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Pleistocene Aquifers in

Coles County, Illinois

(TITLE)

BY

James D. Hopkins

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Arts

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
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I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

June 30, 1971
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June 30, 1971
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James D. Hopkins
June, 1971

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CHAPTER 1

INTRODUCTION

Water is essential to man. Although it is only one of a long list of resources man employs, he requires water more urgently and utilizes more of it than any other earth resource.[1] During the pre-industrial phase of man's evolution, his need for water was rather stabilized. However, with the advent of the industrial revolution and a rapid increase in world population, man's demand for additional water has skyrocketed.[2] The responsibility of planning for an adequate water supply at all levels of government usually rests on trained regional planners. It is a part of their job to project water requirements and plan for future needs. One source generally taken into consideration is groundwater.

The purpose of this paper is to examine Pleistocene aquifers in Coles County, Illinois, to determine the potential groundwater supply available for projected municipal, industrial, and rural use. Principles of historical and structural geology, Pleistocene geography, projected water requirements, and economics of water supply will be discussed.

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[1] Trewartha, Glenn T., Robinson, Arthur H., and Hammond, E. H., Elements of Geography, (New York: McGraw-Hill Book Co., 1967), p. 104.

[2] In 1950, the steel industries of the United States used approximately 416 billion gallons per day or about four and one half times the consumption of the eight million people of New York City. Smith, Guy-Harold, Conservation of Natural Resources, (New York: John Wiley and Sons, Inc., 1950), p. 228.

Little information has been published concerning the geography or hydrology of Coles County. While the area has been reviewed in general by both the federal and state geological surveys and the state water survey, the need for a specific study of Coles County evidently has not warranted the time and efforts of these organizations. Under provision of the Flood Control Act of 1958, the United States Army Corps of Engineers was given the responsibility of research and development of the Embarras River Basin. The results of their research confirmed a previous report[3] that Charleston and vicinity needed a new water source, and recommended a multi-purpose reservoir to fill the needs of the surrounding area.[4]

The future ability of Lake Charleston to furnish treated water to the community appears inadequate. While one paper has been published on major aquifers in glacial drift near Mattoon[5], and one unpublished report has been written on aquifers in the Embarras River Basin[6], no county-wide study has ever been made to determine if groundwater resources can fill this demand. The material necessary to make an analysis of groundwater in the county is available. Bergstrom, Selkregg, Pryor, Kempton, Foster, et al, of the state's geological and water surveys have published information on groundwater geology and general hydrology

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[3]City of Charleston, Illinois, "Water Report", Warren and Van Pragg, Inc., Consulting Engineers, Decatur, Illinois, September, 1959.

[4]On January 25th, 1962, at a public hearing in Greenup, Illinois, the Lincoln Reservoir was officially proposed by HD #202, 89th Congress, 1st Session.

[5]Foster, John W., "Major Aquifers in Glacial Drift Near Mattoon, Illinois," Illinois Academy of Science Transactions, XLIV, (Urbana: University of Illinois Press, 1951).

[6]Walton, W. C., and Csallany, S., "The Potential Yield of Aquifers in the Embarras River Basin, Illinois," Report of Investigation 53, (Unpublished), (Urbana: Department of Registration and Education, 1965).

with a broad reference to Coles County, or a portion of it.[7] Their combined consensus is that the future water requirements of the study area cannot be met by aquifers. However, in local areas, aquifers do exist that will provide an adequate yield for farmsteads or perhaps small communities. The quality of groundwater in east-central Illinois has been studied by Walker, Gluskoter and Larson,[8] whose results show that no serious pollution exists in the Pleistocene materials. Other work on aquifers, well mechanics, reservoir studies, and projected water demands is also available. All work to date has been accomplished by state surveys. Sanderson and Gibb of the water survey have initiated a county by county study of groundwater availability, but only Shelby and Ford Counties have been completed.[9]

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[7]Walton, W. C., "Groundwater Recharge and Runoff in Illinois," Report of Investigation 48, 1965; Smith, H. F., "Artificial Recharge and its Potential in Illinois," Reprint Series No. 71, 1966; Csallany, S., "Yields of Wells in Pennsylvanian and Mississippian Rocks in Illinois," Report of Investigation 55, 1966; Russell, R. R., "Groundwater Levels in Illinois Through 1961," Report of Investigation 45, 1963; (Urbana: Illinois Water Survey, Department of Registration and Education); Piskin, Kemal, "Glacial Drift in Illinois: Thickness and Character," Circular 416, 1967; Foster, John W., and Selkregg, Lydia F., "Water Wells for Farm Supply in Central and Eastern Illinois - A Preliminary Report of Geologic Conditions," Circular 192, 1954; Bergstrom, Robert E., and Selkregg, Lydia F., "Groundwater Maps for General Distribution in Illinois," Reprint Series 1958L, 1958; Kempton, John P., and Selkregg, Lydia F., "Groundwater Geology in East-central Illinois - A Preliminary Geologic Report," Circular 248, 1958; (Urbana: Illinois Geological Survey, Department of Registration and Education).

[8]Walker, William H., "Illinois Groundwater Pollution," Journal American Water Works Association, XLI, No. 1, 1969; Gluskoter, Harold J., "Composition of Groundwater Associated with Coal in Illinois and Indiana," Economic Geology, XL, 1965; Larson, T. E., "Mineral Content of Public Groundwater Supplies in Illinois," Circular 90, (Urbana: Department of Registration and Education, 1963).

[9]Sanderson, E. W., "Groundwater Availability in Shelby County," Circular 92, (Urbana: Department of Registration and Education, 1967); and Gibb, James P., "Groundwater Availability in Ford County," Circular 97, (Urbana: Department of Registration and Education, 1970).

Although aspects of this study concern history, economics, and geology, the paper is written from a geographical point of view. Emphasis will be placed on the significance of Pleistocene aquifers, treating their distribution in relation to population, rather than other avenues of approach. Aquifer analysis shall be based on general geomorphic concepts, drilling logs, water records, and personal interviews. Information about surface elevations, consistency and characteristics of till, and depth to bedrock shall be recorded on a base map. Care will be stressed to attain adequate geographical distribution of samples by using a stratified random sampling technique, if necessary. By correlating and evaluating the sampled cores, thickness of drift and its physical composition shall reveal aquifer locations. Sand and gravel lenses and deposits will be further analyzed, if possible, for potential yields by methods outlined by Walton and Walker[10] of the state water survey. These figures will result in an isopleth map of the county showing expected groundwater yields in gallons per minute (gpm). This information will provide a basis for the projected requirements for industrial, rural, and municipal use.

The projection figures will be derived from two sources. The first source is a theoretical, graphical model developed and cultivated by the American Water Resources Conference,[11] in which the direct relationship between population growth and increased water usage is

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[10]Walton, William C., and Walker, William H., "Evaluating Wells and Aquifers by Analytical Methods," Journal of Geophysical Research, LXVI, 1961, p. 3360.

[11]Csallany, Sandor, "Planning Water for 2,000 A. D.," Proceedings of the Fourth American Water Resources Conference, (Urbana: University of Illinois Press, 1968), p. 168.

examined. Data collection for the second method will be through the use of the interview. Local experts on the planning commissions, the soil conservation service, the water departments, leaders of local industry, and area farmers will provide future water estimates. The two figures will be compared and evaluated. The results will be used as a basis for the following research to shed light on the ability or inability of Pleistocene aquifers to meet the projected water requirements.

The next step of the study will be one of economic analysis. If groundwater pumped from wells will provide a sufficient and dependable source, then the cost of municipal and industrial wells, pumping, transmission, and treatment[12] will be considered. If other sources must be sought, perhaps in addition to wells, then the cost of both small reservoirs and large ones shall be checked by methods outlined by the Illinois Water Survey.[13]

The final portion of this paper will be a recommendation of one or more combinations of water sources that will be the most economical and feasible to meet the projected needs of the county.

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[12]Sanderson, E. W., and Gibb, James P., "Cost of Municipal and Industrial Wells in Illinois, 1964 - 1966," Circular 98, 1969; Ackerman, William C., "Cost of Pumping Water," Technical Letter 9, 1968; "Water Transmission Costs," Technical Letter 7, 1967; and "Cost of Water Treatment in Illinois," Technical Letter 11, 1968; (Urbana: Illinois Water Survey, Department of Registration and Education).

[13]Dawes, J. G., and Wathne, Magne, "Cost of Reservoirs in Illinois," Circular 96, (Urbana: Illinois Water Survey, Department of Registration and Education, 1968).

CHAPTER 2

THE PHYSICAL SETTING FOR GROUNDWATER

Coles County is located in the east-central part of Illinois (Fig. 2-1). It encompasses an area of 506 square miles and is primarily cultivated land. Its two main streams, the Embarras and the Kaskaskia, drain approximately 1,840 square miles.[14] With a population of 47,815,[15] the county continues to show steady growth, largely dependent upon its industry and educational centers. All known water supplies are provided by impounded ponds, lakes, or from groundwater sources. In groundwater studies, as in most fields of geography, it becomes necessary to study related aspects to gain a more thorough grasp of the subject. This chapter presents a discussion of geology, glaciation, and precipitation as each relates to groundwater in Coles County, Illinois. Emphasis will be placed on the effects of these factors, rather than the factors themselves. Lastly, the formation, movement, and general character of groundwater will be presented.

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[14]Author's estimate based upon data by Stall, John B., "Low Flows of Illinois Streams for Impounding Reservoir Design," Illinois State Water Survey Bulletin 51, (Urbana: Department of Registration and Education, 1964), p. 60, 78.

[15]Telephone conversation with Harry Grafton, Coles County Clerk, March 29th, 1971.

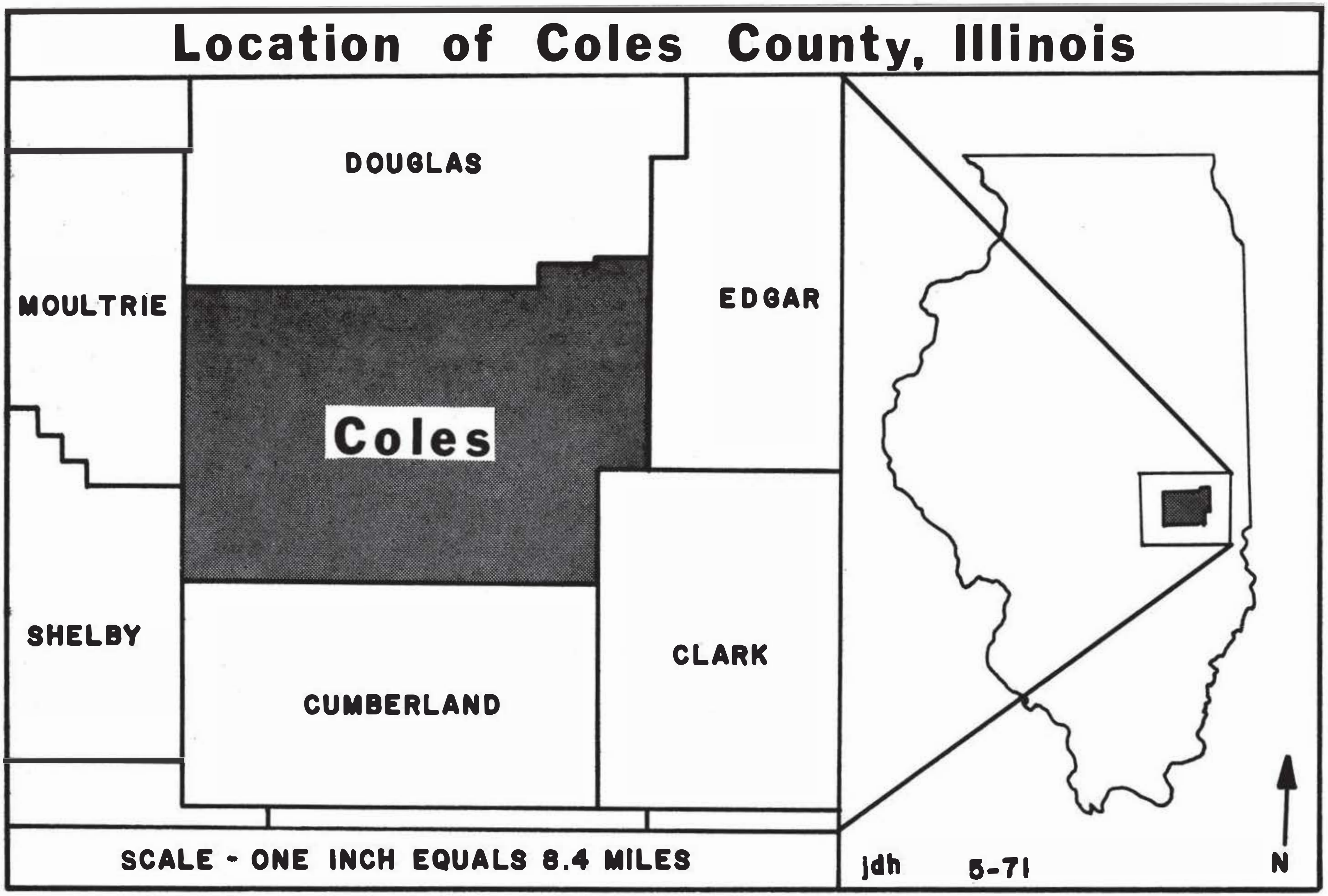
Location of Coles County, Illinois
DOUGLAS
MOULTRIE
EDGAR
Coles
SHELBY
CLARK
CUMBERLAND
SCALE - ONE INCH EQUALS 8.4 MILES
jdh
5-71
N

FIG. 2-1

Historical Geology

One of the principle factors directly influencing groundwater is the nature of the bedrock. Some rocks transmit water, and some do not. The presence of most shales at the surface of the bedrock will prevent further percolation and retard groundwater escape. In Coles County, many areas exist that are underlain by shale, limestone, and sandstone - the uppermost beds of the McLeansboro series (Fig. 2-2). Depending upon the porosity and permeability of each rock type, the amount of groundwater in the vicinity varies. If the uppermost bed is shale, groundwater will remain in the unconsolidated material directly overlying the bedrock.

