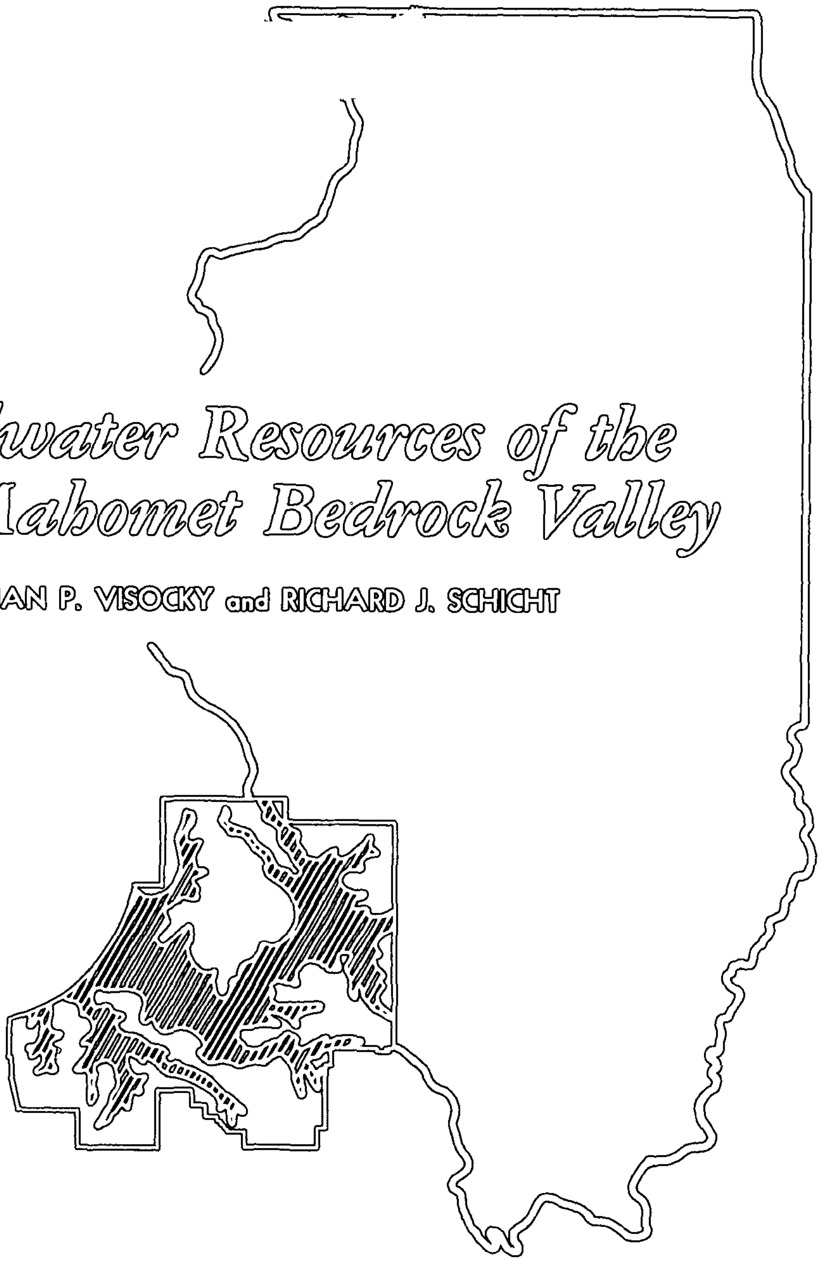
REPORT OF INVESTIGATION 62

STATE OF ILLINOIS

DEPARTMENT OF REGISTRATION AND EDUCATION

Groundwater Resources of the Buried Mahomet Bedrock Valley

by ADRIAN P. VISOCKY and RICHARD J. SCHICHT



ILLINOIS STATE WATER SURVEY

URBANA

1969

REPORT OF INVESTIGATION 62

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Groundwater Resources of the Buried Mahomet Bedrock Valley

by ADRIAN P. VISOCKY and RICHARD J. SCHICHT

Title: Groundwater Resources of the Buried Mahomet Bedrock Valley.

Abstract: The buried Mahomet Bedrock Valley and its major tributaries cover about 3700 square miles in east-central Illinois, and form a large underdeveloped groundwater resource. The largest source of groundwater consists of Kansan sands and gravels, called the deep aquifer; the Illinoian or middle aquifer is a secondary source. Pumpage was 40.2 mgd in 1965. Major pumping centers are at Champaign-Urbana, Rantoul, Lincoln, Taylorville and Hoopeston; the largest is Champaign-Urbana with pumpage of 13.5 mgd in 1965. Recharge in the Champaign-Urbana area was computed to be 115,000 gpd/sq mi for the Illinoian aquifer in 1947 and 107,000 gpd/ sq mi for the Kansan aquifer during 1953-1965. Total groundwater runoff for the valley is estimated to be about 740 mgd during years of normal precipitation. Existing and/or future pumping centers might capture 445 mgd. An electric analog computer was constructed for the Champaign-Urbana area. Withdrawals with a selected pumping scheme would total 30.3 mgd from existing large capacity wells and 15 mgd from five future wells. This study provides data for planning and development of area groundwater resources.

Reference: Visocky, Adrian P., and Richard J. Schicht. Groundwater Resources of the Buried Mahomet Bedrock Valley. Illinois State Water Survey, Urbana, Report of Investigation 62, 1969.

Indexing Terms: analog model, aquifer characteristics, aquifer evaluation, bedrock valley, glacial drift, groundwater development, groundwater recharge, Illinois, leakage, water wells.

STATE OF ILLINOIS
HON. RICHARD B. OGILVIE, Governor

DEPARTMENT OF REGISTRATION AND EDUCATION
WILLIAM H. ROBINSON, Director

STATE WATER SURVEY DIVISION
WILLIAM C. ACKERMANN, Chief

URBANA
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by Adrian P. Visocky and Richard J. Schicht

SUMMARY

The buried Mahomet Bedrock Valley and its major tributaries cover an area of about 3700 square miles in east-central Illinois. Large supplies of groundwater chiefly for municipal use are withdrawn from wells in permeable sands and gravels in thick deposits of glacial drift in the area. The glacial drift exceeds 400 feet in thickness in places.

The largest source of groundwater consists of the sands and gravels of the Kansan deposits, called the deep aquifer, which occupy the deepest portions of the Mahomet Valley channel. Intercalated in the glacial drift above the Kansan deposits are sands and gravels of the Illinoian deposits, called the middle aquifer. The middle aquifer is a secondary source of groundwater.

The coefficients of permeability and storage for the middle aquifer range from 230 to 4080 gallons per day per square foot (gpd/sq ft) and from 0.00001 to 0.083, respectively. They range from 310 to 4100 gpd/sq ft and from 0.000022 to 0.0023, respectively, for the deep aquifer. The coefficients of the vertical permeability of the confining beds above the middle and deep aquifers range from 0.0026 to 0.04 gpd/sq ft and 0.005 to 0.42 gpd/sq ft, respectively.

Pumpage from wells increased from 8.5 million gallons per day (mgd) in 1890 to 46.3 mgd in 1960 and was 40.2 mgd in 1965. Of the 1965 total pumpage, 64.2 percent was for municipal supplies, 19.1 percent was for rural uses, and 16.7 percent was for industrial use. Wells in the deep aquifer accounted for 49.3 percent of the 1965 total; wells in the middle aquifer, 31.8 percent; wells in shallow unconsolidated deposits, 17.4 percent; and wells in bedrock aquifers, 1.5 percent. Major pumping centers with pumpage exceeding 1 mgd are located at Champaign-Urbana, Rantoul, Lincoln, Taylorville, and Hoopeston.

As a result of heavy pumpage, water levels in the middle aquifer at Champaign-Urbana declined as much as 100 feet between 1885 and 1947. Subsequent shifting of pumpage to the deep aquifer west of Champaign resulted in water levels in the middle aquifer recovering from 30 to 55 feet. Because of increased withdrawals, water levels in the deep aquifer declined some 35 feet during 1948-1963. Recovery of water levels in 1964 and 1965 resulted from a decline in pumpage. Similar though smaller water-level declines have occurred in many of the other pumping centers in the Mahomet Valley area.

Recharge to buried aquifers in the Mahomet Valley occurs chiefly as leakage of water from a source bed in the shallow deposits across a confining layer. Potential recharge to these aquifers, considering only available head losses across the confining layers, is great. Computations for the Illinoian aquifer at Champaign-Urbana indicate a recharge rate of 115,000 gpd/sq mi in 1947. Similar computations for the Kansan aquifer west of Champaign during the period 1953 through 1965 indicated an average recharge rate of 107,000 gpd/sq mi. Total groundwater runoff for the valley is estimated to be about 740 mgd during years of normal precipitation. It is not unreasonable to assume that existing and/or future pumping centers could capture 60 percent of groundwater runoff, or 445 mgd.

An electric analog computer consisting of an analog model and associated electronic equipment was constructed for the middle and deep aquifers and their confining and source beds in the vicinity of Champaign-Urbana to aid in studying the effects of groundwater pumpage on water levels in the Mahomet Valley. The accuracy of the computer was established by a study of records of past pumpage and water levels in three observation wells.

The analog computer was used to determine pumping levels with a selected scheme of pumping from existing and future large capacity wells in the Kansan aquifer west of Champaign. Withdrawals with the selected pumping scheme would total 30.3 mgd from existing large capacity wells and 15 mgd from five future wells; pumping levels would be above the top of the Kansan aquifer.

INTRODUCTION

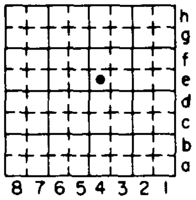
The deeply buried sand and gravel aquifer in the Mahomet Bedrock Valley and its major tributaries is an underdeveloped source of groundwater for large municipal and industrial supplies in east-central Illinois. Present withdrawals, the largest of which are in the Champaign-Urbana area, are considered to be only a small fraction of the available resource.

The potential yield of the deeply buried sand and gravel aquifer is evaluated in this report. Basic geologic, hydrologic, and chemical data, maps, and interpretations pertinent to the area are included to aid in water resource planning. The use of an electric analog computer constructed for aquifers and confining beds in the Champaign-Urbana area is described. This report can be considered only a preliminary report since conclusions and interpretations herein are based on limited hydrologic data.

The geology of the area has received considerable study and many reports have been published. The major reports are listed in the references for this investigation.

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 1/8-mile squares. Each 1/8-mile square contains 10 acres and corresponds to a quarter of a quarter of a quarter section. A normal section of one square mile contains eight rows of 1/8-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.



Champaign County
T19N, R9E
Section 25

The number of the well shown is CHM 19N9E-25.4e. 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.

Any number assigned to the well by the owner is shown in parentheses after the location well number. For example, the first well listed in table 2 is owned by the village of Ivesdale and is known as Village Well No. 1, which is indicated by (1) in the well number CHM 17N7E-7.6d(1). Directional titles used by the owner are indicated by (S) for South Well, etc.; test wells are indicated by (T).

The abbreviations for counties in this report are:

CHM	Champaign	MCN	Macon
CHR	Christian	MSN	Mason
COL	Coles	MCL	McLean
DWT	De Witt	MEN	Menard
DGL	Douglas	MOU	Moultrie
FRD	Ford	PIA	Piatt
IRO	Iroquois	SAN	Sangamon
LAS	La Salle	TAZ	Tazewell
LIV	Livingston	VER	Vermilion
LOG	Logan	WDF	Woodford

Other abbreviations used in the tables are: (C) City owned, (T) Town owned, (V) Village owned, CCb. Country Club, Sbd. Subdivision.

Acknowledgments

This report was prepared under the general supervision of William C. Ackermann, Chief of the Illinois State Water Survey, and H. F. Smith, Head of the Hydrology Section.

Special thanks are offered to T. A. Prickett for his time and assistance in instructing the authors in the use of the electric analog model and its excitation-response components. The Champaign-Urbana analog was built largely through his efforts, and later additions and modifications to the model were also made possible by his ideas and physical assistance. G. E. Reitz, Jr., former State Water Survey Hydrologist, collected much of the early data and assisted in the construction of the large analog model. Former and present members of the Water Survey wrote earlier special reports which have been used as reference materials. Grateful acknowledgment is made, therefore, to W. C. Walton, W. H. Walker, and W. H. Baker, Jr. John W. Brother, Jr., and William Motherway, Jr., prepared the illustrations.

GEOGRAPHY AND CLIMATE

The buried Mahomet Bedrock Valley and its major tributaries lie within portions of 20 counties in east-central Illinois (figure 1). The valley system covers an area of about 3700 square miles, stretching from the Indiana line approximately 120 miles westward to the Illinois River Valley.

The area lies within the Till Plains Section of the Central Lowland Physiographic Province (Leighton, Ekblaw, and Horberg, 1948). The area is further subdivided: the main channel of the valley is in the Bloomington Ridged Plain; the extreme northeastern portion is in the Kankakee Plain; and the western end is in the Springfield Plain.

Large portions of the land surface have level or gently rolling topography, interrupted by low, broad morainic ridges. Most of the ridges have gentle slopes so that local relief is normally low. Elevations range from 920 feet in southeast McLean County to 500 feet along the Sangamon River at the western edge of the area. Local relief averages 50 feet, but along a few streams rises to 150 feet. Drainage in the area is primarily toward the streams shown in figure 1 which traverse the area.

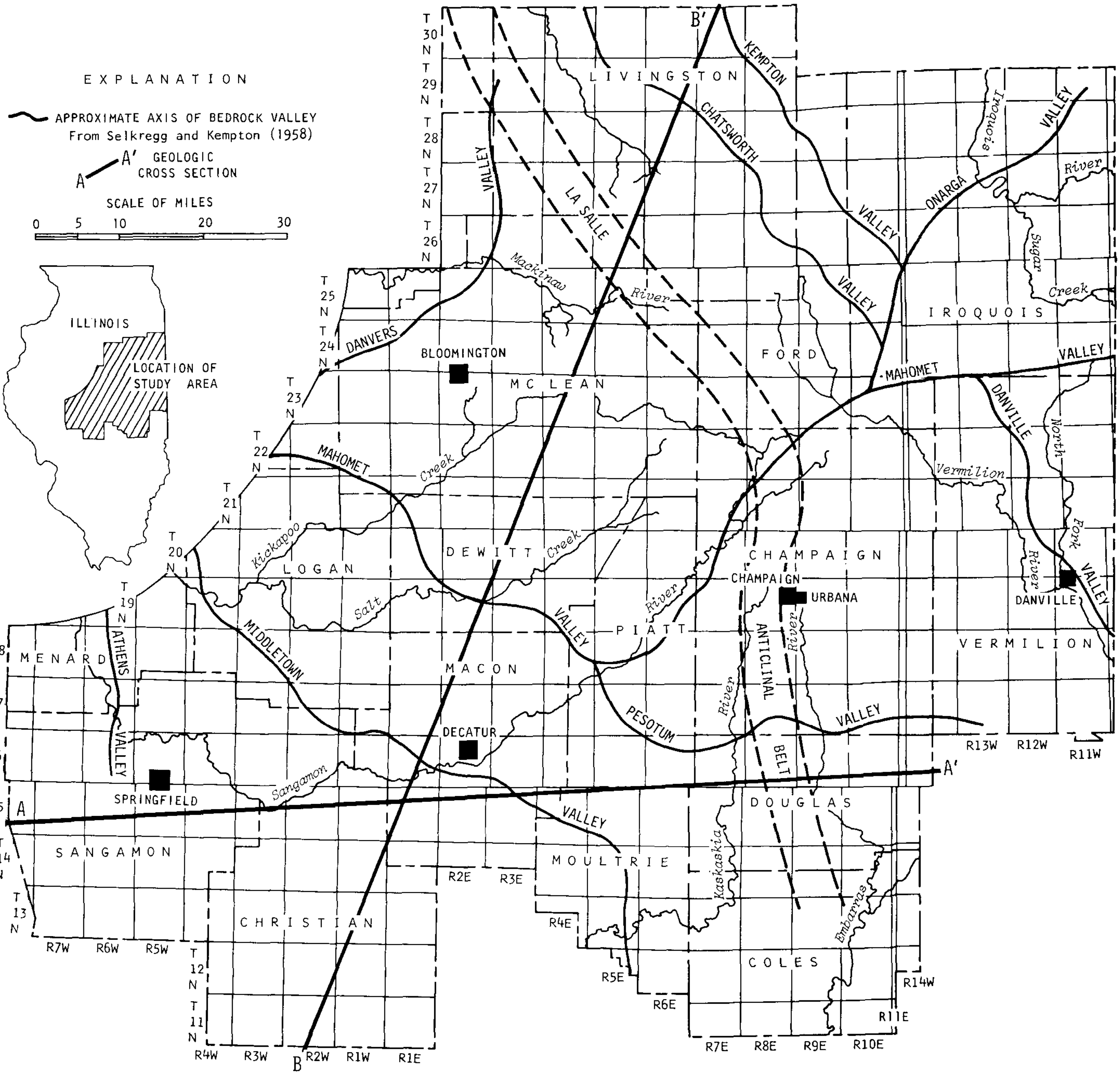


Figure 1. Location of bedrock valleys, La Salle anticlinal belt, and geologic cross sections A—A' and B—B'

The climate of the study area is a humid continental type, characterized by cold, relatively dry winters and warm to hot, wet summers. Precipitation and temperatures exhibit a north-south distribution. According to the *Atlas of Illinois Resources, Section 1 (1958),* the mean annual precipitation increases from 33.5 inches in the northern part of the study area to 39 inches in the extreme south-central part. Sixty percent of the annual precipitation falls in the warm half of the year from April through September, with June generally being the wettest month. The average number of days with snowfalls of 1 inch or more varies from 5 to 6 in the south and from 7 to 8 in the north. Normally February is the driest month.

The mean July temperature in the area varies only 2 degrees north to south, from 75.5 to 77.5 degrees, but the mean January temperature varies from 26.0 to 30.5 degrees north to south. The average growing season in the area varies between 170 and 180 days.

GEOLOGY AND HYDROLOGY

Nature and Water-Yielding Properties of the Bedrock

For a detailed discussion of the geology of the buried Mahomet Bedrock Valley system and east-central Illinois the reader is referred to Foster and Buhle (1951); Heigold, McGinnis, and Howard (1964) ; Horberg (1945 and 1950) ; and Stephenson (1967). The following section is based largely upon these reports.

The sequence and structure of the rocks are shown in the cross sections in figure 2, and locations of the cross sections are shown in figure 1. The geologic nomenclature and characteristics, drilling and casing conditions, and water-yielding properties of the bedrock are summarized in figure 3.

The bedrock dips eastward and southward to form part of a saucer-like structure known as the Illinois Basin. The deepest part of the basin is south of the area in White County. From western Livingston County southeast to Ford County and then south to Coles County a narrow band of rocks have been warped upward into an arch-like structure or anticline called the La Salle anticlinal belt (figure 1).

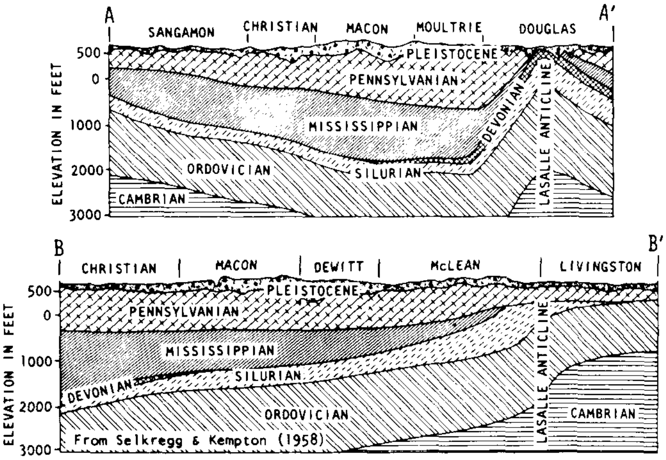
Rocks of Pennsylvanian age form the bedrock surface (figure 4) except in the northeastern part of the area and along the La Salle anticlinal belt where rocks of Mississippian, Devonian, and Silurian age form the bedrock surface. Rocks of Ordovician age form the bedrock surface in the extreme northwest corner of Iroquois County.

Groundwater in the bedrock formations becomes highly mineralized with increasing depth. Formations that yield potable water in the northern part of the area and along the La Salle anticlinal belt where they are near the surface contain highly mineralized water where they are deeply buried.

Because of their low permeability and poor water quality with depth, the Pennsylvanian rocks do not constitute an important aquifer in the area. On the bedrock uplands, however, where the glacial drift is thin and permeable sands and gravels are missing, they have been developed for domestic and small municipal supplies. Csallany (1966) summarized yields of wells in the Pennsylvanian rocks.

In the northern part of the area, wells finished in the Silurian dolomite and the Glenwood-St. Peter sandstone of Ordovician age may yield moderate to large quantities of groundwater. According to Csallany and Walton (1963) yields of wells finished in the Silurian dolomite may exceed 500 gpm in parts of Iroquois and Livingston Counties (figure 5). In northern Livingston, Ford, and Iroquois Counties wells finished in the Glenwood-St. Peter sandstone may yield up to 100 gpm (*Water for Illinois, A Plan for Action,* 1967).

Along the La Salle anticlinal belt in parts of Douglas, Champaign, and Ford Counties domestic and farm supplies can be developed in Silurian and Devonian limestone and dolomite where they are present just below the drift or are thinly covered by Pennsylvanian rocks. Wells finished in the Silurian dolomite supply the city of Tuscola.



From Selkregg & Kempton (1958)

Figure 2. Geologic cross sections A—A' and B—B'

Mississippian rocks are not an important aquifer in the area because they are either too deeply buried or, where near the surface, are composed of shale.

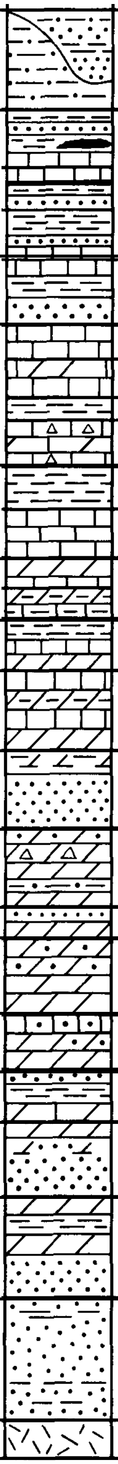
Bedrock Topography

A contour map showing the topography of the bedrock surface is shown in figure 6. Features of the bedrock topography were previously discussed by Horberg (1950) and Stephenson (1967). Stephenson revised a large part of Horberg's map in the central part of the area on the basis of additional data.

The main feature of the bedrock topography is the Mahomet Valley which enters the state in the southeastern corner of Iroquois County *(also see, figure 1).* The valley continues westward to Ford County, then southwestward across the northwestern part of Champaign County to Piatt County where it turns northwestward and joins the Havana Lowlands.

According to Horberg (1950), well records and outcrop data suggested that the Mahomet Valley enters Illinois from Indiana as part of the ancient Teays River and that it represents the lower course of a master preglacial stream which headed in North Carolina and discharged into the ancient Mississippi River Valley. This ancient drainage system is considered the preglacial ancestor of the present Ohio River.

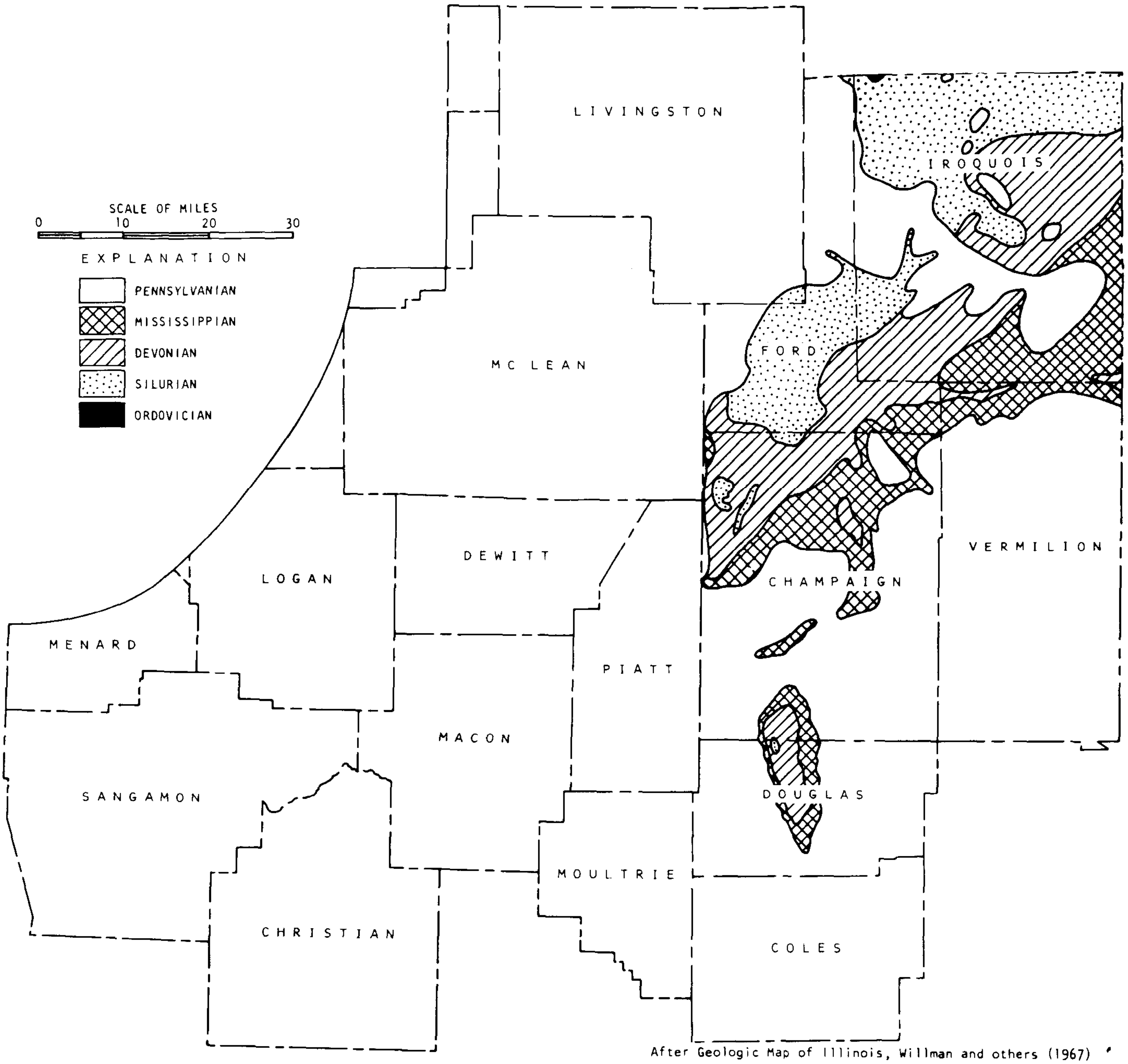
Rock elevations along the valley are less than 400 feet above sea level, or 200 to 300 feet below the adjoining bedrock uplands. The width of the valley varies from about 4 miles, as it enters the state, to about 14 miles in De Witt County. Horberg (1950) notes that the widening of the valley suggests a floodplain development. There is also evidence that the valley was eroded during two cycles, so that the valley is entrenched below a broad outer valley, 500 to 600 feet above sea level.



SYSTEM	SERIES OR GROUP	FORMATION THICKNESS (FT) (not to scale)	GRAPHIC LOG	ROCK TYPE (DRILLERS TERMS)	WATER-YIELDING CHARACTERISTICS; DRILLING AND WELL CONSTRUCTION DETAILS
	PLEISTOCENE	0-500		UNCONSOLIDATED GLACIAL DEPOSITS, ALLUVIUM AND WIND-BLOWN SILT (DRIFT, SURFACE, OVERBURDEN	WATER-YIELDING CHARACTER VARIABLE. LARGE YIELDS FROM THICKER SAND AND GRAVEL DEPOSITS IN BEDROCK VALLEY. WELLS USUALLY REQUIRE SCREENS AND CAREFUL DEVELOPMENT. CHIEF AQUIFER IN AREA.
PENNSYLVANIAN	McLEANSBORO	0-1000		MAINLY SHALE WITH THIN LIMESTONE, SANDSTONE AND COAL BEDS (COAL MEASURES)	WATER-YIELDING CHARACTER VARIABLES. LOCALLY SHALLOW SANDSTONE AND CREVICED LIMESTONE YIELD SMALL SUPPLIES. WATER QUALITY USUALLY BECOMES POORER WITH INCREASING DEPTH. MAY REQUIRE CASTING.
	CARBONDALE	0-150			
	TRADEWATER CASEYVILLE	0-600			
MISSISSIPPIAN	CHESTER	0-500		LIMESTONE, SANDSTONE AND SHALE	TOO DEEP TO BE CONSIDERED AS A SOURCE OF GROUNDWATER IN THIS AREA.
	VALMEYER	STE. GENEVIEVE 0-120		LIMESTONE	MAY BE WATER-YIELDING IN MASON COUNTY WHERE THESE FORMATION ARE AT A SHALLOW DEPTH. IN THE REST OF THE AREA, TOO DEEP TO BE CONSIDERED AS A SOURCE OF GROUNDWATER.
		ST. LOUIS-SALEM 0-270		LIMESTONE	
		WARSAW 0-130		SHALE	
		KEOKUK BURLINGTON 0-300		CHERTY LIMESTONE	
	KINDERHOOK	0-200		SHALE	NOT WATER-YIELDING
DEVONIAN		0-70		LIMESTONE	WATER-YIELDING FROM CREVICES WHERE ENCOUNTERED AT A SHALLOW DEPTH. IN MOST OF THE AREA, TOO DEEP TO BE CONSIDERED AS A SOURCE OF GROUNDWATER.
SILURIAN	NIAGARAN	0-350		DOLOMITE AND LIMESTONE	
	ALEXANDRIAN	0-100			
ORDOVICIAN	CINCINNATIAN	MAQUOKETA 0-200		SHALE WITH LIMESTONE AND DOLOMITE BEDS	NOT WATER-YIELDING AT MOST PLACES; CASING REQUIRED.
	MOHAWKIAN	GALENA-PLATTEVILLE 300-430		LIMESTONE AND DOLOMITE	NOT IMPORTANT AS AQUIFERS, CREVICED DOLOMITE PROBABLY YIELDS SOME WATER TO WELLS DRILLED INTO UNDERLYING SANDSTONE.
	CHAZY	GLENWOOD-ST. PETER 150-300		SANDSTONE, CLEAN, WHITE, THIN DOLOMITE AND SHALE AT TOP (ST. PETER)	DEPENDABLE SOURCE OF GROUNDWATER IN THE NORTHERN PART OF THE AREA, WATER BECOMES HIGHLY MINERALIZED WITH INCREASING DEPTH.
	PRAIRIE DU CHIEN	SHAKOPEE 200-410		CHERTY DOLOMITE THIN BEDS OF SANDSTONE	NOT IMPORTANT AS AQUIFER. LINERS IN LOWER ST. PETER SANDSTONE ARE COMMONLY SEATED IN UPPER PART OF SHAKOPEE
		NEW RICHMOND 0-175		SANDSTONE AND DOLOMITE	NOT IMPORTANT AS AQUIFERS IN THIS AREA.
		ONEOTA 300-500		DOLOMITE WITH SOME SANDSTONE BEDS (LOWER MAGNESIAN)	
CAMBRIAN	ST. CROIXAN	TREMPEALEAU 200-250		DOLOMITE WITH SOME SANDSTONE BEDS	LIMESTONE AND SANDSTONE BEDS ARE WATER-YIELDING. WATER HIGHLY MINERALIZED OR "BRINE" IN MOST OF THE AREA IN THE NORTHERN PART, QUALITY OF WATER UNKNOWN.
		FRANCONIA 100-200		SANDSTONE, SHALE, AND DOLOMITE	
		IRONTON-GALESVILLE 125-215		SANDSTONE, CLEAN, WHITE, THIN DOLOMITE BED AT THE TOP (DRESBACH)	
		EAU CLAIRE 350-500		SHALE, DOLOMITE AND SANDSTONE	
		MT. SIMON 1200+		SANDSTONE, WITH THIN RED SHALE BEDS	
	PRE-CAMBRIAN			GRANITE AND OTHER	CRYSTALLINE ROCKS EXTENDING TO GREAT DEPTHS.

