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GEOHYDROLOGY AND GROUND-WATER POTENTIAL OF LAKE COUNTY, INDIANA

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ABSTRACT

Lake County, in the extreme northwestern corner of Indiana, is underlain by a sequence of about 4,500 feet of sedimentary rocks ranging in age from Cambrian to Quaternary. Some ground water is produced from the rocks of each age represented in the sequence. The principal sources of ground water occur within the upper 350 to 400 feet of rocks. These rocks form a single but complex hydrologic system consisting of three aquifers and two confining layers. Recharge is derived from local precipitation. The system's potential yield is estimated to be 200 mgd (million gallons per day) of which about 7.5 mgd is currently being withdrawn.

The upper 100 feet of the dolomite of Silurian age forms the lowermost aquifer of the system. Recharge to this aquifer through its principal confining layer, unit 4-- clay till, is about 6 mgd under present hydrologic conditions. However, the estimated potential yield is 24 mgd. Natural discharge takes place locally by upward movement, where the head in the Silurian exceeds the head in the overlying rocks, and by downward movement into underlying rocks. Discharge by pumping is about 1.4 mgd, or about 18 percent of the ground water pumped.

Unit 3, a sand, forms the principal Pleistocene aquifer. The aquifer is partly artesian and partly water-table. Recharge to the artesian part is about 100,000 gpd per square mile or 30 mgd under present hydrologic conditions. The estimated potential yield is 60 mgd. Recharge to the water-table part is about 1.2 mgd per square mile and the estimated potential yield 100 mgd. Development of the potential of the water-table part is complicated by the continuing practice of ditching, which dewaters part of the aquifer, and by the aquifer's susceptibility to contamination by industrial and septic wastes.

Natural discharge from the unit takes place by effluent seepage to streams and ditches, evapotranspiration, and downward movement of water to the Silurian aquifer. An estimated 9,248 million gallons was discharged by evapotranspiration from the water-table part during the 1960 growing season. Pumpage from the unit is about 4 mgd, or about 53 percent of the ground water pumped.

Unit 2, a clay till, is the confining layer for the principal Pleistocene aquifer. The unit may have as much as 3 million acre-feet of water in storage. Production from the unit is limited to intertill sand and gravel zones and is estimated to be 100,000 gpd.

The hydrology of unit 2 is significant to both ground- and surface-water resources of the county. Under present hydrologic conditions the unit discharges an estimated 100 mgd of ground water to streams and ditches during the nongrowing season. Evapotranspiration decreases this discharge, and during the 1960 growing season an estimated 7,400 million gallons was discharged by this process.

Unit 1, a sand, is chiefly a water-table aquifer. Under present hydrologic conditions recharge is probably less than 600,000 gpd per square mile. The rate of recharge may have been decreased by more than 50 percent owing to extensive alteration of the unit's hydrology by industrial and urban development. Natural discharge takes place by evapotranspiration and by effluent seepage to streams, ditches, and Lake Michigan. Estimated pumpage from the unit is 1.9 million gpd, or about 25 percent of the ground water pumped. Under present hydrologic conditions the potential yield of the unit is about 30 to 40 million gpd. Development of this potential may be impeded by the unit's susceptibility to contamination by industrial and septic wastes.

INTRODUCTION

Purpose and Scope

A ground-water investigation is currently in progress in northwestern Indiana by the U. S. Geological Survey, in cooperation with the Division of Water Resources, Indiana Department of Conservation. Its purpose is to define the aquifers; their ground-water geology and hydrology and that of their associated beds; factors affecting and problems related to their development; and to estimate their current and potential yields. This report presents an evaluation of that part of the State underlying Lake County and provides information to serve as a guide for sound development and responsible management of the ground-water resources of the county. Standard methods of investigation were used.

Lake County lies adjacent to the heavily industrialized and intensely populated greater Chicago area (fig. 1). The county's industry and population should increase sharply within the next few decades as a result of economic growth of the greater Chicago area and the general economic development of the Great Lakes region. The rural nonfarm population has shown a rapid increase in the northwestern part of the county, particularly in the area adjacent to Illinois. The continued growth of the population southward from Lake Michigan and the potential for industrial development in the northern half of the county will increase greatly the demand for ground water. Interstate competition for ground water available in those sources that underlie both the county and the adjacent area in Illinois will be intensified in the future.

Previous Investigations

Detailed evaluation of the ground-water resources and geology of the county has not been previously published. Publications referring to Lake County are cited in various sections of the report and listed in the selected references.