Over a billion years of geologic history is represented by bedrock in Coles County. Physiographically, the county lies in the Central Lowlands Province of the United States. Although it is the largest of all provinces, structurally it is perhaps the least complex. Its basic structure is a series of sedimentary rocks built upon a base of igneous material which forms the continental nucleus. Paleozoic sandstones, limestones, conglomerates, shales, and coal extend in nearly horizontal positions westward from the Appalachian Plateau. These are the foundation materials of the Central Lowlands. Southward they pass beneath the sediments of the Coastal Plain and westward beneath the surface of the Great Plains.

The actual deposition of the sediment resulted from four major marine transgressions. The first of these inundations was the Sauk. Beginning in Proterozoic time, over a billion years ago, it lasted

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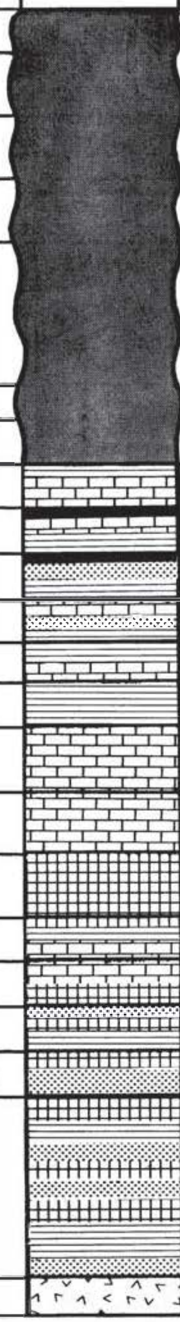
[16]Atwood, Wallace W., The Physiographic Provinces of North America, (New York: Ginn and Company, 1940), p. 188.

General Stratigraphy Of Coles County, Illinois



SYSTEM	SERIES	FORMATION THICKNESS*	ROCK TYPE	GENERAL GROUNDWATER INFORMATION
RECENT	WISCONSINAN: CERRO GORDO	0-10	TILL - Texture varies from clay to gravel, oxidized, calcareous, gray to brown in color, with some loess	Water yielding character variable. Large yields from thicker sand and gravel deposits in bedrock valleys. Wells usually require screens and careful development. Chief aquifer in area.
PLEISTOCENE	WISCONSINAN: TAZEWELL	0-35		
PLEISTOCENE	WISCONSINAN: SHELBYVILLE	0-25		
PLEISTOCENE	SANGAMON INTERGLACIAL	0-20		
PLEISTOCENE	ILLINOISIAN	0-100		
PLEISTOCENE	YARMOUTH INTERGLACIAL	0-15		
PLEISTOCENE	KANSAN	0-10		
PENNSYLVANIAN	McLEANSBORO	0-1000	SHALE, THIN LIMESTONE, SANDSTONE, AND COAL	Water yielding character variable. Locally shallow sandstone and creviced limestone yield small supply. Water quality becomes poorer with depth. May require casing.
PENNSYLVANIAN	CARBONDALE	0-150		
PENNSYLVANIAN	TRADEWATER CASEYVILLE	0-600		
MISSISSIPPIAN	CHESTER	0-500	LS, SS, SH	Too deep to be considered as a groundwater supply. Highly mineralized, nearly a brine.
MISSISSIPPIAN	VALMEYER	0-800	LS, SH	
MISSISSIPPIAN	KINDERHOOK	0-200	SHALE	
DEVONIAN		0-70	LIMESTONE	
SILURIAN	NIAGARAN	0-350	LIMESTONE AND DOLOMITE	
SILURIAN	ALEXANDRIAN	0-100		
ORDOVICIAN	CINCINNATIAN	0-200	DOL, SH, LS	
ORDOVICIAN	MOHAWKIAN	0-420	LS, DOL	
ORDOVICIAN	CHAZY	0-300	SS, DOL, SH	
ORDOVICIAN	PRAIRIE DU CHIEN	0-1000	DOL, SS	
CAMBRIAN	ST. CROIXAN	0-1500	DOLOMITE, SANDSTONE, AND SHALE	
PRE-CAMBRIAN		UNKNOWN	GRANITE	

After Selkregg, Kempton (1958), Visocky, Schicht (1969), Willman, Frye (1970).

*Not to scale

5/71 jdh

Fig. 2-2

into the lower Ordovician. In Coles County this transgression deposited sediments later to compact into limestone, sandstone, shale, and dolomite. Although the Sauk deposited generally even thicknesses from New York into the Midwest, much deeper thicknesses accumulated in downwarped areas such as the Illinois Basin. The Tippecanoe followed the Sauk lasting 75,000,000 years into the lower Devonian Period. Many more sedimentary layers were deposited during this time, the most notable locally being the St. Peter Sandstone. The third transgression, the Kaskaskia, started in lower Devonian time, but did not occur immediately after the Tippecanoe. Between these two periods of deposition, the land was uplifted and subjected to erosion and weathering. The last layer of rock to be deposited during the Kaskaskia phase was the Chattanooga Shale. The last of the four invasions was called the Absaroka. It started in the Pennsylvanian Period and lasted into the middle of the Mesozoic Era. Locally, the deposits were characterized by cyclothems. Each cyclothem, if fully developed, would include the following sequence, although at most localities some beds are absent: sandstone, sandy shale, limestone, underclay, coal, shale, marine limestone, black shale, marine limestone, and shale with ironstone.[17] Through drilling and electric resistivity studies, nearly fifty of these cyclothems have been recorded in Coles County. Two of the marine limestones and one sandstone unit outcrop in various parts of the county.

Structural Geology

The second principle factor influencing the distribution of groundwater is the geologic structure of the study area. Along with the

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[17] Clark, Thomas H., and Stearn, Colin W., Geological Evolution of North America, (New York: Ronald Press Company, 1968), p. 177.

temporary base levels cut into the drift and bedrock by the Embarras and the Kaskaskia Rivers, these structures help control the hydraulic gradient, the hydrostatic pressure, and the direction of groundwater movement in the county. The horizontal sedimentary layers in Coles County, deposited over a period of nearly 400,000,000 years, were subjected to compressive forces of diastrophism, resulting in several structural features. The most notable structural feature is the La Salle Anticlinal Belt,[18] (Fig. 2-3). It is an asymmetrically folded anticline, axially oriented NNW to SSE, plunges southeast, and bisects Coles County two miles west of Charleston. Its eastern limb dips gently toward Ashmore, while its western flank dips more steeply under Mattoon (Fig. 2-4). The anticline roughly devides the county into two areas of equal size, the structurally higher Bellair-Champaign Uplift on the east and the deep basin area on the west. Compounding the Bellair-Champaign Uplift are several smaller structural features. The east flank of the La Salle Anticline is also the west flank of the Murdock Syncline. It extends from Douglas County south and southwestward into Coles County. The Oakland Anticlinal Belt is a series of partially aligned domes in the extreme eastern part of the county. The Mattoon Anticline extends a few miles north and south of Mattoon and then swings into Shelby County. To the north of the Mattoon Anticline, separated by a small saddle, is the Cook's Mill Anticline. This feature is oriented southwest to northeast and merges into the west flank of the La Salle Anticline. Other features which partly extend into the study area include the Chesterville and Bourbon Structures. No faults are known

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[18]Clegg, Kenneth E., "Subsurface Geology and Coal Resources of the Pennsylvanian System in Douglas, Coles, and Cumberland Counties in Illinois," Illinois State Geological Survey Circular 271, (Urbana: Department of Registration and Education, 1959), pp. 3, 13, and 14.

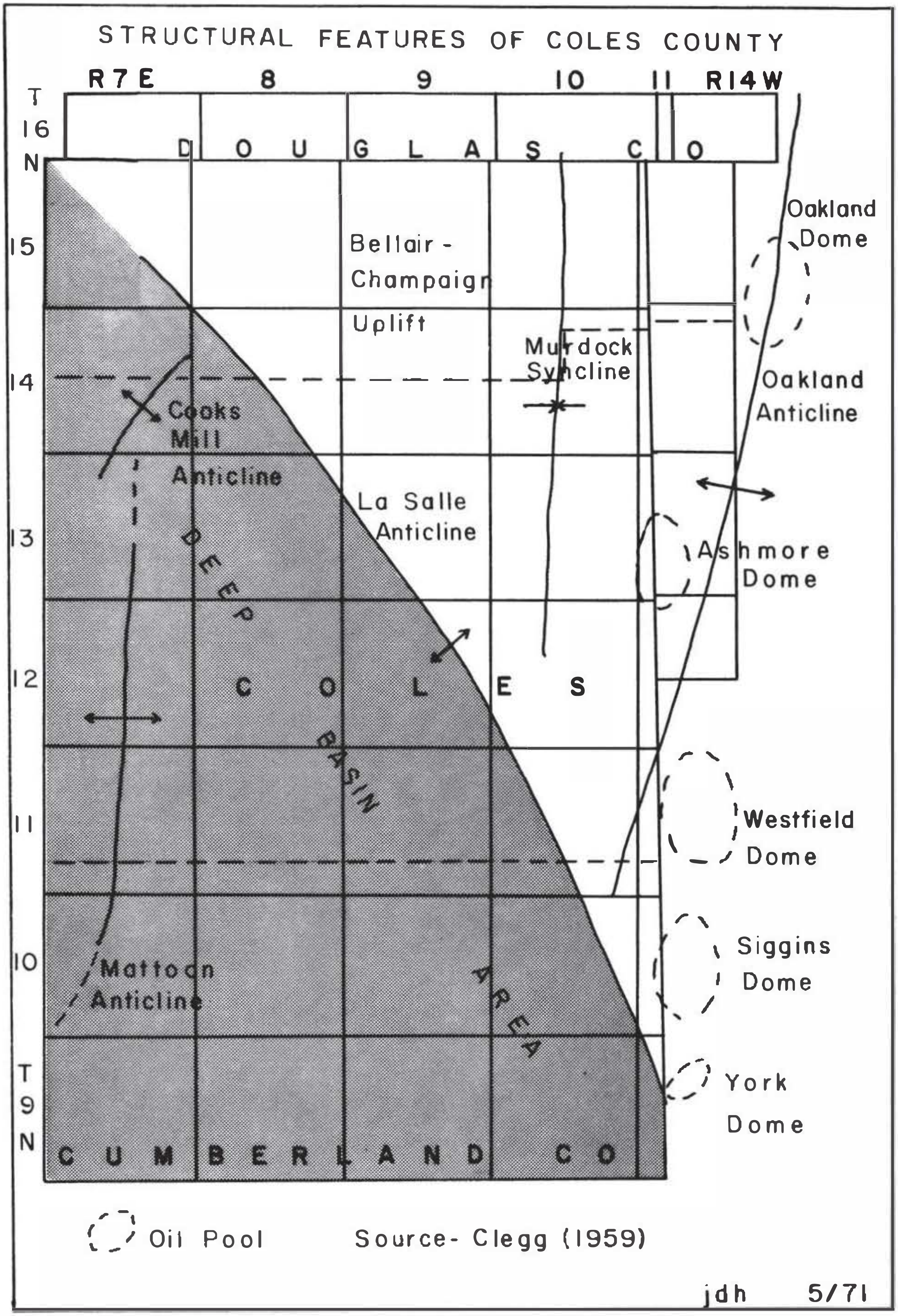
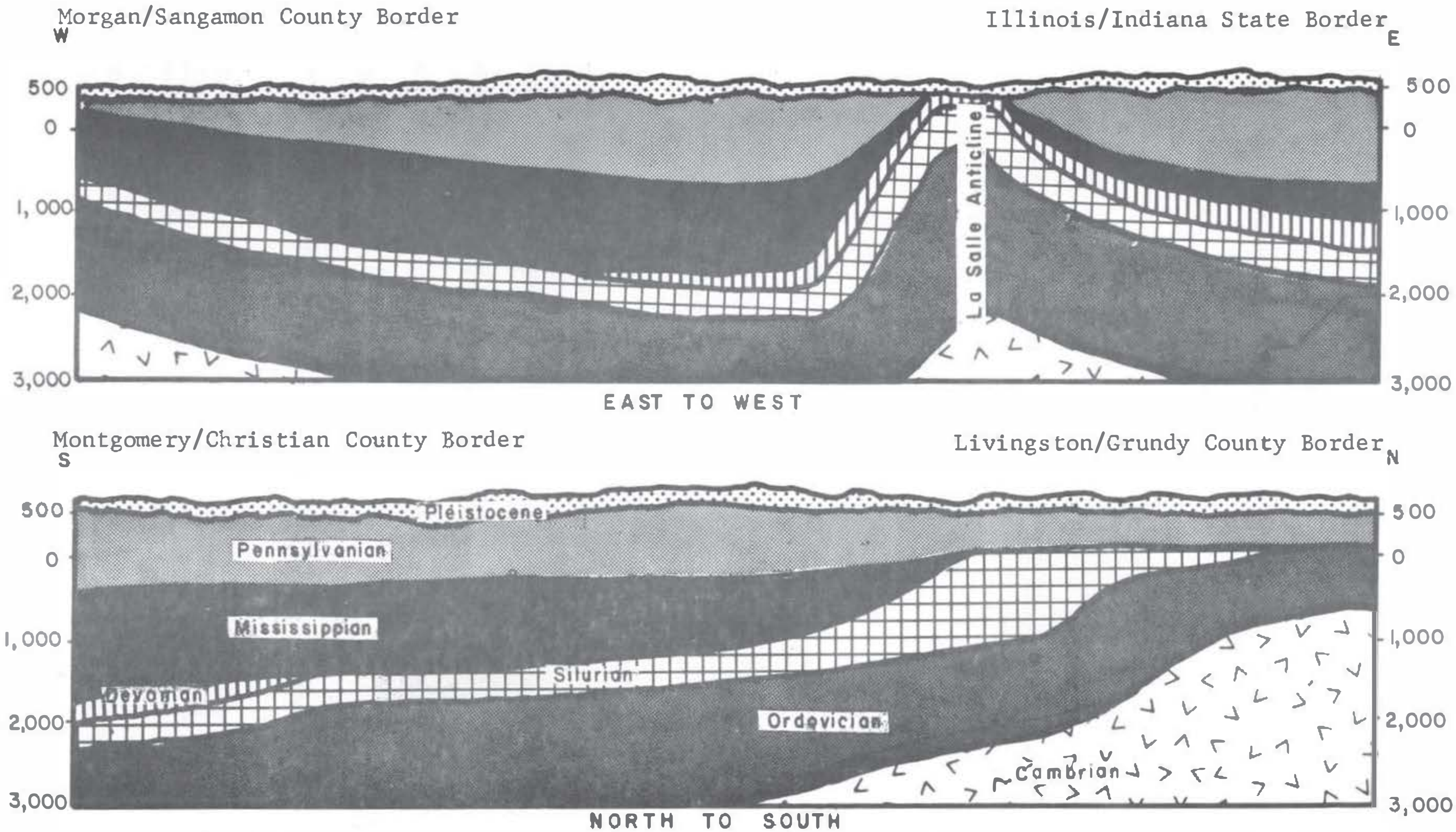