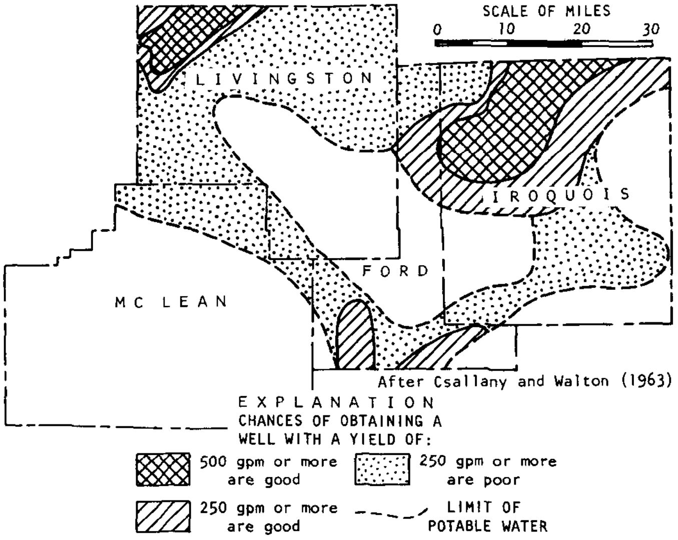
After Selkregg & Kempton (1958)

Figure 3. Generalized column of rock formations in east-central Illinois



After Geologic Map of Illinois, Willman and others (1967)

Figure 4. Areal geology of bedrock surface in east-central Illinois



After Csallany and Walton (1963)

Figure 5. Estimated yields of shallow dolomite wells in northern part of area

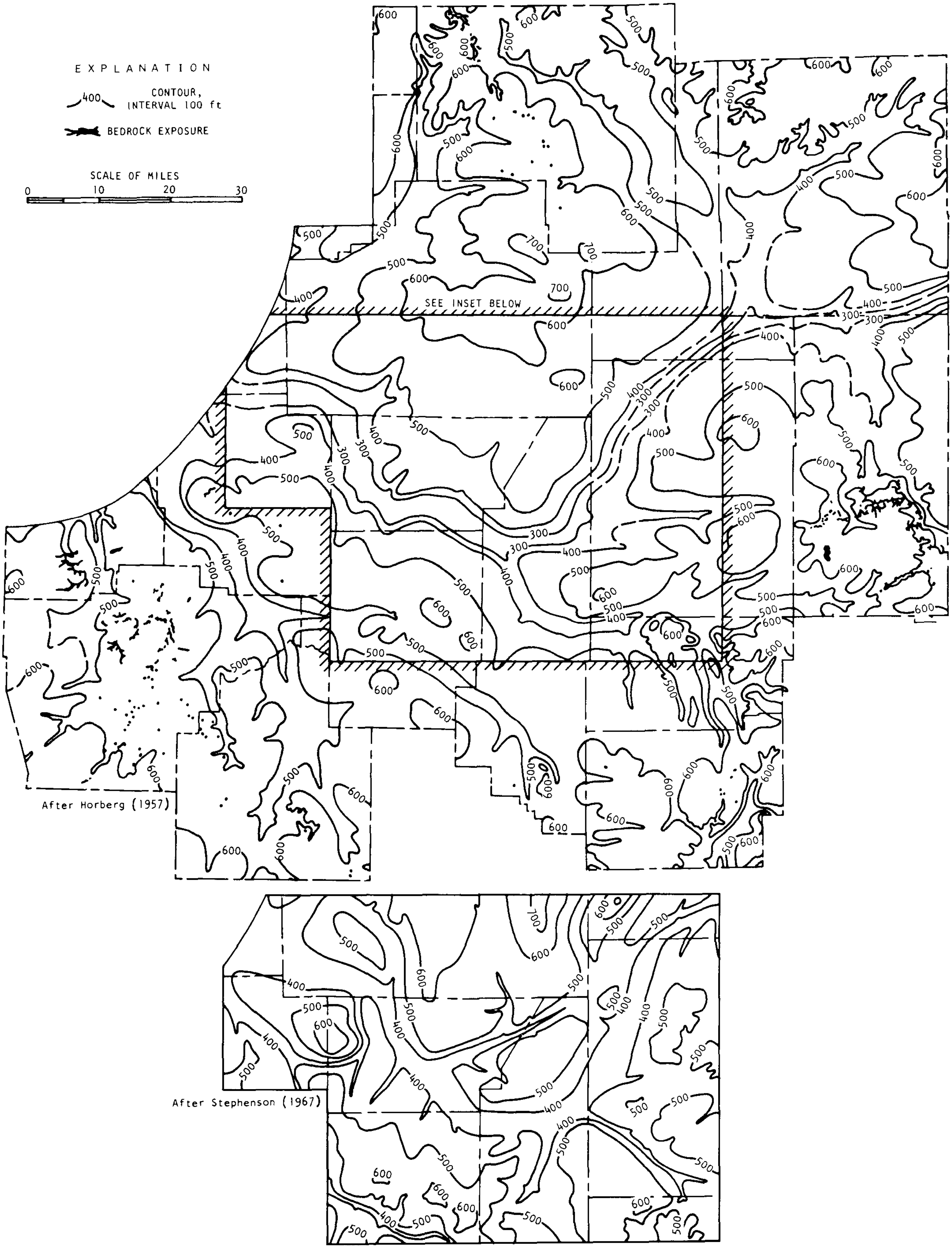


Figure 6. Bedrock topography of east-central Illinois

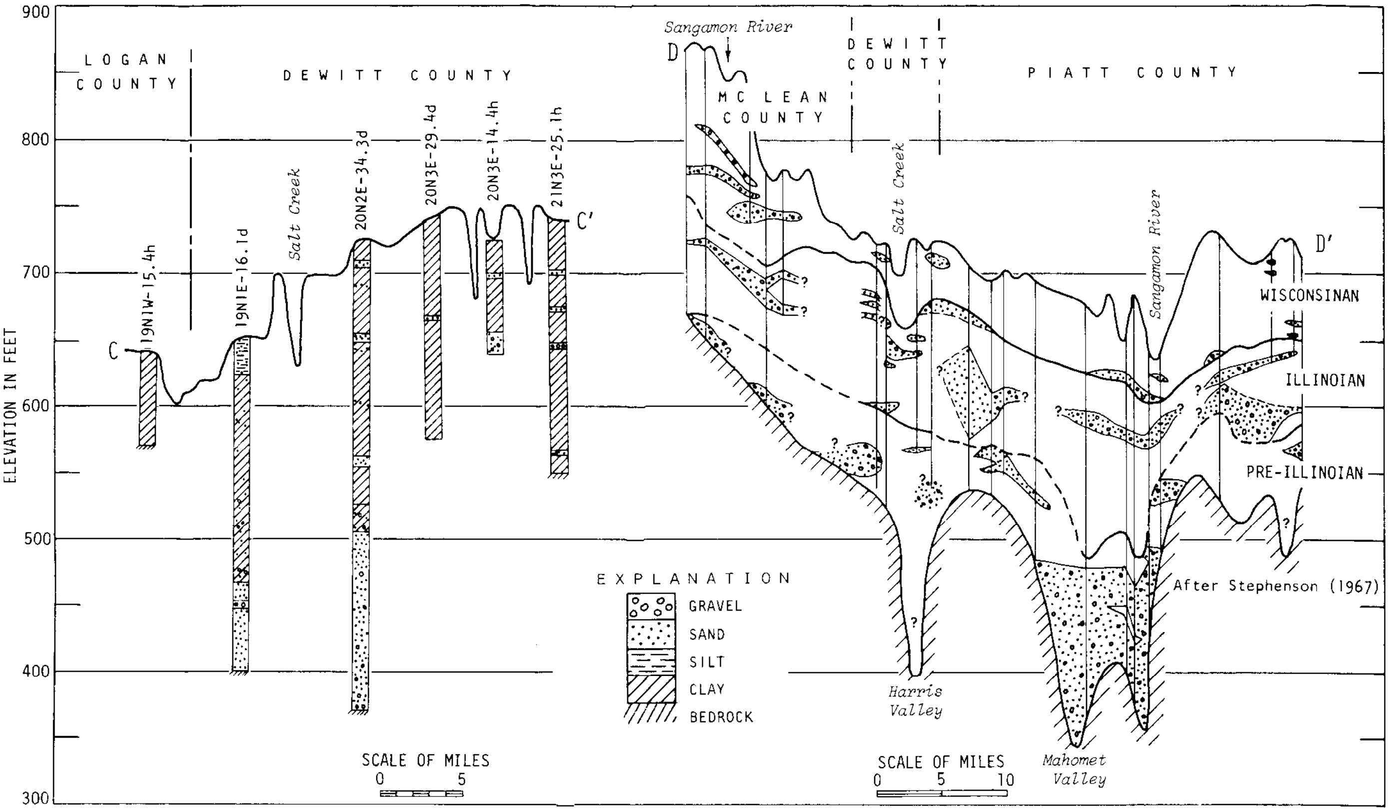


Figure 7. Geologic cross sections of the glacial drift

The major tributaries to the valley are shown in figure 1. The Kempton Valley, with its major tributaries the Onarga and Chatsworth Valleys, enters the Mahomet Valley in southern Ford County and is the only important tributary from the north. Entering the state in southern Vermilion County, the Danville Valley passes northward to enter the main valley at the northern county line. The Pesotum Valley passes westward through southern Champaign County and meets the main channel in central Piatt County. Although tributary to the Illinois Bedrock Valley and not to the Mahomet Valley, three other bedrock valleys are shown because of their proximity to the Mahomet Valley: the Middletown Valley passing from the southeast to the northwest through Logan County where it enters the Havana Lowland area *(see* Walker, Bergstorm, and Walton, 1965, for a detailed description of this region); the Athens Valley, entering the Havana Lowland from the south in northern Menard County; and the Danvers Valley, heading in Livingston County and joining the Mackinaw tributary of the Illinois Valley in Tazewell County.

The main valley floor has a gradual slope downstream, descending about 1.65 inches per mile between Oxford, Indiana, and the lower Illinois Bedrock Valley.

Stephenson's revised map for the central part of the area (figure 6) shows a new valley cutting across northern Piatt and eastern De Witt Counties. The new valley's location is based upon geophysical evidence. Stephenson states, however, that exploratory drilling has raised doubts as to the existence of the new valley and that no well logs are available to corroborate it.

Unconsolidated Deposits

The cross sections in figure 7 illustrate in general the nature of the unconsolidated deposits. The locations of the cross sections are shown in figure 8. Glacial drift almost completely covers the bedrock, to a depth of 200 feet or more over much of the area (figure 9). The drift thickness varies from a featheredge in bedrock exposures to more than 400 feet in the Mahomet Valley in parts of northern Champaign, southeastern Ford, southern Iroquois, and northern Vermilion Counties. Piskin and Bergstrom (1967) suggest that thicknesses as much as 500 feet may occur in the Mahomet Valley in the eastern part of the area.

The unconsolidated glacial deposits in the area are mainly Wisconsinan, Illinoian, and Kansan in age. According to Horberg (1953) remnants of till which may be Nebraskan in age occur along the north margin of the lower Mahomet Valley in De Witt and southwestern McLean Counties and along the Danvers Valley in northern McLean and western Livingston Counties. Piskin and Bergstrom (1967) stated that Nebraskan deposits probably constitute an insignificant part of the drift mantle in Illinois.

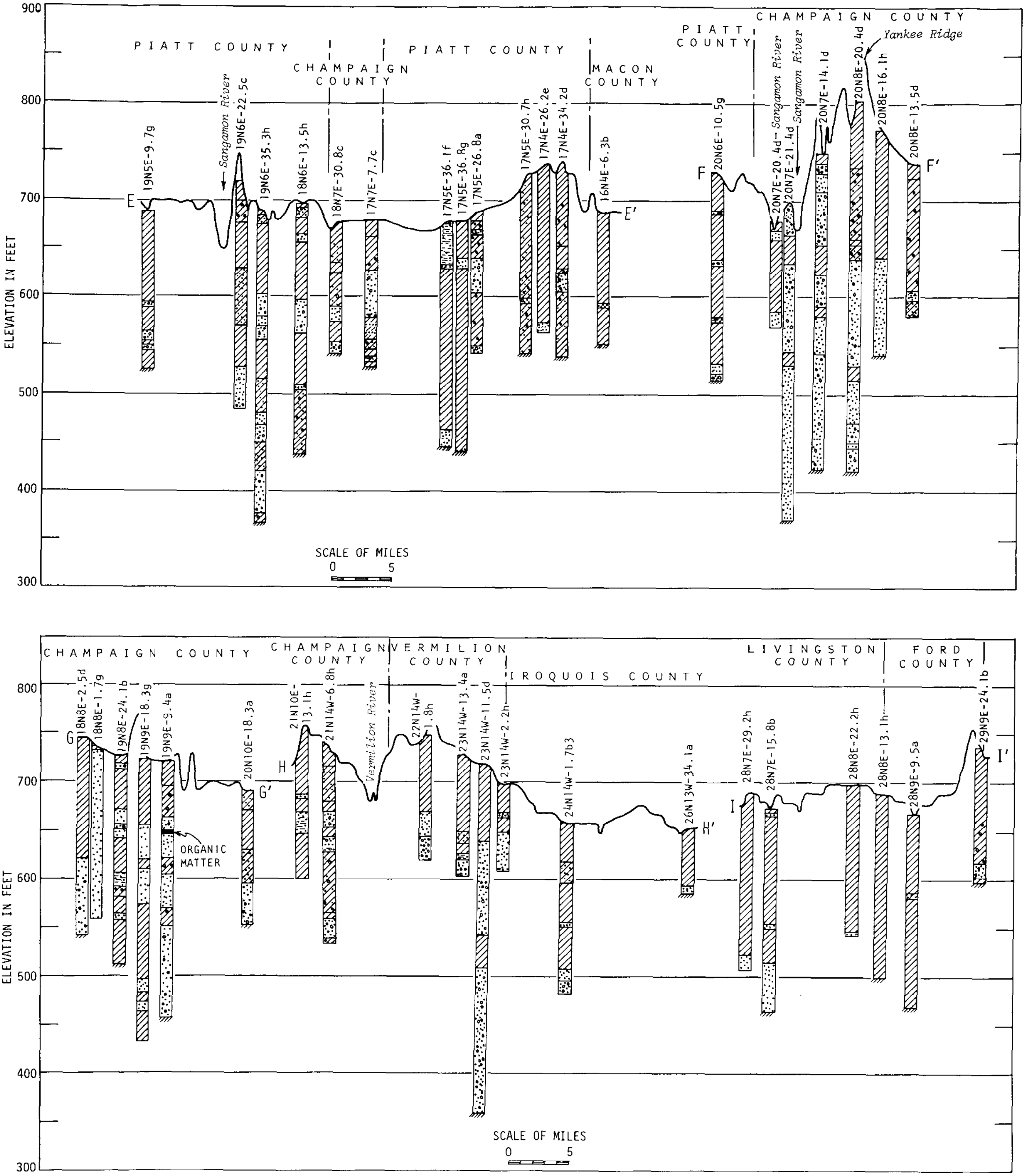


Figure 7 (Continued)

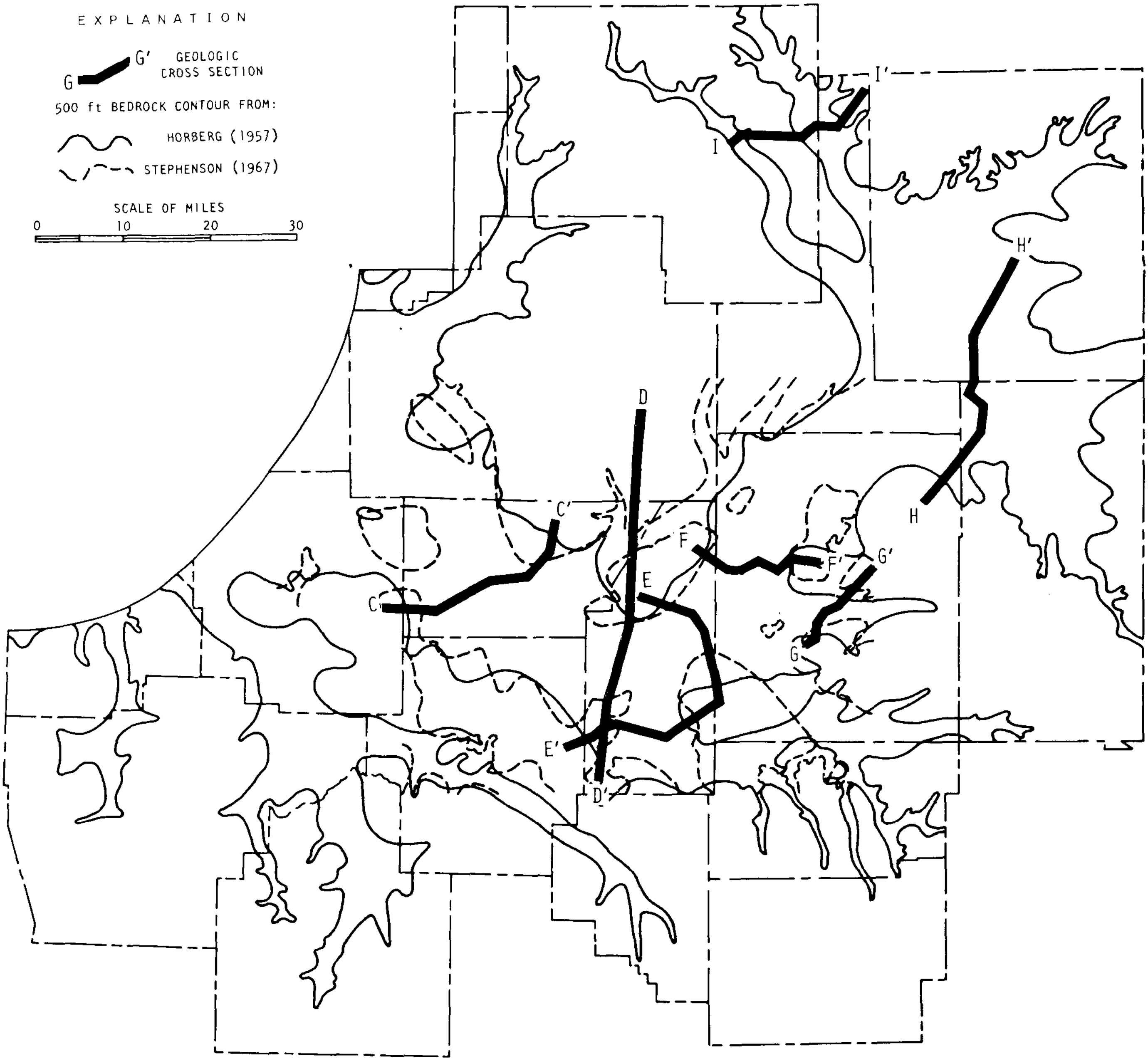


Figure 8. Locations of glacial drift cross sections and 500-foot bedrock contour

Wisconsinan deposits are the uppermost glacial materials in most of the area, and are chiefly till or fine sands except for local occurrences of sand and gravel. The limit of the Wisconsinan glaciation is shown in figure 10. Although generally poor as a source for large groundwater supplies, hundreds of farm and domestic wells have been developed in the Wisconsinan deposits.

Illinoian deposits underlie Wisconsinan deposits in most of the area. According to Horberg (1953) there is no record of buried Illinoian drift in northern Iroquois, Ford, most of Livingston, and small areas in Vermilion, Coles, and Edgar Counties. South of the limit of the Wisconsinan glaciation, Illinoian deposits with a cover of Wisconsinan loess form the bulk of the glacial materials. Illinoian deposits contain rather widespread lenses of sand and gravel intercalated in the glacial drift and are the source of groundwater supplies for many municipalities and industries along the Mahomet Valley.

The largest source of groundwater consists of the sands and gravels of the Pre-Illinoian (Kansan) deposits which occupy the deepest portions of the Mahomet Valley channel. Kansan deposits occur extensively along the Mahomet Valley and consist of silty till underlain by thick beds of sand and gravel. Horberg (1953) gave the name Mahomet sand to the

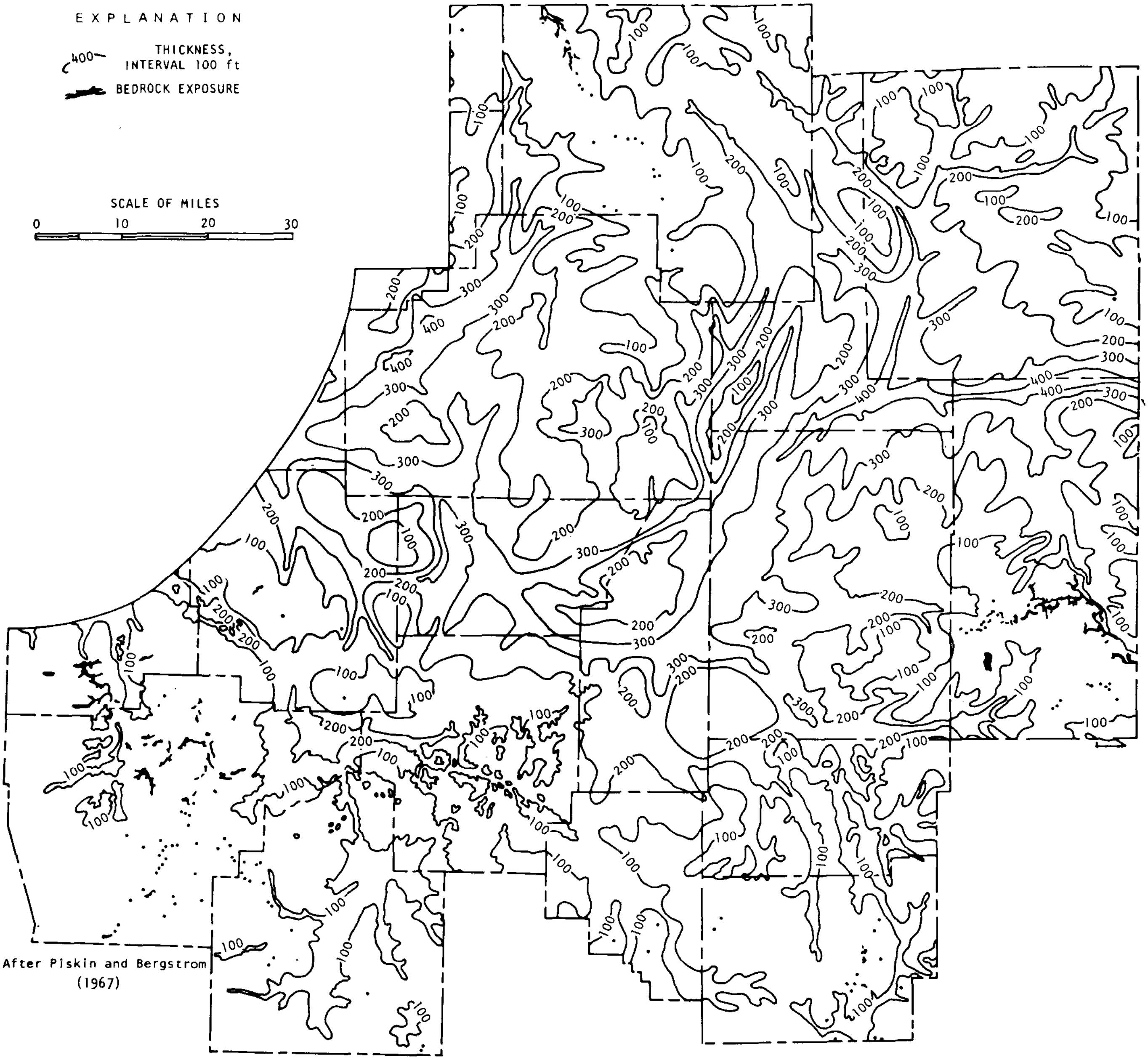
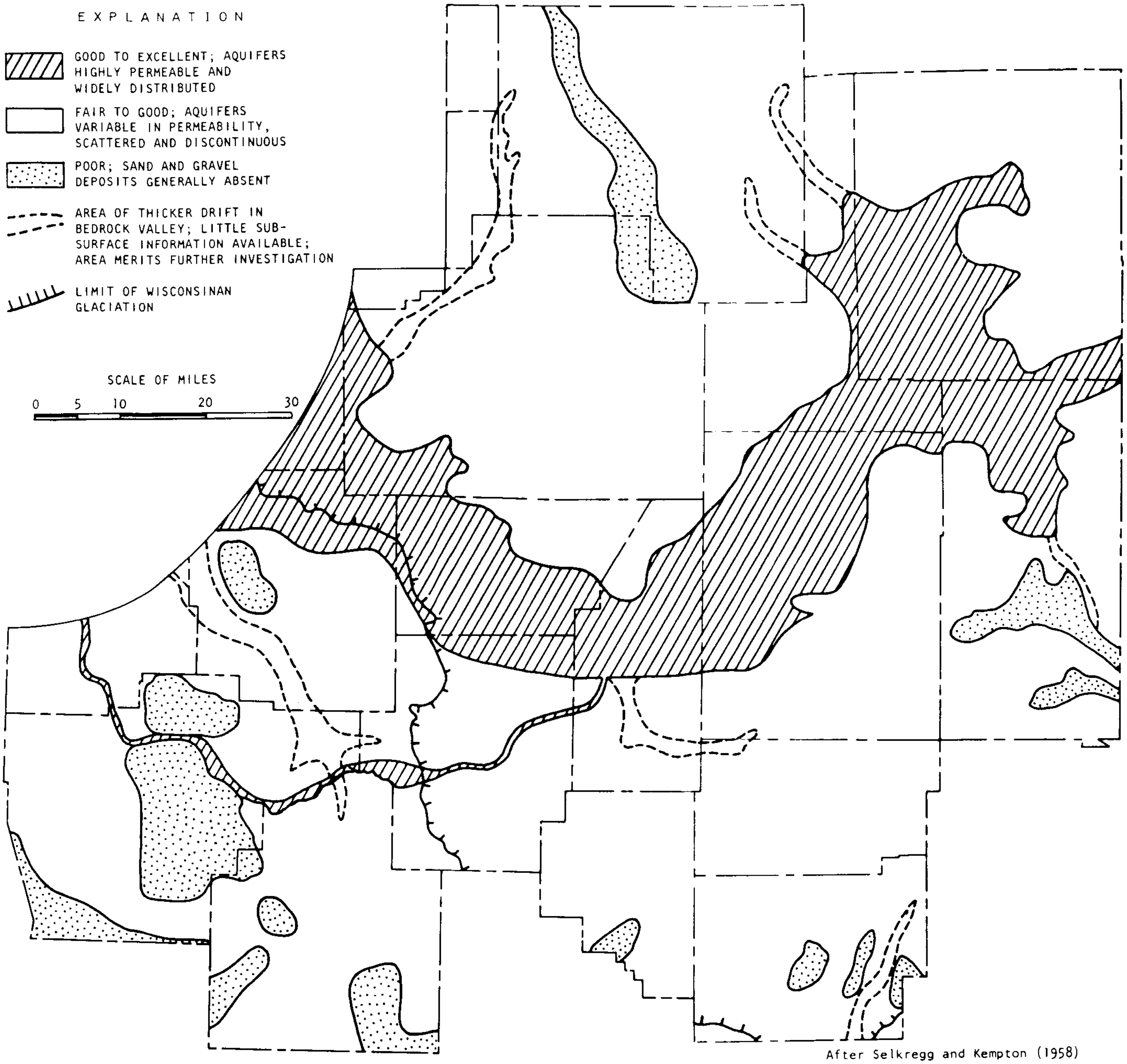


Figure 9. Thickness of drift

thick sand and gravel deposits overlying the bedrock in the valley. According to Horberg (1953) available data indicate that the sand is a continuous fill along the buried bedrock valley from De Witt County eastward into Champaign County and that it may continue eastward into Indiana. Horberg (1953) stated that elevations of the top of the sand range from 465 to 530 feet, with most of the elevations near 500 feet. This corresponds with the elevation of the Sankoty sand, a similar basal sand and gravel (Horberg, 1953) in the Havana Lowlands and northward in the ancient Mississippi Valley. The Sankoty sand probably extends into the Mahomet Valley in the western part of the study area. Sample study logs by the Illinois State Geological Survey of test holes (table 1) show the character of the glacial drift in the Mahomet Valley.

Figure 10 shows the probability of occurrence of sand and gravel aquifers (Selkregg and Kempton, 1958). The wide area classified as “good to excellent; aquifers highly permeable and widely distributed” is associated with the Mahomet Valley. The very narrow meandering strip with the same classification in Macon, Sangamon, and Menard Counties is associated with the Sangamon River. The aquifer deposits along the Sangamon River are very shallow in comparison with the deposits in the Mahomet Valley.



After Selkregg and Kempton (1958)

Figure 10. Probability of occurrence and nature of sand and gravel aquifers

Occurrence of Groundwater

Groundwater in the unconsolidated deposits in the Mahomet Valley occurs under leaky artesian and water-table conditions. Leaky artesian conditions exist where till or other fine-grained deposits overlie the aquifer and impede or retard the vertical movement of groundwater, thus confining water in the aquifer under artesian pressure. Leaky artesian conditions exist in the middle and deep aquifers in the valley. Under leaky artesian conditions a pressure difference between water above and below the till or other fine-grained deposits (confining bed) allows water to move vertically through the confining bed from one aquifer to another. Leakage is possible in either direction, but in the Mahomet Valley downward leakage is more common, especially under conditions of heavy groundwater pumpage from the deep aquifer. Water-table conditions occur in the shallow sand and gravel zones of the Wisconsinan drift where water is unconfined. The water table is in direct connection with surface streams in many places.

Table 1. Selected Sample Study Logs

City of Decatur Well No. 3, NW 1/4 NE 1/4 NE 1/4 Sec. 17, T18N, R5E, Willow Branch Township, Piatt County. Elevation: 680 feet. Drilled by Lavne-Western Drilling Co., 1954. Sample set no. 24148, described by D. A. Stephenson.

Formation	Depth to base *(ft)*	Elevation *(ft)*
Pleistocene Series		
Wisconsinan Stage		
Silt, sandy, mottled dark gray and yellow-gray; till and loess	10	670
Silt, sandy, gray, calcareous, becoming gravelly to the bottom till	27	653
Silt, sandy, gravelly, pinkish gray-brown, calcareous, till	52	628
Sangamonian Stage		
Silt, sandy, clayey, green-gray, calcareous, colluvium	62	618
Illinoian Stage		
Silt, sandy, gravelly, predominantly gray, zones of organic silt, calcareous, till and/or colluvium	125	555
Silt, sandy, pinkish brown-gray, calcareous, becoming gravelly silt at 180 feet, till	200	480
Pre-Illinoian Stage		
Gravel, sandy, silty, subrounded to rounded, some organic silt and wood, outwash, probably top of Mahomet sand, not clean	295	385
Sand and gravel, quartzose sand, medium to coarse grained, clean, Mahomet sand	315	365
Silt, sandy, clayey, gray, slightly calcareous, till or lacustrine, or weathered bedrock	318	362
Pennsylvanian Series		
Shale		

L. Mueller well, SE 1/4 SW 1/4 SW 1/4 Sec. 26, T16N, R2E, South Wheatland Township, Macon County. Elevation: 675 feet. Drilled by Woolen, 1943. Sample set no. 9544, described by L. Horberg.

Formation	Depth to base *(ft)*	Elevation *(ft)*
Pleistocene Series		
Wisconsinan Stage		
Silt, leached, oxidized, till	20	655
Silt, gray, pink tint, calcareous till	50	625
Sangamonian Stage		
Silt, dark brown, humus	55	620
Illinoian Stage		
Silt, gray-green, leached, oxidized, colluvium	65	610
Silt, light gray, calcareous, till	85	590
Sand, medium grained	90	585
Gravel, ½-inch diameter, clean above, dirty below	100	575
Yarmouthian Stage		
Silt, brown, calcareous, sandy	105	570
Silt, same as above, and granular gravel	110	565
Sand and gravel, brown, slightly calcareous	115	560
Silt, brown, few sand grains, calcareous, loess-like	120	555
Kansan Stage		
Silt, similar to above, sandy and gravelly	145	530
Silt, gravelly, greenish brown, calcareous, till	170	505
Gravel, yellow, oxidized, sandy	175	500

(from Stephenson, 1967)

Village of Kenney well, SE 1/4 NE 1/4 SE 1/4 Sec. 16, T19N, R1E, Tunbridge Township, De Witt County. Elevation: 650 feet. Drilled by Mashburn, 1956. Sample set no. 27080, described by J. Hackett.

Formation	Depth to base *(ft)*	Eleva. tion *(ft)*
Pleistocene Series		
Wisconsinan Stage		
Silt, noncalcareous, loess	9	641
Sand, fine to coarse grained, silty	15	635
Sand, medium to coarse grained, silty	20	630
Sand, coarse grained, fine gravel, some wood	25	625
Illinoian Stage		
Sand, fine to coarse grained, tine gravel, very silty, organic	40	610
Sand, fine to coarse grained	60	590
Gravel, sandy	70	580
Sand, fine to coarse grained	75	575
Silt, sandy, gravelly, brown-gray, calcareous, till	90	560
Sand, medium to coarse grained	95	555
Silt, sandy, gravelly, brown-gray, till	120	530
Silt, gravelly, brown-gray to light brown, calcareous, till	125	525
Kansan Stage		
Silt, gravelly, light brown, mixed with soil, till	130	520
Silt, gravelly, light brown to dark gray, calcareous, till	150	500
Gravel, fine grained	175	475
Sand, fine to coarse grained, clean from 250 feet	262	388
Pennsylvanian Series		
Limestone		

S. L. Rogers well, NE 1/4 NW 1/4 SW 1/4 Sec. 22, T19N, R4E, Goose Creek Township, Piatt County. Elevation: 700 feet. Drilled by Woolen, 1943. Sample set no. 9384, described by D. A. Stephenson.

