salty taste at concentrations above 250 to 400 mg/L, depending on individual's tolerance. High concentrations are corrosive to most metals.
Fluoride, dissolved, mg/L	HEALTH--Has a beneficial effect on structure and resistance to decay of children's teeth. Concentrations above 2.0 mg/L may cause mottling of tooth enamel. The MCL is 4 mg/L. The SMCL is 2 mg/L. Concentrations greater than 4.0 mg/L may cause crippling skeletal fluorosis.
Bromide, dissolved, mg/L	No health or aesthetic implications for the range of concentrations determined in this study. In the presence of organic substances, may form undesirable halogenated hydrocarbons if water is subjected to chlorination.
Silica, dissolved, mg/L as SiO_2	No health or aesthetic implications for the range of concentrations determined in this study. Contributes to scale in water heaters and pipes.
Solids, residue on evaporation at 180 °C, dissolved, mg/L	AESTHETIC--SMCL is 500 mg/L. Concentrations greater than 1,000 mg/L may cause objectionable tastes and laxative effects. May also cause foaming of water and corrosion of some metals.
Nitrite, dissolved, mg/L as N	HEALTH--Proposed MCL is 1 mg/L. Waters with nitrite concentrations over 1 mg/L should not be used for infant feeding.
Nitrite plus nitrate dissolved, mg/L as N	HEALTH--MCL for nitrate is 10 mg/L because of the potential risk of bottle-fed infant methemoglobinemia (blue-baby syndrome). At concentrations above 0.30 mg/L, indicates that water supply may be vulnerable to infiltration of surface drainage.
Ammonia, dissolved, mg/L as N	No health or aesthetic implications for the range of concentrations determined in this study. Possible indication of bacterial activity in water or contribution from ammonia or organic nitrogen used in agriculture.
Ammonia plus organic nitrogen, dissolved, mg/L as N	Same as for ammonia.
Phosphorus, orthophosphate, dissolved, mg/L as P	No health or aesthetic implications for the range of concentrations determined in this study.

Table 15.--Concentration limits defined by National Primary and Secondary Public Drinking-Water Regulations and implications for domestic water use of selected properties and chemical, bacteriological, and radiological constituents in water--Continued

Property or constituent and unit of measurement	Concentration limits and implications for domestic water use[1]
Aluminum, dissolved, µg/L	AESTHETIC--Presently (October 1989) no MCL or SMCL has been established for aluminum, but an SMCL of 50 µg/L is proposed to prevent flocculation following water treatment.
Arsenic, dissolved, µg/L	HEALTH--MCL is 50 µg/L; based on high toxicity effects on humans.
Antimony, dissolved, µg/L	Presently (October 1989) no MCL has been established, but future regulations are expected.
Barium, dissolved, µg/L	HEALTH--MCL is 1,000 µg/L, based on circulatory system effects. A proposed revision to the MCL is 5,000 µg/L .
Boron, dissolved, µg/L	No health or aesthetic implications for the range of concentrations determined in this study. Essential for plant nutrition, but excess is toxic to some plants. Fruit trees and nut trees are sensitive to boron, especially at concentrations greater than 1,000 µg/L.
Cadmium, dissolved, µg/L	HEALTH--MCL is 10 µg/L, based on toxic effects. A proposed revision to the MCL is 5 µg/L.
Chromium, dissolved, µg/L	HEALTH--MCL is 50 µg/L, based on toxic effects. A proposed revision to the MCL is 100 µg/L.
Copper, dissolved, µg/L	AESTHETIC--SMCL is 1,000 µg/L, because of taste effects and staining of porcelain fixtures.
Iron, dissolved, µg/L	AESTHETIC--SMCL is 300 µg/L. At concentrations greater than 300 µg/L, iron contributes to metallic tastes and staining of fixtures, utensils, and laundry. Higher concentrations form reddish-brown sediment and water-line deposits. The combined SMCL for iron plus manganese is 300 µg/L.
Lead, dissolved, µg/L	HEALTH--MCL is 50 µg/L based on toxic effects (especially in children and fetuses) and probable carcinogenic effects.
Lithium, dissolved, µg/L	No health or aesthetic implications for the range of concentrations determined in this study.
Manganese, dissolved, µg/L	AESTHETIC--SMCL is 50 µg/L. May cause dark brown or black staining of fixtures, laundry, and utensils.
Mercury, dissolved, µg/L	HEALTH--MCL is 2 µg/L, based on toxicity to humans.
Nickel, dissolved, µg/L	Presently (October 1989) no MCL for nickel has been established, but future regulations are expected.
Selenium, dissolved, µg/L	HEALTH--MCL is 10 µg/L, based on toxic and gastrointestinal effects.

Table 15.--Concentration limits defined by National Primary and Secondary Public Drinking-Water Regulations and implications for domestic water use of selected properties and chemical, bacteriological, and radiological constituents in water--Continued

Property or constituent and unit of measurement	Concentration limits and implications for domestic water use[1]
Silver, dissolved, µg/L	HEALTH--MCL is 50 µg/L, based on skin-discoloration effects (argyria). An SMCL is proposed at 90 µg/L to prevent the effects of argyria.
Strontium, dissolved, µg/L	No health or aesthetic implications for the range of concentrations determined in this study; however, contributes to hardness in water.
Zinc, dissolved, µg/L	AESTHETIC--SMCL is 5,000 µg/L, based on taste imparted to water.
Carbon, organic, dissolved mg/L as C	No health or aesthetic implications for the range of concentrations determined in this study. Concentrations greater than 4 mg/L may indicate that the water supply is vulnerable to surface drainage, that hydrocarbons may be present, or that shale strata may yield water to the well.
Cyanide, total, mg/L	HEALTH--Presently (October 1989) no MCL for cyanide has been established. A suggested limit is 0.20 mg/L, and future regulations are expected.
Gross alpha particle radioactivity, dissolved, µg/L as uranium	HEALTH--MCL is 15 pCi/L. Converting the concentration in µg/L to pCi/L[2] and subtracting the uranium concentration from gross alpha-particle radioactivity gives a value that can be approximately compared to MCL of 15 pCi/L. Radon concentration (not determined in this study) also is to be subtracted for a more precise comparison to the MCL.
Gross beta particle radioactivity, dissolved, pCi/L as Cesium-137 or pCi/L as strontium/yttrium-90	HEALTH--If concentration exceeds 50 pCi/L, additional testing to identify major radioactive constituents is needed.
Uranium, dissolved, µg/L	Presently (October 1989) no MCL has been established for uranium in drinking water, but future regulations are expected.

[1] U.S. Environmental Protection Agency, 1976; 1986a; 1986b; 1986c; 1986d; 1988a; 1988b; 1988c; 1989b)
[2] Conversion factor from µg/L as uranium to picoCuries per liter; multiply by 0.68.

Table 16.-- Supplementary data on water quality in the carbonate aquifer in Woodville Township, Sandusky County, Ohio

[Data from Sypniewski (1982, Appendixes A and B). Well numbers correspond to those of the original work, and well locations are mapped on plate 8. All values are dissolved concentrations in milligrams per liter, except for pH and where noted otherwise. Hardness concentration in mg/L as $CaCO_3$, nitrate concentration in mg/L as N. Dissolved solids calculated by use of equation (1) and specific conductance. Noncarbonate hardness calculated by converting bicarbonate to alkalinity and subtracting alkalinity from total hardness. ug/L, micrograms per liter.]

Well number	Silica	Iron	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Fluoride	Nitrate	Dissolved solids	Hardness: Total	Hardness: Noncarbonate	pH	Lead (ug/L)	Barium (ug/L)	Strontium (ug/L)	Zinc (ug/L)
1	4.7	.23	111	55	2.1	.6	405	130	6	1.30	3.1	471	504	172	7.1	3	310	35,000	30
2	4.2	.21	83	44	1.3	.9	367	57	10	.30	2.6	408	387	86	7.0	2	770	1,200	46
3	16.0	.03	69	42	.6	1.4	426	115	6	1.50	3.1	471	456	106	7.0	2	140	38,000	18
4	7.4	.08	105	33	1.2	1.3	393	88	12	1.15	3.1	354	398	75	7.0	2	290	2,900	178
5	14.5	.27	142	44	3.1	1.8	460	145	23	.24	3.3	607	537	159	6.6	2	80	39,000	33
6	8.2	.04	92	36	9.2	.6	376	51	86	.23	3.1	393	378	69	7.2	2	420	9,300	182
7	17.0	1.90	131	48	60.0	3.7	408	145	42	.59	2.2	725	526	191	7.0	2	250	8,000	288
8	4.4	.04	88	46	28.6	1.7	391	45	13	.14	20.2	510	408	87	7.0	2	580	920	91
9	15.0	2.00	82	38	3.1	1.2	378	26	19	.36	2.6	393	360	50	7.2	2	470	6,100	279
10	10.3	.03	71	31	9.0	50.0	335	45	3	.12	28.2	393	305	30	7.2	3	130	170	287
11	7.5	3.20	70	36	.1	.9	376	7	53	.18	1.8	275	324	15	7.4	2	1,580	210	304
12	14.0	1.28	110	38	23.0	1.8	384	90	10	.46	2.6	471	433	118	7.2	2	170	8,400	196
13	8.5	.02	119	52	.7	.3	495	115	26	.11	3.1	471	512	106	6.6	2	620	8,400	190
14	11.0	2.20	126	57	14.0	3.8	413	165	69	.48	2.2	705	548	209	7.0	2	440	5,900	196
15	5.0	.10	128	61	14.8	53.3	435	190	7	1.70	2.6	705	571	214	7.0	4	220	280	36
16	14.0	1.50	116	48	9.3	1.7	426	165	11	.76	3.1	510	488	138	6.8	2	220	38,000	223
17	15.0	5.70	108	37	6.6	3.5	352	150	5	.33	1.3	549	423	134	7.3	3	190	30,000	156
18	2.4	.01	68	43	4.3	5.1	326	48	26	.36	13.2	338	349	81	7.0	2	510	5,100	99
19	5.7	.17	91	37	9.2	.6	368	46	28	1.05	2.2	412	379	77	7.1	3	770	27,000	51
20	6.6	.14	118	56	41.4	1.8	555	125	20	.60	3.5	627	528	73	7.0	3	710	10,000	145
21	11.4	2.40	132	30	15.4	1.7	339	150	23	.11	3.1	518	456	178	7.2	3	340	240	177
22	13.0	.94	198	48	9.7	1.5	469	260	23	.13	2.2	705	691	306	6.6	4	100	740	8
23	14.8	.23	114	42	5.7	1.8	371	150	7	.45	2.6	471	458	153	7.0	5	80	37,000	148
24	12.0	.19	117	40	2.1	1.3	383	150	4	1.40	3.1	549	457	143	7.0	4	60	48,000	212
25	5.9	.03	130	64	11.3	1.0	495	150	28	.76	2.2	627	590	184	7.0	5	840	8,400	7
26	2.8	.16	99	53	50.9	1.8	384	110	75	.52	2.6	549	468	153	7.2	5	690	460	164
27	15.0	.09	76	39	22.6	2.6	319	91	14	.84	2.6	393	350	88	7.4	5	380	36,000	54
28	6.6	.03	109	75	8.3	5.1	541	120	11	1.27	3.5	627	582	138	6.8	5	350	14,000	62
29	6.5	.88	88	41	--	1.5	395	36	50	1.11	2.6	471	390	66	7.2	--	--	--	--
30	4.7	.02	124	49	6.6	18.2	391	145	16	.25	11.0	588	513	192	7.2	5	150	32,000	147
31	5.4	.03	106	46	5.6	17.0	393	140	11	.17	15.0	471	454	131	7.2	5	150	22,000	216
32	10.9	.21	75	34	11.9	.9	373	13	8	.25	2.6	315	328	22	7.2	3	220	4,600	13
33	8.7	.18	122	47	11.5	1.7	438	125	24	.36	2.6	549	497	137	7.0	3	130	19,000	87
34	4.6	.02	116	65	20.9	8.7	308	230	72	.58	3.5	627	558	305	7.4	3	40	41,000	130
35	4.6	.02	143	66	24.4	4.6	411	265	79	.44	3.7	705	628	291	7.2	4	20	35,000	288
36	6.1	.05	172	91	28.2	4.7	463	300	110	.18	3.1	861	805	425	7.2	4	120	39,000	189
37	3.9	.04	95	115	14.6	2.9	334	190	8	.48	2.2	666	710	436	6.8	3	70	28,000	34
38	15.0	1.08	134	45	11.6	2.9	361	225	9	.41	2.6	354	520	224	7.0	3	60	34,000	128
39	8.9	2.30	104	34	1.1	1.0	405	81	5	.52	1.8	393	399	67	7.0	3	90	55,000	39
40	13.7	1.60	86	44	10.3	1.7	--	145	20	.29	4.4	432	397	--	6.9	3	80	13,000	180
41	8.0	.40	102	33	4.5	1.1	385	90	7	.54	3.1	549	391	75	6.8	4	90	56,000	254
42	14.7	.68	100	41	5.8	1.2	402	64	11	.36	2.6	432	421	91	6.8	4	690	13,000	38
43	17.0	.03	--	--	51.3	5.8	452	240	41	.34	2.6	900	--	--	7.1	10	10	1,200	117
44	7.7	.65	118	44	49.3	.8	384	94	68	.94	2.6	627	476	161	7.0	3	260	8,500	39
45	11.0	1.15	166	73	6.6	1.7	523	230	15	.15	2.6	697	717	288	6.8	3	350	33,000	32
46	4.7	.08	97	52	2.3	7.8	401	135	13	1.03	2.6	471	459	130	7.2	3	350	460	116