STRUCTURAL FEATURES OF COLES COUNTY
R7E
8
9
10
11
R14W
T 16 N
15
14
13
12
11
10
T 9 N
DOUGLAS CO
Bellair - Champaign Uplift
Murdock Syncline
Oakland Dome
Oakland Anticline
Cooks Mill Anticline
La Salle Anticline
Ashmore Dome
DEEP COLES BASIN AREA
Westfield Dome
Siggins Dome
Mattoon Anticline
York Dome
CUMBERLAND CO
Oil Pool
Source- Clegg (1959)
jdh 5/71

Fig. 2-3

CROSS SECTIONS OF EAST-CENTRAL ILLINOIS



Source — Clegg (1959), Selkregg, Kempton (1958)

idh 5/71

Fig. 2-4

to exist anywhere in the study area.

No rock has been discovered in the study area to be younger than Pennsylvanian age. While it is possible that various formations were deposited and later eroded away (including much of the Pennsylvanian system), it is more probable that no rock was ever deposited. Most geologists cite this as evidence that this portion of the continental interior was above sea level and has remained so during the last 200,000,000 years. Upon this erosion surface, 198,000,000 years later, came the ice age and the subsequent glaciations of the Pleistocene Epoch.

Pleistocene Geography

The third factor, and locally the most important aspect related to groundwater, is the Pleistocene geography of the county. Preglacial Coles County was located in the Pennsylvanian Lowland, a physiographic province, approximately 600 to 650 feet above sea level. The surface material consisted of weak shales, thin limestones, and some sandstones of Pennsylvanian age.[19] Preglacial topography was characterized by maturely eroded, rolling hills with a maximum relief of about 150 feet[20] and well developed stream patterns. This is particularly true of the preglacial Embarras River.[21]

Approximately 2,000,000 years ago marked the beginning of the

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[19] Horberg, Leland, "Bedrock Topography of Illinois," Illinois State Geological Survey Bulletin 73, (Urbana: Department of Registration and Education, 1950), p. 35.

[20] Fenneman, Nevin M., Physiography of the Eastern United States, (New York: McGraw Hill Book Company, 1938), p. 503.

[21] Horberg, Ibid, p. 85.

Pleistocene Epoch during which much of the present land surface material of Coles County was deposited. Although three of four glacial advances (the Kansan, Illinoian, and the Wisconsinan, respectively) are represented in Coles County,[22] little is known about the effects of the Kansan stage due to the age of the material and subsequent glacial deposition. MacClintock[23] has located and described the only published Kansan exposure in Coles County. It was described as "till and silt, leached and weathered, containing much preserved vegetation," overlying a second layer described as "calcareous till". In the south part of the same exposure in the NW¼ of the SE¼ of Sec. 22, T. 11 N., R. 10 E., of the third principle meridian, three additional layers of Kansan drift were found. These were of "Loess-like silt, very leached, calcareous, with wood incorporated throughout its middle portion." Drilling has documented samples of a yellowish, fine to coarse, silty sand with an abundance of humus. It is said to represent a Yarmouth interglacial alluvial deposit.[24] This deposit, found in Sec. 18, T. 11 N., R. 7 E., is the oldest sample of Pleistocene material thus far discovered by drilling in Coles County.

The Illinoian glacial advance leveled many of the existing topographical features and deposited a relatively uniform layer of drift, varying from thirty to one hundred feet thick[25] upon the area. The

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[22]Willman, H. B., and Frye, John C., "Pleistocene Stratigraphy in Illinois," Illinois State Geological Survey Bulletin 94, (Urbana: Department of Registration and Education, 1970), p. 25.

[23]MacClintock, Paul, "Recent Discoveries of Pre-Illinoian Drift in Southern Illinois," Illinois State Geological Survey Report of Investigation 19, (Urbana: Department of Registration and Education, 1929), p. 40.

[24]Foster, Ibid, p. 89.

[25]Leverett, Frank, "The Illinois Glacial Lobe," United States Geological Survey Monograph 38, (Washington: United States Government Printing Office, 1899), p. 27.

Wisconsin glacial advance began approximately 50,000 years ago and reached its maximum southern extent in Illinois, as marked by the Shelbyville Moraine, about 20,000 years ago[26] (Fig. 2-5). The dating of a log found by John P. Ford, northeast of Charleston revealed its age to be 19,500 plus or minus 200 years.[27] The Shelbyville Moraine cuts across the central and southern portions of the county and is the most notable topographic feature in Coles County. Much of the moraine reaches an elevation of between 720 and 750 feet above sea level. However, the region in the study area lying north of the moraine is approximately 680 to 690 feet while those areas lying to the south are approximately 640 to 660 feet above sea level. The highest elevation in the county is about 785 feet in Sec. 31, T. 12 N., R. 8 E., south of Mattoon.[28]

The surficial material in Coles County is of glacial origin except for minor outcroppings of the Pennsylvanian system. That area of the county lying on and to the north of the Shelbyville Moraine has surface material composed of friable, calcareous Wisconsin till and an overlying layer of loess varying in thickness from fifteen to sixty inches. The surface color of the till is usually quite dark, but the subsurface is brownish yellow for eight to twenty feet below the surface

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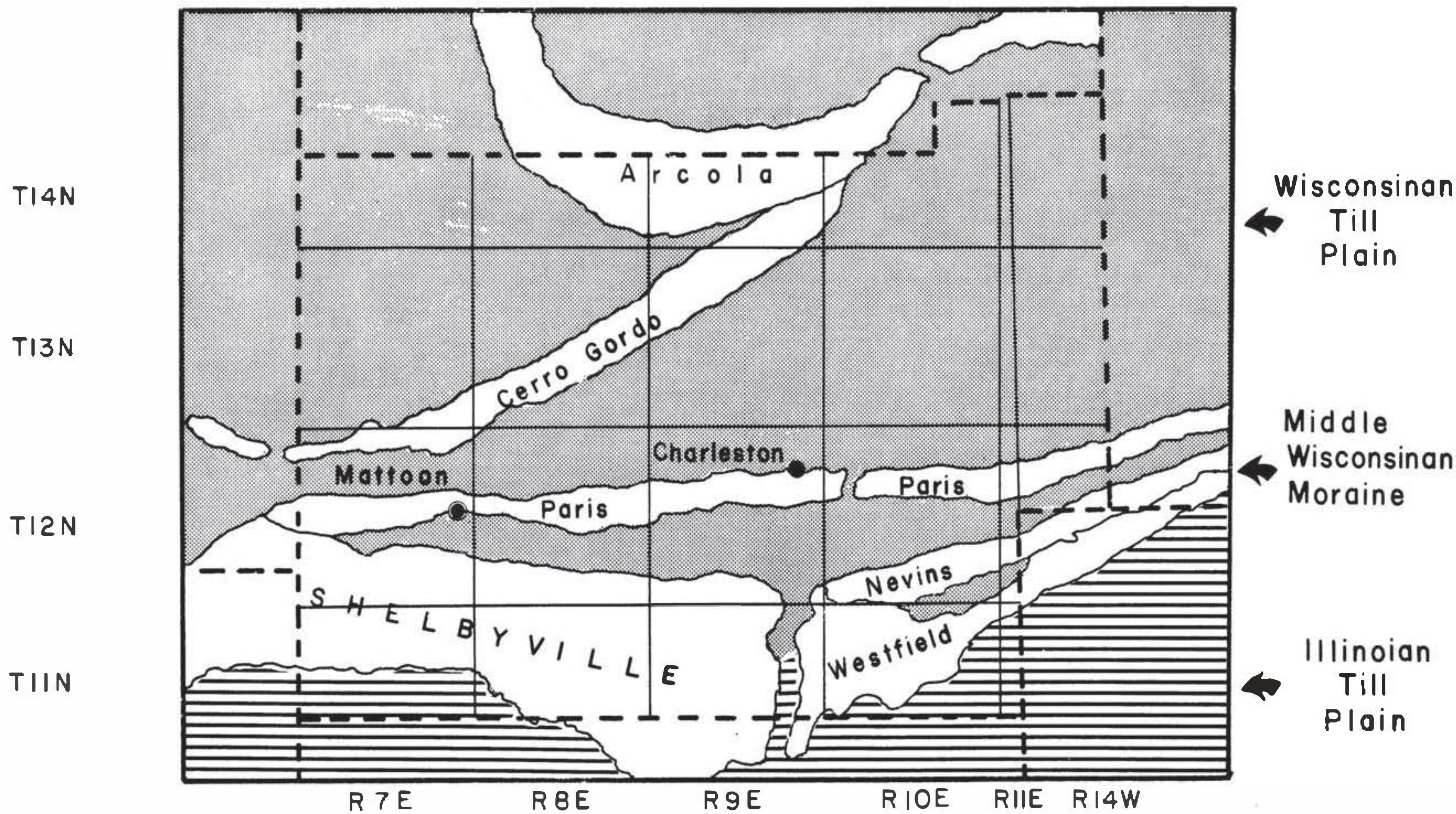
[26] Wascher, Herman L., et al, "Characteristics of Soils Associated with Glacial Tills in Northeastern Illinois," University of Illinois Agricultural Experimental Station Bulletin 665, (Urbana: University of Illinois Press, 1960), pp. 16-17.

[27] Illinois State Geological Survey, Report of Age Determination, Number 27, 1969.

[28] Geological Survey, United States Department of the Interior, Topographic Maps, 15 Minute Series, Mattoon (1936).