Formation	Depth to base *(ft)*	Eleva. tion *(ft)*
Pleistocene Series		
Wisconsinan Stage		
Silt, yellow-brown, oxidized, sandy, loess	15	685
Silt, sandy, gray, some gravel, till (Cerro Gordo?)	25	675
Silt, sandy, red-gray-brown to dark gray, some wood, non- to slightly calcareous, till (Shelbyville?)	53	647
Illinoian Stage		
Silt, brown, organic, bog	70	630
Sand, gravelly, outwash	75	625
Silt, sandy, gray-brown, gravelly, clayey, till	80	620
Gravel and silty gravel, sorted gravel over coarse till	90	610
Gravel, sand, and silt, gray, till	105	595
Sand, silty, and silt, sandy, gray-brown, till	125	575
Gravel	130	570
Silt, sandy, gray-brown, till	140	560
Kansan (?) Stage		
Silt, gray-brown, probably bog	145	555
Silt, sandy, brown-gray, till	155	545
Silt, sandy, yellow-brown to brown	170	530
Pennsylvanian Series		
Limestone		

HYDRAULIC PROPERTIES

The principal hydraulic properties of an aquifer and its confining bed influencing well yields and water-level declines within the Mahomet Valley are the coefficients of permeability or transmissibility, storage, and vertical permeability. (The coefficient of transmissibility will be referred to as transmissivity throughout the rest of this report.) The capacity of a formation to transmit groundwater is expressed by the transmissivity T which 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 100 percent (1 foot per foot) at the prevailing temperature of the water. The transmissivity is the product of the saturated thickness of the aquifer m and the permeability P (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 100 percent at the prevailing temperature of the water). The storage properties of an aquifer are expressed by the coefficient of storage S, which is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in head normal to that surface.

The rate of vertical leakage of groundwater through a confining bed in response to a given vertical hydraulic gradient is dependent upon the vertical permeability of the confining bed P'. In cases where the confining bed is not well defined or is unknown the ratio P'/m' (where m' is the thickness of the confining bed), termed the leakage coefficient by Hantush (1956), is used. The leakage coefficient is defined as

Table 2. Results of Aquifer Tests in Illinoian Deposits

Well number	Owner	Depth *(ft)*	Date of test	Length of test *(min)*	Pumping rate *(gpm)*	Lithology		Method* of analysis	Transmissivity *(gpd/ft)*	Saturated thickness *(ft)*	Permeability *(gpd/sq ft)*	Coefficient of storage	Leakage coefficient *(gpd/sqft*	Thickness of confining layer *(ft)*	Coefficient of vertical permeability *(gpd/sq ft)*
						Aquifer	Confining bed								
CHM—															
17N7E-															
7.6d(1)	Ivesdale (V)	85	9/24/65	180	50	Coarse, dirty sand	Hardpan	T-D(1)	12,000	10	1200			15	
18N8E-															
25.5d(10)	Tolono (V)	181	10/28/65	180	121	Coarse sand & gravel	Clay, some boulders	D-D(1)ow	14,100	40	350	0.00017		18	
25.6c(11)	Tolono (V)	181	2/16-17/66	1440	216	Fine to coarse sand, gravel	Clay, boulders	T-D(1)	15,600	24	650			27	
19N9E-															
6.5f3(3)	Swift & Co.	161	1/26/49	420	500	Fine sand, gravel	Clay	T-D(1)	63,450	38	1670	0.00001			
16.1h	Champaign Co. Office Bldg.	156	7/26/66	90	5	Fine sand, silt	Clay, hardpan	T-D(1)	4,890	13	375				
19N10E-															
14.6h(1)	St. Joseph (V)	76	5/28/58	30	170			T-D (2) ow	13,000	16	810	0.0001	0.001	35	0.035
14.7h(2)	St. Joseph (V)	73	6/5/58	375	138	Sand	Gravelly clay	T-D(1)ow	17,800	16	1110				
19N14W															
7.7e	State of Ill.	63	5/4/65	180	30	Sand, some gravel	Gravelly clay	T-D(1)	3,440	8	4.30	0.00022		41	
20N9E--															
31.5a4(4)	Clifford-Jacobs Forging Co.	166	6/6/51	100	150	Sand & gravel	Gravelly clay	T-D(1)	20,000	21	950			24	
31.5a5(5)	Clifford-Jacobs Forging Co.	166	5/21/56	180	340			T-D(2)ow	22,900	21	1090	0.0035	1.31	24	31.4
21N10E-															
1.7f(2)	Gifford (V)	165	3/1-2/66	1380	155	Fine sand to medium gravel	Clay	T-D(1)	10,370	12	865			42	
DWT—															
19N4E-															
9.3e(2)	Weldon (V)	164	4/19/62	22	52	Coarse sand		T-D(1)	869						
9.5c(3)	Weldon (V)	167	8/13/63	360	100	Fine sand		T-D(1)	3,500						
FRD—															
25N9E-															
21.5g6(6)	Roberts (V)	278	11/7/60	60	128	Sand	Clay. hardpan	T-D(1)	3,230	14	230				
LIV—															
26N8E--															
3.8g(3)	Chatsworth (T)	99	6/6/58	540	160	Sand, gravel, boulders	Gravelly clay	T-D(1)	21,500	10	2150				
LOG—															
19N2W-															
35.5c(T)	Mt. Pulaski (C)	32	7/10/63	240	100	Medium to coarse sand & gravel		D-D(1)ow	96,000	23.5	4080				
MEN—															
18N7W-															
13.8e5(4)	Petersburg (C)	58	9/12/63	375	305	Sand, gravel boulders, some clay		T-D(3)ow	46,000	40	1150	0.083			
13.8e6(5)	Petersburg (C)	55	8/29/66	164	350	Fine to coarse sand, some clay		T-D(3)	32,160	31.5	1020				
VER—															
23N12W-															
11.3e4(3)	Hoopeston (C)	110	7/26/63	1000	765	Sand	Clay	T-D(1)ow	145,000	70	2070	0.000366			
11.3e5(4)	Hoopeston (C)	110	7/26/63	1000	765			T-D(1)	135,000	70	1930				
11.3e6(5)	Hoopeston (C)	104	3/4/65	240	1543	Sand, gravel, boulders	Clay, boulders	T-D(1)ow	147,000	70	2100	0.000246			

*T-D = *time-drawdown;* D-D = *distance-drawdown*
1 = *nonequilibrium formulas;* 2 = *leaky artesian formulas*
3 = *water-table analysis;* ow = *observation well data*

the quantity of water, in gallons per day, that crosses a 1-square-foot area of the interface between an aquifer and its confining bed per foot of head difference across the confining bed.

Aquifer Tests

The hydraulic properties of aquifers and confining beds 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, are used to solve formulas which express the relation between the hydraulic properties of an aquifer and its confining bed, if present, and the lowering of water levels in the vicinity of a pumped well.

The data collected during aquifer tests may be analyzed by use of the leaky artesian formula (Hantush and Jacob, 1955), the nonequilibrium formula (Theis, 1935), or the modified nonequilibrium formula (Cooper and Jacob, 1946). Hantush (1956) and Walton (1960) described methods for analyzing test data under leaky artesian conditions. Type-curve and straight-line methods for solving the nonequilibrium formula and the modified nonequilibrium formula with logarithmic or semilogarithmic time-drawdown or distance-drawdown graphs were described by Walton (1962). Test data collected under water-table conditions may be analyzed by methods devised by Boulton (1963) and described by Prickett (1965). Where geohydrologic boundaries are known to exist, their effect on the response of an

Table 3. Results of Aquifer Tests in Kansan Deposits

Well number	Owner	Depth (ft)	Date of test	Length of test (min)	Pumping rate (gpm)	Lithology: Aquifer	Lithology: Confining bed	Method* of analysis	Transmissivity *(gpd/ft)*	Saturated thickness *(ft)*	Permeability *(gpd/ sq ft)*	Coefficient of storage	Leakage coefficient *(gpd/ cu ft)*	Thickness of confining layer *(ft)*	Coefficient of vertical permeability *(gpd/ sq ft*
CHM— 18N8E-															
2.4e(1)	Univ. of Ill. Golf Course	218	11/6/63	90	232			T-D(1)ow	117,500	70	1680	0.00014			
19N8E-															
5.1g1(49)	No. Ill. Water Corp	297	8/26/50	2.70	1000			T-D(2)ow	325,000	100	3250	0.00041	0.00509	35	0.178
18.3d(2)	Petro Chemicals Corp.	272	10/29/52	1440	1767	Sand & gravel, some clay	Sandy clay	T-D(2)ow	252,000	75	3350	0.00031	0.0061	35	0.214
18.4b(3)	Petro Chemicals Corp.	272	1/30/56	360	1550			D-D(1)ow	205,000	100	2050	0.0023			
18.4d(l)	Petro Chemicals Corp.	278	10/23/52	480	1683	Sand & gravel	Clay, dirty sand, coal, some gravel	T-D(2)ow	236,000	83	2840	0.00031	0.00836	50	0.42
29.7h	Urbana-Champaign San. Dist.	205	10/3/66	120	70	Fine sand, coal	Gravelly clay	T-D(l)	5,130.						
20N8E-															
33.8a1(50)	No. Illinois water Corp.	299	8/26/50	270	1270	Sand & gravel, some clay	Clay, gravelly	T-D(2)ow	325,000	90	3620	0.00041	0.00509	35	0.178
DWT- 20N2E-															
34.2d2(6)	Clinton (C)	345	3/2-3/60	1440	500	Sand & gravel	Hardpan	T-D(2)ow	82,000	100	820	0.0006	0.0466	75	3.5
IRO— 24N14W.															
1.7b(5)	Cissna Park (V)	176	10/13/66	110	493	Fine to coarse sand, gravel	Clay	T-D(2)ow	72,500	26	2780	0.00093	0.282	14	12.2
26N14W-															
6.5h12(2)	Gilman (C)	197	9/9/60	60	280	Sand	Clay	T-D(l)	38,900	30	1300			37	
27N12W.															
32.2b4(5)	Watseka (C)	175	6/10/52	210	110	Sand & gravel	Clay & quicksand	T-D(l)	185,000	45	4100				
LIV- 27N8E.															
34.6b(4)	Chatsworth (T)	232	6/7/60	360	207	Gravel, coarse sand	Gravelly clay	T-D(1)	20,200	27	750				
34.6d(5)	Chatsworth (T)	223	9/19/60	240	200	Fine to coarse sand, gravel	Gravelly clay	T-D(2)ow	83,000	21	3950	0.000093	0.000123	74	0.0091
LOG- 21N1W-															
20.5e1(T)	Atlanta (C)	150	9/13/65	180	21	Sand & gravel	Hardpan, drift	T-D(l)	16,300	18	905				
20.5e2(4)	Atlanta (C)	150	11/4/65	200	110	Sand & gravel	Hardpan, drift	T-D(l)	17,000	18	945				
MCL- 26N3E.															
4.3b1(3)	Gridley (V)	286	7/13/53	480	220	Gravel, boulders	Clay, boulders	T-D(2)ow	5,600	18	310	0.0000217	0.00012	200	0.024
4.3h2(4)	Gridley (V)	294	9/24/63	200	262	Fine to medium gravel, sand	Clay, silt	T-D (2)ow	9,500	23	410	0.0006	0.021	68	1.43
PIA— 18N5E-.															
30.7a(2)	Decatur (C)	252	7/29/54	430	2550	Fine to coarse Sand & gravel	Clay	T-D(2)ow	270,000	150	1910	0.000136	0.00111	75	0.083
31.7g(1)	Decatur (C)	244	9/6/55	35	1655	Medium to coarse sand & gravel	Clay, some sand	T-D(1)ow	276,000	150	1840	0.000231		75	

*T-D = *time-drawdown;* D-D = *distance-drawdown*
1 = *nonequilibrium formulas;* 2 = *leaky artesian formulas*
ow = *observation well data*

aquifer to pumping can be determined by means of the image well theory described by Ferris (1959).

Controlled aquifer tests in Kansan and Illinoian deposits were made at 40 sites within the study area during the period 1949 through 1966. The results of analyses of test data to determine aquifer and confining bed properties are summarized in tables 2 and 3.

Tests involving only the pumped well were made at 19 sites. The effects of leakage on drawdowns in the pumped well were negligible during the tests, and analysis was limited to the use of the nonleaky or modified nonequilibrium artesian formulas. The storage coefficient was not estimated from data collected during these tests, since its determination from pumped well data involves appreciable error.

The leaky artesian formula was used to analyze data from tests at 12 sites where data were available from one or more observation wells. The leaky artesian formula can be expressed by the following relation:

$$s = (114.6\, Q/T)\, W(u, r/B) \qquad (1)$$

where

$$W(u, r/B) = \int_u^\infty (1/u) \exp\left(-u - r^2/4B^2u\right)du$$

$$u = 2693 r^2 S/Tt$$

and

$$r/B = r/\sqrt{T/(P'/m')}$$

s = drawdown in observation well, in ft
r = distance from pumped well to observation well, in ft
Q = discharge, in gpm
t = time after pumping started, in min
T = transmissivity of aquifer, in gpd/ft
S = coefficient of storage of aquifer, fraction
P' = vertical permeability of confining bed, in gpd/sq ft
m' = saturated thickness of confining bed through which leakage occurs, in ft

Application of the leaky artesian formula to analyze aquifer test data is described in the following example. The data analyzed were collected from an aquifer test conducted by Layne-Western Company on October 29, 1952, for the U. S. Industrial Chemicals Corporation (Petro Chemicals Corporation). The test site was located in section 18, T19N, R8E, approximately 3.5 miles west of Champaign. The effects of pumping well CHM 19N8E-18.3d(2) were measured in observation well 18.4d(1). The locations of wells used in the test and that of a nearby test well are shown in figure 11, and generalized logs are shown in figure 12.

Pumping was started at 8:17 a.m. on October 29 and was continued for about 24 hours at a constant rate of 1767 gpm until 8:00 a.m. on October 30. Drawdowns in the observation well were recorded and plotted against time on logarithmic paper. The time-drawdown field data graph for well 18.4d(1) is given in figure 13.

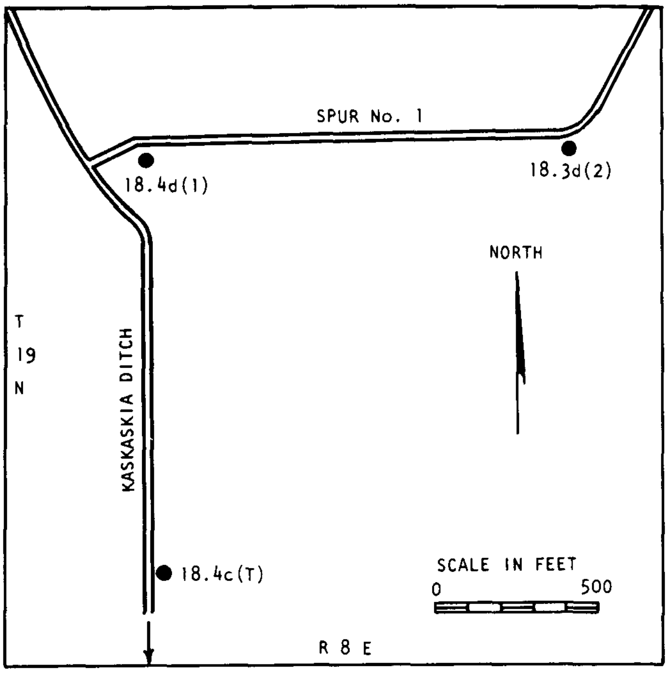


Figure 11. Location of wells used in aquifer test and of nearby test hole

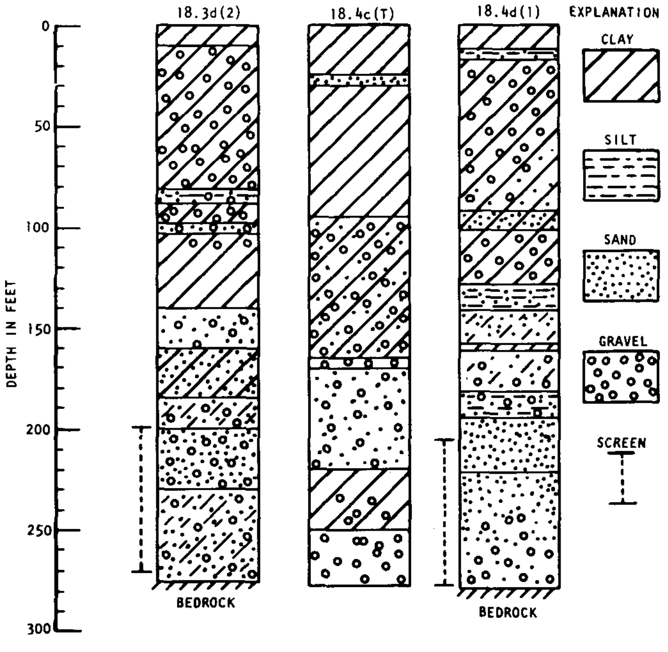


Figure 12. Generalized logs of wells in aquifer test area

The time-drawdown field data graph was superimposed on the family of nonsteady-state leaky artesian type curves (Walton, 1960) and closely followed the trace of the r/B = 0.2 type curve. Match point coordinates and an r/B value of 0.2 were substituted into the leaky artesian formula to compute the transmissivity, vertical permeability, and coefficient of storage. Computations are shown in figure 13. Transmissivity, vertical permeability, and the coefficient of storage were computed to be 252,000 gpd/ft, 0.214 gpd/sq ft, and 0.00031, respectively.

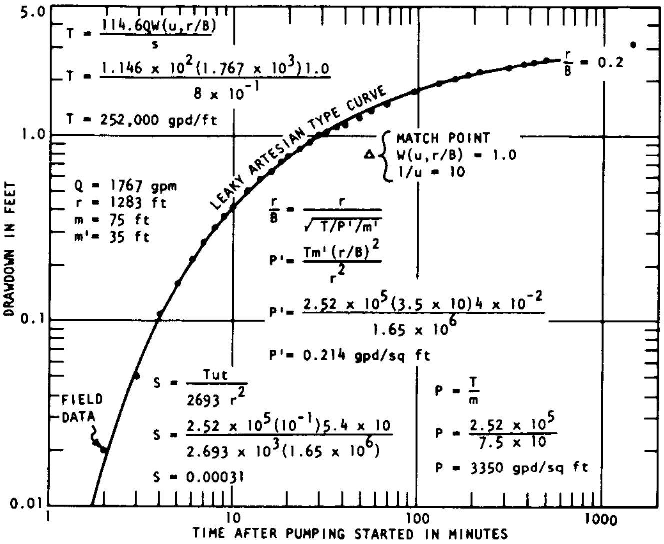


Figure 13. Time-drawdown data for well CHM 19N8E-18.4d(1)

The proximity of the Kaskaskia Ditch to the test site did not affect the test results. Available geohydrologic data indicate that this stream is not a recharge boundary for the deep aquifer. The streambed is separated from the aquifer by a thick section of clay.

Observation well data were available from nine additional test sites. Data from two of the tests which occurred under water-table conditions were analyzed by methods outlined by Prickett (1965). Data from seven of the tests which occurred under leaky artesian conditions were analyzed by the nonequilibrium formula, because the effects of leakage on water levels in the observation wells were not apparent.

Aquifer tests given in tables 2 and 3 had considerable ranges in length and pumping rate. The lengths of tests ranged from 22 minutes to 24 hours. Pumping rates ranged from 5 to 2550 gpm. Wells tested in Illinoian sands and gravels ranged in depth from 32 to 278 feet. Tests in Kansan deposits were conducted in wells whose depths ranged from 150 to 345 feet.

Permeability coefficients obtained from aquifer tests in Illinoian deposits ranged from 230 to 4080 gpd/sq ft. Storage coefficients obtained from tests under leaky artesian conditions in Illinoian deposits ranged from 0.00001 to 0.0035. A storage coefficient obtained from a test under water-table conditions in Illinoian deposits was 0.083.

Permeability coefficients obtained from tests in Kansan deposits ranged in value from 310 to 4100 gpd/sq ft. Storage coefficients ranged from 0.0000217 to 0.0023.

Observation well data from 12 test sites were analyzed by use of the leaky artesian formula to determine the coefficients of leakage and vertical permeability of confining bed materials. Observation well data from only two of the seven tests in Illinoian deposits were analyzed by the leaky artesian formula. Since the effects of leakage were not apparent in the five other Illinoian tests involving observation wells, it is believed that vertical head losses created during the time of these tests were not sufficient to cause leakage across the confining layers in the vicinity of observation wells. Of the two vertical permeabilities determined from Illinoian test data, 0.035 and 31.4 gpd/sq ft, the latter value is probably not representative of the confining layer for extensive distances from the pumped well.

Coefficients of vertical permeability were determined for confining bed materials above Kansan sand and gravel deposits at 10 sites and range from 0.0091 to 12.2 gpd/sq ft. The latter value is probably representative of only the confining bed in the immediate vicinity of the tested well (IRO 24N14W-1.7b). High values of vertical permeability were also determined from test data at Clinton (well DWT 20N2E-34.2d2) and Gridley (well MCL 26N3E-4.3b2). The average vertical permeability of confining layers above Kansan aquifers (not including the three high values discussed above) determined from test data analyses was 0.158 gpd/sq ft.

Inherent with leaky artesian conditions is the source bed, separated from the aquifer by the confining layer. The source bed may be above or below the aquifer; however, major leaky artesian aquifers in the Mahomet Valley derive leakage from source beds above. The source bed for Illinoian aquifers under leaky conditions is generally the local water table. Kansan aquifers may also induce leakage from the water table. Generally, however, the Illinoian aquifer provides the source bed for leakage to Kansan deposits. Water levels in Illinoian deposits usually are at a higher elevation than those in Kansan sands and gravels, so that downward leakage occurs naturally in many places. This difference in water levels gradually diminishes westward down the valley until Illinoian and Kansan water levels are near the same elevation. Illinoian sands and gravels, although extensive, are not continuous over the entire valley but exist as sheets or lenses. Where Illinoian aquifers are thin or are absent, leakage to the Kansan aquifer must come from shallower sources. As a cone of depression created by heavy Kansan pumpage grows, it may locally encounter a complex hydrologic regime wherein a portion of water from leakage is derived from a finite Illinoian aquifer and the remainder is derived from shallower sources.

Table 4. Results of Well-Field Case History Analyses

Well field	Pumpage 1965 *(mgd)*	Estimated aquifer thickness *(ft)*	Estimated transmissivity *(gpd/ft)*	Estimated confining bed thickness *(ft)*	Leakage coefficient *(gpd/ cu ft)*	Coefficient of vertical permeability *(gpd/sqft)*
Illinoian deposits						
Arcola	.120	20	10,000	70	0.000571	0.04
Hoopeston	1.255	52	142,000	60	0.000652	0.039
Rantoul	0.750	50	72,000	80	0.0000325	0.0026
Kansan deposits						
Fisher	0.100	90	76,000	87	0.000462	0.04
Monticello	0.625	94	200,000	60	0.000384	0.023
Rantoul	2.750	55	135,000	75	0.0000667	0.005
Watseka	0.905	45	202,000	100	0.0001	0.01

Table 5. Results of Step-Drawdown Tests in Illinoian Deposits

Well number	Owner	Screen length (ft)	Screen diameter (in)	Screen material and/or manufacturer	Screen slot number	Date well drilled	Date of test	Well-loss coefficient *(sec2/ft6)*
CHM— 17N7E- 7.6d(l)	Ivesdale (V)	8 2	8 8	Johnson Stainless Steel Johnson Stainless Steel	30 35	9/65	9/24/65	73
19N8E- 12.3c2	S. S. Kresge Co.	11.5 12.5	8 8		12 18	1/37	1/9/37	44
19N9E- 6.5f3(3)	Swift & Co.	24	17X72	Concrete		1/49	1/24-26/49	7.5
18.4h2(6)	Univ. of Ill.	70	24	Shutter	6	1/16		2.9
19N10E- 14.6h(1)	St. Joseph (V)	13	8	Johnson Red Brass	70	1940	2/7/64	31.8
19N14W- 7.7e	State of Illinois	8	6	Johnson Red Brass	18	4/65	5/4/65	60
20N9E- 31.2c1(2)	Illinois Central RR	28.5	8	Keystone	30	1/6/44 1/44	1/6/44	34
31.5a4(4)	Clifford-Jacobs Forging Co.	16	10	Johnson Everdur	60	5.6/51	6/6/51	4.0
21N9E- 15.7h(1)	Shull Mobile Homes Co.	10.6	6	Johnson Silicon Red Brass	10	9/64	9/21/64	12.6
21N10E- 1.7g(1)	Gifford (V)	15	8	Keystone Wirewound	30	9/61	9/5/61	17.6
22N9E- 34.2a8(2)	Rantoul (V)	9 11	12 12	Johnson Everdur Johnson Everdur	30 10	5/49	5/23/49	8.2
DWT— 19N4E- 9.5c(3)	Weldon (V)	10	8		6	8/63	8/13/63	63
FRD— 23N10E- 7.7d(6)	Paxton (C)	6 5 9	10 10 10	Johnson Johnson Johnson	30 25 18	1950	7/27/50	3.5
25N9E- 21.5g5(5)	Roberts (V)	5 6	8 8	Johnson Everdur Johnson Everdur	10 20	9/50	9/22/50	6.5
IRO— 25N10E- 6.5h(l)	Thawville (V)	4 6	8 8	Johnson Everdur Johnson Everdur	15 20	8/50	8/9/50	42.0
26.6d(2)	Buckley (V)	6 6	8 8	Johnson Everdur Johnson Everdur	20 40	11/58	11/13/58	17.7
LOG— 19N2W- 35.5c(T)	Mt. Pulaski (C)	8	10	Stainless Steel		7/63	7/10/63	6.1
MCN— 16N1W- 2.1c2(2)	Niantic (V)	9.5	10	Cook Red Brass Wirewound	22	8/.58	8/13/58	37.2
MEN— 18N7W— 13.8e6(5)	Petersburg (C)	10	16	Cook Stainless Steel Wirewound	100	8/66	8/29/66	2.2
MOU— 13N5E- 13.4e(3)	Sullivan CCb.	10	10		40	1954	6/24/54	13.4
VER— 23N12W- 11.3e4(3)	Hoopeston (C)	14	10	Cook	10	1906	7/17-19/63	0.9
11.3e5(4)	Hoopeston (C)	14	12			1927	7/18/63	2.5
11.3e6 (5)	Hoopeston (C)	15	18	Layne Stainless Steel Shutter	2	3165	3/3/65	0.3

Well-Field Analyses

Coefficients of vertical permeability and leakage coefficients were also determined from case histories of groundwater development in six municipal well fields in the Mahomet Valley area (table 4). Two of the well fields were developed in Illinoian deposits; four were developed in Kansan deposits. An analysis of the Illinoian deposits at Arcola (Walker and Walton, 1961) is also included in table 4 for comparison, although this well field was not located within the area of the major valley or its tributaries.

Complex aquifer conditions in the vicinity of the well fields were simulated with simplified model aquifers. With the exception of the aquifer in the vicinity of the Watseka well field, aquifer conditions were simulated by an aquifer of infinite areal extent overlain by a confining bed. The

Table 6. Results of Step-Drawdown Tests in Kansan Deposits

Well number	Owner	Screen length (ft)	Screen diameter (in)	Screen material and/or manufacturer	Screen slot number	Date well drilled	Date of test	Well-loss coefficient (sec^2/ft)
CHM—								
19N8E-								
5.1g1(49)	No. Illinois Water Corp.	50	14	Layne Silicon Bronze Shutter	5	4/47	4/2-12/47	5.1
20N7E-								
10.1e(1)	Briarcliff Subdivision	10	6	Cook Bronze	20	9/63	9/27/63	20.9
15.7e3(3)	Mahomet (V)	40	12	Layne Stainless Steel Shutter	4	7/63	7/3/63	0.5
20N8E-								
32.2a1(51)	No. Illinois Water Corp.	76	17x22	Concrete	*	8/50	8/14/50	1.3
32.2a2(54)	No. Illinois Water Corp.	75	24			1957	11/26-30/56	0.2
33.8a1(50j	No. Illinois Water Corp.	72	17x22	Concrete	*	11/47	11/21-22/47	1.4
21N9E-								
28.8a1(1)	Thomasboro (V)		10	Everdur Wirewound	40	1960	4/18/60	1.4
28.8a(2)	Thomasboro (V)	15	10	Cook Everdur Wirewound	40	2/66	3/1/66	14.0
22N7E-								
36.2d2(2)	Fisher (V)	10	8	Johnson Everdur	30	11/47	6/26/48	4.8
22N9E-								
34.2a6(6)	Rantoul (V)	15	7.5		40	1934	5/21/34	20.5
DWT—								
20N2E-								
34.2d2(6)	Clinton (C)	40	12	Layne Shutter		10/48	3/2-3/60	3.2
34.2d3(7)	Clinton (C)	40	18	Layne Stainless Steel	4	9/54	3/2-3/60	3..1
34.3d8(5)	Clinton (C)	40	12	Layne Armco Iron Shutter	6	1/46	3/2-3/60	29.2
FRD—								
23N9E-								
14.2g(7)	Paxton (C)	100	16	Cater	80	1956	11/7-8/56	0.29
IRO—								
24N14W-								
1.7b(5)	Cissna Park (V)	6	8	Johnson Everdur	15	10/66	10/13/66	1.1
		2	8	Johnson Everdur	20			
		7	8	Johnson Everdur	30			
		5	8	Johnson Everdur	40			
26N14W-								
6.5h11(1)	Gilman (C)	8	5	Houston Stainless Steel	14	7/52	8/20/52	8.4
		8	5	Houston Stainless Steel	16			
LIV—								
27N8E-								
34.6b(4)	Chatsworth (T)	7	12	Johnson Everdur	20	6/60	6/7/60	34.1
		5	12	Johnson Everdur	40			
		10	12	Johnson Everdur	20			
		5	12	Johnson Everdur	50			
34.6d(5)	Chatsworth (T)	5	12	Johnson Everdur	12	9/60	9/19/62	12.0
		4	12	Johnson Everdur	20			
		5	12	Johnson Everdur	30			
		4	12	Johnson Everdur	20			
		3	12	Johnson Everdur	15			
LOG—								
21N1W-								
20.3e(3)	Atlanta (C)	14	12	Layne Shutter	7	6/62	6/21/62	25.0
MCL—								
26N3E-								
4.3b2(4)	Gridley (V)	20	10	Layne Shutter	6	9/63	9/24/63	5.6
PIA—								
18N5E-								
31.7g(1)	Decatur (C)	50	16		70	7/54	9/6/55	3.2
		40	16		50			
18N6E-								
7.6b2(4)	Monticello (C)	20	12	Layne Stainless Steel Shutter	6	5-6/58	6/9-10/58	0.05
VER—								
21N13W-								
3.2e4(4)	Potomac (V)	10	5	Johnson Red Brass	18	12/64	12/22/64	30.0

**Size 6-3/4 x 3/16 inches*

aquifer in the vicinity of the Watseka well field was simulated by a wedge-shaped aquifer. Aquifer and effective confining bed thicknesses were determined for each well field and are given in table 4. Transmissivities in table 4 were determined from the results of aquifer and specific-capacity tests in tables 2, 3, 7, and 8.