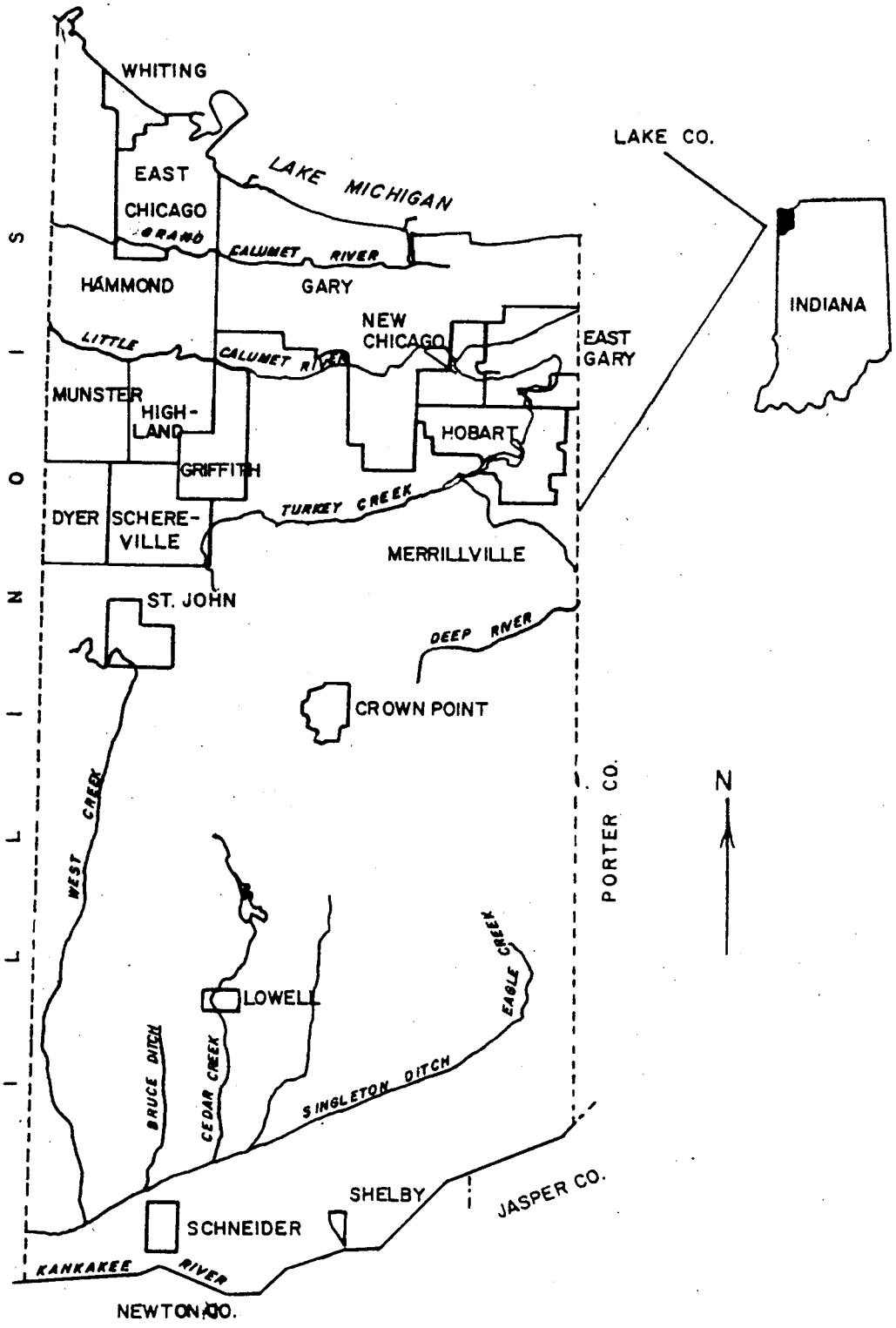


FIGURE 1.-- Map of Indiana showing area covered by this report.

Well-Numbering System

Each well referred to in this report is assigned a number that indicates its location according to the official rectangular public-land survey. A comprehensive description of the well-number system is given in Rosenshein (1961, p. 4).

Acknowledgments

The authors thank all persons who contributed time, information, and assistance during the preparation of this report. The investigation was under the immediate supervision of C. M. Roberts, district geologist of the Ground Water Branch of the Geological Survey. J. E. Hackett of the Illinois Geological Survey provided information concerning the geology and hydrology of northeastern Illinois. R. J. Vig, formerly of the U. S. Geological Survey, collected and processed part of the data used in the preparation of the report and assisted in the geologic reconnaissance. Well drillers supplied logs and related information.