PLEISTOCENE DEPOSITS IN COLES COUNTY



Source- Willman, Frye (1970)

jdh 5/71

FIG. 2-5

and grades into a blue-gray color in the main body of the till.[29]

Glacial drift of Illinoian age is found in the river valleys and in the southeast and southwest corners of the county. It is much older than the Wisconsinan material and has been intensely weathered and leached. Hence, colors normally vary from a light yellow or brown to light gray, but may be somewhat darker dependent on the amounts of humus and loess. The light surface colors normally blend into darker shades of gray or brown in the subsoil and at a depth of between eight and twenty feet, the color becomes a dark bluish-gray. Another consideration of the subsoil is the existence of a claypan. While it is largely impermeable south of the Shelbyville Moraine, it still affects groundwater percolation in the entire county, both on and off the moraine. In some areas where the pan isn't too deep, it may be broken or otherwise disturbed by discing and plowing, thereby facilitating drainage and infiltration.

Precipitation

The fourth major aspect influencing groundwater is the precipitation in the study area. Continental location and cyclonic storms are the two principle controls of the precipitation in Coles County. Approximately twenty-five frontal passages occur yearly and are responsible for the variety of weather and much of the annual precipitation. The average yearly precipitation in the county is 38.43 inches[30], (Fig. 2-6),

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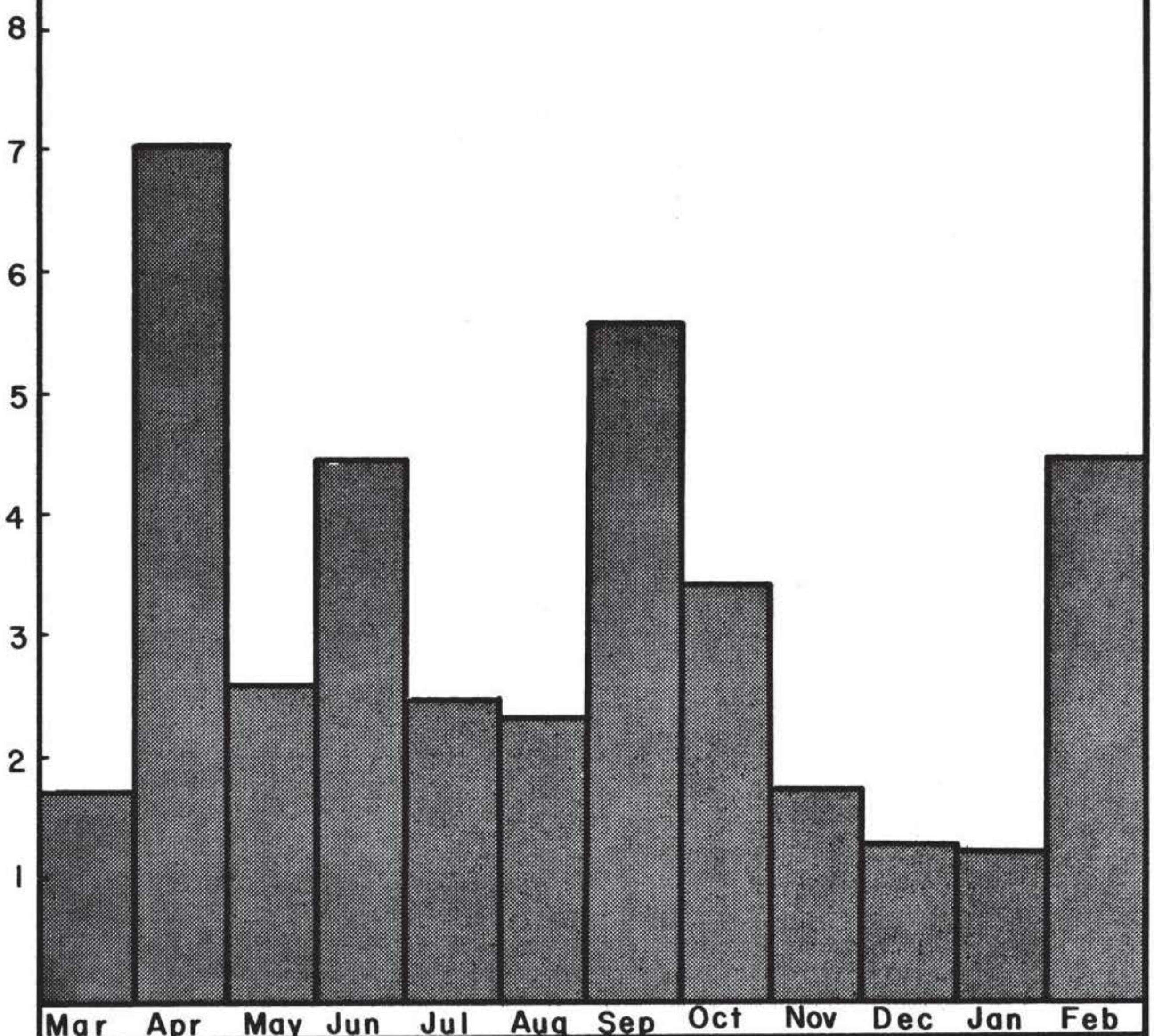
[29]Klink, John, "A Geographical Interpretation of Coles County Soils Through A Comparative Analysis of Modern Soil Classification Systems, Masters Thesis, Eastern Illinois University, 1967, p. 14.

[30]Page, John, "Climate of Illinois," University of Illinois Agricultural Experimental Station Bulletin 532, (Urbana: University of Illinois Press, 1949), p. 99.

Precipitation By Month In Coles County, Illinois (Mar. 1970 - Feb. 1971)



Source - Department of Commerce, ESSA

Data for Charleston, Illinois 5/71 jdh

FIG. 2-6

with an average monthly precipitation varying from 1.95 inches in February to 4.20 inches in May. During the period March 1970 to February 1971, a total of 38.88 inches of precipitation fell in Charleston, varying from 1.25 inches in January to 7.02 inches last April.[31] April to September showers account for fifty-eight percent of the total precipitation (Table One). The water budget for this county provides more water annually than can be utilized by the groundcover (Table Two). The rest evaporates, sinks into the ground, or becomes runoff. Various textures and structures exist in the soils of Coles County due to differences in age, parent material, slope, and natural vegetation. One result of this difference is that water percolates through the solum at different rates. The rates vary for Coles County from 4.0 to .02 inches per hour.[32] Infiltration is measured quantitatively in terms of rate of flow of water through a unit cross section of soil in a unit time under specified conditions of temperature and hydraulic conditions. The results of different infiltration rates is that some areas of the county are supplied with more groundwater than others, a factor to be discussed below.

The Nature of Groundwater

> "Geology affords the framework upon which groundwater hydrology is built; more accurately, it deals with the stratigraphy and structure of the rock formations that make up the great and intricate systems of natural

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[31]United States Department of Commerce, Environmental Science Services Administration, Weather Bureau, Record of River and Climatological Observations, Charleston, Illinois, 1970-1971.

[32]United States Soil Conservation Service, "Permeability", Coles County Work Unit Handbook, Part Four, Soil Conservation Service, Charleston, Illinois.

TABLE 1

AVERAGE PRECIPITATION FOR THE GROWING SEASON, 1939 - 1946

Period	Precipitation	Period	Precipitation
April 1-10	1.40	July 1-10	1.18
11-20	1.38	11-20	1.00
21-31	1.06	21-31	1.08
May 1-10	1.61	Aug 1-10	1.28
11-20	1.88	11-20	1.54
21-31	1.44	21-31	.92
June 1-10	1.46	Sept 1-10	1.48
11-20	1.38	11-20	1.05
21-30	1.25	21-30	1.20

TABLE 2

MONTHLY PRECIPITATION FOR GROWING SEASON, 1952 - 1962

Month	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
April	3.18	1.97	3.23	3.54	3.49	8.22	2.72	3.16	2.07	3.22	1.64
May	2.30	3.66	2.16	5.31	3.92	4.69	3.69	3.45	5.20	5.36	5.30
June	5.58	2.90	1.90	4.18	2.99	13.98	5.61	1.50	7.93	2.57	3.92
July	3.33	3.83	1.45	3.98	3.44	2.39	6.60	2.17	1.54	5.80	4.80
August	2.01	.77	4.08	1.16	4.14	2.79	5.72	3.05	1.17	4.01	2.70
Sept	2.21	.67	1.77	5.56	1.19	2.04	3.60	?	.78	4.41	1.40

waterworks the functioning of which forms the essential part of the subject of groundwater hydrology."[33]

Although there were early attempts to provide useful information as to the water-bearing properties of different rocks, the subject of

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[33]Meinzer, O. E., (ed.), Hydrology, (New York: Dover Publications, National Research Council, Physics of the Earth, Vol. IX, 1942), p. 386.

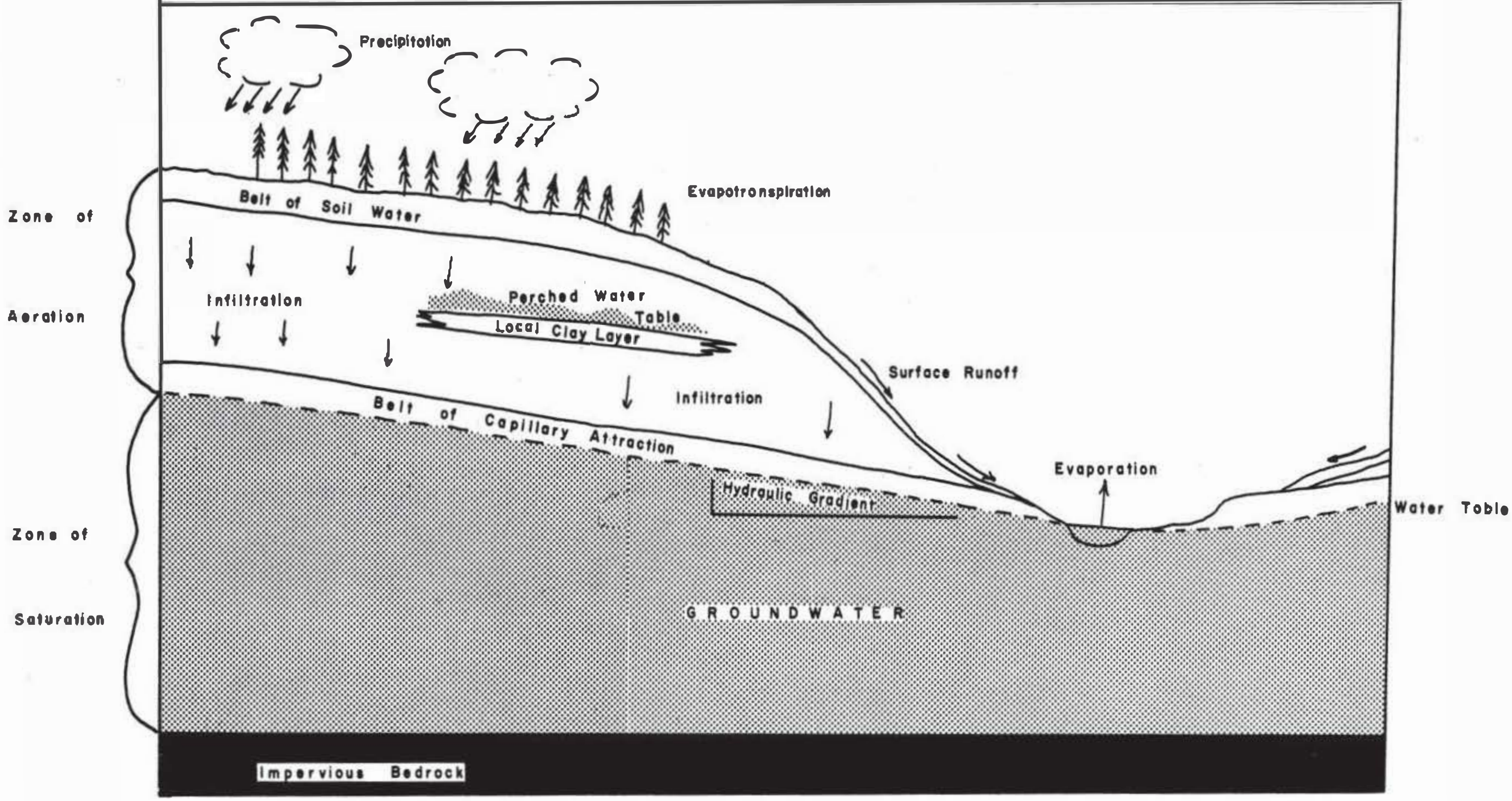
groundwater hydrology could not be examined in detail until the fundamental details of geology and physiography were established during the eighteenth century. While geology is concerned primarily with the solid parts of the rocks, the science of hydrology focuses on the open spaces, or interstices, within the rocks.