Actual water-level declines (obtained from data in State Water Survey files) in wells in each well field were compared with declines computed using the model aquifer, aquifer properties, the steady-state leaky artesian formula (see Walton, 1962, page 6), the image well theory (Ferris and others, 1962) for the Watseka well field, and several assumed

Table 7. Specific-Capacity Data for Wells in Illinoian Deposits

Well number	Owner	Depth (ft)	Screen diameter (in)	Screen length (ft)	Date of test	Length of test (min)	Non-pumping water level (*ftbelow land surface)*	Pumping rate (gpm)	Draw-down (ft)	Measured specific capacity (gpm/ft)	Adjusted specific capacity (gpm/ft)	Transmis sivity (gpd/ft)	Satu-rated thick-ness (ft))	Perme ability (gpd/ sq ft)
CHM—														
17NEE-														
22.1d(1)	Pesotum (V)	190	8	10	2/2.3 /56	700	71.5	81	17.5	4.63	5.84	14,000	IO	1400
18N8E-														
2.2h(2)	Univ. of III. Golf Course	168	6	9	10/4/49	25	90	44	7	6.22	12.1	22,000	25	880
	Unity High School	150	4	10	5/31/57	388	76.5	42	6	7.0		12,500	40	310
25.8f(5)	Tolono (V)	185	10	15	7/25/38	270	76	98	62	1.58		3,000	15	200
19N8E-														
12.3c2	S. S. Kresge Co.	180	8	24	3/24/37	270	101.5	100	5.5	18.2	30.3	64,000	24	2670
12.3c3	Robeson's Dept. Store	189	8	12	11/21/62	45	118.32	86	12.12	7.1	12.6	23,000		
24.4d	Studio Lodge Motel	154	6	5	6/23/53	30	80.3	19	5.05	3.66	11.5	20,000	24	830
36.6a(T)	Univ. of Illinois	168	8	13	6/27/44	175	75	248	14	17.7	26.8	50,000	25	2000
25	Paradise Inn Motel	160	6	10	2/29/56	70	84.0	47	5.0	9.4		17,000		
19N9E-														
6.4a1(43)	No. III. Water Corp.	225	31	48.6	12/38		146.42	810	16.83	48.1	53.1	100,000		1820
6.5fl(T)	Swift & Co.	162	8	16	3/l/48	105	109.8	200	15.7	12.7	15	29,000	38	760
6.5f2(2)	Swift & Co.	162	22	32	4/13/48	180	112.8	295	22.5	13.1		26,000	38	685
6.6h(1)	Swift & Co.	170	8	18	8/27/37	480	101.4	144	7	5.34	6.6	14,000	38	370
7.2h(40)	No. III. Water Corp.	212	16	14	3/28		137.7	610	36..8	16.6	38.4	72,000	55	1310
7.3h4(39)	No. III. Water Corp.	216	10	48.8	7/26		126	743	18	41.2	56.4	115,000	55	2090
7.3h5(41)	No. III. Water Corp.	224	20	52	/33		149.7	700	9.75	71.8	81.9	160,000	55	2910
7.3h6(42)	No. III. Water Corp.	218	26	50	6 /37		139.5	1000	10	100	102	200,000	55	3640
7.3h8(46)	No. III. Water Corp.	241	16	30	6/46		163.2	400	7.0	57.2	81.0	156,000	55	2740
7.3h9(47)	No. III. Water Corp.	217	16	32	6/27/46		165	380	29.9	12.7	14.9	28,000	55	510
7.4a2(11)	Univ. of Illinois	160	26	25	6/3/35	2880		1000	16.1	62	64	117,000	44	2660
7.4h(34)	No. Ill. Water Corp.	216			12/12/22	1200	106	388	28.5	13.6	16.4	39,000	55	710
7.5h(38)	No. Ill. Water Corp.	166	18	45.5	12/31/25	360	111.6	423	45.5	9.3		20,000	55	364
7.8b2(2)	Meadow Gold Dairy	184	8	15.6	8/11/44	180	122	101	7	14.4	62.5	130,000	54	2400
7.8g	Collegiate Cap & Gown	170			9/10/59	45		33	4.0	8.2		14,500	40	360
8.4a	Cinema Theater	151	6	13.5	3/23/50	180	99.8	49	3.7	13.0		25,400	31	820
18.4h2(6)	Univ. of Illinois	169	16	70	8/2/16			596	35	17.1		31,000	47	660
18.5h1(7)	Univ. of Illinois	172	24	66	11/l/23			423	41.8	10.1		17,000	56	304
20N9E-														
31.2b(4)	Illinois Central RR	160	8	26.6	4/11/44	210	100.85	206	27	7.62	8.95	16,500		
31.2cl(2)	Illinois Central RR	165		28.5	l/6/44	870	103.8	175	10	17.5	36.1	71,000	30	2360
31.2c2(3)	Illinois Central RR	170	16	60	3/3/44	900	95	160	25	6.4	21.1	16,000	42	380
31.5a3(3)	Clifford-Jacobs Forging Co.	171	8	12	5/14/43	150	106.25	110	10	11.0	21.5	41,500	31	1340
21N9E-														
15.7h(1)	Shull Mobile Homes Co.	157	6	10.6	9/21/64	120	56.1	30	6.5	4.62		8,100	18	450
21N10E-														
1.7g(1)	Gifford (V)	157	8	15	9/11/61	30	93.0	115 480	11	10.5	11.6	21,000	16	1310
22N9E-														
1.4b2(2)	Ludlow (V)	123	8	12.5	3/17/60	120	72	160	15	10.65	14.4	27,000		
34.2a.7(7)	Rantoul (V)	137	10	22	12/6/39	270	64	480	28	17.1	56.5	115,000	57	2020
34.2a8(2)	Rantoul (V)	139	12	20	5/23/49	120	69.7	354	44	8.05	14.4	28,000	50	560
FRD—														
23N9E-														
14.2g1(T)	Paxton (C)	125	10	10	10/23/56	12,000	65	400	15.36	26.0		60,000	45	1330
23N10E-														
7.1c(4)	Paxton (C)	150	10	21	10/21/48	420		180	28	6.4		14,000	21	667
7.1d(5)	Paxton (C)	149	8	23	10/10/45	45	101	155	13	11.9	19.1	36,500	32	1140
7.7d(6)	Paxton (C)	153	10	20	7/27/50	100	100.2	150	14.3	10.9	15.2	29,000	45	645
25N9E-														
21.5g5(5)	Roberts (V)	226	8	11.5	9/22/50	60	79.6	80	26.7	3.0	3.19	5,200	16	325
IRO—														
24N10E-														
28.4h(1)	Loda (V)	156	8	10	9/4/40	240	101.5	160	111.5	16	51.0	61,000	36	1720
25N10E-														
6.5h(1)	Thawville (V)	120	8	10	8/9/50	67	9.3	69	8.2	8.4	20.4	39,000	39	1000
26.6d(2)	Buckley (V)	152	8	12	11/13/58	43	18.59	130	9.46	13.75	16	30,000	15	2000
26N14W-														
6.5h9(S)	Gilman (C)	128	8	5	/48	180		120	23	5.2		8,400	15	560
6.5h10	Gilman (C)	129	5	5	6/8/50	60	0.88	29	11.92	2.43	3.47	5,700	7	815
LIV—														
30N7E-														
3.5f	Dwight Sewage Plant	142	8	6	6/30/55	300	26	100	7	11.71	13.9	26,000	7	3720
	Blackstone Theater	130	7	7	6/36	30	32	65	6.4	10.15	29.8	53,000		
Z.3g1(1)	Dwight (V)	140	10	11	5/20/47	12	32	375	64.7	5.8	10	18.500	28	660
9.3g5(5) 9	Dwight (V)	142	10	8	5/56	12		450	19.5	23.05	44.2	90,008	28	3200
LOG-														
19N2W.														
35(T)	Mt. Pulaski (C)	46	6	10	9/17/59	60	15.3	76	4.6	16.5	69	78,000		
MCN-														
16N1W-														
2.1c2(2)	Niantic (V)	50	10	9.5	8/13/58	26	8.16	59	11.48	5.14	15.8	23,000	39	590
MOU-														
13N5E.														
13.4e(3)	Sullivan CCb.	90	10	10	6/24/54		48.2	150	7.0	25.9	55.0	124.000	39	3180
23.3g1(T)	Sullivan (C)	120	18		2/34	600	55	500	17.5	28.6	40.2	53,000	65	815
23.3g2(1)	Sullivan (C)	115	18	45	7/31/26		58	660	19	34.7	57	61.000	65	940
23.4g(3)	Sullivan (C)	91	10	21	10/6/54	320	54	165	4.25	38.9	41	53,000	40	1320
PIA-														
18N5E-														
7.lh	WILL TV Tower	195	4	4	1/19/66	120	64.7	17	7.9	2.15	4.7	8,000	17	470
VER-														
22N12W-														
12.7e1(2)	Rossville (V)	132	8	14	5/60			150	40	3.75	14.1	25,000	65	385
12.7e3(3)	Rossville (V)	133	8	20	5/6/46			150	28	5.35	13.6	24,000	65	370

Table 8. Specific-Capacity Data for Wells in Kansan Deposits

Well number	Owner	Depth (ft)	Screen diameter (in)	Screen length (ft)	Date of test	Length of test (min)	Non-pumping Water level (ft below land surface)	Pumping rate (gpm)	Draw-down (ft)	Measured specific capacity (gpm/ft)	Adjusted specific capacity (gpm/ft)	Transmis-sivity (gpd/ft)	Satu rated thick-ness (ft)	Perme-ability (gpd/sq ft)
CHM—														
19N8E-														
2.8e(53)	No. III. Water Corp.	289	16	57	12/26-29/56	120	117.8	1016	8.9	115	192	426,000	55	7750
51g2(55)	No. III. Water Corp.	300	14	50	5/2/58	2880		900	9.24	97.5	166	415,000	130	3190
11.7f(1)	Humko Corp.	291	16	50	3/56	120	119	928	8.0	116		243,000	55	‘1320
11.8f(2)	Humko Corp.	277	16		/56	480	111	800	7.0	114		270,000	55	4910
18.8h(4)	Petro Chemicals Corp.	310	18	100	8/30/65	310	86.04	1400	6.76	207		490,000	100	4900
19N9E-														
18.4h3(9)	Univ. of Illinois	247.5	30,22	60,24	7/1/31	1440		425	69.0	6.2		14,000	55	255
18.5g	Coed Theater	245	4	15	4/21/50	300	77	36	20	1.8	2.15	4,200	15	280
20N7E-														
10.1e(l)	Briarcliff Sbd.	240	6	10	9/27/63	200	83.52	111	5.60	19.8	72	152,000	45	3370
12.le(l)	Parkhill Trailer Ct.	274	4	12	3/1/66	170	105	76	13	5.85	34.5	72,700	47	1550
15.7e3(3)	Mahomet (V)	251.6	12	40	7 /3/63	276	80	630	9.0	70	120	275,000	90	3060
36.5a(52)	No. III. Water Corp.	313	24	75	9/20-21/56	2880	76.45	1092	5.85	187	206	510,000	105	4850
20N8E-														
32.2a1(51)	No. III. Water Corp.	296	17x22	76	8/14/50	1440	74.5	965	11.0	87.7	120	300,000	125	2400
32.2a2(54)	No. III. Water Corp.	330	24	75	11/26-29/56	2880	87.8	3000	28.3	106	140	350,000	130	2690
33,8a1(50)	No. III. Water Corp.	299	17x22	72	11/21-22/47	664	78.9	1090	13.4	81.3	135	325,000	90	3620
34.4a(48)	No. III. Water Corp.	232	24	38	5/12-13/47	720	113.5	1030	18.5	55.5	76.5	180,00O	67	2690
21N9E-														
28.8a1(l)	Thomasboro (V)	229	10	10	4/18/60	360	65	214	12.1	17.7	28.9	68,000	30	2260
28.8a2(2)	Thomasboro (V)	238	10	1.5	3/1/66	180	67.5	239	9.0	26.5	35.8	75,400	30	2510
22N7E-														
36.2d1(1)	Fisher (V)	236	6	10	4/10/36	480	30	182	26	7.0	16.8	37,000	84	440
36.2d2(2)	Fisher (V)	274	8	33.6	5/55	180	32	205	4	51.2		105,000	63	1670
36.2d3(3)	Fisher (V)	270	10	20	8/59	480		300	7	42.9		87,000	99	880
22N9E-														
34.2a6(6)	Rantoul (V)	293	8	15	5/21/34	60	65	260	52	5.0	8.5	15,000	35	430
DWT—														
20N2E-														
34.2d3(7)	Clinton (C)	345	18	40	10/12/54	360	109	685	16.5	41.5		100,000	106	942
FRD—														
23N9E-														
14.1g(8)	Paxton (C)	340	16	100	8/20/59	1440	66	1200	8.0	150		385,000	105	3670
14.2g(7)	Paxton (C)	340	16	100	11/7/56	25	65.5	880	5.3	166		330,000	135	2445
IRO—														
26N14W-														
6.5h11(1)	Gilman (C)	195	12	16	8/20/52	54	0.0	302	19.5	15.5	19.7	38,500	30	1270
27N12W-														
33.4h(6)	Watseka (C)	160	12	15	6/7/61	60	10.2	575	5.1	13		220,000	45	4890
MCL—														
24N1W-														
23.1h(4)	Danvers (V)	438	8	20	9/20/61	50	276.8	110	16.2	6.8	12.7	24,000	46	520
26N3E.														
4.5b1(1)	Gridley (V)	290	8	20	1/23/23	3180	54	50	6.0	8.3	20.8	50,000	28	1790
4.5b2(2)	Gridley (V)	291	8	9.5	6/20/45	60	65.0	110	31.5	3.5	4.45	7,600	10	760
PIA—														
18N6E-														
7.6h2(4)	Monticello (C)	263	12	20	6/9-10/58	1440	34	1009	12.5	80.6	242	390.000	75	5200
7.7b3(3)	Viobin Corp.	212	10	25	6/26/61	30	22.23	270	10.9	24.8	90.3	174,000	100	1740
20N6E-														
10.7e(2)	Mansfield (V)	210	8	10	10/15/53	36	61.5	172	17.5	9.8	13.8	23,000	15	1530
VER—														
21N13W-														
3.2e4(4)	Potomac (V)	189	5	10	12/22/64	165	1.10	76	2.05	37.1	62.8	130,000	89	1460

values of the vertical permeability of the confining bed. The vertical permeability which gave computed declines equal to actual declines was assigned to the confining bed.

Specific-Capacity Tests

One means of expressing the yield of a well is by use of the term specific capacity, defined as the yield of the well in gallons per minute per foot of drawdown (gpm/ft) for a given pumping period and rate. As shown by Walton (1962), the Theis nonequilibrium formula can be expressed in terms of the theoretical specific capacity of a well discharging at a constant rate in a homogeneous, isotropic, and areally infinite artesian aquifer.

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 greater than that of a 12-inch diameter well. 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 continuously increases with time as the cone of depression of the well expands. The relationship between the theoretical specific capacity of a well and the transmissivity for a well radius of 6 inches, a pumping period of 24 hours, and a storage coefficient in the artesian range (0.0001) is shown in figure 14.

Drawdown data for wells that do not completely penetrate an aquifer must be corrected. Drawdowns in production wells not completely penetrating the aquifer or open to only part of an aquifer are greater than drawdowns in a fully penetrating production well. Methods described by Butler (1957) may be used to correct for the effects of partial penetration.

There is generally head loss or drawdown (well loss) in a

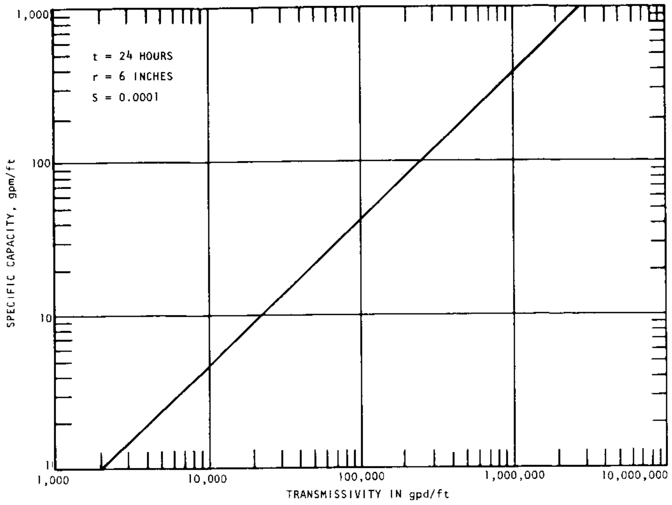


Figure 14. Theoretical relation between specific capacity and transmissivity

Table 9. Summary of Aquifer Test and Specific-Capacity Data

Hydraulic property	Wells in Illinoian deposits	Wells in Kansan deposits
Aquifer tests		
Range in coefficients of transmissivity *(gpd/ft)*	869 to 147,000	5130 to 325,000
Range in coefficients of permeability *(gpd/sq ft)*	230 to 4080	310 to 4100
Range in storage coefficients	0.00001 to 0.083	0.0000217 to 0.0023
Specific-capacity data		
Range in unadjusted specific capacities *(gpm/ft)*	1.58 to 100	1.8 to 207
Range in coefficients of transmissivity *(gpd/ft)*	3000 to 200,000	4200 to 510,000
Range in coefficients of permeability *(gpd/sq ft)*	200 to 3720	255 to 7750

production well due to turbulent flow of water as it enters the well itself and flows upward through the bore hole. Jacob (1946) described a method for computing the well-loss coefficient *C* from data collected during a step-drawdown test in which the well is operated during three successive and equal time periods at constant fractions of full capacity. Data from 46 step-drawdown tests in wells finished in Illinoian and Kansan deposits in the study area are summarized in tables 5 and 6, respectively.

Values of the well-loss coefficient in Illinoian wells ranged from 0.3 to 73 sec ^{2}/ft^5. Of the 23 values, 2 were less than 1 sec^2/ft^5, 9 ranged from 1 to 10 sec^2/ft^5, 7 ranged from 11 to 40 sec^2/ft^5, and 5 ranged from 41 to 73 sec^2/ft^5. The 23 well-loss coefficients for Kansan wells ranged from 0.05 to 34.1 sec^2/ft^5. Of these, 4 coefficients were less than 1 sec^2/ft^5, 11 were between 1 and 10 sec^2/ft^5, and 8 were between 11 and 34.1 sec^2/ft^5. No high degree of accuracy is implied in the well-loss coefficients in tables 5 and 6; however, they can be useful in adjusting measured specific-capacity data to theoretical values.

Specific-capacity data collected during well-production tests made in 92 wells are given in tables 7 and 8. The tests consisted of pumping a well at a constant rate and frequently measuring the drawdown in the pumped well. The length of tests ranged from 12 minutes to 200 hours. Pumping rates ranged from 17 to 3000 gpm. Screen diameters ranged from 4 to 31 inches.

The data collected from these tests were not suitable for aquifer test analysis; however, transmissivity was estimated from graphs similar to figure 14 relating theoretical specific capacity to transmissivity. The theoretical specific capacity was estimated by correcting the measured specific capacity for partial penetration and well loss and adjusting to a common time and radius. The data in tables 7 and 8 are considered only an approximation of the transmissivity and permeability, since they are based on an estimated coefficient of storage. In addition, corrections made for well loss and partial penetration are not precise.

Summary of Hydraulic Properties

Table 9 gives ranges of the transmissivity, permeability, and storage coefficient as determined from aquifer tests in Illinoian and Kansan aquifers within the Mahomet Valley. Specific-capacity data from wells in Illinoian and Kansan deposits are also summarized in table 9; ranges are given for unadjusted specific capacities, transmissivities, and permeabilities. Data are generally inadequate to allow correlations to be made between hydrologic and geologic properties of the aquifers; however, permeabilities of Kansan sands and gravels tended to be greater in the deeper portions of the bedrock valleys.

Leakage coefficients and vertical permeabilities determined from well tests and well-field analyses are summarized in table 10. Coefficients of vertical permeability for the confining layer above Illinoian sand and gravel deposits averaged 0.029 gpd/sq ft (not including the value from well CHM 20N9E-31.5a5), whereas the average vertical permeability for Kansan confining layers is 0.108 gpd/sq ft (not including values for DWT 20N2E-34.2d2, IRO 24N14W-1.7b, and MCL 26N3E-4.3b2). Available data thus indicate that the average vertical permeability of the confining layer above Kansan sands and gravels is 3 to 4 times larger than that above Illinoian deposits.

Walton (1965) summarized coefficients of vertical permeability for glacial drift and bedrock confining layers in several areas of northeastern, central, and western Illinois. Coefficients were computed from aquifer tests, flow net analyses, and model aquifer analyses. Walton found that values of *P'* for drift deposits consisting largely of sand and gravel exceeded 1.0 gpd/sq ft and averaged 1.31 gpd/sq ft. As the

Table 10. Summary of Coefficients of Leakage and Vertical Permeability

Well number or well field	Leakage coefficient (*gpd/cu ft*)	Confining layer thickness (*ft*)	Coefficient of vertical permeability (*gpd/ sq ft*)
Illinoian deposits			
Arcola	0.000571	70	0.04
CHM 19N10E-14.6h	0.001	35	0.035
*CHM 20N9E-31.5a5	1.31	24	31.4
Hoopeston	0.000652	60	0.039
Rantoul	0.0000325	80	0.0026
Kansan deposits			
CHM 19N8E-5.1g1	0.00509	35	0.178
-18.3d	0.0061	35	0.214
-18.46	0.00836	50	0.42
CHM 20N8E-33.8a1	0.00509	35	0.178
*DWT 20N2E-34.2d2	0.0466	75	3.5
Fisher	0.000462	87	0.04
*IRO 24N14W-1.7b	0.282	14	12.2
LIV 27N8E-34.6d	0.000123	74	0.0091
MCL 26N3E-4.3b1	0.00012	200	0.024
* -4.3b2	0.021	68	1.43
Monticello	0.000384	60	0.023
PIA 18N5E -30.7a	0.00111	75	0.083
Rantoul	0.0000667	75	0.005
Watseka	0.0001	100	0.01

**Not representative*

Table 11. Summary of Coefficients of Leakage and Vertical Permeability in Illinois

Lithology	Leakage coefficient (*gpd/cu ft*) range	Vertical permeability (*gpd/sq ft*) range	average
Drift, sand and gravel, some clay and silt	0.034 to 0.23	1.02 to 1.60	1.31
Drift, clay and silt with considerable sand and gravel	0.0061 to 0.052	0.10 to 0.63	0.25
Drift, clay and silt with some sand and gravel	0.000083 to 0.005	0.01 to 0.08	0.03
Drift, clay and silt with some sand and gravel and dolomite	0.000045 to 0.00032	0.005 to 0.011	0.008
Drift, clay and silt with some sand and gravel and shaly dolomite	0.000051	0.005	0.005
Dolomite shale	0.00000025	0.00005	0.00005

(from Walton, 1965)

clay content increased, values of *P'* decreased, averaging 0.25 gpd/sq ft when considerable sand and gravel was present and 0.03 gpd/sq ft when little sand and gravel was present. No similar attempt was made in this report to correlate *P'* values with confining bed lithology, since well log descriptions were found to be rather uncertain or generalized. Walton's findings are summarized in table 11 for comparison purposes.

CONSTRUCTION FEATURES OF WELLS

Large-capacity municipal and industrial wells finished in Kansan or Illinoian aquifers within the Mahomet Valley system are drilled by the cable tool or the reverse hydraulic rotary methods. Production wells generally are cased through the fine overlying materials and have perforated casings or commercial screens opposite the more permeable zones in the aquifer. There are two types of drilled wells in the area: natural pack and artificial pack. Materials surrounding the well are developed in place for the natural pack well; materials having a coarser and more uniform grain size than the natural formation are added around the well for the artificial pack. Available data indicate that only about one-third of the municipal and industrial wells finished in Illinoian aquifers were constructed with artificial gravel packs, whereas one-half of the Kansan wells on file have gravel packs. As shown in tables 12 and 13, gravel packs of Illinoian wells generally range from 4 to 16 inches in thickness but average about 6 inches, while Kansan wells have gravel-pack thicknesses from 6 to 14 inches, averaging slightly more than 10½ inches.

Generally, commercial screens used in the area are of stainless steel, red brass, silicon bronze, or other relatively noncorrosive metal. Some wells, however, are constructed with concrete casing plus sections of perforated concrete screen. Many screened wells in both Kansan and Illinoian aquifers use several slot sizes. Such a slot size variation within a single well reflects a corresponding variation in grain size distribution within the portion of aquifer opposite each screen section. Screen diameters range from 6 to 26 inches in Illinoian wells and from 4 to 24 inches in Kansan wells, while screen lengths vary from 8 to 52 feet and from 10 to 100 feet, respectively.

The generally larger withdrawals from Kansan wells is reflected in available information on pump capacities. Tables 12 and 13 show ranges in reported pump capacities of Illinoian wells as 80 to 1500 gpm and those of Kansan wells as 100 to 3500 gpm.

Well Design Criteria

One of the problems associated with the development of groundwater resources can be the life expectancy of wells. The results of mechanical analyses of samples for wells within the Mahomet Valley system, shown in figure 15, suggest that the deposits contain a high percentage of fine materials which could, under heavy pumping conditions, migrate toward a screen and partially clog the well wall and screen

Table 12. Construction Features of Selected Illinoian Wells

Well number	Owner	Depth (ft)	Casing depth* (ft)	Casing diameter (in)	Screen length (ft)	Screen diameter (in)	Screen material and/or manufacturer	Screen slot number	Artificial gravel-pack thickness (in)	Pump rating capacity/head (gpm) / (ft)
CHM—										
19N8E-										
12.3c1	Virginia Theater	176	0-161	2	15	12			none	350
12.3c2	S. S. Kresge Co.	180	0-156	8	11.5	8		12	none	180
					12.5	8		80		
12.3c3	Robenson's Dept. Store	189	0-177	8	12	8	Johnson	100	none	315
19N9E-										
6.4al(43)	No. Illinois Water Corp.	224.5	+1.5-166.2	36	48.8	26	Layne		5	700
			+1.5-175	26						
6.5f3(3)	Swift & Co.	161	0-137	17x22	24	17x22	Concrete		8	
6.5f3(3)	Swift & Co.	170	0-152	8	18	8				
7.2hl(40)	No. Illinois Water Corp.	212	0-164	20	16	12	Ohio Bar		4	280
			+2-190	12						
7.3hl(35)	No. Illinois Water Corp.	204	0-181.8	18	22	18	Cook	60	none	440
7.3312(36)	No. Illinois Water Corp.	201		12						230
7.3h5(41)	No. Illinois Water Corp.	224	0-139	24	52	16	Ohio Angle		4	600
			0-172.5	16						
7.3316(42)	No. Illinois Water Corp.	217.5	0-155	36	50	26	Layne Shutter	5	5	700
			+2-167.5	26						
7.3h7(45)	No. Illinois Water Corp.	199	+2-178	16	21	10	Johnson Armco Iron		none	330
			+2-176	10						
7.3h8(46)	No. Illinois Water Corp.	241	+2-209	16	10	16	Johnson Everdur	14	none	375
					7	16	Johnson Everdur	20		
					13	16	Johnson Everdur	60		
7.3h9(47)	No. Illinois Water Corp.	217.5	+2-191.3	16	5	16	Silicon Red Brass	60	none	305
					7	16	Silicon Red Brass	40		
					8	16	Silicon Red Brass	18		
					5	16	Silicon Red Brass	12		
8.4a	Cinema Theater	151	0-138	6	3	6	Johnson	12	none	100
					10	6	Johnson	16		
17.4g	Urbana-Lincoln Hotel	155	0-146	6	3	6	Johnson Silicon Red Brass	20	none	300
					6	6	Johnson Silicon Red Brass	40		
20N9E-										
31.2d(l)	Illinois Central RR	159	0-139	27	20	16	Layne Shutter			
			0-139	16					5.5	
31.3b(3)	Illinois Central RR	157.6	+1.8-140	26	17.6	15	Layne Shutter			
			+1.8-140	15					5.5	
22N9E-										
34.2a8(2)	Rantoul (V)	139	+1.5-120.6	12	9	12	Johnson Everdur	30	none	700
					11	12	Johnson Everdur	10		
34.2a10(4)	Rantoul (V)	142		12					none	500/54.5
34.2a11(5)	Rantoul (V)	139		12					none	500
FRD—										
23Nl0E-										
7.1d(5)	Paxton (C)	149	+2-126	8	23	8	Johnson Armco Iron	40	none	100
7.7d(6)	Paxton (C)	153	+2-133	10	6	10	Johnson	30	none	200
					5	10	Johnson	25		
					9	10	Johnson	18		
LIV—										
26N8E-										
3.8e(2)	Chatsworth (T)	67	+1.5-57.3	12	10	12	Johnson Everdur	40	none	131/50
3.8g(3)	Chatsworth (T)	99.5	+3-91.7	12	8	12	Johnson Everdur	35	none	120
30N7E-										
9.3g1(l)	Dwight (V)	140	0-118	10	11	10	Cook	10	none	375/100
9.3g4(4)	Dwight (V)	140		12					none	450/100
9.3g5(5)	Dwight (V)	142	0-134	10	8	10	Brass		none	450/200
MEN—										
18N7W-										
13.7e2(3)	Petersburg (C)	56	+9-46	12	10	12			none	300/250
13.8e3(1)	Petersburg (C)	44	+1.5-44	2880			27-Inch Thick Brick Lining		none	380/240
13.8e5(4)	Petersburg (C)	58	+ 10-48	16	10	16	Shutter	2	16	400

Table 12 (Concluded)

Well number	Owner	Depth (ft)	Casing depth* (ft)	Casing diameter (in)	Screen length (ft)	Screen diameter (in)	Screen material and/or manufacturer	Screen Slot number	Artificial gravel-pack thickness (in)	Pump rating capacity /bead (gpm) /(ft)
13.8e6(5)	Petersburg (C)	55	0-45	16	10	16	Cook Stainless Steel Wirewound	100	4	350/277
MOU— 13N5E.										
23.3g2(1)	Sullivan (C)	129	0-70 0-70	24	45	18			6	450
23.3g3(2)	Sullivan (C)	120	0-70 0-70	24	45	18			6	450
23.4g(3)	Sullivan (C)	91	0-67 0-72	24 10	19	10			7	450
VER— 22N12W-										
12.6e1(3)	Rossville Packing Co.	112	0-97	12	15	12			none	250
12.7e1(2)	Rossville (V)	131	0-131						none	80
12.7e2(1)	Rossville (V)	132	0-116	8		8	Cook	58	none	200
12.7e3(3)	Rossville (V)	133	0-116	8	20	8	Cook	30	none	200/180
23N12W-										
11.3e4(3)	Hoopeston (C)	110	0-96			10	Cook	10	none	625
11.3e5(4)	Hoopeston (C)	110	0-96	10	14	12			none	950
11.3e6(5)	Hoopeston (C)	104	0-89	18	15	18	Layne Stainless Steel Shutter	2	none	1550/90

**Plus (+) indicates extent above land surface, in feet*

Table 13. Construction Features of Selected Kansan Wells

Well number	Owner	Depth (ft)	Casing depth* (ft)	Casing diameter (in)	Screen length (ft)	Screen diameter (in)	Screen material and/or manufacturer	Screen slot number cm size (in)	Artificial gravel-pack thickness (in)	Pump rating capacity/head (gpm) /(ft)
CHM— 18N8E-										
2.4e(l)	Univ. of Illinois Golf Course	218	+2-204.6	8	13.4	8	Johnson Everdur	60	none	250/130
19N8E-										
2.8e(53)	No. Illinois Water Corp.	289	0-214 0-214	26 16	75	16	Stainless Steel		13	1975/165
3.4a(57)	No. Illinois Water Corp.	305.5	+1.5-245 +1.5-245	26 16	55	16	Layne Shutter	5	13	2100/172
3.4f(56)	No. Illinois Water Corp.	318	+1.5-265 +1.5-265	26 16	53	16			13	2100/165
3.7a(58)	No. Illinois Water Corp.	329	+3-256 +3-256	30 30	70	20	Stainless Steel	5	11	2800/177
5.1g2(55)	No. Illinois Water Corp.	300	0-250 0-250	24 14	50	14			14	1000/225
11.6g(2)	Kraft Foods Corp.	292.5	0-248.5	12	44	12	Stainless Steel		none	
11.7f(l)	Humko Corp.	291	+1.5-241	16	50	16	Layne Shutter	5	11	
11.8f(2)	Humko Corp.	277		16					11	
18.3d(2)	Petro Chemicals Corp.	271.5	+3-20 8-199.5	36 18	72	18	Layne Shutter	5	10	2100/100
18.4b(3)	Petro Chemicals Corp.	272	0-172	18	100	18	Layne Stainless Steel	5	9	2800/130
18.4d(l)	Petro Chemicals Corp.	277.5	+2-20 6-205.5	36 18	72	18	Layne Shutter	5	10	2800/130
18.8h(4)	Petro Chemicals Corp.	310	0-45 0.210	36 18	100	18	Layne Shutter	5	9	3500/110
19N9E-										
18.5g	Coed Theater	245	+1.5-209.8 +1.5-230	6 4	15	4	Johnson Everdur	14	none	100
20N7E-										
15.7e3(3)	Mahomet (V)	251.5	0-212	12	40	12	Layne Stainless Steel Shutter	4	12	300/115
20N8E-										
32.2a2(54)	No. Illinois Water Corp.	330	0-255 0-255	35 24	75	24			12	3000/250
33.8a2(59)	No. Illinois Water Corp.	339	+3.3-230.4 +3.3-230.4 250.4-303.4	26 16 16	20 35	16 16	Stainless Steel	5	13	2100/250
34.4a(48)	No. Illinois Water Corp.	232	+2-188 208.216 232-233	17x22 17x22 17x22	20 16	17x22 17x22	Concrete Concrete	6-3/4x3/16 6-3/4x3/16	8	700/232

Table 13 (Concluded)

Well number	Owner	Depth *(ft)*	Casing depth* *(ft)*	Casing diameter *(in)*	Screen length *(ft)*	Screen diameter *(in)*	Screen material and/or manufacturer	Screen slot number or size *(in)*	Artificial gravel-pack thickness *(in)*	Pump rating capacity/head *(gpm)/(ft)*
22N7E-										
36.2dl(l)	Fisher (V)	236	0-204	8	10	6	Johnson Everdur		none	12.5/90
			204.226	6						
36.2d3(3)	Fisher (V)	270	0-250	10	20	10	Cook Stainless Steel		8.5	125/86
22N9E-										
34.2a9(3)	Rantoul (V)	291	0-271	12	20	12			none	650
DWT— 20N2E-										
34.2d1(4)	Clinton (C)	345	0-308	6	20	5	Johnson Everdur	3/32	none	250/150
34.2d2(6)	Clinton (C)	345	0-305	26	35	12	Layne Shutter		6	600/187
			0-197	14	5	12×24	Layne Cone-Shaped Shutter			
			197-305	12						
34.2d3(7)	Clinton (C)	345	+1-260.5	30	40	18	Layne Stainless Steel	4	8	800
			+2-303	18						
34.3d5(1)	Clinton (C)	340	0.320	12	20	12	Brass		none	200
34.3d7(3)	Clinton (C)	360	0-340	12	20	12	Iron Pipe	1/4	none	350
FRD— 23N9E-										
14.lg(8)	Paxton (C)	340	+2-235	16	100	16	Stainless Steel			1000
14.26(7)	Paxton (C)	340	0-240	16	100	16	Cater	80	10	1000
IRO— 26N14W-										
6.5hll(l)	Gilman (C)	195	+2.5-178.5	12	8	5	Houston Stainless Steel	14	none	300
					8	5	Houston Stainless Steel	16		
6.53112(2)	Gilman (C)	197	+3-185	12	4	12	Johnson Stainless Steel	15	none	300
					4	12	Johnson Stainless Steel	18		
					4	12	Johnson Stainless Steel	20		
IRO– 27N12W-										
32.lbl	Watseka Dairy	150		8						
32.1132(4)	Watseka (C)	160	0-130	8	30	8	Johnson	40	none	200
32.2b3(31	Watseka (C)	168	0-141	10	27	10			none	400
32.2b4(5)	Watseka (c)	175	0-155	10	20	10	Johnson Everdur		none	400
33.4b(6)	Watseka (C)	160	0-145	12	15	12	Johnson	125	none	500/170
	TRW Electronics CO.	148	0-138	8	10	8	Johnson	40	none	
LIV— 27N8E-										
34.6b(4)	Chatsworth (T)	232	+1-205	12	7	12	Johnson Everdur	20	none	200
					7	12	Johnson Everdur	40		
					10	12	Johnson Everdur	20		
					5	12	Johnson Everdur	50		
34.6d(5)	Chatsworth (T)	223	+3-203	12	5	12	Johnson Everdur	12	none	200
					4	12	Johnson Everdur	20		
					5	12	Johnson Everdur	30		
					4	12	Johnson Everdur	20		
					3	12	Johnson Everdur	15		
PIA— 18N5E-										
13.1a	General Cable Corp.	255	+2-230	10	25	10		8	none	200
18N6E-										
7.6a4(1)	Monticello (C)	228	0-193	12	19	8			none	425/100
			193-208	10						
			188-209	8						
7.6bl(2)	Monticello (C)	212	0-196	12	16	12	Cook		none	475/120
7.6332(4)	Monticello (C)	263	0-25	26	20	12	Layne Stainless Steel Shutter	6	11	1000/150
			0-243	12						
7.8b3(3)	Viobin Corp.	212	2-184	10	5				none	600/233
						10		12		
					12	10		25		