The authors also thank the following government agencies which provided information: Geological Survey, Indiana Department of Conservation; Divisions of Oil and Gas and Water Resources, Indiana Department of Conservation; Indiana State Highway Department; Indiana Toll Road Commission; and Indiana State Board of Health.

CLIMATE AND GEOGRAPHY

Climatic setting:--Lake County has a climate characteristic of the northern midcontinent region. The average annual precipitation is about 33 inches (fig. 2 and the average annual air temperature is about 52°F. at Whiting. Figure 3 shows monthly precipitation and temperature at Whiting from 1910 through 1961.

Topography and drainage:--The Valparaiso morainal system is the chief topographic feature of the county (pl. 3). It extends from west to east across the central three-quarters of the county. A principal drainage divide follows the crest of this morainal system and separates the St. Lawrence River basin from the Mississippi River basin. The maps in this report show the configuration of the principal streams and ditches. Courses of most streams have been straightened since the 1900's. Points of highest elevation are in the morainal system. The lowest elevation in the county is the shoreline of Lake Michigan. Maximum relief is about 210 feet.

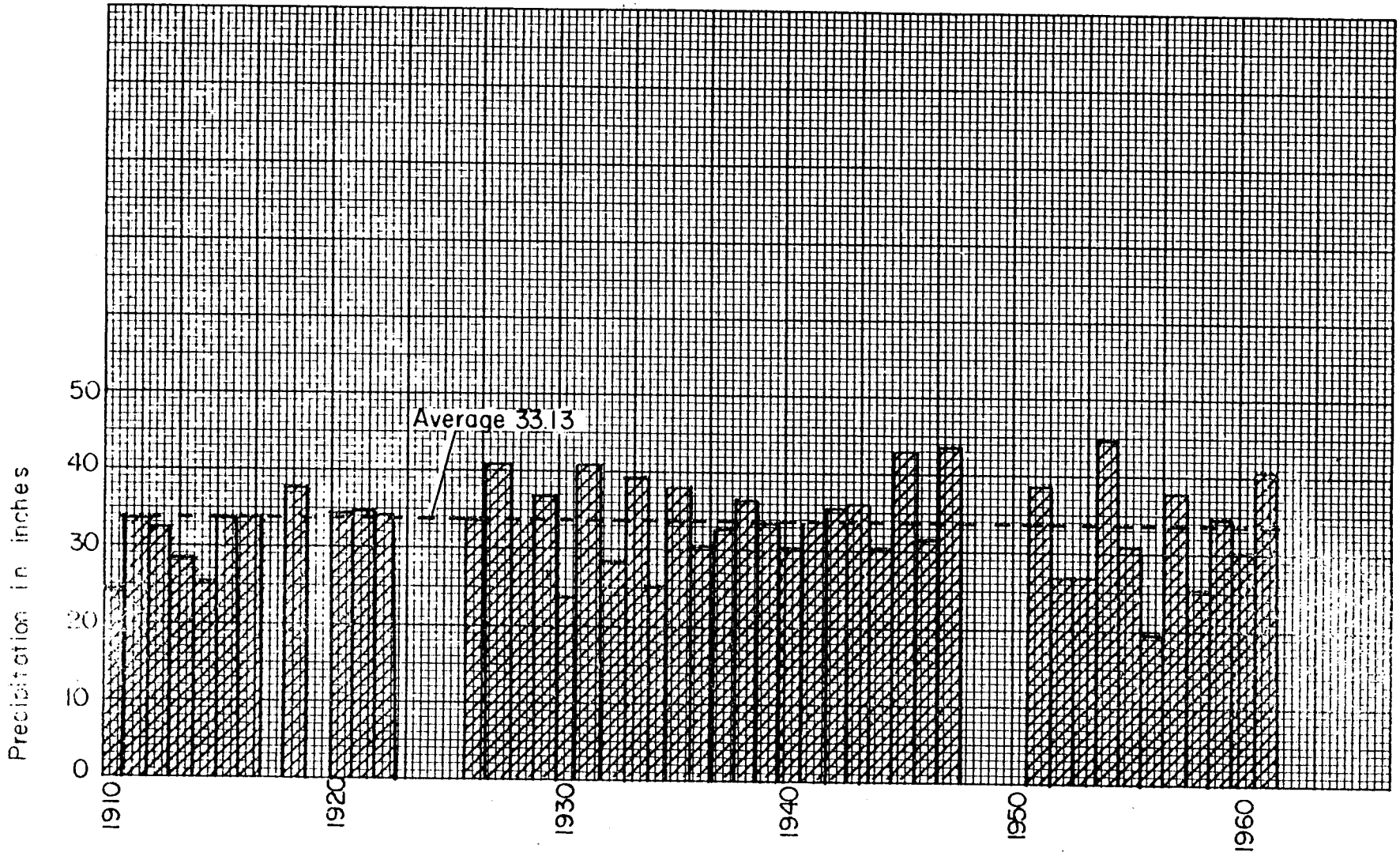
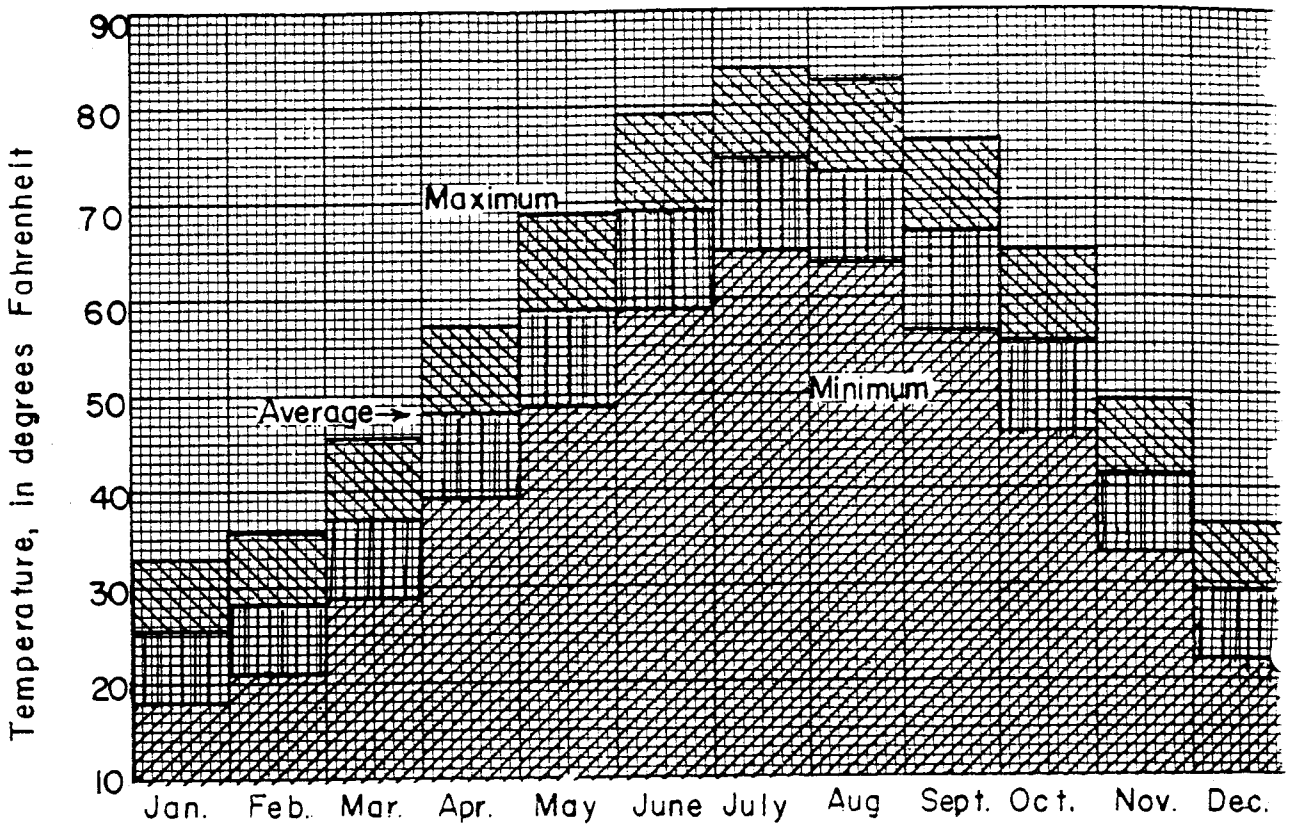


