ILLINOIS STATE WATER SURVEY

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TO Report of Investigation 53

Yields of Aquifers in
Embarras River

Walton & Csallany

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Walton, W.C.
POTENTIAL YIELD OF
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REPORT OF INVESTIGATION 53

Potential Yield of Aquifers in Embarras River Basin, Illinois

by W. C. Walton and Sandor Csallany

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1 col Figure 2. Principal geographic features

1 col Figure 3. Average annual precipitation

1 col Figure 4. Lowest annual precipitation expected once in 50 years

1 col Figure 5. Lowest annual precipitation expected once in 50 years

1 col Figure 6. Highest annual precipitation expected once in 5 years

1 col Figure 7. Highest annual precipitation expected once in 50 years

2 col Figure 8. Probabilities of occurence and distribution of sand and gravel aquifers (A), and areal distribution, type, and water-yielding character of upper bedrock formations (B)

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1 col Figure 10. Topography of bedrock surface

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Potential Yield of Aquifers in Embarras River Basin, Illinois

by W. C. Walton and Sandor Csallany

ABSTRACT

The potential yield of aquifers in the Embarras River Basin was evaluated on the basis of available data. The basin, extending from east-central to southeastern Illinois, covers an area of 2487 square miles and is primarily an agricultural region.

Rocks of Pennsylvanian age form the bedrock surface in all but a small area in the northern part of the basin where bedrock is Mississippian and Devonian in age. Most prominent feature of the bedrock surface is a deep, wide, southeastward-trending valley that bisects the basin and is joined by a major tributary bedrock valley in the southern part of the basin; bedrock crops out mostly in this southern area. Till covers most of the bedrock uplands; sand and gravel deposits occur along the courses of streams and in the fill of buried bedrock valleys. The major buried valley is from 1 to 5 miles wide, and glacial drift in it is from 100 to 200 feet thick.

The water table in the Embarras Basin fluctuated in an annual cycle, but no permanent or general decline in water levels is indicated. Total ground-water pumpage in 1960 was 6.3 million gallons per day (mgd), of which 83.5 percent was derived from glacial drift. Of the total 1960 pumpage, 39 percent was for urban use, 12.5 percent for industrial, 15.5 percent rural, and 33 percent for livestock. Wells in the basin range in depth

from 20 to 240 feet and have an average depth of 55 feet. Casing diameters range from 4 to 24 inches.

Results of eight aquifer tests indicate that the coefficients of permeability and storage of sand and gravel aquifers range from 410 to 2500 gallons per day per square foot (gpd/sq ft) and from 0.00003 to 0.04, respectively. Sand and gravel wells in buried bedrock valleys, in alluvium, and outside major buried bedrock valleys have median specific capacities of 42, 10, and 1.6 gallons per minute per foot of drawdown (gpm/ft) respectively, and have median coefficients of permeability of 1800, 820, and 320 gpd/sq ft respectively.

Under heavy pumping conditions recharge rates for aquifers overlain by till are estimated to average between 60,000 and 150,000 gpd/sq mi. Where sand and gravel deposits occur from the surface to bedrock, recharge is estimated to range from 200,000 gpd/sq mi during years of below normal precipitation to 350,000 gpd/sq mi during years of near normal precipitation. Recharge by induced infiltration of surface water is estimated to range from ½ to 1 mgd per mile of the Embarras River in the upper and lower reaches of the stream, respectively. Ground-water runoff during a year of normal precipitation ranges from 0.28 cubic foot per second per square miles (cfs/sq mi) in the northern part of the basin to 0.40 cfs/sq mi in the southern part.

Studies indicate that the order of magnitude of the potential yield of principal aquifers in the Embarras River Basin is 62 mgd. The principal aquifers are the sand and gravel aquifers in mapped buried bedrock valleys and along streams, and the Devonian-Silurian rocks in Douglas County; Pennsylvanian rocks are the source of supply for many domestic wells. Of the total potential yield about 59 mgd is derived from sand and gravel aquifers, and about 58 percent of this potential is concentrated in Lawrence County.

INTRODUCTION

This report presents a quantitative evaluation of the ground-water resources of the Embarras River Basin in southeastern Illinois. Geologic, hydrologic, geographic, and climatic factors are discussed, together with the history of ground-water development and the quality of ground water. The interrelation between ground water and surface water is described. Special emphasis is placed on the extensive sand and gravel deposits along the Embarras River and its tributaries, and in buried bedrock valleys which are the principal aquifers. The potential yield of the sand and gravel deposits is evaluated and area for possible heavy industrial and municipal development are delineated. The geology and hydrology of the bedrock formations are discussed only briefly, since these formations contain limited quantities of ground water. Data on water levels, pumpage, well construction features, ground-water temperature, mineral quality of ground water, and well-production and aquifer tests are presented. The maps, data, and interpretations provide a basis for ground-water resource planning and a guide to the development and conservation of ground water in the basin.

Although this report summarizes present-day knowledge of ground-water conditions in the basin, it must be considered a preliminary report in the sense that it is part of a continuing study of the ground-water resources, and its conclusions and interpretations may be modified and expanded as more data are obtained.

Base maps of the study area were drawn from U. S. Geological Survey topographic maps and from Illinois State Division of Highways county highway maps. All elevations given in this report were taken from these maps.

Well-numbering system

The well-numbering system used in this report is based on the location of the well, and uses the township, range, and section for identification. The well number consists of five parts: county abbreviation, township, range, section, and coordinate within the section. Sections are divided into rows of one-eighth mile squares. Each one-eighth-mile square contains 10 acres and corresponds to a quarter of a quarter of a quarter section. A normal section of 1 square mile contains eight rows of eighth-mile squares; an odd-sized section contains more or fewer rows. Rows are numbered from east to west and lettered from south to north as shown in the diagram below. The number of the well shown is: CHM 18N9E-22.7d. Where there is more than one well in a 10-acre square they are identified by arabic numbers after the lower case letter in the well number. In the listing of wells owned by municipalities, the place-name is followed by V, T, or C in parenthesis to indicate whether it is a village, town, or city. The abbreviations used for counties are:

Champaign	CHM	Edgar	EDG
Clark	CLK	Effingham	EFF
Coles	COL	Jasper	JAS
Crawford	CRF	Lawrence	LAW
Cumberland	CUM	Richland	RCH
Douglas	DGL	Vermilion	VER

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Champaign County
T18N, R9E
Section 22

Acknowledgments

This report was prepared under the general supervision of William C. Ackermann, Chief of the State Water Survey, and Harman F. Smith, Head of the Engineering Section. J. W. Brother prepared the illustrations.

Many former and present members of the State Water Survey and the State Geological Survey assisted in the collection of water-level data, wrote earlier special reports which have been used as

reference materials, or aided the writers indirectly in preparing this report. The writers express their appreciation for the courteous and generous assistance of municipal officials, industrial officials, consulting engineers, water well contractors, private well owners and members of state agencies who contributed information and aided in the collection of field data for this report.

GEOGRAPHY

Location

The Embarras River basin extends from Champaign to Lawrenceville in southeastern Illinois as shown in figure 1 and includes portions of the following counties: Champaign, Clark, Coles, Crawford, Cumberland, Douglas, Edgar, Effingham, Jasper, Lawrence, Richland and Vermilion. The basin covers an area of 2487 square miles;. ~~more than 300 square miles of~~ Coles, Cumberland, Douglas and Jasper Counties lie within the basin. ~~The~~ basin is approximately 100 miles long, has a maximum width of about 34 miles and includes parts of Townships 3 to 19 North, Ranges 7 to 10 West.

Topography and Drainage

The Embarras River basin lies in the Till Plains section of the Central Lowland Physiographic Province; a glaciated lowland that extends from the Appalachian Plateau on the east to the Great Plains of Kansas, Nebraska, and the Dakotas on the west. The northern part of the basin is in the Bloomington ridge plain subdivision; the central part is in the Springfield plain subdivision; and the extreme southern part is in the Mt. Vernon hill country subdivision.

The part of the basin within the Bloomington ridge plain subdivision is characterized by a concentric system of morainal ridges alternating with till plains. Low broad morainic ridges alternate with intervening wide stretches of relatively flat or gently undulating till plains. Glacial deposits of Wisconsinan age are relatively thick, and exposures of bedrock are seldom encountered except along major stream valleys.

Throughout much of the part of the basin that is in within the Springfield plain subdivision, the topography is relatively level to gently undulating except where dissection has proceeded along the major river valleys. Morainic ridges are absent; the topography is primarily constructional ~~due to~~ because of the presence of Illinoian drift. The Springfield plain subdivision is underlain almost continuously by Illinoian and older glacial drift which is thick enough to obscure all but the major variations in the topography of the bedrock.

The Illinoian drift is thin and the topography is controlled principally by the character of the underlying bedrock in the part of the basin ~~within~~ that is in the Mt. Vernon hill country subdivision. Most streams have broad valleys with low gradients.

In most places within the basin, relief of upland areas is less than 70 feet. Relief is generally greater along major river valleys bordered by moraines and often reaches 70 feet. The upland surface rises gradually toward the northwest and attains an elevation of about 750 feet near Champaign-Urbana. The lowest elevation is 450 feet in the Embarras River valley just southeast of the city of Lawrenceville. The maximum relief in the basin therefore is about 300 feet.

According to Morris (1962) the Embarras River originates in the upland prairies of central ~~southern~~ Champaign County in Urbana, Illinois as shown in figure 2. The river flows southward to Jasper County, thence southeastward, and joins the Wabash River in the southeastern corner of Lawrence County.

The northernmost headwater streams form as water collects on the Champaign Moraine and flows out onto the nearly level prairies of southern Champaign County and northern Douglas County. Here the Embarras flows as a sluggish prairie stream meandering for several miles across the level uplands; a low-banked river fed by numerous low-gradient tributaries. These tributaries, many of them channelized, form the outlets for the numerous drainage districts which maintain surface ditches and tile lines to remove the excess water from several hundred thousand acres of highly productive farmland.

Near the Coles-Douglas County line the river drops abruptly into the valley it has cut into the Wisconsin Till Plain. This steep-walled, V-shaped valley extends southward to about the Route 16 highway bridge near Charleston, Illinois. For the next 20 ~~twenty~~ miles the Embarras River follows in a preglacial channel through the Shelbyville Moraine. Within this moraine the main stream is joined by several tributaries. Thus for about 45 miles, twenty miles within moraines and 25 miles within the Wisconsin Till Plain, the Embarras flows at the bottom of a steep-walled valley 50 to 70 feet below the adjacent upland.

In the till plain area the main stream is fed by numerous short tributaries most of which have been extended back from the river through ditching to accomplish drainage of the nearly level prairie farms. Near the main stream these tributaries have steep gradients, often 20 or more feet per mile.

Near the Coles-Cumberland County line the Wisconsinan Terminal Moraine drops abruptly to the lower Illinoian Till Plain. In this section of the basin the river, flowing in a preglacial channel, occupies a broad flat-bottomed valley with steep valley walls rising sharply to the upland. Although the differences in elevation are not as great as those found farther up stream, rather large acreages of 20 to 30 percent slopes occur where the uplands drop to the valley bottoms. The river throughout its course occupies a sharply defined valley, lying abruptly below the upland; the upland in the lower part of the basin is more rolling and presents fewer and smaller areas of level prairie land. Seven watershed areas ranging in size from 141,866 acres to 255,066 acres are indentified in the Embarras basin.

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POPULATION

The Embarras River basin includes portions of twelve counties and 44 incorporated municipalities ~~places~~ (see Figure 2). The counties were established between 1816 and 1859; Crawford in 1816, Clark in 1819, Lawrence in 1821, Edgar in 1823, Vermillion in 1826, Coles in 1830, Effingham in 1831, Jasper in 1831, Champaign in 1833, Richland in 1841, Cumberland in 1843 and Douglas in 1859. All municipalities incorporated ~~places~~ in 1960 were incorporated prior to 1911 except ~~but~~ Savoy which dates from ~~was incorporated in~~ 1956. In 1910 the total population in the basin reached a peak of 126,000, of which 53 percent were rural residents. Between 1910 and 1960 the total population declined and was 117,000 in 1960; most of the decline was in rural population. This rural loss was considerably greater than the 14 percent loss of rural population on a statewide basis from ~~during the period~~ 1910 to 1960. In the same period the urban population increased gradually except for a slight decline in 1930. In 1960 the distribution of the population was 66 percent urban (77,500) and 34 percent rural (39,500). The urban population refers only to those residing in incorporated places. The Embarras River basin as a whole accounts for about 1 percent of the state population and 4.5 percent of the State area. Population of incorporated municipalities in 1960 is given in table 1. table 1

Economy

According to Morris (1962), the Embarras River basin is primarily an agricultural region with 80 to 95 percent of the area of each county in farms. The counties with the largest percentages of nearly level land have more than 90 percent of the total county area in farms, while Crawford and Lawrence Counties with a higher percentage of hilly land have somewhat in excess of 80 percent of the area in farms. Much of the land is devoted to harvestable grain crops.

The basin has been an important mineral-producing area for the past 50 years. The greatest economic contribution has been from petroleum production ~~with~~ and minor and spasmodic operations have provid~~ing~~ed coal, limestone, sand, and gravel. Petroleum has been produced in the basin since the early part of the 20th century, prior to the last 20 years from shallow wells. Deeper drilling and water flooding which began in 1943 have produced increasing yields of oil in recent years. About 7 million barrels have been produced in Lawrence County alone. Although two refineries serve the area, one at Lawrenceville and the other at Robinson, much of the oil produced goes to the Chicago and East St. Louis-Wood River areas for refining. Large deposits of natural gas often occur in association with oil.

Although Coal reserves underlie most of the Embarras River basin ~~yet,~~ only two coal mines were in operation in 1960. and ~~These two coal~~ mines produced 505,984 tons in 1960. of high volatile bituminous coal in that year. ~~The coal is high volatile bituminous coal.~~

In much of the basin no limestone deposits occur near enough to the surface to permit quarrying. There were Only six quarry operations, existed in the basin in 1960; ~~these are~~ located in Coles and Clark counties. Agricultural and crushed stone were produced at these quarries with annual production averaging 200,000 to 250,000 tons. Sand and gravel deposits are found scattered throughout the basin; and ~~ten~~ 10 companies provide sand and gravel for road construction, ~~and~~ buildings and ~~to the building industries as well as for~~ other uses. Little use is made of clay in the basin. ~~One company at Robinson manufactures bathroom fixtures and uses clay brought from outside the basin.~~

Climate

Temperature and precipitation are the climatic factors directly related to the availability, storage, movement, and withdrawal of ground water. Temperature influences evapotranspiration and recharge, and also affects the rate and distribution of ground-water withdrawal. The climate of the Embarras River basin is a humid continental type, with cold and moderately dry winters and warm to hot and wet summers.

About ~~sixty~~ 60 percent of the average annual precipitation occurs during the warmer half-year, April to September. The average annual number of thunderstorms in the basin is about 44. About 6 percent of the average annual precipitation is snowfall. Normally May and June are the wettest months, and February and December ~~are~~ the driest ones. Average annual and monthly precipitation for five stations located in or near the basin are shown in table 2. Average annual precipitation ranges from less than 37 inches in the northern part of the basin to more than 41 inches in the southern part as shown in figure 3.

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The frequency of annual maximum and minimum precipitation is shown in figures 4-7 (State of Illinois, 1958). Annual precipitation of 32 to 36 inches can be expected once in 5 years; annual precipitation of 24 to 28 inches can be expected once in 50 years. Annual precipitation averaging about 46 inches can be expected once in 5 years; annual precipitation averaging about 56 inches can be expected once in 50 years.

The average monthly and annual snowfall at Urbana is given in table 3. In December, January and February, the months of greatest average snowfall, approximately 23 percent of the average monthly precipitation is snowfall. Average annual snowfall ranges from more than 21 inches in the northern part of the basin to less than 16 inches in the Central part. Between 5 and 6 days have 1 inch or more of snow cover.

The growing season (or period between killing frosts, ranges from 170 to 180 days) for the northern half of the basin ~~ranges from 170 to 180 days and~~ for the southern half ~~ranges~~ and from 180 to 190 days. The beginning and end of the growing season ~~(the period between killing frosts)~~ most commonly occur in the middle of April and in the middle of October, respectively.

Table 3 shows a wide range of mean temperature at Urbana. July has the highest average temperature and January is ~~on average~~ usually, the coldest month. Monthly and annual temperatures vary with latitude within the basin. The difference in mean January temperature between the north and the south parts of the basin is about 5°F (from 29 to 34°F), and the difference in mean July temperature between the north and south parts of the basin is about 2°F (from 77 to 79°F). On the average, 113 days per year have daily mean temperatures below freezing. Temperatures equal to or greater than 90 degrees occur 26 days per year.

GEOLOGY

For a detailed discussion of the geology in the Embarras River basin, the reader is referred to Selkregg, et al. (1957), Selkregg and Kempton (1958) and Horberg (1950). The following sections are based largely on and contains abstracts from these reports.

Bedrock stratigraphy and structure

Rocks of Pennsylvanian age form the bedrock surface throughout the basin except in north-central Douglas County and south-central Champaign County where the bedrock is Mississippian and Devonian in age. Pennsylvanian rocks consist of shale, sandstones, coals, and limestones. Many domestic and farm wells obtain water from the sandstones, thin limestones and fractured shale at various depths. Fresh water is encountered at depths generally less than 300 feet and commonly in the upper 150 feet of bedrock.

use hyphen

In north-central Douglas County and south-central Champaign County bedrock of the Mississippian and Devonian systems directly underlies the drift (figure 8B). In this area ground water is

Fig 8

obtained from the Devonian and underlying Silurian dolomites. The Mississippian shales are not water-yielding.

The bedrocks form part of a saucer-like structure known as the Illinois basin. The deepest part of the basin is in White County. In the Embarras River basin there is a narrow band along which the rocks have been warped upward into an arch-like structure or anticline (figure 9). This structure, the LaSalle anticlinal belt, extends from Ogle County in northern Illinois to Wabash County in southeastern Illinois. Along this belt some of the formations, which in most parts of the Illinois basin are too deep to yield potable ground water, are near the surface and are locally important ground-water sources. Pennsylvanian rocks at depths greater than 300 feet below the land surface and Mississippian, Devonian, Silurian, Ordovician, and Cambrian rocks generally contain water highly mineralized, or brine. These bedrock strata rest on a basement of ancient crystalline rocks composed of granite. fig 9

Bedrock topography

A contour map showing the topography of the bedrock surface of the Embarras River Basin is shown in figure 10. The most prominent feature of the bedrock-surface map is the deep, wide, southeastward-trending valley which bisects the basin. The floor of the valley is at an elevation of about 450 feet in Coles County and 350 feet in Cumberland County, and is about 2 miles wide. The valley joins the Wabash River buried valley near Lawrenceville in Lawrence fig 10

County. There the elevation of the valley floor is about 350 feet. The Embarras River overlies the bedrock valley only in the southwestern part of Crawford County and Lawrence County. The North Fork of Embarras River overlies the bedrock valley only in the eastern part of Jasper County. The main bedrock valley heads in northeastern Coles County and leaves the basin in eastern Lawrence County.

A major tributary bedrock valley extends southward from the northern part of Clark County to join the main bedrock valley in west-central Crawford County. The floor of the tributary bedrock valley is at an elevation of 400 feet in west-central Clark County and at an elevation of 350 feet in northwestern Crawford County. The bedrock valley is about 1 mile wide in its upper reaches. ~~The North Fork of the Embarras River overlies the bedrock valley only in south-central Clark County and northeastern Jasper County.~~

A deep, wide, westward-trending buried bedrock valley and several tributaries occur in southern Champaign County and Douglas County. This bedrock valley system joins the Mahomet bedrock valley west of Monticello in Piatt County. The floor of the bedrock valley in southern Champaign County is at an elevation of 450 feet and is about 3 miles wide.

The elevation of the upland surface of the bedrock ranges from 650 feet in the northern part of the basin to 550 feet in the southern part of the basin. Bedrock exposures occur along the valley of the Embarras River in eastern Coles County, central

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Cumberland County, and central Jasper County. The bedrock crops out at the land surface at places in southwestern Clark County, central and southeastern Crawford County, northeastern Richland County and northern Lawrence County.

Glacial deposits

Unconsolidated deposits of glacial origin almost completely cover the bedrock in the basin. Glacial ice sheets that advanced outward from centers of snow accumulation in Canada transported a great volume of rock debris and in melting deposited it as an irregular blanket that covered the eroded layered bedrock. Till, an unsorted mixture of clay, silt, sand, and pebbles, was laid down under the advancing ice or dumped during its melting. Beyond the ice front, sediment-laden meltwaters flowed down valleys, partially filling them with deposits of outwash that consist of sorted sand, gravel, and finer material. River flats, kept free of vegetation by frequent glacial flooding, were subject to wind erosion, and great volumes of silt were blown onto the uplands bordering the valleys to form loess deposits. Till, outwash, loess, and the sediments of modern streams now almost completely cover the bedrock surface. Some of the bedrock valleys coincide with present stream valleys, but others are partly or completely buried and there is little or no evidence of their presence at the surface.

Sand and gravel deposits are the most important aquifers along the courses of streams and in the fill of buried bedrock valleys. They are also important sources of ground water in bedrock upland areas where the glacial drift is thick. Figure 8A shows the probability of occurrence of sand and gravel aquifers (Selkregg, et al, 1957, and Selkregg and Kempton, 1958). The areas shown as "good to excellent" are underlain by thick deposits of unconsolidated material containing sand and gravel aquifers. The probabilities for construction of high-capacity wells for industries and municipalities are good, although test drilling is necessary to locate suitable sand and gravel deposits. The areas shown as "fair to good" are underlain by moderate thicknesses of unconsolidated materials that fill shallow bedrock valleys or lie on the uplands bordering the main bedrock valleys. These materials contain thin and discontinuous deposits of sand and gravel. The probabilities of obtaining supplies of water for industrial and municipal purposes are poor to fair. Extensive test drilling generally is necessary to locate water-yielding deposits. The areas outlined by dashes correspond to buried bedrock valleys that contain deposits of unconsolidated materials as much as 150 to 200 feet thick. Few well records are available in these areas and therefore the presence and extent of sand and gravel deposits is not known. The areas, however, merit special attention in exploration for water-yielding sand and gravel. The areas shown as "poor" are primarily on bedrock uplands. Glacial deposits, if present, are thin or are composed mainly of tight till; sand and gravel deposits are rare. The character and thickness of the glacial drift is illustrated in figure 11 and by the logs of wells fig. 11

given in the appendix. The buried valley bisecting the basin ranges in width from one to 5 miles and the unconsolidated deposits in the buried valley range in thickness from 100 to 200 feet.

The following sections on glacial deposits in specific counties were taken from Selkregg, et al. (1957), and Selkregg and Kempton (1958).

In the buried and partially buried bedrock valleys in the western part of Crawford County, thick deposits of permeable sand and gravel are potential sources of ground water for municipal and industrial supplies. In the area outlined by dashes in figure 8A, thick drift is reported and several wells obtain large ground-water supplies from sand and gravel. The area appears worthy of testing for municipal and industrial supplies.

The glacial deposits over most of Richland County are thin and lacking in sand and gravel.

In Lawrence County along the bottomlands and partly buried bedrock valleys of the Embarras and Wabash Rivers, thick deposits of permeable sand and gravel are sources of ground water for municipal and industrial supplies. Some thin, scattered sand and gravel deposits occur along the smaller tributaries of these larger streams. In the western and central parts of the County the glacial drift is thin and for the most part ~~it~~ is not suitable for the construction of drilled wells.

Sand and gravel deposits favorable for development of domestic and farm ground-water supplies are generally scattered over Douglas

County, but in the northwestern and central part of the county they occur somewhat more consistently. Here the drift is ~~as much as~~ 150 feet or more ~~thick~~ in the buried Pesotum Valley and in two minor tributary valleys. Small municipal ground-water supplies have been developed from sand and gravel at Arcola and Newman.

Sand and gravel deposits favorable for domestic and farm supplies are present throughout Coles County except for small areas where the drift is thin. These sand and gravel deposits occur at various depths ranging from 40 to 100 feet below land surface. In Ts, 11N., 12N., 13N., and 14N., and Rs, 7E. and 8E., sand and gravel deposits are more continuous than in other parts of the county and at some places may be the source for small municipal and industrial supplies.

The Mattoon city wells located outside of the Embarras Watershed in sec. 30, T. 12N., R. 8E., and in sec. 18, T. 11N., R. 7E., are finished at depths ranging from 40 to 70 feet. In the buried valley of the Embarras River (figure 8A, area outlined by dashes), the drift is thick and locally may contain favorable sand and gravel deposits.

In Champaign County the glacial drift is generally more than 150 feet thick and contains sand and gravel deposits suitable for domestic and farm supplies. Locally municipal supplies have been obtained at Tolono, Pesotum, and Philo. In the southeastern part of the county, sand and gravel deposits are locally absent. Intensive test drilling was needed to locate the water supply for Broadlands and Long View.

Sand and gravel deposits favorable for domestic and farm supplies are present at many places in the western part of Edgar County. In the eastern part the drift is generally thin. Bedrock crops out at many places east of Paris. Small municipal water supplies have been obtained locally after intensive test drilling to locate favorable sand and gravel aquifers. The towns of Hume, Metcalf, and Kansas obtain water supplies from wells finished in unconsolidated material at depths of 55, 93, 85, and 103 feet, respectively.

Glacial deposits in the central and western parts of Clark County are generally thin and not suitable for development of sand and gravel wells. In the southeastern part of the county, along the Wabash River valley, are thick permeable deposits of sand and gravel that are potential sources of ground water for industrial supplies, ~~are present. The presence of~~ a buried valley in the southwestern part of the county is indicated by records of scattered wells that have encountered thick drift in the area outlined by dashes on figure 8A. It is possible that sand and gravel suitable for large ground-water supplies may be located by testing in the area.

In the bottomlands of the Embarras River, particularly in the partially buried bedrock valley, thick deposits of sand and gravel are potential sources of groundwater for municipal and industrial purposes in Cumberland County. Thin, discontinuous deposits of sand and gravel are present locally in the north-central and western parts of Cumberland County, in the bottomlands adjacent to Hurricane Creek and other small streams tributary to the Embarras River.

Glacial deposits throughout most of Jasper County are thin and bedrock crops out at many places, particularly in the central part of the County. In the northeastern part relatively thick deposits of sand and gravel are associated with the partially buried Embarras River Valley and are potential sources of large quantities of ground water. Thin discontinuous sand and gravel deposits are present locally in the bottomlands of the Embarras River and in the bottomlands of small streams in the southwestern part of the county.

Surface deposits

The general character of the surface deposits in the Embarras River basin is shown in figure 12 (Thornburn, 1960). Ground Moraine is the predominating surface deposit in the southern part of the basin, glacial till is the principal constituent of the deposit. Ground Moraine also occurs in extensive areas in the northern part of the basin. Morainic ridges are the predomina~~ting~~nt surface deposit feature in the northern part of the basin; no Morainic ridges are found in the southern part of the basin. The principal constituent of the moraines is glacial till; however, there are many more inclusions of water-worked material than normally are encountered in Ground Moraine. Moraines are usually found to contain pockets, lenses, and even tubes of water-sorted gravels, sands, and silts. Locally they may even contain water-sorted silts and clays which have been laid down in temporary lakes. As is the case with Ground Moraine, the characteristics of the till itself may vary from one moraine to another.

Outwash plains are associated with moraines and lie in front of them. Normally, one would expect to find the coarsest-textured sediments of sand and gravel and the thickest deposits immediately in front of a morainic ridge. Closely associated with the outwash plains are the deposits of water-sorted materials laid down in the major stream valleys. Figure 12 shows the locations of the major alluviated valleys, but it is not possible to say with certainty that granular materials of high-quality will be found in any specific location in these valleys. The Embarras River and the North Fork of the Embarras River flow in alluviated valleys.

The only important and extensive areas of lakebed sediments are in Douglas and Lawrence Counties. Under the conditions of lacustrine deposition which prevailed, layers of fine-grained sediments were built-up.

Deposits of wind-blown silt (loess) cover nearly all the basin to a depth of 4 feet or more.

GROUND WATER

(10/12 pt SS Bold all CAPS, with [illegible] centered in 43½ picas

Source, Movement, and Occurrence

The general principles underlying the source, movement, and occurrence of ground water have been presented in papers by

Meinzer (1923, 1932, and 1942) and Wenzel (1942), among manty others. The following discussion is a brief outline of those general principles that are essential to an understanding of ground-water conditions in the Embarras River Basin.

The unconsolidated sediments and underlying bedrock are not solid throughout but contain numerous openings called pores or interstices. These interstices are the receptacles that hold and transmit water found beneath the surface of the land. For the most part, the interstices are small, irregular in shape, and interconnected so that water can move from one opening to another. Water in interstices is controlled largely by two forces, gravity and molecular attraction. Gravity causes water to move in response to hydraulic gradients; that is, it is the force that causes water to discharge into streams and springs, and to enter wells. The molecular forces, adhesion and cohesion, tend to resist flow.

Only part of the water in an aquifer can be withdrawn; much of the water is held in aquifers against the force of gravity by molecular attraction. The ratio of the volume of water an aquifer will yield by gravity drainage to the total volume of the aquifer is the specific yield. A sand and gravel having a porosity of 30 to 40 percent may have a specific yield of 15 to 25 percent.

Under natural conditions the water table roughly parallels the surface topography, rising under the uplands and intersecting the ground surface along perennial streams, lakes, and swamps into which ground water is discharged by gravity flow from adjacent areas where the water table is higher. The water table is not static but fluctuates with daily, seasonal, and yearly variations in precipitation and in discharge of ground water to streams, the atmosphere, and wells and springs. During periods when discharge of ground water is greater than recharge, the water table declines and water is taken from storage within the aquifer by gravity drainage of interstices.

If an aquifer is confined between relatively impermeable beds and water is supplied to it from an elevation higher than the top of the aquifer, the water is under hydraulic pressure. If a well is drilled through the confining bed and into the aquifer, the water in the well will rise above the top of the aquifer, but may or may not flow over the top of the well. Ground water that is confined under pressure in this manner is said to occur under artesian conditions. If leakage through the confining bed into the aquifer is appreciable, ground water is said to occur under leaky artesian conditions. The surface to which water will rise under artesian conditions, as defined by water levels in a number of wells, is the piezometric surface.

The direction of ground-water movement is at right angles to water-table or piezometric-surface contours. Under natural conditions, precipitation reaching the water table percolates towards streams; however, the roots of plants and soil capillaries intercept and discharge into the atmosphere some of the water which otherwise would become ground-water runoff.

The nonpumping level is the level at which water stands in a well not influenced by pumping in the immediate vicinity of the well. The pumping level is the level to which the water surface lowers in wells during pumping. The difference between the nonpumping and pumping levels in a well is called drawdown. When the pump is stopped, water levels rise; this rise is called recovery.

10/12 pt
33 Fl Rom
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on 21 picas

Water Levels

Water levels in wells are almost constantly fluctuating, and decline or rise a fraction of an inch or many feet within a relatively short time. Water levels in wells in artesian aquifers generally fluctuate to a much greater extent than water levels in water-table aquifers, and are sensitive to such factors as changes in atmospheric pressure, earthquakes, earth tides, and changes in surface loading. Artesian wells also are influenced by withdrawals from wells and springs, and by recharge from precipitation although the effects of recharge are sometimes not noticeable immediately.

Water levels in water-table aquifers are affected by direct recharge from precipitation, evapotranspiration, withdrawals from wells, discharge to streams, and changes in surface-water stage. Fluctuations in water levels indicate changes in the actual quantity of water stored in aquifers, and movement of ground water. The amount of water taken from or added to storage per unit change in water levels under water-table conditions is generally many times larger than under artesian conditions.

The water table in the Embarras River Basin under natural conditions recedes in late spring, summer, and early fall, when discharge by evapotranspiration and by ground-water runoff to streams is greater than recharge from precipitation. Water levels begin to recover in wells late in the fall, when evapotranspiration losses are small and conditions are favorable for the infiltration of rainfall, first to replenish depleted soil moisture and later to percolate to the water table. The rise of water levels is especially pronounced in the wet spring months, when the groundwater reservoir receives most of its annual recharge. The high and low points of the annual cycle of water levels occur at different times of the year, depending in large part upon the seasonal and areal distribution and intensity of rainfall.

The water levels in a shallow dug well (COL 11N9E-19.5g) near Janesville in Coles County were continuously measured with a recorder during the period 1960 ~~to~~ through 1963. The well is 15 feet deep, 66 inches in diameter, and is in glacial drift. A hydrograph for the well is shown in figure 13. Water levels have a seasonal fluctuation ranging from 2 to 5 feet. Year-end water levels vary from one year to another year chiefly because of climatic conditions. The water level in well COL 11N9E-19.5g was about 2.5 feet lower in December 1963 than it was in December 1961, largely because precipitation during 1962 and 1963 was below normal. The hydrographs indicate no general or permanent decline in water levels. Water levels are at low stages during dry periods; however, as precipitation increases, water levels return to higher stages.

In heavily pumped areas, changes in water levels caused by pumping are superimposed on natural ~~seasonal and se~~cular fluctuations. ~~due to natural phenomena.~~ When a well is pumped, water levels decline and a cone of depression is formed with the lowest point at the pumped well. An observation well located within the cone of depression will show a lowering of water level; the amount of decline depends largely on the distance from the observation well to the pumped well, the rate of pumping, the hydraulic properties of the aquifer, and the distances from the observation well to recharge areas and boundaries of the aquifer. With continuous pumping, the cone of depression grows in size and depth at a diminishing rate until: 1) the lowering of water levels results in increased recharge to, the aquifer ~~and~~/or decreased natural discharge from the aquifer, or both; and 2) hydraulic gradients are established sufficient to bring from recharge or natural discharge areas the amount~~s~~ of water being pumped.

Water levels are influenced by seasonal fluctuations in pumping rate. During the late spring and summer increased pumpage of ground water for cooling and irrigation results in a local or regional decline in water levels. During the fall, winter, and early spring months decreases in air temperature result in a reduction in pumpage and a recovery in water levels.

In heavily pumped areas a downward trend of water levels may continue for many years because of continual increases in pumpage, or withdrawals in excess of recharge, or both. During periods of below normal precipitation, cones of depression in some areas deepen and expand as recharge decreases; cones of depression often shrink during periods of near or above normal precipitation. In some instances large developments of ground water have caused pronounced and serious declines of water levels.

An example of fluctuations of water levels in wells within a pumping center is shown by the hydrograph for well DGL 14N8E-4.4d in figure 14. Well DGL 14N8E-4.4d at Arcola is 102 feet deep, 10 inches in diameter, and is open to a deeply buried sand and gravel aquifer. A large increase in pumpage (about 45,000 gpd) starting in 1947 caused water levels in the well to decline over 30 feet within a period of only 8 years. This decline was three times as much as had been observed during the preceding 25-year period. As the result of large water-level declines, two new production wells were developed about 1/2 mile and 1 mile from the observation well, and pumpage was shifted to a new pumping center. As a result of the shift in pumping centers, water levels recovered about 40 feet from 1955 to 1960. However, pumpage at Arcola continued to grow at a rapid rate and was about 150,000 gpd in 1960. Water levels declined about 35 feet from 1960 to 1964 as pumpage increased and there was appreciable mutual interference between the old and new well fields.

Water-level data for wells in other pumping centers are given in table 4. Water-level data for selected wells outside pumping centers are given in table 5.

Pumpage

Total pumpage from wells within the Embarras River basin has increased steadily since the first wells were drilled in

1890, as shown in figure 15. During the period from 1890 to 1960 total pumpage increased from 3.5 mgd to 6.34 mgd at an average annual rate of about 40,000 gpd.

Data in table 6 indicate that of the total water pumped from wells in 1960, 83.5 percent was derived from glacial drift aquifers, 10.5 percent from Pennsylvanian rocks, and 6.0 percent from Devonian and Silurian rocks. In 1960 withdrawals for urban water-supply systems amounted to about 39 percent of the total pumpage; industrial pumpage was 12.5 percent of the total; rural pumpage was about 15.5 percent of the total; and livestock pumpage was 33 percent of the total.

Records of pumpage are fairly complete for the period 1944 to 1960; very few records of pumpage are available for years prior to 1942. The graphs in figure 15 were constructed by considering population growth, percent population served and per capita consumption, number of wells and their yields, and reported or estimated pumpage.

Pumpage-use data are classified in this report according to four main categories: 1) *urban*, including pumpage for municipalities, subdivisions, institutions, and from private sources within incorporated areas; 2) *industrial*, including commercial businesses and cemeteries; 3) *rural*, including farms and nonfarms outside incorporated areas; and 4) *livestock*. Most public water-supply systems furnish water for several types of use: domestic (houses, hotels, etc.), public (schools, hospitals, fire protection, etc.), commercial and industrial ~~use~~ (department stores, office buildings, commercial plants, industries, etc.). No attempt has been made to determine the various uses within categories. Any water pumped by a municipality is called an urban supply, regardless of the use of water.

The reliability of pumpage data varies greatly. Municipal pumpage is often metered in cities and larger villages, but most smaller villages ~~do not meter their pumpage~~. Total ground-water withdrawal from farm wells and individual residential wells was estimated on the basis of detailed use surveys made in a few selected parts of the basin considered typical. Pumpage for livestock is based on accepted water consumption rates per head, ~~of animals~~.

10/12 ital.

Wells in bedrock

Total pumpage from wells in bedrock was about 1.06 mgd in 1960. More than 63 percent of ~~the~~ this total pumpage was from Pennsylvanian rocks; the remaining 37 percent was withdrawn from Devonian and Silurian rocks. It is estimated that 24 percent of the rural population and livestock obtained water from bedrock wells. In 1960, ~~the cities~~ of Villa Grove, Tuscola and the Village of Camargo were the only municipalities obtaining water from bedrock wells in Devonian and Silurian rocks. No municipality in the basin withdrew water from the Pennsylvanian rocks in 1960. Urban pumpage was 0.314 mgd in 1960, or about 27 percent of the total pumpage from bedrock wells.

Most bedrock wells owned by industries are in Tuscola and Villa Grove and obtain water from Devonian and Silurian rocks. Pumpage for industrial supplies was 0.030 mgd in 1960, or about 3 percent of the total pumpage from bedrock wells.

Pumpage from bedrock wells, 1890 to 1960, subdivided by use, is shown in figures 16 and 17. There has been very little change in pumpage over the 70-year period.

Wells in glacial drift.

Pumpage from glacial drift wells was about 2.8 mgd in 1890. The first public water supplies were developed in 1885 at Mattoon and in 1890 at Arcola. Total municipal pumpage was 180,000 gpd in 1890. Pumpage for public (urban) use increased steadily at a uniform rate, as shown in figure 18, and in 1960 was 2.21 mgd or about 42 percent of the water pumped from the glacial drift. Pumpage for public supplies has increased at about the same rate as the urban population. Public pumpage in 1960 was about 68 percent more that in 1920 and urban population in 1960 was about 79 percent more that in 1920.

Municipal pumpage amounted to approximately 91 percent of the urban pumpage and was 2.77 mgd in 1960. The remaining 9 percent was distributed between subdivisions, institutions, and domestic supplies. Most of the municipalities in the basin obtained all of their water supply from wells in glacial drift (see figure 19).

It is estimated that total pumpage for industrial purposes was 0.75 mgd in 1960.

Rural pumpage, including rural farm and rural non-farm use, was estimated by considering rural (outside incorporated places) population as reported by the U. S. Bureau of the census and per capita use. Based on a survey of metered supplies the per capita use averaged about 30 gpd in 1960. Well-log data in the files of the State Geological Survey indicate that on the average about 76 percent of the total rural and livestock pumpage is from wells in glacial drift and 24 percent is from wells in bedrock.

The rural and livestock pumpage has not increased significantly since 1890 because rural population has decreased steadily. Total domestic pumpage was 2.32 mgd or 40 percent of the total water withdrawn from the glacial drift. Water for domestic use is from small wells of low capacity that are widely distributed throughout the basin.

Distribution and Density of Pumpage

The pumpage from glacial drift wells was grouped into 13 major pumping centers based upon areas of concentration of wells. The location of these pumping centers and the distribution of pumpage in 1960 are shown in figure 20 and table 7, respectively. In 1960, the largest amounts of water were withdrawn from wells in pumping centers 12 and 13. Pumpage growth curves for each of the pumping centers with wells in glacial drift are shown in figures 21 - 24. The pumpage growth curves show only the public (urban) and industrial withdrawals.

Pumpage from bedrock and glacial drift wells was distributed to the counties within the basin, and the average pumpage per square mile (density of pumpage) for each county was computed. Total pumpage and density of pumpage for each ~~township~~ county ~~is~~ are given in table 8. Pumpage from bedrock wells is mostly concentrated in the Tuscola and Villa Grove areas.

rom

CONSTRUCTION FEATURES OF WELLS

Most wells in the Embarras River Basin were drilled by the cable tool method. Wells in glacial drift aquifers range in depth from 20 to 240 feet and have an average depth of about 55 feet. The wells are mostly the tubular type with commercial screens or slotted pipe. Casing diameters range from 4 to 24 inches and commonly exceed 10 inches. A few concrete wells were built by the Thorpe Well Company, [illegible] and the Kelley Well Company, [illegible]; ~~and Kelley~~ Companies; the inside diameters of these wells are usually 17 inches. Generalized graphic logs of typical wells in glacial drift are given in figure 25.