The most familiar theory of groundwater occurrence is the "infiltration theory." This theory states that some of the precipitation that falls on the land sinks beneath the surface. As the water percolates downward due to gravity, some of it is lost due to evapotranspiration of plant roots in the belt of soil moisture, while even more remains stationary due to capillary attraction of soil particles (Fig. 2-7). The remainder continues to infiltrate until all the pores, cracks, and crevices in the surrounding material are saturated with water. For the purposes of this paper, groundwater may be defined as "any intersticial water in glacial material or bedrock found below the capillary fringe." Above the zone of saturation is a zone of aeration which often serves as a temporary reservoir for percolating water. Between these two zones exists a continuous surface commonly called the water table.

In some areas above the capillary fringe, nearly impermeable layers retard infiltration sufficiently to form another water table above the hydraulically controlled one. This feature, called a "perched water table," may vary in area from a few acres to several square miles. Several such features occur in Coles County.

Water in the zone of saturation is either confined or unconfined. It is confined if it is trapped between impermeable layers, usually clay, and is hydraulically independent of the water above. Typically, confined water is artesian in character, and when tapped by a well, attempts

GENERAL OCCURRENCE OF GROUNDWATER



Source - Meinzer (1942), Tolman (1937), and Gibb (1970).

5/71 jdh

FIG. 2-7

to "reach its own level". However, the confined groundwater in the study area is best illustrated in Fig. 2-8. The upper portion represents a present valley system, while the lower shows an ancient buried valley system. The vast majority of all groundwater in Coles County is unconfined. It is controlled only by gravity, and flows freely.

The rate of groundwater movement is controlled by the porosity and permeability of the material through which it moves. Porosity is the ratio between pore volume and total volume, expressed as a percent. It depends upon (1) the shape of the mineral grains, (2) the degree of sorting (3) and the degree of cementation.[34] Permeability refers to the ability of a material to transmit a fluid. Therefore, rapid groundwater movement requires many pores, the larger the better, and that these pores be interconnected. When these two conditions are met, the material will yield water rapidly to wells and is said to be an aquifer. The exact yield depends upon other factors, among which is the wells ability to recharge itself. In addition to porosity and permeability, rates of groundwater movement are directly influenced by pressure. The slope, or hydraulic gradient of the water table, represents the difference in elevation (head) between any two points on the water table, and the horizontal distance between the two points. Normal ratios vary between one to ten feet vertically per thousand feet horizontally.[35] While porosity and permeability determine the rate of movement, the hydraulic gradient determines the direction.

Although aquifers exist in Coles County both in glacial material

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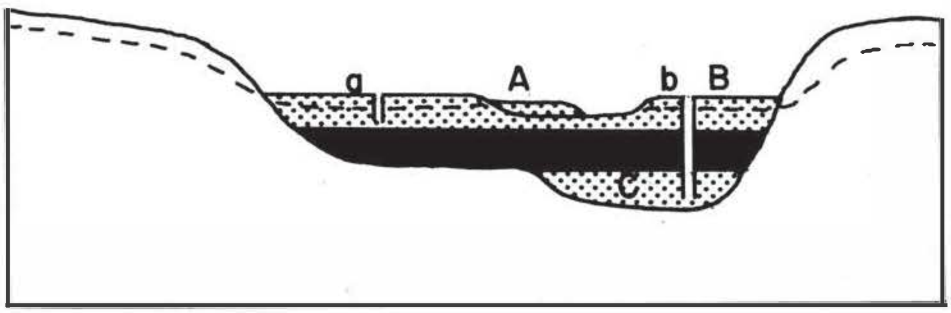
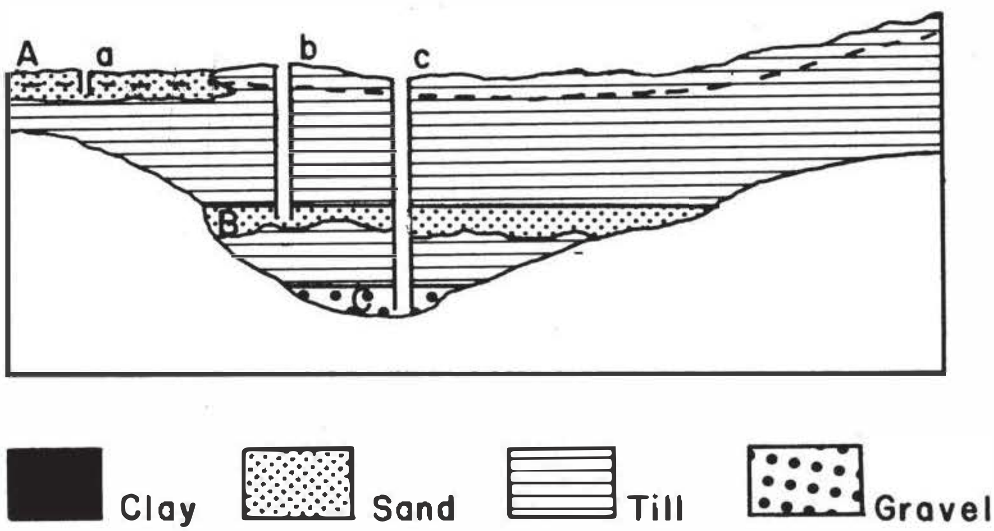
[34] Gilluly, James, Waters, A. C., and Woodford, A. O., Principles of Geology, (San Francisco: W. H. Freeman and Company, 1959), p. 255.

[35] Gilluly, Ibid, p. 259.

CONFINED AND UNCONFINED GLACIAL AQUIFERS





Source— Horberg (1950)

5/71 jdh

FIG. 2-8

and in bedrock, this paper limits its scope to those aquifers in Pleistocene material. Relatively few wells in the study area are finished in bedrock. Selkregg and Kempton[36] have shown poor to fair conditions for bedrock aquifers throughout most of the county, and expect future aquifers of any importance to come from glacial drift.

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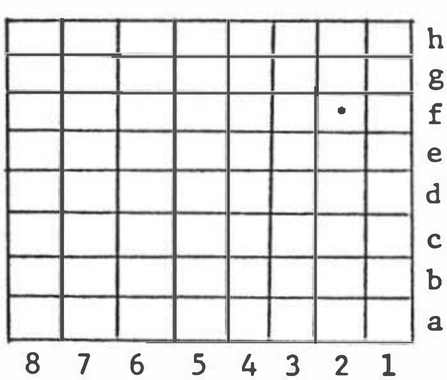
[36]Selkregg, Lydia F., and Kempton, John P., Op. Cit., p. 7, 23.

CHAPTER 3

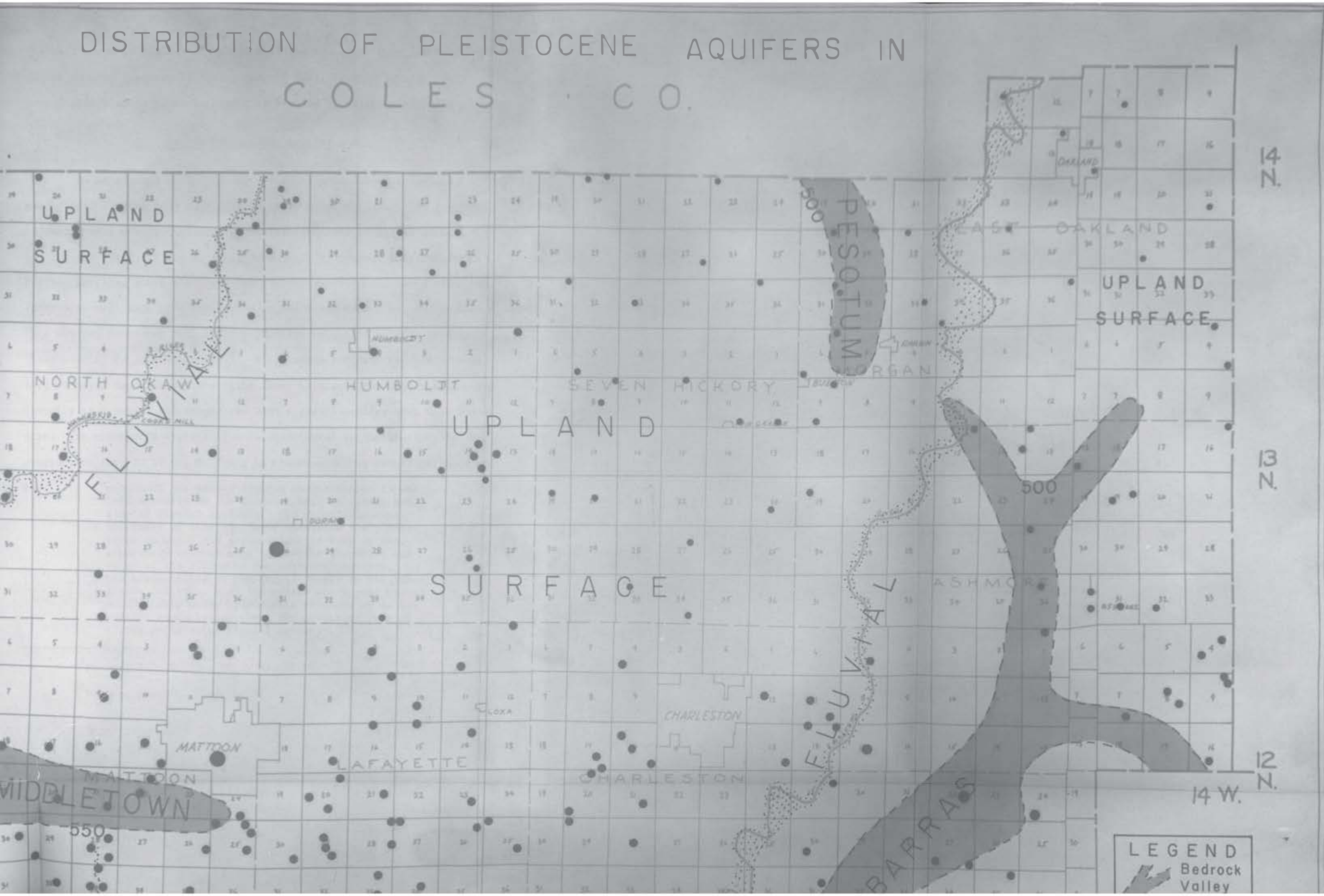
AQUIFER ANALYSIS AND EVALUATION

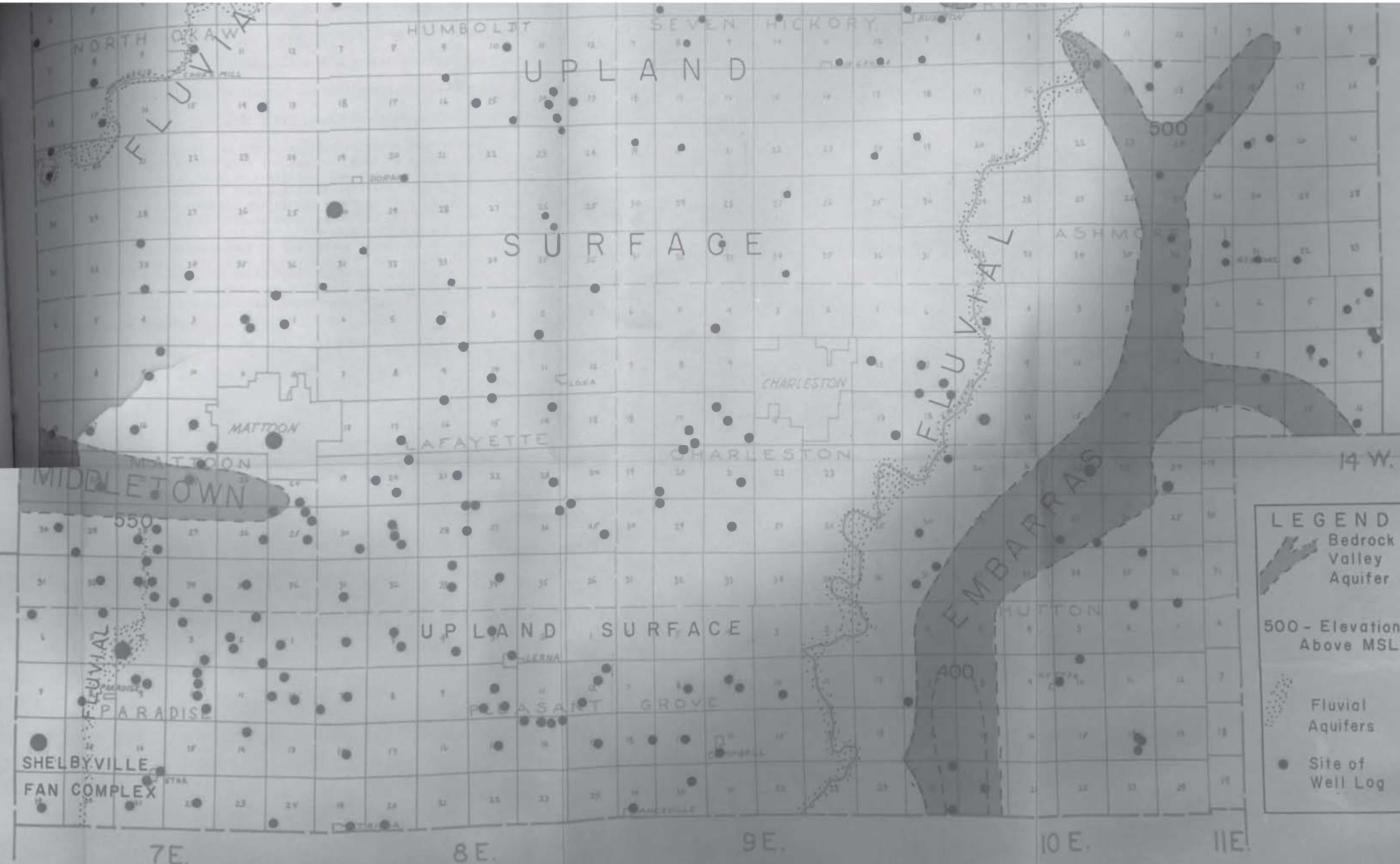
Subsurface correlation of groundwater data was based on over 450 water well logs distributed throughout Coles County. The number of samples was deemed adequate to give sufficient geographic coverage of the area under study. This chapter presents a discussion of the groundwater resources of Coles County. The distribution of groundwater in relation to population and industry will be evaluated. Four aquifer conditions were found to exist (Fig. 3-1). Each will be treated separately. Lastly, man's method of retrieving groundwater - wells, and their mechanics, will be presented.