FIGURE 2.- Annual precipitation at Whiting, Ind: available records, 1910-1961



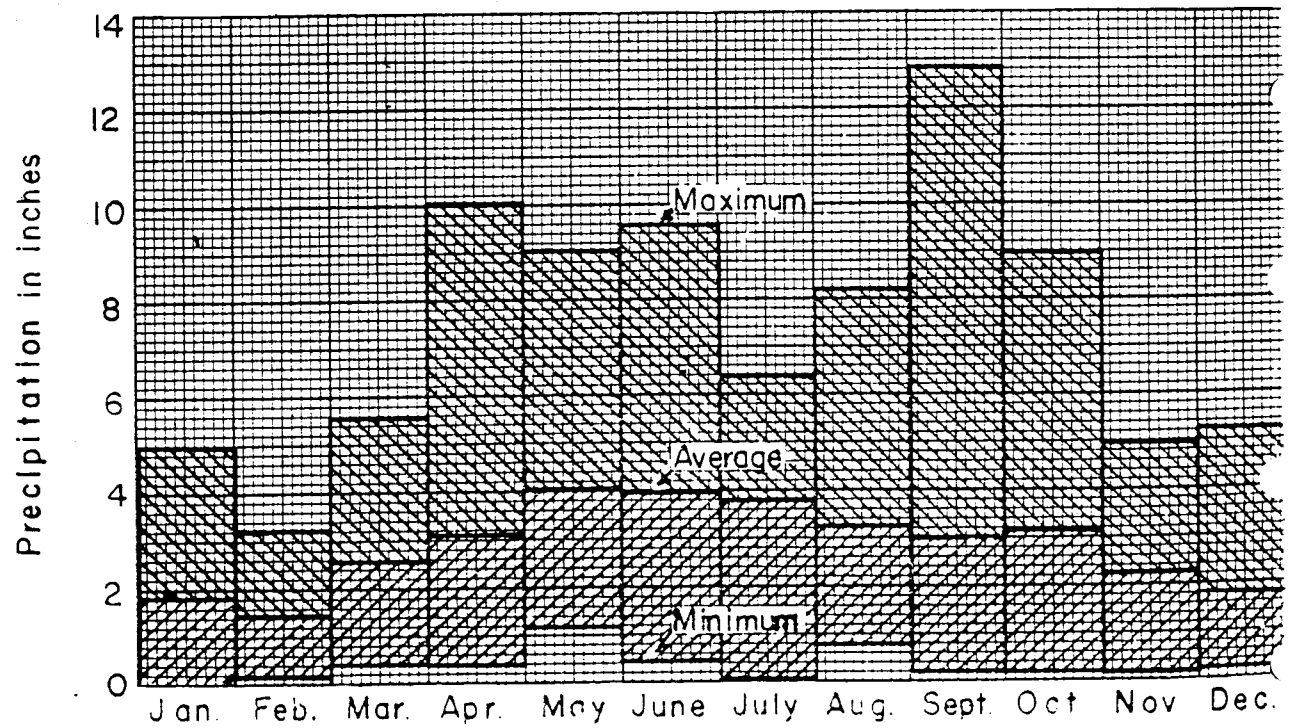


FIGURE 3.-- Monthly temperature and precipitation at Whiting, Ind.: available records, 1931 to 1959

GEOHYDROLOGY OF THE PRINCIPAL ROCK UNITS

Lake County is underlain by a sequence of about 4,500 feet of sedimentary rocks, which range in age from Cambrian to Quaternary. The stratigraphy and geohydrologic properties of these rocks are summarized in table 1. Some ground water is produced from the rocks of each geologic age in the sequence. The rocks in the upper 350 to 400 feet are used extensively as a source of water and have the greatest potential for future water supply development. These rocks are principally of Silurian and Quaternary ages and form a single but complex hydrologic system underlying the county.

Cambrian and Ordovician Systems

Water-bearing characteristics:--The sandstone and related dolomite of Cambrian and Ordovician ages (table 1) form a deep aquifer that is used extensively in northeastern Illinois. In northwestern Indiana the estimated production is less than 40,000 gpd; all of which is pumped by industrial wells. Walton and Csallany (1962, figs. 14 and 15, p. 21 and 22) have shown that the specific capacities (definition, p. 33) of wells tapping the aquifer in Illinois decrease eastward toward Indiana. This evaluation and limited information available in Indiana indicate that specific capacities of about 1 gpm per foot of drawdown or less can be expected from wells tapping this source in Lake County.

Table 1.-- Summary of stratigraphic section and water bearing properties of rock units, Lake County, Indiana