Only a few high capacity wells are developed in the bedrock. Wells in Douglas County penetrate the Devonian and/or ~~the~~ Silurian rocks. These wells are the sources of public water supplies. Construction features of selected bedrock wells in Douglas County are shown in figure 2~~5~~6. The deepest water well in use ~~known~~ in the basin is Tuscola City Well No. 4 with a depth of 694 feet (see well DGL 16N9E-34.4c in figure 26).

35

The wells in the Pennsylvanian rocks, producing more than 10 gallons per minute (gpm), range in depth from 80 to 390 feet and have an average depth of about 160 feet. These wells are usually cased through glacial deposits to bedrock and do not penetrate the entire thickness of the Pennsylvanian rocks because the upper part is more water yielding and the water quality becomes poorer with increasing depth. The diameters of the casings range between 6 and 12 inches.

Hydraulic properties of Aquifers

The coefficients of permeability or transmissibility and storage are the major hydraulic properties of aquifers influencing water-level decline and the yields of wells. The rate of flow of ground water in response to a given hydraulic gradient is dependent upon the permeability of the aquifer. The field coefficient of permeability, P, is defined as the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot of the aquifer under a hydraulic gradient of 1 foot per foot at the prevailing temperature of the water. A related term, the coefficient of transmissibility, T, indicates the capacity of an aquifer as a whole to transmit water and is equal to the coefficient of permeability multiplied by the saturated thickness of the aquifer, m, in feet. The coefficient of transmissibility is defined as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness under a hydraulic gradient of 1 foot per foot at the prevailing temperature of the water.

The storage properties of an aquifer are expressed by its coefficient of storage, S, which is defined as the volume of water the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Under artesian conditions, when the piezometric surface is lowered by pumping, water is derived from storage by the compaction of the aquifer and its associated beds and by expansion of water itself, while the interstices remain saturated. Under water-table conditions, when the water table is lowered by pumping, ground water is derived from storage mainly by the gravity drainage of the interstices in the portion of the aquifer unwatered by the pumping.

Aquifer tests

The hydraulic properties of aquifers may be determined by means of aquifer tests, wherein the effect of pumping a well at a known constant rate is measured in the pumped well and in observation wells penetrating the aquifer. Graphs of drawdown versus time after pumping started, ~~and/~~or of drawdown versus distance from the pumped well, or both, are used to solve formulas which express the relation between the hydraulic properties of an aquifer and the lowering of water levels in the vicinity of a pumped well.

The data collected during the aquifer tests may be analyzed by use of the Theis (1935) nonequilibrium formula. Type-curve and straight-line methods for solving this formula with logarithmic or semilogarithmis time-drawdown or distance-drawdown graphs were described by Walton (1962). In the same publication a method is described for applying this formula to aquifer test data collected under water-table conditions, and equations are given for compensating observed values of drawdown for decreases in the saturated thickness of an aquifer.

Controlled aquifer tests have been made at Martinsville, Lawrenceville, Arcola, Flat Rock, Jewett, Greenup, Savoy, and Newton to determine the hydraulic properties of the sand and gravel aquifers in the Embarras River Basin. Test 3 at Arcola was described by Walker and Walton (1961). The data for the other tests follow.

Test 1, Martinsville

An aquifer test was made by the State Water Survey on July 27, 1948. Wells (figure 27) located within the corporate limits of Martinsville in T10N, R13W were used. Generalized graphic logs of the wells are given in figure 27. The effects of pumping well CLK 10N13W-7.3c1. Pumping was started at 11:05 a.m. and was continued for almost 4 hours at a constant rate of 58 gpm until 2:47 p.m. Well 7.3c1 is 80 feet southeast of well 7.3c2.

CLK 10N13W-7.3c2 were measured in the pumped well and in observation well

Drawdowns in the observation well were determined by comparing the extrapolated graphs of water levels measured before pumping started with the graphs of water levels measured during pumping. Drawdowns were plotted against time on semilogarithmic paper. The time-drawdown graph for the observation well is shown in figure 2~~9~~8. A straight line was fitted to data and the slope of the straight line was used to determine the coefficient of transmissibility as shown in figure 2~~9~~8. The zero-drawdown intercept of the straight line was used to determine the coefficient of storage.

fig 28

Test 2, Lawrenceville

An aquifer test was made by the State Water Survey, during ~~the period~~ May 17 - ~~to May~~ 18, 1950. Wells (figure ~~30~~ 29) located within the property limits of the Texas Company in T3N, R11W (about 4 miles east-southeast of Lawrenceville) were used. The generalized graphic log of the pumped well is given in figure ~~31~~ 29. The effects of pumping well LAW 3N11W-11.6d were measured in the pumped well and in observation wells. Thirteen observation wells were available during the pumping period. Observation wells were designated "A" through "L" and "6-inch". With the exceptions of "K", "L", "C", and "6-inch", all observation wells were 2-inch diameter well points, 20 feet deep. Observation wells "C" and "K" were 2 inches in diameter and 40 feet deep; observation well "L" was ~~1 1/2~~ 1.5 inches in diameter and 8 feet deep; observation well "6-inch" was 6 inches in diameter and 104 feet deep with a screen installed at the bottom. Pumping was started at 8:38 a.m. on

fig 29

(31)

May 17 and was continued for ~~a period of~~ 24 hours at a constant rate of 1000 gpm until 8:40 a.m. on May 18, or about 24 hours.

Drawdowns in the observation wells and the pumped well were determined and adjusted for the effects of dewatering. Adjusted drawdowns were plotted against time on logarithmic or semi-logarithmic paper. The time-drawdown graph for the "6-inch" observation well is shown in figure 30 and the distance-drawdown graph for a pumping period of 1 day is shown in figure 31. (fig 30) (fig 31)

The W(u) versus $\frac{1}{u}$ or W(u) versus u type curves (see Walton, 1962) were fitted to field data, taking into consideration the effects of gravity drainage and coefficients of transmissibility and storage were computed as shown in figures 30 and 31. The average computed coefficients of transmissibility and storage are 250,000 gpd/ft and 0.04 respectively.

~~Test 3, Arcola~~

(12 pts #)

~~The aquifer test at Arcola was described by Walker and Walton (1961).~~

Test 4, Flat Rock

An aquifer test was made by the State Water Survey on December 5, 1961, in which wells (figure 32) located about 2.5 miles south of ~~the Village~~ of Flat Rock in T5N, R11W were used. ~~The~~ Generalized graphic logs of the wells are given in figure 32. The effects of pumping well CRF 5N11W-18.5a were measured in the pumped well and (fig 32) in observation well CRF 5N11W-18.4a, ~~Well 18.4a~~ which is 465 feet east of well 18.5a. Pumping was started at 8:30 a.m. on December 5 and was continued for ~~a period of~~ 5 hours at a constant rate of 126 gpm until 1:30 p.m.

Drawdowns in the pumped and observation wells were measured with an airline. Drawdowns in the pumped well were plotted against time on semilogarithmic paper, and drawdowns in the observation well were plotted against time on logarithmic paper. The time-drawdown graph for the observation well is given in figure 3~~4~~3.

fig 33

The graph indicates that the vertical leakage through the clayey deposits overlying the aquifer was negligible during the test. The W(u) versus $\frac{1}{u}$ $1/u$ type curve was fitted to field data, and the coefficients of transmissibility and storage were computed as shown in figure 3~~4~~3.

Test 5, Jewett

An aquifer test was made by the State Water Survey on May 1, 1963, using the ~~W~~wells (figure 3~~7~~4) located within the corporate limits of ~~the Village of~~ Jewett in T9N, R8E ~~were used~~. The generalized graphic logs of the wells are given in figure 3~~5~~4. The effects of pumping well CUM 9N8E-24.2d1 were measured in the pumped well and in observation well CUM 9N8E-24.2d2, ~~Well 2d2~~ which is 153 feet southeast of well 2d1. Pumping was started at 12:00 noon on May 1 and was continued until 4:00 p.m. ~~The~~ at a constant pumping rate ~~was~~ of 31 gpm.

fig 34

41

Drawdowns in the pumped and observation wells were measured by electric dropline and by steel tape, respectively. Drawdowns in the pumped well were plotted against time on semilogarithmic paper, and drawdowns in the observation well were plotted against time on logarithmic paper. The time-drawdown graph for the observation well is given in figure 3~~9~~5. The W(u) versus $\frac{1}{u}$ 1/u type curve was fitted to field data, and the coefficients of transmissibility and storage were computed as shown in figure 3~~9~~5. Leakage through the clayey deposits overlying the aquifer was not measurable during the test.

fig 35

Test 6, Greenup

An aquifer test was made by the State Water Survey on September 20, 1963, in which the Wells (figure ~~40~~ 36) located outside the corporate limits of ~~the Village~~ of Greenup in T9N, R9E were used. ~~The~~ generalized graphic logs of the wells are given in figure ~~41~~ 36. The effects of pumping well CUM 9N9E-2.8g1 were measured in the pumped well and in observation well CUM 9N9E-2.8g2, which is ~~Well 2.8g2 is~~ 42 feet west of well 2.8g1. Pumping was started at 11:15 a.m. on September 20 and was continued for ~~a period of~~ 3.5 hours at a constant rate of 175 gpm until 2:40 p.m.

fig 36

Drawdowns in the pumped well were determined by electric dropline, and the water levels in the observation well were measured by steel tape. Drawdowns adjusted for the effects of dewatering, in the pumped well were plotted against time on semilogarithmic paper, and recovery adjusted for the effects of dewatering in the observation well were plotted against time on logarithmic paper. The time-recovery graph for the observation well is given in figure ~~42~~ 37. (fig 37)

The W(u) versus $\frac{1}{u}$ type curve was fitted to early data (data prior to the time ~~when~~ the effects of gravity drainage became appreciable), and coefficients of transmissibility and storage were determined as shown in figure ~~42~~ 37. Later time-recovery data deviate from the type-curve trace because of the effects of gravity drainage under water-table conditions.

(12 pt 11)

Test 7, Savoy

An aquifer test was made by the State Water Survey on November 6, 1963. Wells (figure ~~43~~ 38) located about 0.7 mile southwest of the Village of Savoy in T18N, R8E were used. The generalized graphic logs of the wells are given in figure ~~44~~ 38. The effects of pumping well CHM 18N8E-2.4e were measured in the pumped well and in observation well CHM 18N8E-2.5d, which ~~Well 2.5d~~ is 700 feet southwest of well 2.4e. Pumping was started at 2:26 p.m. on November 6 and was continued for ~~a period of~~ almost 2 hours at a constant rate of 23$\frac{1}{4}$ gpm. (fig 38)

Drawdowns in the pumped and observation wells were computed. The time-drawdown graph for the observation well is given in figure ~~45~~ 39. (fig 39)

The W(u) versus $\frac{1}{u}$, type curve was fitted to field data, and coefficients of transmissibility and storage were determined as shown in figure ~~45~~ 39. Leakage through the clayey deposits overlying the aquifer was not measurable during the test.

Test 8, Newton

An aquifer test was made by the State Water Survey on November 12, 1963. Wells (figure ~~46~~ 40) located outside of the city limits of Newton in T7N, R9E were used. The generalized graphic logs of the wells are given in figure ~~47~~ 40. The effects of pumping well JAS 7N9E-36.3f1 were measured in the pumped well and in observation wells JAS 7N9E-36.3f2, JAS 7N9E-36.3f3, and JAS 7N9E-36.3f4. Pumping was started at 11:30 a.m. on November 12 and was continued for ~~a period of~~ 3 hours at a constant rate of 64 gpm until 2:30 p.m. Fig 40

Drawdowns in the pumped well were determined by electric dropline, and drawdowns in the observation wells were measured by steel tape. Drawdowns in the observation wells for a pumping period of 150 minutes were plotted against distances on logarithmic paper. The distance-drawdown graph for the observation wells is given in figure ~~48~~ 41. The W(u) versus u type curve (see Walton, 1962) was matched to field data, and coefficients of transmissibility and storage were computed as shown in figure ~~48~~ 41. Fig 41

The results of the ~~8~~ eight aquifer tests made in the Embarras River basin are given in table 9. Coefficients of transmissibility range from 6,120 to 250,000 gpd/ft; coefficients of permeability range from 410 to 2,500 gpd/sq ft. Coefficients of storage range from 0.00003 to 0.04. TW-69

Ital

(49)

Specific-capacity data

The yield of a well may be expressed in terms of its specific capacity. The specific capacity of a well is defined as the yield of the well in gallons per minute per feet of drawdown (gpm/ft) for a stated pumping period and rate. Walton (1962) gave an equation ~~from~~ which can be used ~~it is possible~~ to compute ~~ahd~~ theoretical specific capacity of a well discharging at a constant rate in a homogeneous, isotropic, artesian aquifer infinite in areal extent.

The theoretical specific capacity of the well depends in part upon the radius of the well and the pumping period. A 30-inch diameter well has a specific capacity about 13 percent more than that of a 12-inch diameter well. It is evident that large increases in the radius of a well are accompanied by comparatively small increases in specific capacity. The theoretical specific capacity decreases with the length of the pumping period because the drawdown continually increases with time ~~am~~ as the cone of depression of the wall expands.

There is generally a head loss or drawdown (well loss) in a production well due to the turbulent flow of water as it enters the well itself and flows upward through the bore hole. Well loss and the well-loss coefficient may be computed by equations given by Jacob (1946).

Production wells ovten do not completely penetrate aquifers or are open only to part of an aquifer. The drawdown in a production well partially penetrating an aquifer is greater than the drawdown in a fully penetrating production well. An equation given by Butler (1957) may be used to estimate the drawdown in a partially penetrating production well.

During the period 1918 to 1963, well-production tests were made on more than 90 wells in the Embarras River basin. The well-production tests consisted of pumping a well at a constant rate and frequently measuring the drawdown in the pumped wells. Drawdowns were commonly measured with an airline or electric dropline; rates of pumping were largely measured by means of a circular orifice at the end of the pump discharge pipe.

(tables 10 and 11)

The results of the tests are summarized in tables 1~~1~~0 and 1~~2~~1. The aquifers contributing to the yields of the wells are listed, and well-construction data are given.

The lengths of tests made on bedrock wells range from less than ~~one~~ 1 hour to 18 hours and average about ~~4-1/2~~ 4.5 hours. Pumping rates range from 5 to 600 gpm; pumping rates for most wells in Pennsylvanian rocks are less than 20 gpm. Diameters of casings range from 5 to 12 inches and average 8 inches.

The lengths of tests made on sand and gravel wells range from less than 1 hour to 24 hours and average about 7 hours. Pumping rates range from 8 to 2000 gpm and average about 185 gpm. Diameters of casings range from 4 to 24 inches and average about 10 inches.

Bedrock wells

Many wells are open to only rocks of Pennsylvanian age; some wells are open to rocks both of Devonian and Silurian age (at Tuscola); and a few wells are open to only rocks of Devonian age (at Villa Grove). The total depth of wells and thickness of bedrock open to wells were determined by studies of well logs. The depth of wells in Pennsylvanian rocks ranges from 77 to 390 feet and averages 158 feet; thickness of Pennsylvanian rocks open to wells ranges from 6.5 to 174 feet and averages 65 feet. The depth of wells in Devonian and Silurian rocks ranges from 694 to 300 feet and averages 518 feet; thickness of Devonian and Silurian rocks open to wells ranges from 172 to 418 feet and averages 350 feet. Two wells in Devonian rocks have an average depth of 636 feet and are open to an average of 30 feet of Devonian rocks.

Wells were segregated into three categories, Pennsylvanian, Devonian-Silurian, ~~Pen, Dev-Sil~~ and Devonian, ~~Dev~~ depending upon the rocks open to wells. Specific capacities of wells in the Pennsylvanian and Silurian-Devonian ~~Pen and Dev-Sil~~ categories were tabulated in order of magnitude and frequencies were computed by the Kimball (1946) method. Values of specific capacity were then plotted against percent of wells on logarithmic probability paper as shown in figure ~~49~~ 42. fig 42

The specific capacities of wells in rocks of Devonian- ~~and~~ Silurian age are much greater than the specific capacities of wells in rocks of Pennsylvanian age. Based on the specific capacities measured in 50 percent of wells, the productivity of Devonian- ~~and~~ Silurian rocks is about 6 times the productivity of Pennsylvanian rocks. Specific capacities of wells in Devonian- ~~and~~ Silurian rocks range from 0.60 to 6.26 gpm/ft and have a median of 2.40 gpm/ft. Specific capacities of wells in Pennsylvanian rocks range from 0.12 to 11 gpm/ft and have a median of 0.37 gpm/ft. The average specific capacity of the two wells in Devonian rocks (35 gpm/ft) is much higher than the median specific capacities of wells in Pennsylvanian and Devonian-~~and~~ Silurian rocks. The productivities of both Pennsylvanian and Devonian-~~and~~ Silurian rocks are highly inconsistent as indicated by the steep slopes of the specific-capacity frequency graphs.

Step-drawdown test data are available for wells DGL 16N8E-34.1b and DGL 16N9E-10.1h2. Well DGL 16N8E-34.1b is open to both Devonian and Silurian rocks; well DGL 16N9E-10.1h2 is open to only Devonian rocks. Analysis of available data indicates that the well-loss coefficients for wells DGL 16N8E-34.1b and DGL 16N9E-10.1h2 are 350 and 8 $\mathrm{sec}^2/\mathrm{ft}^5$, respectively. Taking into account well loss, the high value of C was computed for a well having a low specific capacity, and the low value of C was computed for a well having a high specific capacity. Well DGL 16N8E-34.1b encountered dolomite with some limestone and thin siltstone beds of Devonian age; well DGL 16N9E-10.1h2 encountered more permeable sandstone of Devonian age. Apparently turbulence, and therefore the well-loss coefficient, increases as the coefficient of transmissibility of the aquifer decreases. The coefficient of transmissibility becomes smaller with a decrease in the size or ~~and/or~~ number of interconnected openings in the aquifer.

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no space

Sand and gravel wells.

The depths of sand and gravel wells range from 20 to 240 feet and average about 89 feet. Thickness of aquifers at well sites range from 4 to 54 feet and average about 27 feet.

Wells were segregated into three categories; 1) wells in the major buried bedrock valley or its tributaries; 2) wells in alluvium along Embarras River or its tributaries; and 3) wells outside major buried bedrock valleys. Specific capacities of wells (see table 1~~2~~1) in the four categories were tabulated in order of magnitude and frequencies were computed. Values of specific capacity were then plotted against percent of wells on logarithmic probability paper as shown in figure ~~50~~ 43. fig 43

The specific capacities of wells in the major buried bedrock valley systems and in alluvium are much greater than the specific capacities of wells outside major buried bedrock valleys. Wells in the major buried bedrock valley system, alluvium, and outside major buried bedrock valleys have median specific capacities of 42, 10, and 1.6 gpm/ft, respectively. The specific capacities of wells outside major buried bedrock valleys are greater than the specific capacities of wells in Pennsylvanian rocks but less than the specific capacities of wells in Devonian ~~and~~ Silurian rocks. ~~Specific capacities of wells outside major buried bedrock valleys are much more inconsistent than the specific capacities of wells in the other three categories.~~ Specific capacities of wells in the major buried bedrock valley system range from 11 to 256 gpm/ft; specific capacities of wells in alluvium range from 5.6 to 17 gpm/ft; and specific capacities of wells outside major buried bedrock valleys range from 0.13 to 8.5 gpm/ft.

The coefficients of permeability of sand and gravel aquifers in the vicinity of production wells were estimated ~~based on~~ from well-log, water-level, and specific-capacity data. Well-log and water-level data indicate that artesian conditions existed during most well-production tests. Data on specific capacities, pumping periods, well radii, and an artesian coefficient of storage (0.0004) were used to compute ~~substituted into equation 5 and~~ values of the coefficient of transmissibility of aquifers in the vicinity of production wells ~~were computed~~. Thicknesses of aquifers at well sites were determined from well logs. Coefficients of transmissibility were then divided by thicknesses of aquifer to obtain the values of the coefficient of permeability listed in table 12.

The specific capacity of a well cannot be an exact criterion of the coefficient of transmissibility because specific capacity is often affected by partial penetration, well loss, and geohydrologic boundaries. In most cases these factors adversely affect specific capacity, and the actual coefficient of transmissibility is greater than the coefficient of transmissibility computed with specific-capacity data. Data for wells whose specific capacities are thought to be greatly affected by partial penetration and well loss were not used to estimate coefficients of permeability.

Coefficients of permeability were segregated according to the three well categories mentioned earlier, tabulated in order of magnitude, and frequencies were computed. Values of the coefficient of permeability were then plotted against percent of wells on logarithmic probability paper as shown in figure ~~51~~ 44.

fig 44

The coefficients of permeability of sand and gravel aquifers in the major buried bedrock valley systems and in alluvium are much greater than the coefficients of permeability of aquifers outside major buried bedrock valleys. Aquifers in the major buried bedrock valley systems, alluvium and outside major buried bedrock valleys have median coefficients of permeability of 1800, 820 and 320 gpd/sq ft, respectively. Coefficients of permeability of aquifers in the major buried bedrock valley systems range from 630 to 4700 gpd/sq ft; coefficients of permeability of aquifers in alluvium range from 380 to 1900 gpd/sq ft; and coefficients of permeability of aquifers outside major buried bedrock valleys range from 110 to 620 gpd/sq ft.

Step-drawdown test data are available for several sand and gravel wells. Well-loss coefficients for sand and gravel wells computed with equations 7 and 8 are given in table 1$\overset{2}{3}$. Values of C greater than 10 sec^2/ft^5 indicate that clogging of screens and openings of the formation surrounding the well is severe and/or the open area of the screen is inadequate for the pumping rate, and turbulent head losses are great (Walton, 1962). Well-loss coefficients for properly designed and developed wells usually are less than 5 sec^2/ft^5.

table 14

Set superscripts

Drilling processes often partially clog the voids of the well face and well wall and/or the openings of the well screen. Maximum yield per foot of drawdown cannot be obtained unless development is sufficient to remove these fine materials. The effectiveness of development can be appraised from the results of a step-drawdown test. Wells of diminished capacity can often be returned to near original capacity by one of several rehabilitation methods. The success of rehabilitation work can be appraised from the results of step-drawdown tests made prior to and after treatment.

Well Fields. The specific capacity of a well field is defined here as the total pumpage from wells within a given well field per foo~~d~~ of average drawdown within the given well field. Specific capacities of well fields vary greatly from plac~~t~~ to place depending primarily upon the number of production wells in the well field, the average spacing of wells, and the water-yielding properties and geohydrologic boundaries of the aquifer penetrated by wells.

Specific capacities of 4950 and 3340 gpd/ft are recorded for well fields in Devonian and Silurian rocks (see table 13). In contrast, specific capacity of 850 gpd/ft was measured for a well field in Pennsylvanian rocks.

Specific capacities for well fields ranging from 1590 to 3270 gpd/ft are recorded in sand and gravel aquifers outside major buried bedrock valleys. Well fields in sand and gravel aquifers in major buried bedrock valleys or in alluvium along the Embarras River or its tributaries have specific capacities ranging from 6,600 to 300,520 gpd/ft.

Well field specific capacities for well fields in sand and gravel aquifers are much greater than the well field specific capacity for a well field in Pennsylvanian rocks. However, well field specific capacities for well fields in sand and gravel aquifers outside major buried bedrock valleys are a little less than well field specific capacities for well fields in Devonian and Silurian rocks.

Recharge

The major sources of recharge to aquifers in the Embarras River basin are direct precipitation on intake areas and downward percolation of stream runoff (induced infiltration). Recharge from precipitation on intake areas is irregularly distributed in time and place; recharge is greatest in spring months of heavy rainfall and least in the summer, fall, and winter months. Most recharge occurs during spring months when evapotranspiration is small and soil moisture is maintained at or above field capacity by frequent rains. During summer and early fall months evapotranspiration and soil-moisture requirements have first priority on precipitation and are so great that little precipitation percolates to the water table except during periods of excessive rainfall. Recharge during winter months when the ground is frozen is negligible. Only a small fraction of the annual precipitation percolates downward to the water table. A large proportion of precipitation runs overland to streams or is discharged by the process of evapotranspiration before it reaches aquifers. The amount of precipitation that reaches the zone of saturation depends upon several factors. Among these are the character and thickness of the soil and other deposits above and below the water table; the topography; vegetal cover; land use; soil-moisture content; the depth to the water table; the intensity, duration, and seasonal distribution of rainfall; the occurrence of precipitation as rain or snow; and the air temperature.

Recharge to aquifers by induced infiltration of surface water occurs when the water table is below the water surface of a stream and the streambed is permeable. The rate of induced infiltration depends upon several factors including the surface water temperature, the permeability of the streambed and the aquifer, the thickness of the streambed, the position of the water table, and the depth of water in the stream. Few streambeds remain stable over a long period because of alternate sedimentation and scouring by the stream. During periods of low stream flow, fine sediment may settle from the slowly moving water and greatly reduce the permeability of the streambed. At high stages the fine sediments are scoured from the streambed and the permeability is increased.

Recharge direct from precipitation and by induced infiltration of surface water involve the vertical movement of water under the influence of vertical head differentials. Thus, recharge is

58) (61)

vertical leakage of water through deposits. The quantity of vertical leakage varies from place to place and is controlled by the vertical permeability and thickness of the deposits through which leakage occurs, the head differential between sources of water and the aquifer, and the area through which leakage occurs.

The rate of recharge or infiltration may be expressed mathematically by the following form of Darcy's law:

All letter symbols ital

times sign

Greek delta

$$(Q_c/A_c) = 2.8 \times 10^7 \; (P'/m') \; \Delta h \qquad (1)$$

$$\frac{Q_c}{A_c} = 2.8 \times 10^7 \, \frac{P'}{m'} \; \Delta h \qquad \text{~~(10)~~}$$

where:

(Q_c/A_c) = recharge rate, in gpd/sq mi

line up = signs and run letter symbols flush right preceding the = signs

Q_c = leakage (recharge) through deposits, in gpd

A_c = area of diversion, in sq mi

P' = coefficient of vertical permeability of deposits, in gpd/sq ft

m' = saturated thickness of deposits, in ft

Greek delta

Δh = difference between the head in the aquifer and in the source bed above deposits through which leakage occurs, in ft

As shown in equation 10, the recharge rate varies with the vertical head loss associated with leakage of water through deposits. The recharge rate per unit area being dependent upon vertical head loss is not constant but varies in space and time. The recharge

(59)

rate is generally greatest in the deepest parts of cones of depression and decreases with distance from a pumping center. The recharge rate increases as the piezometric surface declines and vertical head loss increases. The recharge rate per unit area is at a maximum when the piezometric surface of the aquifer is at the base of the deposits through which leakage occurs, provided the head in the source bed above the deposits remains fairly constant.

The sand and gravel aquifers in the Embarras River basin are commonly interbedded and/or overlain by deposits of till that contain a high percentage of silt and clay and have a low permeability. In many areas, recharge to these aquifers is derived from vertical leakage through the till. Sand and gravel aquifers at places extend to the land surface, and recharge is derived from vertical leakage through fairly coarse-grained deposits. Bedrock aquifers are commonly overlain by deposits of till, and recharge is derived from vertical leakage through the till.

Recharge rates under heavy pumping conditions for several aquifers in Illinois were computed by Walton (196~~4~~5) and are given in table 15. Recharge rates for dolomite aquifers of Silurian age overlain largely with till range from 52,000 to 225,000 gpd/sq mi. Low rates are computed for areas where shaly dolomite beds overlie permeable zones within the dolomite aquifers. In areas where permeable zones within the dolomite aquifers are overlain by permeable dolomite beds and thick glacial drift consisting largely of till, the recharge rate averages about 150,000 gpd/sq mi.

Table 16

Recharge rates for glacial sand and gravel aquifers range from 115,000 to 500,000 gpd/sq mi. The lowest rate is for an area where the sand and gravel aquifer is overlain by thick glacial drift consisting largely of till. In areas where sand and gravel deposits occur from the surface to bedrock, recharge rates for sand and gravel aquifers commonly exceed 300,000 gpd/sq mi.

In light of the data in table 15 and geohydrologic conditions in the Embarras River basin, it is not unreasonable to believe that under heavy pumping conditions recharge rates for aquifers overlain by till may average 150,000 gpd/sq mi, and in areas where sand and gravel deposits occur from the surface to bedrock, recharge to aquifers may average 350,000 gpd/sq mi.

Infiltration rates for several streambeds computed by Walton (1963) are given in table 16. In light of the data in table 1~~6~~5 and a study of stream flow records and geologic conditions, it is not unreasonable to believe that under heavy pumping conditions induced infiltration may range from 1/4 mgd per mile of the Embarras River in the upper reaches of the stream to 1 mgd per mile of the Embarras River in the lower reaches of the stream.

Runoff

Streamflow consists of surface runoff and ground-water runoff. Surface runoff is here defined as precipitation that finds its way into the stream channel without infiltrating into the soil. Ground-water runoff is precipitation that infiltrates into the soil or to the water table and then percolates into the stream channel. Ground-water runoff includes bank storage.

Streamflow data in the Water-Supply Papers published by the U. S. Geological Survey were used to determine annual ground-water runoff from 5 subdrainage basins within the Embarras River Basin. Streamflow data for years of near normal (1948), below normal (1953 or 1956), and above normal (1942 or 1951) ~~normal~~ precipitation were investigated. Daily mean streamflow at 5 gaging stations (see table 17) were plotted on semilogarithmic hydrograph paper. Hydrographs were divided into two components, surface runoff and ground-water runoff, with streamflow hydrograph separation methods outlined by Linsley, Kohler, and Paulhus (1958) taking into consideration information given by Schicht and Walton (1961), or with methods outlined by Walton (196~~4~~5). Annual ground-water runoff during years of near, below, and above normal precipitation for the 5 drainage basins is given in table 17.

Flow-duration curves (figures ~~52~~ 45 and ~~53~~ 46) were used in making comparisons of the ground-water runoff characteristics of the 5 subdrainage basins. The shape of the flow-duration curve is governed in large part by the water-yielding properties and areal extent of the unconsolidated and consolidated deposits within a basin. The more nearly horizontal the curve, the greater are the values of the water-yielding properties and/or the areal extent of deposits. Thus, the shape of the flow-duration curve is in part an index of the effects of geology of a basin on streamflow.

figs 45 and 46

Grain-size frequency distribution curves (see Dapples, 1959) are somewhat analogous to flow-duration curves in that their shapes are indicative of the water-yielding properties of deposits. A measure of the degree to which all the grains approach one size, and therefore the slope of the grain-size frequency distribution curve, is the sorting. One parameter of sorting is obtained by the ratio (Pettijohn, 1949) $(D_{25}/D_{75})^{\frac{1}{2}}$, where D_{25} ~~=~~ is the size ~~which~~ that has 25 percent larger and 75 percent smaller grains in the distribution and D_{75} ~~=~~ is the size ~~which~~ that has 75 percent larger and 25 percent smaller grains in the distribution.

Because geology and therefore grain-size frequency distribution affects streamflow to a great degree, the parameter selected to describe the slope of the flow-duration curve is the ratio $(Q_{25}/Q_{75})^{\frac{1}{2}}$, where Q_{25} ~~=~~ is the streamflow equalled or exceeded 25 percent of the time and Q_{75} ~~=~~ is the streamflow equalled or exceeded 75 percent of the time. Ratios for the 5 subdrainage basins are given in table 17.

The characteristics of the ~~5~~ four subdrainage basins were determined with such maps as are shown in figures 8, 10, and 12. The relations between ground-water runoff during years of near, below, and above normal precipitation, the ratios $(Q_{25}/Q_{75})^{\frac{1}{2}}$, and the basin characteristics were studied.

Ground-water runoffs from subdrainage basins of the Embarras River above Oakland, Diona, Ste. Marie, and Lawrenceville are typical of ground-water runoffs from basins with the following characteristics (see Walton, 1965): Glaciated, relatively impermeable bedrock, thick drift commonly exceeding 50 feet, good to fair possibility for occurrence of sand and gravel within drift, considerable surface sand and gravel of limited areal extent, ground moraine and morainic ridges, slight to moderate stream gradient, and little forest and woodland. Ground-water runoff during a year of normal precipitation ranges from 0.28 cfs/sq mi above Oakland to 0.40 cfs/sq mi above Lawrenceville. Ground-water runoff increases greatly between Ste. Marie and Lawrenceville where the Embarras River meanders over permeable outwash sand and gravel in a major buried bedrock valley. The ratios for subdrainage basins above Oakland and Diona are much greater than the ratios for subdrainage basins above Ste. Marie and Lawrenceville. The gaging stations near Oakland and Diona are above the limit of Wisconsinan glaciation and the Shelbyville Moraine, whereas the gaging stations at Ste. Marie and Lawrenceville are below the Shelbyville Moraine. Ground-water runoff, ratios, and geologic data suggest that the permeability and/or areal extent and thickness of the surface sand and gravel and outwash deposits are much less above the Shelbyville Moraine than below ~~the Shelbyville Moraine~~ it. Ground-water runoff during a year of below normal precipitation is much less above the Shelbyville Moraine than below ~~the Shelbyville Moraine~~ it.

Ground-water runoff from the North Fork of Embarras River is typical of ground-water runoff from basins with the following characteristics: glaciated, relatively impermeable bedrock, thick drift commonly exceeding 50 feet, bedrock valleys, fair or poor possibility for occurrence of sand and gravel within drift, little surface sand and gravel of limited areal extent, ground moraine or morainic ridges, slight to moderate stream gradient, and little forest and woodland. The ratio is low, suggesting that ground-water runoff from deposits in the buried valley in Jasper County is appreciable. Ground-water runoff from the North Fork is much less than ground-water runoff from the main stream of the Embarras River. As indicated by ~~Based on~~ ground-water runoff data, the surface sand and gravel deposits along the North Fork are greatly limited in areal extent and/or thickness and permeability. Outwash sand and gravel in the major buried valley within the Embarras River basin has a fairly large areal extent and/or thickness and permeability. The areal extent and/or thickness and permeability of the surface sand and gravel along the North Fork are much less than those of the surface sand and gravel along the main stem of the Embarras River above Ste. Marie.

Potential yield of aquifers

Studies were made to determine the order of magnitude of the potential yield of principal aquifers in the Embarras River basin. The potential yield is here defined as the amount of ground water that can be continuously withdrawn from a reasonable number of wells and well fields without creating critical water levels or exceeding recharge. The principal aquifers are 1) the sand and gravel deposits in mapped buried bedrock valleys and along streams, and 2) the Devonian-Silurian rocks in Douglas County. The Pennsylvanian rocks yield a few gallons per minute to wells and are the source of supply for many domestic wells. However, development of the Pennsylvanian rocks for commercial, industrial, irrigation, or medium-to-large municipal use is not possible, and the potential yield of the aquifer is insignificant ~~when~~ compared will ~~to~~ the potential yield of the principal aquifers. Data for the sand and gravel aquifers in unmapped buried bedrock valleys or interbedded in the glacial drift outside buried bedrock valleys ~~is~~ are missing or meager. Inclusion of the calculations for these aquifers would add only relatively small amounts to the total potential yield.

Aside from economic considerations, the potential yield is dependent on the rate of recharge, dimensions of aquifers, and hydraulic properties of aquifers. In 1964, water levels in pumping centers within the Embarras River basin were nowhere at critical levels; ~~and~~ further there were large areas, where well development is possible, not influenced by present pumpage, indicating that the potential yield is much greater than present withdrawals.

Geohydrologic Hydrogeologic data presented earlier in this report suggest: 1) the potential yield of sand and gravel aquifers in the major buried bedrock valley in Cumberland, Jasper, Crawford, and Lawrence Counties is probably high enough to support heavy industrial or municipal well development in many areas; 2) the most favorable areas for development of large water supplies are in southwestern Crawford County and northeastern Lawrence County where the Embarras

River meanders over thick sand and gravel deposits in the major buried valley; 3) the potential yield of sand and gravel aquifers in the major buried bedrock valley in Coles County and the tributary buried bedrock valley in Clark and Crawford Counties is probably high enough to support light industrial or medium municipal well development in many areas; 4) the potential yield of Devonian and Silurian rocks in Douglas County is probably high enough to support light industrial or medium municipal well development in many areas; and 5) the potential yield of the thin alluvial deposits along the Embarras River in Douglas, Coles, Cumberland, and Jasper Counties and along the North Fork of the Embarras River in Clark and Crawford Counties is probably high enough to support small to medium municipal well development in many areas. Small domestic water supplies can probably be obtained from wells in Pennsylvanian rocks in most areas of the Embarras River basin.

The dimensions of the principal aquifers (length, width, and saturated thickness) were determined from ~~using~~ well-log data, water-level data, and existing geologic maps. Hydraulic properties of the principal aquifers were estimated from ~~based on~~ aquifer-test and specific-capacity data and geologic maps. Recharge directly from precipitation and by the induced infiltration of water in the Embarras River were estimated by studying the character and thickness of deposits overlying aquifers, streamflow records, and profiles of the stream channel (average depth of water in the stream and the average width of streambed). Actual ground-water conditions were simulated with model aquifers (see Walton, 1962) having straightline boundaries and effective widths, lengths, and thicknesses. Model aquifers are sometimes overlain by confining beds having effective thicknesses. Mathematical models (Walton, 1962) were constructed on the basis of hydraulic properties of model aquifers, the image-well theory, ground-water formulas, and a consideration of recharge. The mathematical models were used to describe the effects of selected schemes of development involving reasonable well and well field spacings, and to determine the potential yield of the aquifer under assumed practical pumping conditions. On a gross basis, in most cases aquifers with proper development are capable of yielding more water to wells than will be recharged under heavy pumping conditions. The factors considered and assumptions made in computations are as follows:

1) Recharge to deeply buried sand and gravel aquifers overlain by till will occur at an average rate of 150,000 gpd/sq mi under heavy pumping conditions.
2) Recharge to thick sand and gravel aquifers overlain by coarse-grained and permeable deposits will occur at an average rate of 350,000 gpd/sq mi under heavy pumping conditions.
3) Recharge to permeable zones within bedrock aquifers overlain by till will occur at an average rate of 60,000 gpd/sq mi under heavy pumping conditions.
4) Recharge to thin sand and gravel aquifers overlain by coarse-grained and permeable deposits will occur at an average rate of 200,000 gpd/sq mi during a year of below normal precipitation under heavy pumping conditions.

5) under heavy pumping conditions the induced infiltration rate of the Embarras riverbed will average 100,000 gpd/acre/ft during a year of below normal precipitation.

6) flow in the Embarras River (averaging about 15 cfs during fall and winter months of a year of below normal precipitation) is great enough to replenish large withdrawals from sand and gravel deposits along the river. Recharge by induced infiltration of water in the North Fork of the Embarras River will be negligible during years of below normal precipitation because flow in the North Fork is less than 0.1 cfs during many months of extended dry periods.

7) in areas where the saturated thickness of sand and gravel aquifers exceeds 50 feet, or sand and gravel aquifers are deeply buried, there is sufficient amount of water in storage within aquifers to balance large withdrawals of water in ~~access~~ excess of recharge during extended dry periods. In areas where the saturated thickness of shallow sand and gravel aquifers is less than 50 feet, there is a limited amount of water in storage within aquifers to balance large withdrawals in ~~access~~ excess of recharge during extended dry periods.

8) it is probable that available ground-water resources of Devonian and Silurian rocks can be developed with a reasonable number of wells and well fields in about 50 percent of areas where these aquifers occur.

9) It is probable that available ground-water resources of sand and gravel aquifers can be developed with a reasonable number of wells and well fields in about 33 percent of areas where possibilities of occurrence of sand and gravel in buried bedrock valleys are fair to good.

10) It is probable that available ground-water resources of sand and gravel aquifers can be developed with a reasonable number of wells and well fields in about 50 percent of areas where possibilities of occurrence of sand and gravel in buried bedrock valleys are good to excellent.

11) It is probable that available ground-water resources of sand and gravel aquifers can be developed with a reasonable number of wells and well fields in about 25 percent of areas where alluvium occurs along streams.

Taking into consideration the above factors and assumptions, and available geohydrologic data, the potential yields of the principal aquifers in the Embarras River Basin are as follows: sand and gravel in buried bedrock valleys, 45 mgd; alluvium, 14 mgd; and Devonian and Silurian rocks, 3 mgd. [illegible]

Three

The total potential yield of principal aquifers is 62 mgd. Of the total potential yield, about 14 mgd is derived by the induced infiltration of surface water. About 58 percent of the potential yield of sand and gravel aquifers, as well as ~~is concentrated in Lawrence~~ County; about 42 percent of the total potential yield of ~~the~~ all three principal aquifers, is concentrated in Lawrence County.