Prior to the discussion of aquifers, the method of locating wells must be understood. The method used in this paper is the same as the one employed by hydrologists at the Geological and Water Surveys in Urbana, Illinois. Each county in the state has been given a three digit abbreviation - COL, for Coles County. Normal section, township, range designations are employed. However, the location within the section is further broken down with the use of a grid system as shown below.



Sec. 19, T. 11 N., R. 9 E.


DISTRIBUTION OF PLEISTOCENE AQUIFERS IN
COLES CO.
UPLAND SURFACE
UPLAND SURFACE
UPLAND SURFACE
EAST OAKLAND
OAKLAND
PESOTUM
500
NORTH OKAW
HUMBOLDT
SEVEN HICKORY
MORGAN
FLUVIAL
FLUVIAL
500
ASHMORE
CHARLESTON
CHARLESTON
MATTOON
MATTOON
LAFAYETTE
LOXA
MIDDLETOWN
550
BARRAS
14 N.
13 N.
12 N.
14 W.
LEGEND
Bedrock Valley



Source - Illinois State Geological and Water Surveys, Logs of Water Wells

5/71 jdh

FIG 3-1

The well shown in the example above would be numbered COL - 11N9E 19.2f, (Coles County, Township 11 North, Range 9 East, Section 19.2f). This method allows wells to be located in a section to within a ten acre plot.

Shelbyville Fan-Complex Aquifer

In an attempt to locate new favorable groundwater locations, geophysical studies were conducted in 1944 around Mattoon. The fourteen by twelve mile survey indicated unusual thicknesses of gravel in Sec. 17, 18, 19, and 20, T. 11 N., R. 7 E., just south of present Lake Paradise. Further drilling tests confirmed the aquifer's potential, and a total of forty-nine well logs have been filed at the State Geological Survey. This Mattoon Southwest Well Field represents an upland surface anomaly, first studied by John W. Foster.[37] His studies indicate two gravel aquifers of major importance. The first layer is a thin but rather widespread gravelly sand veneer interconnected with a gravel aquifer near Lake Paradise. Its widespread distribution was attributed to the Shelbyville ice progression into T. 12 N., R. 7 E., in mid-Wisconsinan (Woodfordian) time. The

> "nature of the gravel aquifer suggests that it was laid directly on the Sangamon Soil by strong proglacial fluvial activity. The relatively even thickness of this aquifer illustrates the persistence on which the coarse clastics were spread, apparently without much regard for the hills and dales of the Illinoian (or Sangamon) surface. The adaptability of the gravel veneer to the topography indicates that the veneer was spread either subglacially under hydrostatic pressure or as ice contact accumulation along the advancing zone of strong periglacial fluvial activity."[38]

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[37]Foster, John W., Op. Cit., pp. 85-94.

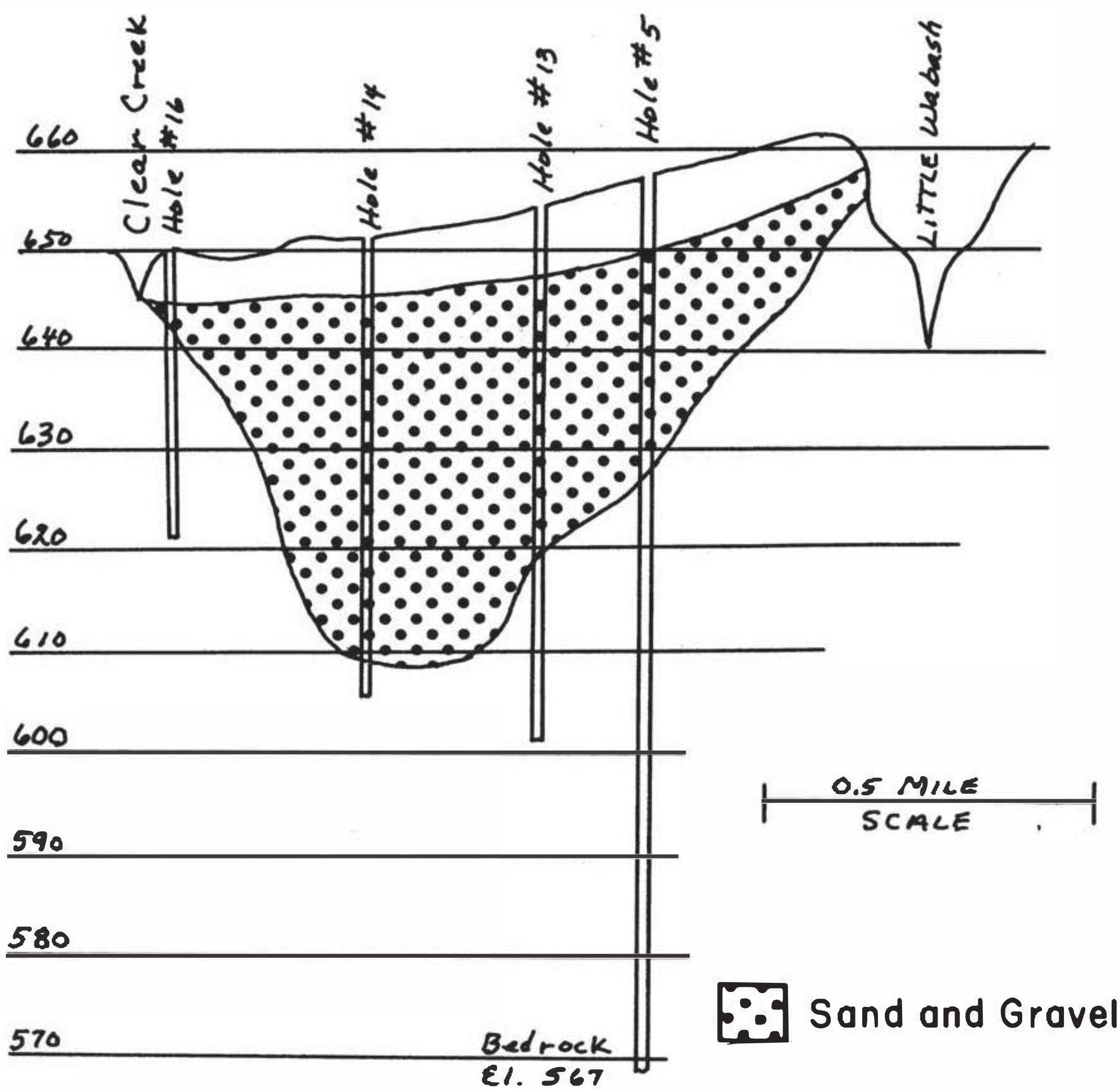
[38]Foster, John W., Ibid, p. 91

This may be accounted for because without such pressure spreading the gravels, the deposition would be much thicker in the Illinoian sags and consequently thinner, if deposited at all, on the topographic highs. The widespread character of the veneer suggests the ice-contact origin rather than the sub-glacial origin.

The second major aquifer, and more important as a groundwater source, resembles an alluvial fan and outwash complex (Fig. 3-2, 3-3). It too, is an extension of the same gravel veneer at Lake Paradise. The fan was built by a deterioration of the ice at its terminus just north of sections 17, 18, 19, and 20. The clastic material started accumulating in a local sag in the Illinoian drift. Foster attributes the sag to a partially obscurred bedrock valley, however, analysis of drift thickness, bedrock elevation, and well logs in the area fails to indicate the presence of any such valley. Foster attributes the course of the Little Wabash to an ice-fed torrent, borne of the ice front, and accounts for the fan shape through general geomorphic concepts of sedimentation and transportation. Dry holes in the western half of Sec. 21, T. 11 N., R. 8 E., indicate the lack of peripherial expansion to the east. Geohydrologic tests of this aquifer complex reveal its true character. In widespread areas, the veneer exhibits a three to ten foot bed of fine sand at the base of the aquifer, just above the Sangamon soil. In such areas, well construction, even for domestic groundwater, is difficult. The remainder of the area is underlain by a very coarse gravel deposit which appears more than adequate for domestic groundwater supplies. While the two aquifers seem to be only one continuous layer, the veneer and fan complex are distinct, both geologically and hydrologically, and are there-

Extent and Depth of Sand and Gravel Deposits,

Mattoon Southwest Well Field



East-West Cross Section

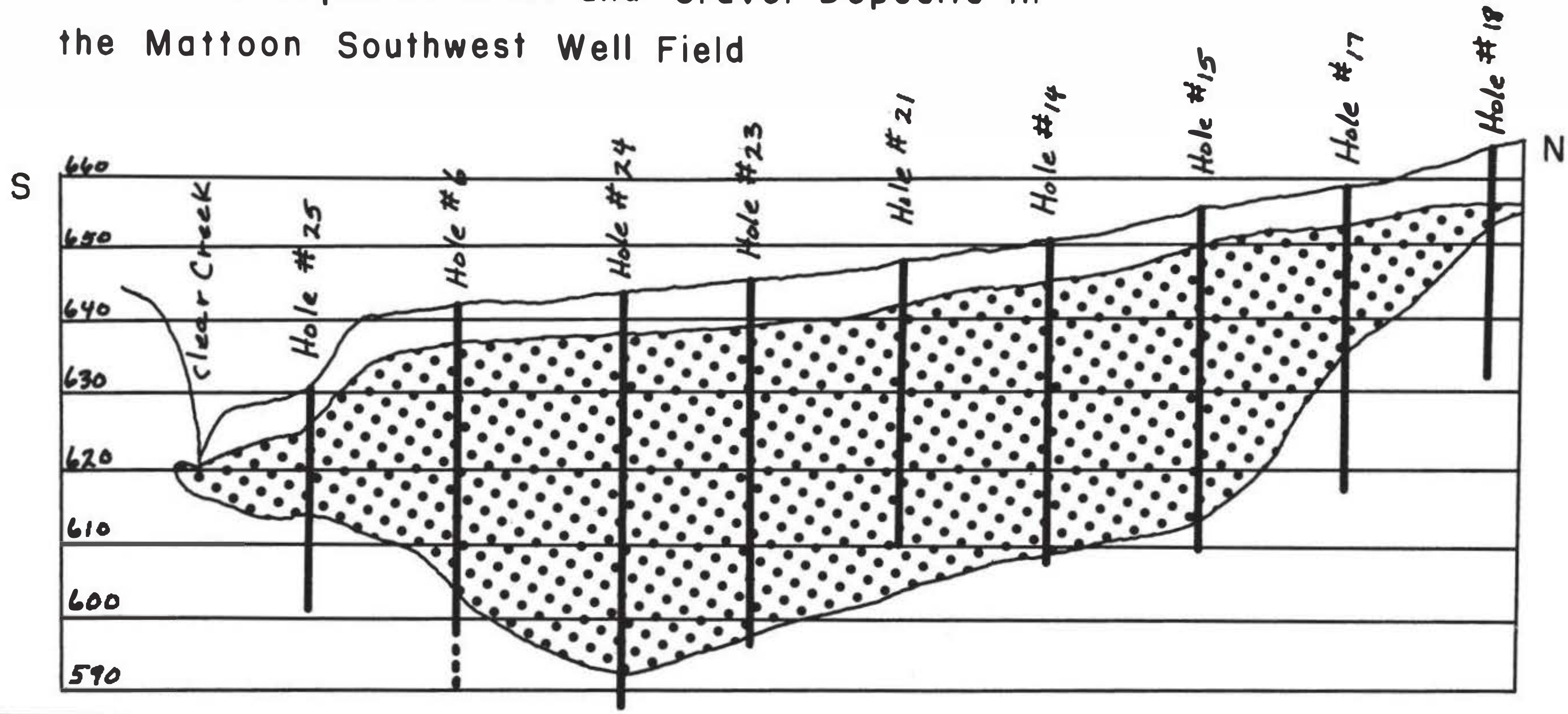
Location – Sec. 18, T11N, R7E, 3rd Principle Meridian

Source – ISGS, Unpublished Resistivity Survey, 1944

5/71 idh

Fig. 3-2

Extent and Depth of Sand and Gravel Deposits in the Mattoon Southwest Well Field



North - South Cross Section

Location - Sec. 18, T11N, R7E, 3rd Principle Meridian

Source - ISGS, Unpublished Resistivity Survey, 1944

0.5 Mile

Sand and Gravel

5/71 jdh

Fig. 3-3

fore being considered as two aquifers. Analysis of several logs in Paradise Township shows gravel extending from the ground surface to the top of the Illinoian drift with thicknesses up to sixty-five feet. In some areas of the fan complex, two or more layers of water-bearing sand and gravel are present with combined thicknesses of twenty feet or more.