**Plus (+) indicates extent above land surface, in feet*

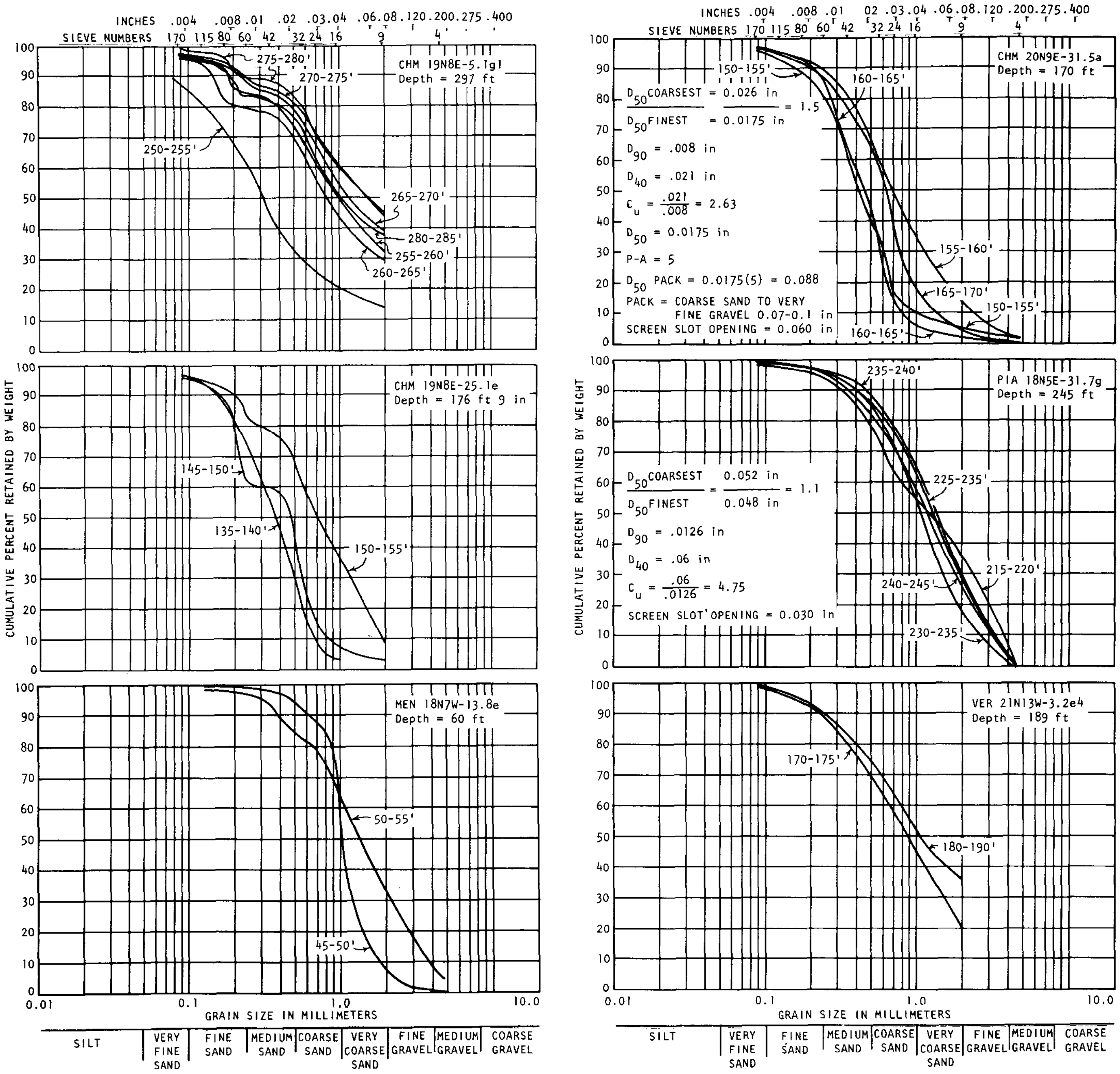


Figure 15. Mechanical analyses of samples from wells

openings. Data obtained from several municipalities indicate that with time many wells have declined in specific capacity and must be either abandoned or periodically rehabilitated.

Walton (1962) presented well design criteria for wells in unconsolidated materials in Illinois with the purpose of designing an efficient and economical well with a service life of at least 10 years.

Artificial gravel pack wells (Ahrens, 1957) are usually justified when the aquifer is homogeneous, has a uniformity coefficient less than 3.0, and/or has an effective grain size less than 0.01 inch. The uniformity coefficient, C_u, is the ratio of the sieve size that retains 40 percent of the aquifer materials to the effective size. The sieve size that retains 90 percent of the aquifer materials is the effective size. In addition, an artificial pack is sometimes needed to stabilize well-graded aquifers having a significant amount of fine materials in order to avoid excessive settlement of materials above the screen or to permit the use of larger screen slots.

Selection of the artificial pack is based on the mechanical analysis of the aquifer sample. Smith (1954) reported that a successful criterion in Illinois for selecting an artificial pack is that the ratio of the 50-percent sizes of the pack and the aquifer (the P-A ratio) be 5. Suggested ranges in pack thickness have been given by Walton (1962) as 6 to 9 inches and by Ahrens (1957) as 4 to 9 inches.

To avoid segregation or bridging during placement, a uniform grain size pack should be used. The screen slot opening should be designed to retain at least 90 percent of the pack materials (Walton, 1962).

Design of natural pack wells involves the use of the uniformity coefficient as well as knowledge of the materials overlying the aquifer. With a uniformity coefficient greater than 6 (a heterogeneous aquifer) and where overlying materials will not easily cave, the screen slot size should be one that will retain 30 percent of the aquifer materials (Walton, 1962). For the same uniformity coefficient but where overlying materials will easily cave, the screen slot size should retain 50 percent of the aquifer materials. With a uniformity coefficient as low as 3 (a homogeneous aquifer) and where overlying materials will not easily cave, the screen slot size should be one that will retain 40 percent of the aquifer materials. For the same case but where caving of overlying materials will easily occur, the screen should be chosen so as to retain 60 percent of the aquifer materials.

Sometimes several layers of sand and gravel with different grain sizes and gradations are encountered. If the 50-percent size of the coarsest layer is less than 4 times that of the finest layer, the slot size and pack should be selected on the basis of the mechanical analysis of the finest layer (Ahrens, 1957). Otherwise, the slot size and pack should be tailored to individual layers.

The results of studies involving the mechanical analyses of the aquifer at two sites demonstrate some of the principles involved in the design of sand and gravel wells. In the first example the design was based on the mechanical analysis of samples from well CHM 20N9E-31.5a (figure 15). Since the 50-percent size of the coarsest material from 155 to 160 feet is less than 4 times the 50-percent size of the finest material from 150 to 155 feet, the screen or pack must be designed on the basis of results of the analysis of the finest materials. The uniformity coefficient of the finer materials is 2.6, and the effective grain size is 0.008 inch, indicating a gravel pack should be used. The 50-percent size is 0.0175 inch; therefore, with a pack-aquifer ratio of 5, the 50-percent size of the pack should be 0.088 inch. A gravel pack with particles ranging in diameter from 0.07 to 0.1 inch (coarse sand to fine gravel) is indicated. To retain 90 percent of the pack a screen with a slot size of about 0.06 inch would be required.

The second example considers the design of a natural pack well and is based on the mechanical analysis of samples for well PIA 18N5E-31.7g (figure 15). The 50-percent size of the coarsest material is less than 4 times the 50-percent size of the finest material; therefore, the slot size should be based upon the analysis of the finest sample (from 215 to 220 feet). The uniformity coefficients are greater than 3, and the effective grain sizes are greater than 0.01 inch, indicating a natural pack design. The materials overlying the aquifer will easily cave, so the screen slot size should be one which will retain 60 percent of the aquifer (0.03 inch).

GROUNDWATER WITHDRAWALS

Figure 16 shows the estimated groundwater pumpage within the Mahomet Valley area (as defined by the 500-foot bedrock contour in figure 8) from 1890 through 1965, subdivided by use. Before the 1920s groundwater was primarily used for rural supplies. Since then, however, public and industrial groundwater developments have increased and together account for more than 80 percent of the total pumpage. Total withdrawals increased gradually from 8.5 mgd in 1890 to 46.3 mgd in 1963 and then declined to 40.2 mgd in 1965. Of the 1965 total pumpage, withdrawals for public water-supply systems amounted to 64.2 percent, or 25.8 mgd; industrial pumpage was 16.7 percent, or 6.7 mgd; and rural pumpage was 19.1 percent, or 7.7 mgd.

Pumpage-use data are, for this report, classified into three categories: 1) *public,* including municipal and institutional; 2) *industrial;* and 3) *rural.* Most public water-supply systems furnish water for several types of use. Any water pumped by a public water-supply system is called a public supply, regardless of its use. Institutional supplies furnish water to schools, prisons, and other institutions. Industrial supplies may include nonmanufacturing uses, such as drinking and air conditioning. Rural supplies serve farms, including use by both humans and livestock, and individual residences.

Petersburgs developed the first municipal groundwater supply in the area in 1878, and the villages of Blue Mound (Macon County) and Danvers (McLean County) developed supplies in 1882. In 1900, 30 municipalties were pumping groundwater. The number of municipal system increased to 77 by 1965. Public pumpage increased gradually from about 1 mgd in 1890 to 11.4 mgd by 1940. Since 1940 it has more than doubled and was 25.8 mgd 1965, or 64.2 percent of total pumpage. Municipal pumpage at Champaign-Urbana in 1965 was 10.27 mgd or 39.8 percent of the total public pumpage. Records are available for 77 municipal groundwater supplies in use within the Mahomet valley system in 1965. Fifty-nine of these supplies pumped less than 100,000 gpd. 13 pumped between 100,000 gpd and 1 mgd, and 5 (Champaign-Urbana, Rantoul, Lincoln, Taylorville, and Hoopeston) had pumpages exceeding 1 mgd. Pumpage from wells at institutions was negligible in 1965.

Records of industrial groundwater development within the valley area date back to the early 1890s when railroads began pumping wells for their water supplies. Industrial pumpage increased from about 50,000 gpd in 1895 to nearly 11 mgd in 1954. A peak of 12.8 mgd was reached in 1963, which included 7.1 mgd pumpage from wells near Champaign owned by the U. S. Industrials Chemicals Corporation. Pumpage by this industry fluctuates greatly from year to year and was only 1.2 mgd during 1965 when total industrial pumpage decline to 6.7 mgd.

The major uses of industrial water within the Mahomet Valley area are for processing soybean, petroleum, food, pharmaceutical, and paper products. Pumpage for processing soybeans accounted for 2.3 mgd in 1965, or 34.2 percent of the total industrial pumpage. The industrial use of groundwater is summarized in table 14.

Data were obtained from 61 industries. A large part of the industrial pumpage is not metered and is estimated on the basis of time of pump operation and pump capacity.

Rural pumpage, including farm and rural nonfarm use, was estimated partly by considering rural population as reported by the U. S. Bureau of Census. Per capita usage, beginning with the 1960 census, was estimated at 50 gpd, and progressively lower per capita use figures were employed for census periods prior to 1960. Livestock use was obtained by considering livestock population and animal water-consumption data reported by the U. S. Department of

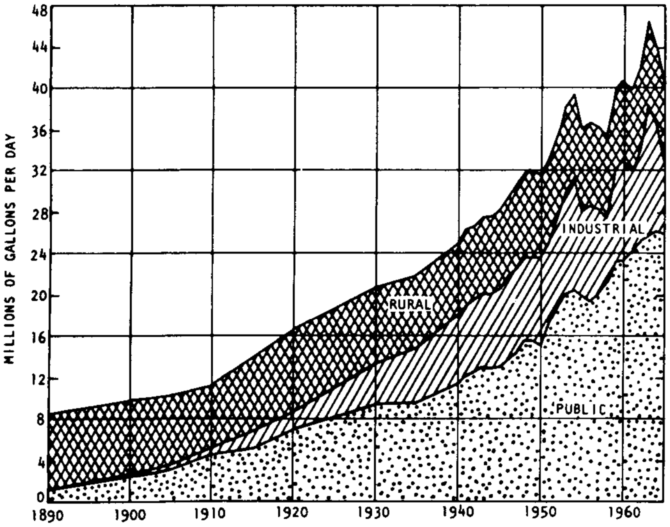


Figure 16. Estimated pumpage within Mahomet Valley, 1890- 1965, subdivided by use

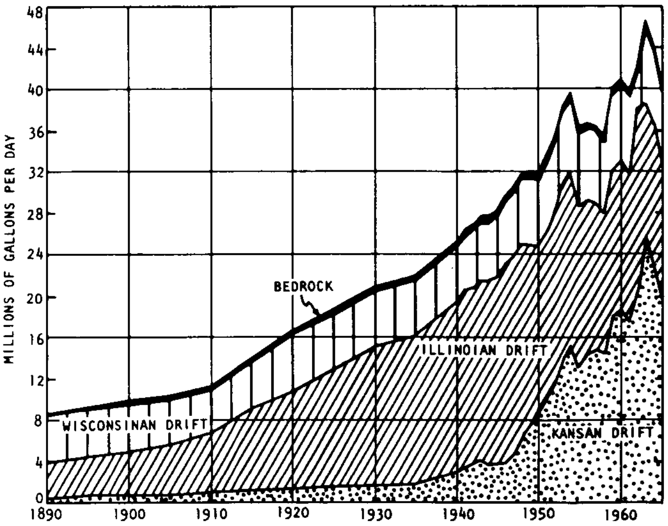


Figure 17. Estimated pumpage within Mahomet Valley, 1890-1965 , subdivided by source

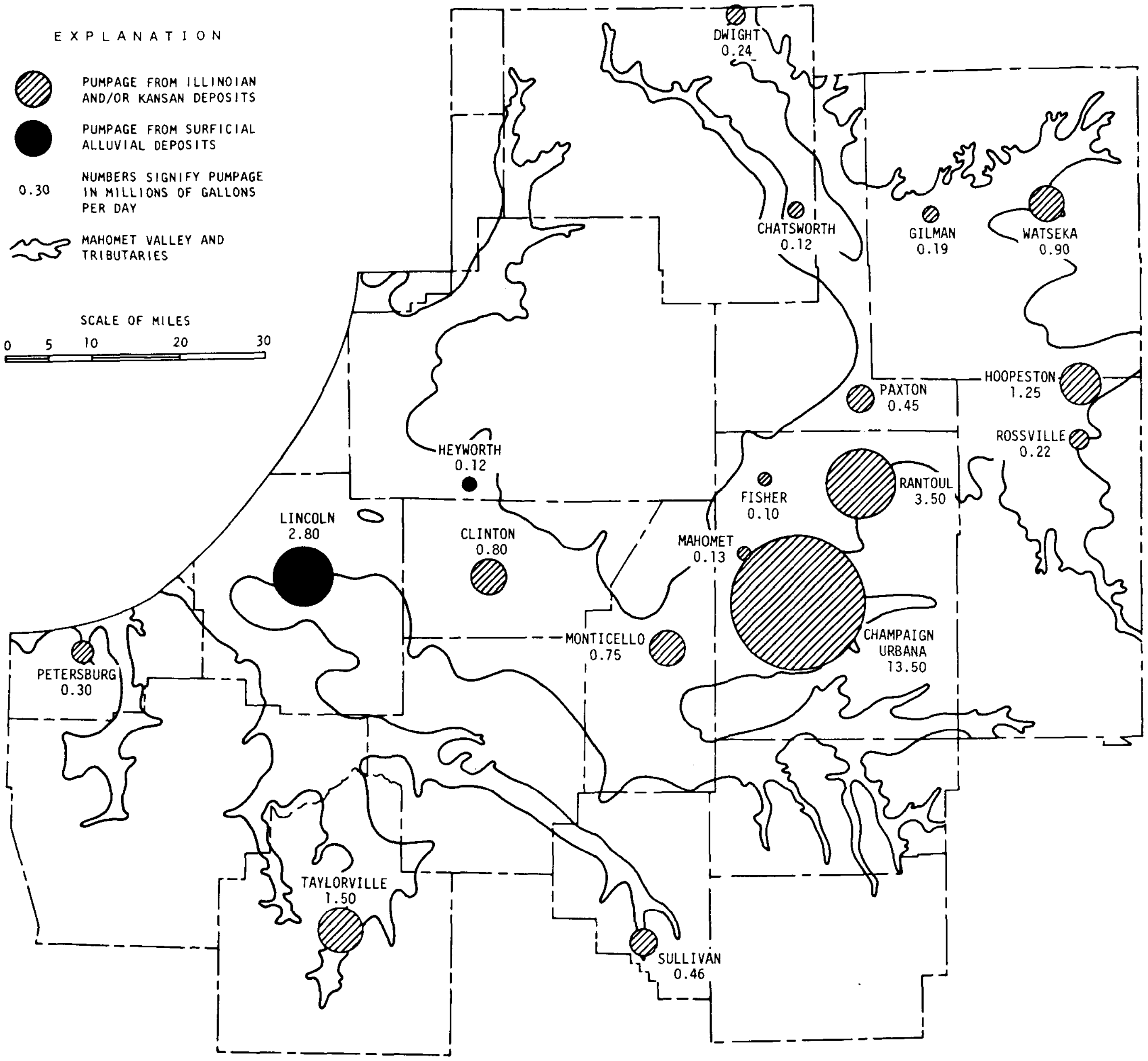


Figure 18. Location of major pumping centers

Agriculture. Adjustments in rural pumpage were made to correct for an increased use of farm ponds for water supplies in recent years. Pumpage for rural supplies was 7.7 mgd in 1965, or 19.1 percent of the total pumpage within the Mahomet Valley area.

Table 14. Industrial Use of Groundwater in 1965

Use	Pumpage (*mgd*)	Percent of total pumpage
Soybean processing	2.308	34.2
Petroleum products	1.150	17.1
Food products	0.573	8.5
Pharmaceutical products	0.180	2.7
Paper products	0.144	2.1
Others	2.386	35.4
Totals	6.741	100.0

Figure 17 shows the estimated groundwater pumpage within the Mahomet Valley area from 1890 through 1965, subdivided by source. The largest source of groundwater before 1900 was from shallow dug wells in Wisconsinan deposits. By the early 1900s the largest source of groundwater was from the Illinoian deposits. This was primarily due to the development of municipal supplies in the more productive Illinoian deposits. Illinoian pumpage declined after reaching a peak of 19.2 mgd in the middle 1940s, as the deeper Kansan aquifer was developed to a greater ex-

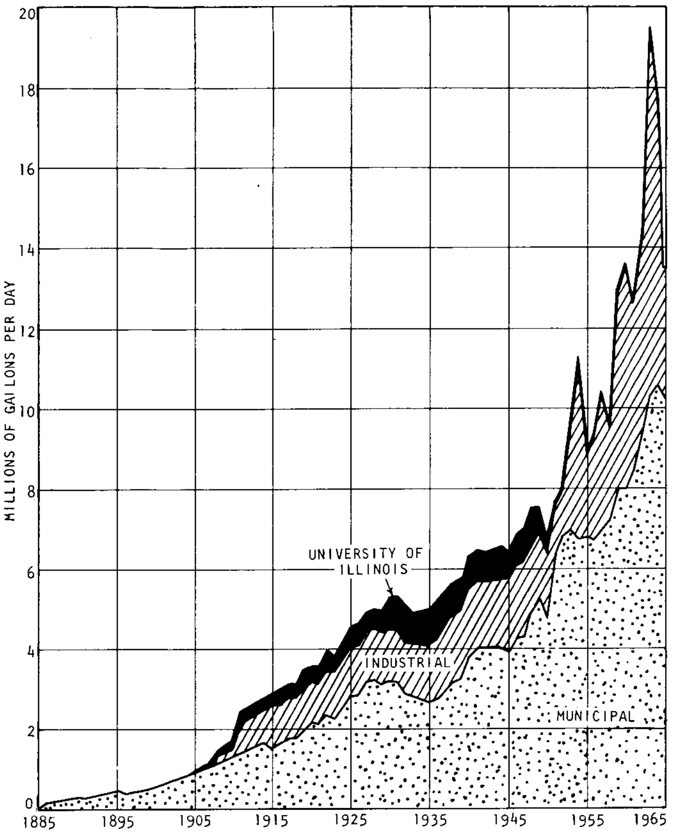


Figure 19. Estimated pumpage, Champaign-Urbana area, 1885-l965, subdivided by use

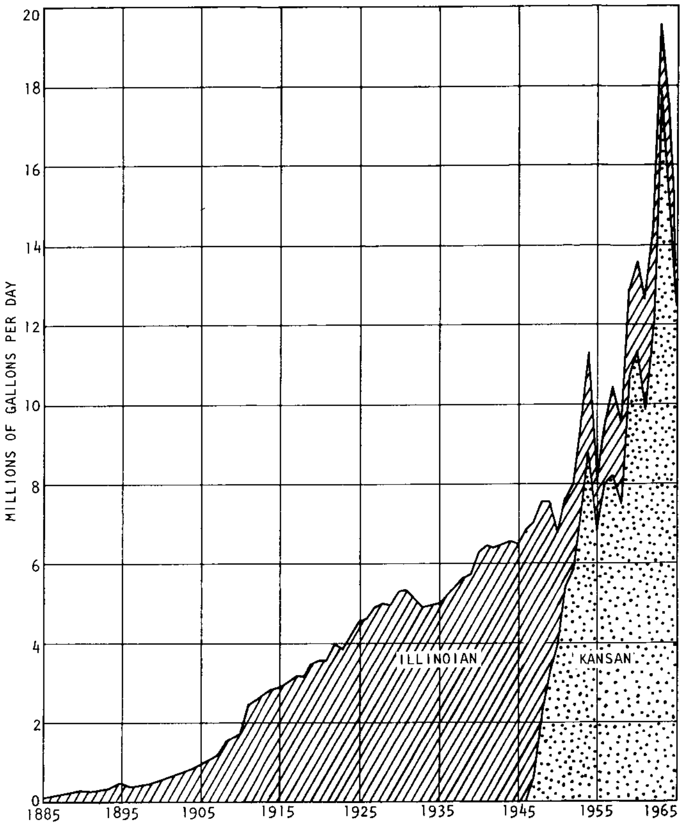


Figure 20. Estimated pumpage, Champaign-Urbana area, 1885-1965, subdivided by source

tent. In the late 1940s the Northern Illinois Water Corporation developed a municipal well field in the Kansan deposits near Champaign-Urbana. The U.S. Industrial Chemicals Corporation developed an industrial well field the Kansan deposits near Champaign-Urbana in the early 1950s. These well fields helped boost Kansan. pumpage to 25.6 *mgd* in 1963, or 55.4 percent of the total pumpage.

Pumpage from wells in bedrock aquifers within the area has never been greater than about 0.61 mgd. The bedrock is primarily used as a source in areas where sand and gravel deposits are missing.

In 1965 a total of 40.2 mgd was withdrawn from all sources within the Mahomet Valley area. Of the 1965 total pumpage, withdrawals from Kansan deposits amounted to 49.3 percent, or 19.8 mgd; Illinoian pumpage was 31.8 percent, or 12.8 mgd; Wisconsinan pumpage was 17.4 percent, or 7.0 mgd; and bedrock pumpage was 1.5 percent, or 0.6 mgd.

The locations of major pumping centers within the Mahomet Valley area in 1965 are shown in figure 18. Only pumping centers withdrawing water from wells finished in unconsolidated deposits are shown. Pumping centers include public withdrawals and any nearby industrial pumpage, such as at Rossville, Dwight, Monticello, Clinton, Watseka, Hoopeston, and Taylorville. The Champaign-Urbana pumping center includes municipal, local industrial, and minor University of Illinois pumpages, as well as pumpage by U. S. Industrial Chemicals Corporation wells at Bondville. The pumping center at Rantoul includes municipal and Chanute Air Force Base pumpages. Eighteen pumping centers, each shaving a total withdrawal of at least 0.1 mgd, are shown in figure 18, and the pumpage growth relationships for each are shown in figures 19 through 22.

Several of the pumpage graphs in figures 21 and 22 do not exhibit normal pumpage growth characteristics but show declines following pumpage peaks in the 1950s or early 1960s. Total pumpage at Taylorville declined after peak withdrawals in 1953, as critical declines in pumping levels forced industrial water conservation practices to be implemented thereafter. At Clinton and Monticello, decreases in pumpage resulted from repairs in leaky distribution systems. Lower water usage also resulted at Dwight when leaks were repaired and water meters were installed, after the peak years of 1960 and 1961. Pumpage at Gilman reached a peak in 1948, when the Illinois Central Railroad began changing from steam to diesel engines with subsequent steady declines in railroad pumpages. At Sullivan, water usage dropped sharply after 1955 when water supplied to an industry was no longer required.

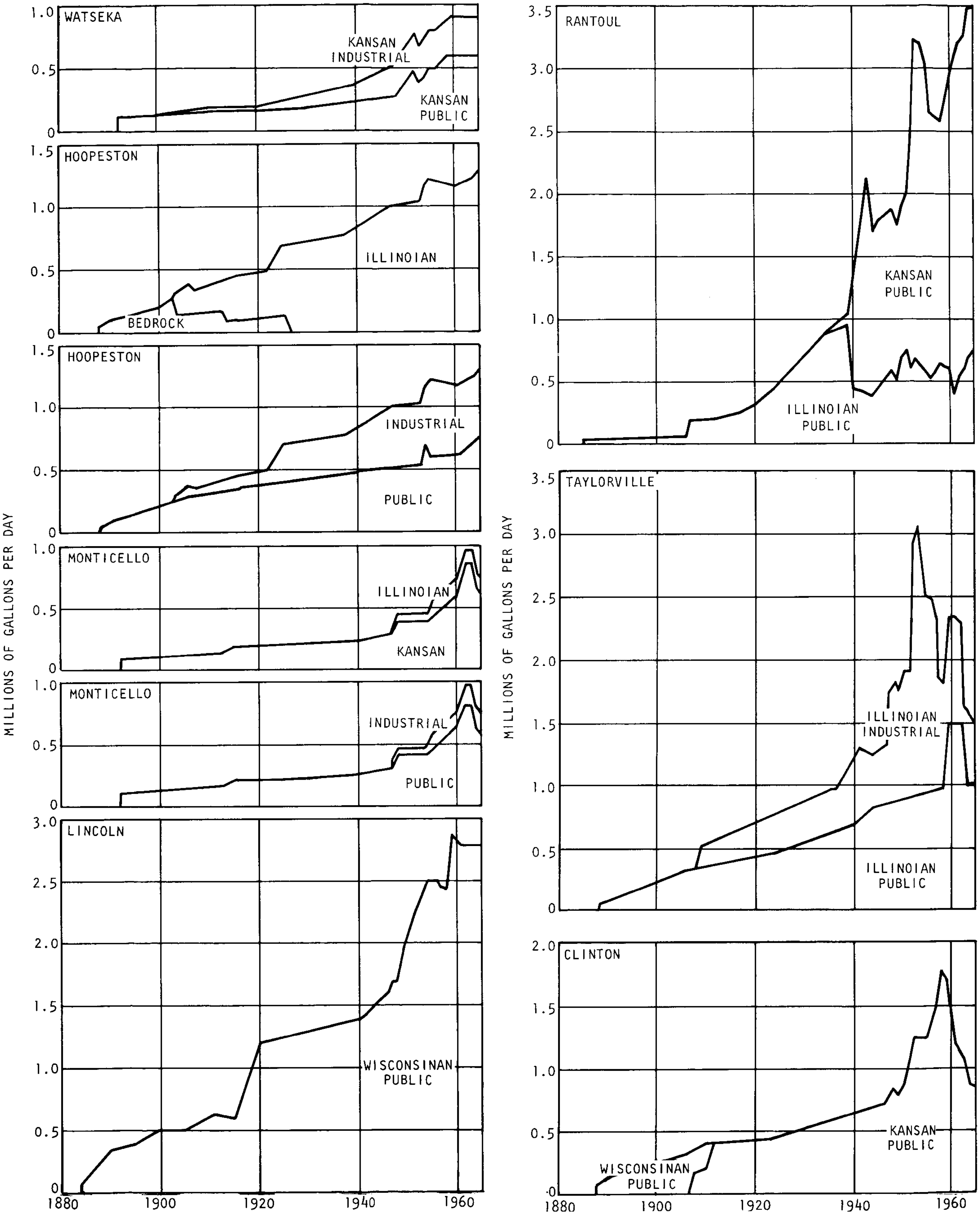


Figure 21. Estimated pumpage by use and source at Watseka, Hoopeston, Monticello, Lincoln, Rantoul, Taylorville, and Clinton

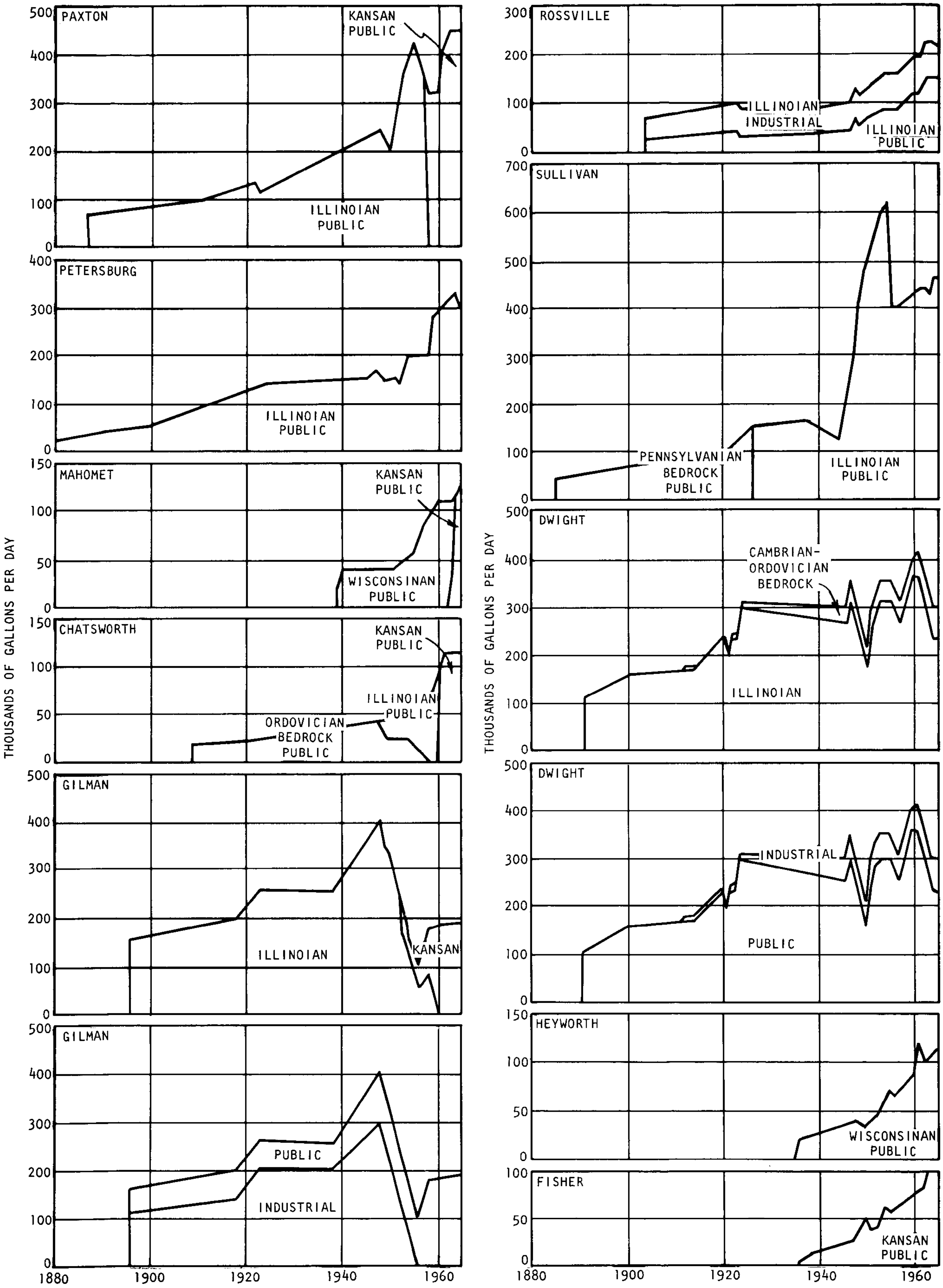


Figure 22. Estimated pumpage by use and source at Paxton, Petersburg, Mahomet, Chatsworth, Gilman, Rossville, Sullivan, Dwight, Heyworth, and Fisher

WATER LEVELS IN WELLS

Systematic measurement of groundwater levels in the vicinity of pumping centers was started in the Champaign-Urbana area in the early 1940s. Prior to 1940 only infrequent measurements were made, primarily in municipal wells. In 1950 periodic measurements of water levels were started in municipal and industrial wells at Taylorville, and in 1953 and 1957 similar measurements were started in municipal wells at Arcola and Tallula, respectively (Walker and Walton, 1961). In recent years the State Water Survey began periodic water-level measurements in municipal wells at Arthur and Gibson City. Measurements were started in 1950 in shallow observation wells in areas remote from pumping centers, which are located as shown in figure 23. Descriptive records are given in table 15.