The potential yield was computed for extended dry periods. The potential yields do not have a high degree of accuracy but merely indicate the order of magnitude of available ground-water resources and should be used for planning purposes only. Development in any area must be preceded by extensive test drilling and aquifer test programs. An estimate of the potential yield with a high degree of accuracy will have to await more detailed data and improved methods of analysis. Refinement and periodic revaluation of estimates and the collection of additional data will be necessary, and should be anticipated. Potential yields are presented with the warning that the figures can be changed by a factor of 50 percent by small changes in any one of several assumptions.

Stream flow will probably not be diminished to any great extent by full development of aquifers because most water pumped from wells and diverted from streamflow will be discharged back into the streams as effluent from sewage treatment plants. However the quality of the water in the streams will be adversely affected.

Predicting future water-level declines

The results of aquifer tests were used to prepare theoretical distance-drawdown graphs for prediction of future water-level declines. Values of the coefficient of transmissibility and storage covering the range of aquifer properties likely to be encountered in the Embarras River Basin were substituted into the Theis (1935) nonequilibrium equation, and drawdowns at various distances from a pumped well discharging at a continuous rate of 100 gpm were computed. A pumping period of 6 months was selected because usually water must be taken from storage for an accumulated period of 6 months when little recharge occurs during summer, fall, and early winter months. Theoretical distance-drawdown curves are shown in figure 47.

Drawdown is directly proportional to the rate of pumping. If the rate of pumping were 200 instead of 100 gpm, declines in figure 47 would be twice as much. Distance-drawdown graphs for other aquifer and pumping conditions can be prepared with the nonequilibrium equation.

An aquifer infinite in areal extent was assumed in computations. The effects of geohydrologic boundaries can be simulated with image wells (Walton, 1962). Methods were cited earlier for computing drawdowns in pumped wells, and for taking into consideration partial penetration of pumped wells and dewatering under water-table and leaky artesian conditions. Production wells should be spaced parallel to and as far away from the edges of the aquifers as possible. Wells should be spaced on a line parallel to recharge boundaries and as close to the source of recharge as possible. It is generally advisable to separate production by a distance at least equal to twice the saturated thickness of the aquifer to minimize the effects of partial penetration. Experience has shown that in the case of a multiple well system consisting of more than two wells the proper spacing between wells is at least 250 feet. Well design criteria were given by Walton (1962).

Quality

The chemical character of the ground water in the Embarras Riber Basin is known from the anslyses of water from 31 wells. The results of the analyses are given in tables 17 and 18. The constituents listed in the tables are given in ionic form in parts per million (ppm).

Information collected on the temperature of ground water is also presented in the tables. The temperature of water was measured at the time samples of water were collected.

Ground water in the Embarras River Basin varies in quality between the different aquifers and also within individual aquifers at different geographical locations.

Glacial Drift

The chemical analyses of water from glacial drift wells in table 17 show iron contents ranging from 0.1 to 16 ppm with an average of 3.0 ppm. Water from 21 of the 25 wells contains more than 0.6 ppm of iron. The chloride content ranges from 4.0 to 370 ppm and averages 36 ppm. Of the 25 samples, 14 show chloride contents of 10 ppm or above.

The hardness ranges from 203 to 414 ppm and averages 290 ppm. The sulfate content ranges from 0 to 81.5 ppm with ~~an median~~ average of 24 ppm.

Waters from the glacial drift have temperatures ranging from 52.5 to 57.5°F.

Bedrock

The hardness of waters from Devonian and Silurian rocks ranges from 230 to 246 ppm and averages 238 ppm (see table ~~19~~ 18). The hardness of waters from Pennsylvanian rocks ranges from 26 to 264 ppm and averages 128 ppm. The pH of waters from wells in bedrock ranges from 7.4 to 8.2. 3 of the 6 samples in table 18 contained more than 0.6 ppm iron. The iron content ranges from 0.1 to 0.5 ppm and averages 0.3 ppm in waters from Devonian and Silurian rocks, and from 0.3 to 2.5 ppm with an and average~~s~~ of 1.5 ppm in waters from Pennsylvanian rocks.

The sulfate content~~s~~ of waters from Pennsylvanian rocks ranges from 0.4 to 5.0 ppm and averages 3.1 ppm. The sulfate content of waters from Devonian and Silurian rocks ranges from 5.6 to 11.5 ppm and averages 8.5 ppm.

The temperature of waters from bedrock ranges from 57 to ~~57°F~~ 63.5 F and averages about ~~63.5~~ 60.2°F.

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Table 1. Population of Incorporated Municipalities

Municipality	Population, 1960	Municipality	Population, 1960
Allerton* (V)	282	Metcalf*(V)	278
Arcola* (C)	2,273	Montrose*(V)	320
Ashmore (V)	447	Newman (C)	1,097
Birds (V)	235	Oakland (C)	939
Bridgeport (C)	2,260	Oblong (V)	1,817
Broadlands (V)	344	Philo (V)	740
Brocton (V)	380	Pesotum (V)	468
Camargo (V)	276	Redmon (V)	175
Casey (C)	2,890	Robinson* (C)	7,226
Champaign (C)	49,583	Rose Hill (V)	117
Charleston (C)	10,505	Savoy (V)	339
Flat Rock (V)	497	St. Marie (V)	347
Greenup (V)	1,477	Stoy (V)	185
Hidalgo (V)	126	Sumner (C)	1,035
Hindsboro (V)	376	Toledo (V)	998
Hume (V)	449	Tolono (V)	1,539
Jewett (V)	238	Tuscola (C)	3,875
Kansas (V)	815	Urbana* (C)	27,294
Lawrenceville (C)	5,492	Villa Grove (C)	2,308
Lerna (V)	296	Westfield (V)	636
Long View (V)	270	Willow Hill (V)	335
Martinsville (C)	1,351	Yale (V)	123
Mattoon*(C)	19,088		

*Only a part of the municipality located in the Embarras River Basin

Table 2. Monthly and Annual Precipitation, in Inches

Station Location (Length of record)	Month												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Urbana (1889-1960)	2.20	1.93	3.20	3.74	4.05	3.93	3.32	3.29	3.16	2.82	2.43	2.12	36.18
Tuscola (1894-1960)	2.32	2.05	3.40	3.73	4.09	4.22	3.22	3.45	3.50	2.85	2.70	2.30	37.82
Charleston (1878-1960)	2.47	2.38	3.41	3.55	4.25	4.35	3.54	3.32	3.28	2.90	3.05	2.37	38.86
Newton (1931-1960)	2.66	2.37	3.24	3.66	4.27	3.83	3.34	2.92	3.00	2.69	3.22	2.70	38.42
Lawrenceville (1943-1960)	3.94	3.42	3.98	4.48	4.86	4.29	4.37	3.40	3.36	2.89	3.83	2.94	42.69

End of Table 2

Table 3. Monthly and Annual Climatic Data

(based on 1889 to 1962 period)

Month	Mean Temperature (°F)	Average Precipitation (in)	Highest Precipitation (in)	(yr)	~~Least~~ Lowest Precipitation (in)	(yr)	Average Snowfall (in)
January	26.9	2.16	6.21	1949	0.17	1900	4.8
February	29.3	1.97	5.80	1909	0.24	1907	5.1
March	39.4	3.12	8.35	1922	0.38	1910	4.3
April	51.1	3.57	7.68	1893	0.50	1899	0.7
May	61.7	4.09	11.20	1943	0.22	1925	0.0
June	71.2	4.06	11.58	1902	0.47	1936	0.0
July	75.3	3.38	9.57	1962	0.47	1930	0.0
August	73.4	3.17	9.80	1902	0.06	1893	0.0
September	66.7	3.06	9.76	1926	0.25	1954	0.0
October	55.1	2.65	9.01	1941	0.21	1895 1908	0.1
November	40.9	2.55	6.77	1927	~~Trace~~	1904	1.6
December	30.2	2.07	6.13	1924	0.05	1890	4.5
Annual	51.8	35.85	55.64	1927	23.87	1894	21.1

End of table 3

Table 4. Water-Level Data for Selected Wells within Pumping Centers

Well number	Owner	Depth of well (ft)	Aquifer*	Depth to+ water (ft)	Date measured
CHM--					
16N10E-					
4.8h(1)	Long View(V)	50	dr	4.3	5/55
4.4h(1)	Long View(V)	50	dr	1.2	1952
17N8E-					
22.1d(1)	Pesotum(V)	190	dr	71.5	1956
17N10E-					
34.7c	Long View(V)	250	br	22.4	9/53
34.8c	Long View(V)	700	br	22.4	9/53
17N11E-					
30.2g(1)	Broadlands(V)	120	dr	16.5	9/54
30.2g(1-55)	Broadlands(V)	71	dr	6.5	3/55
18N8E-					
25.6d(11)	Tolono(V)	180	dr	85.5	1961
25.8d(9)	Tolono(V)	179	dr	80.0	1956
25.8f(5)	Tolono(V)	185	dr	76.0	7/38

Table 4 page 2 continued

25.8f(5)	Tolono(V)	185	dr	76.0	6/42
26.1c(3)	Tolono(V)	158	dr	70.0	1928
26.1c(3)	Tolono(V)	158	dr	80.0	6/42
26.1c(4)	Tolono(V)	186	dr	72.0	7/34
26.1c(3)	Tolono(V)	158	dr	40.0	1914
26.1c4(4)	Tolono(V)	186	dr	72.0	7/34
26.1c7(7)	Tolono(V)	164	dr	78.4	1952
26.1c8(8)	Tolono(V)	160	dr	80.5	1950
26.1f(6)	Tolono(V)	145	dr	75.5	6/42
26.8f(5)	Tolono(V)	185	dr	77.5	1950
18N9E-					
22.1f(3)	Philo(V)	30	dr	15.0	1954
22.1h(4)	Philo(V)	26	dr	13.5	10/62
22.4e(2)	Philo(V)	44	dr	7.0	5/45
22.7d(4)	Philo(V)	29	dr	11.8	1961
23.7g(1)	Philo(V)	81	dr	32.0	3/39
CLK---					
10N13W-					
7.3cd(4)	Martinsville(C)	51	dr	18.2	7/48

ble 4 page 3 continued

7.3c5(5)	Martinsville(C)	58	dr	14.0	1948
7.3c6(6)	Martinsville(C)	56	dr	15.3	1950
19.8e1(1)	Casey(C)	89	dr	1.5	1916
19.8e2(2)	Casey(C)	131	dr	9.0	1916
19.8e2(2)	Casey(C)	89	dr	11.0	10/16
19.8e6(6)	Casey(C)	80	dr	6.5	1940
12N14W-					
20.7d(5)	Westfield(V)	50	br	0.0	11/57
29.8c(1)	Westfield(V)	155	br	45.0	1919
29.8c(1)	Westfield(V)	155	br	60.0	1921
29.8c(1)	Westfield(V)	155	br	60.0	1939
30.1c(3)	Westfield(V)	150	br	72.0	5/40
COL--					
11N8E-					
10.4g(1-58)	Lerna(V)	32	dr	5.5	1958
10.4g(2-58)	Lerna(V)	34	dr	5.2	1958
12N11E-					
6.7h(1)	Ashmore(V)	42	dr	21.9	5/55

Ta le 4 page 4 continued

CRF--					
5N11W-					
18.4a(1)	Flat Rock(V)	52	dr	11.0	1956
18.4a(1)	Flat Rock(V)	52	dr	11.0	9/56
18.5a(2)	Flat Rock(V)	63	dr	13.5	1961
10N9E-					
29.7b4(T3-52)	Toledo(V)	57	dr	6.5	1952
CUM--					
9N8E-					
24.2d1(1)	Jewett(V)	134	dr	58.6	11/63
24.2d1(1)	Jewett(V)	134	dr	58.5	10/63
24.2d2(T2)	Jewett(V)	136	dr	60.9	5/63
9N9E-					
2.8f1(1)	Greenup(V)	46	dr	12.0	7/39
2.8f2(2)	Greenup(V)	43	dr	13.5	11/40
2.8f3(3)	Greenup(V)	43	dr	15.0	11/46
2.8f4(4)	Greenup(V)	40	dr	10.0	3/51
2.8f4(4)	Greenup(V)	40	dr	16.1	1950
2.8g(5)	Greenup(V)	41	dr	16.1	9/63

T e 4 page 5 continued

10N9E-					
29.7b1(1)	Toledo(V)	20	dr	4.5	8/25
29.7b1(1)	Toledo(V)	20	dr	4.3	1928
29.7b2(2)	Toledo(V)	18	dr	8.0	1941
29.7b2(2)	Toledo(V)	18	dr	4.0	3/48
29.7b3(3)	Toledo(V)	29	dr	5.7	7/52
DGL--					
14N10E-					
6b2(2)	Hindsboro(V)	88	dr	3.6	1955
6.6b1(1)	Hindsboro(V)	83	dr	10.0	10/54
6.6b3(3)	Hindsboro(V)	28	dr	8.4	1961
16N8E-					
34.1b(5)	Tuscola(C)	553	br	112.0	11/48
34.1b(5)	Tuscola(C)	553	br	126.0	4/49
34.4c(4)	Tuscola(C)	694	br	119.0	10/47
34.1d1(1)	Tuscola(C)	287	br	179.0	7/46
34.1d2(2)	Tuscola(C)	300	br	82.0	3/18
34.1d2(2)	Tuscola(C)	300	br	91.0	8/45
34.2d(3)	Tuscola(C)	523	br	193.0	6/46

Table 4 page 6 continued

34.7f	Tuscola(C)	3017	br	28.0	1898
34.7f	Tuscola(C)	3017	br	90.0	1914
16N9E-					
10.1h1(1)	Villa Grove(C)	629	br	91.0	1915
10.1h1(1)	Villa Grove(C)	645	br	91.0	5/40
10.1h2(2)	Villa Grove(C)	627	br	90.0	1924
10.1h2(2)	Villa Grove(C)	627	br	114.0	3/54
34.1e(1-61)	Camargo(V)	80	dr	4.2	1961
34.2f(1)	Camargo(V)	165	br	20.0	4/56
16N14W-					
31.4d(1)	Newman(C)	127	dr	16.0	7/33
31.7d(2)	Newman(C)	143	dr	0.5	1/35
31.4h(4)	Newman(C)	58	dr	8.4	6/53
32.5a(3)	Newman(C)	30	dr	4.5	11/49
EDG--					
13N14W-					
26.6e1(1)	Kansas(V)	80	dr	14.0	1918
26.6e2(2)	Kansas(V)	76	dr	13.0	1945

Table 4 page 7 continued

15N14W-					
25.4f(1)	Brocton(V)	38	dr	4.8	5/62
16N13W-					
31.3c(1)	Hume(V)	55	dr	10.0	10/54
34.1d(1)	Metcalf(V)	75	dr	13.5	2/55
JAS--					
6N14W-					
19.8a(1)	St. Marie(V)	54	dr	11.0	9/53
LAN--					
4N11W-					
26.7a(2)	George Field	68	dr	15.7	1942
26.7h(1)	George Field	74	dr	15.7	1942
LAW--					
3N11W-					
2.8d1(1)	Lawrenceville(C)	60	dr	6.0	1924
2.8d2(2)	Lawrenceville(C)	60	dr	11.0	1927

Table 4 page 8 continued

2.8d4(4)	Lawrenceville(C)	64	dr	8.5	12/47
2.8d5(5)	Lawrenceville(C)	72	dr	7.5	12/47
2.8d6(6)	Lawrenceville(C)	73	dr	8.1	12/47
4X11 WL					
26.7a(2)	[illegible]	60	dr	15.7	1942
26.7b(1)	[illegible]	74	dr	15.9	1942

* dr, glacial drift; br, bedrock

\+ below measuring point

End of table 4

Table 5. Water-level data for selected wells remote from pumping centers.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water 1/ (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer 2/
CHM-- 19N9E-								
20.4h	Mann	36	2	735	30	705	12/33	Dr
29.5b	J. S. McCullough	116	2	716	50	666	12/33	Dr
29.4d	L. G. Hubbard	40	2	740	20	720	12/33	Dr
30.8g	O'Neill	151	-	720	68	662	3/55	Dr
31.6a	C. C. Lyons	20	2	718	18	700	8/41	Dr
31.2h	C. Grein	42	2	701	39	662	12/33	Dr
32.5e	A. Sheridan	116	2	707	65	642	12/33	Dr
33.5f	J. Rawley	35	36	730	25	705	-	Dr
19N8E-								
24.5c	W. A. Wilson	40	36	755	25	730	3/34	Dr
24.1b	F. Percival	120	2	725	80	645	3/34	Dr
24.5a	WDWS Radio	154	-	728	70	658	1/47	Dr
24.5g	M. M. LeBough	186	4	760	70	690	10/48	Dr
24.6h	G. P. Deyoe	48	4	760	17	743	8/49	Dr
24.1c	G. P. Deyoe	198	6	730	115	615	11/48	Dr
24.4d	Breezeway Motel	154	6	735	82	653	5/53	Dr
25.4g	J. Cruise	120	2	730	70	650	3/34	Dr
35.8a	L. G. Johnston	195	2	751	90	661	3/34	Dr
35.1h	F. G. Campbell Est.	165	2	743	90	653	3/34	Dr
36.6a	E. E. Johnson	164	2	738	80	658	3/34	Dr
36.6f	Dunlap Est.	82	2	740	40	700	3/34	Dr
36.8e	A. F. Hamersmith	160	3	741	75	666	8/42	Dr
36.6e	E. E. Johnson	165	3	738	90	648	7/45	Dr
36.6f	Old Orchard Farm	98	6	720	80	640	2/56	Dr
36.7b	Paradise Inn Motel	160	6	735	84	651	2/56	Dr
36.4e	Parkhill's Lake	144	6	727	75	652	8/60	Dr.

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
EDG, cont.								
15N14W-								
23.3d	B. Payne	207	4	685	35	650	2/34	Dr
25.1h	R. C. Helton	18	54	680	13	667	3/34	Dr
16N13W-								
29.5h	R. E. Holler	95	7	648	20	628	1963	Dr
31.1e	F. Sheets	35	24	652	10	642	3/34	Dr
16N14W-								
25.5e	R. L. Godfrey	14	48	650	8	642	3/34	Dr
11.1d	D. Underwood	110	2	720	50	670	3/34	Dr
COL--								
11N8E-								
6.5a	C. Miller	110	6	750	85	665	1956	Dr
11N9E-								
23.	W. Hutton	183	6	650	43	607	1956	Br
11N10E-								
20.1a	W. Hutton	105	6	620	50	570	1948	Dr
12N7E-								
25.8h	W. G. Welsh	78	2	710	27	683	1/34	Dr
12N8E-								
14.7c	Coles Co. Airport	48	10	705	16	689	8/51	Dr
31.6c	C. Bellew	122	2	780	50	730	1/34	Dr
12N9E-								
14.7e	R. M. Jeffries	210	6	705	100	605	9/44	Br
12N10E-								
14.1h	W. W. Black	63	14	700	8	692	7/45	Dr
13N8E-								
25.1h	J. W. Rosebough	50	16	678	10	668	3/34	Dr
13N9E-								
12.5a	F. Craig	44	6	675	8	667	1948	Dr
13N10E-								
7.6a	M. Winklback	44	6	672	6	666	1948	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
COL, cont.								
13N11E- 31	G. Miller	45	6	692	5	687	1946	Dr
13N14W- 19.1a	D. Hallock	105	8	710	25	685	3/50	Br
14N8E- 24.7h	F. E. Johnson	90	2	678	20	658	3/34	Dr
14N10E- 11.6f	R. Allen	92	6	645	31	614	1955	Br
29	C. Cooper	50	4	650	18	632	1960	Dr
14W14N- 29.1e	L. Honnold	59	7	660	18	642	6/59	Dr
DGL--								
14N8E- 12.7h	M. A. Evans	65	42	653	15	638	2/34	Dr
14N9E- 1.1b	R. Hall	151	6	650	14	636	5/41	Dr
9.2a	Heil	80	6	655	35	620	1/34	Dr
16.8g	Martin	30	42	660	16	644	1/34	Dr
14N10E- 6.7b	W. Thompson	287	3	645	35	610	2/34	Br
9.5e	Emberton	48	3	700	6	694	3/34	Dr
9.7h	R. Allen	93	6	675	27	648	-	Dr
14N14W- 4.6d	O. Fennill	30	42	655	14	641	3/34	Dr
15N8E- 25.8f	A. King	60	48	660	8	652	2/34	Dr
15N9E- 7.8g	N. Murphy	110	6	652	10	642	3/34	Dr
8.8g	J. C. Von Voorhis	19	36	643	9	634	3/34	Dr
20.8d	S. J. Jolley	75	2	640	12	628	2/34	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth of Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
DGL, cont.								
15N10E-								
16.5f	J. Wood	28	36	635	14	621	2/34	Dr
36.1c	J. Davis	58	7	662	12	650	7/59	Dr
15N11E-								
7.8f	W. Roasebee	29	36	640	14	626	3/34	Dr
19.7a	G. W. Furnish	75	36	668	20	648	3/34	Dr
15N14W-								
17.1d	C. M. Murphy	46	36	670	18	652	3/34	Dr
16N8E-								
3.1f	R. Weatherford	210	4	700	90	610	8/62	Br
3.6h	O. E. Gates	108	2	693	55	638	9/40	Dr
21.1b	R. L. Hackett	20	40	660	5	655	3/34	Dr
33.8h	J. Wamsley	70	40	670	10	660	3/34	Dr
16N9E-								
1.2d	Fithian	804	6	650	64	586	3/34	Br
12.3h	M. Henson	30	40	658	10	648	1/34	Dr
13.4h	A. N. Talbert	65	40	660	15	645	2/34	Dr
16N10E-								
11.8a1	Fonner Est.	365	6	694	90	604	1/34	Br
11.8a2	Fonner Est.	65	18	694	30	664	1/34	Dr
16N11E-								
30.8a	J. M. McCown	18	36	696	12	684	1/34	Dr
16N14W-								
29.7a	M. Roller	18	–	640	5	635	1/34	Dr
CHM-								
17N10E-								
30.	J. F. Seltzer	46	18	690	12	678	5/63	Dr
17N9E-								
9.1h	A. T. Gerber	53	4	677	13	664	–	Dr
26.1b	M. E. Dunlap	206	6	655	8	647	2/49	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
18N8E-								
1.7g	John Jones Motel	177	4	740	73	667	6/49	Dr
1.7h1	D. Allison	177	2	740	82	658	1955	Dr
1.7h2	B. B. Clark	173	4	740	80	660	1/54	Dr
2.2h	W. E. Munson	156	2	740	49	691	7/34	Dr
11.8b	J. Fisher	165	3	743	60	683	3/34	Dr
23.6a	Solon Estates	148	2	730	60	670	3/34	Dr
24.1h	Frampton Est.	160	2	710	40	670	3/34	Dr
18N9E-								
4.3a	E. Grove	86	2	752	60	692	1942	Dr
5.1h	First National Bank	115	2	708	50	658	3/34	Dr
6.8h	D. C. Dobbins	100	3	710	50	660	3/34	Dr
7.8h	G. Smalley	83	2	718	40	678	3/34	Dr
17.2g	R. Edwards	130	3	700	30	670	6/47	Dr
18.5a	A. Bowman	140	2	720	60	660	3/32	Dr
19.2h	J. Schlorff	100	3	693	30	663	3/34	Dr
21.5a	G. Maharry	120	4	692	30	660	4/44	Br
30.8c	H. Grove	140	2	710	30	680	3/34	Dr
31.8b	F. Bates	120	-	705	49	656	-	Dr
33.1e	J. S. Thinnes	60	2	680	12	668	10/57	Dr
19.8a	Cutler	150	4	715	80	635	5/59	Dr
22.5h	B. Kater	79	-	710	27	683	10/58	Dr
17N8E-								
2.8e	T. M. Salisbury	130	2	720	25	695	12/33	Dr
4.1g	A. Warfel	118	2	718	25	693	7/40	Dr
12.1h	C. Norton	110	2	700	40	640	7/40	Dr
34.8h	C. Schweighart	102	2	700	25	675	12/33	Dr
33.5a	F. Schultz	205	6	680	70	610	2/62	Br

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
CHH. cont.								
17N9E-								
7.	E. Hickman	115	-	695	37	658	7/56	Dr
9.1h	A. T. Gerber	53	4	677	13	664	-	Dr
26.1b	M. T. Dunlap	206	6	655	8	647	2/49	Dr
27.5a	O. M. Henry	68	3	645	8	637	8/40	Dr
28.7h	S. C. Tucker	56	3	652	14	638	-	Dr
31.8d	N. Dietrich	118	4	692	50	662	7/63	Dr
17N10E-								
30.	J. F. Seltzer	46	18	690	12	678	5/63	Dr
DGL--								
16N8E-								
1.7h	N. Bade	87	2	710	50	660	3/34	Dr
3.1f	R. Weatherford	210	4	700	90	610	8/62	Br
3.6h	O. E. Gates	108	2	693	55	638	9/40	Dr
4.8a	E. Bartholow	90	2	685	45	640	3/40	Dr
5.5a	E. E. Morgan	110	2	697	20	677	3/34	Dr
8.3a	J. C. Bundy	140	6	694	90	604	3/34	Dr
8.8h	Curfman School	110	2	693	20	673	3/34	Dr
9.1g	J. C. Bundy	140	6	675	70	605	3/34	Dr
10.8h	M. R. McNeil	67	3	675	27	648	7/41	Dr
10.8d	J. L. Budy	145	6	670	70	600	3/34	Dr
11.1f	Phinney School	100	2	690	30	660	3/34	Dr
12.6a	W. Folker	110	2	682	30	652	3/34	Dr
13.8h	Wm. Williamson	110	2	680	30	650	3/34	Dr
14.2h	R. W. Gates	100	2	685	20	665	3/34	Dr
14.4c	G. Fulton	220	4	657	10	647	12/63	Br
16N9E-								
15.8e	W. Plowman	85	40	675	18	657	1/34	Dr
17.5a	W. Iles	98	40	687	40	647	1/34	Dr
18.3a	M. Lechar	85	2	695	20	675	3/34	Dr
19.4b	H. Bell	153	2	682	30	652	3/34	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
DGL, cont.								
19.4a	H. Bell	80	40	673	20	653	3/34	Dr
20.5h	J. E. Woolver	83	2	685	12	673	1/34	Dr
21.2h	S. Bragg	250	2	670	125	545	1/34	Br
22.5b	G. V. Schackman	40	40	660	18	642	2/34	Dr
24.1h	F. Cook	40	40	680	18	662	1/34	Dr
25.8b	M. M. Overturn	68	40	670	14	656	3/34	Dr
26.1g	H. E. Scott	30	40	690	10	680	3/34	Dr
27.5c	A. W. Bragg	200	2	670	20	650	2/34	Dr
28.8e	V. Simpson	40	2	680	10	670	1/34	Dr
28.3a	G. Bragg	407	3	668	50	618	2/34	Br
29.8h	C. Jones	101	40	682	25	657	1/34	Dr
30.5h	H. Bell	20	40	680	6	674	3/34	Dr
34.2d	B. & O. R. R.	87	2	650	14	636	1/34	Br
35.4e	Loan Co.	60	40	673	14	659	2/34	Dr
36.8e	John Hancock Ins.	65	40	670	50	620	1/34	Br
16N10E-								
1.3h	Rutherford	56	2	685	3	682	12/33	Dr
2.4a	N. Chapman	30	40	680	18	662	1/34	Dr
3.8a	H. Honner	36	40	670	18	652	2/34	Dr
4.3a	R. J. Warnes	40	18	667	10	657	1/34	Dr
5.5a	---	25	40	660	14	646	2/34	Dr
6.5a	C. Fonner	32	40	658	18	640	2/34	Dr
7.2a	J. Taylor	25	40	668	15	653	1/34	Dr
8.3h	R. Duncan	41	40	665	18	647	2/34	Dr
10.3a	E. Chandler	10	54	690	3	683	1/34	Dr
11.8a1	Fonner Est.	365	6	694	90	604	1/34	Br
11.8a2	Fonner Est.	65	18	694	30	664	1/34	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
16N8E-								
15.8e	H. Gates	40	40	666	8	658	3/34	Dr
15.1f	Bry	90	2	675	26	649	3/34	Dr
16.1a	H. E. Wiesener	153	6	668	70	598	3/34	Dr
17.8a1	J. Kruse	70	36	695	20	675	3/34	Dr
17.8a2	J. Kruse	101	4	695	27	668	3/34	Dr
20.8a	A. L. Moris	70	40	682	20	662	3/34	Dr
21.1b	R. L. Hackett	20	40	660	5	655	3/34	Dr
22.1d	J. Barger	145	6	654	70	584	3/34	Dr
23.8b	A. N. Hackett	145	4	665	70	595	3/34	Dr
24.5h	W. W. Reeves	305	8	675	135	540	3/34	Br & Dr
26.8g	W. Sampoon	130	2	664	30	634	3/34	Dr
26.7a	R. Moris	70	4	658	25	633	3/34	Dr
27.8a	E. D. Hall	22	40	651	10	641	3/34	Dr
29.1c	A. L. Moris	70	40	670	20	650	3/34	Dr
32.5a	J. Hilgeburg	87	40	680	23	657	3/34	Dr
32.2a	L. Clapper	35	40	670	6	663	3/34	Dr
33.8h	J. Wamsley	70	40	670	10	660	3/34	Dr
35.3a	H. Crossman	83	6	645	40	605	3/34	Dr
36.7a	F. Weatherford	160	4	650	65	585	3/34	Dr
16N9E-								
1.5h	M. Richman	190	2	650	3	647	12/33	Br
1.2d	Fithian	804	6	650	64	586	3/34	Br
2.3a	C. Barrick	210	3	652	5	647	1/34	Dr
5.8a	Craft School	80	3	678	15	663	1/34	Dr
5.8h	G. W. Gilles	450	[illegible]	678	30	648	1/34	Br
6.8d	J. Dietrich	96	2	700	50	650	3/34	Dr
7.8d	C. Rutherford	110	2	700	30	670	3/34	Dr
7.1e	G. Meister	556	6	680	120	540	3/34	Br
8.8g	J. Kerns	102	3	665	17	648	3/34	Dr
9.5h	C. A. Richman	70	40	660	14	646	3/34	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
DGL, cont.								
10.8a	F. Richman	50	40	660	10	650	3/34	Dr
11.8f	J. Taylor	28	40	650	18	632	1/34	Dr
12.3h	M. Henson	30	40	658	10	648	1/34	Dr
13.4h	A. N. Talbert	65	40	660	15	645	2/34	Dr
14.8a	T. Schull	50	40	640	10	630	3/34	Dr
15.1b	W. Iles	85	40	645	28	617	1/34	Dr
LAW--								
4N11W-								
19.7b	State of Illinois	90	6	440	28	412	11/55	Dr
33.8a	I. Piper	35	2	430	24	406	3/34	Dr
4N12W-								
21.8h	F. Shibler	39	2	435	17	418	2/34	Dr
24.f1	J. E. Whittaker	490	8	441	60	381	2/34	Br
32.7h	F. C. Parker	195	5	527	50	477	3/34	Br
32.2d	J. T. Griggs	22	36	470	15	455	3/34	Dr
4N13W-								
34.8a	C. Grogan	17	48	470	14	456	3/34	Dr
35.1h	J. Culbertson	27	36	550	18	532	3/34	Br
29.	The Silurian Oil Co.	245	6	485	150	335	-	Br
29.	The Silurian Oil Co.	100	6	490	60	430	-	
5N10W-								
31.	X. Y.	226	6	440	35	405	-	Br
33.7g	D. W. Franchot	67	12	420	11	409	10/54	Dr
3N11W-								
2.8d	Ill. Cities Water Co.	65	24	414	8	406	4/48	Dr
11.6d	The Texas Co.	105	6	412	6	406	1955	Dr
4.	V. Buchanan	31	6	465	9	454	3/34	Br
5.1c	V. Buchanan	118	6	455	60	395	2/34	Br
33.5b	Ohio Oil Co.	72	20	410	15	395	11/61	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
3N12W-								
1.6f	J. N. Stansfield	225	2	480	110	370	2/34	Br
10.6h	J. I. Seed	25	72	480	11	469	2/34	Dr
11.3a	R. M. Kirkwood	131	4	430	10	420	2/34	Dr
17.8b	H. Morehead	24	8	540	14	526	3/34	Dr
4.2h	M. McCleve	12	32	455	11	444	2/34	Dr
3N13W-								
16.4g	C. E. Leffler	54	8	450	15	435	3/34	Br
12.5h	E. Sanders	29	48	550	12	538	3/34	Br
10.5e	I. Harbaugh	15	48	470	6	464	3/34	Dr
RCH--								
3N14W-								
12.	A. Wetzel	40	48	530	10	520	8/47	Br
4N11E-								
6.8f	F. Sterchi	20	72	540	11	529	3/34	Dr
6.8a	H. Smoker	30	60	507	23	484	3/34	Br
JAS--								
5N14E-								
16.4d	J. Graham	110	6	460	20	440	1952	Br
6N10E-								
2.7h	H. T. Kelly	40	30	520	28	492	3/34	Dr
6N11E-								
19.	S. H. Mission House	325	6	416	33	383	9/36	Br
7.1b	L. Wood	30	48	480	10	470	3/34	Dr
6N14W-								
15.8e	C. Ikemire	295	5	490	25	465	3/54	Br
3.5h	A. Perkins	22	36	480	10	470	3/34	Dr
17.1f	P. Hoecher	24	36	460	21	439	3/34	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
7N9E-								
26.7b	C. B. Simmons	70	5	530	10	520	1953	Dr
7N10E-								
16.1g	L. Eaton	395	6	510	32	478	5/58	Br
26.1g	J. Crail	33	30	530	10	520	2/34	Dr
7N11E-								
18.8h	A. Grabenheimes	45	6	520	18	502	9/52	Br
30.7a	J. H. Nagle	25	48	500	15	485	2/34	Dr
7N14W-								
27.5h	C. Faught	200	3	480	100	380	2/34	Br
33.1c	H. LeFerer	23	40	480	17	463	3/34	Dr
8N9E-								
26.4d	R. Warfel	83	6	570	11	559	1953	Dr
8N11E-								
31.1a	J. Kidwell	18	48	538	10	528	2/34	Dr
19.2e	R. I. Baker	128	6	550	25	525	5/48	Dr
8N14W-								
4.4h	F. Ridder	18	36	555	10	545	2/34	Dr
15.2e	Pure Oil Co.	120	10	508	27	481	4/49	Dr
CRF--								
5N11W-								
5.8h	R. Rice	72	6	490	14	476	1/58	Br
7.5e	S. Chappele	18	36	500	12	488	1/34	Dr
19.5h	C. Neal	23	30	445	10	435	1/34	Dr
5N12W-								
2.6h	J. W. Rich	28	42	500	20	480	1/34	Dr
4.2a	Clark School	35	42	540	30	510	2/34	Dr
6.6a	F. M. Frost	24	36	500	12	488	3/34	Dr
13.5a	M. F. Walters	30	42	460	25	435	1/34	Dr
15.4a	E. Conover	68	6	500	38	462	2/34	Br

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
CRF, cont.								
21.3b	W. Flynn	60	6	500	40	460	6/53	Br
5N13W-								
4.2b	Ohio Oil Co.	180	-	470	36	434	7/49	Br
5N11W-								
30.1b	L. Hout	34	48	500	19	481	1/34	Dr
6N12W-								
13.2c	J. M. Smith	75	6	500	10	490	8/56	Dr
16.4d	M. Mitchel	90	6	500	20	480	-	Br
32.6a	C. E. Siler	30	36	525	20	505	3/34	Dr
6N13W-								
17.1e	Ohio Oil Co.	120	7	460	34	426	1950	Br
27.8a	Ohio Oil Co.	395	8	475	147	328	8/48	Br
6N14W-								
35.8e	C. York	80	6	470	12	450	8/53	Br
7N12W-								
30.5a	R. Bains	120	6	500	20	480	2/54	Br
7N13W-								
18.1h	Ohio Oil Co.	122	17	505	42	463	2/50	Dr
21.5g	C. Coulter	43	6	505	5	500	7/52	Dr
7N14W-								
1.8a	L. M. Baker	126	2	500	25	475	2/34	Dr
2.8a	G. Tracy	20	72	510	9	501	2/34	Dr
7N13W-								
4.4h	T. Stephenes	16	36	530	14	516	2/34	Dr
8N13W-								
11.1b	L. T. Poynor	75	6	575	7	568	5/51	Br
8N14W-								
13.6f	H. C. Freeland	24	48	550	13	437	2/34	Dr
14.7d	The Pure Oil Co.	127	16	513	28	485	4/49	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
CUM--[1]								
9N8E-								
2.6f	W. Brewer	15	48	590	13	577	3/34	Dr
30.	J. Flood	90	6	530	45	485	1954	Br
9N9E-								
1.7h	E. Cutright	34	48	590	9	581	12/33	Dr
1.5c	F. Wetherholt	140	4	600	2	598	12/33	Br
2.5e	McPeak	335	8	540	Flows	540	2/34	Br
33.6d	W. E. Roberts	11	48	580	7	573	2/34	Dr
9N10E-								
10.6a	C. Sedgwick	16	54	610	12	598	2/34	Dr
10N7E-								
25.8a	G. W. Kroenlein	28	60	615	20	595	1/34	Br
25.8h	P. Lovins	14	48	620	10	610	2/34	Dr
16.8c	W. J. Pearday	150	6	660	6	654	1959	Br
10N8E-								
26.7h	S. Pedrick	28	54	620	8	612	2/34	Dr
25.8a	C. Oakley	145	7	570	10	560	1951	Br
10N9E-								
2.7h	C. Cottonham	160	5	640	65	575	3/34	Br
12.8d	C. Cottonham	85	3	640	35	605	2/34	Dr
19.4g	J. M. Stipes	26	54	600	12	588	3/34	Dr
10N10E-								
18.	C. D. Cobble	166	6	620	35	575	1948	Dr
31.5b	L. Carrell	26	48	570	9	561	2/34	Dr
11N8E-								
25.5h	W. Thomas	64	16	615	30	585	2/34	Dr
27.1g	M. Ferguson	21	54	635	11	624	2/34	Dr
11N9E-								
28.6d	J. Phipps	32	36	625	24	601	2/34	Dr
35.8b	Z. Jones	130	7	618	80	538	1946	Dr
11N10E-								
33.5e	Forest Oil Co.	27	8	575	20	555	10/52	Dr

Table 5. Water-level data for selected wells remote from pumping centers, cont.

Well Number	Owner	Depth of Well (ft)	Casing Diameter (in)	Surface Elevation (ft above sea level)	Depth to Water (ft)	Water Level Elevation (ft above sea level)	Date of Measurement	Aquifer
CLK--								
9N14W-								
5.8a	B. L. Hove	95	$\frac{1}{4}$	620	19	601	12/53	Br
26.5d	Forest Oil Co.	37	12	550	11	539	2/54	Dr
10N13W-								
33.7b	M. Hudson	145	6	610	10	600	11/52	Br
17.5d	F. Cummins	80	6	615	38	577	11/59	Dr
10N14W-								
6.1a	K. Lamb	114	6	660	20	640	8/53	Br
11N13W-								
16.	Comm. School	91	6	650	3	647	1949	Br
11N14W-								
17.6f	C. B. Craig	350	6	660	10	650	12/53	Br
35.1d	L. Erwin	25	36	645	7	638	5/51	Dr
12N13W-								
30.3a	H. Newlin	105	6	660	38	622	1/53	Br
12N14W-								
2.7h	L. Ross	53	6	710	12	698	10/52	Dr
EDG--								
13N13W-								
2.1e	J. McDanial	40	6	690	3	687	1963	Dr
13N14W-								
23.1a	H. Pinnel	71	6	675	15	660	1947	Dr
10.5a	L. Lacy	114	6	700	11	689	11/62	Br
14N13W-								
15.8h	G. North	106	7	680	12	668	9/59	Dr
15.5d	O. M. Henn	175	6	690	28	662	12/53	Br
14N14W-								
3.5e	C. Norton	16	48	662	9	653	2/34	Dr
22.2h	E. Lamkey	79	7	670	21	649	1951	Dr
15N13W-								
19.3a	T. J. Carroll	20	48	665	10	655	3/34	Dr

Table 6. Distribution of Pumpage from Wells in 1960,
Subdivided by Source and Use.

	Glacial Drift aquifers (mgd)	Pennsylvanian rocks (mgd)	Devonian ~~and~~ Silurian rocks (mgd)	Total pumpage (mgd)
Urban	2.208	-	0.284	2.492
Industrial	0.751	-	0.030	0.781
Rural	0.752	0.213	0.023	0.988
Livestock	1.571	0.455	0.052	2.078
Totals	5.282	0.668	0.389	6.339

End of table

Table 7. Distribution of Pumpage from Wells in Glacial Drift in 1960, Subdivided by Use.

Pumping Center Number	Urban Public Pumpage (mgd)	Industrial Pumpage (mgd)	Total Pumpage (mgd)	Location
1	0.107	0.051	0.158	Philo-Tolono-Pesotum
2	0.032	0.008	0.040	Broadlands-Allerton-Long View
3	0.005	-	0.005	Camargo
4	0.059	-	0.059	Hume-Metcalf-Newman
5	0.140	-	0.140	Arcola
6	0.012	-	0.012	Hindsboro
7	0.068	-	0.068	Kansas-Westfield-Ashmore
8	0.008	-	0.008	Lerna
9	0.253	-	0.253	Casey-Martinsville
10	0.095	0.035	0.130	Toledo-Greenup
11	0.014	-	0.014	Flat Rock
12	0.589	0.210	0.799	Lawrenceville
13	0.826	0.447	1.273	Oblong Obland-Stoy-Robinson
Total	2.208	0.751	2.959	

Table 8. Geographic Distribution and Density of Pumpage From Wells in 1960.