Table 19.-- Physical properties and chemical characteristics of brines in the Trenton Limestone, Wood County, Ohio and Allen County, Indiana

[Well numbers correspond to those of the original reference. All values are concentrations in milligrams per liter, except pH and where noted otherwise. mL, milliliter; g, gram; nd, not detected. Dashes indicate constituent not determined.]

Sample number	Iron	Cal-cium	Mag-ne-sium	Sodi-ium	Po-tas-sium	Stron-tium	Bi-car-bon-ate	Sul-fate	Chlo-ride	Bro-mide	Dis-solved solids	pH	Den-sity (g/mL)	Hydro-gen sul-fide	Reference
C-66-1[1]	0.09	2,050	834	8,840	322	46	110	2,090	19,000	110	33,400	7.9	1.021	--	Keller (1983, p. 27)
C-63-2[1]	141	11,900	2,180	16,400	570	133	0	341	52,400	218	84,300	5.8	1.065	nd	Keller (1983, p. 27)
A-166[1]	--	4,205	1,148	20,270	31	--	12,870	2,210	32,990	63	67,500	--	1.040	15.6	Keller (1983, p. 27)
#108[2]	nd	3,810	1,810	15,000	580	173	166	--	34,900	206	57,100	7.5	1.041	--	Stith (1989, Ohio Geological Survey, written commun.)

[1] Allen County
[2] Wood County

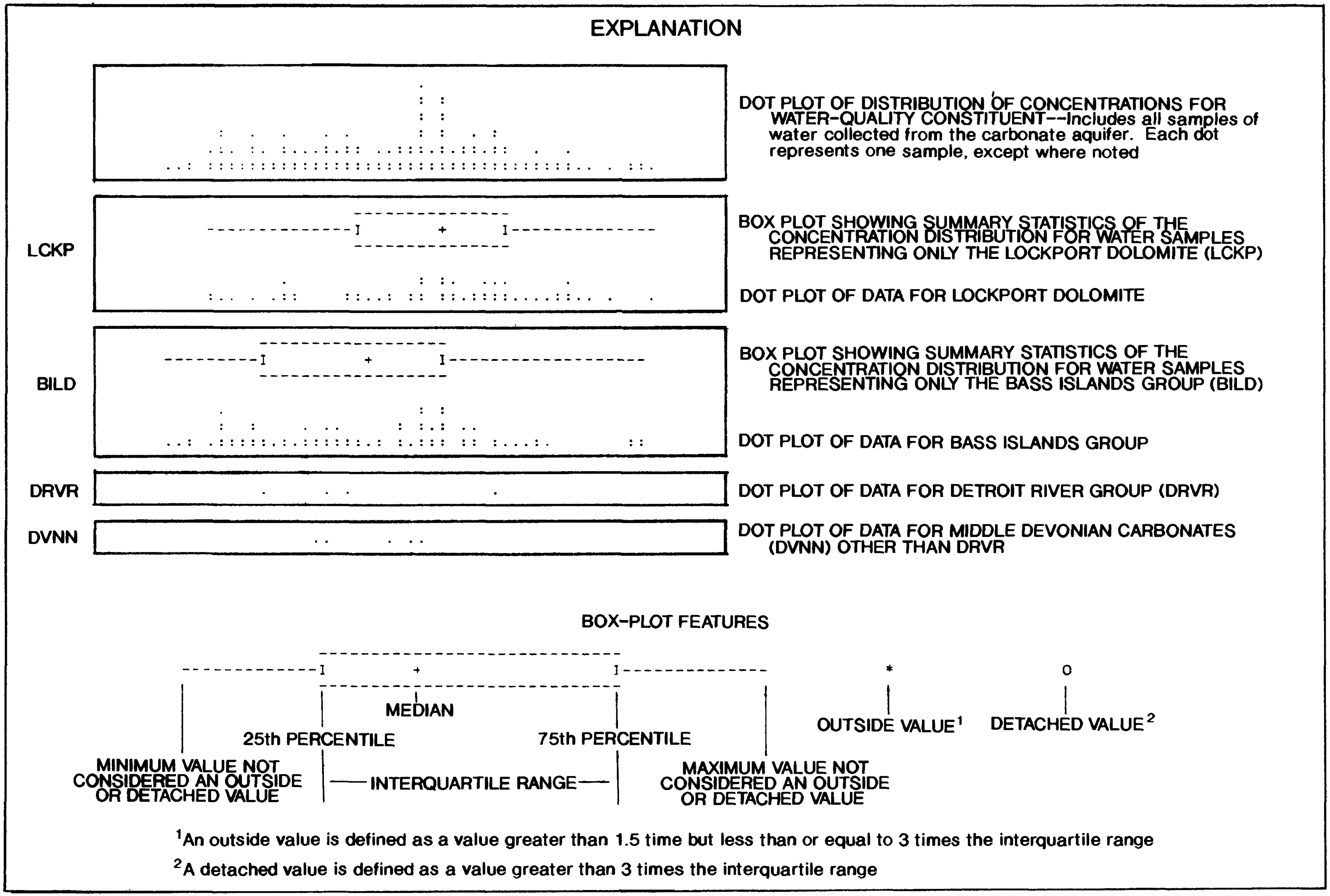

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units.