Table 15. Observation Wells in Mahomet Valley Area

Well number	Owner	Type*	Depth (ft)	Diameter (in)	Main aquifer	Surface elevation (ft above msl)	Measurement** frequency
CHM— 19N7E- 13.1d(0-4)	Petro Chemicals Corp.	D	115	2	Illinoian	707	M
19N8E- 6.1f(0-2)	Petro Chemicals Corp.	D	255	6	Kansan	714	C
7.1d(0-1)	Petro Chemicals	D	213	6	Kansan	706	C
18.3a1	W. C. Dallenbach	D	212	1 1/4	Kansan	705	M
18.3a2(0-3)	Petro Chemicals Corp.	D	122	2	Illinoian	705	M
20.5h(0-5)	Petro Chemicals Corp.	D	125	2 3/8	Illinoian	710	M
30.3h(0-6)	Petro Chemicals Corp.	D	228	4	Kansan	702	M
19N9E- 7.3h2(36)	No. Ill. Water Corp.	D	201	12	Illinoian	745	S-W
7.3h4(39)	No. Ill. Water Corn.	D	216	21	Illinoian	750	S-W
8.7h	Smith Ice Co.	D	179		Illinoian	734	C
18.4h1(4)	Univ. of Illinois	D	143	12	Illinoian	719	W
20N7E- 36.5a(52)	No. Ill. Water Corp.	D	313	24	Kansan	720	S-M
20N8E- 34.4a(48)	No. Ill. Water Corp.	D	232	17×22	Kansan	764	S-W
20N9E- 31.2C	Illinois Central RR	D	169	10	Illinoian	729	C
CHR— 13N1W- 18.8a(2)	Taylorville (C)	D	88	26	Illinoian	635	M
13N2W- 27.2h5(5)	Taylorville (C)	D	119	15	Illinoian	626	M
DGL— 14N8E- 4.4d(2)	Arcola (C)	D	102	10	Illinoian	675	M
15N7E- 30.7h(T)	Arthur (V)	D	91	8	Illinoian	657	M
FRD— 23N7E- 2.4b(3)	Gibson City (C)	D	58	18	Illinoian	753	M
IRO— 26N12W- 12.6a	W. McManuas	d	19.5	42	Wisconsinan	670	C
LIV— 27N3E- 30.1a	J. Murray	d	22		Wisconsinan	719	c
LOG— 19N4W- 22.4c	R. Boward	d	37.5	36	Wisconsinan	540	c
MEN— 18N7W- 31.881	Tallula (V)	d	37.5	36	Wisconsinan	540	M
PIA— 20N6E- 31.6h	B. A. Swartz	d	35.3	48	Wisconsinan	714	c

*Type: D = drilled; d = dug

***Measurements:* C = *continuous (water level recorder)*
W = *weekly;* S.W = *twice per week*
M = *monthly;* S.M = *twice per month*

In addition, the Water Survey has encouraged municipalities to make periodic measurements of water levels and to report these to the Survey monthly. Fourteen municipalities in the area have until recently made monthly reports and currently are submitting yearly reports; these are Allerton, Arrowsmith, Bethany, Colfax, Cooksville, Donovan, Fithian, Gifford, Morrisonville, Ogden, Oreana, Philo, St. Joseph, and Sidney. Two municipalities, Dwight and Homer, continue to make monthly reports to the Water Survey. Locations for municipalities which submit periodic water-level reports are shown in figure 23.

Systematic measurement of groundwater levels in areas remote from pumping centers was started in 1950 when an automatic water-level recorder was installed on a shallow, large-diameter, dug well in Livingston County (well LIV 27N3E-30.1a) to collect groundwater level data for a special study (Schicht and Walton, 1961). In 1954 an observation well was established in Piatt County (well PIA 20N6E-31.6h) for a similar study. These wells were incorporated into the Survey's statewide network of observation wells established in 1958 to obtain data on long-term trends of the water table. Wells LOG 19N4W-22.4c and IRO 26N12W-12.6a, part of this network, were established in 1959 and 1960, respectively.

In 1934 water-level measurements were made in wells over a large part of the area (figure 23) as part of a Civil Works Administration project supervised by the State Water Survey (Gerber and others, 1935). In 1967 the State Water Survey initiated a basic data gathering program, part of which is the measurement of water levels in selected wells in Champaign, Ford, McLean, and Piatt Counties. It is planned to extend this program to other counties in the near future.

Water Levels in Areas Remote from Pumping Centers

Fluctuations of the water table in areas remote from pumping centers are shown by hydrographs in figure 24. The water table in the area under natural conditions recedes in late spring, summer, and early fall when discharge from the groundwater reservoir by evapotranspiration and groundwater runoff exceeds recharge from precipitation. In the winter, water levels begin to recover, and the water table reaches its peak during the spring when conditions for recharge are most favorable. According to the hydrographs in figure 24 the water table has a seasonal fluctuation ranging from 1.5 to 12 feet and averaging about 5 feet. The effect of below normal precipitation on the water table can be seen in figure 24. The water table declined appreciably during the years 1962 and 1963 when the total departures from normal precipitation at nearby Weather Bureau stations in Minonk,

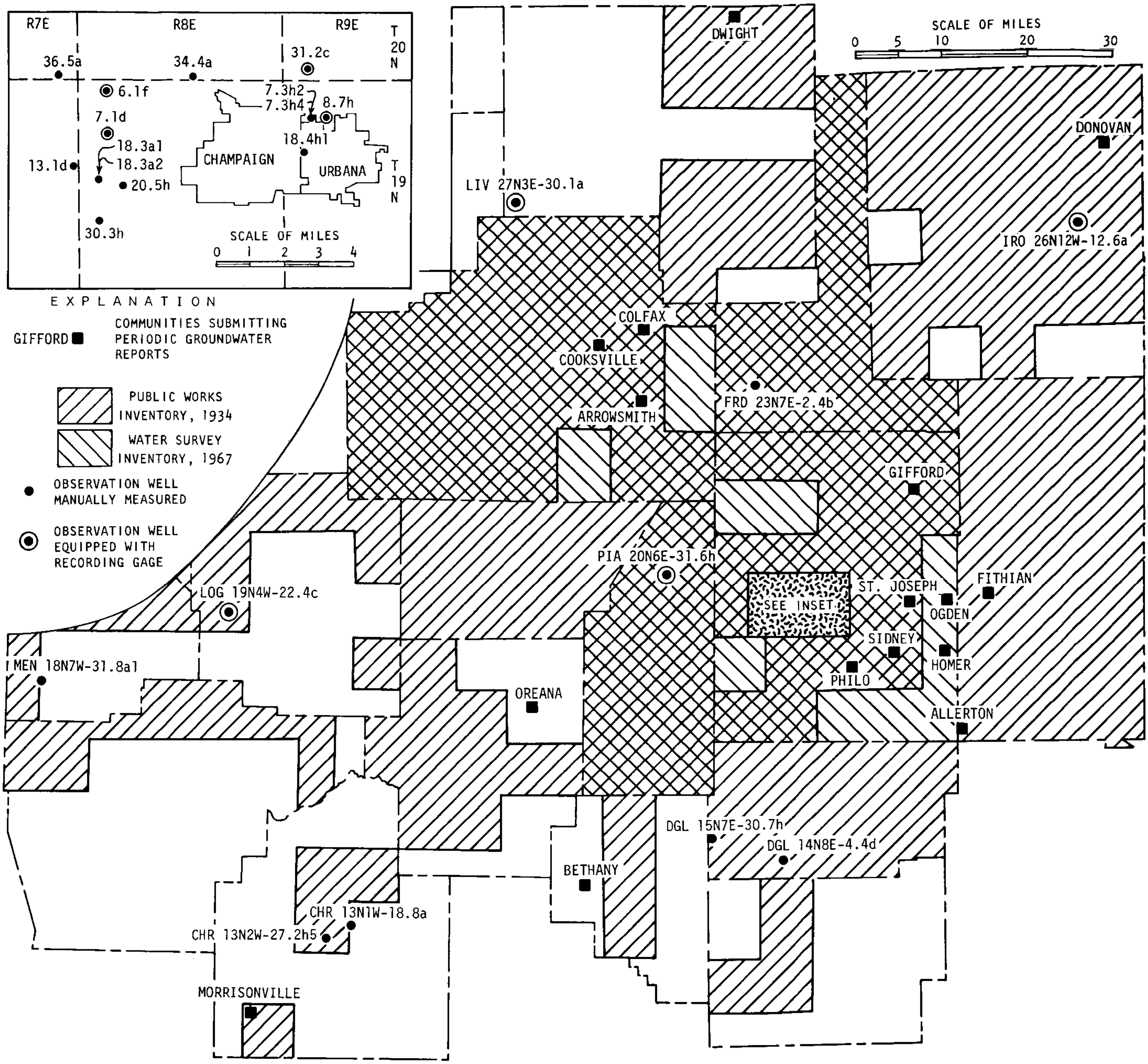


Figure 23. Locations of observation wells

Watseka, Lincoln, and Monticello, were 14.25, 16.61, 12.37, and 9.26 inches, respectively.

Water Levels in the Vicinity of Pumping Centers

Champaign-Urbana Area. The effects of large groundwater withdrawals from the middle (Illinoian) and deep (Kansan) aquifers are illustrated by pumpage and water-level data collected in the Champaign-Urbana area *(also see detailed study, page 41).* Hydrographs of water levels in observation wells and pumpage graphs for the middle and deep aquifers in the area are shown in figures 25 and 26, respectively.

Water levels in the middle aquifer in the North Well Field were reported to be at an elevation of 670 feet in 1885 when the first wells were drilled. By 1920 water levels in the North Field were at an elevation of 640 feet (figure 25A). During the same period pumpage from the middle aquifer increased to 3.6 mgd. By 1947 water levels in well CHM 19N9E-7.3h2 declined to an elevation of 570 feet as pumpage increased steadily to 6.85 mgd. Water levels in 1947 were 20 feet below the top of the aquifer. After 1947 water levels in the North Field started to recover with the shift in pump-

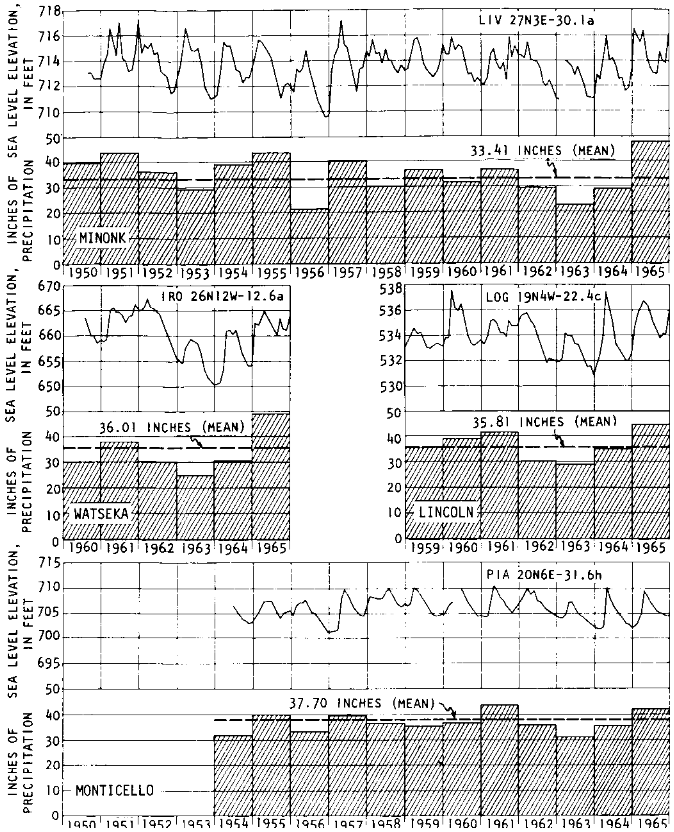


Figure 24. Water levels in areas remote from pumping centers and annual precipitation at nearby Weather Bureau stations

age attending the development of the well field in the deep aquifer west of Champaign. By 1952 water levels had recovered to an elevation of 625 feet as pumpage decreased to 2.1 mgd. Since 1952 water levels have fluctuated between 600 and 625 feet as pumpage has ranged between 1.4 and 2.75 mgd.

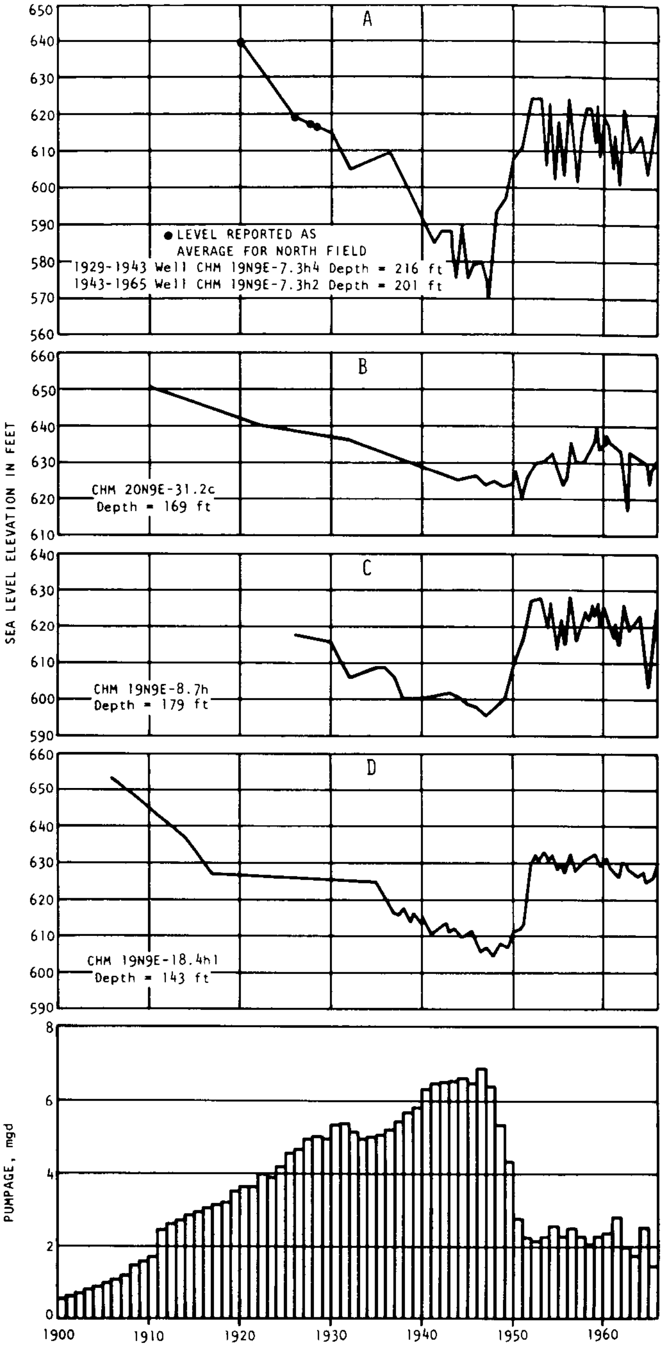


Figure 25. Water levels and pumpage at Champaign- Urbana, Illinion aquifer, 1900-1965

Hydrographs of water levels in wells 31.2c and 18.4hl (figures 25B and D) reflect the effects of local pumpage as well as the effects of pumpage from the North Field. Water levels in well 18.4h1 (figure 25D) were affected to a large extent by pumpage in the University of Illinois Well Field. In 1948 the University began to purchase water from the Northern Illinois Water Corporation. Pumpage by the University declined from 0.93 mgd in 1948 to 0.31 mgd in 1950. By 1951 the University purchased essentially all of its water and as a result water levels recovered sharply. Water levels in well 31.2c (figure 25B) were affected to a degree by pumpage from the Illinois Central Railroad. The use of groundwater by the railroad had been declining since 1943 when 0.77 mgd was pumped; however, the effects on water levels were not entirely evident because of the influence of heavy withdrawals by the water company's nearby North Field. Recoveries were noted after 1950 when railroad pumpage declined from 0.6 mgd to 0.48 mgd in 1951. Railroad pumpage continued to decline until 1960 when 0.05 mgd was withdrawn. Water levels in well 8.7h (figure 25C) also reflect the effects of pumpage from the University Well Field.

The first well in the deep aquifer west of Champaign-Urbana was drilled in 1947. At that time water levels were at an elevation of 655 feet. Systematic measurement of water levels in selected observation wells in the area began in 1947 and was expanded in 1953. At present water-level records west of Champaign-Urbana are available from six observation wells in the deep aquifer and from three wells in the middle aquifer (figure 26).

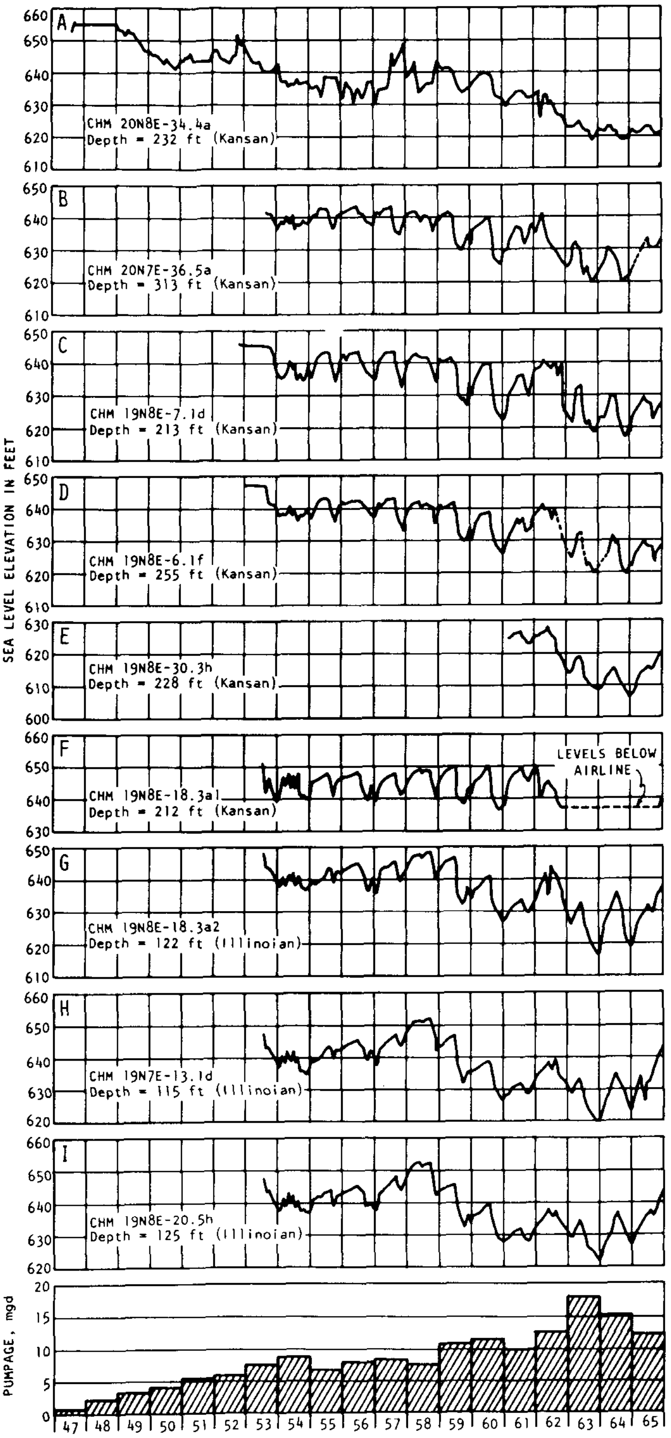


Figure 26. Water levels in Kansan and Illinoian aquifers and pumpage from Kansan aquifer west of Champaign, 1947-1965

The hydrograph for well 20N8E-34.4a (figure 26A) illustrates the effects of pumpage on water levels in the deep aquifer since 1948. From 1948 through 1963 water levels in the well declined 35 feet, an average decline of 2.2 feet per year. Pumpage from the deep aquifer increased from 2.25 mgd to 17.87 mgd during the same period. Water levels stabilized in 1964 and 1965 as pumpage declined to 12.10 mgd in 1965. Hydrographs for other observation wells finished in the deep aquifer show a general decline through 1963. In 1964 and 1965 water levels recovered as a result of the decrease in pumpage.

Water levels in observation wells finished in the middle aquifer (figure 26C-I) declined at an average rate of 1.0 foot per year from 1954 through 1963. Water levels recovered in 1964 and 1965 because of the decrease in pumpage.

Water levels in the wells in figure 26 are influenced by seasonal fluctuations in pumpage and changes in the center of pumpage. U. S. Industrial Chemicals Corporation wells particularly have extreme fluctuations in their daily average pumping rates from year to year. Pumpage is usually confined to the warmer, drier months, and may vary from 0 to more than 11 mgd. The effects of precipitation on water levels in the middle and deep aquifers are not apparent.

Other Selected Pumping Centers. Table 16 summarizes water-level declines in selected pumping centers within the valley. Declines indicate changes from the time the aquifer was initially developed until 1965. Declines were obtained by subtracting average water levels in pumping centers in 1965 from reported or estimated levels at the time the field was developed. Daily average pumpage in 1965 for each pumping center is included in the table.

Table 16. Water-Level Decline in Selected Pumping Centers

Pumping center	Year developed	Decline by 1965 *(ft)*	pumpage 1965 *(mgd)*
Illinoian aquifer			
Dwight	1891	15	0.24
Hoopeston	1903	10	1.25
Rantoul	1895	17	0.75
Kansan aquifer			
Fisher	1936	10	0.10
Mahomet	1963	1	0.125
Monticello	1892	10	0.75
Paxton	1958	1	0.45
Rantoul	1934	27	2.75
Watseka	1892	10	0.90

AQUIFER RECHARGE

Recharge to aquifers in the Mahomet Valley area occurs locally as vertical leakage of water from precipitation through deposits and from downward percolation of stream runoff (induced infiltration).

A large proportion of precipitation runs off to streams or is discharged by evapotranspiration without reaching aquifers. Some precipitation reaches the water table and becomes groundwater. Eventually it either discharges into streams as groundwater runoff or into the atmosphere by the process of evapotranspiration. Part of the water stored temporarily in the upper deposits may move downward into the lower formations. Vertical movement is possible if differentials in head exist between the water table in the upper formations and the piezometric surfaces of the Illinoian and Kansan aquifers. Within the Mahomet Valley area, water table elevations in shallow deposits range from approximately 600 feet at the western end of the valley to about 750 feet in the central and eastern portions. Water-level data indicate that Kansan and Illinoian deposits have piezometric levels ranging from 540 to 700 feet from west to east. Smith (1950) reported water levels in 1947 just west of Champaign to be approximately 700 feet, 660 feet, and 655 feet above sea level for the Wisconsinan, Illinoian, and Kansan deposits, respectively. Since 1947 heavy pumpage from the Kansan aquifer in this area has lowered Kansan and Illinoian water levels in the vicinity of the well field.

For a given period of time the precipitation reaching the water table (groundwater recharge) is balanced largely by groundwater runoff and evapotranspiration, plus or minus changes in groundwater storage. Schicht and Walton (1961) estimated these factors for two small watersheds in east-central Illinois—Panther Creek basin in Woodford and Livingston Counties and Goose Creek basin in De Witt and Piatt Counties. The results of the study are summarized in table 17.

Recharge from precipitation occurs irregularly through the year. During spring months when rainfall is heavy and evapotranspiration losses are low, recharge is greatest. Recharge is generally lower during the summer and early fall, when evapotranspiration and soil-moisture requirements prevent most rainfall from percolating to the water table. Recharge is negligible during winter months when the ground is frozen.

Table 17. Groundwater Budget Factors for Two Basins in East-Central Illinois

Year	Precipitation (in)	Ground water runoff (in)	Groundwater evapotranspiration (in)	Changes in groundwater storage (in)	Groundwater recharge (in)	
					(in)	(gpd/sq mi)
Panther Creek Basin						
1951	44.24	6.00	1.19	+1.19	8.38	400,000
1952	32.62	7.16	2.01	-1.14	8.03	383,000
1957	36.36	0.37	0.74	-0.24	0.87	41,500
Goose Creek Basin						
1955	31.80	1.60	2.66	+2.14	6.40	305,000
1956	27.26	1.52	2.26	-0.21	3.57	170,000
1957	37.18	3.80	3.20	+3.40	10.40	496,000

(after Schicht and Walton. 1961)

Groundwater Runoff

Data on groundwater runoff can be useful in estimating potential recharge to aquifers. Over a period of years, under natural conditions, changes in groundwater storage are negligible, and groundwater recharge is balanced by groundwater runoff and groundwater evapotranspiration. Studies made in Du Page County by Zeizel and others (1962) indicate that 60 percent of groundwater runoff can be diverted into cones of depression in deeply buried aquifers. Data on reduction in groundwater evapotranspiration in Illinois due to lowering of water levels under heavy pumping conditions are not available.

Walton (1965) used streamflow data to determine groundwater runoff from 109 drainage basins within Illinois. Figure 27 shows the distribution of groundwater runoff in the study area during a year of normal precipitation. Runoff during years of below normal precipitation is not considered because water stored in thick deposits of glacial drift is available to deeply buried aquifers and drought periods therefore have little influence on water levels in these aquifers. Groundwater storage in deposits above aquifers and within aquifers permits pumping for short periods at rates greater than recharge. Sixty-seven percent of the area outlined by the 500-foot bedrock contour lies within the 194,000 to 259,000 gpd/sq mi runoff category. Total groundwater runoff within the area outlined by the 500-foot bedrock contour during a year of near normal precipitation is 740 mgd.

As previously stated, not all of the groundwater runoff can be diverted to cones of depression, because even under heavy pumping conditions there is lateral as well as vertical movement of groundwater. The recharge rate of 115,000 gpd/sq mi computed by Walton (1965) for the middle aquifer at Champaign-Urbana is, for example, 51 percent of the estimated groundwater runoff near Champaign. Assuming that existing and/or future centers of pumpage could capture at least 60 percent of groundwater runoff, as much as 445 mgd could be developed from major aquifers in the Mahomet Valley.

Recharge

Recharge to the Illinoian and Kansan aquifers is derived chiefly by vertical leakage through the overlying fine-grained

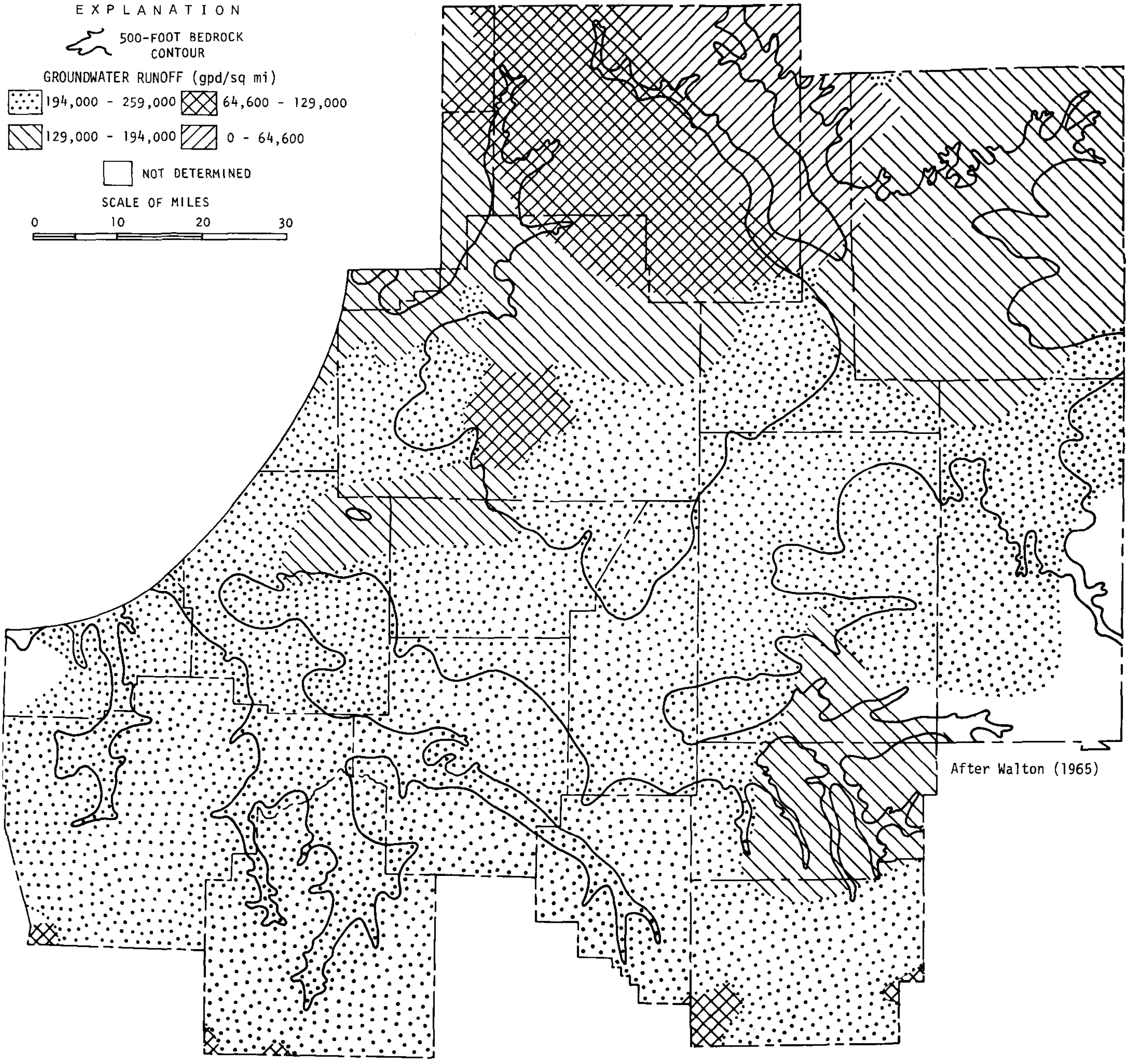


Figure 27. Distribution of groundwater runoff in the study area

deposits. Sand and gravel deposits extend to land surface in places, and recharge may be derived from vertical leakage through fairly coarse-grained deposits. Wisconsinan aquifers may be recharged directly by precipitation where they are near the surface, or by vertical leakage where they are overlain by fine-grained deposits.

Aquifers associated with streams may also be recharged by induced infiltration of surface water. Recharge by induced infiltration 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, the position of the water table, and the depth of water in the stream.

The major streams which drain the Mahomet Valley area are shown in figure 1, and Selkregg and Kempton (1958) described groundwater conditions along these streams. The Sangamon River appears to offer the best possibilities for groundwater development in shallow stream-associated aquifers, especially in Christian and Sangamon Counties and from Petersburg northward in Menard County, Municipal and industrial supplies may also be obtained locally along the Sangamon in Mason County. Other favorable areas appear locally along the Kaskaskia River in Moultrie County, the buried valley of the Embarras River in Coles County, the North Fork of the Vermilion River in Vermilion County, Salt Creek and its major tributaries in Logan County, and Sugar Creek in Iroquois County. Municipalities which obtain groundwater supplies from stream-associated aquifers are Petersburg (Sangamon River), Sullivan (Kaskaskia River), Lincoln (Salt Creek), Heyworth (Deer Creek tributary of Salt Creek), and Milford (Sugar Creek).

Recharge both directly 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 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 leakage or infiltration may be expressed mathematically by the following form of Darcy's law:

$$Q_c/A_c = 2.8\times10^7 \ (P'/m') \ \Delta h \qquad (2)$$

where

Q_C/A_C = recharge rate, in gpd/sq mi
Q_C = leakage (recharge), in gpd
A_C = area of diversion, in sq mi
P' = coefficient of vertical permeability of confining layer, in gpd/sq ft
m' = thickness of confining bed, in ft
h = difference between the head in the aquifer and in the source bed above deposits through which leakage occurs, in ft

As shown in equation 2, 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. The recharge 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. Studies indicate that the water available for development, 445 mgd, can be obtained from a reasonable number of well fields without lowering the piezometric surface below the base of the deposits through which leakage occurs.