County	Total Pumpage (mgd)	Glacial Drift (mgd)	Pennsylvanian Rocks (mgd)	Devonian Silurian Rocks (mgd)	Density of Pumpage (gpd/sq mi)
Champaign & Vermilion	0.379	0.361	0.009	0.009	2,600
Clark	0.566	0.456	0.110	—	2,700
Coles	0.435	0.303	0.042	—	1,300
Crawford	1.638	1.524	0.114	—	5,900
Cumberland	0.522	0.389	0.133	—	1,700
Douglas	0.839	0.424	0.034	0.381	2,900
Edgar	0.308	0.283	0.025	—	1,600
Effingham	0.020	0.017	0.003	—	2,300
Jasper	0.462	0.375	0.087	—	1,400
Lawrence	1.086	1.000	0.086	—	4,500
Richland	0.085	0.060	0.025	—	1,450
Total	6.340	5.282	0.668	0.390	ave. 2,600

Table 9. Results of Aquifer tests.

Test No.	Method of analysis	Coefficient of transmissibility (gpd/ft)	Coefficient of permeability (gpd/sq ft)	Coefficient of storage (fraction)
1	Time-drawdown	12,700	750	0.00003
2	Time-drawdown Distance-drawdown	250,000	2,500	0.04
3	Time-drawdown	18,300	660	--
4	Time-drawdown	11,100	550	0.00016
5	Time-drawdown	6,120	410	0.00007
6	Time-recovery	22,800	1,140	0.0096
7	Time-drawdown	106,000	1,410	0.00010
8	Distance-drawdown	20,900	700	0.033

T-D, time-drawdown; D-D, distance-drawdown; T-R, time-recovery

Table 11. Specific-capacity data for bedrock wells.

Well Number	Owner	Depth of well (ft)	Thickness of bedrock open to well (ft)	Aquifer	Diameter of casing (in)	Date of test	Length of test (hrs)
CLK -- 12N14W-							
30.8c(TS)	Westfield (V) st-	-	-	Pen	-	1940	1.7
30.4d(3)	Westfield (V) st-	150	54	Pen	10	1940	5.0
29.8c(1)	Westfield (V) st-	155	75	Pen	8	1940	1.7
COL-- 11N8E-							
3.4b(3)	Lerna (V) a	159	64	Pen	6	1955	0.5
3.3b(2)	Lerna (V) p	151	51	Pen	8	1955	4.5
3.2a(6)	Lerna (V) p	146	42	Pen	6	1956	0.5
3.1a(1)	Lerna (V) a	184	68	Pen	5	1955	5.0
11N7E-	J. O. Reynolds	130	-	Pen	5	1939	0.7
CRF 7N12W- 33.4d	Robinson Pottery Plant	102	76	Pen	8	1952	-
7.8a	A. J. Trimble	77	10	Pen	6	-	2.0
6N13W- 27.8a	Ohio Oil Co.	390	60	Pen	8	1948	0.5
6N12W- 25.1h(T)	Flat Rock (V)	83	55	Pen	12	1954	18.0

Non-Pumping level (ft)	Pumping rate (gpm)	Draw-down (ft)	Specific capacity (gpm/ft)	Remarks
72.0	15	60.0	0.25	Test well No. 5
72.0	13	63.8	0.20	Village well No. 3
60.0	19	53.0	0.36	Village (old) well No. 1
57.0	6	47.0	0.13	Village well No. 3
51.0	10	73.0	0.14	Village well No. 2
54.2	8	68.3	0.12	Village well No. 6
61.0	9	22.5	0.40	Village well No. 1
30.0	70	75.0	0.93	
[illegible]	60	10.0	6.00	
[illegible]	30	20.0	1.50	
147.0	50	223.0	0.22	
15.5	25	39.0	0.64	Test well

Add [illegible]

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Table 11. Specific-capacity data for bedrock wells, cont.

Well Number	Owner	Depth of well (ft)	Thickness of bedrock open to well (ft)	Aquifer	Diameter of casing (in)	Date of test	Length of test (hrs)
JAS							
7N11E-31.8a	Village of Willow Hill	295	73	Pen	8	1963	2.0
CUM							
11N10E-28.2a	Forrest Oil Co.	92	42	Pen	-	-	-
DGL							
16N9E-34	Village of Camargo	165	6.5	Pen	10	1956	6.0
16N9E-10.1h2	City of Villa Grove	627	37	Dev	12	1933	8.0
16N9E-10.1h1	City of Villa Grove	645	23	Dev	12	1940	6.0
16N8E-34.4c	City of Tuscola	694	412	Dev-Sil	12	1947	2.5
16N8E-34.2d	City of Tuscola	523	403	Dev-Sil	10	1946	2.2
16N8E-34.1b	City of Tuscola	553	418	Dev-Sil	12	1949	1.0
16N8E-34	City of Tuscola	300	172	Dev-Sil	8	1918	0.5
JAS							
14W6N-19.8a	Village of St. Marie	114	90	Pen	10	1953	12.0

Non-Pumping level (ft)	Pumping rate (gpm)	Draw-down (ft)	Specific capacity (gpm/ft)	Remarks
34.6	15	136.0	0.11	Farthing No. 1
–	156	15.0	10.40	
20.0	37	81.5	0.45	Village well No. 1
90.0	205	5.0	41.00	City well No. 2
91.0	600	20.0	30.00	City well No. 1
119.0	74	43.0	1.72	City well No. 4
193.0	73	121.0	0.60	City well No. 3
126.0	90	18.0	5.00	City well No. 5
82.3	72	11.5	6.26	
8.0	5	15.2	0.33	Village well No. 2-53

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Table 11. Specific-capacity data for bedrock wells, cont.

Well number LAW--	Owner	Depth of well (ft)	Thickness of bedrock open to well (ft)	Aquifer	Diameter of casing (in)	Date of test	Length of test (hrs)
3N13W-4.5c(T1)	Sumner (V)	221	174	Pen	8	1951	4.0
3N11W-6(1)	Avalon Theater	205	101	Pen	8	1947	11.0

* Pen, Pennsylvanian rocks; Dev, Devonian rocks; Dev-Sil, Devonian and Silurian rocks

Non-Pumping level (ft)	Pumping rate (gpm)	Draw-down (ft)	Specific capacity (gpm/ft)	Remarks
17.6	10	150.4	0.06	Test well No. 1
55.0	60	70.0	0.86	Well No. 1

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Table 12. Specific-capacity data for sand and gravel wells.

Well Number	Owner	Depth of well (ft)	Length of screen (ft)	Diameter of casing (in)	Date of test	Length of test (hrs)	Non-pumping level (ft)	Pumping rate (gpm)
CHM								
18N9E-23.7g	Village of Philo	81	5	10	1939	2.5	33.0	73
18N9E-22.7d	Village of Philo	29	9	6	1961	3.0	11.8	44
18N9E-22.4e	Village of Philo	44	8	8	1945	4.0	9.5	65
18N9E-22.1f	Village of Philo	30	6	8	1954	3.2	15.0	50
18N9E-22.1h	Village of Philo	26	9	6	1962	1.0	13.5	58
18N8E-26.1c3	Village of Tolono	158	12	8	1948	6.0	–	90
18N8E-26.1c7	Village of Tolono	164	26	18	1952	5.0	78.4	115
18N8E-26.1c8	Village of Tolono	160	28	18	1953	7.0	80.5	80
18N8E-26.1c8	Village of Tolono	186	8	10	1934	1.0	71.8	53
18N8E-26.1f	Village of Tolono	145	4	10	1942	6.0	77.0	97
18N8E-25.8f5	Village of Tolono	185	15	10	1938	4.0	76.0	98
18N8E-25.8f5	Village of Tolono	185	3	10	1950	1.3	77.5	48
18N8E-25.8d	Village of Tolono	179	40	17	1956	4.0	80.0	250
18N8E-25.6d	Village of Tolono	180	42	17	1961	3.5	85.5	369
18N8E-25.4g	Champaign County District No. 7	150	8	6	1957	7.5	76.5	42
18N8E-2.4e	University of Illinois Golf Course	218	13	8	1963	1.5	–	232

Draw-down (ft)	Specific capacity (gpm/ft)	Coefficient of trans-missibility (gpd/ft)	Thickness of aquifer (ft)	Coefficient of permea-bility (gpd/sq ft)	Remarks
31.0	2.35	-	-	-	Village well No. 1
5.2	8.77	16,500	16	1030	Village well No. 4
20.5	3.17	-	-	-	Village well No. 2
6.3	7.95	9,000	12	750	Village well No. 3
5.3	10.95	16,000	16	1000	Village well No. 4
54.0	1.67	-	-	-	Village well No. 3
21.6	5.33	9,000	51	177	Village well No. 7
64.6	1.24	-	-	-	Village well No. 8
81.6	0.65	-	-	-	Village well No. 4
60.0	1.62	-	-	-	Village well No. 6
62.0	1.58	-	-	-	Village well No. 5
61.5	0.79	-	-	-	Village well No. 5
29.0	8.53	14,500	45	330	Village well No. 9
22.7	16.30	28,000	45	623	Village well No. 11
6.0	7.00	13,500	35	386	Well No. 1
11.8	19.50	40,000	-	-	Well No. 1

Table 12. Specific-capacity data for sand and gravel wells, cont.

Well Number	Owner	Depth of well (ft)	Length of screen (ft)	Diameter of casing (in)	Date of test	Length of test (hrs)	Non-pumping level (ft)	Pumping rate (gpm)
CHM								
17N11E-30.2h	Village of Broadlands	120	4	10	1954	6.7	16.5	23
17N11E-19.2e	Village of Broadlands	72	8	10	1955	6.5	6.5	83
17N8E-23.8c	Illinois Central Railroad	240	65	8	1952	24.0	67.0	66
17N8E-22.1d	Village of Pesotum	190	10	8	1956	24.0	71.5	81
16N10E-4.8h	Village of Long View	50	9	10	1952	24.0	1.2	62
CLK								
12N14W-30.7d	Village of Westfield	50	10	10	1957	7.0	3.0	100
10N13W-19.8e6	City of Casey	80	29	12	1941	12.0	6.5	300
10N13W-7.3c4	City of Martinsville	51	6	8	1948	3.5	18.2	59
10N13W-7.3c5	City of Martinsville	58	8	10	1948	2.0	14.0	80
10N13W-7.3c6	City of Martinsville	56	8	10	1950	2.0	15.3	73
9N14W-26.8d	Forrest Oil Company	37	16	12	1954	1.0	11.0	130

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Draw-down (ft)	Specific capacity (gpm/ft)	Coefficient of transmissibility (gpd/ft)	Thickness of aquifer (ft)	Coefficient of permeability (gpd/sq ft)	Remarks
94.5	0.24	-	4	-	Village well No.
38.9	2.15	3,800	8	475	Well No. 1-55
108.0	0.61	-	-	-	
21.5	3.77	-	-	-	Village well No.
13.7	4.56	9,200	20	460	Village well No.
33.0	3.03	-	-	-	Village well No.
4.5	66.70	138,000	70	1975	City well No. 6
18.2	3.25	5,700	17	335	City well No. 4
10.0	8.00	13,800	12	1150	City well No. 5
8.8	8.30	14,200	14	1030	City well No. 6
8.0	16.20	20,000	22	910	Well No. 1

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Table 12. Specific-capacity data for sand and gravel wells, cont.

Well Number	Owner	Depth of well (ft)	Length of screen (ft)	Diameter of casing (in)	Date of test	Length of test (hrs)	Non-pumping level (ft)	Pumping rate (gpm)
COL								
12N11E-6.7h	Village of Ashmore	42	10	10	1955	24.0	22.0	50
12N8E-14.7c	Coles County Airport	48	4	10	1951	6.0	17.9	13
11N9E-18.7g	Fox Ridge State Park	221	9	8	1954	4.0	136.8	11
11N9E-13.6f1	Fox Ridge State Park	157	-	6	1943	5.7	32.0	20
11N9E-13.6f2	Fox Ridge State Park	159	3	8	1954	4.0	122.3	8
11N8E-10.4g1	Village of Lerna	32	10	6	1958	8.0	5.5	19
11N8E-10.4g2	Village of Lerna	34	5	12	1958	24.0	5.2	25
CRF								
8N14W-14.7d	The Pure Oil Co.	127	30	10	1948	-	30.0	145
8N14W-14.6c	The Pure Oil Co.	142	28	10	1948	-	48.0	145
7N13W-18.1h	The Ohio Oil Co.	122	28	17	1949	-	42.5	310
5N11W-18.5a	Village of Flat Rock	63	15	8	1961	5.0	13.5	126
5N11W-18.4a	Village of Flat Rock	52	15	8	1956	19.0	11.0	132

Draw-down (ft)	Specific capacity (gpm/ft)	Coefficient of trans-missibility (gpd/ft)	Thickness of aquifer (ft)	Coefficient of permea-bility (gpd/sq ft)	Remarks
2.7	18.50	40,000	11	3600	Village well No 1
24.4	0.53	1,050	4	263	
56.0	0.19	-	-	-	Well No. 2-54
44.0	0.45	-	-	-	
29.0	0.28	-	-	-	Well No. 1-54
16.5	0.12	-	-	-	No. 1-58
21.4	1.17	1,750	17	103	No. 2-58
10.0	14.50	27,000	41	660	
10.5	13.80	26,000	43	605	
23.5	13.20	25,500	28	912	
18.6	6.80	12,500	30	418	Village well No 2
24.0	5.50	11,000	22	500	Test well

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Table 12. Specific-capacity data for sand and gravel wells, cont.

Well Number	Owner	Depth of well (ft)	Length of screen (ft)	Diameter of casing (in)	Date of test	Length of test (hrs)	Non-pumping level (ft)	Pumping rate (gpm)
CUM								
11N10E-33.5e	Forrest Oil Co.	44	20	17	1952	9.5	8.6	418
11N10E	Forrest Oil Co.	40	6	-	1946	-	3.0	175
10N9E-29.7b1	Village of Toledo	20	10	16	1925	3.0	4.5	75
10N9E-29.7b4	Village of Toledo	57	-	6	1952	5.0	6.5	25
10N9E-29.7b3	Village of Toledo	29	12	10	1952	5.0	7.7	65
9N9E-2.8f1	Village of Greenup	28	8	16	1939	10.0	12.0	155
9N9E-2.8f2	Village of Greenup	47	26	12	1940	0.7	13.5	170
9N9E-2.8f3	Village of Greenup	43	20	10	1946	5.0	15.0	300
9N9E-2.8f3	Village of Greenup	43	20	10	1959	0.2	-	80
9N9E-2.8f4	Village of Greenup	40	20	12	1950	3.0	16.1	100
9N9E-2.8f4	Village of Greenup	40	20	12	1959	0.2	-	50
9N9E-2.8g	Village of Greenup	41	10	8	1963	2.3	16.1	175
8N8E-24.2d11	Village of Jewett	134	8	6	1963	5.0	58.6	25
8N8E-24.2d2	Village of Jewett	136	9	6	1963	4.5	60.9	31
8N8E-24.2d1	Village of Jewett	134	9	6	1963	0.9	58.5	12

Title

Draw-down (ft)	Specific capacity (gpm/ft)	Coefficient of trans-missibility (gpd/ft)	Thickness of aquifer (ft)	Coefficient of permea-bility (gpd/sq ft)	Remarks
12.9	32.40	60,000	25	2400	Well No. 2
17.0	10.30	18,000	10	1800	Well No. 3
15.0	5.00	4,500	10	450	Village (old) well
16.5	1.51	-	-	-	Test well No. 3-52
10.6	6.12	8,100	18	450	Test well No. 4-52
11.4	13.60	19,000	15	1270	Village well No. 1
16.5	10.30	12,000	31	390	Village well No. 2
8.0	37.50	66,000	26	2540	Village well No. 3
5.0	16.00	16,800	26	650	Village well No. 3
5.7	17.55	28,000	23	1220	Village well No. 4
3.6	14.00	18,000	24	750	Village well No. 4
16.9	10.35	18,500	20	925	Village well No. 5
30.4	0.83	-	-	-	Village well No. 1
40.0	0.78	-	-	-	Test Hole No. 2
59.5	0.20	-	-	-	Village well No. 1

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Table 12. Specific-capacity data for sand and gravel wells, cont.

Well Number	Owner	Depth of well (ft)	Length of screen (ft)	Diameter of casing (in)	Date of test	Length of test (hrs)	Non-pumping level (ft)	Pumping rate (gpm)
DGL								
16N14W-32.5a	City of Newman	30	11	10	1949	24.0	4.5	70
16N14W-31.7d	City of Newman	143	12	8	1935	0.7	0.5	115
16N14W-31.4h	City of Newman	58	20	10	1953	5.5	9.8	115
16N14W-31.4d	City of Newman	127	9	8	1934	1.0	21.1	28
14N10E-15	Village of Oakland	95	-	6	1944	1.0	30.0	13
14N10E-6.6b1	Village of Hindsboro	83	10	8	1956	3.0	5.0	30
14N10E-6.6b2	Village of Hindsboro	88	2	4	1955	3.5	3.6	12
14N10E-6.6b3	Village of Hindsboro	28	5	8	1961	4.5	8.4	29
16N9E-34.1e	Village of Camargo	80	5	6	1961	4.5	4.2	25
EDG								
16N13W-31	Village of Hume	55	15	8	1954	-	10.0	103
15N14W-25.4f	Village of Brocton	38	5	10	1962	1.8	4.8	130
15N13W-35	Smith	78	2	7	1957	2.0	10.0	66
JAS								
6N14W-19.8a2	Village of St. Marie	54	10	8	1953	2.7	14.3	36
8N14W-15.1d	~~The~~ Pure Oil Co.	116	20	10	1948	0.3	+2.0	200

Draw-down (ft)	Specific capacity (gpm/ft)	Coefficient of trans-missibility (gpd/ft)	Thickness of aquifer (ft)	Coefficient of permea-bility (gpd/sq ft)	Remarks
9.5	7.40	9,000	20	450	City well No. 3
88.0	1.31	-	-	-	City well No. 2
48.0	2.40	-	-	-	City well No. 4
64.9	0.43	-	-	-	City well No. 1
10.8	1.20	-	-	-	
48.4	0.63	-	-	-	Village well No. 1
7.4	1.62	-	-	-	Test well No. 2
15.6	1.86	2,900	10	290	Village well No. 3
19.6	1.28	2,300	7	330	Test well No. 1-61
2.9	35.40	66,000	45	460	Village well No. 1
18.0	7.22	12,000	8	1500	Village well No. 1
30.0	2.20	3,700	10	370	
10.2	3.50	4,400	37	120	Sheridan well No.
6.0	33.40	55,000	20	2750	

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Table 12. Specific-capacity data for sand and gravel wells, cont.

Well Number	Owner	Depth of well (ft)	Length of screen (ft)	Diameter of casing (in)	Date of test	Length of test (hrs)	Non-pumping level (ft)	Pumping rate (gpm)
JAS								
8N14W-15.2e	The Pure Oil Co.	120	30	10	1948	–	27.0	58
7N8E-31.8b	City of Newton	57	30	6	1963	2.3	15.9	89
7N8E-36.3e	City of Newton	38	8	6	1963	3.0	14.8	64
LAW								
4N12W-5.8c	The Ohio Oil Co.	101	15	20	1961	–	16.0	225
4N11W-26.7h	George Field	74	23	12	1942	24.0	15.7	500
6N14W-6.8h	Village of Willow Hill	125	15	8	1963	2.7	14.8	10
4N11W-26.7a	George Field	68	21	12	1942	22.0	15.7	500
3N11W-11.6d	The Texas Oil Co.	105	25	16	1950	24.0	4.5	1000
3N11W-2.8d1	City of Lawrenceville	60	40	24	1924	–	6.0	700
3N11W-2.8d5	City of Lawrenceville	72	44	17	1947	0.7	7.5	2000
3N11W-2.8d6	City of Lawrenceville	73	44	17	1947	0.7	8.0	2000

Draw-down (ft)	Specific capacity (gpm/ft)	Coefficient of trans-missibility (gpd/ft)	Thickness of aquifer (ft)	Coefficient of permea-bility (gpd/sq ft)	Remarks
10.0	5.80	11,000	30	370	
5.7	15.60	30,500	37	820	Test well No. 2
8.2	7.80	14,500	8	1800	Test well No. 1
68.0	3.30	4,200	16	260	
9.0	55.50	110,000	54	2040	Well No. 1
17.2	0.59	-	-	-	Village well No. I
9.0	55.50	110,000	50	2200	Well No. 2
43.5	23.00	-	-	-	Test well
6.0	117.00	165,000	100	1650	City well No. 1
7.8	256.00	480,000	100	4800	City well No. 5
11.1	180.00	330,000	100	3300	City well No. 6

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Table 13. Well-loss coefficients for sand and gravel wells.

Well Number	Well-loss Coefficient (sec^2/ft^5)
CHM 18N9E-22.4e	130
CHM 18N8E-25.4g	135
CLK 10N13W-7.3c1	0.82
CLK 10N13W-19	2.21
CRF 5N11W-18.5a	95
CUM 9N9E-2.8f4	56
DGL 16N9E-34.1e	158
EDG 16N13W-31	26

Table 13. Data on Specific Capacities of Well Fields

Well Number	Owner	Nonpumping water level (ft) early	Nonpumping water level (ft) recent	Date measured early	Date measured recent	Decline in water level (ft)	Recent pumping rate (gpd)	Specific capacity of well field (gpd/ft)	Acuifer
DGL									
14N8E-4.4d	City of Arcola	40	82	1922	1955	42	112,000	2,670	Sand and gravel
CHM									
18N9E-22.4e	Village of Philo	9.5	21	1945	1954	11.5	18,215	1,590	Sand and gravel
18N8E-26.1c1	Village of Tolono	40	77	1914	1942	33	75,000	2,270	Sand and gravel
12N14W-29.8c	Village of Westfield	45	72	1919	1940	27	23,000	850	Penn rocks
CLK									
10N13W-7.3c1	City of Martinsville	13	18.2	1927	1948	5.2	59,000	11,300	Sand and gravel
10N9E-29.8b1	Village of Toledo	4.5	8	1925	1941	3.5	23,045	6,600	Sand and gravel
CUM									
9N9E-2.8f1	Village of Greenup	12	16.1	1939	1950	4.1	50,000	12,200	Sand and gravel
DGL									
16N14W-31.7d	City of Newman	34	45	1935	1943	11	36,000	3,270	Sand and gravel

Table 14. Well field specific-capacity data, cont.

Well Number	Owner	Nonpumping water-level (ft below MP) Early	Recent	Date of Measurement Early	Recent	Decline in water level (ft)	Recent pumping rate (gpd)	Well field specific capacity (gpd/ft)	Aquifer
LAW									
3N11W-2.8d1	City of Lawrenceville	6	8	1924	1947	2	601,050	300,520	Sand and gravel
DGL									
16N9E-10.1h1	City of Villa Grove	90	115	1924	1954	25	123,900	4,950	Devonian rocks
16N8E-34.2d	City of Tuscola	82	126	1918	1949	44	146,900	3,340	Devonian-Silurian rocks

*Feet below measuring point

[1] S & g, sand and gravel; Pen, Pennsylvanian rocks; Dev, Devonian rocks; Dev-Sil, Devonian and Silurian rocks

end of Table 14

Table 15. Summary of recharge rates (after Walton, 1964)

Location of Study Area	Recharge Rates (gpd/sq mi)	Lithology of Deposits Above Aquifer or Permeable Zones	Aquifer
Champaign-Urbana, Champaign County	115,000	Glacial drift, largely till	Glacial sand and gravel
Havana region, Mason and Tazewell Counties	258,000	Glacial drift, largely till	Glacial sand and gravel
	279,000	Glacial drift, largely till	
	500,000	Glacial drift, largely sand and gravel	
	486,000	Glacial drift, largely sand and gravel	
East St. Louis, Madison and St. Clair Counties	347,000	Glacial drift and alluvium, largely sand and gravel	Glacial sand and gravel
	343,000	Glacial drift and alluvium, largely sand and gravel	
	299,000	Glacial drift and alluvium, largely sand and gravel	
	370,000	Glacial drift and alluvium, largely sand and gravel	

[illegible]

Table 15. Summary of recharge rates

(after Walton, 1964)

Location of Study Area	Recharge Rates (gpd/sq mi)	Lithology of Deposits Above Aquifer or Permeable Zones	Aquifer
Northeastern Illinois	1,330	Maquoketa Formation, largely shale	Cambrian-Ordovician
DeKalb and Kendall Counties	18,000	Glacial drift and units of Cambrian-Ordovician Aquifer	Cambrian-Ordovician
Du Page County	64,000	Glacial drift, largely till, and shaly dolomite	Dolomite of Silurian Age
	138,000	Glacial drift, largely till, and dolomite	
	136,000	Glacial drift, largely till, and dolomite	
	158,000	Glacial drift, largely till, and dolomite	
La Grange, Cook County	161,000	Glacial drift, largely till, and dolomite	Dolomite of Silurian Age
Chicago Heights, Cook County	225,000	Glacial drift, largely till, and dolomite	Dolomite of Silurian Age
Libertyville, Lake County	52,000	Glacial drift, largely till, and shaly dolomite	Glacial sand and gravel
Woodstock, McHenry County	127,000	Glacial drift, largely till	Glacial sand and gravel
Near Joliet, Will County	200,000	Glacial drift, largely silt, and sand	Glacial sand and gravel

Table 15. Summary of Infiltration Rates of Streambeds

(After Walton, 1963)

Owner of wells	Location of test site	Hydraulic properties T (gpd/ft)	P (gpd/sq ft)	S	Q_c/A_c (gpd/acre)	$(Q_c/A_c)/h$ (gpd/acre/ft)	Temperature of surface water (F)
Springfield, Ohio	Along Mad River, about 4 miles northwest of Springfield	547,000	5470	0.01	92,000	1,000,000	39
Southwestern Ohio Water Co.	Along Miami River, 14 miles northwest of Cincinnati	345,000	2760	$\frac{1}{M}$	224,000	168,000	82
Anderson, Indiana	Along White River, immediately upstream from the confluence of White River and Killbuck Creek at Anderson	151,000	4720	0.05	42,000	216,000	54
Canton, Ohio	Along Sandy Creek, 12 miles south of Canton	204,000	1700	0.01	331,000	720,000	69
Anderson, Indiana	Along White River, 1 mile west of Anderson	169,000	4000	0.07	52,100	39,800	35

Table 17. Gaging Station locations and

Annual Ground-water Runoff

$(Q_{25}/Q_{75})^{1/2}$

Gaging Station Location	Latitude of Gaging Station	Basin area (sq mi)	Annual Ground-Water Runoff (cfs/sq mi) ~~Precipitation~~ near*	below*	above*	Ratio ~~25/~~75
Embarras River near Oakland	39° 40' 50"	535	0.28	0.10	0.48	4.32
Embarras River near Diona	39° 20' 40"	903	0.34	0.15	0.60	4.25
Embarras River at Ste. Marie	38° 56' 10"	1540	0.30	0.18	0.42	3.26
Embarras River at Lawrenceville	38° 43' 25"	2260	0.40	0.28	0.62	3.33
North Fork of Embarras River near Oblong	39° 00' 35"	304	0.16	0.09	0.22	3.60

*Data for years of near, below, and above normal precipitation

Table 17. Chemical Analyses of water from wells in glacial drift (chemical constituents in parts per million) 8/9 pt

Owner*	Iron (total) (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Ammonium (NH4)	Sodium (Na)	Silica (SiO_2)	Fluoride (F)
Philo (V), CHM 18N9E-22.4e, 44 ft., 12/12/48	1.9	0.1	72.7	27.2	0.1	3.9	15.6	0.1
Tolono (V), CHM 18N8E-26.1c, 157 ft., 12/15/48	5.2	0.0	109.6	38.9	13.3	113.2	29.8	0.4
Broadlands (V), CHM 17N11E-19.2a, 71 ft., 8/6/57	1.0	Tr	51.0	18.3	1.7	68.0	21.0	1.7
Allerton (V), VER 17N14W-27.4e, 50 ft., 10/24/57	1.4	0.1	75.0	36.9	Tr	12.0	14.6	0.3
Long View (V), CHM 16N10E-4.8h, 50 ft., 8/6/57	1.4	Tr	62.5	26.9	2.4	51.0	18.0	0.5
Pesotum (V), CHM 17N8E-22.1d, 190 ft., 9/27/57	1.0	0.0	58.5	22.6	Tr	85.0	19.8	0.5
Newman (C), DGL 16N14W-31.7d, 143 ft., 7/15/49	3.9	0.0	62.9	23.7	16.6	343.4	23.2	0.3
Arcola (C), DGL 14N8E-4.4e, 128 ft., 6/24/48	6.0	0.3	67.6	29.3	15.1	112.5	26.3	0.2
Hindsboro (V), DGL 14N10E-6.6b, 83 ft., 8/6/57	1.6	Tr	48.0	20.4	0.7	131.0	19.6	0.5

Boron (B)	Chloride (Cl)	Nitrate (NO3)	Sulfate (SO4)	Alkalinity (as CaCO3)	Hardness (as CaCO3)	Total dissolved minerals	pH	Temperature (°F)
	7.0	0.6	81.5	208	294	351	7.2	53.7
	8.0	0.5	1.0	704	434	736	6.8	54.0
1.7	4.0	0.4	3.9	344	203	368		54.5
0.2	4.0	1.2	45.4	312	339	374		54.0
1.5	11.0	0.3	1.0	368	267	404		55.0
0.6	10.0	7.6	0.8	404	240	465		57.0
	370.0	3.0	0.0	524	255	1162		
	51.0	0.2	0.6	504	290	582	6.9	55.5
0.4	36.0	0.1	0.2	440	204	523		56.0

first p. of
table 17

Table 17 page 2 continued

Hume (V), EDG 16N13W-31.3c, 55 ft., 8/6/57	1.7	0.1	73.5	28.1	0.1	10.0	13.1	0.1
Kansas (V), EDG 13N14W-26.6e, 76 ft., 6/18/48	3.1	Tr	93.1	34.9	8.1	21.4	28.0	0.1
Metcalf (V), EDG 16N13W-34.1d, 75 ft., 8/6/57	1.9	0.1	76.0	23.5	3.4	113.0	23.5	0.4
Ashmore (V), COL 12N11E-6.7h, 42 ft., 11/22/60	2.0	0.1	93.4	43.8	Tr	10.0	15.6	0.2
Lerna (V), COL 11N8E-10.4g, 44 ft., 11/24/59	1.8	Tr	1/m	1/m	1/m	1/m	1/m	0.4
Martinsville (C), CLK 10N13W-7.3c, 53 ft., 6/5/48	1.7	0.0	73.3	33.1	4.3	68.3	17.9	0.5
Casey (C), CLK 10N13W-19.8e, 80 ft., 6/5/48	7.0	0.0	76.2	32.2	6.0	88.3	19.3	0.4
Toledo (V), CUM 10N9E-29.7b, 20 ft., 6/2/48	2.0	0.2	57.2	21.1	0.4	36.3	23.8	0.3
Greenup (V), CUM 9N9E-2.8f, 43 ft., 6/3/48	0.3	0.2	75.1	29.6	Tr	2.8	21.1	0.1
Robinson (C), CRF 7N11W-34.5d, 71 ft., 4/29/48	0.1	0.0	82.4	11.8	Tr	15.9	19.4	0.1
Flat Rock (V), CRF 5N11W-18.5a, 52 ft., 9/28/56	0.3	1/m	1/m	1/m	1/m	1/m	1/m	0.1
Lawrenceville (C), LAW 3N11W-2.8d, 64 ft.,	0.3	Tr	61.3	11.6	Tr	0.9	16.1	0.1

0.0	11.0	1.2	74.3	228	300	355	/m	56.0
/m	6.0	Tr	8.6	428	377	423	7.2	55.0
0.2	97.0	1.0	3.5	400	286	589	/m	/m
0.1	16.0	3.5	70.1	336	414	478	/m	52.5
/m	5.0	0.6	/m	388	340	385	/m	/m
/m	78.0	0.4	1.4	368	320	500	7.1	57.5
	97.0	Tr	3.1	392	323	560	7.7	54.7
	16.0	1.1	32.7	252	230	337	7.3	52.5
	5.0	6.8	60.7	240	310	362	7.5	54.2
	10.0	14.8	46.1	216	255	336	7.2	57.3
	11.0	0.3	/m	244	228	268	/m	/m
	7.0	11.6	26.5	156	201	227	7.1	56.0

Second p. of
table 17

Table 17 page 3 continued

St. Marie (V), JAS 6N14W-19.8a, 54 ft., 9/30/53	8.3	0.0	76.9	14.8	0.6	18.0	19.0	0.2
Westfield (V), CLK 12N14W-20.7d, 50 ft., 11/27/57	4.7	1/m	1/m	1/m	1/m	1/m	1/m	0.4
Camargo (V), DGL 16N9E-34.1e, 80 ft., 5/15/61	14.0	0.0	1/m	1/m	1/m	1/m	1/m	0.4

* The well number, depth of well, and sample collection date are shown below each owner.

~~s/and p. 4 table 17~~

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$\frac{1}{m}$	8.0	0.1	20.6	260	253	295	$\frac{1}{m}$	56.0
$\frac{1}{m}$	5.0	2.3	$\frac{1}{m}$	446	404	451	$\frac{1}{m}$	55.0
$\frac{1}{m}$	13.0	6.0	$\frac{1}{m}$	632	332	661	$\frac{1}{m}$	55.0

third page
of table 17

Table 18. Chemical Analyses of Water from Wells in Bedrock

(Chemical constituents in parts per million)

Owner*	Iron (total) (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Ammonium (NH_4)	Sodium (Na)	Silica (SiO_2)	Fluoride (F)	Boron (B)
Villa Grove (C), DGL 16N9E-10.1h, 645 ft., 6/26/48	0.1	0.0	51.7	24.5	0.5	115.9	14.7	0.2	
Tuscola (C), DGL 16N8E-34.3c, 694 ft., 9/21/47	0.5	0.0	55.3	26.1	2.1	66.9	16.1	0.1	
Camargo (V), DGL 16N9E-34, 165 ft., 5/30/61	0.3	0.0	29.0	14.0				0.6	
Westfield (V), CLK 12N14W-30.1c, 150 ft., 6/8/48	2.5	0.0	18.1	12.1	1.3	80.7	13.7	0.9	
L. L. Groff, LAW 3N13W-4.5c, 221 ft., 7/15/51	1.2	0.0	7.8	1.5	0.4	351.4	13.3	2.0	
Lerna (V), COL 11N8E-3.4b, 159 ft., 11/4/55	2.2							0.7	

*Well number, depth of well, and sample collection date are shown after each owner.