System	Series	Stratigraphic Unit	Thickness (feet)		Character and distribution	Geohydrologic properties and significance	Remarks
			Range	Average			
Quaternary	Recent and Pleistocene	Unit 1	0-80	32	Sand, generally fine to medium, somewhat silty, slightly to moderately calcareous, grains generally subrounded; interbedded with zones of beach gravel, silt, and clay; locally organically rich; contains small areas of thinly laminated silt and clay as much as 30 feet thick; underlies about 140 square miles of northern part of county.	Second most utilized aquifer in county; possible source of water for users requiring less than 50 to more than 500 gpm; contributes to base flow of streams. Estimate of average hydraulic properties; permeability, about 450 gpd per square foot; transmissibility, about 15,000 gpd per foot; coefficient of storage, about 0.12.	Geohydrology and topographic expression extensively modified as result of industrial and urban growth in northern part of county.
		Unit 2	0-100+	45	Till; clay, silty, sandy, moderately to highly calcareous, containing some small pebbles; generally olive-gray in lower part, yellowish-gray or pale-to-dark-yellowish-gray in upper part; contains discontinuous lenses of sand and gravel of small areal extent; underlies about 300 square miles of central part of county.	Discontinuous sand and gravel lenses utilized locally as a source of water by some domestic and farm supplies; forms confining layer of unit 3; contributes significantly to base flow of streams. Estimated average vertical permeability, 0.007 gpd per square foot.	Forms dissected ground moraine and terminal moraine of the Valparaiso morainal system; hydrology markedly altered by extensive drainage of upper part of unit. Commonly described by drillers as yellow or brown in upper part and gray to bluish-gray in lower part.
		Unit 3	0-100	40	Sand, generally medium to coarse, somewhat pebbly, silty and clayey, calcareous, grains subrounded to rounded; composed of fragments of shale, quartz, dolomite, limestone, and igneous and metamorphic rocks; contains pyrite fragments and crystals; locally contains thick clays of distinctly limited areal extent; underlies about 370 square miles of southern part of county.	Principal Pleistocene aquifer; possible source of water for users requiring less than 50 to about 700 gpm; contributes to base flow of streams. Estimate of average hydraulic properties of artesian part: permeability, about 600 gpd per square foot; transmissibility, about 24,000 gpd per foot; coefficient of storage, about 0.003: of water-table part; permeability, about 600 gpd per square foot; transmissibility, about 15,000 gpd per foot; coefficient of storage about 0.12.	Exposed at surface in lower part of county.
		Unit 4	0-150	55	Till; clay, silty, sandy, pebbly, slightly to moderately calcareous, locally hard and compact, olive-gray to greenish-gray; contains some relatively thin, discontinuous, intertill sand and gravel zones; in northern part of county contains a relatively thin basal sand and gravel; underlies about 500 square miles of county.	Intertill sand and gravel zones utilized locally as source of water by some domestic and farm supplies; basal sand and gravel, an untapped potential source of water for relatively small supplies; forms confining layer of Silurian aquifer. Estimated average vertical permeability, 0.003 gpd per square foot.	

Table 1.-- Summary of stratigraphic section and water bearing properties of rock units, Lake County, Indiana--Continued

System	Series	Stratigraphic Unit	Thickness (feet)		Character and distribution	Geohydrologic properties and significance	Remarks
			Range	Average			
Devonian	Upper Devonian	New Albany Shale	0-110	20	Shale, somewhat silty, bituminous, sporiferous, thinly laminated, soft in upper part, grayish-black to brownish-black; contains finely disseminated pyrite crystals; underlies about 80 square miles of the eastern part of the county; present locally in the rest of the county as erosional remnants.	Minor source of water for domestic and farm supplies.	Forms upper part of bedrock surface in east-central part of county.
	Middle Devonian	Undifferentiated	0-150	---	Dolomitic limestone and some dolomite; underlies about 150 square miles of the county.	----do----------	
Silurian	Middle Silurian	----do----	400-600	500	Dolomite, generally very fine- to medium-grained, calcitic, slightly to highly argillaceous, yellowish- or light-olive gray to olive- or greenish-gray; contains small pyrite crystals and carbonaceous flakes disseminated throughout; locally contains chert and zones of thinly-bedded dolomitic shale; argillaceous material generally concentrated in interstitial spaces between dolomite grains; underlies entire county.	Third most utilized aquifer in county; generally possible source of water for users requiring less than 10 to about 200 gpm; only upper 100 feet of dolomite sufficiently permeable to be considered part of the aquifer. Estimate of average hydraulic properties; permeability, 55 gpd per square foot; transmissibility, 5,500 gpd per foot; coefficient of storage, 0.0008.	Forms upper part of bedrock surface in much of county. Commonly described by drillers as "lime rock, rock, or limestone".
Ordovician	Upper	----do----	400-670	---	Shale and dolomitic shale in upper part; dolomite in lower part; underlies entire county.	Not a source of water in county.	
	Middle	----do----	50-250	100	Sandstone, fine- to coarse-grained; underlies the entire county.	Minor source of water in county.	
Ordovician and Cambrian	Lower Ordovician and Upper Cambrian	----do----	300-700	500	Dolomite, cherty, and sandstone; underlies the entire county.	----do----------	
Cambrian	Upper Cambrian	----do----	-------	2,600	Sandstone, shale, and dolomite in upper 600 feet; chiefly fine- to coarse-grained sandstone in lower part; underlies the entire county.	----do----------	Deposited on basement complex.