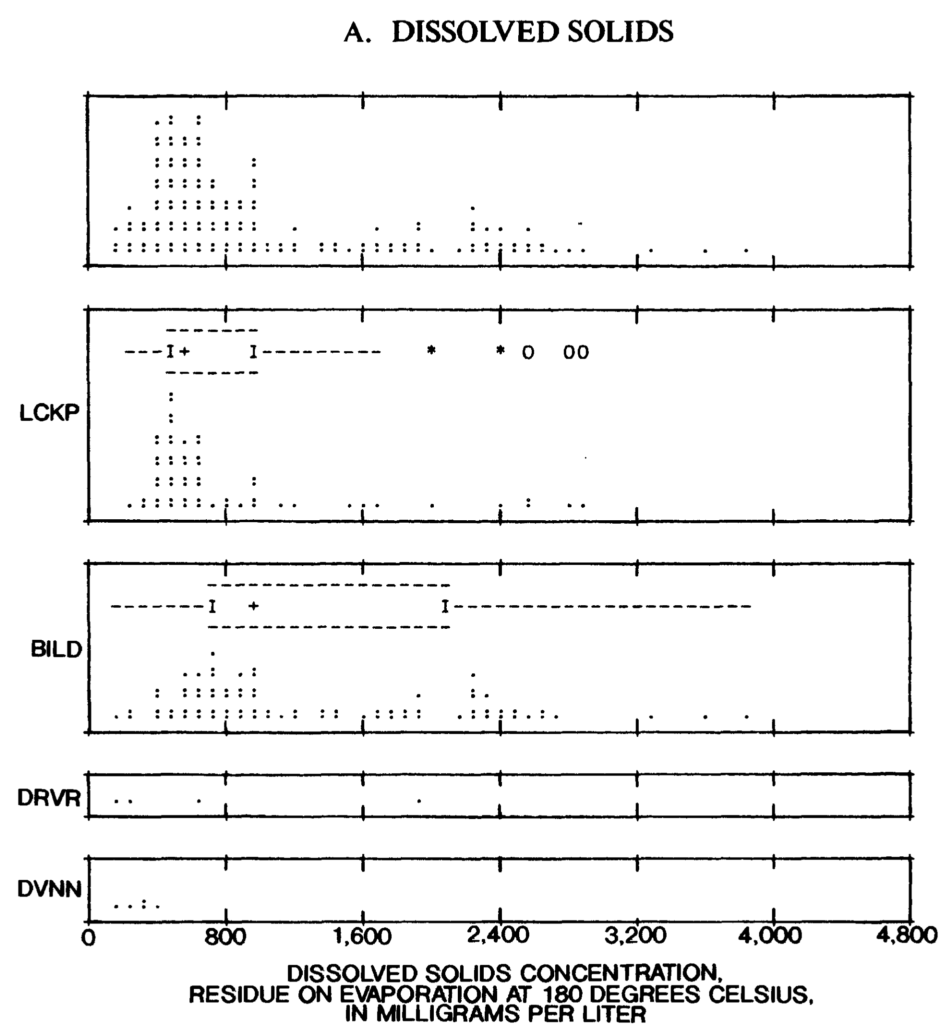

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

B. SPECIFIC CONDUCTANCE

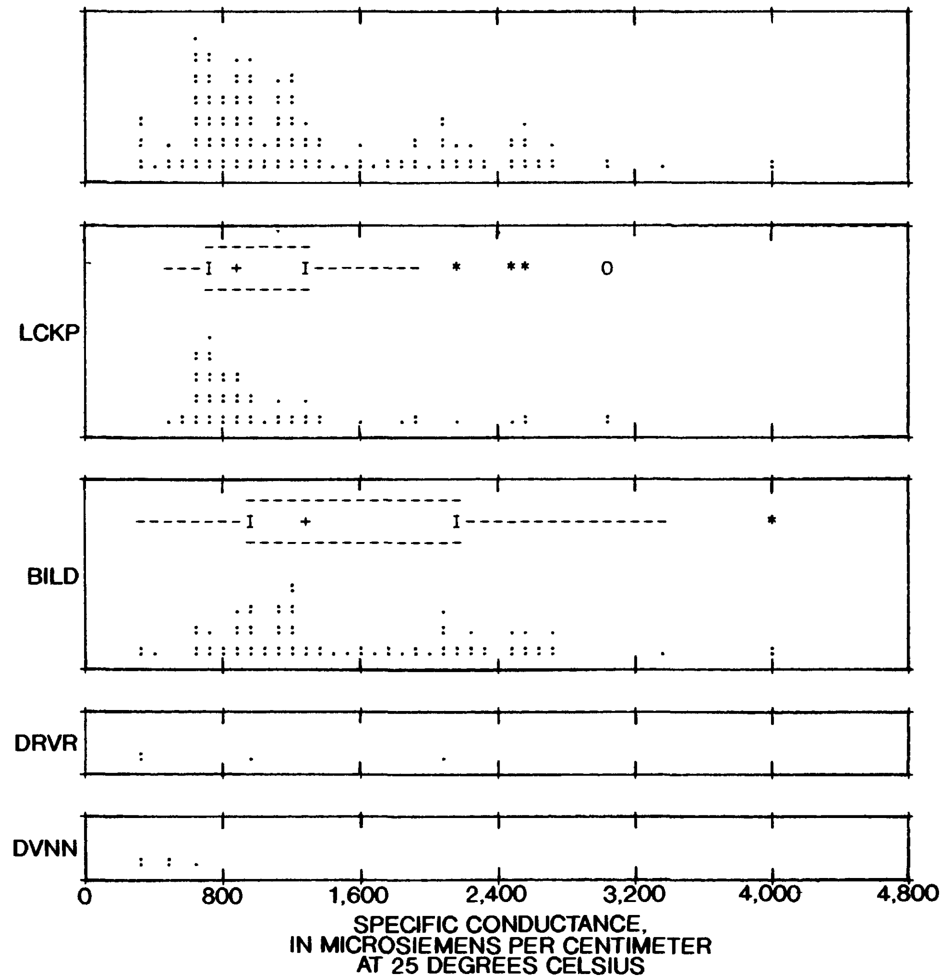

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

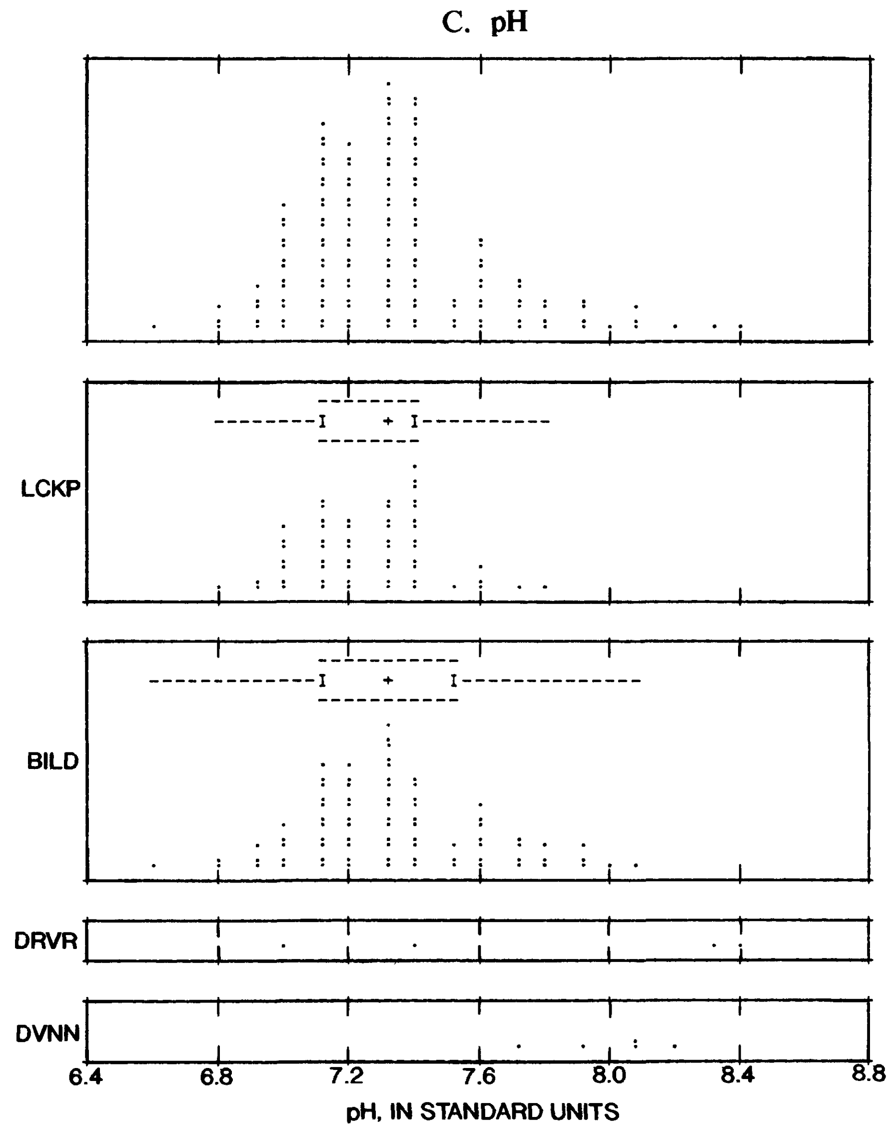

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

D. ALKALINITY

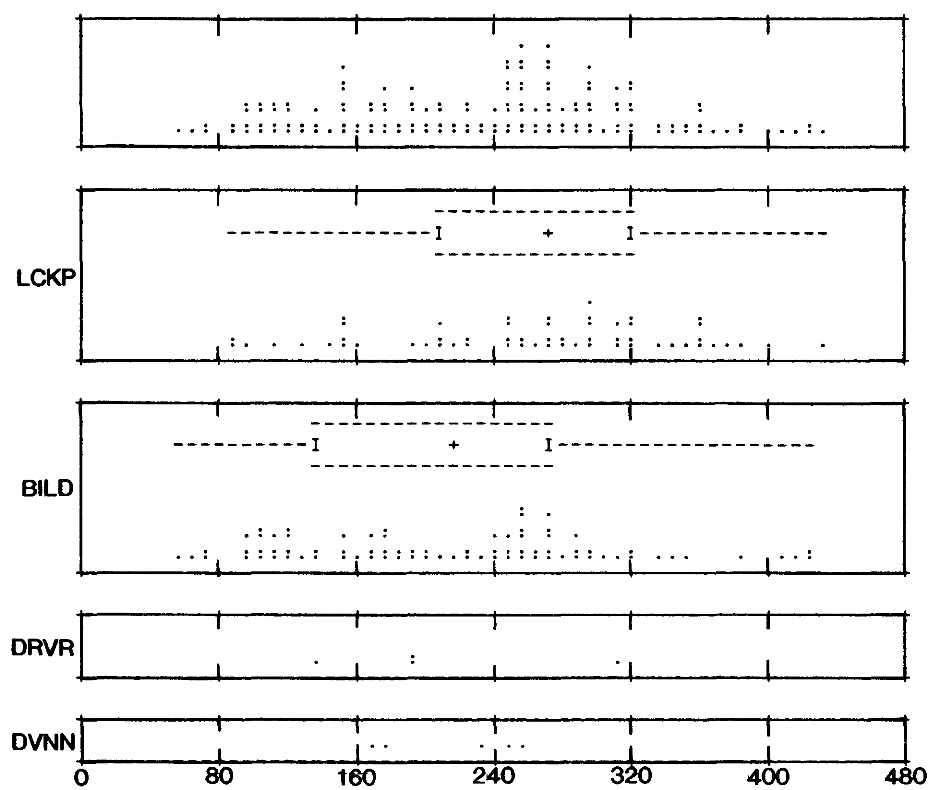

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

E. BICARBONATE

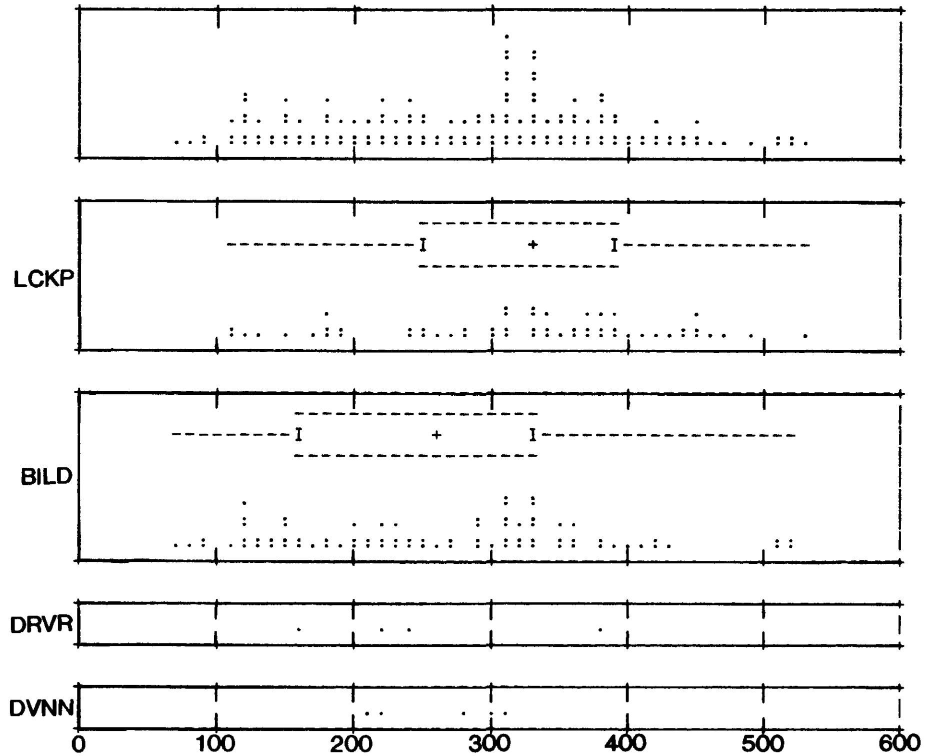

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

F. FLUORIDE

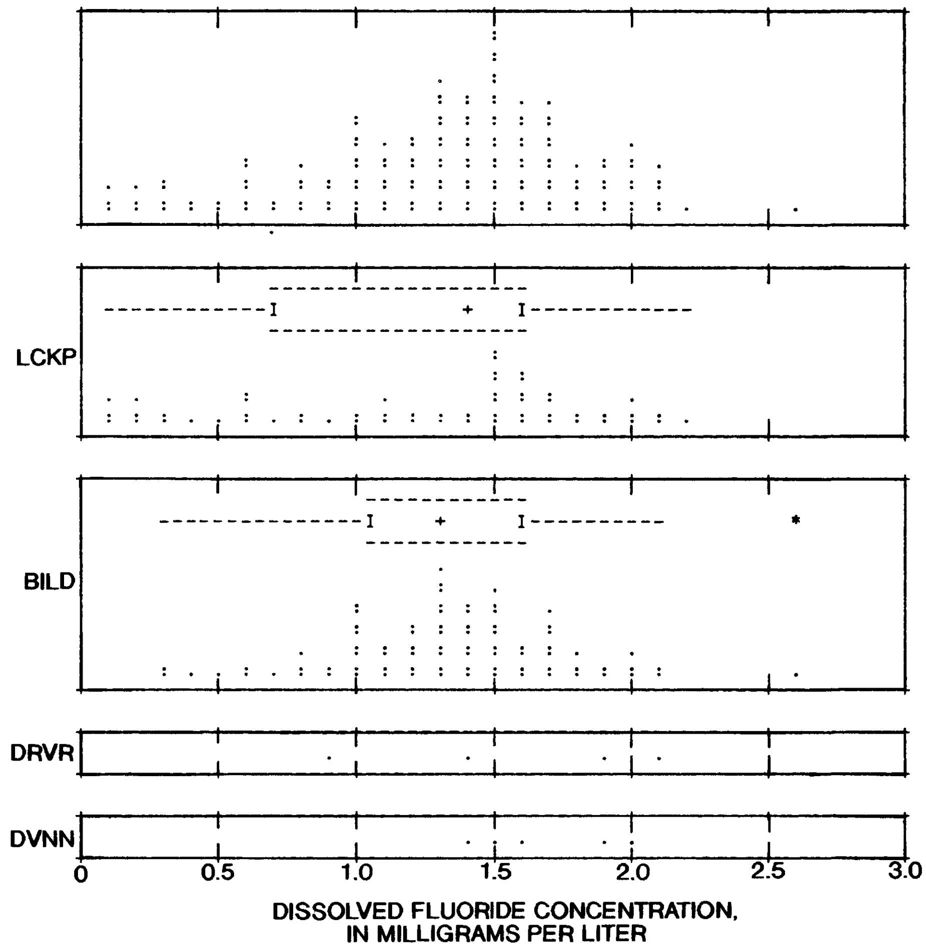

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

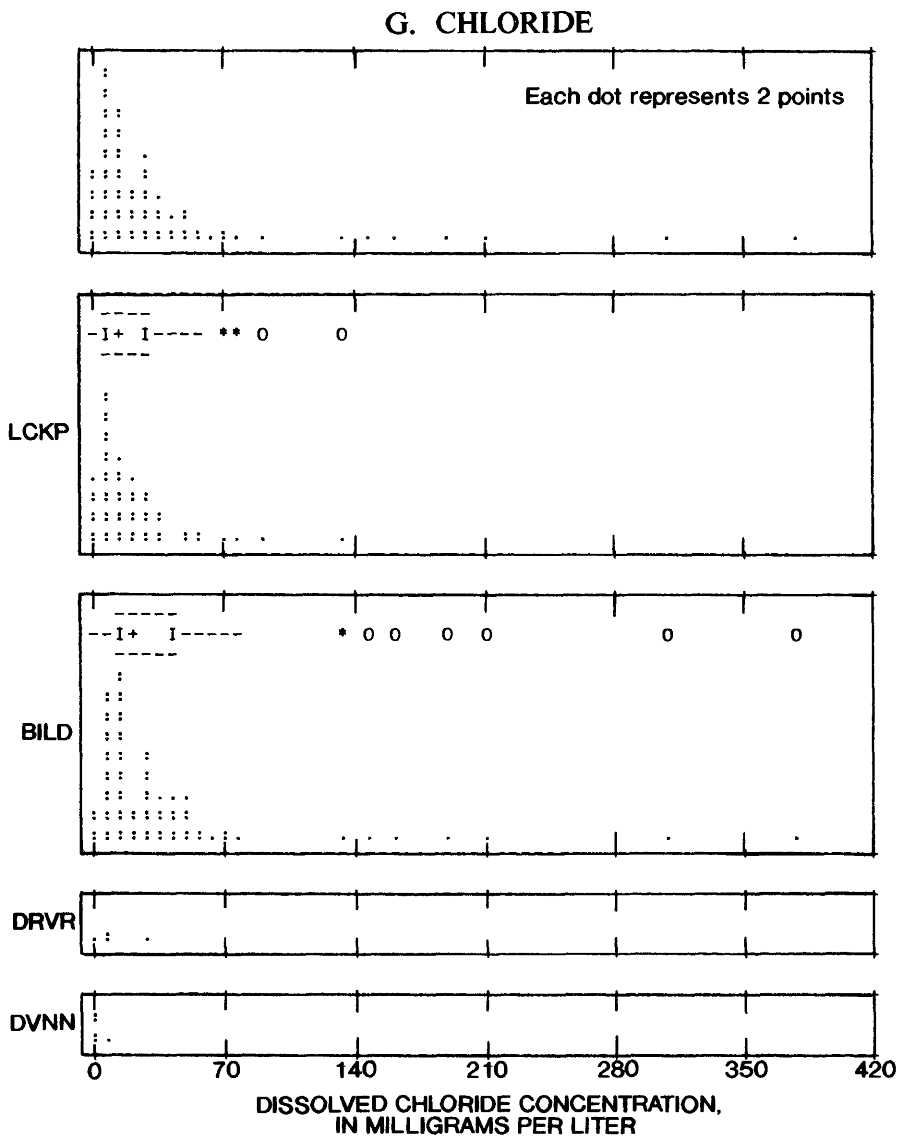

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

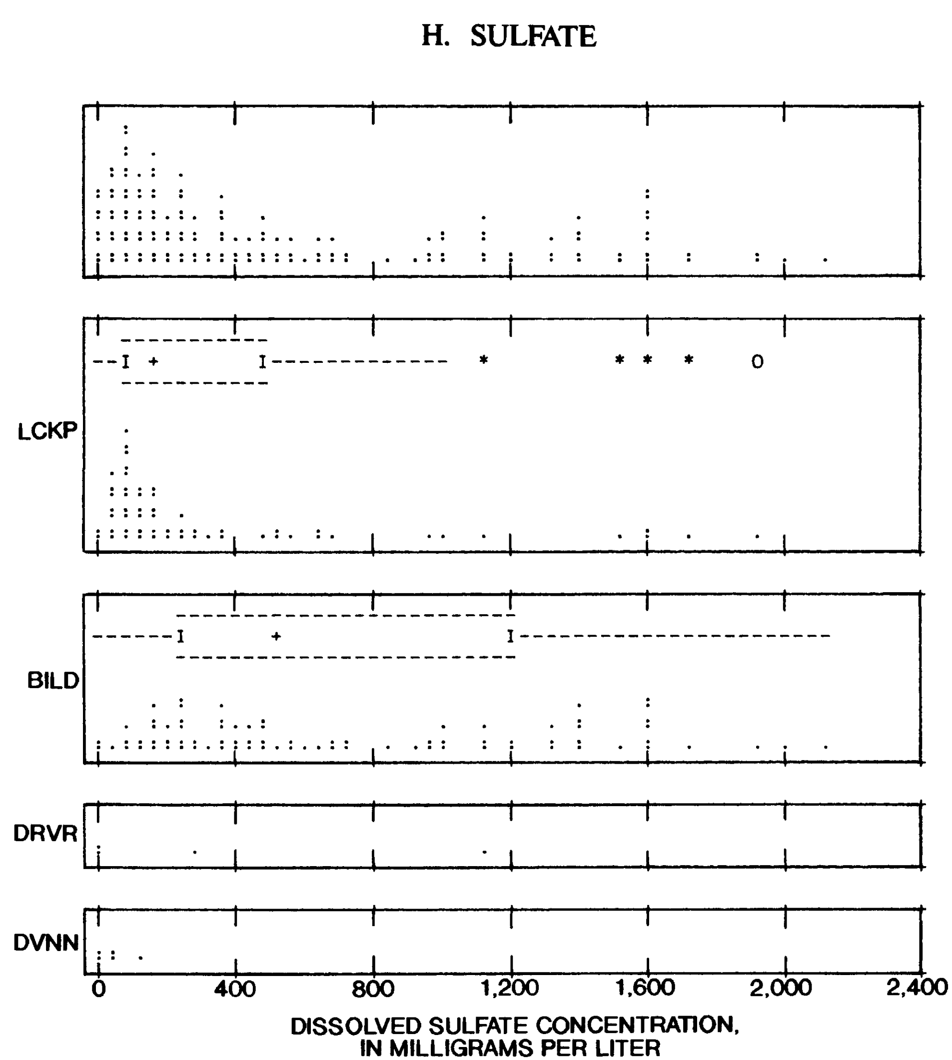

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

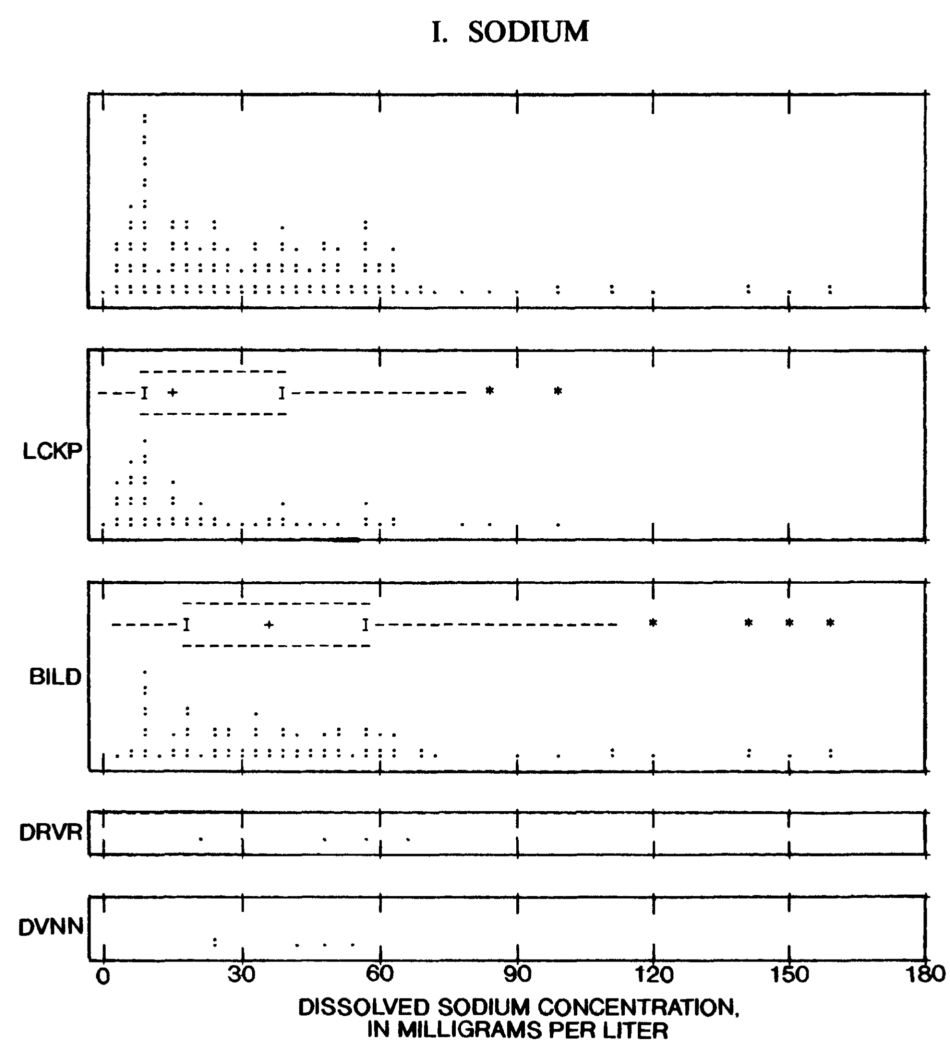

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

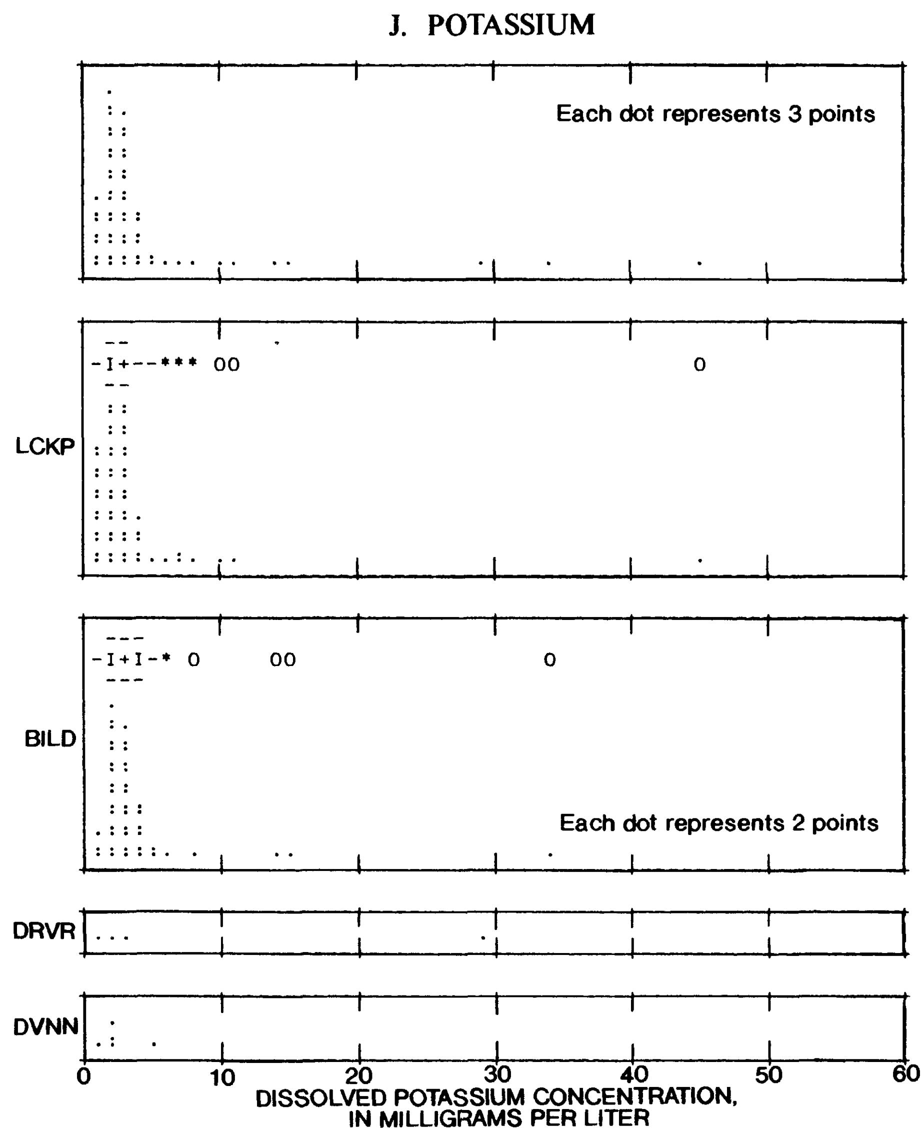

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

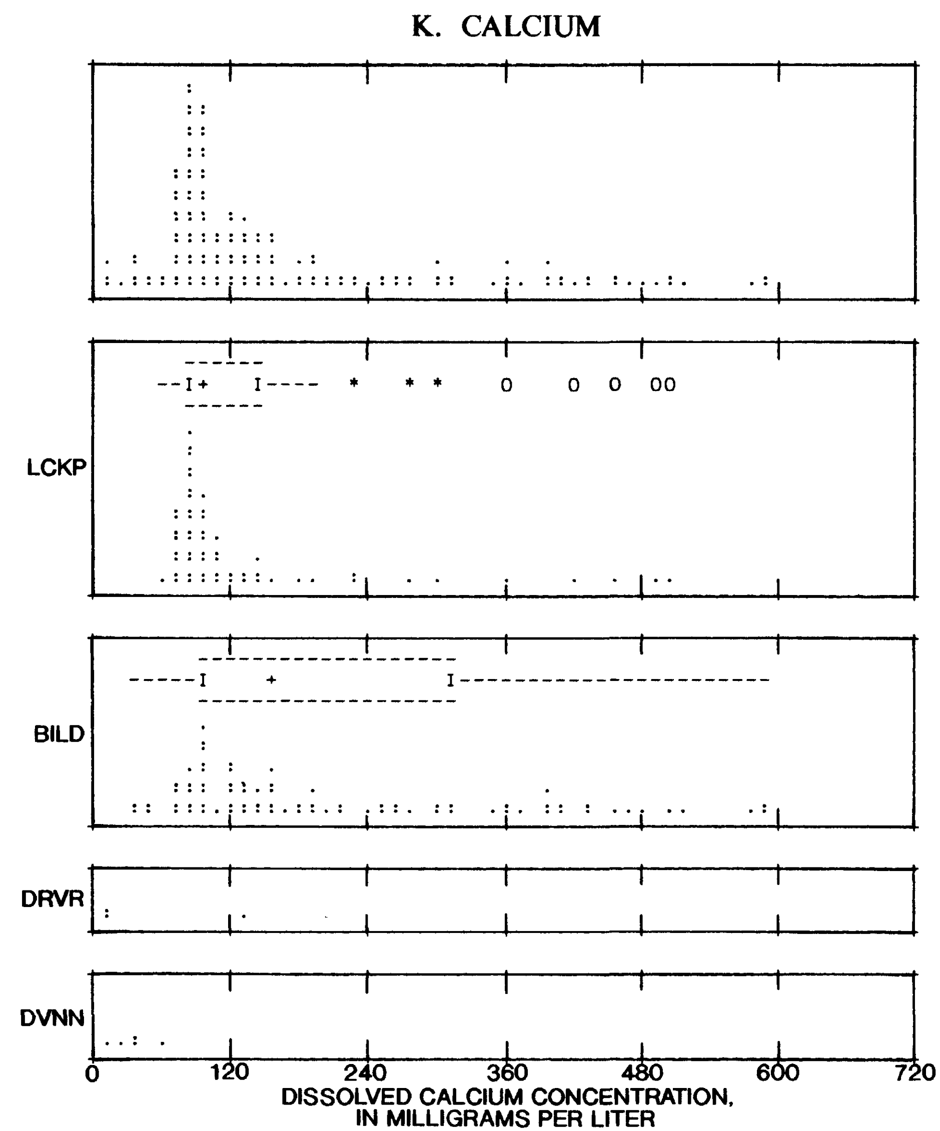

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

L. MAGNESIUM

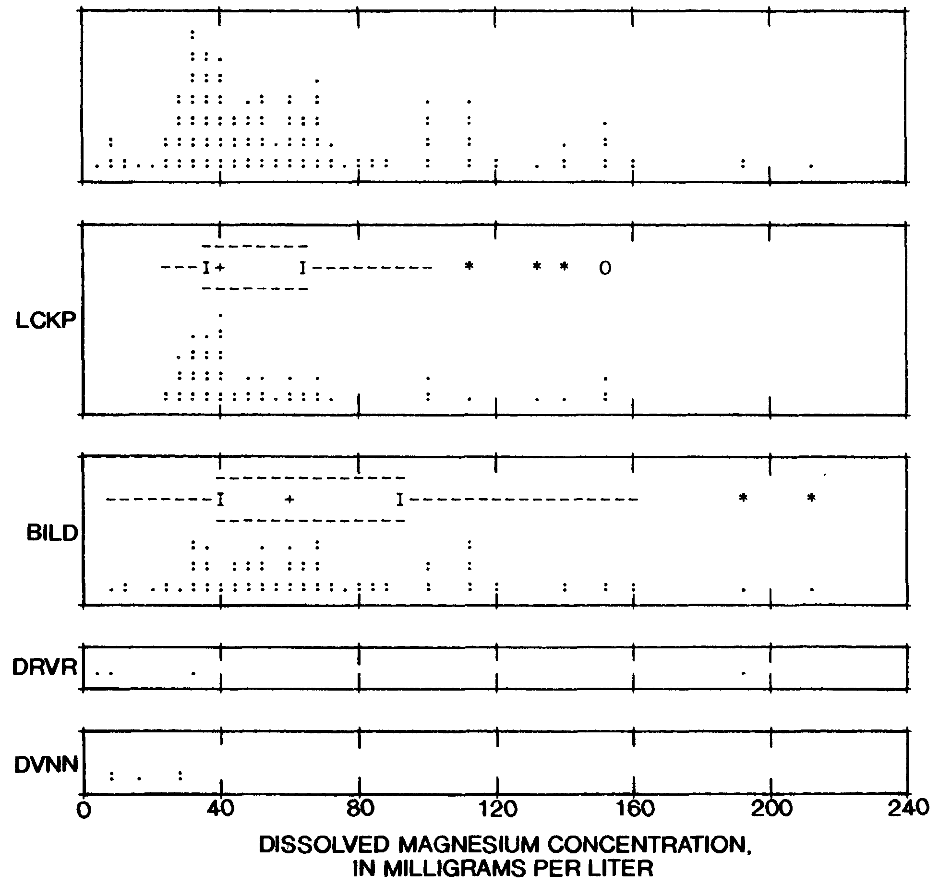

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

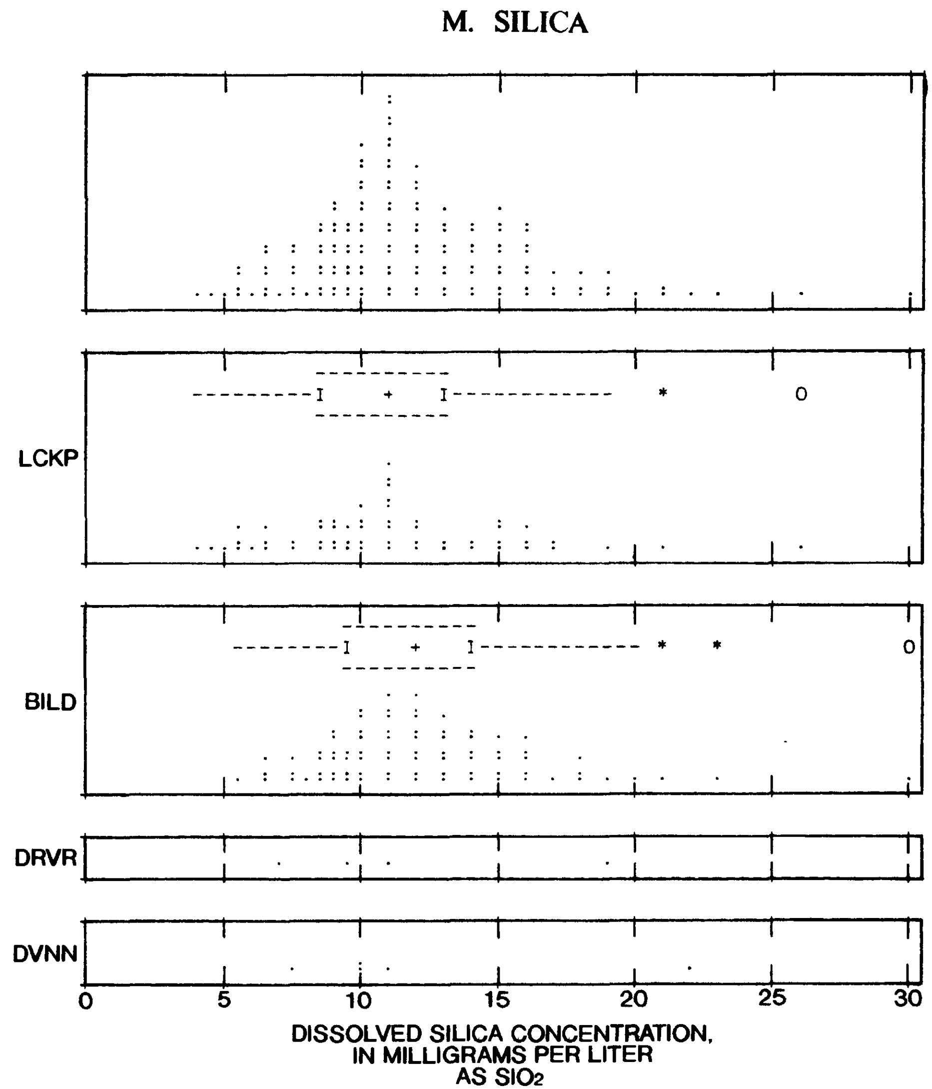

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

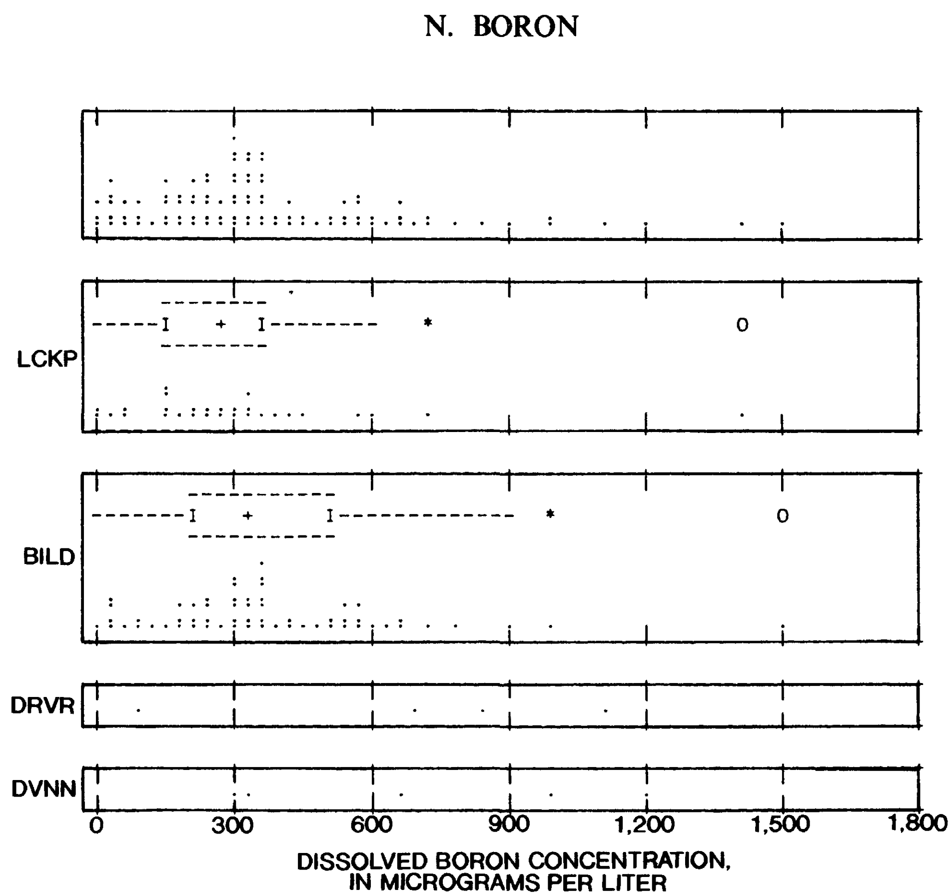

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

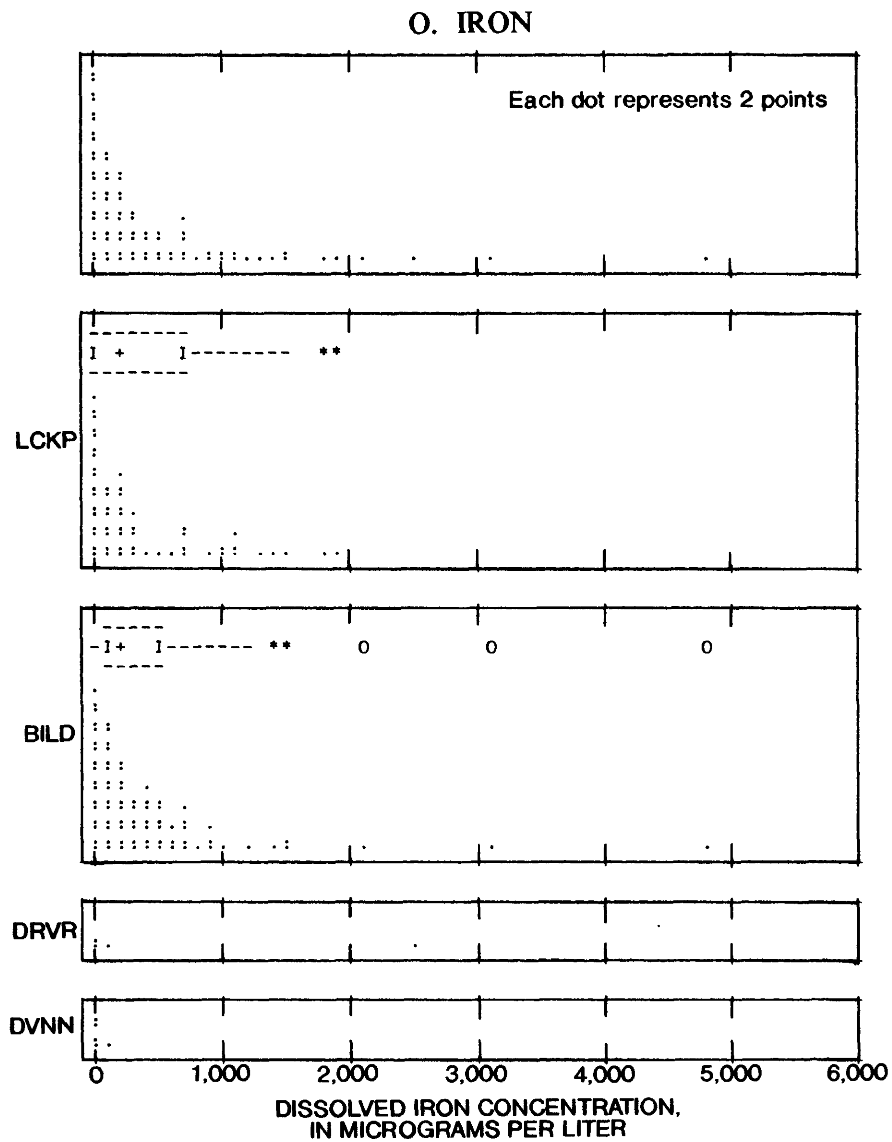

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

P. STRONTIUM

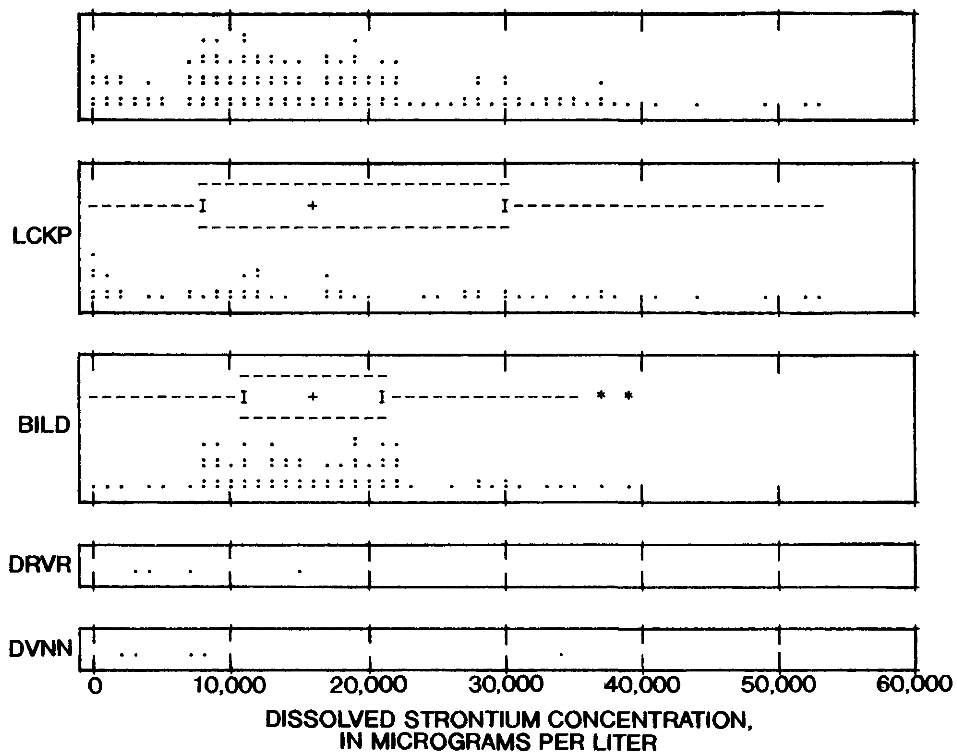