Dev, Devonian; Dev-Sil, Devonian and Silurian; Pen, Pennsylvanian

Chloride (Cl)	Nitrate (NO_3)	Sulfate (SO_4)	Alkalinity	Hardness	Total dissolved minerals	pH	Temperature (°F)	Aquifer
			(as CaCo3)					
79.0	0.1	11.5	360	230	510	7.4	63.5	Dev
25.0	0.1	5.6	356	246	412		59.4	Dev-Sil
240.0	0.0	5.0	428	128	850	7.4		Pen
7.0	Tr	0.4	264	96	282	8.2	57.0	Pen
76.0	0.2	3.9	680	26	867		61.0	Pen
18.0	0.7		472	264	495			Pen

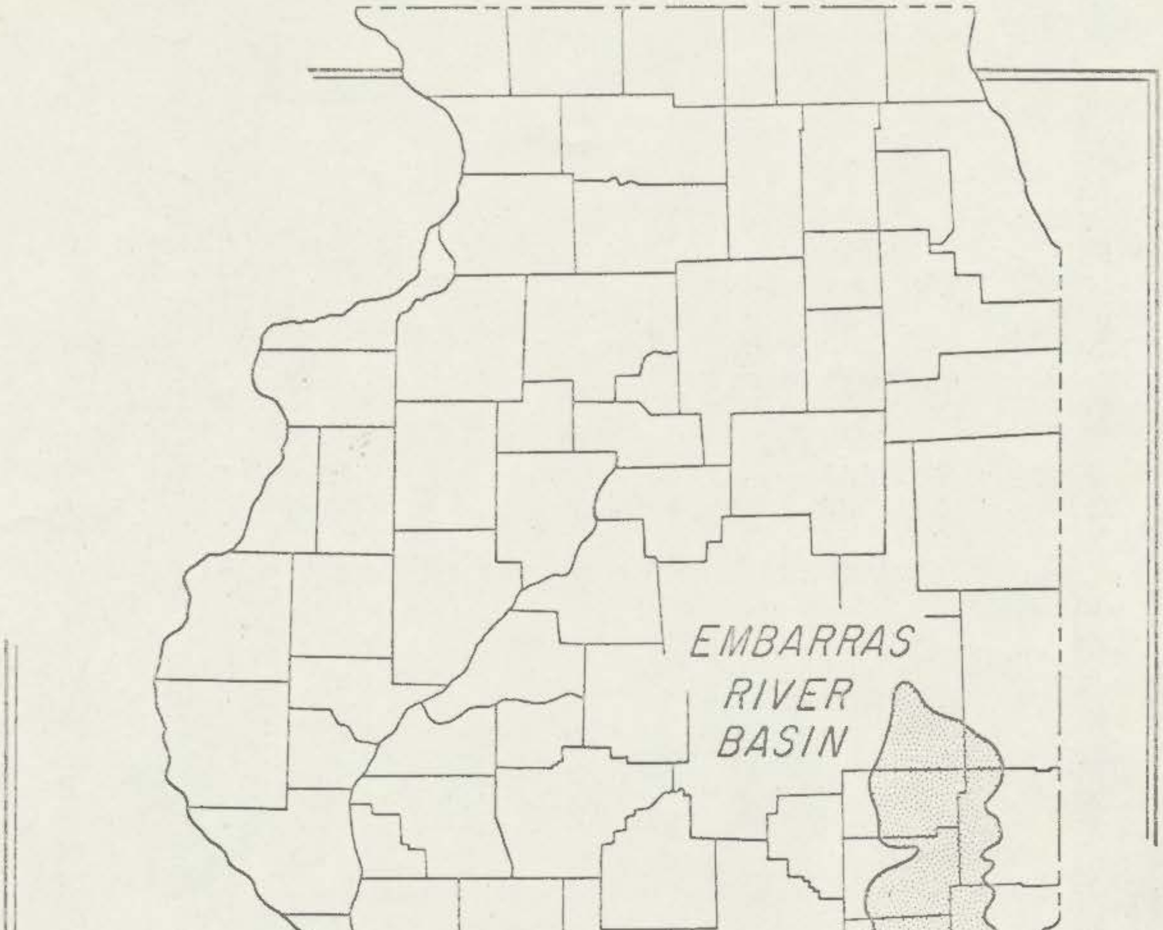


Figure 1. Location of Embarras River Basin

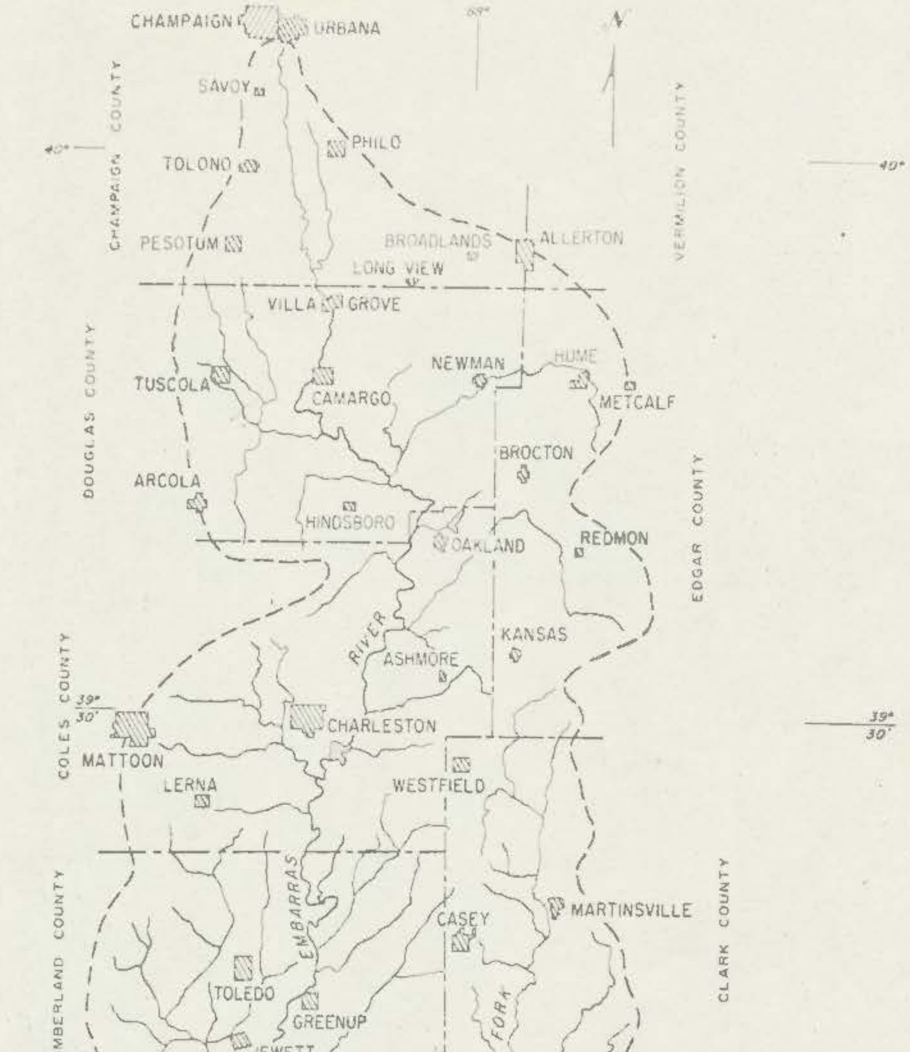


Figure 2. Principal geographic features

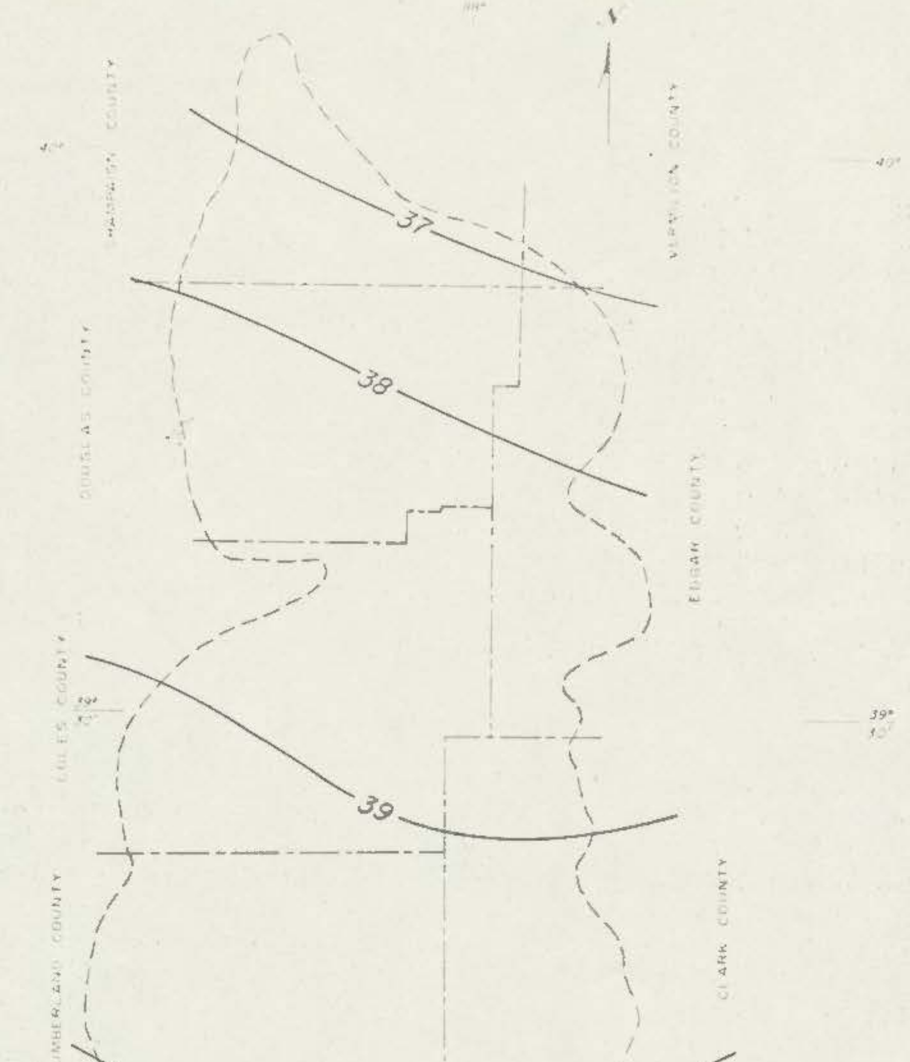


Figure 3. Average annual precipitation

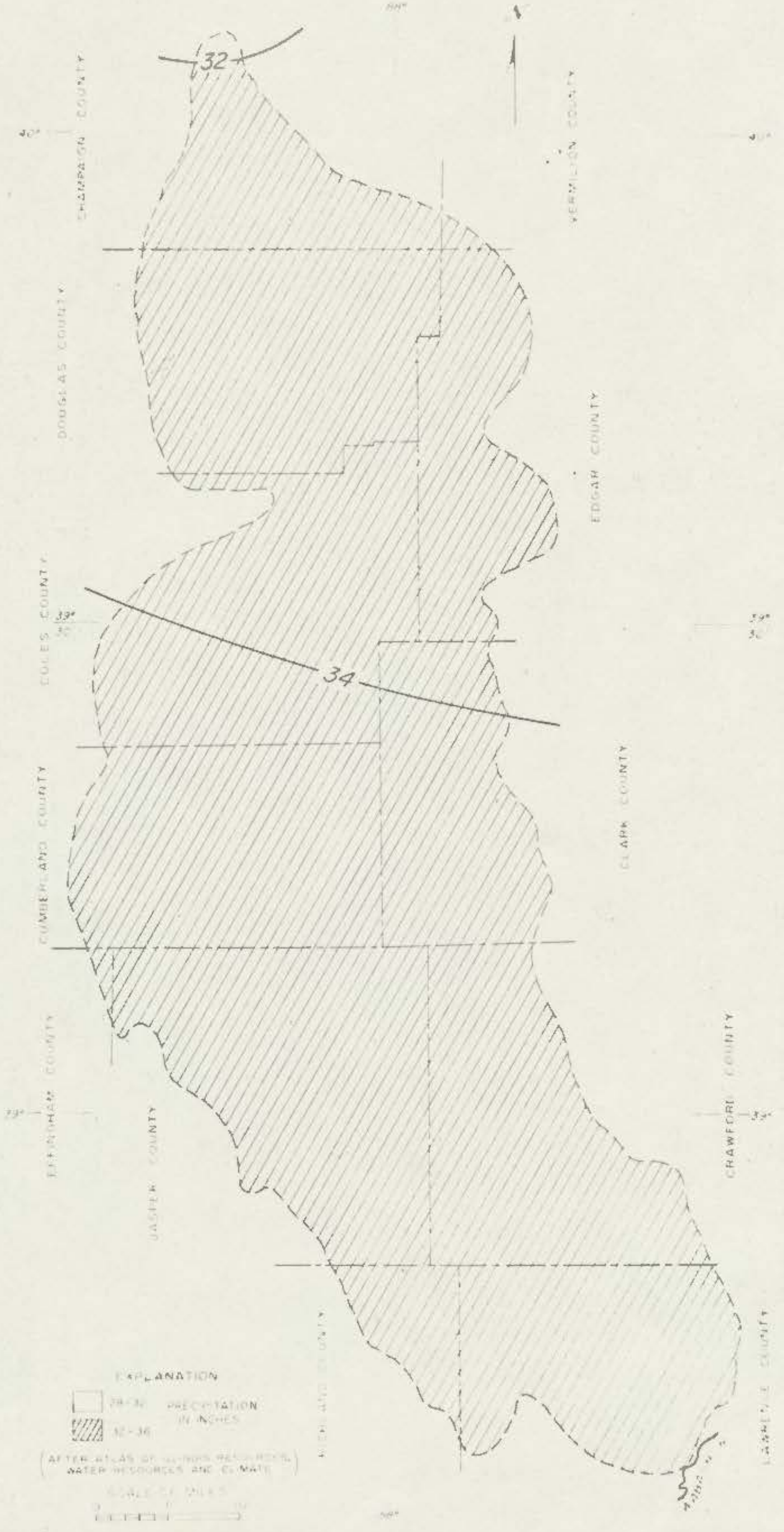
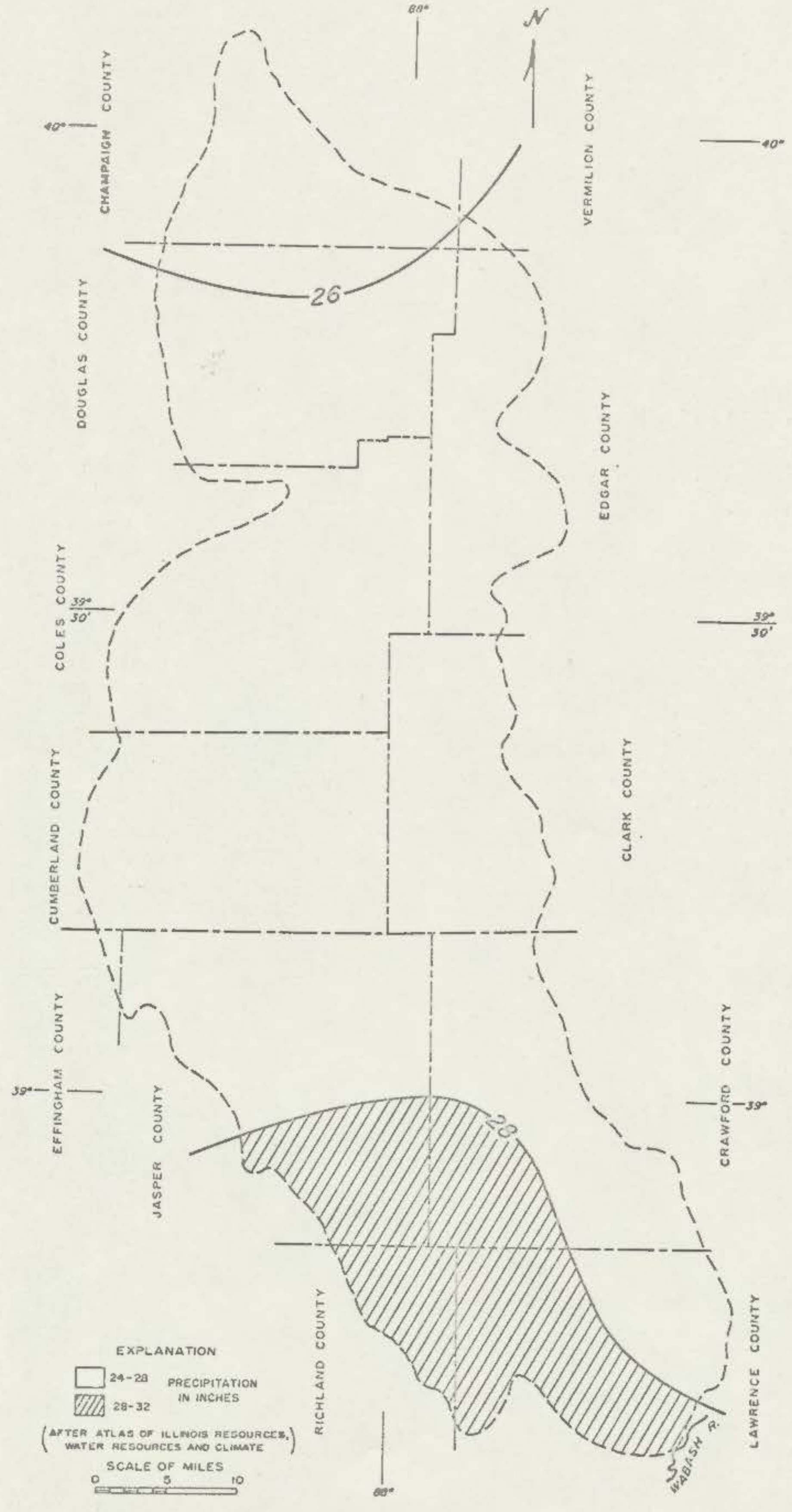


Figure 4. Lowest annual precipitation expected once in 5 years



(AFTER ATLAS OF ILLINOIS RESOURCES, WATER RESOURCES AND CLIMATE)

Figure 5. Lowest annual precipitation expected once in 50 years

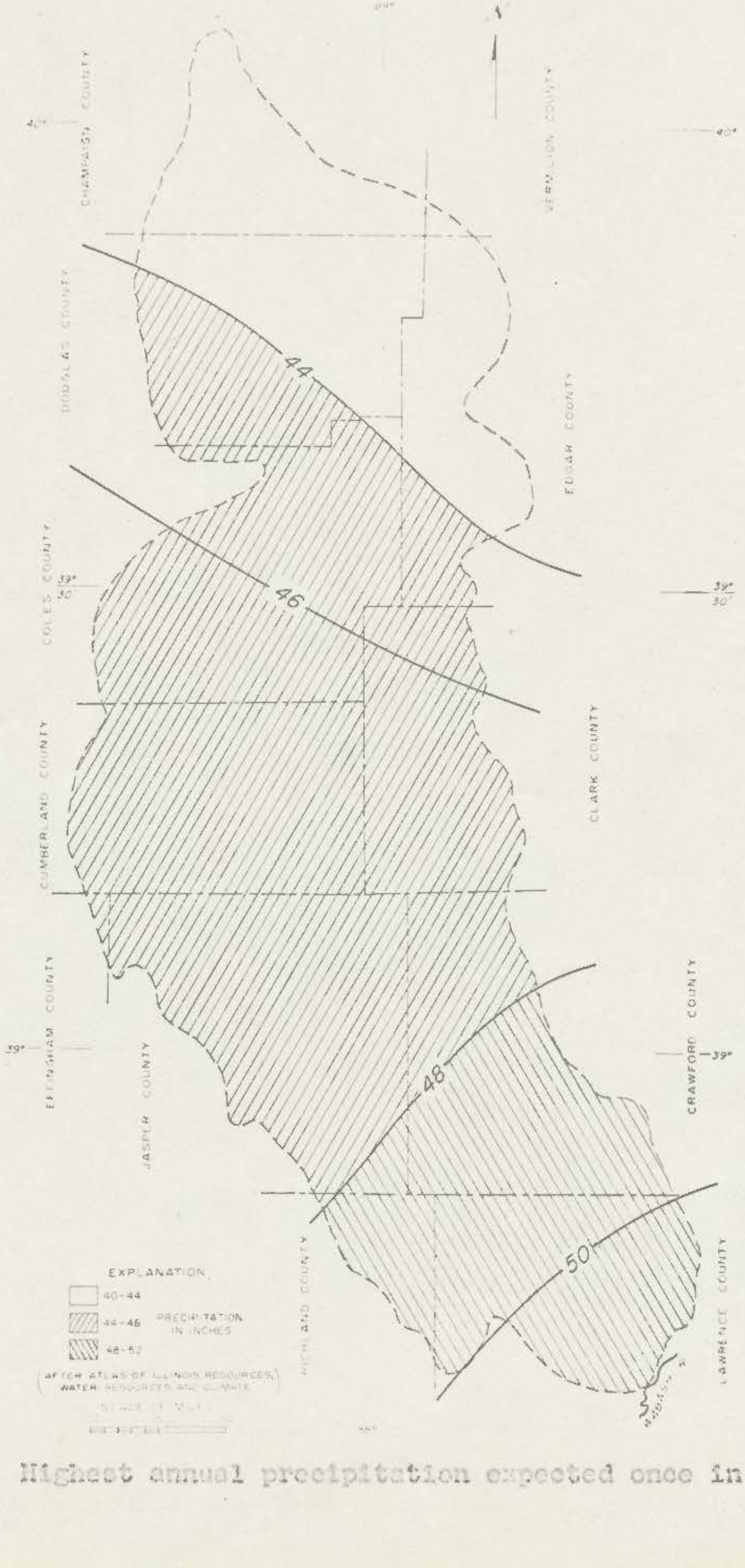


Figure 6. Highest annual precipitation expected once in 5 years

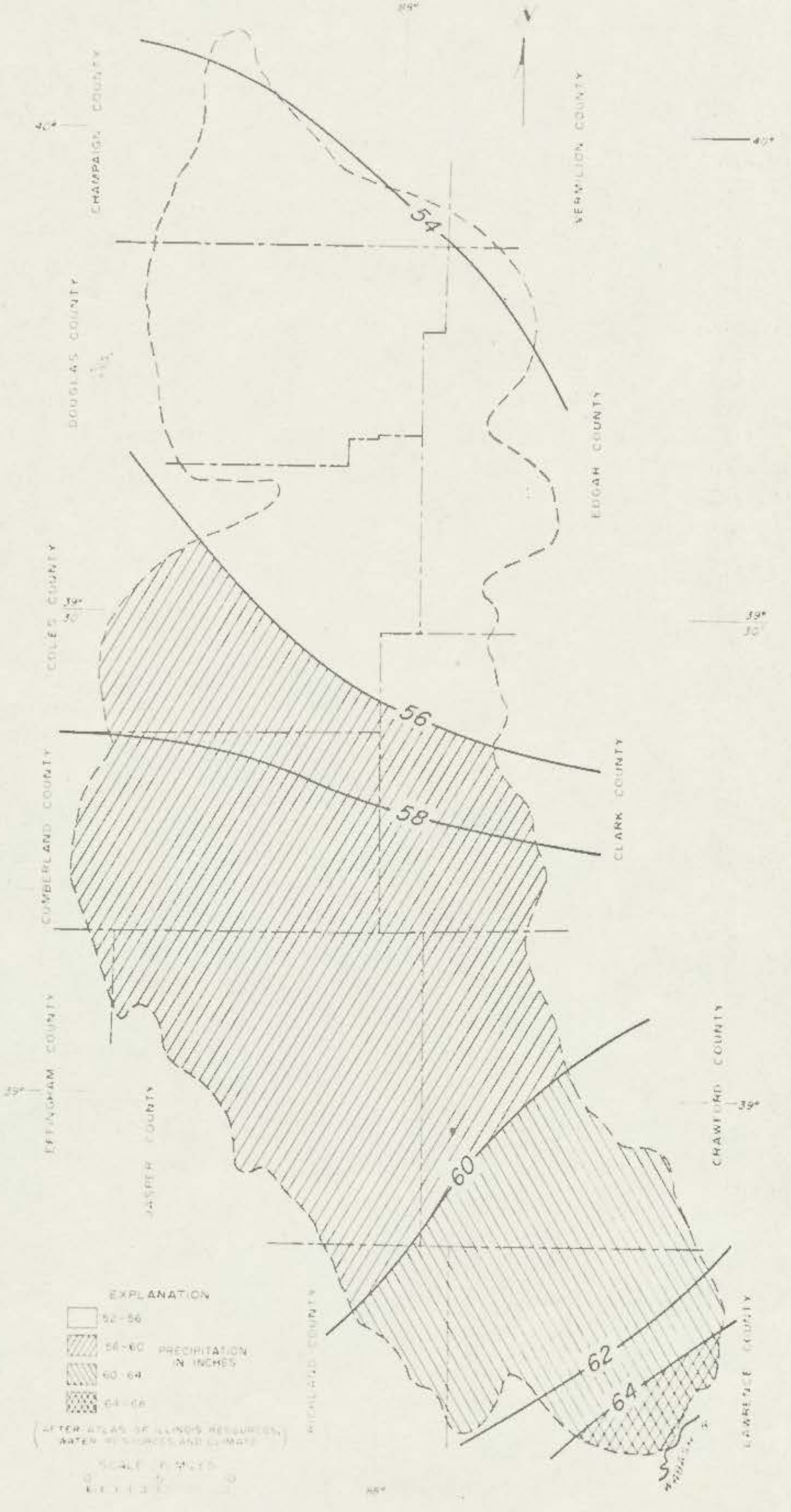
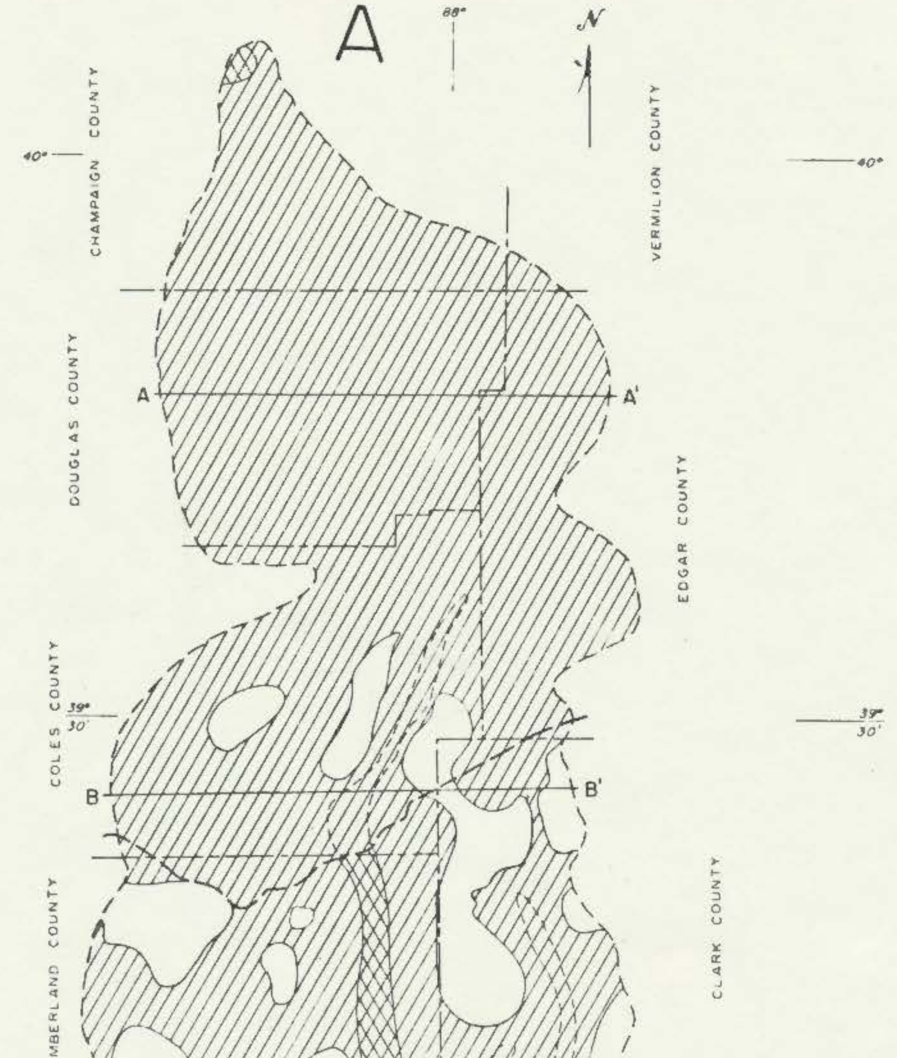


Figure 7. Highest annual precipitation expected once in 50 years

Figure 8. Probabilities of occurrence and distribution of sand and gravel aquifers (A) and areal distribution, type and water-yielding character of upper bedrock formations (B)

A


88°
N
40°
CHAMPAIGN COUNTY
VERMILION COUNTY
40°
DOUGLAS COUNTY
A
A'
EDGAR COUNTY
COLES COUNTY
39° 30'
39° 30'
B
B'
CUMBERLAND COUNTY
CLARK COUNTY
EFFINGHAM COUNTY
JASPER COUNTY
39°
C
C'
CRAWFORD COUNTY
39°
EXPLANATION
GOOD TO EXCELLENT; AQUIFER HIGHLY PERMEABLE AND WIDELY DISTRIBUTED
FAIR TO GOOD; AQUIFERS VARIABLE IN PERMEABILITY, SCATTERED AND DISCONTINUOUS
POOR; SAND AND GRAVEL DEPOSITS GENERALLY ABSENT
AREA OF THICKER DRIFT IN BEDROCK VALLEY; LITTLE SUBSURFACE INFORMATION AVAILABLE; AREA MERITS FURTHER INVESTIGATIONS
LIMIT OF WISCONSIN GLACIATION
GEOLOGIC CROSS SECTION
(AFTER SELKREGG, ET AL, 1957 AND SELKREGG AND KEMPTON, 1958)
SCALE OF MILES
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RICHLAND COUNTY
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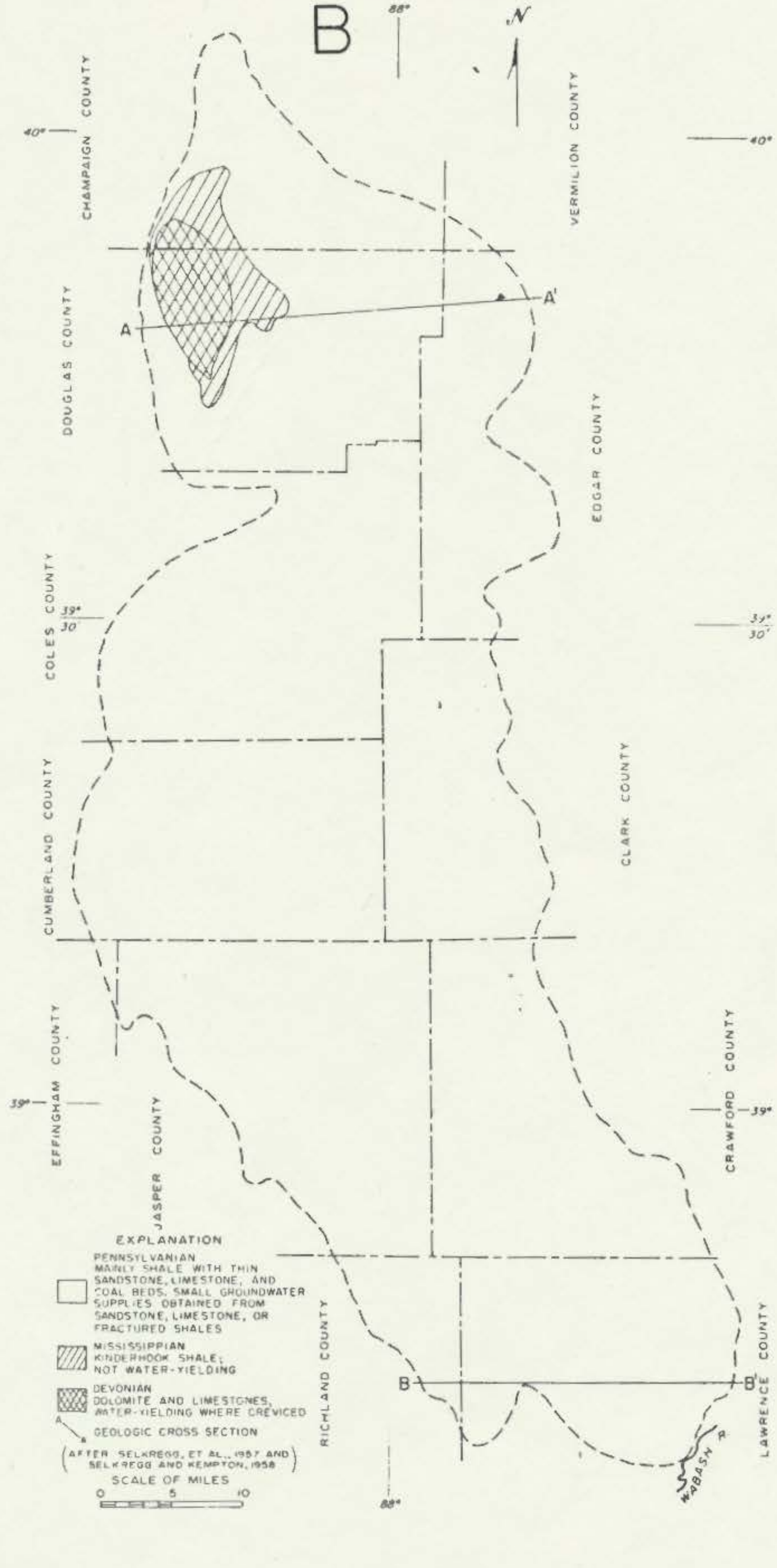
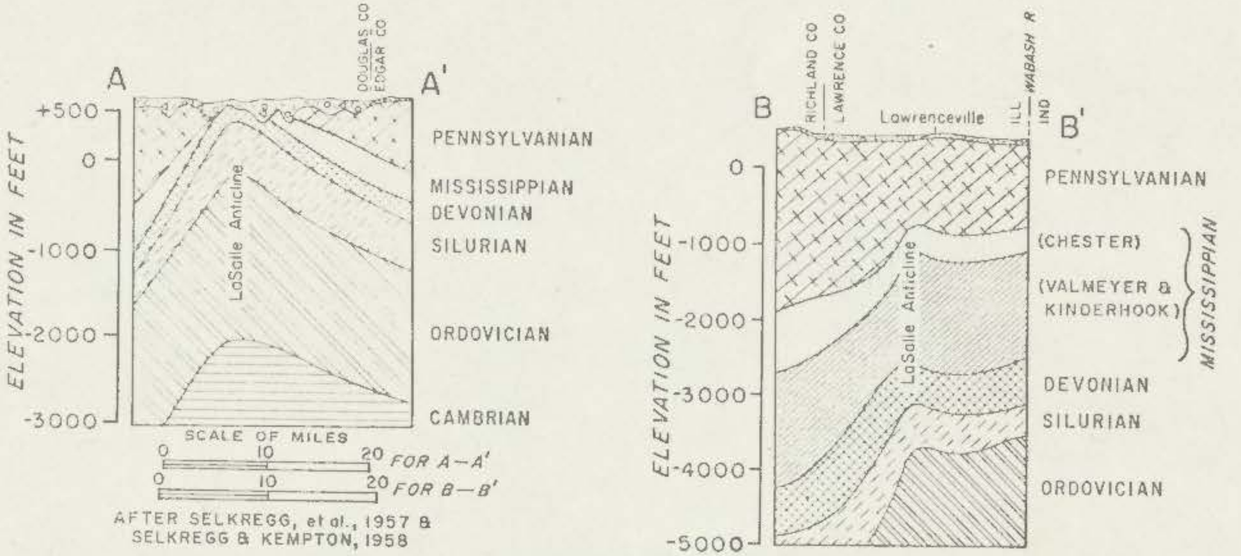
D'
LAWRENCE COUNTY
WABASH R
88°



(AFTER SELKREGG, ET AL., 1957 AND SELKREGG AND KEMPTON, 1958)



AFTER SELKREGG, et al., 1957 &
SELKREGG & KEMPTON, 1958

LOCATIONS OF CROSS SECTIONS
SHOWN IN FIGURE 8B

Figure 9. Cross sections of bedrock formations

Figure 10. Topography of bedrock surface

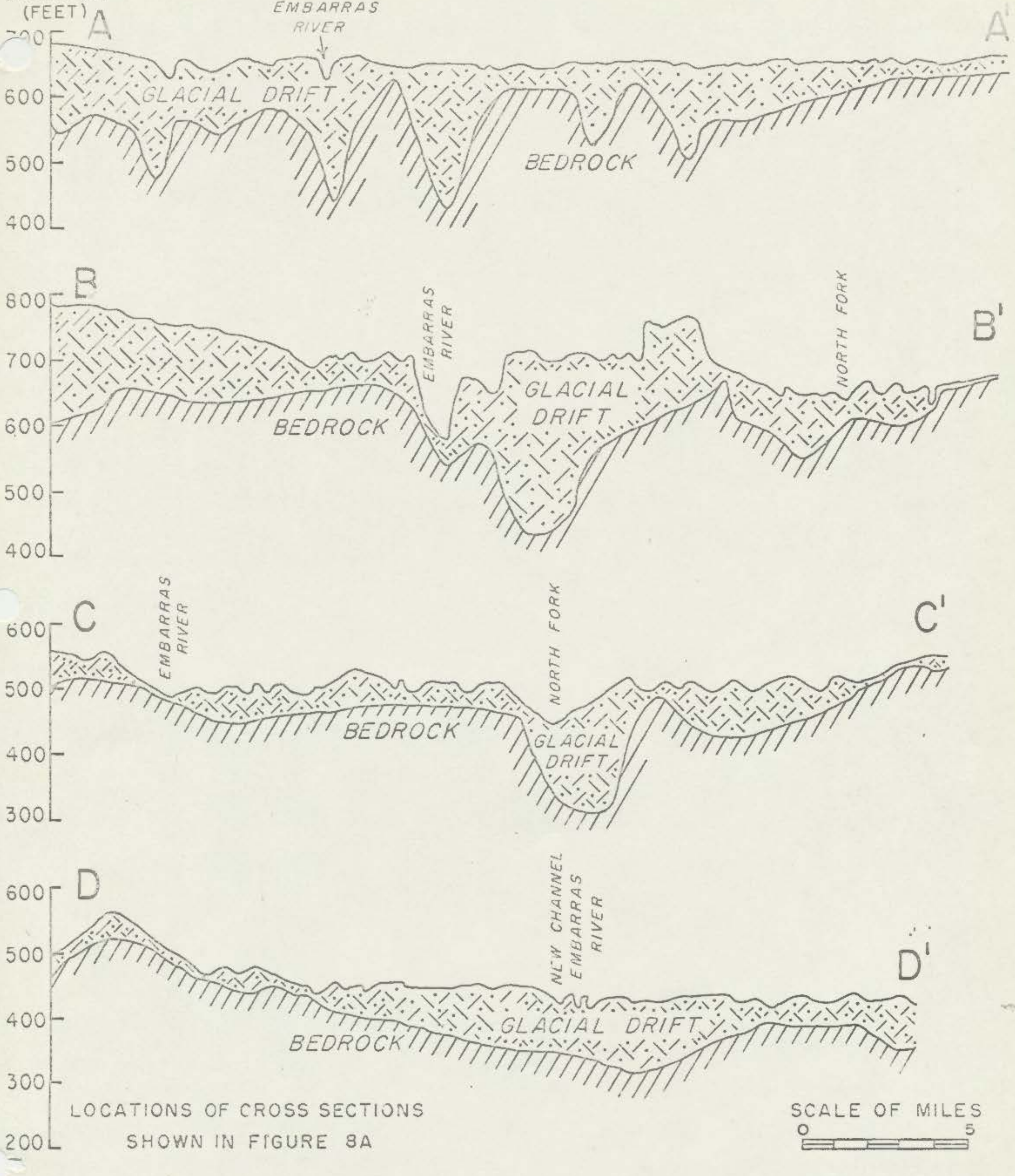


Figure 11. Cross sections of glacial drift

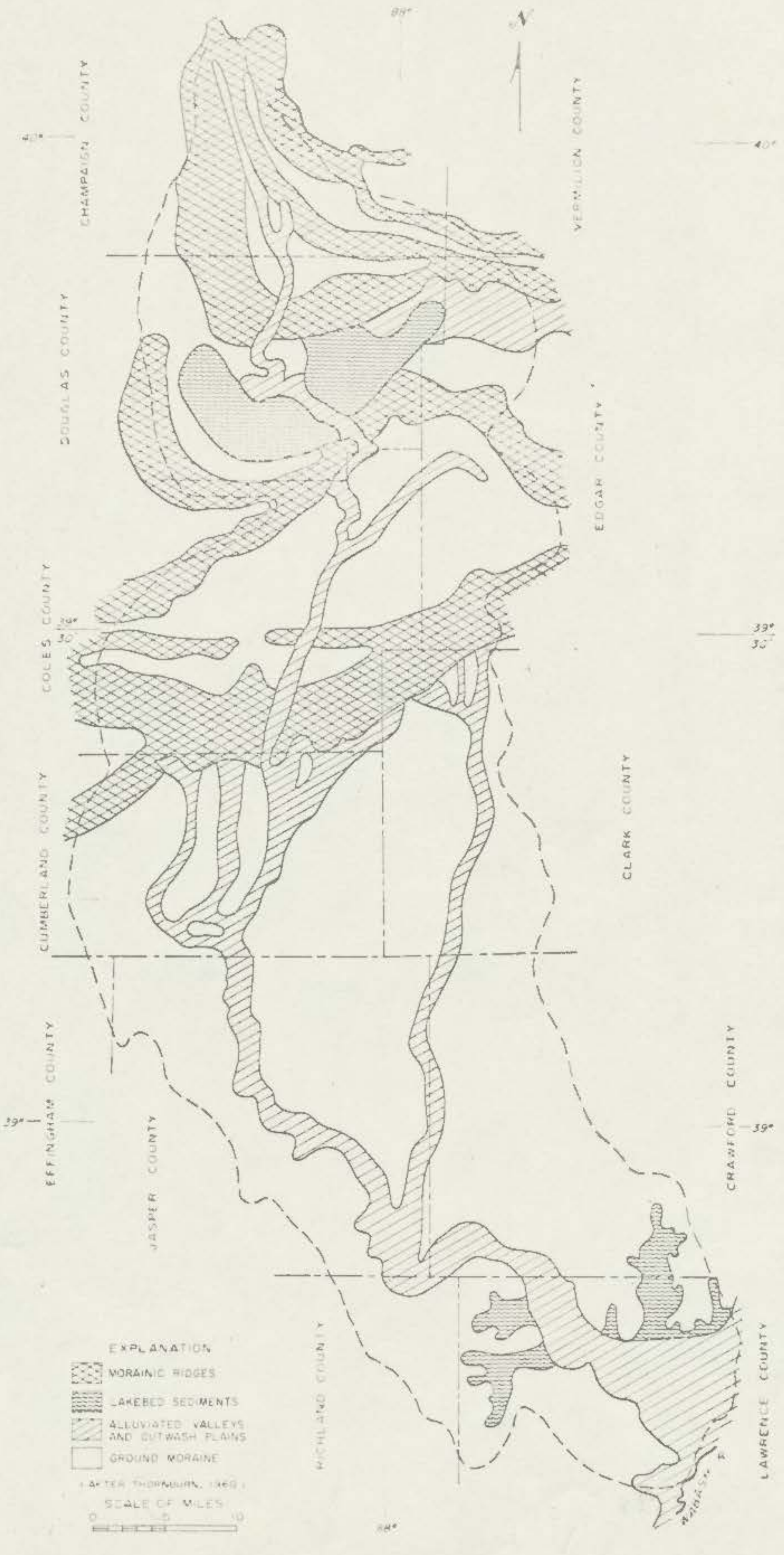


Figure 12. Surface deposits

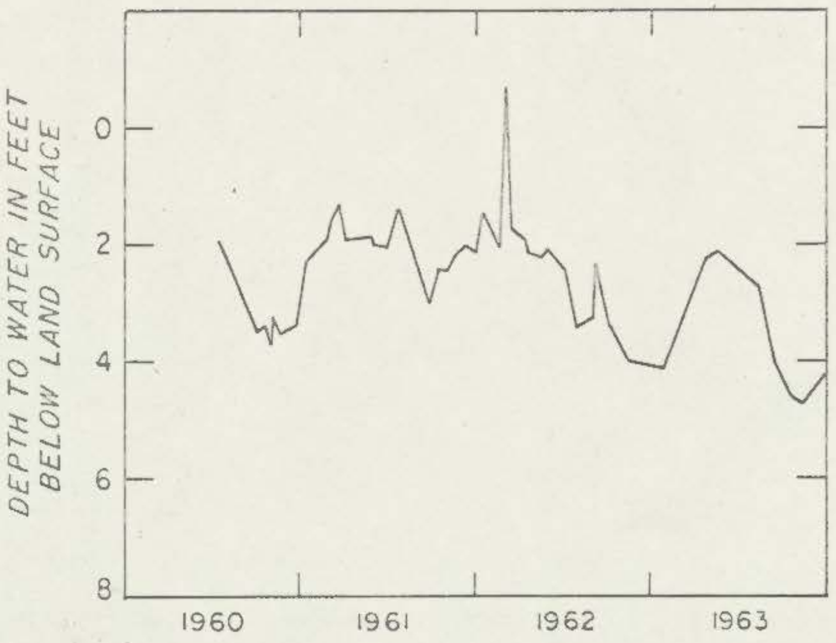


Figure 13. Water levels in well COL 11N9E-19.5g, 1960-1963

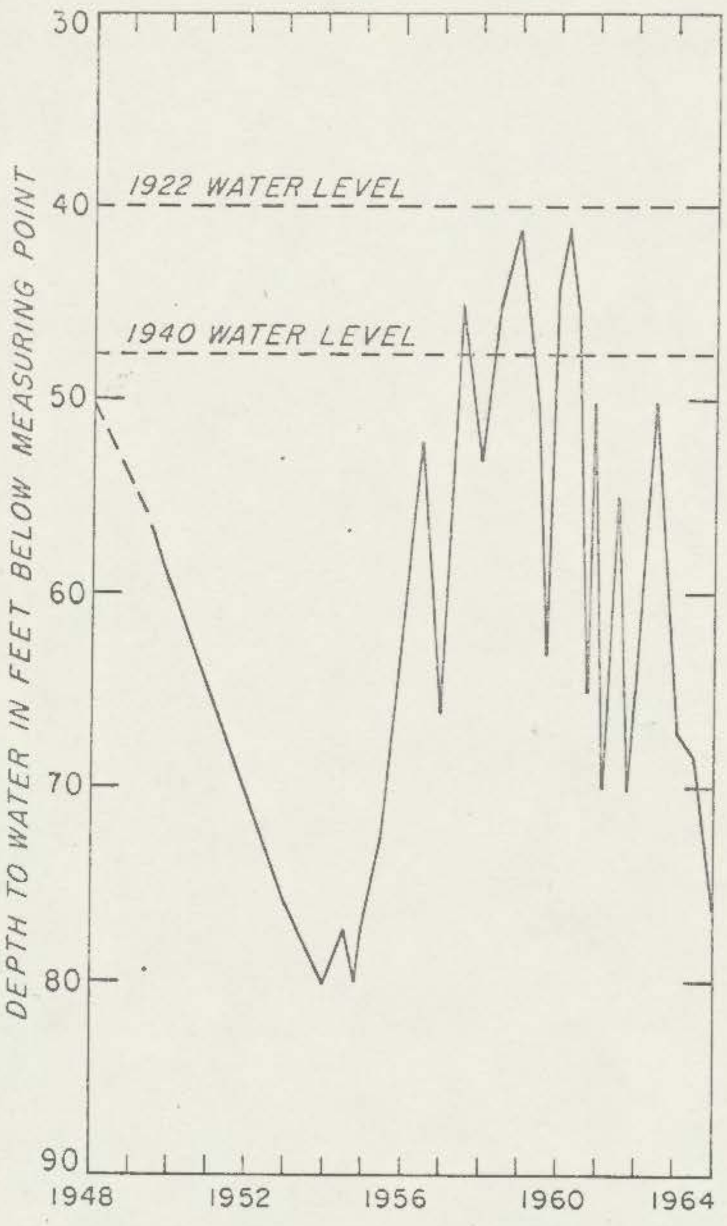


Figure 14. Water levels in well DGL 14N8E-4.4d, 1948-1964

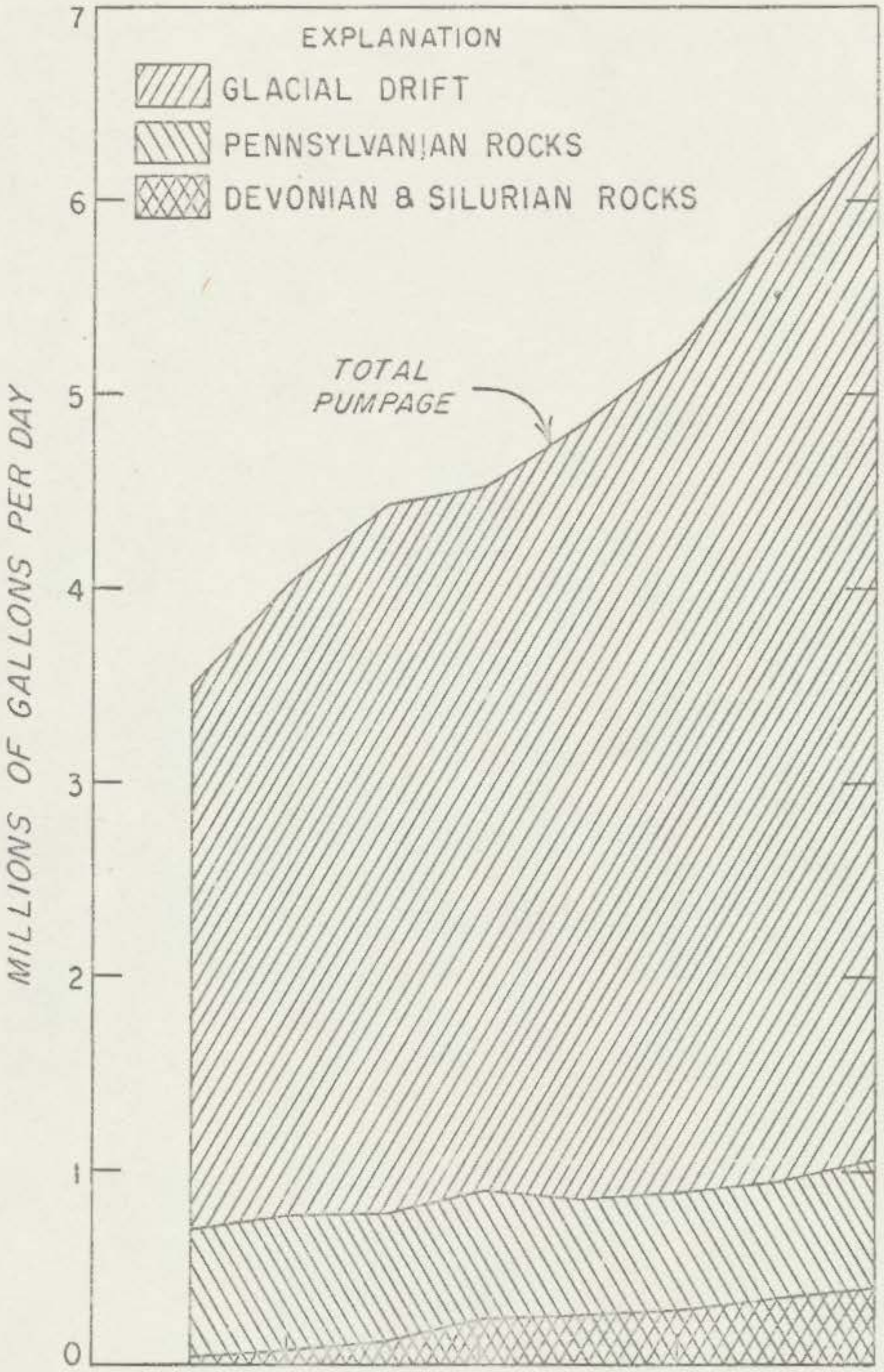


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Figure 15. Pumpage from wells, 1890-1960, subdivided by source