Quality of water:--Water from this aquifer in Indiana is of poor chemical quality for general use. The concentration of dissolved solids ranges from 2,000 to 3,500 ppm (parts per million). The water has a high concentration of sodium, calcium, chloride, and sulfate, a moderate concentration of magnesium and bicarbonate, and is very hard. The concentrations of iron, magnesium, sulfate, chloride, fluoride, and dissolved solids generally greatly exceed the recommended drinking-water standards of the U. S. Public Health Service (1962)

Development and potential:--The rocks of Cambrian and Ordovician ages will probably never become a significant source of water in the county. Well yield are small and construction and pumping costs are high compared with those of wells tapping the available shallower and more productive aquifers.

Water temperature is higher and mineral content much greater than that in the shallower sources. Water quality poses economic problems with respect to treatment and effect upon equipment. Safeguards, such as special well construction and proper treatment or disposal of waste water, are needed to prevent contamination of less mineralized water in the shallower aquifers. These limitations show that extensive use of water from this aquifer is generally no economically feasible.

Silurian System

The rocks of Silurian age consist chiefly of dolomite. This dolomite forms the principal bedrock aquifer and the basal member of the complex hydrologic system underlying the county. It is not exposed at the surface in Lake County. Its lithology, distribution, and general stratigraphic relations are summarized in table 1.

Water-Bearing Characteristics

The porosity (definition, p. 33) of the dolomite, as estimated from well cuttings, is about 5 to 10 percent. This porosity indicates that the rock has a moderate capacity to store fluid. The pores are generally small, many being pinpoint size or smaller, and apparently are not greatly inter-connected. These properties indicate that the natural permeability (definition, p. 33) of the rock is relatively small. This permeability has been increased by exposure of the upper part to chemical and physical weathering during pre-Pleistocene time.

The permeability of the dolomite decreases significantly with depth and only the upper 100 feet of rock is sufficiently permeable to be considered part of the aquifer. Coefficients of transmissibility (definition, p. 33) of this upper part range from about 100 to about 50,000 gpd per foot, and the regional value of transmissibility is estimated to be 5,500 gpd per foot. This regional value is somewhat similar to that obtained by Watkins and Rosenshein (1963) for the Silurian in north-central Indiana.

The areas of high transmissibility in the rock occur generally on the uplands and upper part of the valley walls of the preglacial bedrock surface. The areas of low transmissibility coincide with deeper parts of the bedrock valleys. The control of water-bearing characteristics of the Silurian by

preglacial weathering and erosion is also reported by Watkins and Rosenshein (1963) and Watkins and Ward (1962) in other parts of Indiana. This relationship was used in part to delineate the areas of transmissibility shown on plate 1.

The coefficient of storage (definition, p. 33) for the Silurian aquifer is estimated to average 0.0008. This estimate should be sufficiently accurate for evaluating regional characteristics of the dolomite in the county.

Recharge and Discharge

Fluctuations of the water level in the aquifer owing to seasonal variations in recharge and discharge are shown on figure 4. Recharge to the Silurian aquifer is derived from precipitation. The configuration of the piezometric surface (fig. 5) shows that this recharge occurs locally within the county. Ground water flows north and south from the aquifer's principal divide to points of discharge within the county and locally west and east to points of discharge outside the county. Down gradient from this divide recharge is added, chiefly by percolation through the overlying clayey till (unit 4, p. 21). Rosenshein (1963) has estimated that under present hydrologic conditions this recharge averages about 20,000 gpd per square mile.

Natural discharge takes place by upward movement of water from the Silurian where its head exceeds the head in the overlying rocks and by downward movement into the older rocks. Direct discharge by evapotranspiration can occur only in the extreme southwestern part of the county.

The estimated discharge of wells tapping the aquifer is 1.4 mgd or about 18 percent of the ground water pumped in the county. Of this amount 0.7 mgd is pumped for domestic and farm use, 0.6 mgd for municipal use, and 0.1 mgd for industrial and commercial use. Of the amount pumped by communities for municipal use, Dyer pumps 0.16 mgd, Lowell 0.21 mgd, St. John 0.02 mgd, Schererville 0.17 mgd, and Schneider 0.02 mgd.

Quality of Water

Water in the Silurian aquifer is generally hard although not as hard as that in the overlying drift. The dissolved ions consist chiefly of sodium, calcium, magnesium, and bicarbonate. Concentrations of the dissolved constituents and their significance are summarized in tables 2 and 3.