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

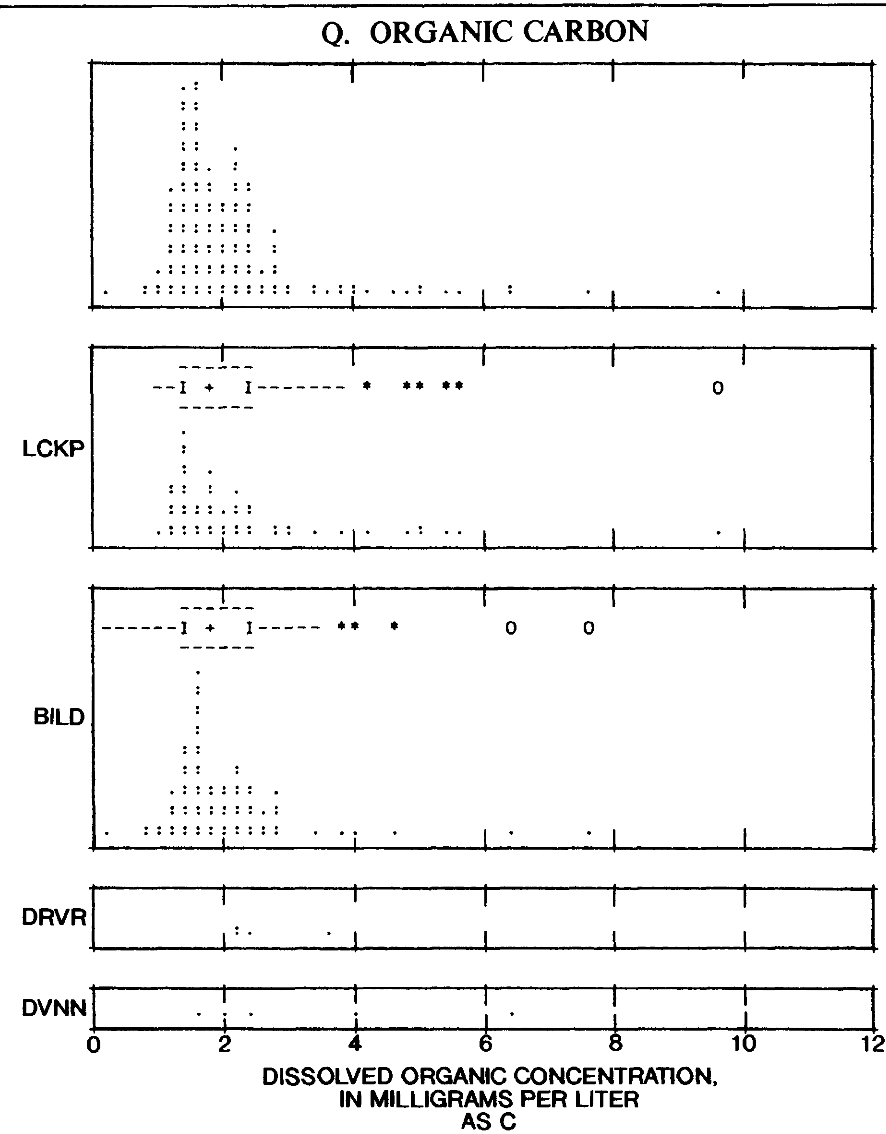

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

R. GROSS BETA PARTICLE RADIOACTIVITY

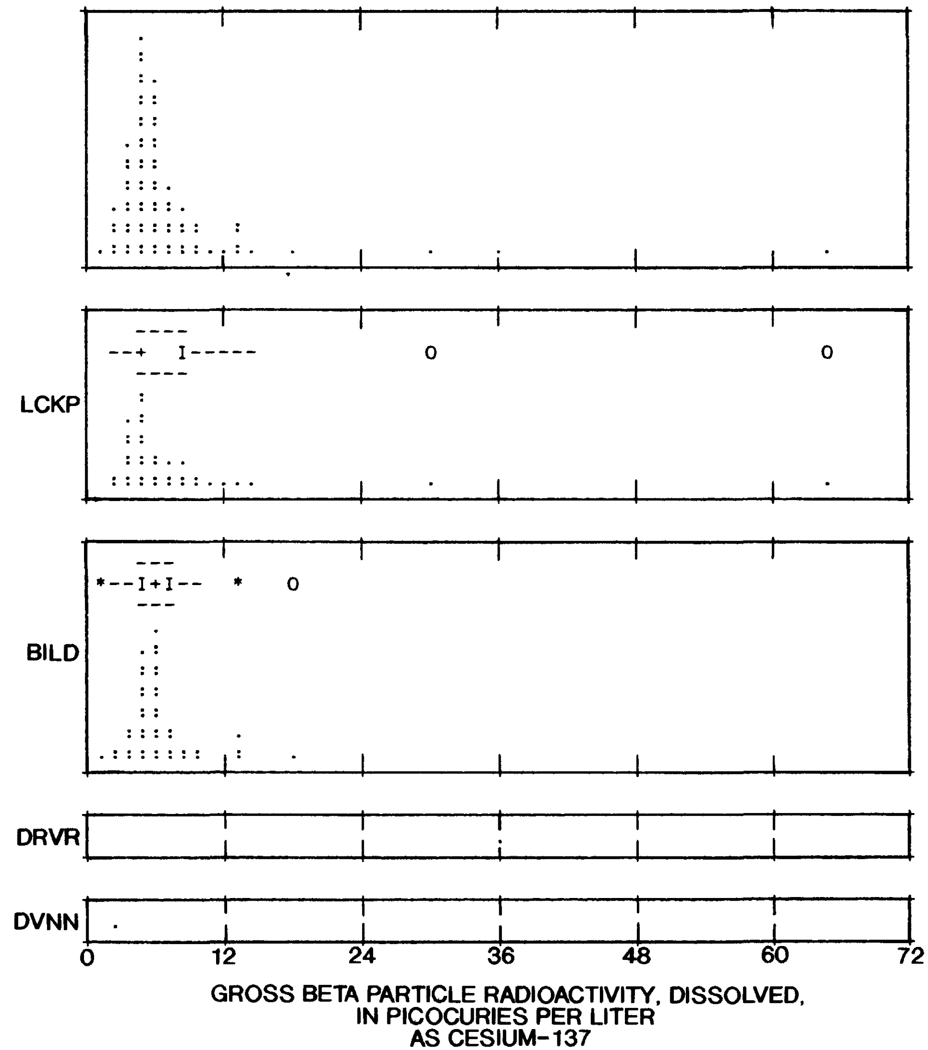

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

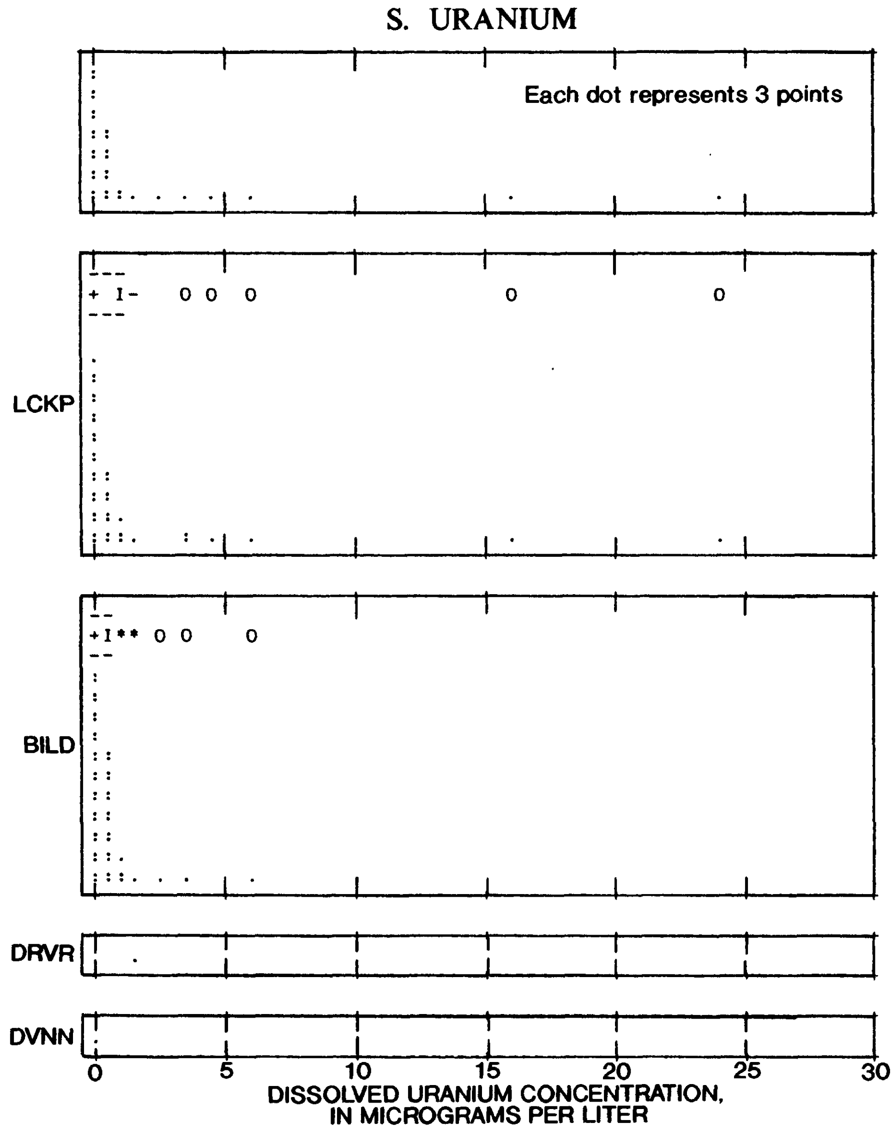

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

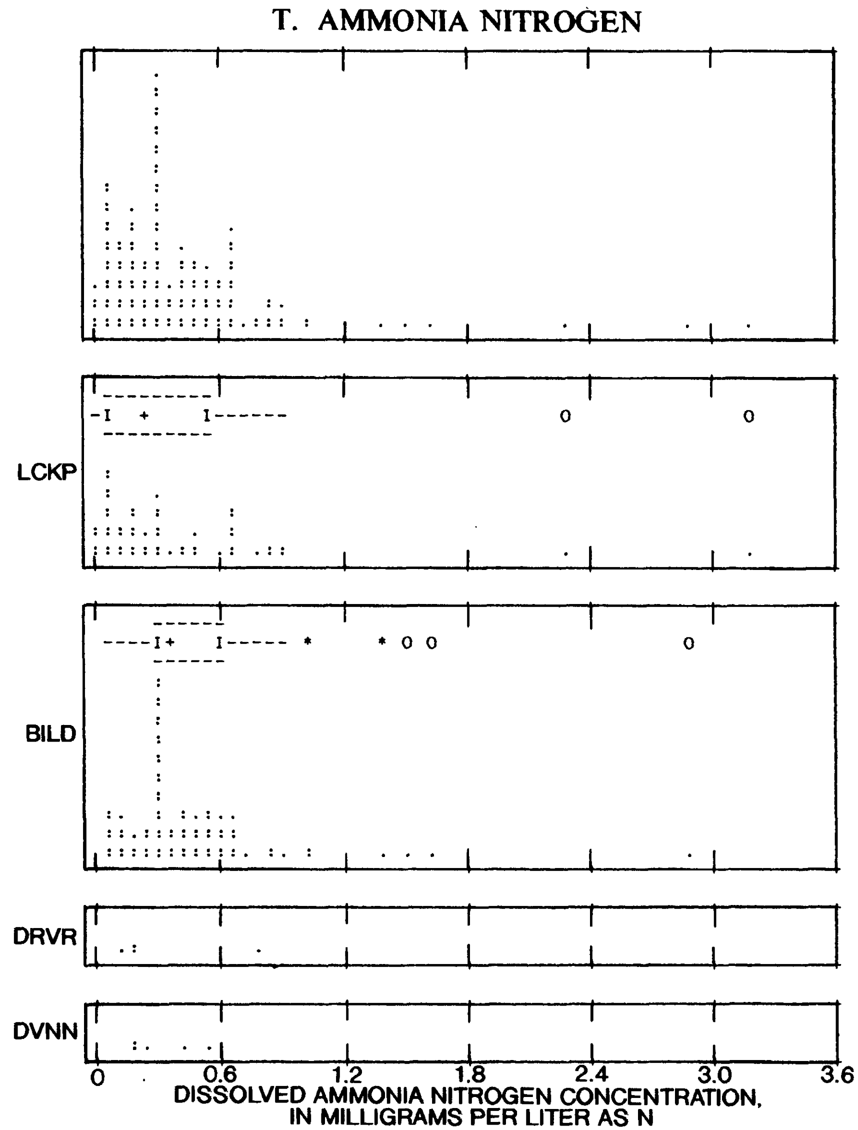

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

V. NONCARBONATE HARDNESS

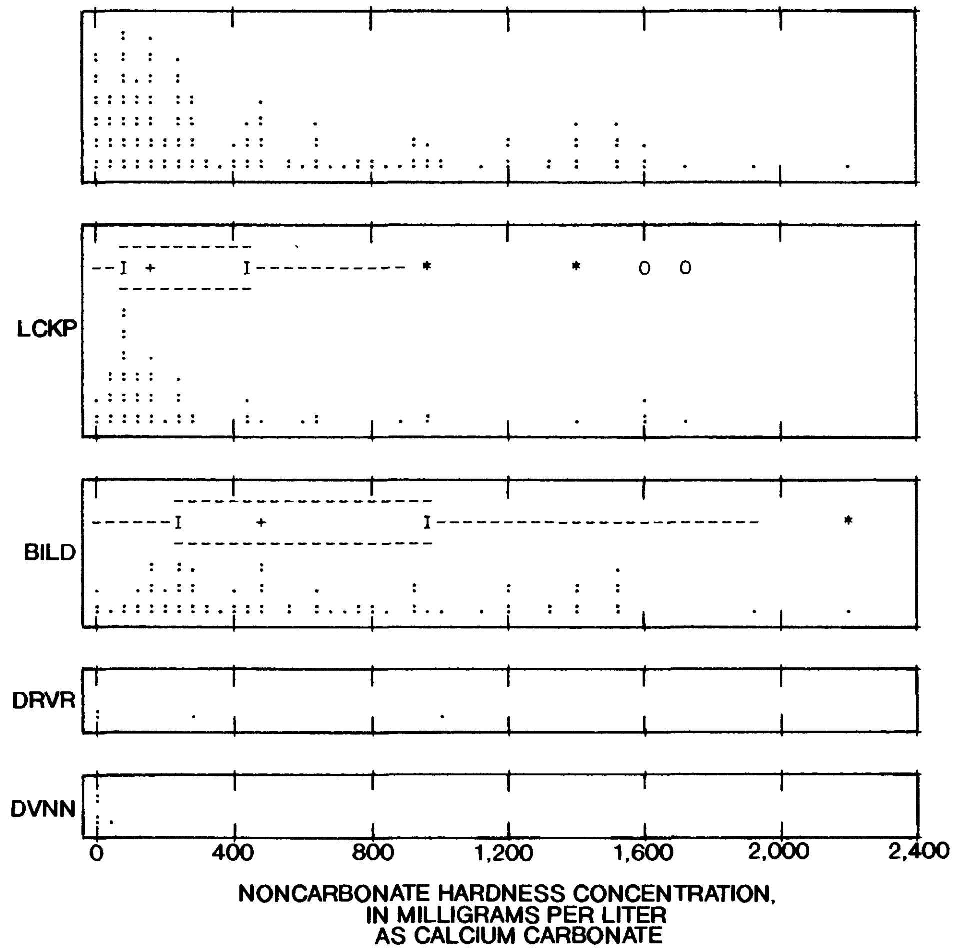

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

APPENDIX--QUALITY ASSURANCE AND QUALITY CONTROL FOR WATER-QUALITY DATA

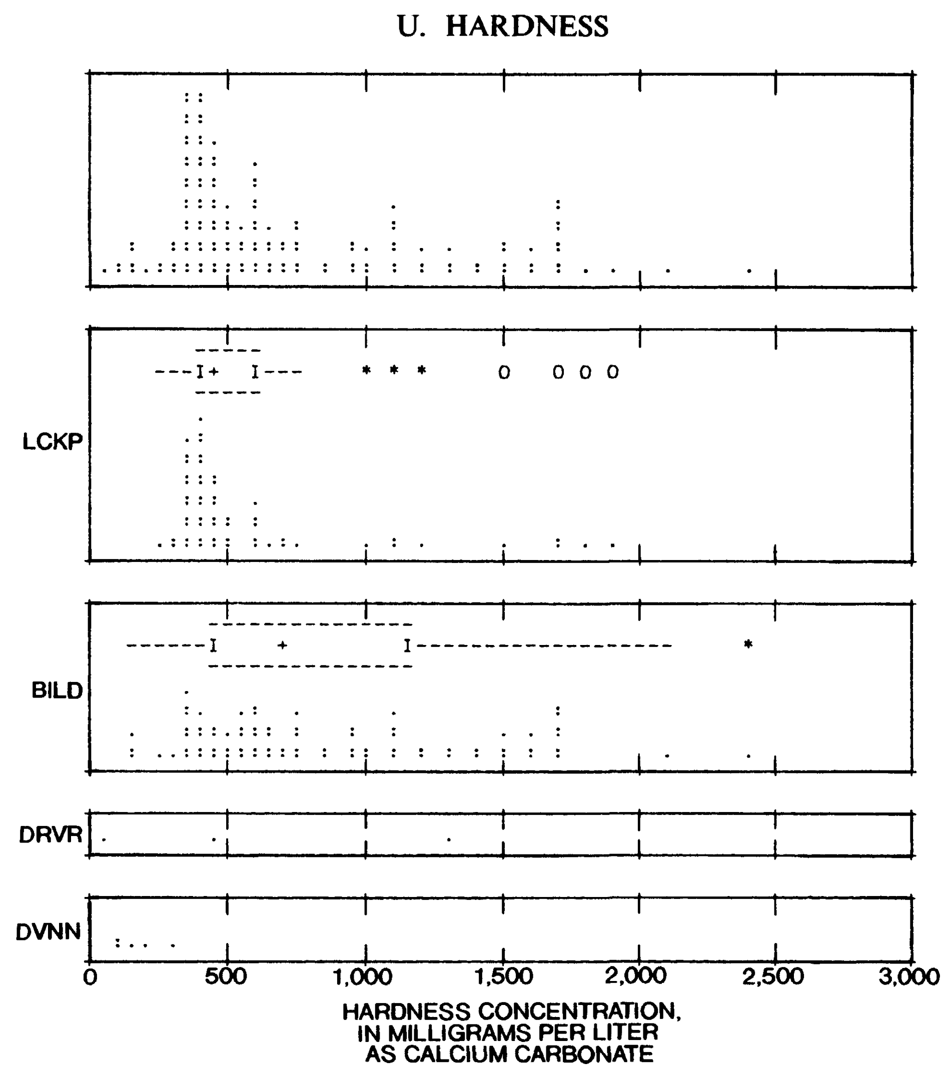

Figure 26.--Dot plot and box plot summaries of distributions of concentrations for selected water-quality constituents in ground waters from the carbonate aquifer, including plots for each of four geologic units--Continued.

APPENDIX--QUALITY ASSURANCE AND QUALITY CONTROL FOR WATER-QUALITY DATA

Standard Reference Water Samples

Standard reference water samples from the U.S. Environmental Protection Agency, Quality Assurance Branch, were submitted to the laboratory for analyses of major and minor constituents and nutrients. The results of these quality-assurance measures were within acceptable limits (95-percent level of confidence). Duplicates and dilutions of field samples also were submitted for quality-assurance purposes. The number of dilutions, duplicates, and standard samples represented about 10 percent of the total number of ground-water samples analyzed for this study.