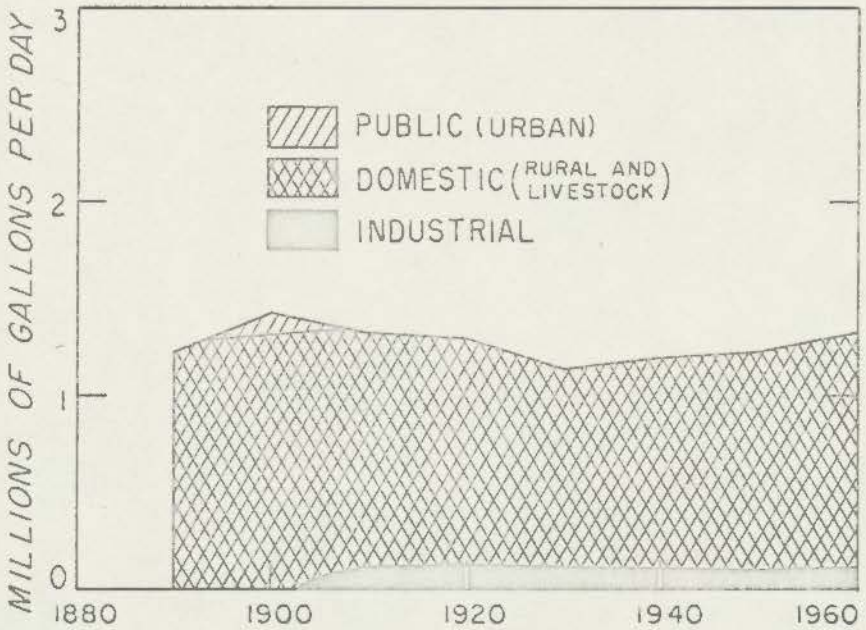

Figure 16. Pumpage from wells in Pennsylvanian rocks, 1890-1960, subdivided by use

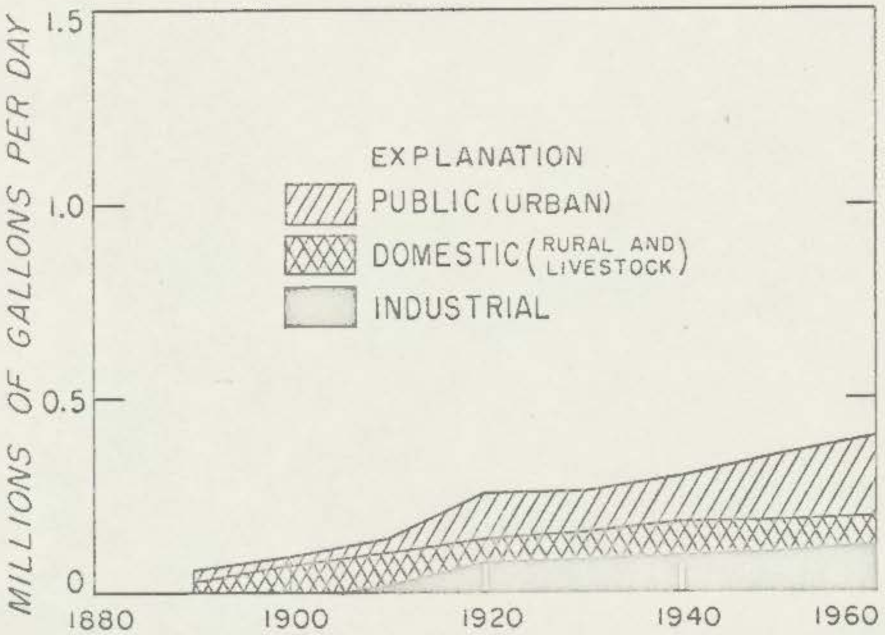

Figure 17. Pumpage from wells in Devonian and Silurian rocks, 1890-1960, subdivided by use

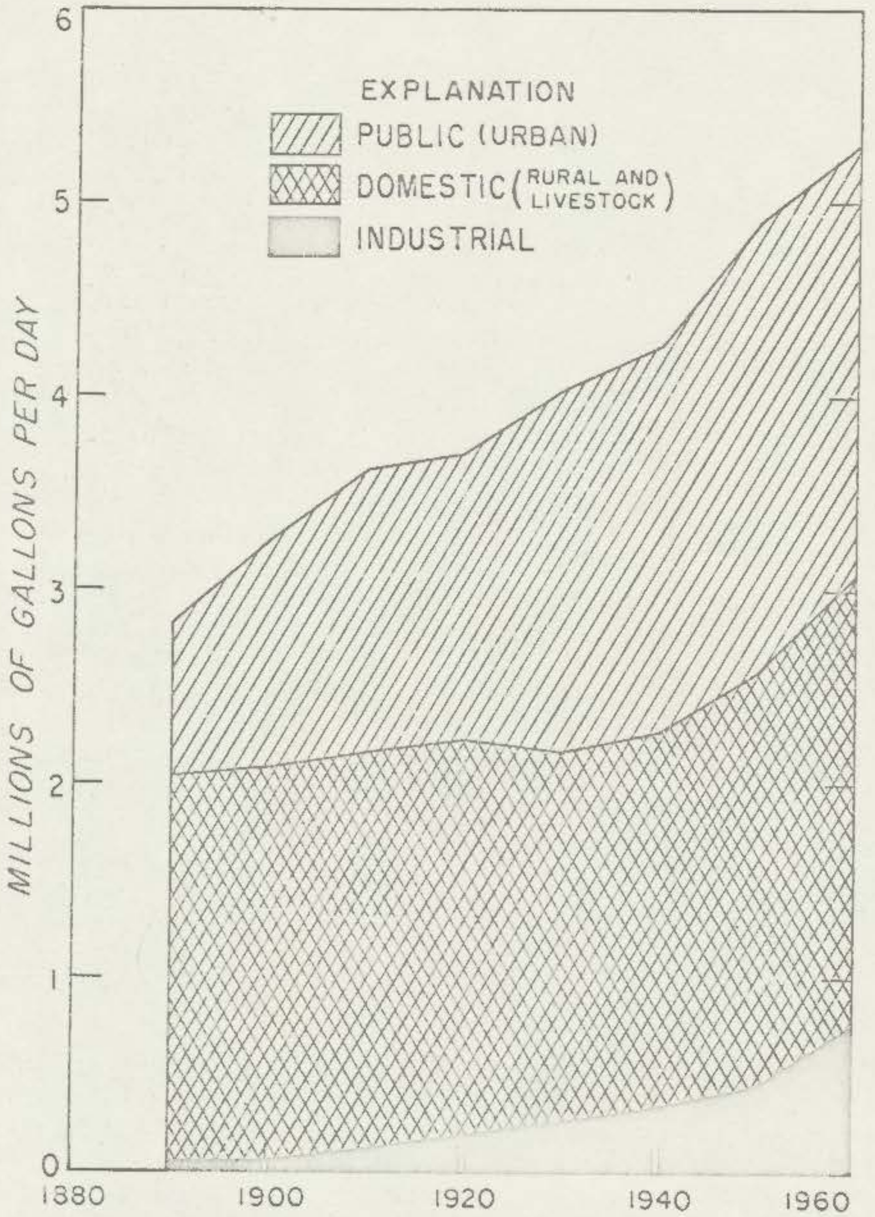

Figure 19. Pumpage from wells in glacial drift, 1890-1960, subdivided by use

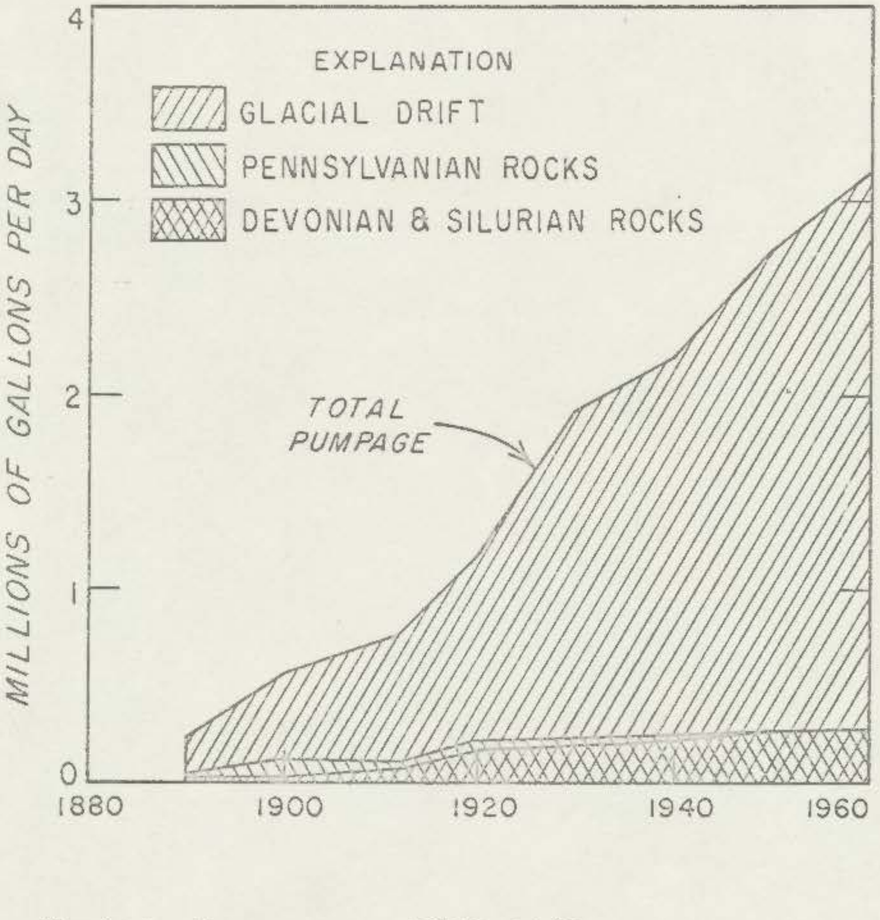

Figure 19. Municipal pumpage, 1890-1960, subdivided by source

Figure 20. Distribution of pumpage from wells in glacial drift in 1960

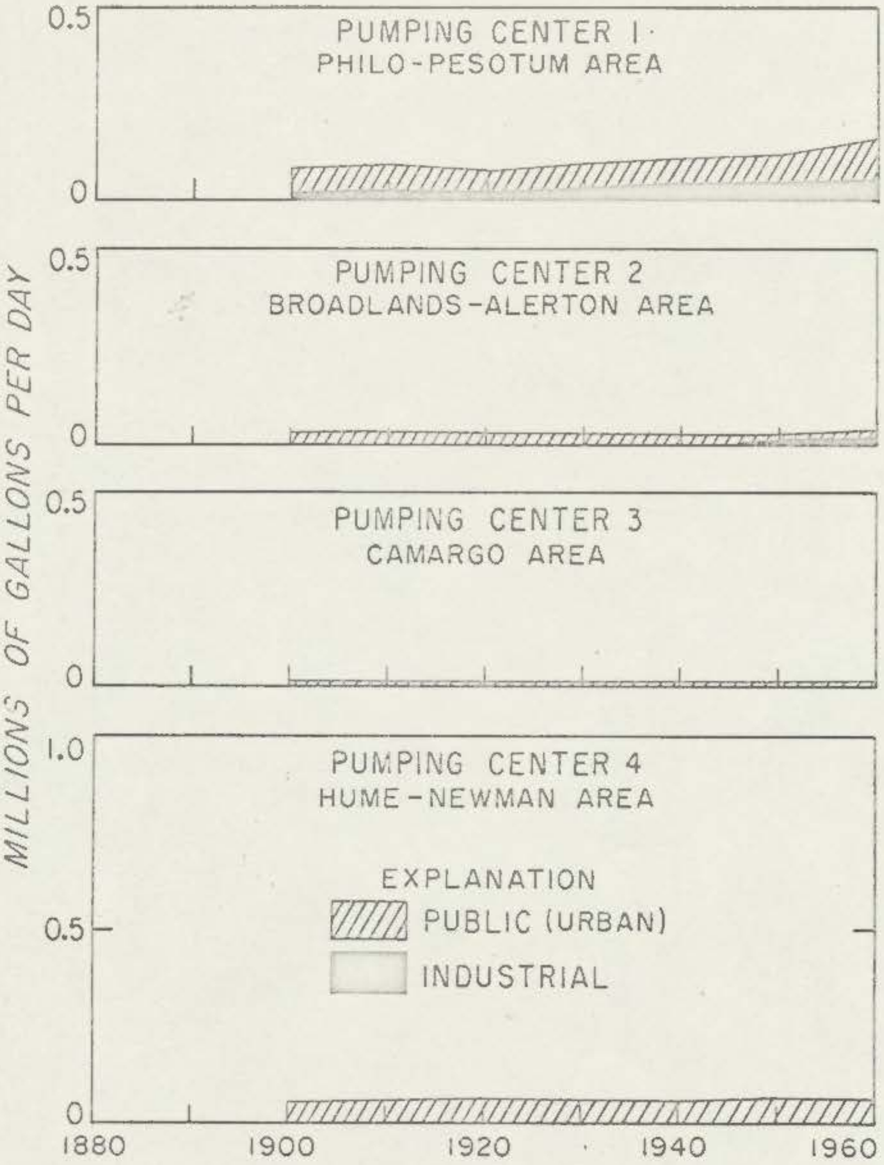

Figure 21. Pumpage in pumping centers 1-4, 1900-1960

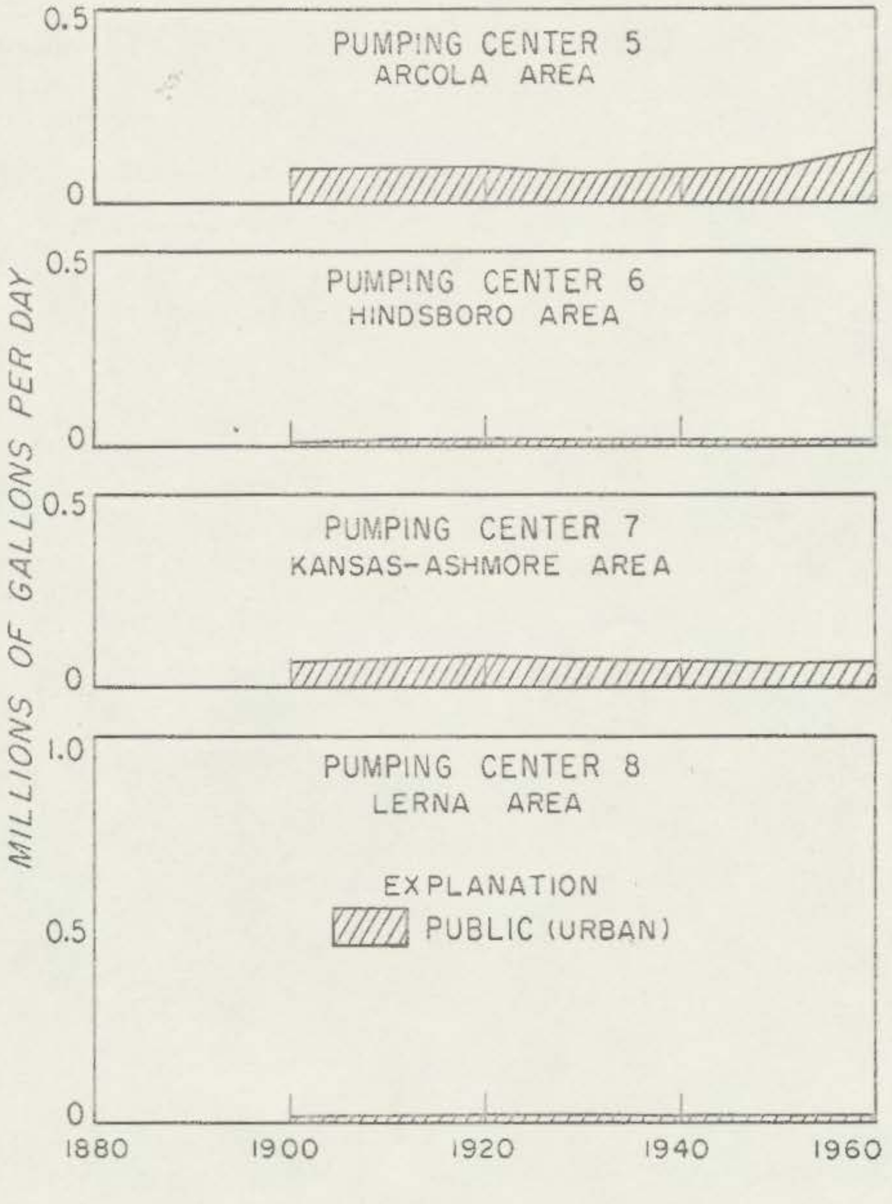

Figure 22. Pumpage in pumping centers 5-8, 1900-1960

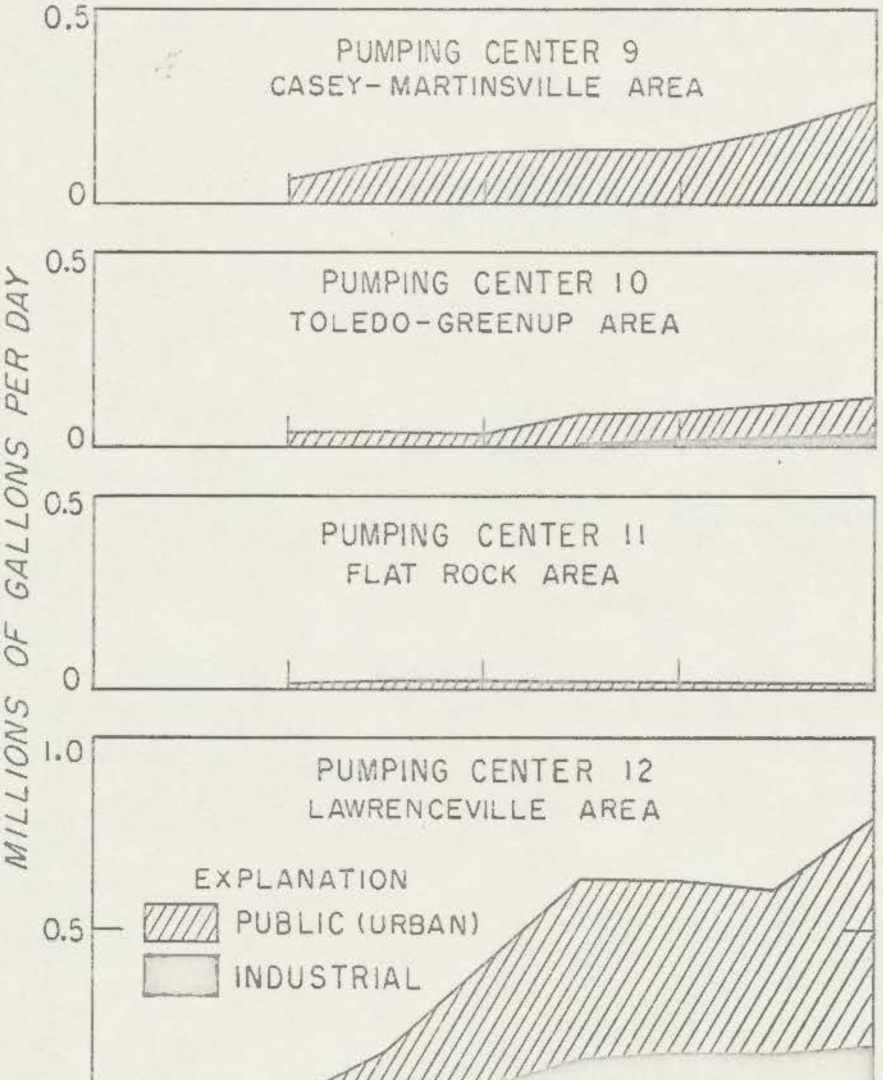

Figure 23. Pumpage in pumping centers 9-12, 1900-1960

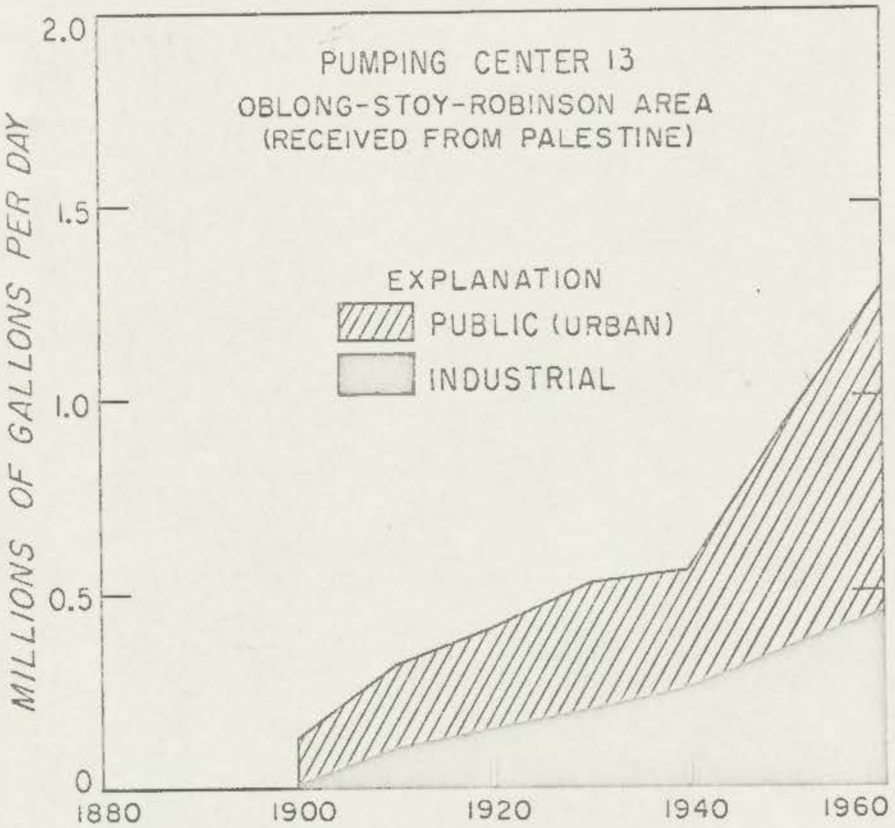

Figure 24. Pumpage in pumping center 13, 1900-1960

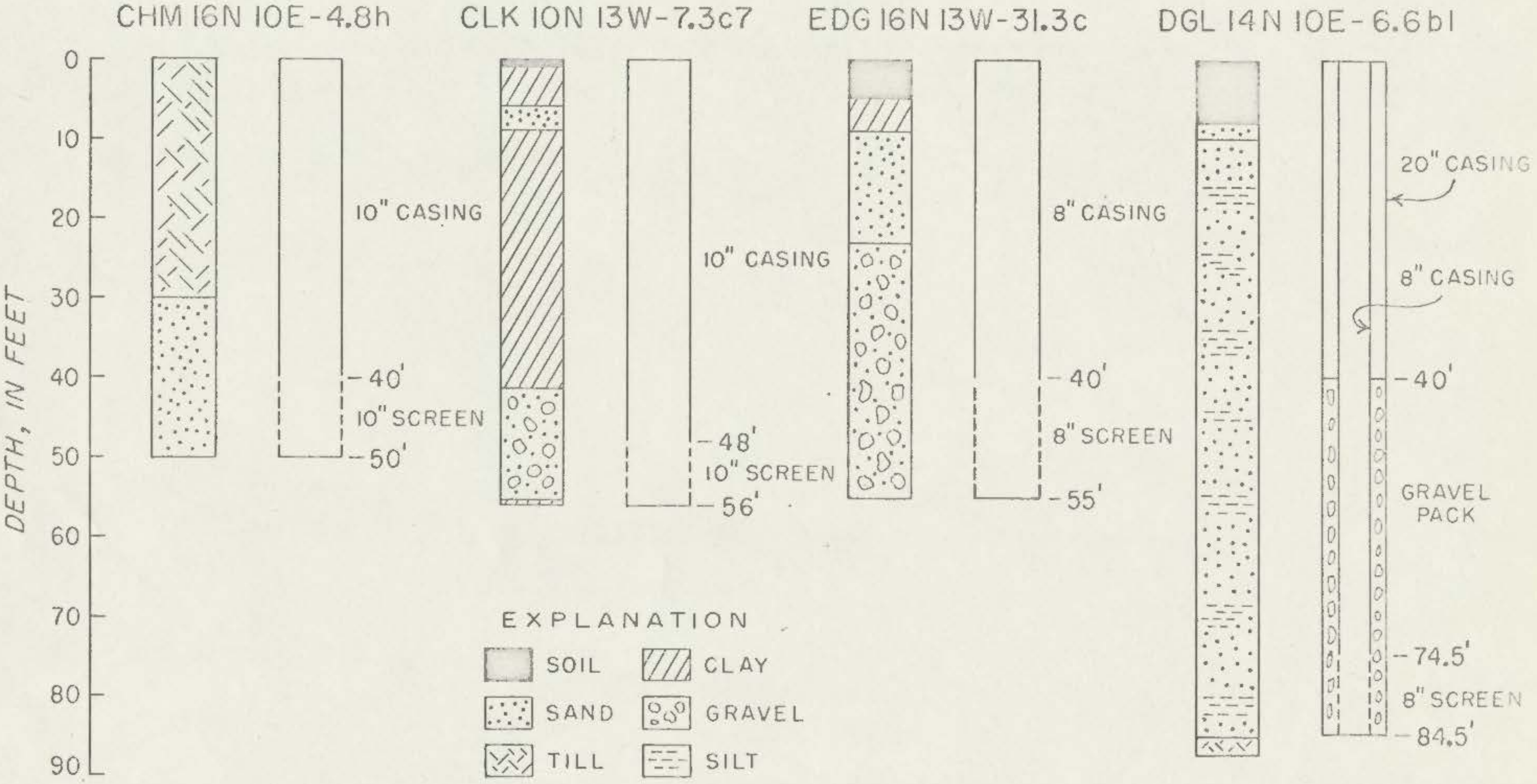

Figure 25. Construction features of selected wells in glacial drift

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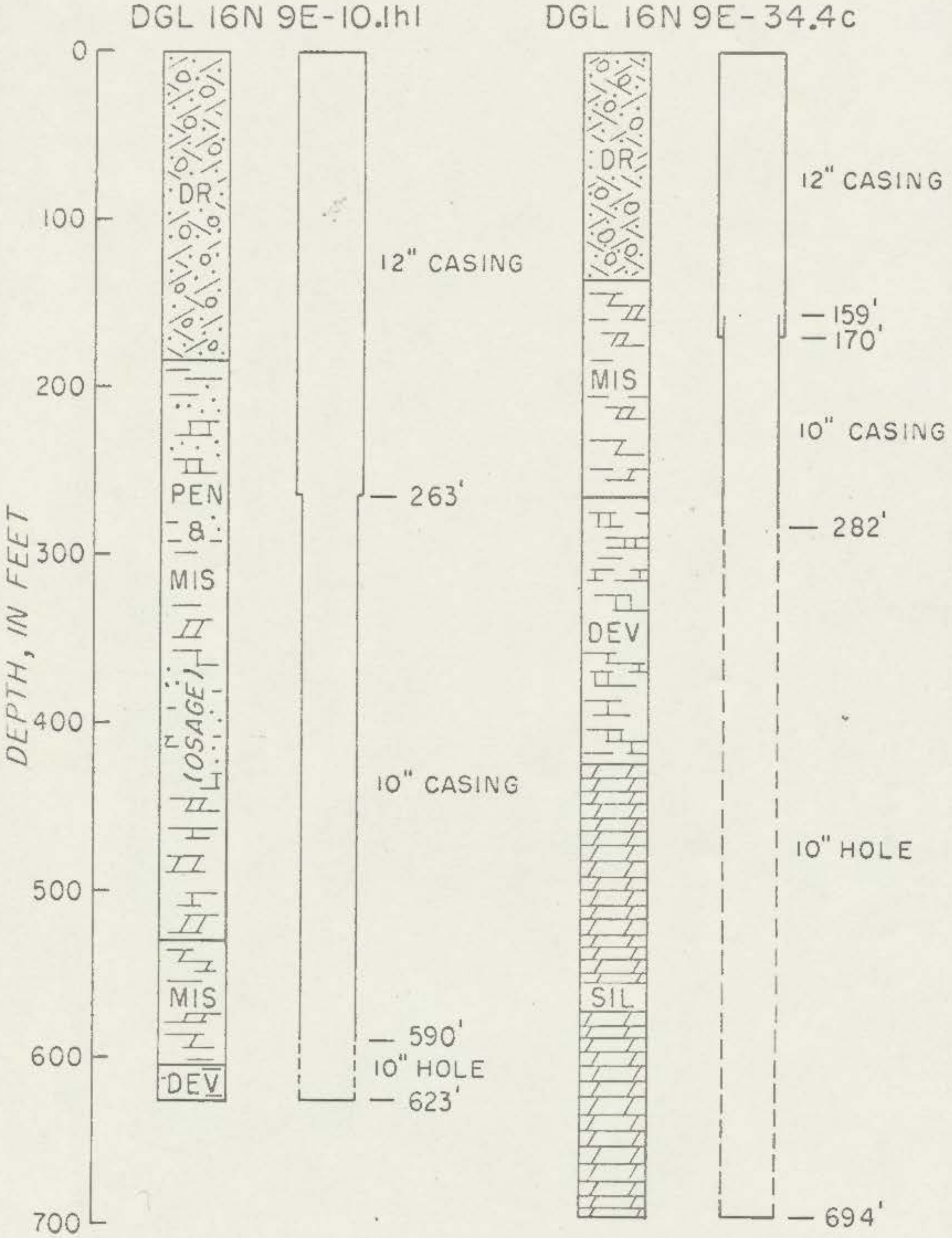


Devonian and

Figure 26. Construction features of selected wells in ~~Silurian~~
~~and/or Devonian rocks~~

to Devonian-Silurian rocks

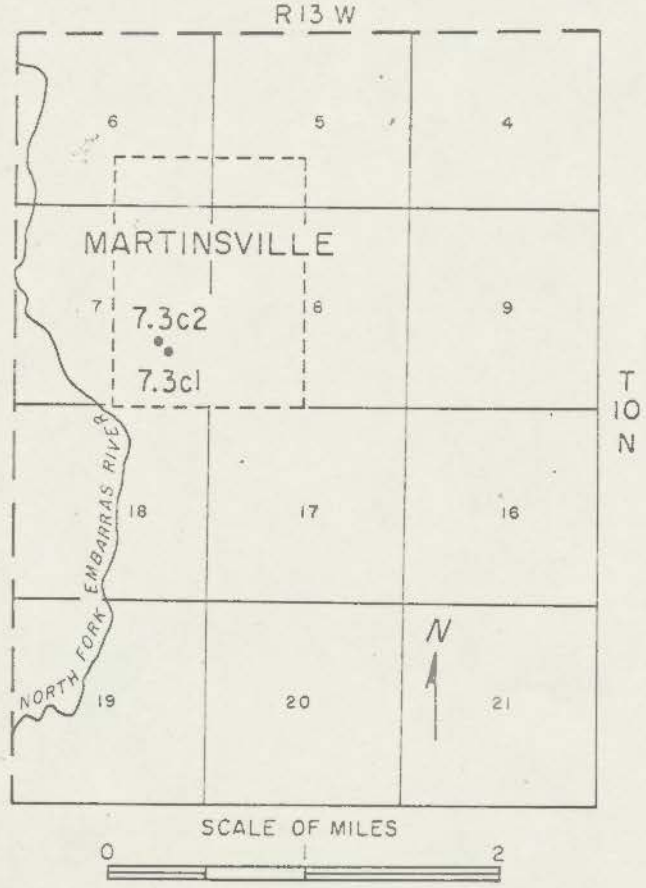


Figure 27. Location of wells used in aquifer test 1

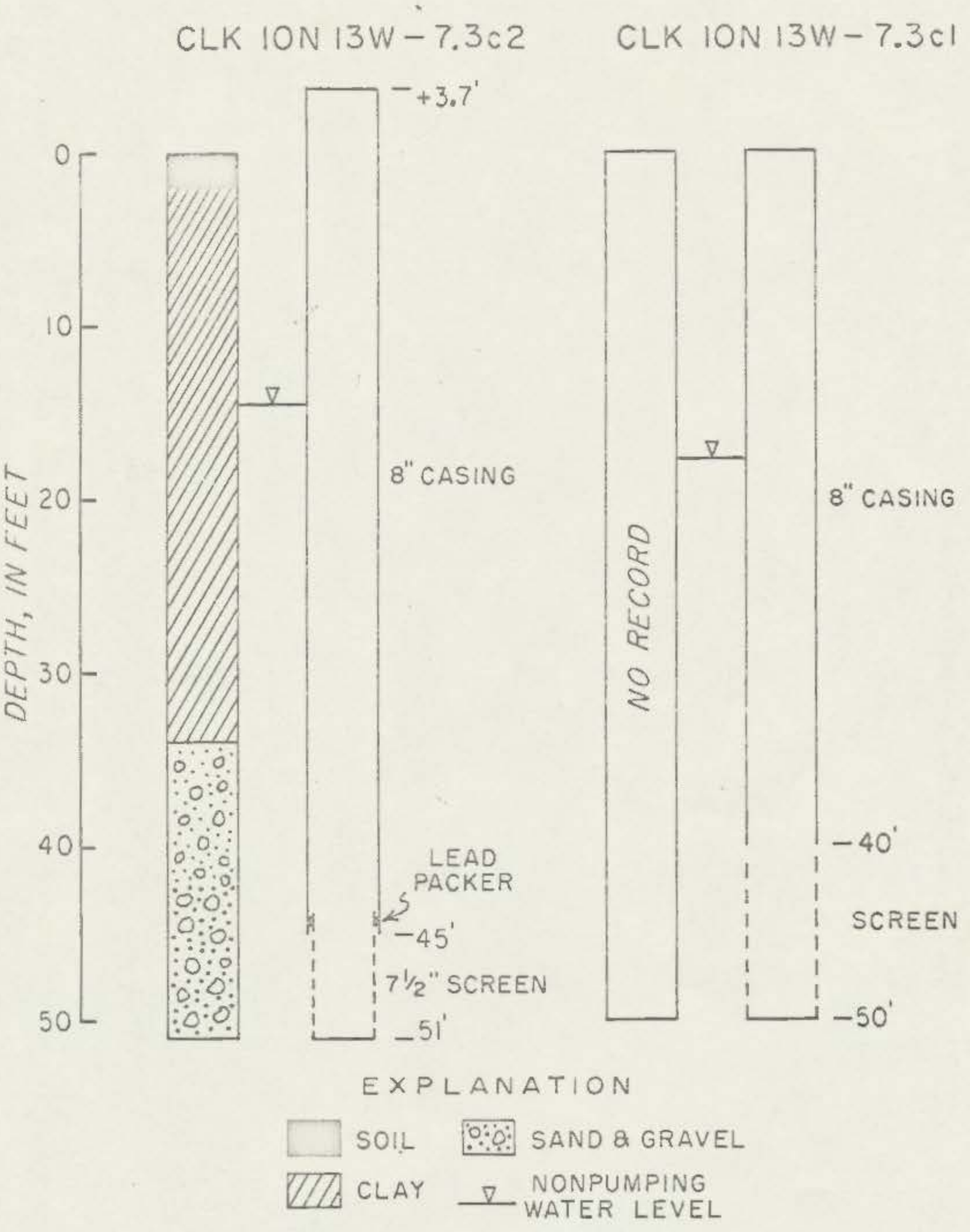
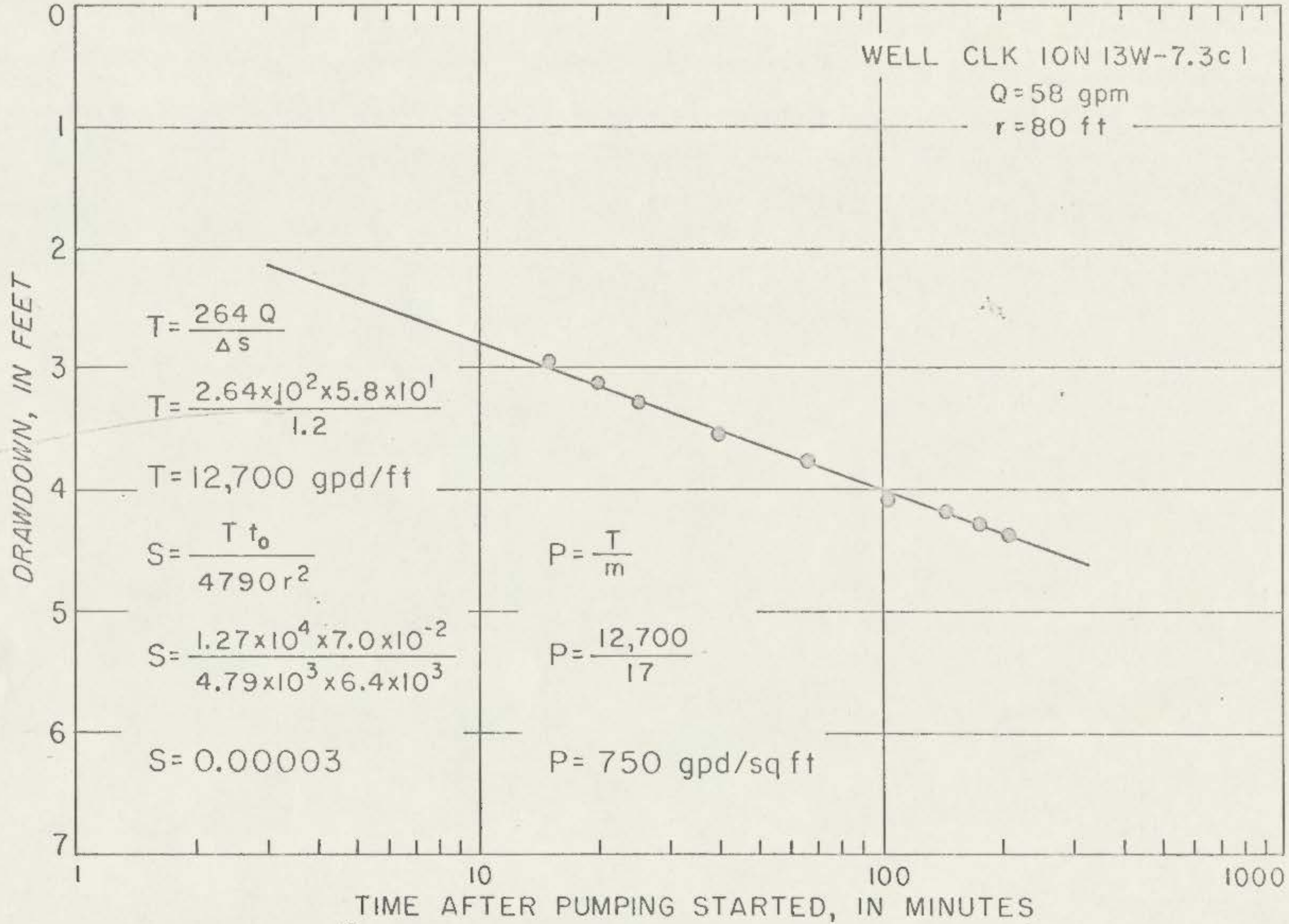