Geohydrologic control:--Recharge to the aquifer percolates through as much as 250 feet of unconsolidated rock. The water has lost much of its ability to dissolve dolomite by the time it reaches the Silurian. As a result, the properties of the water in the Silurian are not greatly influenced by the chemical composition of the rock composing the aquifer. Therefore, the water's chemical characteristics are determined to a large extent by the chemical characteristics of recharge derived from unit 4. As shown by table 2 all of the determined constituents except sodium and a small amount of chloride, are present in equal or greater amount in the water of the overlying principal Pleistocene aquifer, unit 3. Slightly higher concentration of chloride in water from the Silurian has no apparent significance.

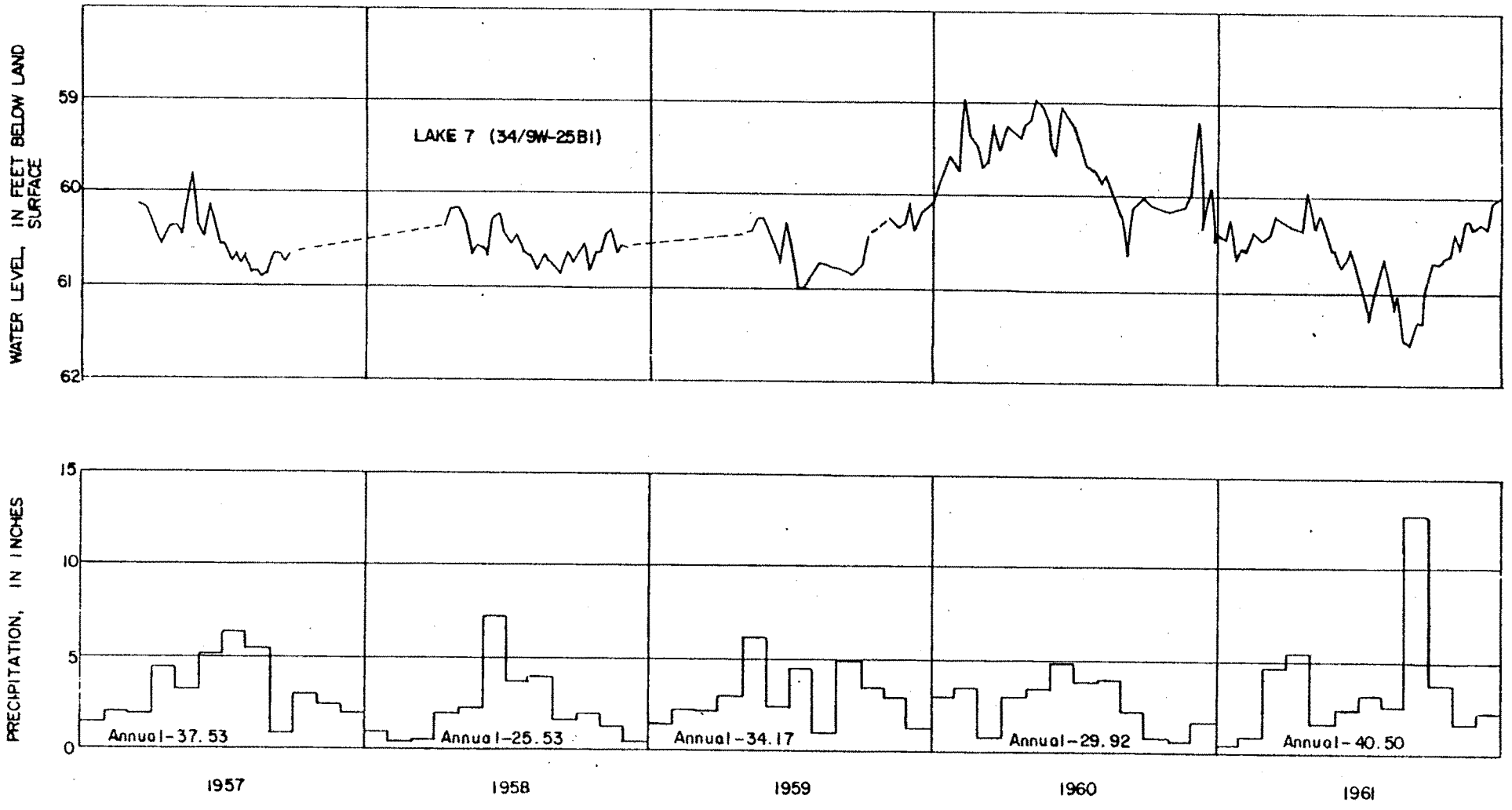


FIGURE 4.--Fluctuation of water level in observation well Lake 7 (34/9W-25B1) in Silurian aquifer and monthly precipitation at Whiting, Ind.