Log of Well 45-1 in Mattoon's Southwest Well Field

Description	Thickness (Feet)	Depth (Feet)
Loam	5	5
Gravel, clean	10	15
Gravel and silt	10	25
Sand and granule gravel	10	35
Gravel, partly silty	5	40
Gravel, silty, soil at bottom	3	43

Production tests conducted by the State Water Survey resulted in yields of 300 gallons per minute with a drawdown of 17.9 feet from a non-pumping water level of 5.2 feet below the ground surface. Three observation wells were driven at sixty, 250, and 600 feet from the well, and water level observations were made during the test. It was reported that "infiltration of water, discharged from the well onto the nearby ground surface during the test, was occurring so fast that the water was being re-circulated through the well, pump, and aquifer."[39] From June 1947 to June 1948, the total pumpage from all Mattoon wells (with the vast majority being in the Southwest field) was 370,000 gallons per day (gpd).

Buried Bedrock Valley Aquifers

Coles County contains three buried bedrock valleys - one of

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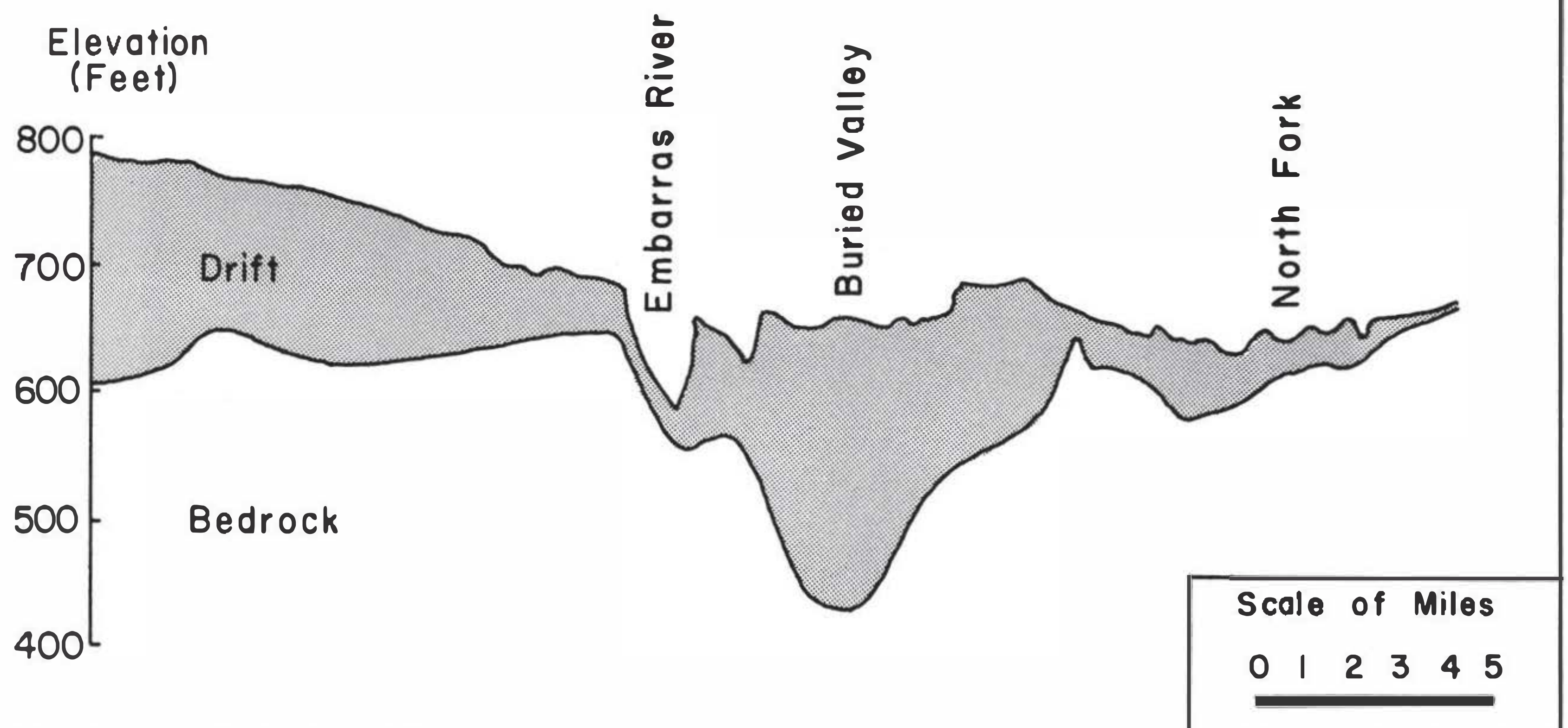
[39] Hanson, Ross, "Public Water Supplies in Illinois," Illinois State Water Survey Bulletin 40, (Urbana: Department of Registration and Education, 1948), p. Mattoon - 6.



CROSS SECTION OF THE EMBARRAS BURIED BEDROCK VALLEY

Location- East-West Along the North Edge of T.11 N.

Source- Walton, Csallany (1965)

5/71 jdh

Fig. 3-4

major significance. They are the Buried Embarras, the Pesotum Branch of the Mahomet Buried Valley System, and the Middletown Buried Valley. It is these features that represent the most ideal location for Pleistocene aquifers, since it is within these valleys that glacial drift is its thickest (Fig. 3-1, 3-4).

The Embarras Buried Bedrock Valley - First recognized by Hubbard,[40] the Buried Embarras Valley lies approximately three to eight miles to the east of the present Embarras River. It formed during the Sangamon Interglacial Period and, acting as a major sluiceway for glacial meltwater, was incised into the Pennsylvanian bedrock to a maximum depth in Coles County of over 225 feet (Fig. 3-4).[41] In Sec. 12, T. 12 N., R. 10 E., two tributaries join to flow south and southwesterly through the county. The eastern tributary originates in Edgar County and trends predominantly westward, while the northern tributary originated near the northern border of T. 13 N., R. 14 W. The valley deepens rather gradually until its surface elevation lies approximately 385 feet above sea level in Sec. 20, T. 11 N., R. 10 E. The gradient of the ancient Embarras River thus figures to be approximately ten to fifteen feet per mile in the study area.

Both advancements of the Illinoian and Wisconsinan glaciers filled the valley to depths of 250 feet with unconsolidated clay, silt, sand, and gravel. The basal 100 to 175 feet is a tight pebbly clay till of Illinoian age. Samples tested at the Geological Survey indicate that the material has very little permeability. Overlying the Illinoian till is

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[40]Hubbard, G. D., "Ancient Embarras River", Journal of Geology, Vol. XII, 1904, pp. 152-60.

[41]Horberg, Leland, "Bedrock Topography of Illinois", Illinois State Geological Survey, Bulletin 73, (Urbana: Department of Registration and Education, 1950), Plate One.

the less weathered Wisconsinan material. It is the primary hydrologic unit in the county due to its known thickness and its widespread distribution. If continuous, the valley aquifer could attain a length of twelve miles.

Well logs attest to the substantial thicknesses of sand and gravel. In Sec. 19, T. 11 N., R. 10 E., thirty-eight feet of sand was encountered at an elevation of 575 feet, some forty-seven feet below the ground surface in Wisconsinan material. Two wells in Sec. 34, T. 12 N., R. 10 E., indicate the bedrock valley lies 148 and 151 feet below the ground. The maximum difference in elevation, 234 feet, is recorded in Urbana as being COL - 12N14W 9. 1h. Here, the base of Illinoian material underlies the crest of the Nevins Moraine. In that location, 145 feet of sand and gravel has been encountered, with yields averaging twenty gpm. Other wells tapping various aquifers in the valley pump less water, ranging from four to nineteen gpm. No dry holes are recorded anywhere in the valley. The logs available on the Buried Embarras Valley reveal aquifers potentially capable of supplying large quantities of groundwater to Charleston and other communities to the south along its course.

<u>The Pesotum Branch of the Buried Mahomet Bedrock Valley</u> - Lying in the western half of T. 14 N., R. 10 E., the Pesotum Branch of the Buried Mahomet Bedrock Valley trends in a northerly direction. At its deepest point in Sec. 20, T. 14 N., R. 10 E., its surface elevation was approximately 485 feet above sea level, and is overlain with nearly 200 feet of glacial drift. Its origin in Sec. 5 lies only one mile from the northern tributary of the Buried Embarras Valley previously discussed. This relative location suggests that this portion of the county, acting

as a hydrographic divide, was being eroded from both the north and south by these two river systems. If the geomorphic process of valley lengthening through headward erosion were allowed to continue for the sufficient time, this "nickpoint" would have disappeared, and may well have led to some form of stream piracy. Since this is not the case, the erosion process was interrupted. While the disruption might have been caused by some activity along the Murdock Syncline (Fig. 2-3), it was probably due to the advance and subsequent deposition of the Illinoian glacier. The Pesotum Buried Valley extends into the study area for about four miles. It has neither the size nor the depth of the Buried Embarras, and therefore it may be expected to contain thinner layers of water-bearing strata. A well located at COL 14N10E 29.4h supplied the only information on this valley. Its yield is ten gpm.

The Middletown Buried Bedrock Valley - Coles County is the eastern terminus for the Middletown Buried Valley. The valley, although extremely shallow, extends nearly six miles into the county, just west of Mattoon. The surface elevation of the valley at its lowest point was approximately 535 feet,[42] but it is overlain with drift thicknesses exceeding 150 feet. This accumulation of glacial mantle is due to the Shelbyville Moraine which lies between 700 and 775 feet above sea level in the vicinity. A well at COL 12N7E 30.2f taps a water-bearing formation twenty-four feet thick at 615 feet above sea level, making the drift in that area at least 164 feet thick. Yields throughout the western portion of T. 12 N., R. 7 E., are more than sufficient for domestic use, ranging from two to fifteen gpm. More than one level of strata has been encountered in various parts of the valley. While abundant water is found in scattered locations, dry

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[42] Piskin, Kemal, Op. Cit., Plate One.

holes in the valley attest to the limited areal extent of the aquifers (Fig. 3-1).

Upland Surface Aquifers

The Upland Surface aquifers have the greatest distribution of the four, and provide more people with groundwater than any other type of aquifer in Coles County. At any individual site, however, they are thin, discontinuous, and are likely to produce only a few gallons per minute. The upland surface lies at an altitude of between 650 and 750 feet above sea level. It is bisected by the Shelbyville Morainal System, a mid-Wisconsinan feature, which accounts for the higher elevations in the county. Besides this morainal system, the Cerro Gordo, Arcola, and a ground moraine constitute the glacial drift in Coles County. Although some exceptions occur,[43] the glacial drift is predominantly Illinoian and Wisconsinan in age, and varies from nineteen to over 100 feet thick. Consequently, the chances of locating an adequate sand and gravel deposit are much better in areas of thicker glacial overburden.

While upland surface aquifers are found at all levels vertically throughout the drift, they are most commonly encountered in the basal material of Wisconsinan age, just above the Illinoian surface. At this level in the drift, sand and gravel deposits often overlie clay deposits. The clay, being less permeable than the sand and gravel, retards further percolation and creates a perched water table in some areas. Often the aquifers rest upon a layer of peat, a product of weathering of the Sangamon Interglacial Period.[44] As a general rule, upland surface aquifers

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[43] MacClintock, Paul, Op. Cit., p. 40.