Figure 28. Generalized graphic logs of wells used in aquifer test 1



Check figure and Corr. if needed

Figure 2$\overset{8}{9}$. Time-drawdown graph for aquifer test 1

Figure ~~30~~ 29. Location of wells in aquifer test 2

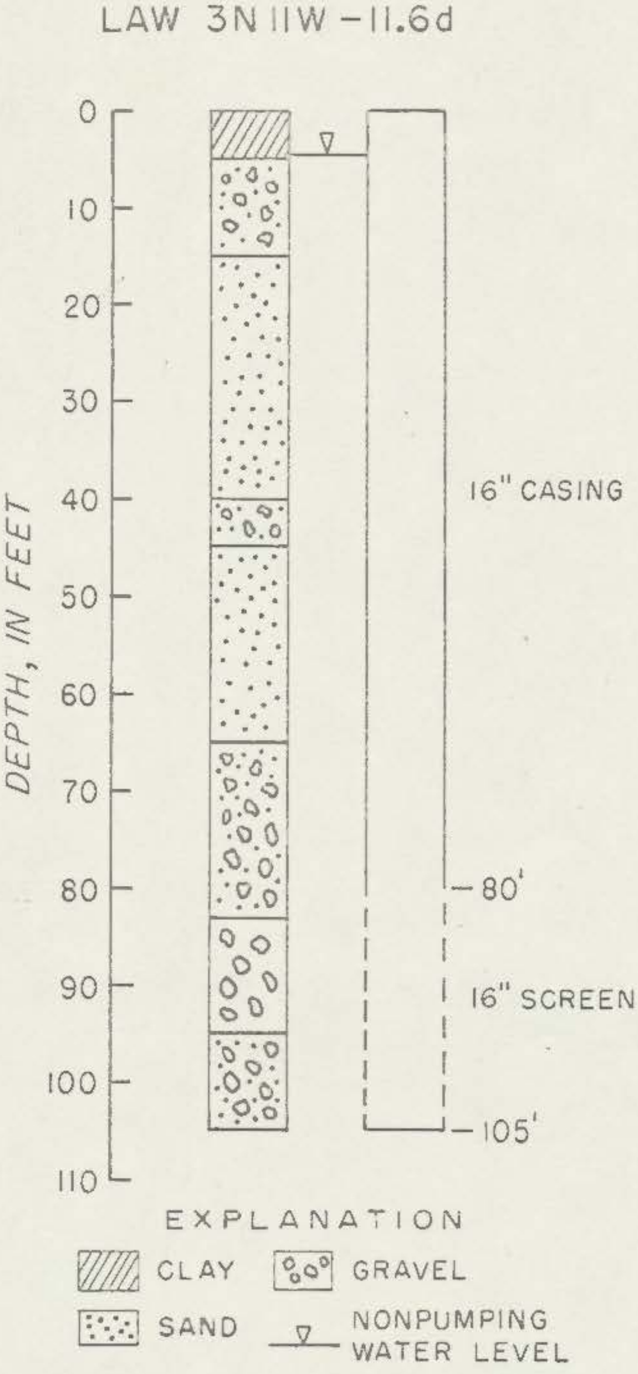


Figure 31. Generalized graphic log of pumped well used in aquifer test 2

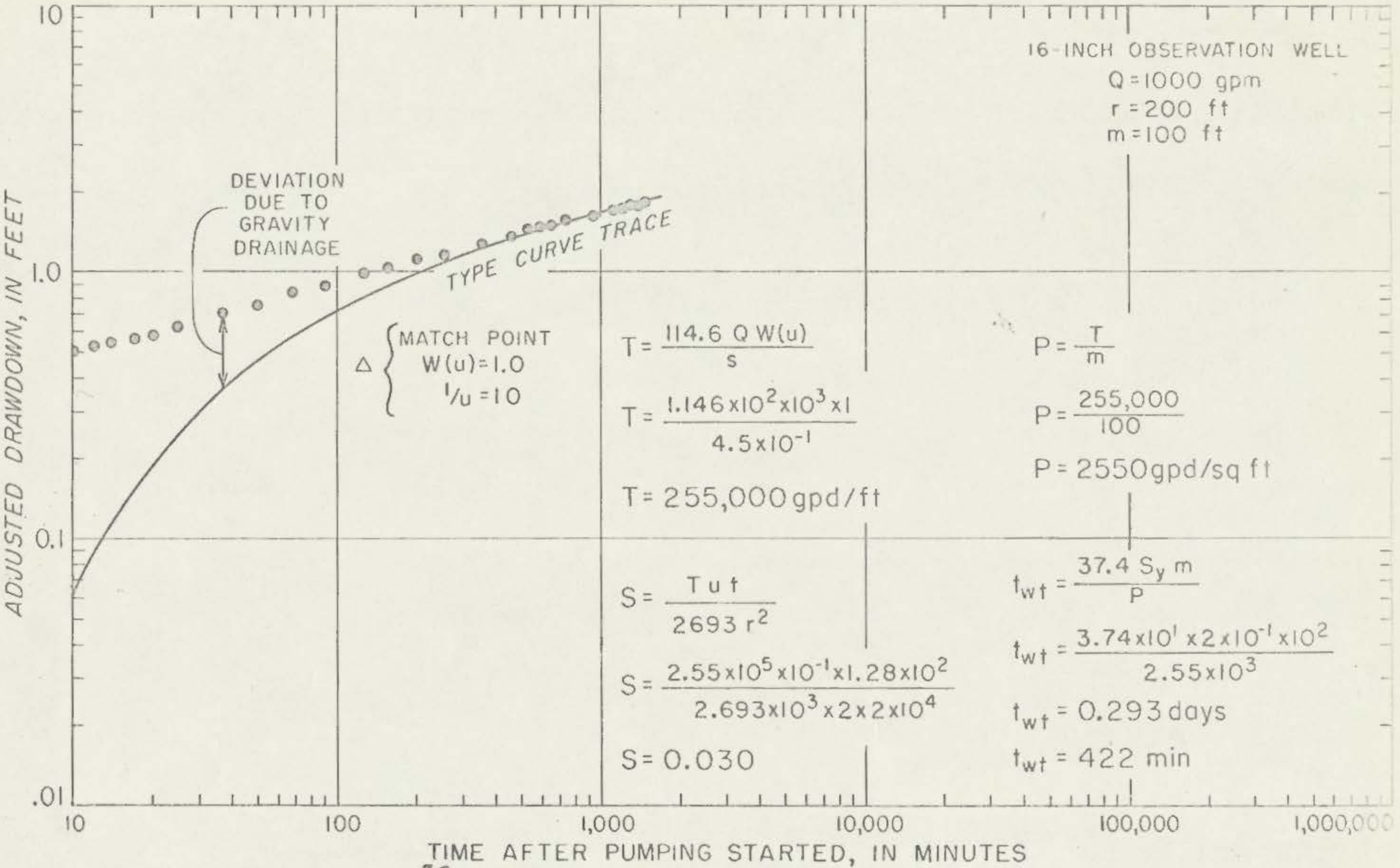


Figure ~~32~~ 30. Time-drawdown graph for aquifer test 2

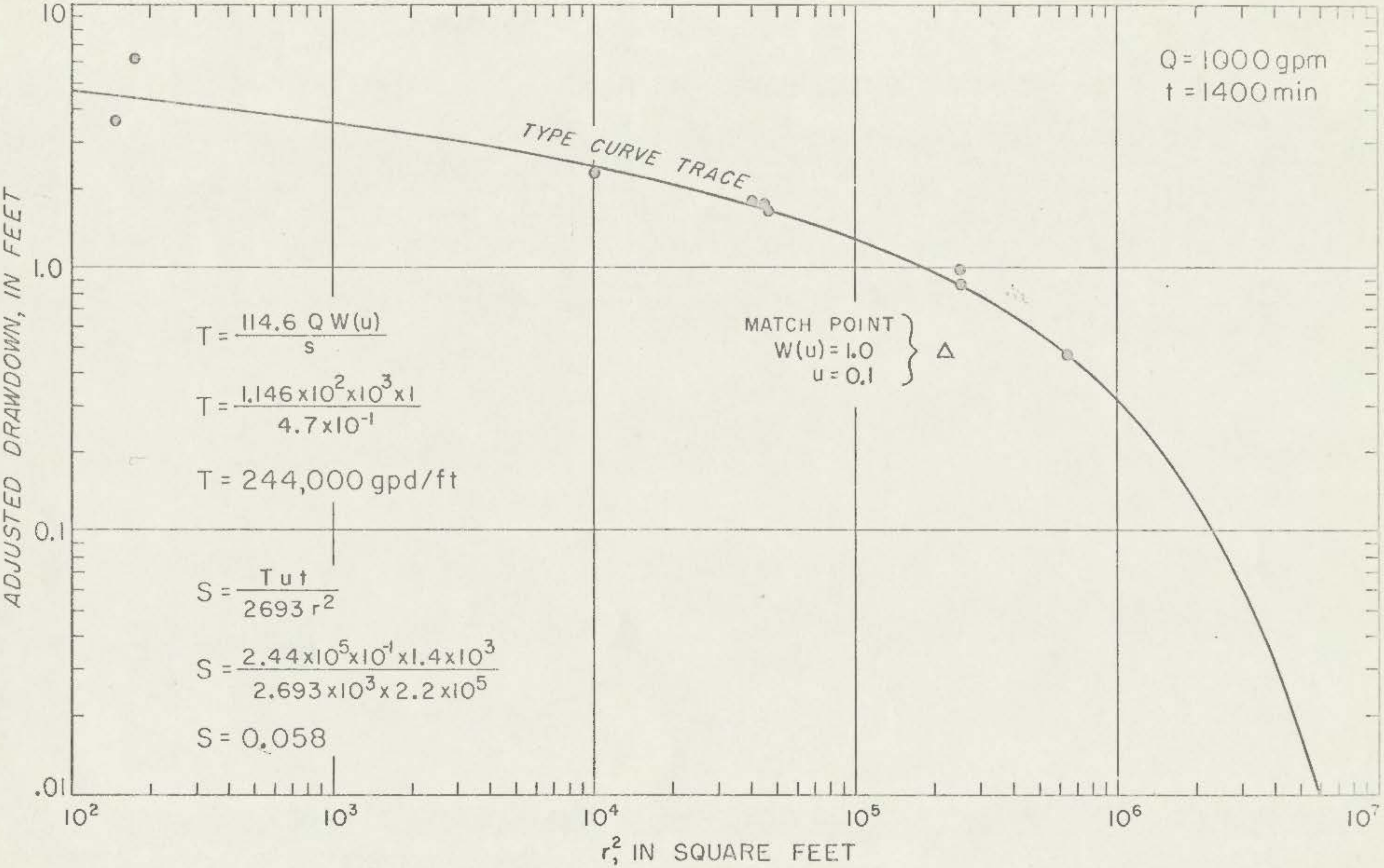
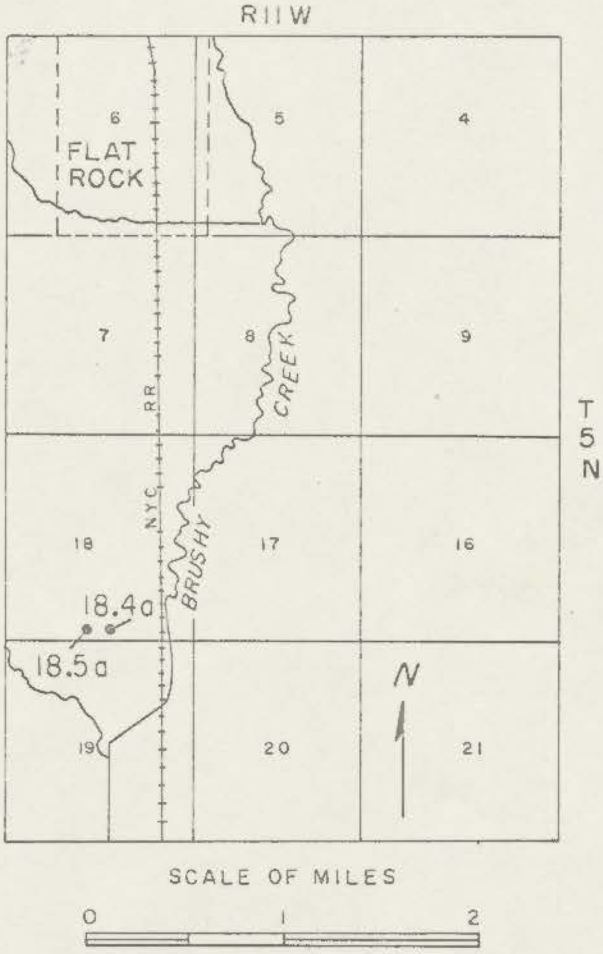


Figure 3~~3~~4. Distance-drawdown graph for aquifer test 2



Combine with fig 35

2

Figure 3~~4~~1. Location of wells used in aquifer test 4

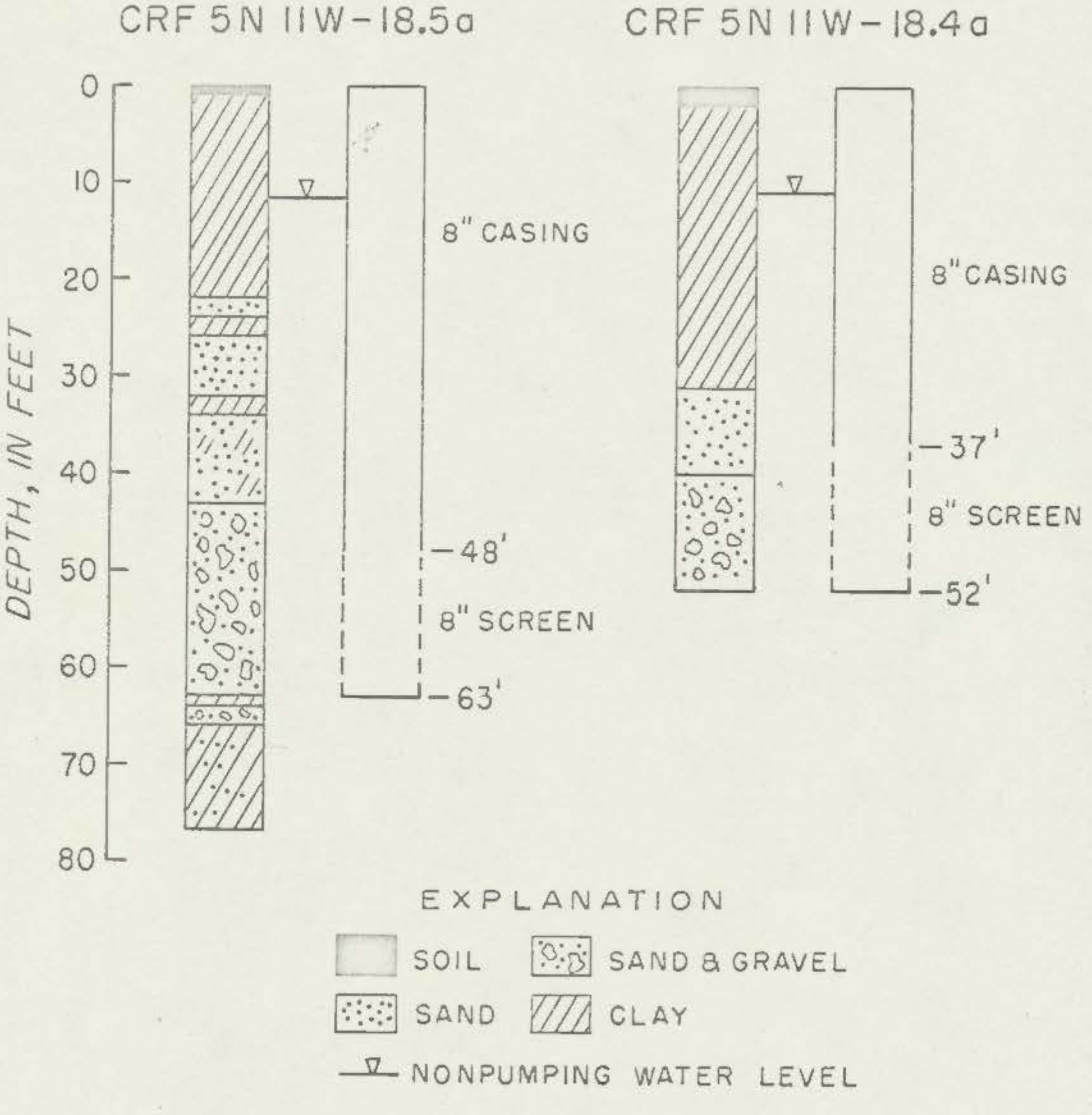


Figure 35. Generalized graphic logs of wells used in aquifer test 4

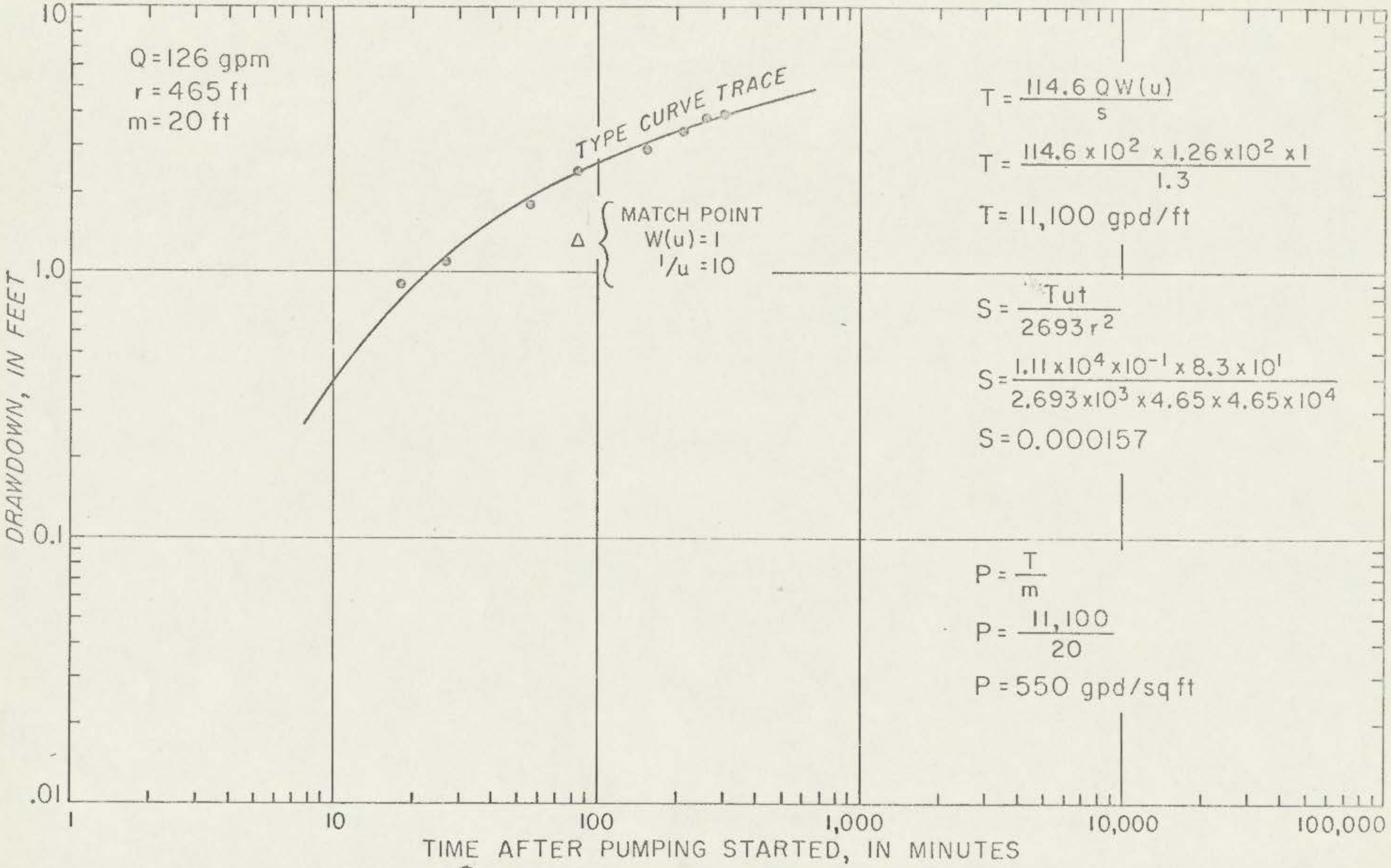
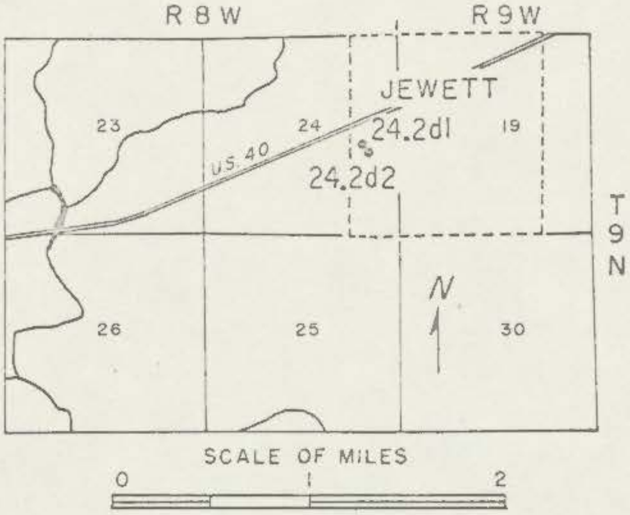


Figure 3~~4~~3. Time-drawdown graph for aquifer test 4



[illegible]

Figure 3~~7~~11. Location of wells used in aquifer test 5

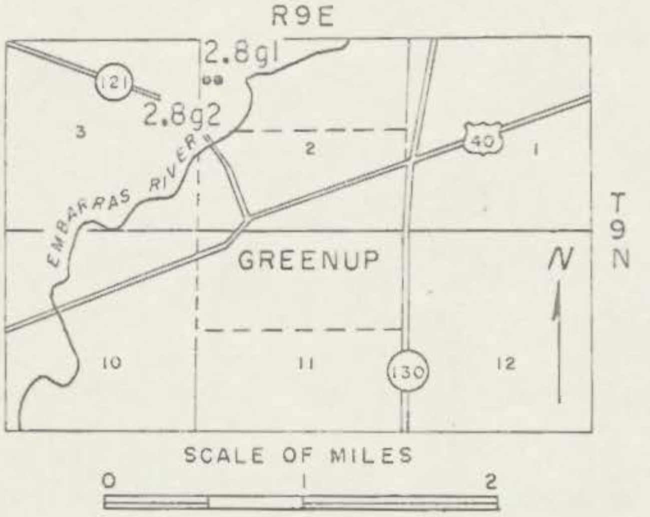


Figure ~~49~~ 36. Location of wells used in aquifer test 6

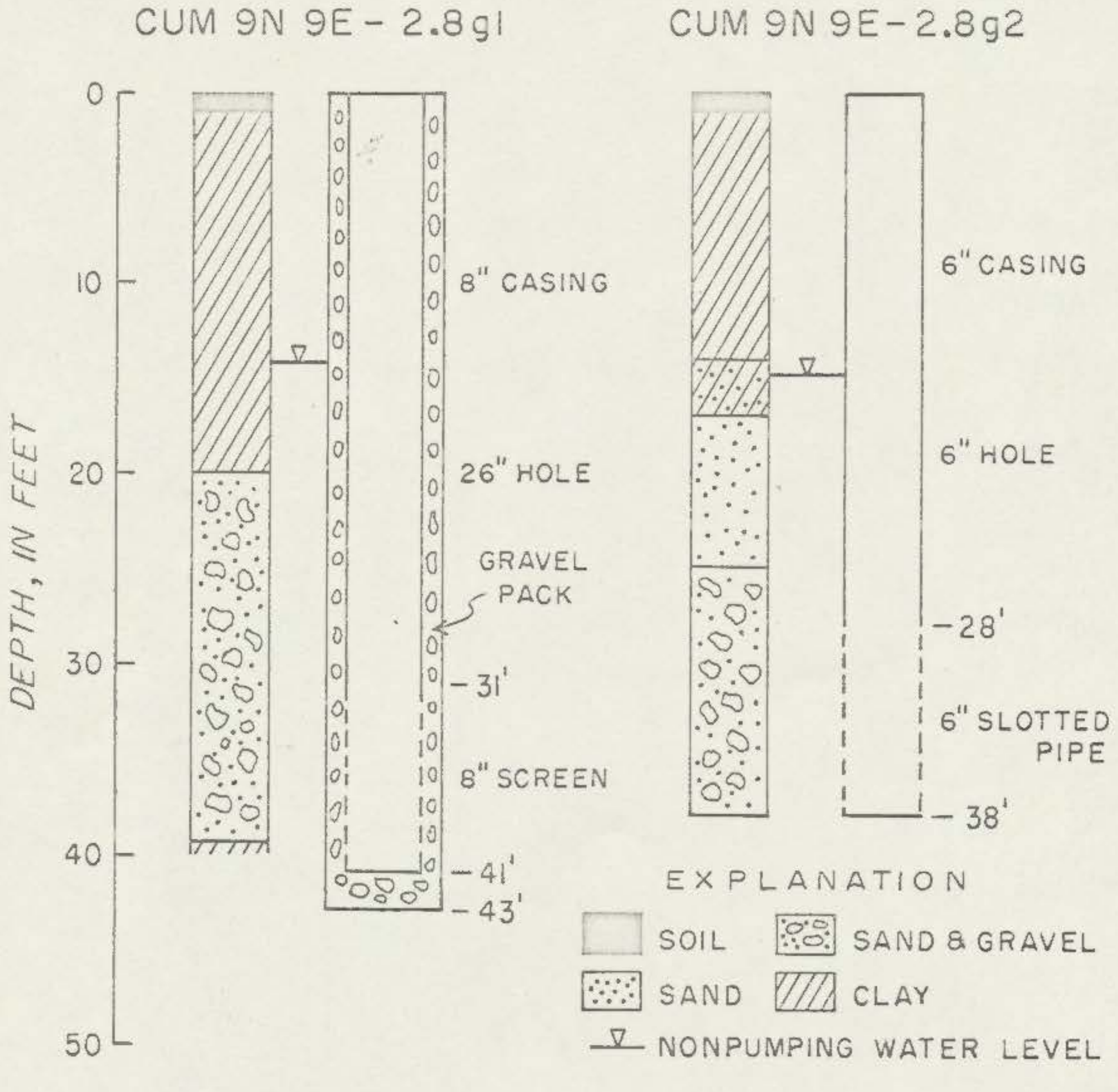
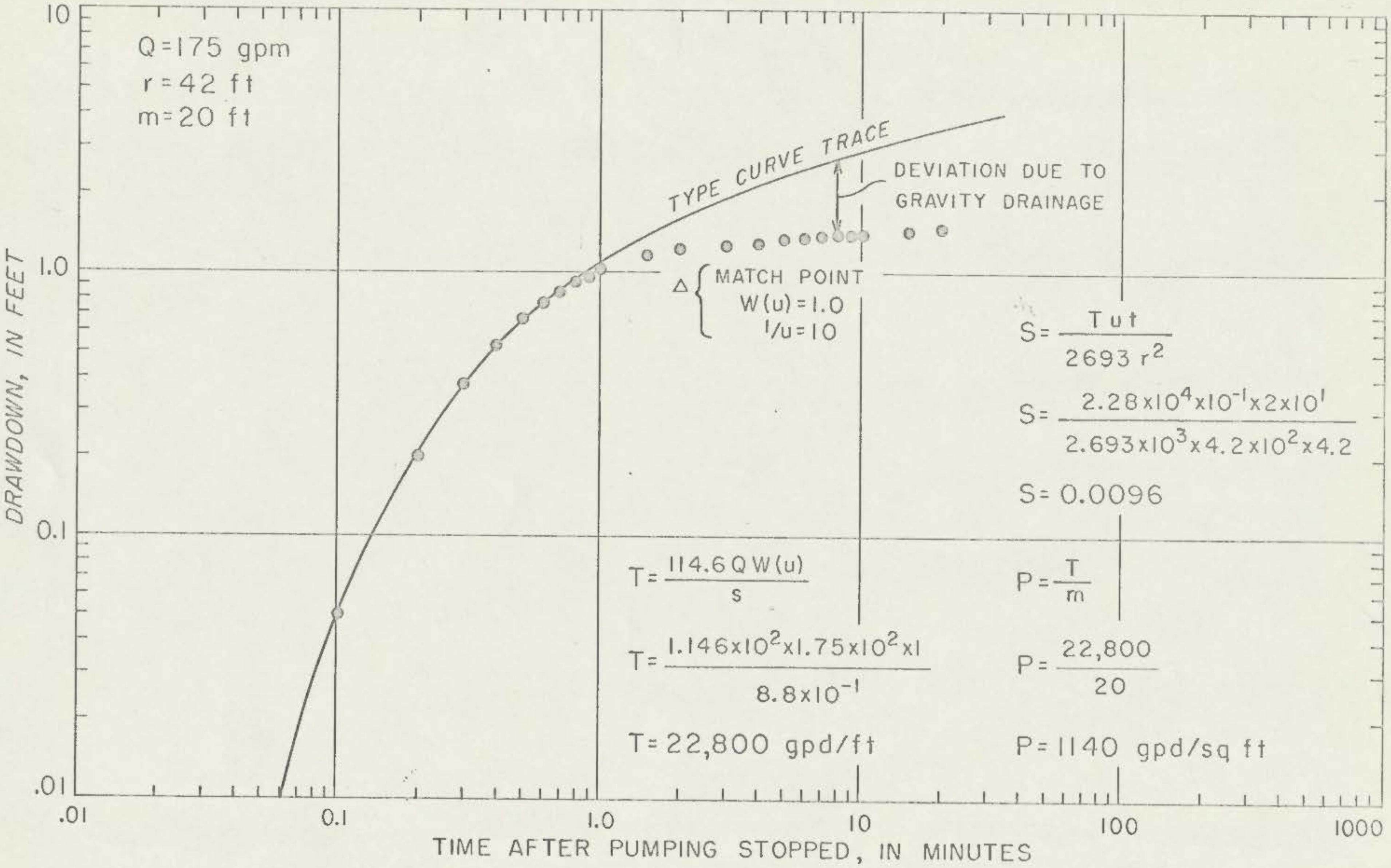