Cation-to-anion balance calculations for major inorganic ions

To ensure high-quality analyses of the concentrations of dissolved major inorganic ions, the total charge balance between positively charged constituents and negatively charged constituents is determined (Hem, 1985, p. 164). Analytical concentrations are first converted from milligrams per liter (mg/L) to milliequivalents per liter (meq/L) by multiplying by the conversion factors found in Hem (1985, p. 56). The percentage imbalance is then computed from:

$$\text{cation-anion imbalance (percent)} = \frac{[\Sigma \text{ cations}] - [\Sigma \text{ anions}]}{[\Sigma \text{ cations}] + [\Sigma \text{ anions}]} \times 100,$$

where cations include Ca, Mg, Na, Sr, K, Fe, Mn, and anions include bicarbonate, sulfate, chloride, fluoride, nitrate, and nitrite. A negative imbalance indicates that more anions are present than cations. A positive imbalance indicates that the opposite is true. Analyses reported for this study generally have imbalances within ± 3 percent. (See table 19.) A few imbalances are sometimes more negative than -3 percent and are generally associated with sulfate-rich waters (sulfate concentrations greater than 1,000 mg/L). The reason that elevated sulfate concentrations are related to negative imbalances is not well understood.

Split-sample program for gross alpha-particle radioactivity