Little quantitative data is available on recharge rates in the area. Walton (1965) investigated recharge to the Illinoian aquifer at Champaign-Urbana. The Illinoian aquifer averages 43 feet in thickness in the immediate vicinity of Champaign-Urbana, and is overlain by a confining layer averaging 120 feet thick. Walton compared pumpage and water-level data for the Illinoian aquifer and found that water-level declines were directly proportional to increases in pumpage and that within a relatively short time after each increase in pumping rate, leakage through the confining bed increased proportionately to pumpage and balanced discharge.

Walton found that it was possible to simulate the Illinoian aquifer at Champaign-Urbana with an idealized model aquifer. The model was a layer of sand and gravel extending beyond cones of depression, averaging 43 feet in thickness and overlain by a confining layer averaging 120 feet in thickness. From aquifer test analyses, coefficients of transmissivity and storage for the model aquifer were determined to be 37,000 gpd/ft and 0.00024, respectively. Water-level declines were computed by using the model aquifer, the computed hydraulic properties, estimated pumpage data, the steady-state leaky artesian equation (Jacob, 1946), and several assumed values of the coefficient of vertical permeability of the confining bed. The computed declines were then compared with actual declines. Water-level declines based on a coefficient of vertical permeability of 0.01 gpd/sq ft compared favorably with actual declines so that this value was used in recharge computations.

The average head loss associated with vertical leakage was estimated by Walton to be about 50 feet, based on the distance-drawdown graph for the model aquifer and confining bed and on data for water levels in shallow and deep deposits prior to development. The estimated average head loss, computed coefficient of vertical permeability of the confining bed, saturated thickness of the confining bed, and estimated pumpage data were substituted into equation 2 to determine the area of diversion associated with recharge. The area of diversion in 1947 was determined to be about 55 square miles. The recharge rate for the Illinoian aquifer at Champaign-Urbana, computed as the quotient of pumpage and area of diversion, was about 115,000 gpd/sq mi in 1947.

Studies were made of recharge to the Kansan aquifer west of Champaign. The Kansan aquifer and confining layer in the immediate area average about 100 feet and 40 feet in thickness, respectively. The Illinoian aquifer and its confining layer average about 65 feet and 100 feet in thickness respectively. Geologic data (figure 7) indicate that the confining layer separating the Kansan and Illinoian aquifers is not continuous. Water-level data from wells in both the Kansan and the Illinoian aquifers (figure 26) in the vicinity of pumped wells indicate that, during periods of heavy Kansan pumpage, Kansan and Illinoian piezometric levels decline to nearly common elevations and stabilize. This suggests that the deep and middle aquifers act as a single hydraulic unit under steady-state conditions during periods of large Kansan groundwater withdrawals. Thus, head losses due to vertical leakage to the deep aquifer can be determined from differences between the water levels in shallow and deep deposits.

Before development in the deep aquifer began in 1947, shallow and deep water levels were approximately at elevations of 700 and 655 feet respectively (Smith, 1950), so that a difference in head of 45 feet existed between the water table and Kansan piezometric surface elevations. Head differences greater than 45 feet have resulted from subsequent large Kansan withdrawals. Water table data suggest that, except for normal seasonal fluctuations, water levels in shallow deposits have remained essentially unchanged since 1947. The increase in loss in head in the immediate vicinity of the well field attributed to pumpage could therefore be determined by subtracting 45 feet from the total head loss. The average value of head loss for the entire area of recharge was estimated to be about one-third of the head loss attributed to pumpage in the immediate vicinity of the well field.

The thickness of the effective confining layer above the Kansan aquifer west of Champaign was estimated to be the sum of the thickness of the Kansan and Illinoian confining layers, or about 140 feet (it was assumed that the Illinoian aquifer could transmit leakage freely from one confining layer to the other, since vertical permeabilities within the Illinoian aquifer are great in relation to confining layer vertical permeabilities). Vertical permeabilities of the Kansan confining layer (about 0.25 gpd/sq ft west of Champaign, based on aquifer test data) and of the Illinoian confining layer (determined by Walton to be 0.01 gpd/sq ft) were averaged together, using a weighted average based on relative thicknesses of confining layers. The resultant value of 0.0786 gpd/sq ft was estimated to be the vertical permeability of the effective confining layer. By substituting data on vertical permeability, confining bed thickness, head loss, and pumpage into equation 2, areas of diversion were determined. Recharge rates were then computed as quotients of pumpage and corresponding areas of diversion. The average annual recharge rate to the Kansan aquifer for 1953 through 1965 was computed to be 107,000 gpd/sq mi.

ELECTRIC ANALOG MODEL STUDY NEAR CHAMPAIGN-URBANA

An electric analog computer (Walton and Prickett, 1963) was constructed on the basis of available data for the Illinoian and Kansan aquifers and their confining and source beds in the vicinity of Champaign-Urbana. The computer, constructed to aid in studying the effects of groundwater pumpage on water levels in the Mahomet Valley, consists of an analog model and associated electronic equipment.

The analog model is a scaled-down three-dimensional representation of the aquifer, consisting of uniformly spaced resistors and capacitors. Resistors are inversely proportional to the aquifer transmissivity and the vertical permeability of the confining bed. Capacitors are directly proportional to the aquifer storage properties. Aquifer and confining bed properties were estimated from aquifer and specific-capacity test data. Aquifer and confining bed dimensions were determined from geologic logs of wells and geologic reports previously referenced.

The electronic equipment (excitation-response apparatus) consists of pulse and waveform generator components and an oscilloscope. The pulse and waveform generator components force electrical current to flow in the analog model in the proper time sequence. The oscilloscope measures the resulting time-variant potential levels of the analog model. The oscilloscope traces (time-voltage graphs) are analogous to time-drawdown graphs.

Description of the Study Area

Champaign-Urbana is located in east-central Illinois about 134 miles south of Chicago. The study area as shown in figure 28 includes most of Champaign and Piatt Counties and parts of Vermilion, McLean, and De Witt Counties. The study area is rectangular and includes about 1300 square miles. A smaller rectangular area of 32 square miles including most of Champaign and Urbana was studied in more detail.

The land surface is moderately level to rolling upland prairie. Elevations within the study area range from 610 feet along the Salt Fork in T19N, R14W, to over 870 feet in the northwest corner of T22N, R5E. Drainage is by many streams that traverse the area. The normal annual precipitation at Champaign-Urbana is 37 inches; average annual temperature is 52.7 F.

Detailed discussion of the geology in the area has been given by Foster and Buhle (1951), Horberg (1950), Selkregg and Kempton (1958), and Stephenson (1967), and the following geologic description is based largely on these reports. The Mahomet Valley averages about 12 miles in a width in the area and is largely filled with glacial drift varying in thickness from less than 50 feet to more than 400 feet (figure 9). The glacial drift is composed chiefly of pebbly silty till and deposits of glaciofluvial sand and gravel. Cross-sections of the glacial drift are shown in figure 7.

The bedrock directly beneath the drift in the immediate vicinity of Champaign-Urbana is composed mainly of Pennsylvanian shale with thin beds of limestone, sandstone, and coal. As shown in figure 4, rocks of Mississippian and Devonian age form the bedrock surface in the northern part of the area. Rocks of Mississippian age form the bedrock surface in a small area just south of Champaign-Urbana. The bedrock surface has a maximum relief of over 300 feet (figure 29). As shown in figure 29 the channel of the Mahomet Valley lies about 9 miles west of the corporate limits of

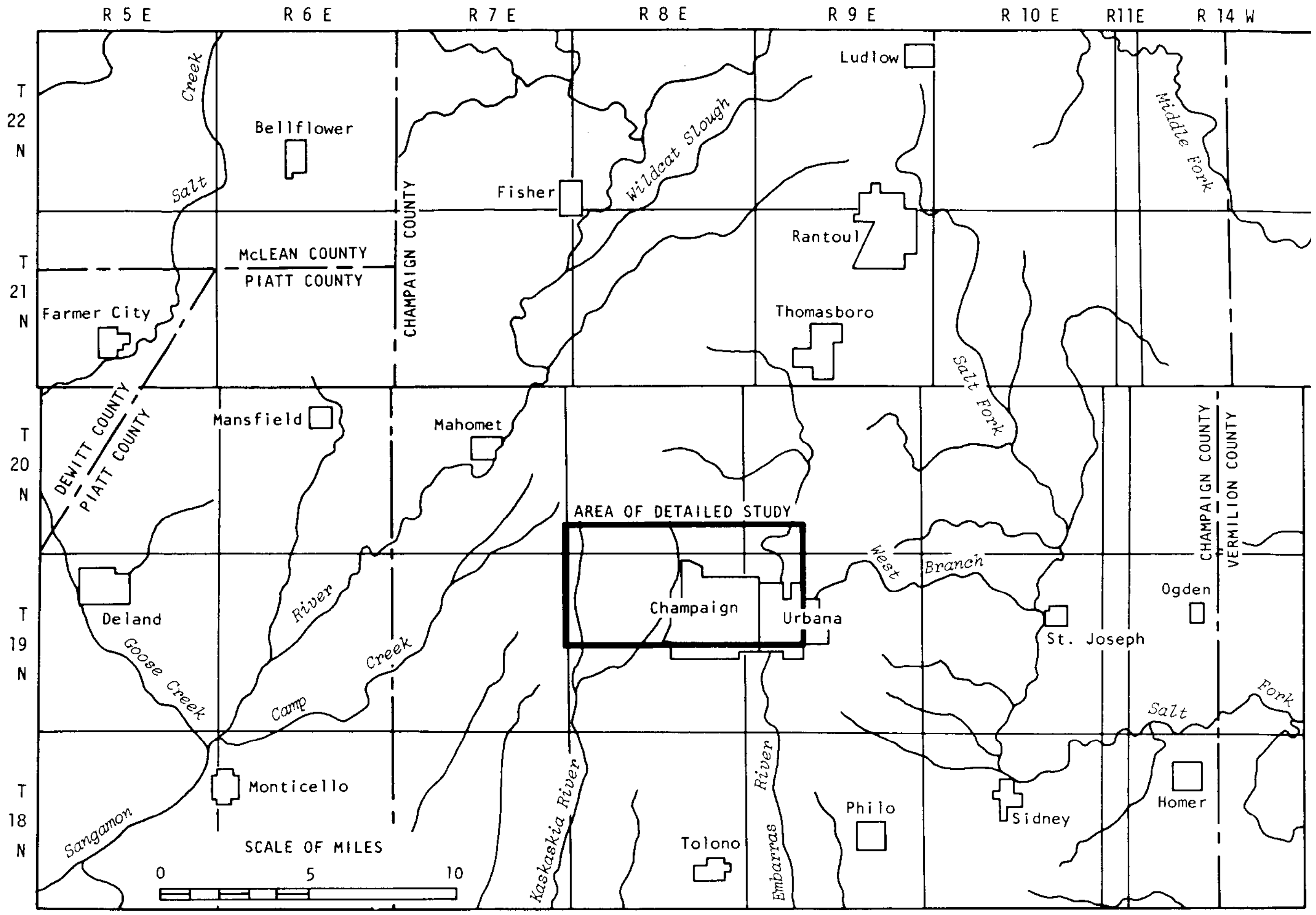


Figure 28. Location of the Champaign-Urbana study area

Champaign. A minor bedrock tributary valley trending west lies south of Champaign-Urbana.

Sand and gravel are encountered within the glacial drift at depths between 60 and 120 feet (Wisconsinan, upper aquifer), 140 and 170 feet (Illinoian, middle aquifer), and below a depth of 200 feet (Kansan, lower aquifer). The upper Wisconsinan aquifer is thin, discontinuous, scattered, and lenticular in nature, whereas the other two aquifers have fairly large areal extents. The middle Illinoian aquifer varies in thickness from less than 20 feet to more than 60 feet, as shown in figure 30, and has an average thickness of about 43 feet in the immediate vicinity of Champaign-Urbana. The middle aquifer is overlain in most places by a confining bed (upper) consisting largely of clayey silt with varying amounts of sand. The thickness of the confining bed varies from more than 150 feet to less than 50 feet and averages about 120 feet in the immediate vicinity of Champaign-Urbana, as shown in figure 31. The upper aquifer is intercalated in the confining bed at places. The lower Kansan aquifer, partially filling the deep channel of the buried Mahomet Bedrock Valley, often exceeds 100 feet in thickness west of Champaign-Urbana. Except in local areas, basal Illinoian till, typically composed of pebbly silt with a varying amount of clay, separates the middle and lower aquifers. The lower confining bed averages about 30 feet thick. Complex facies changes and interfingering silt is typical of the aquifers. The log in figure 32 illustrates the character of the glacial drift at Champaign-Urbana.

Recharge to aquifers at Champaign-Urbana occurs as vertical leakage of water through overlying confining beds. Quantities of leakage through confining beds vary from place to place, and are primarily controlled by vertical permeabilities and thicknesses of confining beds and by the differences between the heads in aquifers and in shallower deposits.

History of Groundwater Withdrawals

Large groundwater withdrawals at Champaign-Urbana began in 1885 when wells for a municipal supply were constructed in the Illinoian aquifer in northwest Urbana (North Field, figure 33). As a result of serious water-level declines in the North Field, the Northern Illinois Water Corporation

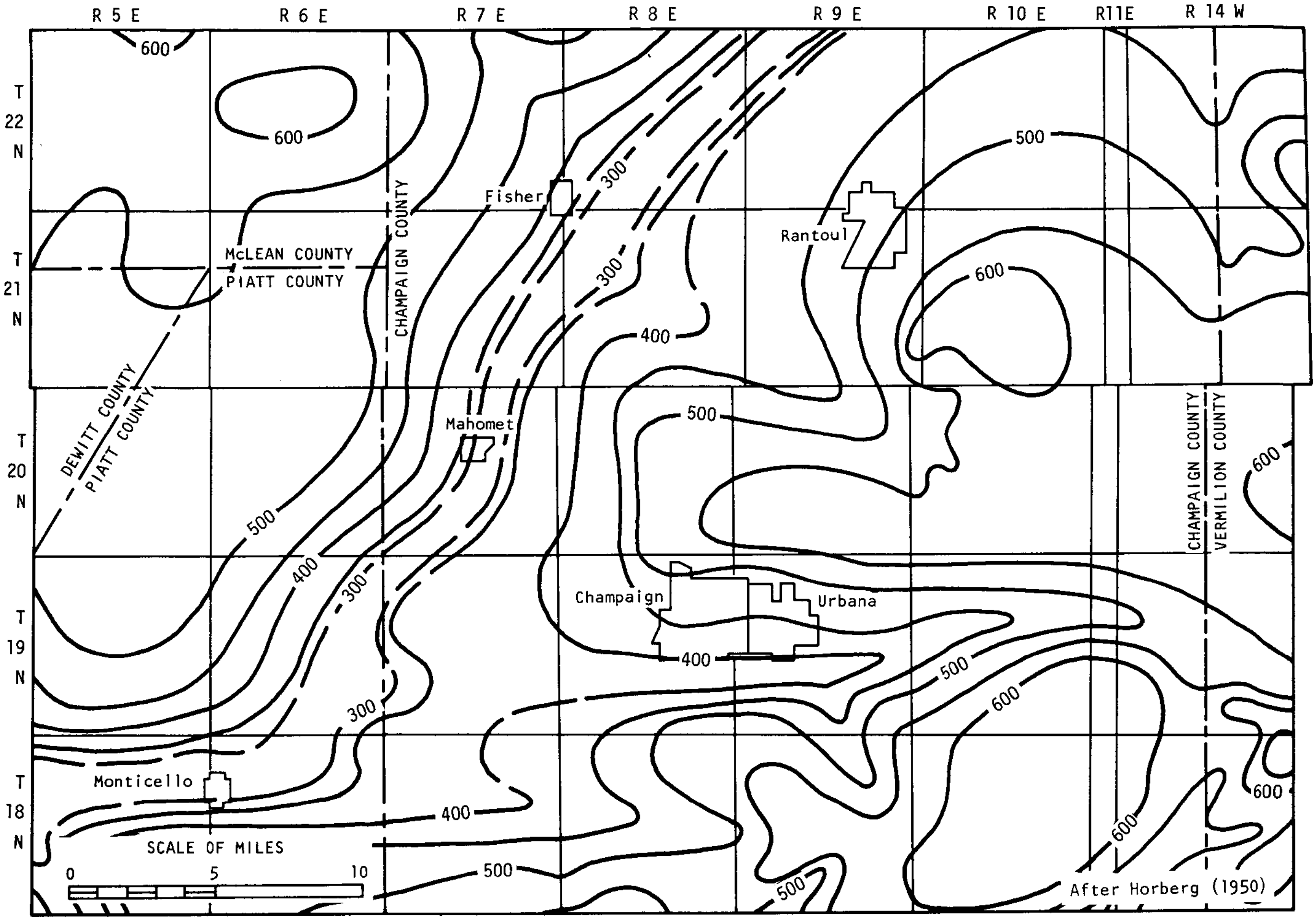


Figure 29. Bedrock topography of the Champaign-Urbana area

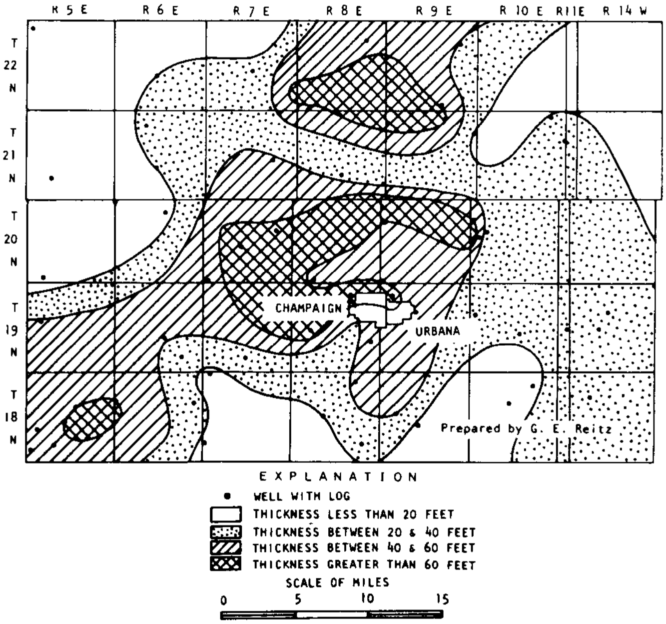


Figure 30. Thickness of the middle sand and gravel aquifer in the Champaign-Urbana area

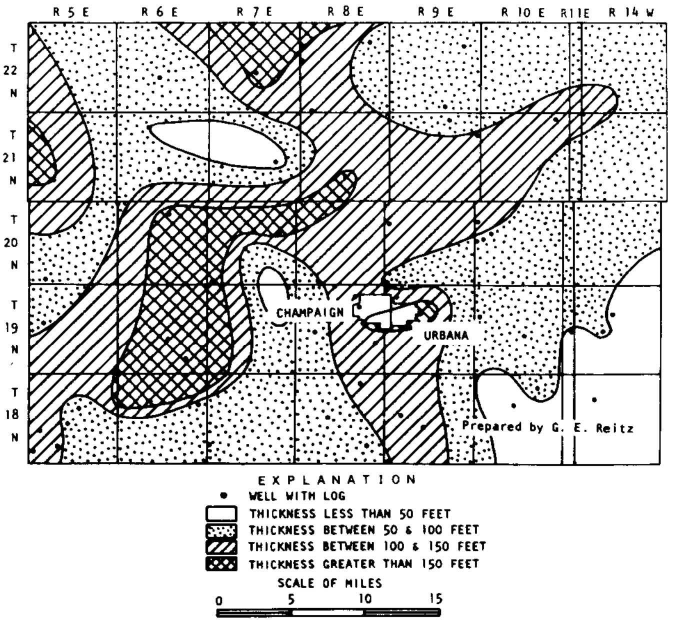
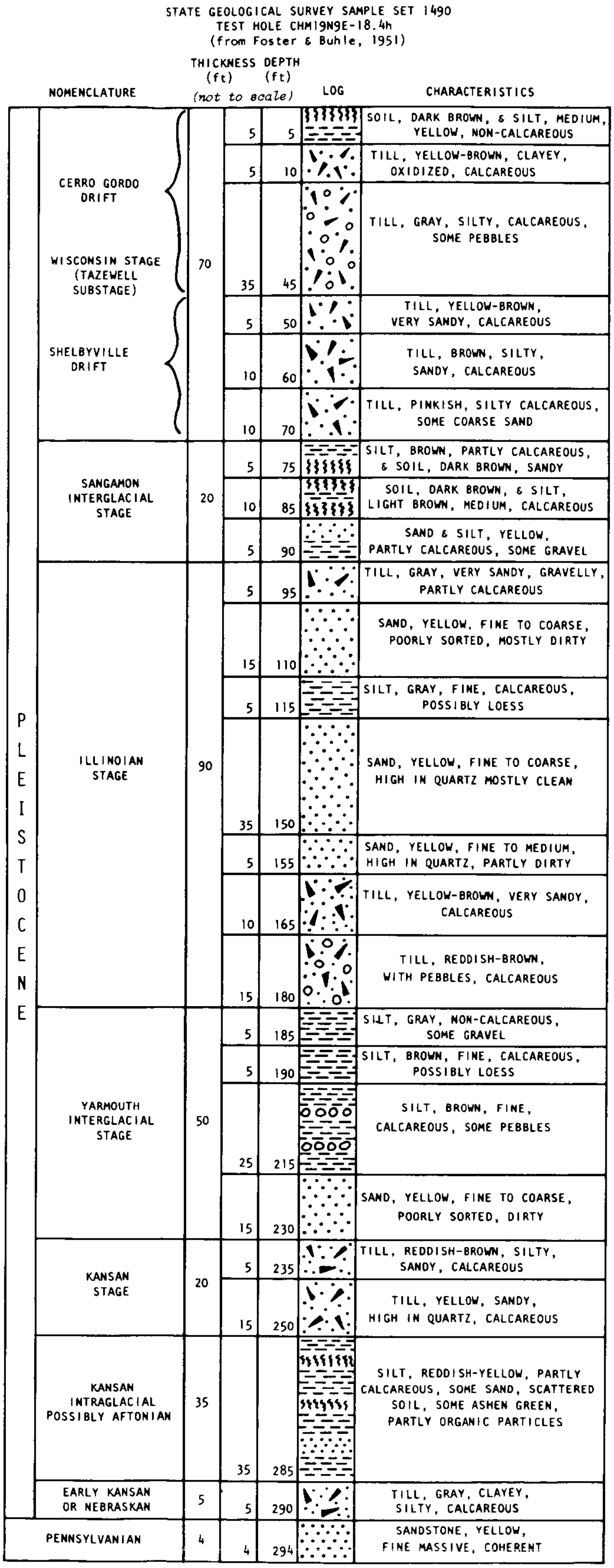


Figure 31. Thickness of the upper confining bed in the Champaign-Urbana area



STATE GEOLOGICAL SURVEY SAMPLE SET 1490
TEST HOLE CHM19N9E-18.4h
(from Foster & Buhle, 1951)

NOMENCLATURE			THICKNESS (ft) (not to scale)		DEPTH (ft)	CHARACTERISTICS
PLEISTOCENE	WISCONSIN STAGE (TAZEWELL SUBSTAGE)	CERRO GORDO DRIFT	70	5	5	SOIL, DARK BROWN, & SILT, MEDIUM, YELLOW, NON-CALCAREOUS
				5	10	TILL, YELLOW-BROWN, CLAYEY, OXIDIZED, CALCAREOUS
				35	45	TILL, GRAY, SILTY, CALCAREOUS, SOME PEBBLES
		SHELBYVILLE DRIFT		5	50	TILL, YELLOW-BROWN, VERY SANDY, CALCAREOUS
				10	60	TILL, BROWN, SILTY, SANDY, CALCAREOUS
				10	70	TILL, PINKISH, SILTY CALCAREOUS, SOME COARSE SAND
	SANGAMON INTERGLACIAL STAGE		20	5	75	SILT, BROWN, PARTLY CALCAREOUS, & SOIL, DARK BROWN, SANDY
				10	85	SOIL, DARK BROWN, & SILT, LIGHT BROWN, MEDIUM, CALCAREOUS
				5	90	SAND & SILT, YELLOW, PARTLY CALCAREOUS, SOME GRAVEL
	ILLINOIAN STAGE		90	5	95	TILL, GRAY, VERY SANDY, GRAVELLY, PARTLY CALCAREOUS
				15	110	SAND, YELLOW, FINE TO COARSE, POORLY SORTED, MOSTLY DIRTY
				5	115	SILT, GRAY, FINE, CALCAREOUS, POSSIBLY LOESS
				35	150	SAND, YELLOW, FINE TO COARSE, HIGH IN QUARTZ MOSTLY CLEAN
				5	155	SAND, YELLOW, FINE TO MEDIUM, HIGH IN QUARTZ, PARTLY DIRTY
				10	165	TILL, YELLOW-BROWN, VERY SANDY, CALCAREOUS
				15	180	TILL, REDDISH-BROWN, WITH PEBBLES, CALCAREOUS
	YARMOUTH INTERGLACIAL STAGE		50	5	185	SILT, GRAY, NON-CALCAREOUS, SOME GRAVEL
				5	190	SILT, BROWN, FINE, CALCAREOUS, POSSIBLY LOESS
				25	215	SILT, BROWN, FINE, CALCAREOUS, SOME PEBBLES
				15	230	SAND, YELLOW, FINE TO COARSE, POORLY SORTED, DIRTY
	KANSAN STAGE		20	5	235	TILL, REDDISH-BROWN, SILTY, SANDY, CALCAREOUS
				15	250	TILL, YELLOW, SANDY, HIGH IN QUARTZ, CALCAREOUS
	KANSAN INTRAGLACIAL POSSIBLY AFTONIAN		35	35	285	SILT, REDDISH-YELLOW, PARTLY CALCAREOUS, SOME SAND, SCATTERED SOIL, SOME ASHEN GREEN, PARTLY ORGANIC PARTICLES
	EARLY KANSAN OR NEBRASKAN		5	5	290	TILL, GRAY, CLAYEY, SILTY, CALCAREOUS
PENNSYLVANIAN			4	4	294	SANDSTONE, YELLOW, FINE MASSIVE, COHERENT

Figure 32.Log of well at Champaign-Urbana

began constructing wells west of Champaign (figure 33) in the Kansan aquifer in 1947. Twelve municipal wells were drilled in the Kansan aquifer between 1947 and 1964, and eight are currently in operation. Pumpage from the Kansan aquifer for municipal use reached a peak of 9.29 mgd in 1963.

Withdrawals from the Illinoian aquifer for industrial use began in 1905 and reached a peak of 1.89 mgd in 1947. Withdrawals from the Kansan aquifer for industrial use began in 1953 at the west edge of Champaign. Industrial pumpage from the Kansan aquifer was greatest, 8.54 mgd, in 1963. The University of Illinois began pumping from wells in the middle aquifer in 1900 and by 1935 had drilled 11 wells. Peak withdrawals of 0.93 mgd were reached in 1932, 1936, and 1948. The University began purchasing water from the water company in 1950, and the University wells are no longer in use. Average annual pumpages for Champaign-Urbana from 1885 to 1965 subdivided by use and source are shown in figures 19 and 20.

Electric Analog Computer

An electric analog computer (Walton and Prickett, 1963) was constructed for the Champaign-Urbana area so that reasonable predictions could be made of the consequences of further groundwater development, the practical sustained yield of existing wells and pumping centers, and the potential yield of the multiple-aquifer system near Champaign with a selected scheme of development. An area of about 1300 square miles (figure 28) was included in the model study.

The analog model was patterned after analog models developed by Skibitzke (1960) and consists of arrays of electrical resistors and capacitors simulating a scaled-down version of the aquifers. Resistor values are selected so as to be inversely proportional to aquifer transmissivity values, while capacitor values are directly proportional to aquifer storage properties. The multiple-aquifer system at Champaign consists of two horizontal arrays of resistors and capacitors (lower and middle aquifers) and one horizontal ground wire array (water table), interconnected by two vertical arrays of resistors (lower and upper confining beds). Vertical resistor values are inversely proportional to the coefficient of leakage of the confining layer. The analogy between the electrical network and the aquifer system is apparent in a comparison of the finite-difference equations of electrical and groundwater movement (Skibitzke, 1960). Electrical units (volts, coulombs, amperes, and seconds) correspond to groundwater hydraulic units (feet of head, gallons, gallons per day, and days). Appropriate scale factors connect corresponding units.

The analog model was designed on a scale of 1 inch equaling 1 mile and was constructed with 7500 resistors and capacitors mounted in 1/8-inch pegboard measuring approxi-

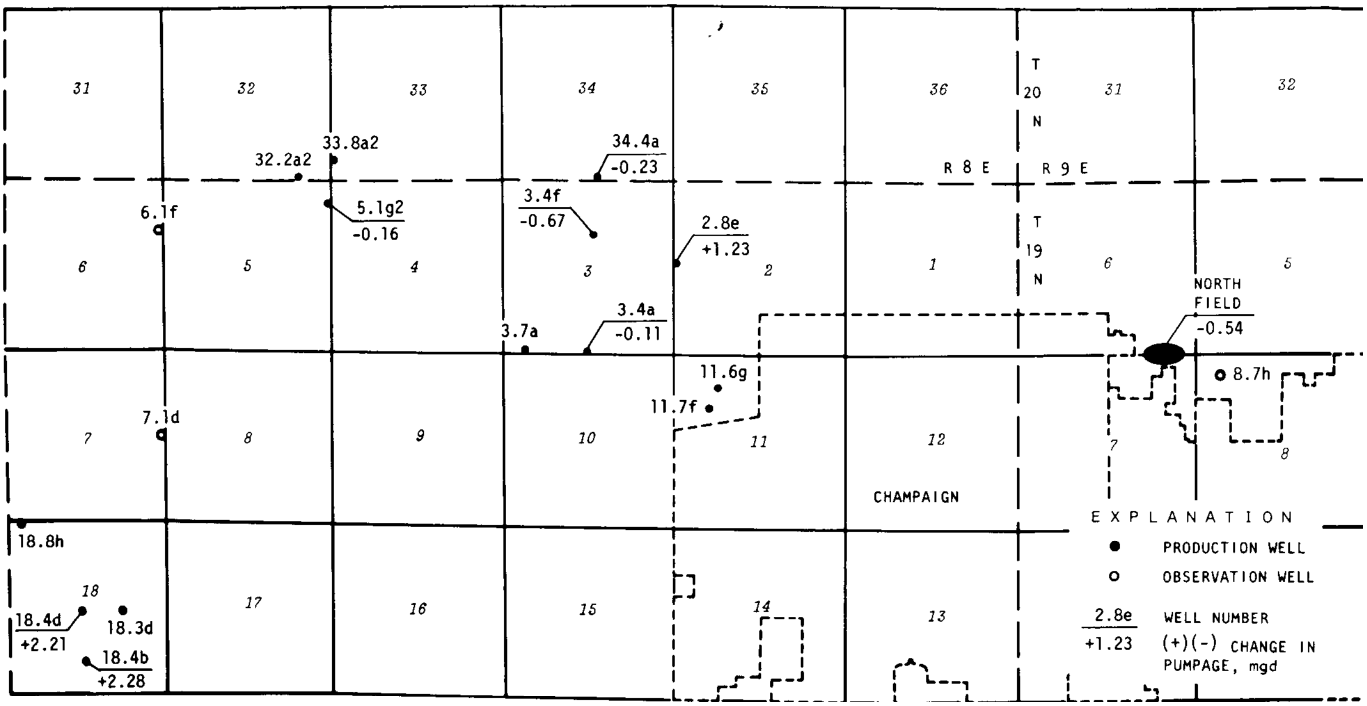


Figure 33. Area of detailed study

mately 4 by 5 feet. Holes perforated the pegboard in a 1-inch square pattern, and shoe eyelets inserted in the holes provided terminals for resistors and capacitors of the lower aquifer. Four horizontal resistors, one vertical resistor, and a capacitor were soldered to each interior terminal, and the capacitor was grounded. Boundaries were constructed in a stepwise fashion to approximate the actual boundary of the lower aquifer. Boundary terminals were connected to either two or three horizontal resistors (depending upon the geometry of the boundary), to a vertical resistor, and to a capacitor. Lower aquifer boundaries were simulated by an open circuit. Electronic components for boundary terminals were chosen through the use of the vector volume technique (Karplus, 1958). In a similar manner the middle layer was constructed, removed from its pegboard, and soldered to the vertical resistors representing the lower confining bed between the lower and middle aquifers. The upper confining bed resistors and the capacitors of the middle layer were connected to a horizontal network of ground wires representing the water table. A termination strip (Karplus, 1958) at the edges of the analog model extended the model another 14 miles in each direction.

Scale factors were chosen which related electrical units and groundwater units and which were compatible with the excitation-response apparatus. The following scale factors were selected:

$K_1 = 3.65 \times 10^{13}$ gallons/coulomb
$K_2 = 10$ feet/volt
$K_3 = 10^9$ gallons/day/ampere
$K_4 = 3.65 \times 10^4$ days/second

Values of resistors used ranged from 1 to 68,000 ohms, while values of capacitors ranged from 10^{-6} to 10^{-8} farads.