Figure 41. Generalized graphic logs of wells used in aquifer test 6



37
Figure 42. Time-recovery graph for aquifer test 6

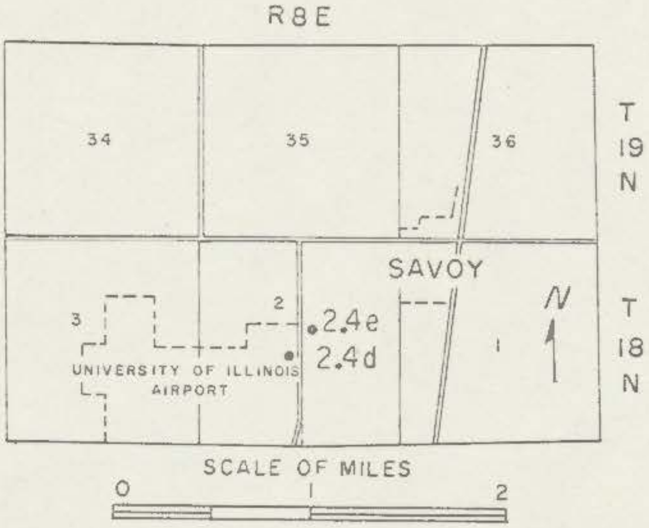


Figure ~~43~~ 38. Location of wells used in aquifer test 7

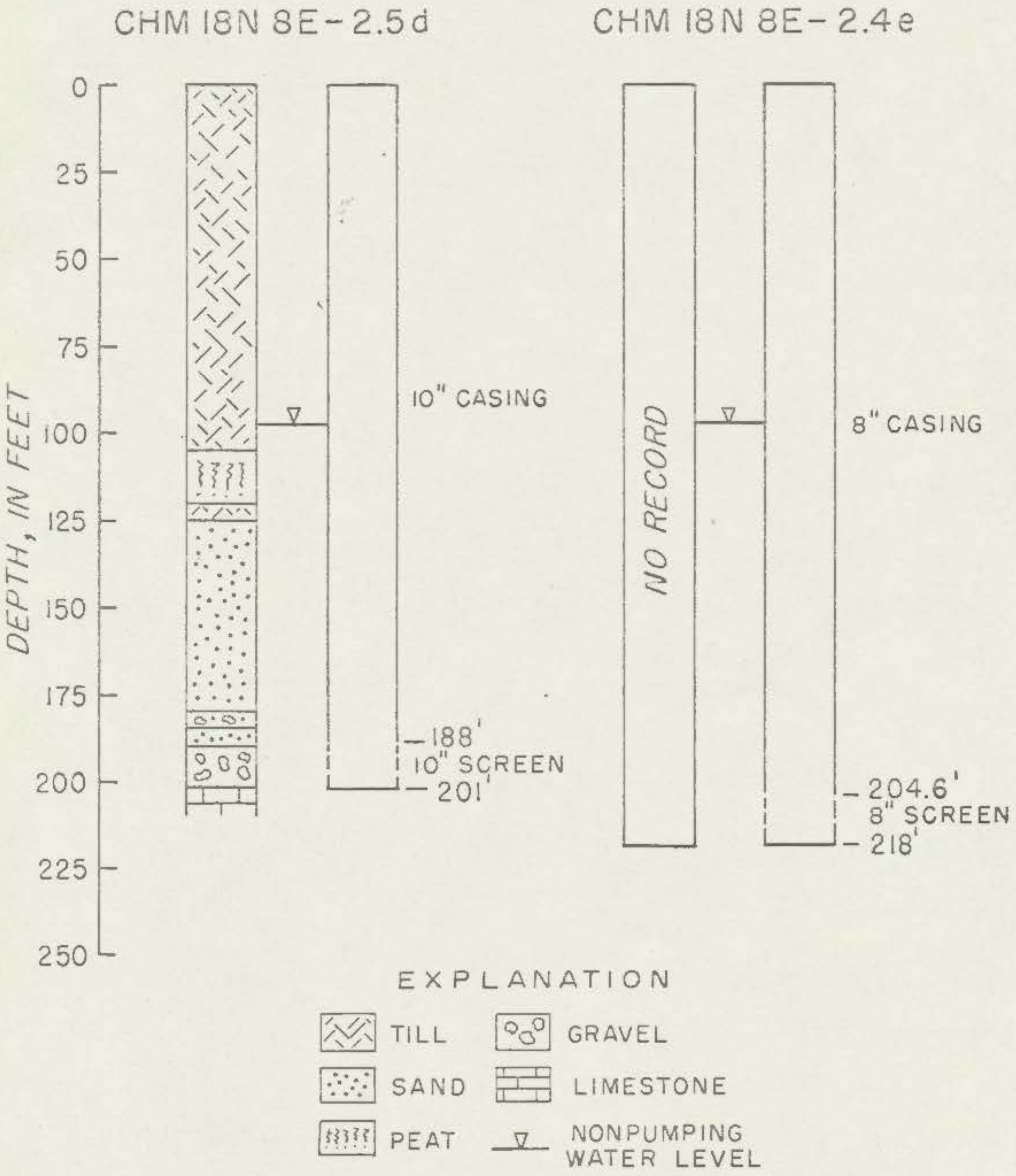


Figure 44. Generalized graphic logs of wells used in aquifer test 7

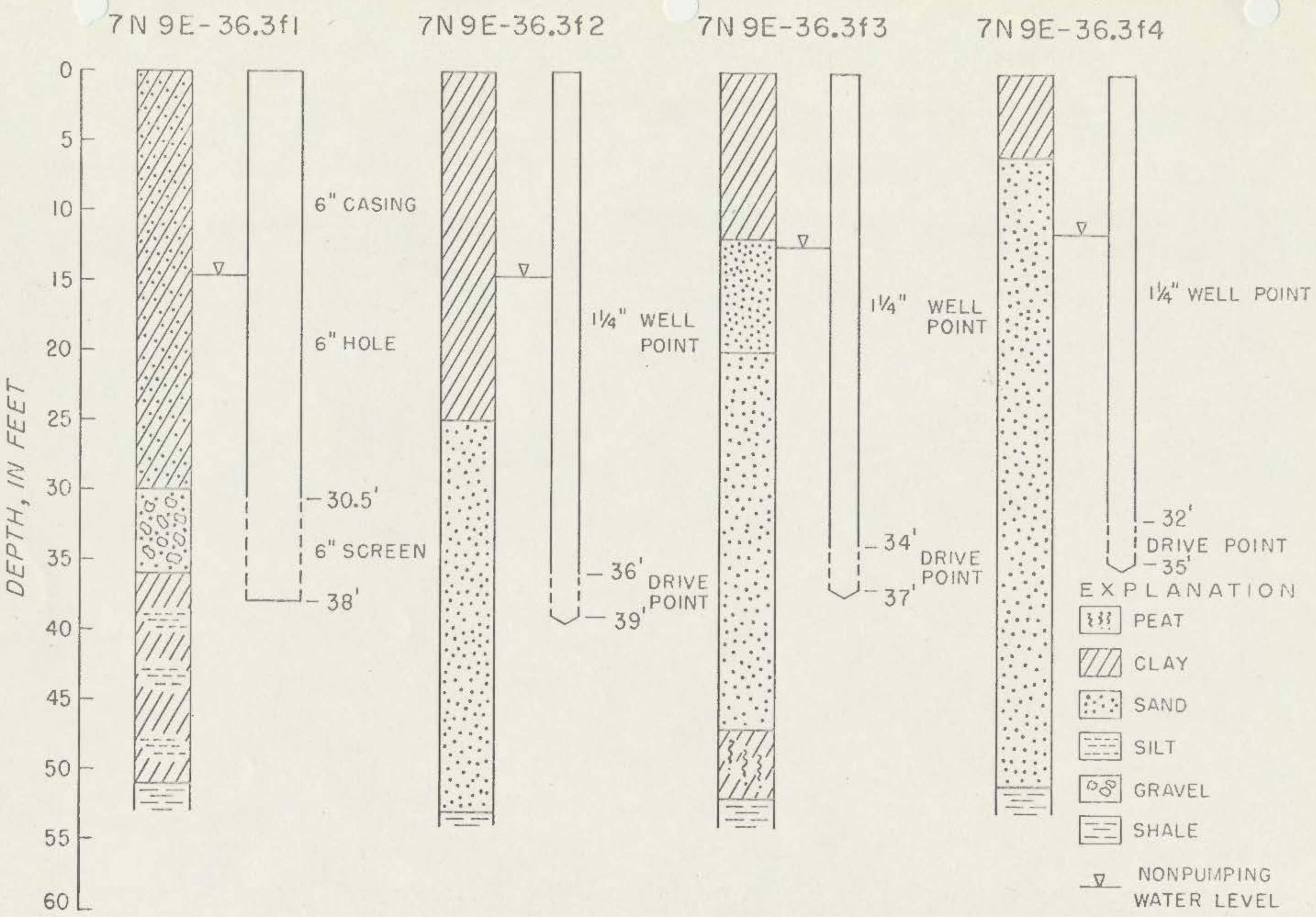


Figure 47. Generalized graphic logs of wells used in aquifer test 8

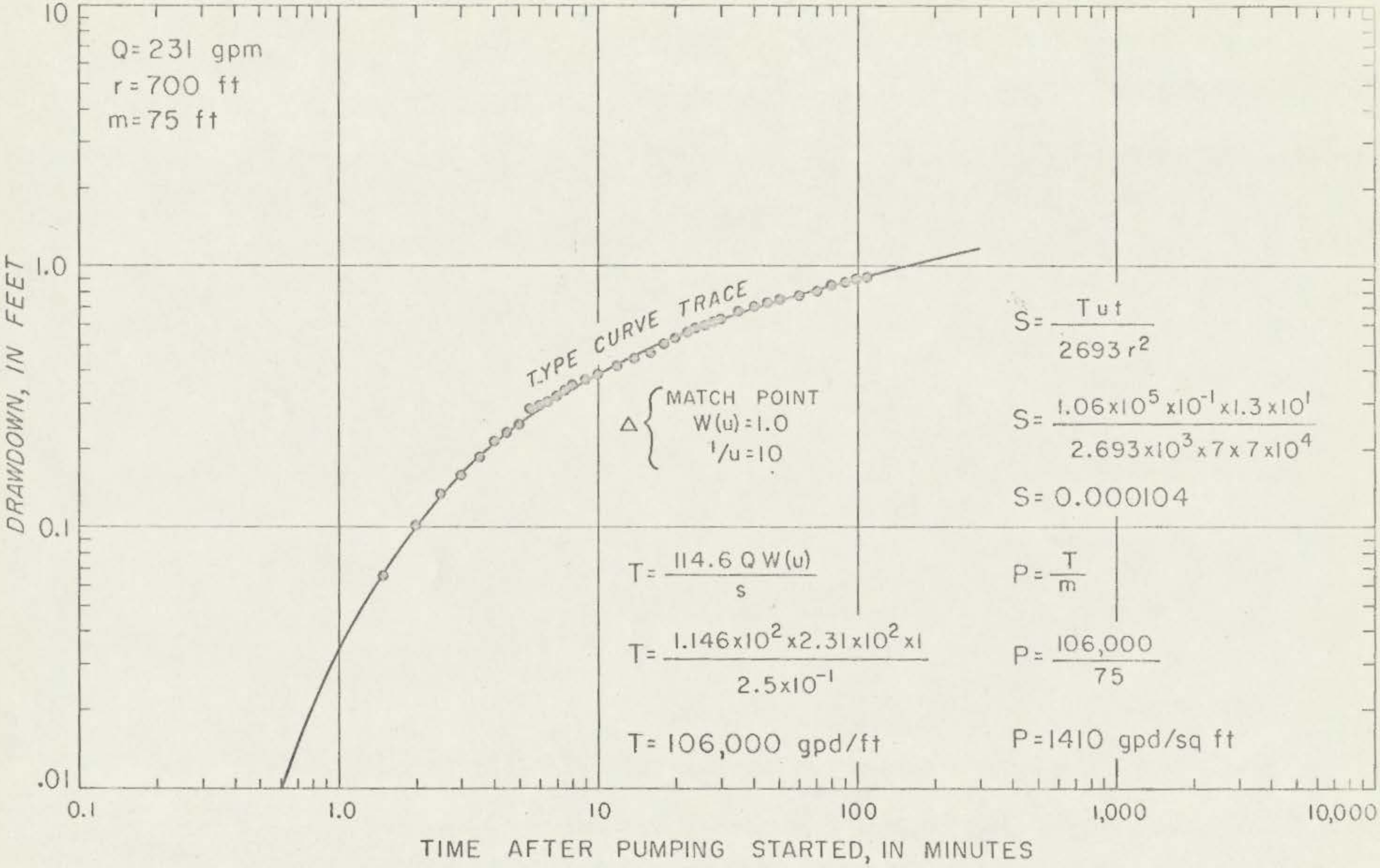


Figure ~~45~~ 39. Time-drawdown graph for aquifer test 7

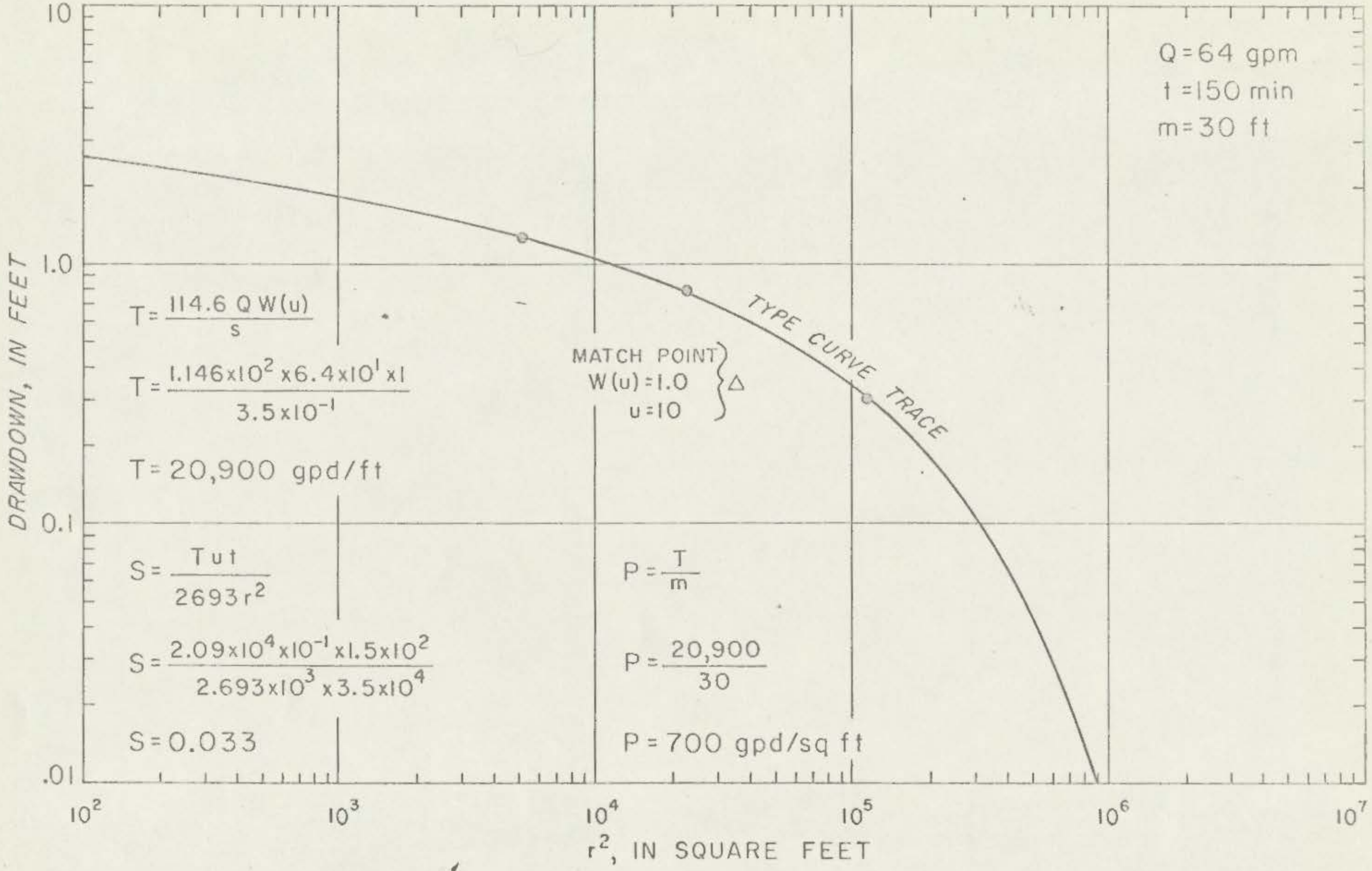


Figure 48. Distance-drawdown graph for aquifer test 8

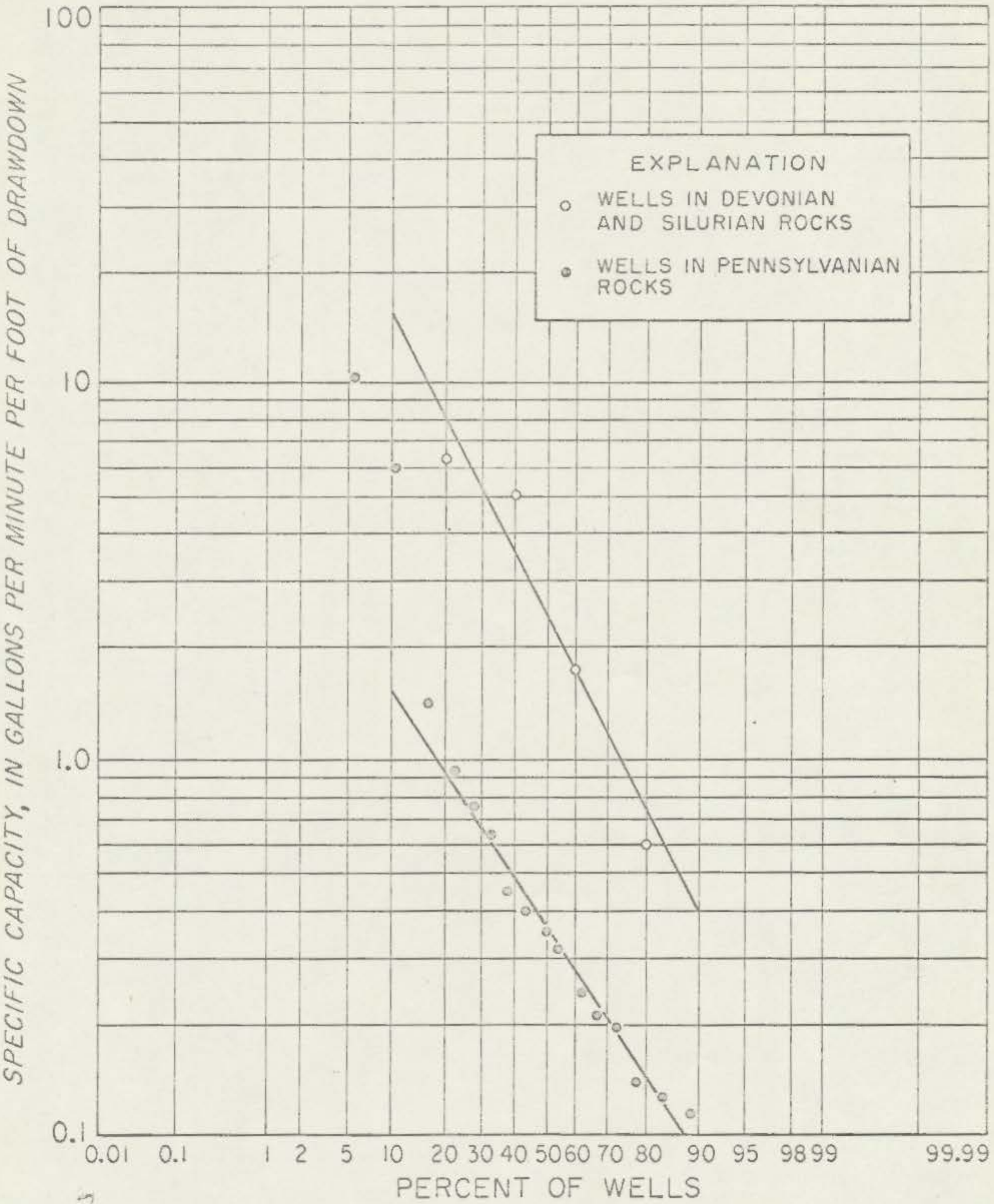


Figure 4~~9~~2. Specific-capacity frequency graphs for bedrock wells

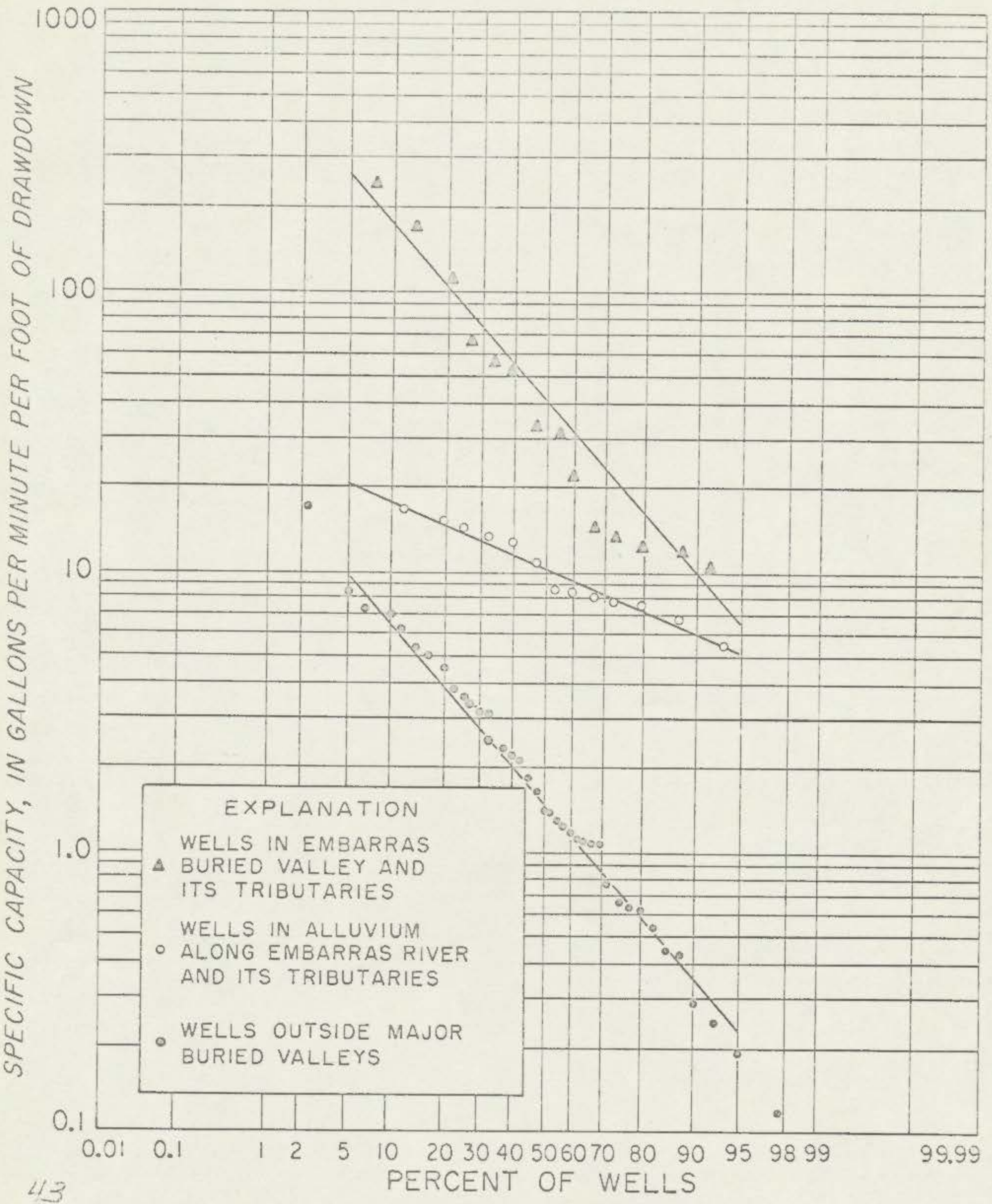


Figure ~~50~~ 43. Specific-capacity frequency graphs for sand and gravel wells

1 col

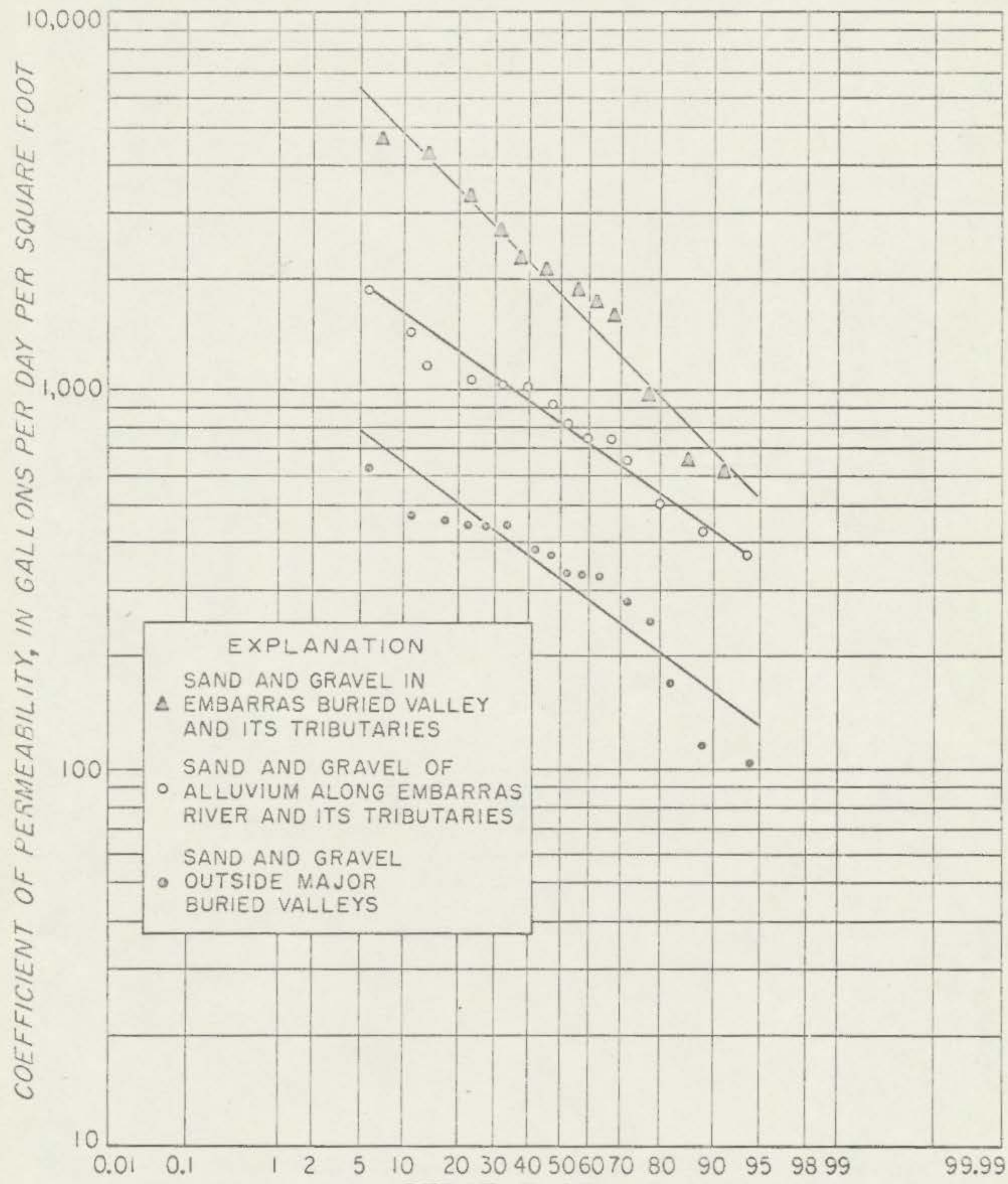


Figure ~~51~~ 44 Coefficient of permeability frequency graphs for sand and gravel aquifers

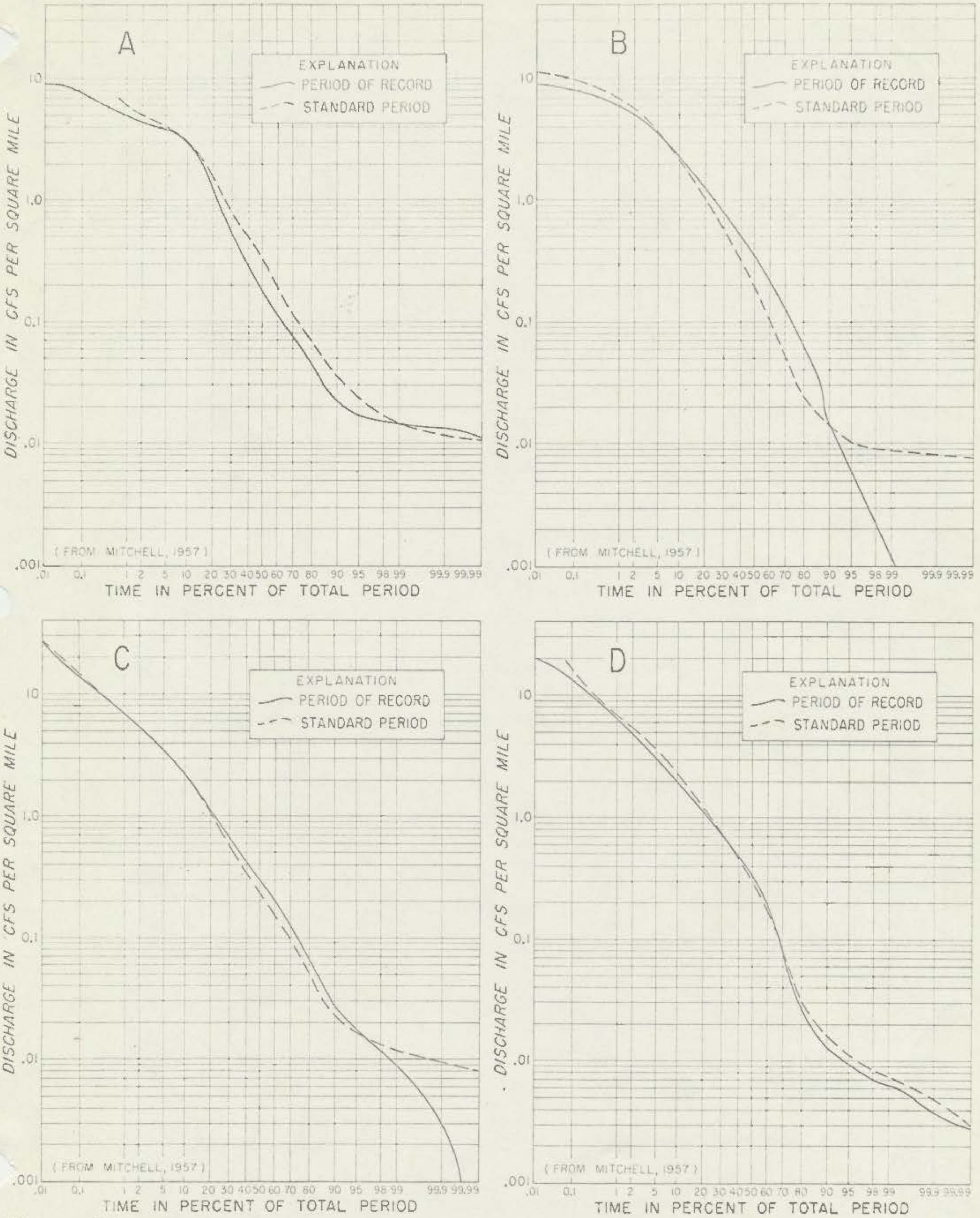


Figure 52. Flow-duration curves for Embarras River at Lawrenceville (A), Oakland (B), St. Marie (C), and Diona (D)

45

2 col wide

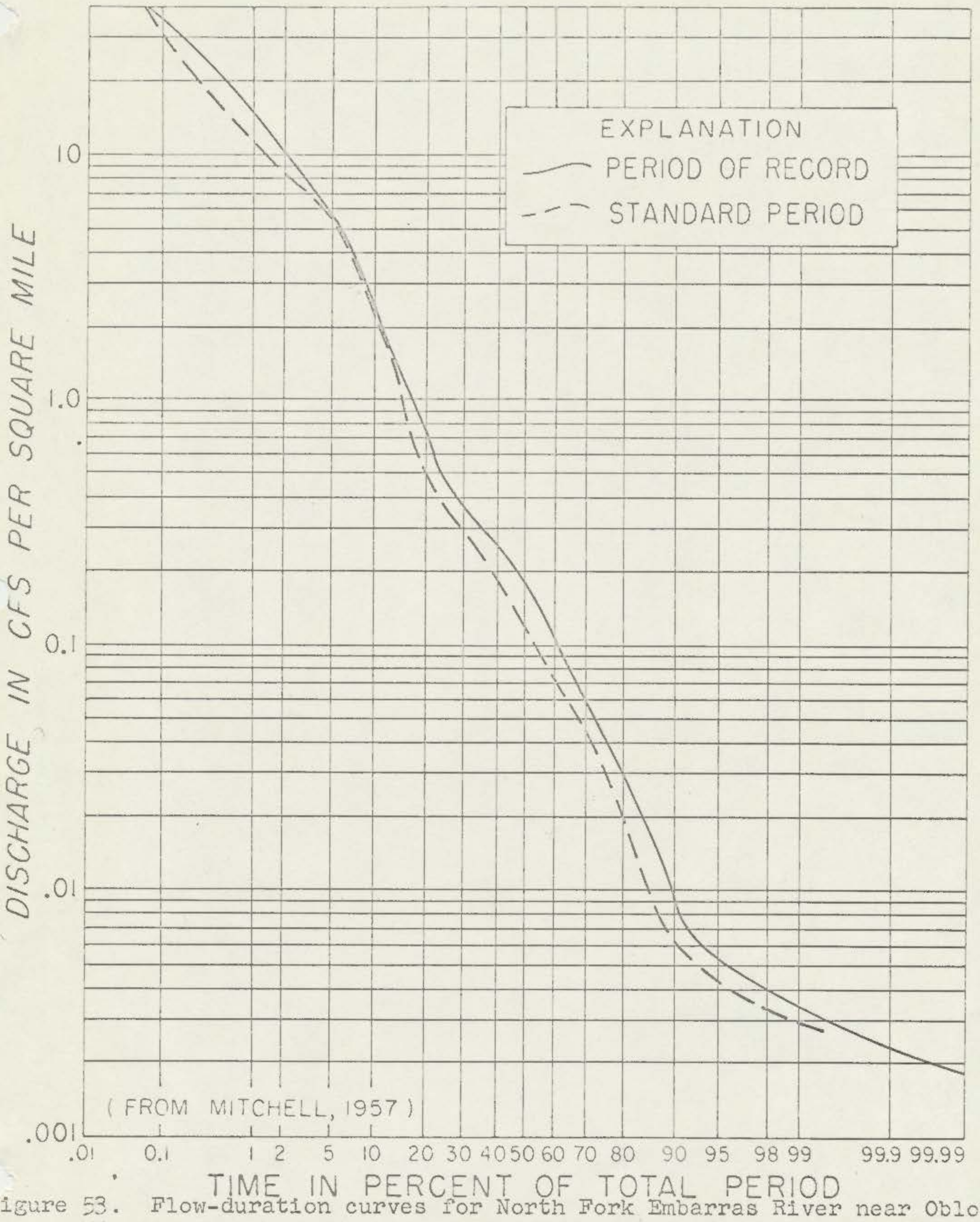


Figure 53. Flow-duration curves for North Fork Embarras River near Oblong

46

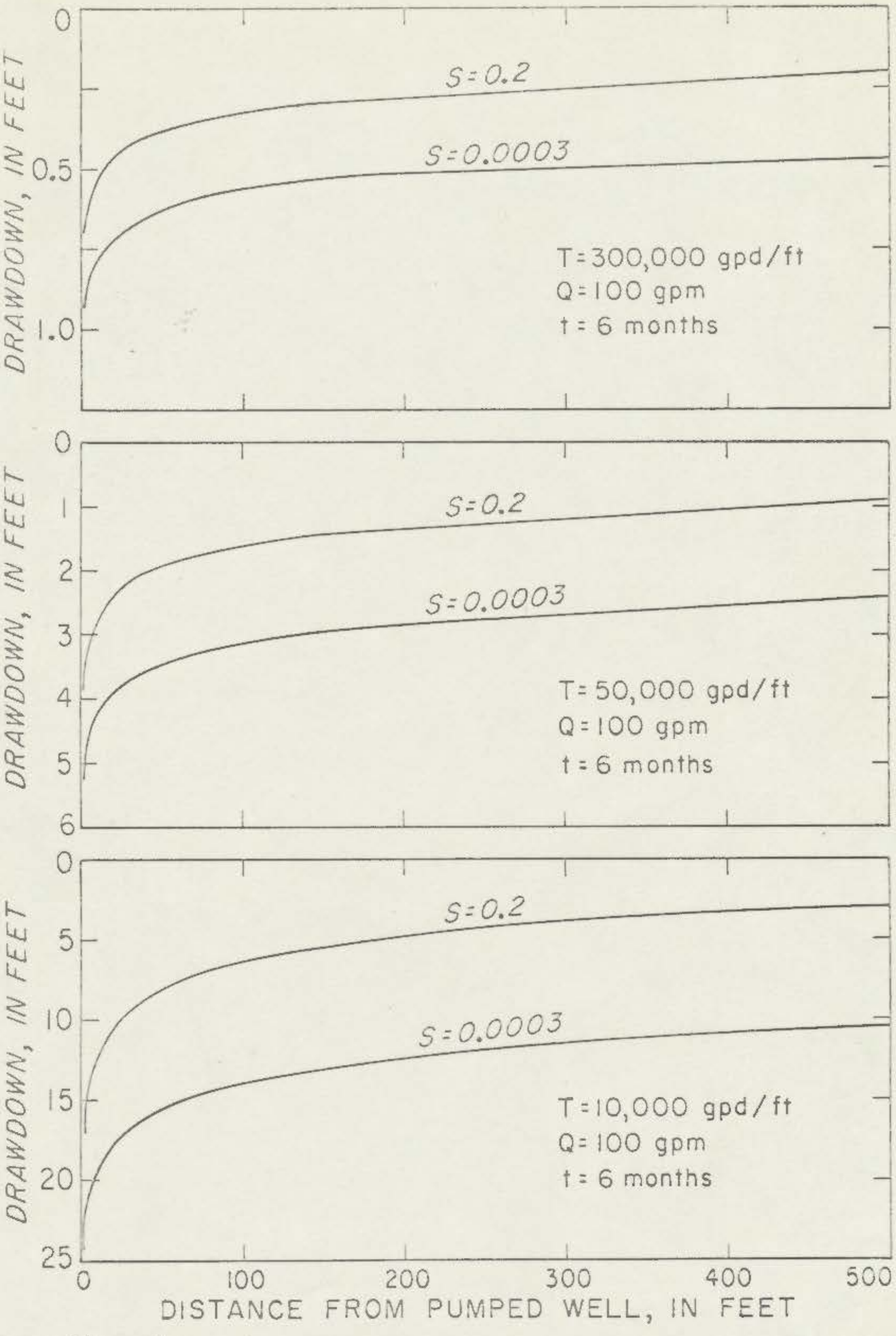


Figure 54. Theoretical distance-drawdown graphs

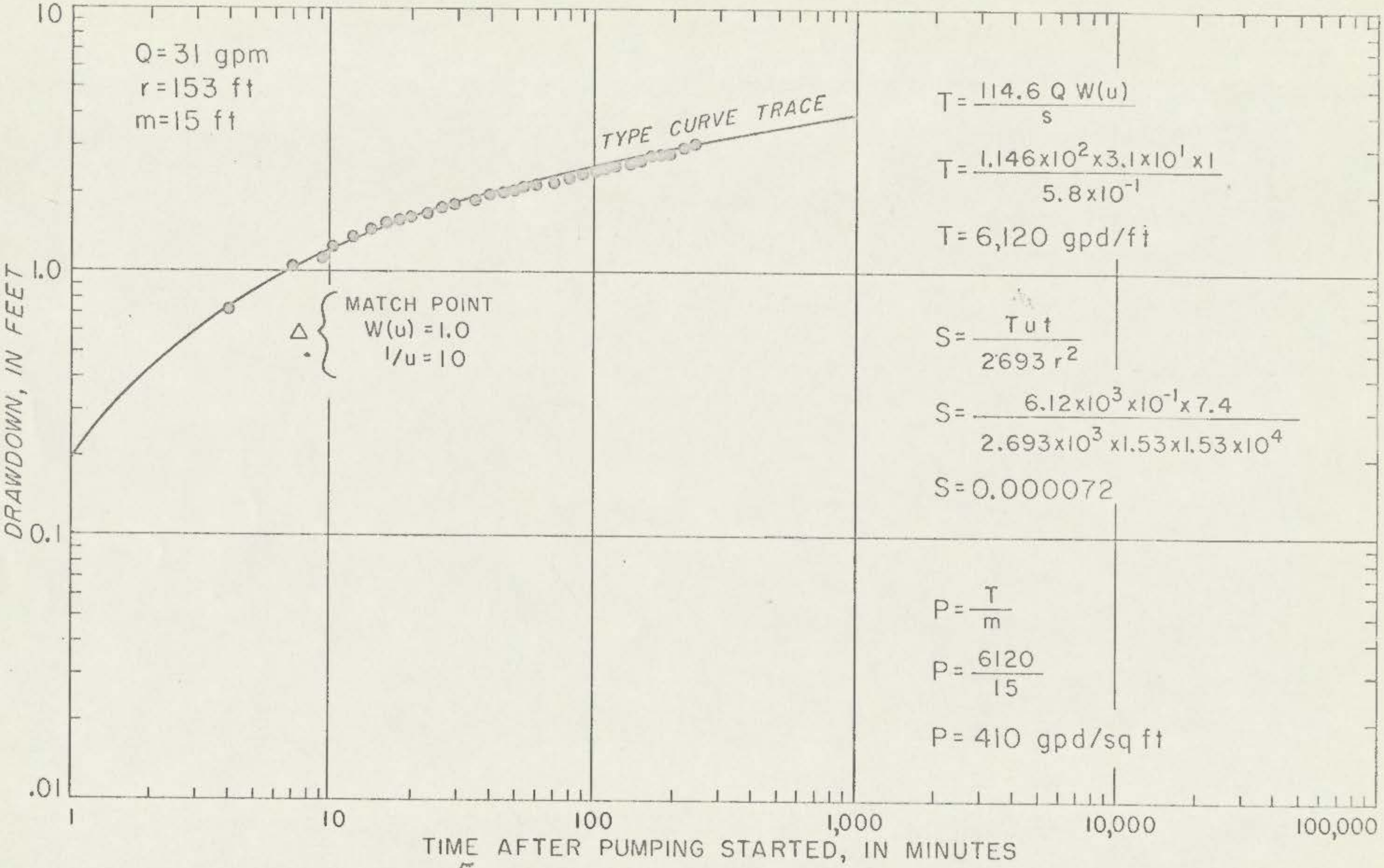
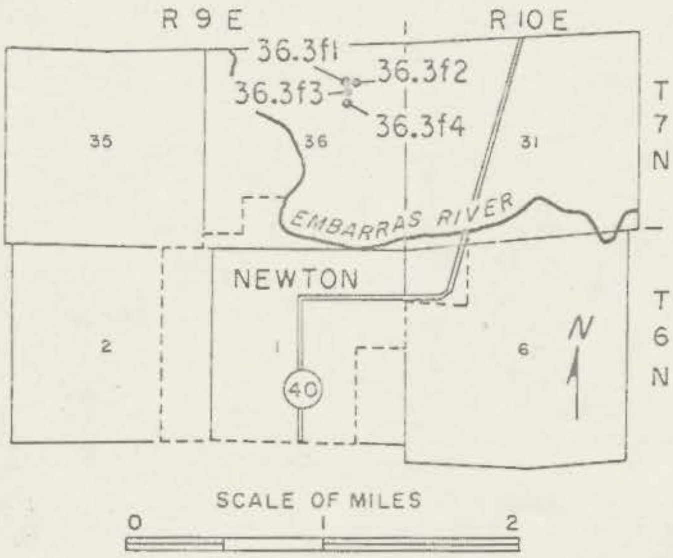


Figure $\overset{5}{39}$. Time-drawdown graph for aquifer test 5

1 col



Combine with fig 4c

Figure 4D. Location of wells used in aquifer test 8

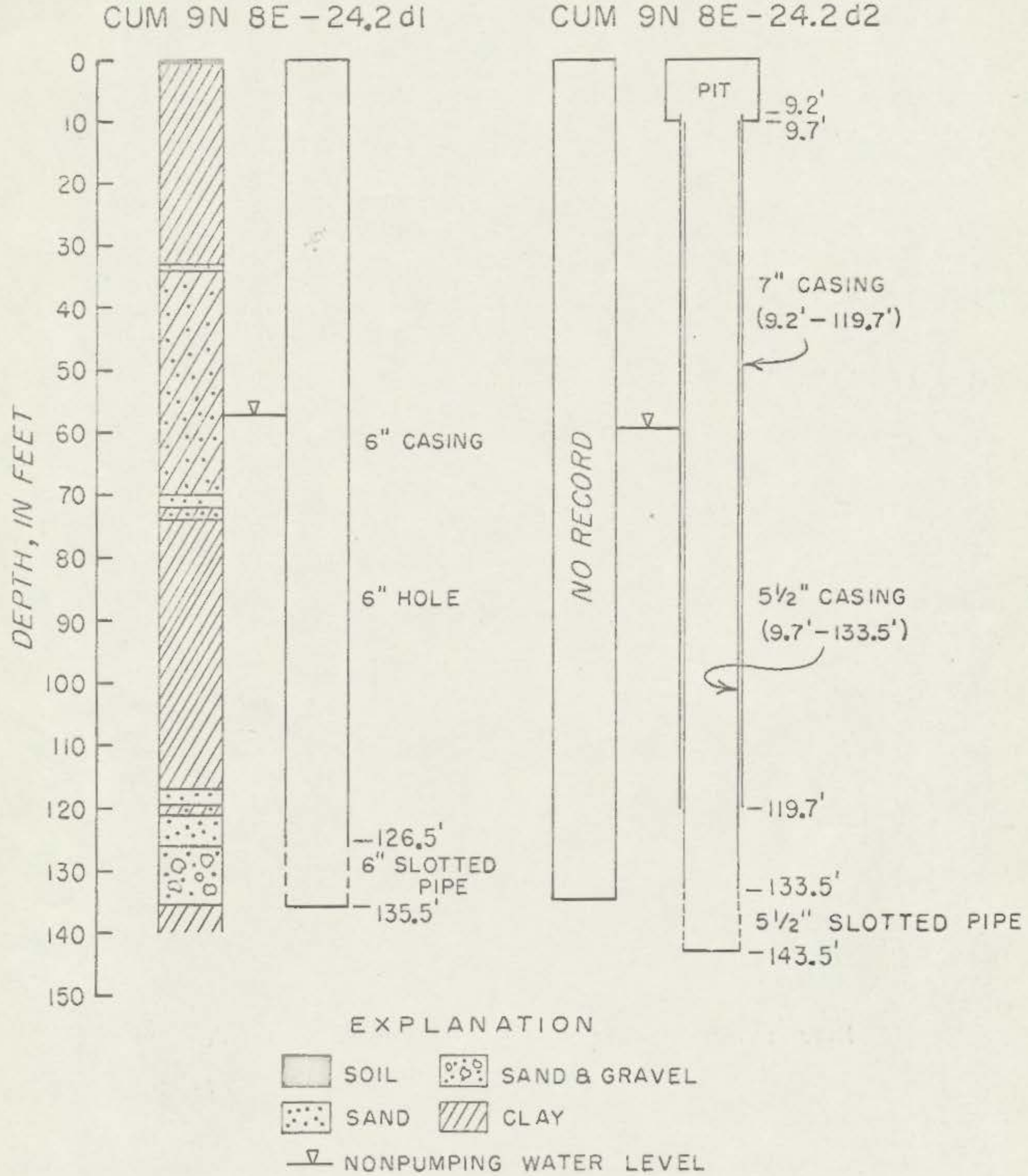


Figure 38. Generalized graphic logs of wells used in aquifer test 5