Split samples were sent to two laboratories as a check on interlaboratory variability. A USGS water-quality laboratory and an Ohio Department of Health (ODH) laboratory were used for the comparison. Results from the ODH analyses are reported in picocuries per liter (pCi/L); the USGS results are given in μg/L (micrograms per liter) as uranium-natural. A conversion factor of 1 μg = 0.68 pCi (considering U-234, U-235, and U-238 isotopes) was applied to the USGS results to enable comparison of concentrations from the two laboratories.

The lowest concentration that the ODH laboratory reports is 3 pCi/L. The lowest concentration the USGS laboratory reports is 0.3 pCi/L (0.4 µg/L x 0.68). Sixty-four samples were split and analyzed by the two laboratories; 38 samples had concentrations above the detection concentration of both laboratories.

Results from the two laboratories are compared to a line representing complete agreement between laboratories (fig. 48). The results indicate that the concentrations from the ODH laboratory are usually higher than those from the USGS laboratory. As concentrations from the USGS laboratory increase, the tendency is for ODH results to plot below the line of equal concentration.

The cause of the interlaboratory difference is due, in part, to different internal standards used by USGS (pure uranium ore) and ODH (americium-241). The measurements from the ODH laboratory are completely adequate for the screening of waters for alpha-particle radioactivity. Interpretations in this report, however, are based on the USGS results because of the need to establish baseline conditions in waters with less than 3 pCi/L of gross alpha-particle radioactivity.

Blank samples for dissolved organic carbon (DOC)