Although the scale of the model was chosen to minimize errors due to the finite difference approximation, it was subsequently learned that the spacing selected was insufficient to adequately reduce errors in the well fields west of Champaign. An enlargement therefore was made of a 32-square-mile area to the west of, and including, Champaign-Urbana (see figure 33). The enlargement was designed on a scale of approximately 1 inch equal to 2100 feet and consists of about 1500 resistors and 500 capacitors. Matching strips (Karplus, 1958) were included along the edge of the enlarged area to minimize errors between the fine mesh of the enlarged area and the coarse mesh of the surrounding area. Resistor values used in the enlargement ranged from 68 to 390,000 ohms, while capacitors used ranged from 10^{-8} to 1.8×10^{-9} farads.

Electronic equipment used with the analog model to activate the electric analog computer is frequently referred to as the excitation-response apparatus and consists of a waveform generator, a pulse generator, and an oscilloscope. This equipment is used to force electrical energy in the proper time phase into the analog model and to measure the energy level response within the model network. The waveform generator, which produces sawtooth and square wave pulses, is used to control the repetition rate of computation and to synchronize the oscilloscope's horizontal sweep with the output of the pulse generator. The pulse generator, which produces rectangular pulses whose duration and amplitude are analogous to the pumping period and pumping rate, respectively, is coupled to the junction in the analog model representing the pumped well. The oscilloscope is connected to junctions in the analog model representing observation wells. The oscilloscope provides a time-voltage graph which is analogous to the time-drawdown graph of an observation well.

A new approach to examining water levels in pumping wells was the addition to the analog of a series of 'well resistors.' Inherent in the finite-difference approximation of analog design is the error involved in drawdown computations at or near a pumped well or well field. Studies made by Prickett (1967) indicate that the additional drawdown required at the pumped well node to simulate the diameter of the well can be provided by inserting an additional resistor in series with the pulse generator. These studies showed a relationship between the resistor required and the node spacing as follows:

$$R = (K_3/K_2T)\ \log\ (0.416a/D)^{0.37} \qquad (3)$$

where

R = value of 'well resistor,' in ohms
K_2 = scale factor relating head and voltage, in ft/volt
K_3 = scale factor relating gpd and amperes, in gpd/amp
T = aquifer transmissivity in the vicinity of pumped well, in gpd/ft
a = grid interval of model, in ft
D = diameter of desired well, in ft

Values of resistors were computed with equation 3, and appropriate resistors were added to the enlarged portion of the analog model at nodes corresponding to municipal and industrial well locations. The addition of such 'well resistors' facilitated the use of the analog model for evaluating the practical sustained yield.

Analog Verification and Use

The accuracy of the electric analog computer was assessed by a study of records of past pumpage and water levels. Water-level declines were determined with the aid of the computer from detailed pumpage data available for individual production wells. The accuracy of an analog model may be tested by computing a water-level change map and comparing it with a map of observed water-level changes. This method requires simultaneous water-level data from many wells, which were not available in the study area. However, continuous water levels recorded in two observation wells in the Kansan aquifer west of Champaign (wells 19N8E-7.1d and 6.1f) and in an observation well in the Illinoian aquifer near the North Well Field (well 19N8E-8.7h) were available to appraise the accuracy of the computer. The locations of production and observation wells are shown in figure 33. Water levels in the observation wells respond quickly to changes in pumpage because of the high aquifer transmissivity and high leakage coefficients of the confining beds. Thus water-level declines or recoveries occur for relatively brief periods of time. Water levels either stabilize quickly or are influenced by a new change in the pumping scheme.

The accuracy of the computer was appraised for periods when water-level hydrographs for the three observation wells indicated a well-defined water-level trend followed by a sharp significant water-level decline of relatively short duration. An example is shown by the hydrograph for well 19N8E-7.1d (figure 34) for the period June 6-9, 1963. The actual water-level decline is estimated by subtracting the water level at the end of the decline from the extended water-level trend and was 2.40 feet as shown in figure 34. Significant error in estimating the water-level decline is introduced by extending the water-level trend for lengthy periods.

The water-level decline was computed by connecting the pulse generator to the analog model nodes representing pumping wells and then adjusting its output to simulate the appropriate pumping period length and pumping rates. The length of the pumping period corresponds to the length of the period of water-level decline. The pumping rates are the increments of pumpage which produced the water-level decline; that is, the difference between the pumping rate preceding the water-level decline and the pumping rate during the decline. Increments of pumpage which produced the decline shown in figure 34 are given in figure 33 for each production well. As shown in figure 33 some increments are negative. Also, some production wells were not in operation during the period or were pumped at a constant rate.

The effects of pumping on water levels in the observation well were computed by connecting the oscilloscope to the node representing the observation well and observing the time-voltage graph (analogous to the time-drawdown in the

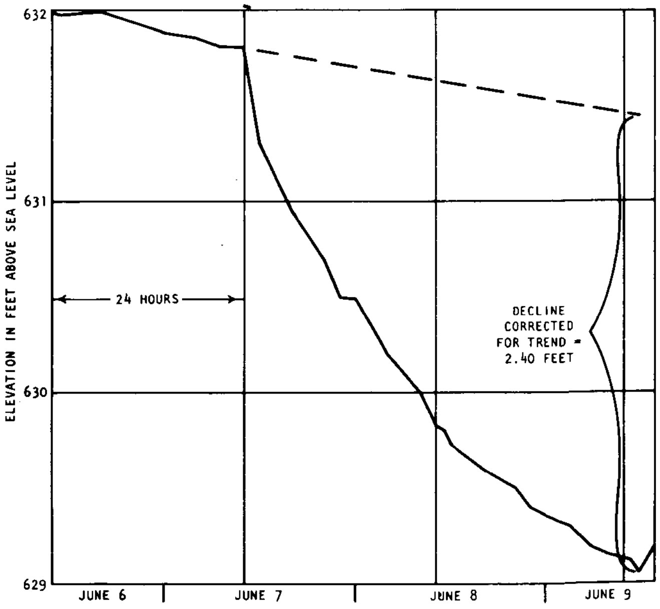


Figure 34. Water levels in well CHM 19N8E-7.1d, June 7-9, 1963

observation well). The decline was computed to be 2.48 feet which compares well with the actual decline of 2.40 feet.

The results of 30 comparisons made for each of the three observation wells are summarized in table 18 and figure 35. Not all results were so accurate as that shown in the above example. However, as shown in figure 35 the correlation between observed and computed declines is good, suggesting the model is reasonably accurate even for evaluating water-level response in the middle aquifer to deep pumpage (well CHM 19N9E-8.7h).

Table 18. Comparison of Actual and Computed Water-Levels Changes

Well CHM 19N8E-6.1f

Observation period	Water-level change (ft) com-puted	actual	% error
3/6/63-4/1/63	5.69	5.60	1.6
7/22/63-7/26/63	1.82	2.40	—24.2
1/4/64-1/5/64	1.22	1.60	—23.7
2/26/64-2/28/64	2.48	1.85	34.1
4/16/64	1.23	1.45	—15.2
4/22/64	1.04	1.30	—20.0
5/3/64-5/4/64	1.51	1.23	22.8
6/5/64-6/6/64	2.08	2.30	—9.6
6/19/64-6/21/64	2.15	2.60	—17.3
8/10/64-8/20/64	1.88	2.60	—27.7
8/21/64	0.89	1.30	—31.5
9/6/64	1.17	1.02	14.7
9/14/64-9/15/64	1.53	1.60	—4.4
9/24/64-9/25/64	1.05	1.20	—12.5
9/24/64-9/29/64	1.33	1.50	—11.3
10/26/64-10/31/64	1.78	1.50	18.6
11/20/64-11/22/64	2.39	2.00	19.5
1/11/65-1/15/65	2.02	2.15	—6.0
1/25/65-1/28/65	3.37	2.62	28.6
4/13/65	0.74	1.30	—43.1
4/13/65-4/15/65	1.57	1.35	16.3
4/19/65	0.82	1.80	—51.1
6/13/65-6/17/65	2.59	2.80	—7.5
8/2/65-8/13/65	4.03	5.00	—19.4
9/1/65-9/2/65	1.74	1.60	21.2
11/22/65-11/23/65	0.84	1.00	—16.0
12/10/63-12/12/65	1.43	1.30	10.0
12/13/65-12/15/65	1.06	1.04	1.9
12/17/65-12/20/65	1.92	2.20	—12.7
12/21/65-12/22/65	2.62	2.10	24.7

% Average absolute error = 18.9

Well CHM 19N8E-7.1d

Observation period	Water-level change (ft) com-puted	actual	% error
1/11/63-1/13/63	3.40	3.10	9.7
6/7/63-6/9/63	2.48	2.40	3.3
2/11/64-2/23/64	4.07	4.40	—7.5
2/24/64-2/28/64	3.83	3.75	2.1
6/5/64-6/7/64	1.38	1.20	15.0
9/6/64-9/7/64	2.30	2.00	15.0
9/14/64-9/15/64	1.84	1.75	5.1
10/11/64-10/13/64	1.10	1.28	—14.1
10/25/64-10/29/64	1.20	1.50	—20.0
11/27/64-11/28/64	0.57	1.10	—48.2
12/4/64-12/5/64	1.98	2.10	—5.7
12/13/64-12/14/64	0.44	0.50	—12.0
2/4/65-2/5/65	0.45	0.41	9.8
2/8/65	0.18	0.29	—37.9
2/8/65-2/9/65	0.54	0.60	—10.0
2/g/65-2/10/65	0.59	0.55	7.3
8/1/65	0.86	0.95	—9.5
8/2/65-8/3/65	3.60	3.40	5.9
8/6/65-8/9/65	1.80	2.90	—37.9
9/7/65-9/10/65	1.18	1.10	7.3
9/15/65-9/16/65	1.26	1.55	—18.7
9/16/65-9/22/65	4.90	4.60	6.5
10/5/65-10/6/65	0.29	1.00	—71.0
11/5/65-11/19/65	0.78	0.82	—4.9
11/15/65-U/16/65	0.55	0.55	0.0
11/22/65	0.40	0.36	11.1
12/4/65-12/5/65	0.29	0.35	—17.1
12/12/65-12/15/65	1.35	1.50	—10.0
12/21/65-12/22/65	1.50	1.65	—9.1
12/27/65	0.50	0.57	—12.3

% Average absolute error = 14.8

Well CHM 19N9E-8.7h

Observation period	Water level change (ft) com-puted	actual	%error
10/3/62-10/5/62	0.39	0.48	—18.7
10/17/62-10/21/62	2.16	1.55	39.4
11/16/62-11/23/62	2.20	2.32	—5.2
1/25/63-1/28/63	2.03	1.75	16.0
5/10/63	0.36	0.35	2.9
5/15/63-5/27/63	2.58	2.95	—12.5
7/12/63-7/19/63	3.25	2.75	18.2
7/22/63-7/26/63	3.21	2.50	28.4
9/12/63-9/17/63	3.00	2.25	33.3
9/27/63-9/28/63	0.63	0.60	5.0
2/19/64-2/21/64	1.65	1.45	13.8
4/21/64-4/23/64	1.48	1.25	18.4
4/24/64-4/25/64	1.51	1.10	37.3
5/2/64-5/12/64	1.46	1.35	8.1
5/19/64-5/26/64	2.95	2.00	47.5
7/5/64-7/8/64	0.65	0.63	3.2
7/14/64-7/17/64	1.03	0.95	8.4
7/21/64-7/30/64	2.06	1.80	14.4
10/18/64-10/31/64	1.34	1.20	11.7
12/22/64-12/28/64	1.19	2.21	—46.2
2/11/65-2/15/65	1.95	2.40	—18.7
2/22/65-2/29/65	4.71	5.00	—5.8
4/6/65-4/9/65	2.12	2.60	—18.5
4/10/65	1.35	1.30	3.8
4/11/65-4/12/65	2.23	2.80	—20.4
4/14/65	1.96	1.80	8.9
7/31/65-8/8/65	3.29	3.05	7.9
8/13/65-8/22/65	1.67	1.40	19.3
9/12/65-11/31/65	7.70	5.90	30.5
12/10/65-12/U/65	0.34	0.60	—43.4

% Average absolute error = 18.9

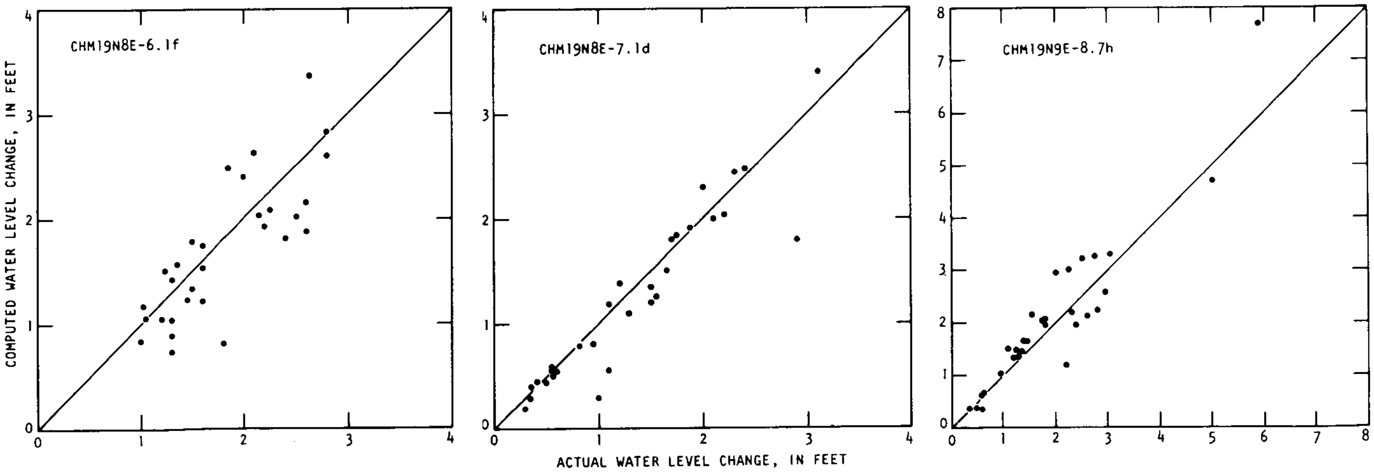


Figure 35. Actual and computed water-level changes in observation wells near Champaign-Urbana

Selected Pumping Scheme

The electric analog computer was used to determine pumping levels with a selected scheme of pumping from existing large-capacity municipal and industrial wells in the Kansan aquifer west of Champaign. Six of the eight operating municipal wells were selected. The selected scheme was based on maximum expected industrial pumpage and a distribution of pumpage in the municipal well field that would minimize interference among wells.

The results of the selected pumping scheme are shown in table 19. Pumping rates given in table 19 for municipal wells correspond to existing pump capacities and are for continuous pumping. Maximum pumping rates computed solely on the basis of long-term specific capacity and available drawdown were not used because they are extremely high and unrealistic.

Withdrawals with the selected pumping scheme total 30.3 mgd, municipal pumpage accounting for 18.6 mgd and industrial pumpage for 11.7 mgd.

Table 19. Estimated Pumping Levels with Selected Pumping Scheme

Well number	Pumping rate *(gpm)*	Land surface elevation *(ft)*	Elevation top of aquifer *(ft)*	Elevation top of screen *(ft)*	Average 1966 pumping rate *(gpm)*	Estimated* pumping level elevation *(ft)*	Average 1966 pumping level elevation *(ft)*
Municipal wells							
2.8e	1975	765	555	551	854	563	602
3.4a	2100	752	535	507	982	563	595
3.4f	2100	760	545	495	958	559	597
3.7a	2800	766	535	510	1233	563	611
5.1g2	1000	735	520	485	356	593	604
32.2a2	3000	722	522	467	1179	583	586
Industrial wells							
11.6g	520	760	540	512	450	583	615?
11.7f	625	762	539	521	540	589	615?
18.3d	1360	701	517	502	548	588	592
18.4b	1850	700	528**	528	653	587	575
18.4d	1850	704	522	499	805	584	577
18.8h	1850	706	509	496	473	590	603

Pumping levels may be lower if well losses are appreciable
***Elevation of top of screen, drillers log not available*

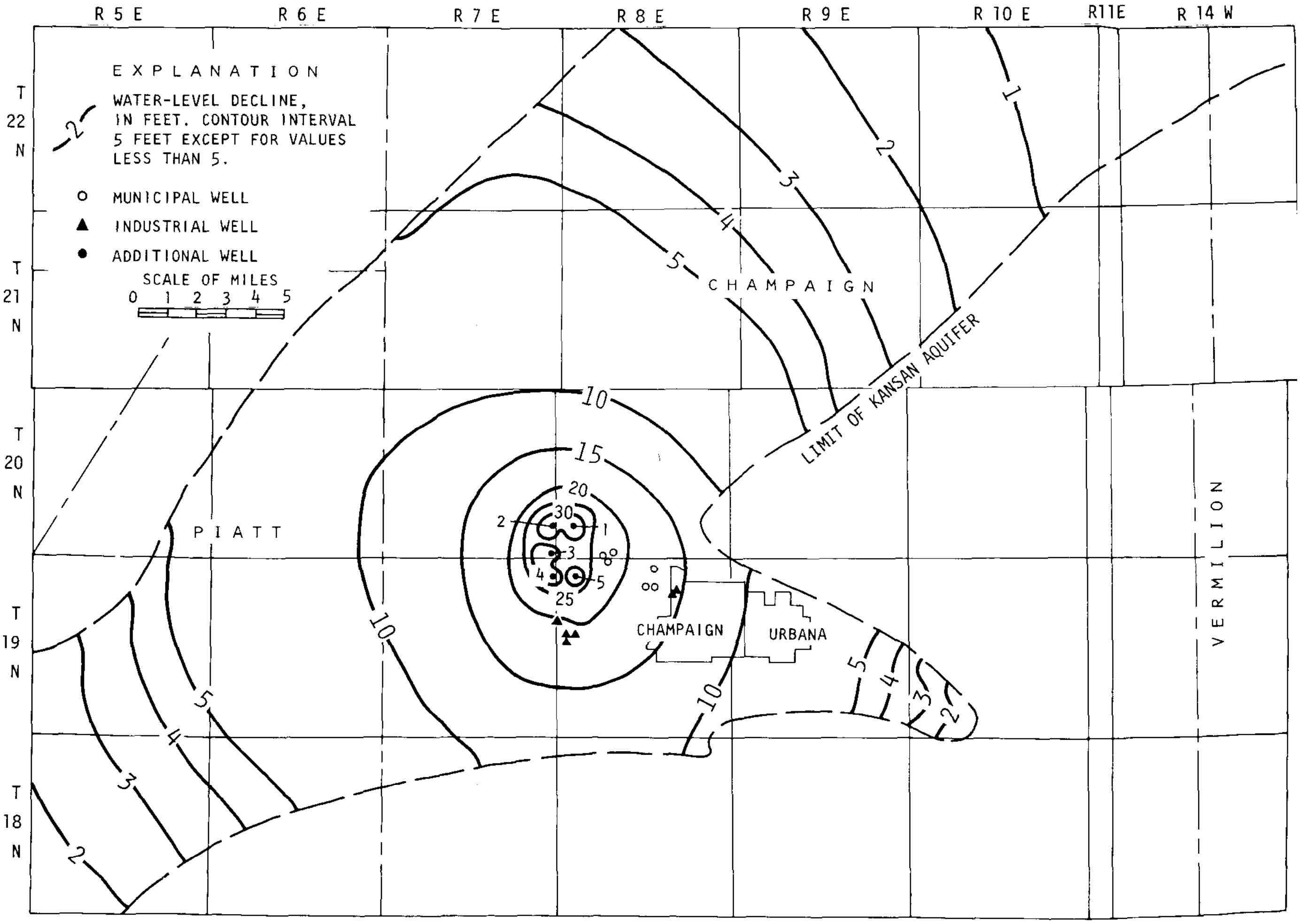


Figure 36. Predicted decline of water levels in deep aquifer in response to 15 mgd pumpage from five additional deep wells

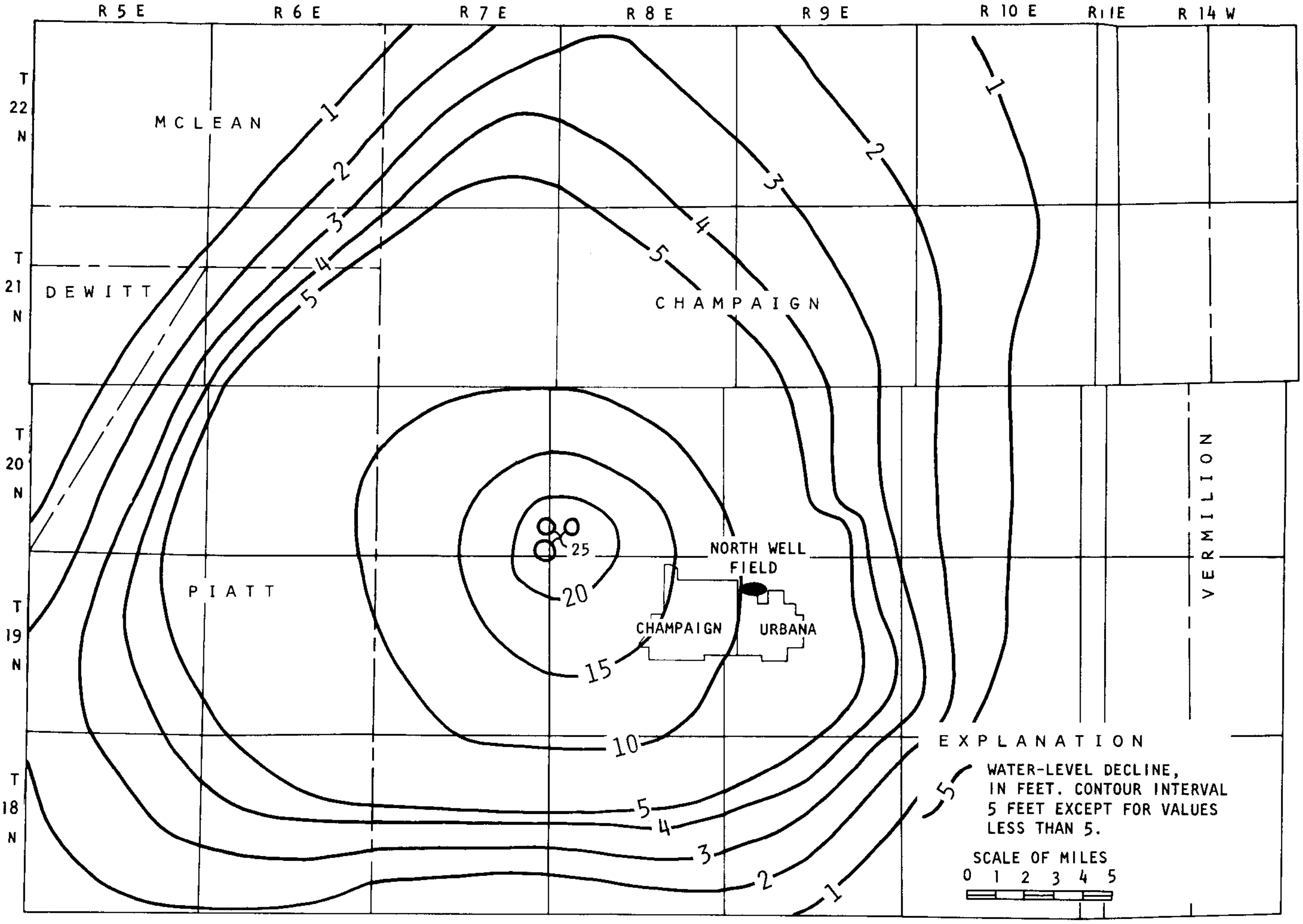


Figure 37. Predicted decline of water levels in middle aquifer in response to 15 mgd pumpage from five additional deep wells

Additional Wells

Extrapolation of pumpage for Champaign-Urbana indicates that an additional 15 mgd will be required by the year 2000. The effect of the additional withdrawals on water levels in wells finished in the Kansan and Illinoian aquifers was studied with the electric analog computer. The model was used to determine the effects of five additional wells pumping 3 mgd each. Various well locations were tried, considering such factors as well spacing, interference with existing wells, transmission distances, and model node spacing.

The locations of the five additional wells and their effects on water levels in the Kansan and Illinoian wells are shown in figures 36 and 37. Predicted long-term pumping levels resulting from the additional 15 mgd withdrawal and the selected pumping scheme are given in table 20.

Table 20. Estimated Pumping Levels Resulting from 15 mgd Withdrawal from Five Additional Wells

Well number	Pumping rate *(gpm)*	Estimated* pumping level elevation *(ft)*	Approximate elevation of top of aquifer *(ft)*
Municipal wells			
2.8e	1975	547	555
3.4a	2100	546	535
3.4f	2100	542	545
3.7a	2800	546	535
5.1g2	1000	570	520
32.2a2	3000	559	522
Industrial wells			
11.6g	520	567	540
11.7f	625	573	539
18.3d	1360	570	517
18.4b	1850	569	528**
18.4d	1850	565	522
18.8h	1850	571	509
Additional wells			
1	2080	584	515
2	2080	588	515
3	2080	583	515
4	2080	581	515
5	2080	579	515

**Pumping levels may be lower if well losses are appreciable*
***Elevation of top of screen drillers log not available*

WATER QUALITY

The chemical character of the groundwater in the Mahomet Valley is known from the analyses of water samples from 622 wells. The analyses were made by the Chemistry Section of the State Water Survey. The ranges and mean values of certain chemical constituents are summarized in table 21 from data given in table 22 for mineral analyses of water samples from selected wells in Illinoian and Kansan deposits. As shown in table 21, the quality of waters sampled from wells in Illinoian deposits does not differ substantially from that of water from wells in Kansan desposits.

Table 21. Ranges and Mean Values of Certain Mineral Constituents for Selected Well Water Samples

(Chemical constituents in parts per million)

Constituents	Illinoian aquifer range	Illinoian aquifer mean	Kansan aquifer range	Kansan aquifer mean
Iron (Fe)	0.6-3.2	1.8	0.2-3.0	1.2
Chloride (Cl)	T-37	4.1	T-66	11
Sulfate (So$_4$)	0-9	2.3	0-5	0.9
Alkalinity (as $CaCO_3$)	278-475	363	284-454	363
Hardness (as $CaCO_3$)	170-595	299	150-438	293
Total dissolved minerals	310-478	379	295-636	414

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(Continued on page 52)

Table 22. Chemical Analyses of Water from Selected Wells

(Chemical constituents in parts per million)

Well number	Owner	Depth (*ft*)	Main* aquifer	Date collected	Iron (Fe)	Manganese (Mn)	Ammonium (NH_4)	Fluoride (F)	Nitrate (NO_3)	Chloride (C1)	Sulfate (SO_4)	Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)	Total dissolved minerals
CHM—														
18N7E.														
6.7b	Maude Nolte	135	I	10/l/62	1.5					T		336	298	342
19N7E-														
10.1a	C. A. Hinton	130	I	2/24/48	0.9					T		352	252	358
19N8E														
2.8e(53)	No. Ill. Water Corp.	289	K	12/29/56	0.6	0.1	1.9	0.3	0.3	4	4	292	261	308
3.7a(58)	No. III. Water Corp.	329	K	8/12/64	0.6	0.1	1.8	0.3	0.1	1.0	0.4	318	258	317
5.1g1(49)	No. Ill. Water Corp.	297	K	4/11/47	0.8	T	0.8	0.1	0:2	2		292	260	295
6.1b	Burnham Estate	130	I	4/20/64	2.4			T	0.6	2		380	232	402
18.8h(4)	Petro Chemicals Corp.	310	K	8/30/65	0.6	T		0.3	1.3	10		284	276	362
19N9E-														
6.5f3(3)	Swift & Co.	161	I	5/31/60	1.2					T		328	232	326
20N7E-														
15.2a	Guy R. Jones	130	I	5/16/63	1.8			0.3		T		376	284	375
15.7e3(3)	Mahomet (V)	252	K	7/63	0.6	0.07		0.3	1.0	T		360	332	372
20N8E-														
6.1c	A. W. Thrasher	130	I	1/29/46	1.9					2	8	376	221	396
29.8h	Evelyn Miller	300	K	8/65	1.4				1.7	3		352	276	360
33.8a2(59)	No.Ill. Water Corp.	342	K	6/8/62	0.3		0.8			3	2	300	240	316
21N7E														
35.3e	W. E. McCoy	135	I	5/24/61	1.3					2		364	352	376
21N8E-														
15.8g	Burdette Griffiths	290	K	2/55	1.2					5		368	316	366
24.1h	Seeber Farms	135	I	10/49	1.2		0.5		0.7	T	T	328	286	345
27.1a	C. E. Coffin	265	K	8/6/65	1.3		6.9			3		392	268	395
21N9E-														
15.7h(1)	Shull Mobile Homes	158	I	9/21/64	2.4	T		0.3	1.0	2		372	318	357
22N7E-														
36.2d3(3)	Fisher (V)	270	K	8/7/59	0.2	0.1		0.3	5.1	3		364	368	479
22N9E-														
23.4a	J. N. Moore	269	K	9/58	0.6					5		376	248	403
34.2a8(2)	Rantoul (V)	139	I	5/24/49	1.9	0.0	T	0.1	11.0	2	0.0	332	342	341
34.2a9(3)	Rantoul (V)	293	K	7/26/57	0.8					2		382	326	394
DWT—														
19N4E-														
9.3d1(2)	Weldon (V)	165	I	10/22/48	2.4	0.2	1.10	0.5	2.0	4	T	400	257	449
32.1b	Prudential Ins. Co.	293	K	1/25/34	1.4	0.0	3.6		1.4	32	T	434	321	501
20N2E-														
3.2f	Wapella High School	312	K	1/23/34	-0.7	0.1	4.9		0.2	36	T	426	243	506
34.3d8(5)	Clinton (C)	360	K	8/21/64	2.6	0.08		0.7	0.4	66		454	316	551
FRD—														
23N9E-														
14.1g(8)	Paxton (C)	340	K	4/18/60	2.0	0.1	2.6	0.4	0.0	3	0.0	368	364	400
14.2g2(T)	Paxton (C)	125	I	11/56	2.0	0.2		0.3	0.2	4		340	284	343
27.1h	R. J. Frette	140	I	1/18/34	1.7	T	1.1		0.7	2	6.	362	356	357
23N10E-														
7.1d(5)	Paxton (C)	149	I	10/10/45	1.4	0.0	3.2		2.3	T	T	304	194	311
23N14W.														
9.8g	C. D. Kirtpatrick	135	I	1/4/34	0.6	0.0	8.3		1.7	2	9	440	378	449
IRO—														
26N13W-														
1.1g	Richard Breeden	129	I	7/60	0.6				5.3	16		278	170	312
27N1ZW-														
33.4b(6)	Watseka (C)	160	K	6/5/61	0.7	0.0		0.4	1.2	3		284	150	319
27N13W-														
33.8b	Maude Albrecht	140	I	7/60	0.9				2.8	10		340	290	374
LIV—														
27N8E-														
34.6d(5)	Chatsworth (T)	223	K	9/19/60	2.2	0.0		0.6	9.7	T		380	438	636
LOG—														
Z1N1W-														
20.3e1(2)	Atlanta (C)	147	I	1/24/61	1.8	0.2	4.3	0.3	0.0	37	3	424	212	470
MCL—														
22N1W-														
35.2c	H. M. Palmer	125	I	6/15/15	3.0	0.0			0.7	T		475	595	478
35.4c	McLean High Schoo	350	K	10/27/33	3.0	0.0	3.4		0.1	1.0	T	426	275	614
MCN-														
18NZE-														
2.8b3(3)	Maroa (C)	288	K	8/24/48	0.8	0.0	2.9	0.3	0.5	60	5	404	326	522
MOU—														
13N5E-														
23.3g2(1)	Sullivan (C)	129	I	7/12/55	3.2	T	0.4	0.1	3.4	5.0	4.1	344	335	349
PIA—														
18N5E-														
7.1h-	WILL-TV	195	K	1/19/66	2.1		3.2			7		412	312	451
11.7h	Equitable Ins. Co.	120	I	1/6/34	1.8	0.0	0.5		0.7	3	T	350	289	358
31.7g(1)	Decatur (C)	245	K	9/7/55	1.9	0.0	0.8	0.1	2.9	11	T	380	327	398
18N6E														
7.6b2(4)	Monticello (C)	263	K	11/22/60	1.6	0.1	0.5	0.2	1.3	5.0	0.0	332	265	356
7.7b1(1)	Viobin Corp.	130	I	3/30/61	1.6					5		388	302	376
9.6f	Paul B. Olson	360	K	2/10/55	1.7					5		328	244	328
22.5a	W. N. Sievers	160	I	1/5/34	2.5	0.0	2.2		0.9	T	T	404	314	421
VER—														
23NlZW.														
11.7c	McFerren Park	177	I	6/3/32	2.6	0.0	0.1		0.6	T	T	324	290	310
23N14W-														
ll.1d2(l)	Rankin (V)	270	K	8/26/38	1.0	0.0	T		7.1	7	T	360	322	408
25.8b	Univ. of Illinois	160	I	1/54	1.4					2		340	396	478

*I = *Illinoian;* K = *Kansan*

(Continued from page 50)

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