Field blanks and laboratory blanks were submitted for DOC analysis at the same time as the ground-water samples. Laboratory blanks consisted of water distilled in glass and stored in a plastic bottle. Field blanks consisted of glass-distilled water transported to the field in plastic carboys and processed through a clean stainless-steel barrel filter holder and silver filter membrane. About 100 mL of distilled water was filtered to waste before collection of the DOC blank sample. All samples were held at 4 °C after collection and during shipment to the laboratory. All DOC blank samples had concentrations larger than the 0.1-mg/L detection limit for the analysis. Concentrations in blank samples ranged from 0.4 to 1.0 mg/L. Thus, for interpretation of results for ground waters, 1.0 mg/L is considered the reporting level for the DOC analyses. Concentrations in ground-water samples were not corrected by subtracting the concentrations in distilled-water blanks. The concentrations of DOC are a gross indicator of the relative concentration present in water samples collected for this study.

Blank and duplicate bacteria determinations

To ensure sterile filtration equipment and sterile rinse water for bacterial determinations, filter blanks of rinse water were cultured and incubated for each of the three bacteria tests--total coliform, fecal coliform, and fecal streptococci. Culture plates for each test were processed with sterile rinse water (blanks) for each sample of ground water. Plates of samples of ground water were prepared in duplicate as a quality-control check. The results of the duplicate plate counts were

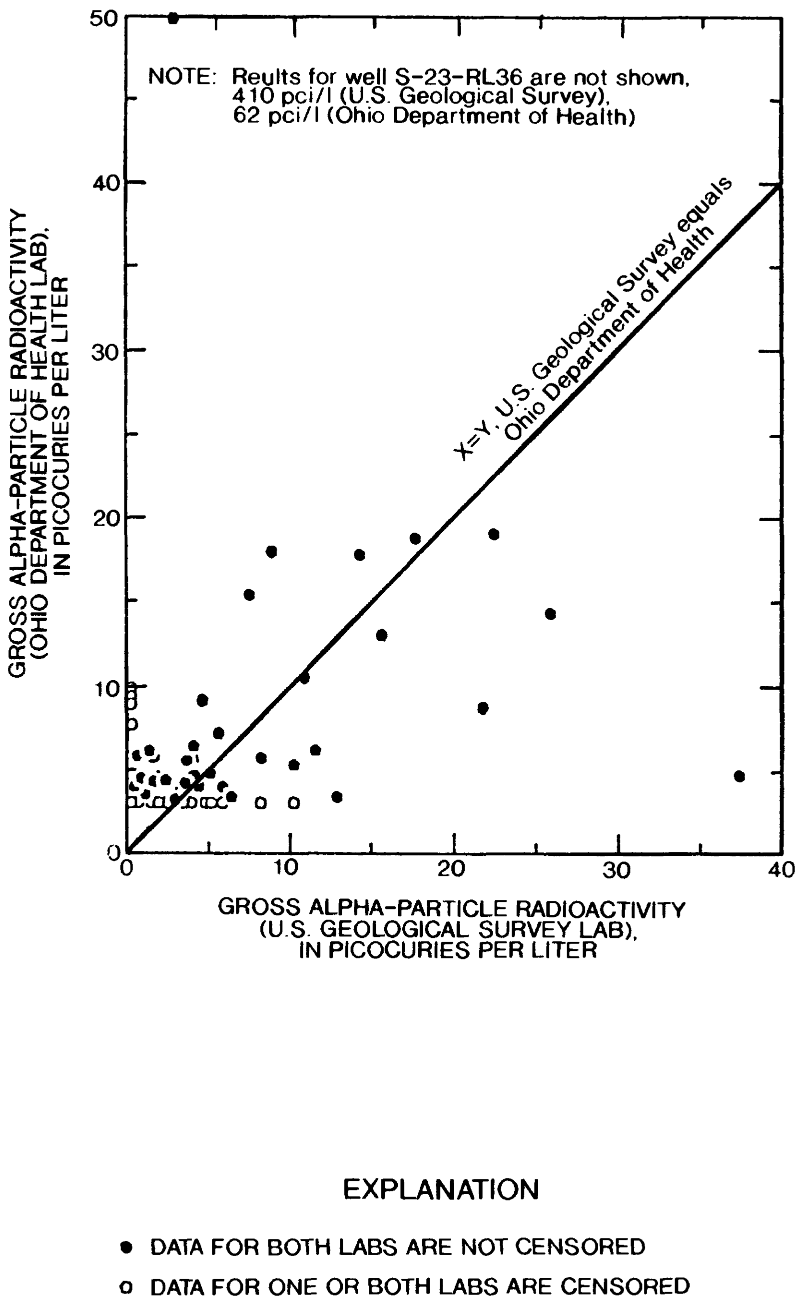

Figure 48.--Comparison of gross alpha-particle radioactivity in ground water as measured in split samples at two laboratories.

averaged for the final reported value. Less than one percent of the blanks for total coliform showed development of colonies. These colonies did not have the metallic sheen characteristic of coliform bacteria and thus did not interfere with the plate counts for total coliform. No fecal coliform or fecal streptococci colonies were identified in blank samples.

Supplementary data on quality of ground water

The files of the USGS, state agencies, and local agencies were examined to obtain supplementary data on water quality. Detailed ground-water-quality data from studies of landfills and other specific sites were reviewed but were excluded in the data base used for statistical summaries; thus, the possible bias due to local concentrations of sampled wells was minimized. Some state or local agencies supplied data for major-ion concentrations that were used for added definition in areas where water quality was highly variable. These data are generally not associated with complete water analyses. Such data were not used in computing any statistical summary of water quality because a cation-to-anion imbalance could not be calculated to assure the quality of the analytical results. Data from two previous USGS studies were incorporated into the data base (five sampling sites), because techniques of sample collection could be documented, and complete water analyses were available.