[44] Foster, John W., Op. Cit., p. 89.

are adequate for domestic or farm use only, but occasionally, yield a sufficient quantity of water to supply a small municipality. Yields of three to five gpm are common from the thin and discontinuous formations. The vast majority of the upland surface varies to the extent that any general discussion would omit most of the cases studied. For this reason, the avenue of approach will be a regional one, based upon a description and evaluation of the hydrologic conditions at most centers of population in Coles County and their environs.

Ashmore - The village of Ashmore in Sec. 31, T. 13 N., R. 11 E., is underlain by fifty to 100 feet of unconsolidated material, and borders the buried Embarras Valley. The drift thickens both eastward and westward, giving rise to two levels of water-bearing strata. A log of well No. 1 reveals both layers of sand, and in addition, sheds light on the thickness of residual clay deposits in this part of the county.

Log of Well COL 13N11E 31.4d

Description	Thickness (Feet)	Depth (Feet)
Soil and Till	3	3
Sand	1	4
Yellowish Clay Till	14	18
Blue Clay	16	34
Sand and Gravel	8	42

Although the areal extent of this sand and gravel formation is unknown, wells in surrounding sections indicate the aquifer extends for at least two miles east-west. One-half mile north of well No. 1, another city well encountered the aquifer at 660 feet above sea level, and found it to be twenty-seven feet thick at that location. The yield of the well is reported to be thirteen gpm. Well No. 1, finished at 657 feet is two feet wide and gravel packed. In 1955, a production test determined the yield at fifty gpm after 23½ hours of pumping, with a drawdown of 2.7

feet.[45] Such a low drawdown indicates that the aquifer is extremely permeable at this location, and has very little trouble recharging itself. The chemical analysis of the well is found in Table 3. Pumpage of this city well was estimated in 1955 to be 22,000 gallons per day (gpd). No other well within three miles of Ashmore produces as much water. In most areas, the aquifer thins to a few feet thick, and yields decrease to about one to six gpm. It appears that the village is quite capable of supplying its population of about 1,000 with a dependable water supply from drift wells in the vicinity. No water shortage is foreseen in this part of Coles County.

TABLE 3

MINERAL CONTENTS OF SELECTED WELLS[46]

Location	Hardness*	Residue*	Iron Content*
1. Kickapoo Station	406	506	1.36
2. Mattoon Well #27	378	532	3.80
3. Mattoon Wells #16-19, 21, and 23	383	440	0.60
4. Mattoon Well #115070	386	440	3.80
5. Pipe Yard Well	641	813	2.60
6. Dorans Field #2	359	417	3.50
7. Dorans Field #1A	340	364	1.40
8. SW Field, #45-1	274	24	0.70
9. SW Field, #45-3	334	369	1.10
10. Ashmore #1	---	478	2.00
11. Fox Ridge #1	78	575	1.00
12. Fox Ridge #2	68	562	3.10
13. Lerna, #1	409	632	3.40
14. Lerna, #2	479	738	65.00
15. Fairgrange	630	1160	----

* Measured in parts per million (ppm)

[45]Hanson, Ross, Op. Cit., Supplement II, 1960, p. Ashmore - 1.

[46]Hanson, Ross, Ibid, p. Ashmore - 1, Mattoon 1-7, Fox Ridge - 1, and Larson, T. E., Op. Cit., pp. 15 and 20.

Cook's Mill - The land surface elevation of Cook's Mill in Sec. 10, T. 13 N., R. 7 E., is approximately 620 to 665 feet. The unconsolidated glacial drift which overlies the bedrock is less than fifty feet thick. The material is described by Sherman[47] as "a pebbly clay till...with some thin, discontinuous beds of sand and gravel." The deposits thus far tapped are recorded at depths of between thirty-eight and fifty feet, near the base of the drift. Yields vary from one to eight gpm in Cook's Mill. While the exact potential of the drift wells in this portion of the county is unknown, it appears doubtful that they would produce either an adequate or a dependable water supply for the residents of the village. The probability of developing groundwater supplies in the vicinity of twenty-five to fifty gpm from glacial drift is extremely poor in the area. The most favorable location for a well would be on the flats of the Kaskaskia River, to be evaluated below.[48]

Etna - Lying in Sec. 16 and 21, T. 11 N., R. 7 E., Etna overlies approximately sixty feet of drift. The drift rests just in front of the Shelbyville Moraine from which large quantities of sand and gravel were spread out to cover the ground in a thin veneer.[49] The following log provides some valuable information.

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[47]Sherman, Frank B., "Geologic Report on the Groundwater Conditions For a Public Water Supply in the Vicinity of Cook's Mill, Coles County, Illinois," Illinois State Geological Survey Groundwater Report, (Unpublished), 1968.

[48]Infra, p. 51.

[49]Cartwright, Keros, "Geological Report on the Groundwater Conditions For a Municipal Supply in the Vicinity of Etna, Coles County, Illinois, Illinois State Geological Survey Groundwater Report (Unpublished), 1964.

Log of Well COL 11N7E 16.3c

Description	Thickness (Feet)	Depth (Feet)
Soil and Clay	5	5
Clay, Yellow	10	15
Clay, Blue	8	23
Gravel	4	27
Clay, Yellow	3	30
Clay, Blue	5	35
Clay, Brown	10	45
Shale (Bedrock)	15	60

The well is evidence of two important points. In the southwestern portion of the county around Etna, the Illinoian till lying at the surface (Fig. 2-5) has undergone more extensive weathering than other areas in the county. This can be seen from the nearly forty feet of clay in only forty-five feet of drift. Secondly, the above log reflects the discontinuous nature of the sand and gravel deposits of the upland surface. Only one mile west of Etna, several wells report excellent yields. Other wells in the surrounding area vary from dry holes to yields of more than twenty gpm. In summary, the possibility of developing municipal groundwater supplies in Pleistocene drift is good.

Fairgrange, Bushton, and Rardin - This portion of north-central Coles County is underlain by greater accumulations of glacial till, ranging from seventy-five feet at Fairgrange to nearly 200 feet at Rardin. The three villages lie at the front of the gently sloping Cerro Gordo Moraine at an average elevation of 670 feet above sea level. Available logs of wells in the surrounding area reveal fairly widespread sand and gravel deposits. While these deposits are only three to six feet thick, they are reported to produce from three to ten gpm. Most of the domestic and farm supplies are obtained by small diameter drilled wells tapping water-bearing sand and gravel aquifers located just above the bedrock. However, the chances of developing an adequate water supply from these deposits appear only poor to fair.

Log of Well COL 13N9E 12.5a

Description	Thickness (Feet)	Depth (Feet)
Soil	2	2
Yellow Clay	8	10
Blue Clay	8	18
Mud Sand	2	20
Blue Clay	15	35
Gravel	8	43
Blue Clay	1	44

This log illustrates the layering necessary to create a perched water table. Although the major aquifer is the gravel bed forty-three feet below the surface, some water is obtained from the Mud Sand, some twenty-three feet above.

Log of Well COL 13N10E 6.8a

Description	Thickness (Feet)	Depth (Feet)
Soil	2	2
Yellow Clay	10	12
Blue Sandy Clay	12	24
Blue Sand and Gravel	14	38
Blue Clay	1	39

This log indicates that the drift thickens in a northeasterly direction from Fairgrange. One aspect of well drilling should be indicated at this point. The quantity of water demanded usually determines the depth of the well. Although the drift is nearly 100 feet thick at the site of the above log, a sufficient water supply was encountered at twenty-four feet, so there was no reason to drill deeper (which could have tapped a better producing aquifer). In the vicinity of one mile northeast of Rardin, there are indications of deposits capable of producing the required quantity of water on a long term basis, but the aquifers there are in the Pesotum Branch of the Mahomet Bedrock Valley. The possibility of developing a groundwater supply for municipal use in the range of twenty-five to fifty gpm appears poor to fair from upland surface aquifers.[50] Other sources in the area will yield the amount desired.

Humboldt - Humboldt, located in the northwest quadrant of Coles County, lies between the Kaskaskia and Embarras Rivers. It is an excellent example of an area of upland surface aquifers.

Log of Well COL 13N8E 4.7e

Description	Thickness (Feet)	Depth (Feet)
Soil	2	2
Yellow Clay	13	15
Blue Clay	4	19
Blue Hardpan	12	31
Dirty Sand	2	33
Blue Clay	4	37
Green Packed Gravel	20	57
Blue Packed Gravel	3	60
Sand and Gravel	4	64

The log is typical. Thin stringers of sand and gravel occupy different layers within the unconsolidated material.[51] Glacial drift in this region varies in thickness from fifty to 100 feet, while the land surface lies at an elevation of 655 feet. Dug wells around Humboldt range from fourteen to thirty-six feet deep with non-pumping water levels of five to fifteen feet below the ground surface. Yields vary according to pumping capacity, screen size, etc., from about three to eight gpm to the east and north, to about eighteen to twenty gpm at two locations west

[50] Sanderson, E. W., "Report of Groundwater Conditions in the Vicinity of Fairgrange, Bushton, and Rardin, Coles County, Illinois," Illinois State Water Survey Groundwater Report, (Unpublished), 1967; and Timblin, R. C., "Report on Groundwater Resources in Section 11, T. 13 N., R. 9 E., Coles County," Illinois State Water Survey, Groundwater Report (Unpublished), 1960.

[51] Timblin, R. C., "Report on Groundwater Resources for the Village of Humboldt, Coles County," Illinois State Water Survey, Groundwater Report, (Unpublished), 1960.

of the village. All of these wells are subject to seasonal variations in water levels. Drilled wells have depths ranging from twenty to eighty feet below the ground surface. Their yields are about five to eight gpm.

In the past, water for the inhabitants of Humboldt was pumped by wells, until the Dorans Field was constructed. For several years the village received some of the total pumpage of the Dorans Field, while the remainder was piped into Mattoon. As of May, 1971, Humboldt buys treated water from Mattoon and the Dorans Field supply has been shifted elsewhere. The possibility of developing a municipal supply from drift aquifers near Humboldt is poor. It is estimated that at least 25,000 gpd would be required of a municipal well system. However, an adequate supply for domestic and farm use from Pleistocene deposits appears probable from available records.

Mattoon - By far the largest consumer of water in Coles County, Mattoon has relied on drift wells among its water sources for over one hundred years. The city, in the eastern portion of T. 12 N., R. 7 E., is built upon the Paris Moraine, a member of the Shelbyville Morainal System. The land surface varies from 700 to 730 feet above sea level. Under most of Mattoon the glacial drift varies from 100 to 200 feet thick, but thins to the north, south, and east to about sixty feet. The initial well system located at 12th and Marshall Streets was dug in 1885.[52] It encountered sand and gravel at a surface elevation of 670 feet, but yield and aquifer thickness data are unknown. Wells at the Kickapoo Station built in 1912, tapped a water-bearing formation at 622 feet above sea level. The stratum there is only about five feet thick, but yields an average of thirty-two gpm per well. Two wells dug on the north

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[52]Hanson, Ross, Op. Cit., p. Mattoon - 1.

side of Marshall and 35th Street struck water in five feet of gravel at 638 feet above sea level. The average yield was forty-five gallons per minute. All but five of the "South Side" wells have been abandoned, since they failed to supply the amount of water demanded. The total combined production was 220 gpm, and if necessary, can be placed back into production. As of May, 1971, all wells have been shut down, or placed as standby units for the Dorans Field. All municipal water used by Mattoon is pumped from Lake Paradise.[53] The Dorans Field was originally dug in 1927. The field, about four miles north of Mattoon, lies at an elevation of 690 feet.

Log of Well COL 13N8E 30.5d

Description	Thickness (Feet)	Depth (Feet)
Loam and Clay	26	26
Sand and Gravel	17	43
Peat	2	45
Clay, Yellow to Blue	11	56
Bedrock (Limestone)	1	57

Production tests conducted by the State Water Survey in 1940 showed nine wells drawing water from the sand and gravel aquifer from between thirty-five and forty feet below the land surface. Their combined production was 778 gpm at maximum capacity. Their average yield to the treatment plant varies from 160 to 240 gpm. Various well logs scattered in T. 11 N., T. 12 N., T. 13 N., and R. 7 E., and R. 8 E., indicate the restricted distribution of the thicker aquifers. Yields west of Mattoon in the thicker drift range from two to twenty-four gpm, while the other areas yield two to ten gpm. Several dry wells have been drilled throughout the western part of the county.

Lerna - Information derived from logs indicates that Lerna is underlain by fifty to 100 feet of unconsolidated glacial material ranging

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[53]Interview, Dean Van Wie, Mattoon Sewer and Water Commissioner, April 23, 1971.

from gravel to clay. The village itself lies at an elevation of about 750 feet.

Log of Well COL 11N8E 3.1a

Description	Thickness (Feet)	Depth (Feet)
Top Soil	1	1
Yellow Clay	9	10
Sandy Yellow Clay	10	20
Blue Clay	19	39
Sand	½	39½
Gray-Blue Clay, Sandy	50½	90
Soft Brown Clay	5	95
Soft Green Clay	8	103
Bedrock	1	104

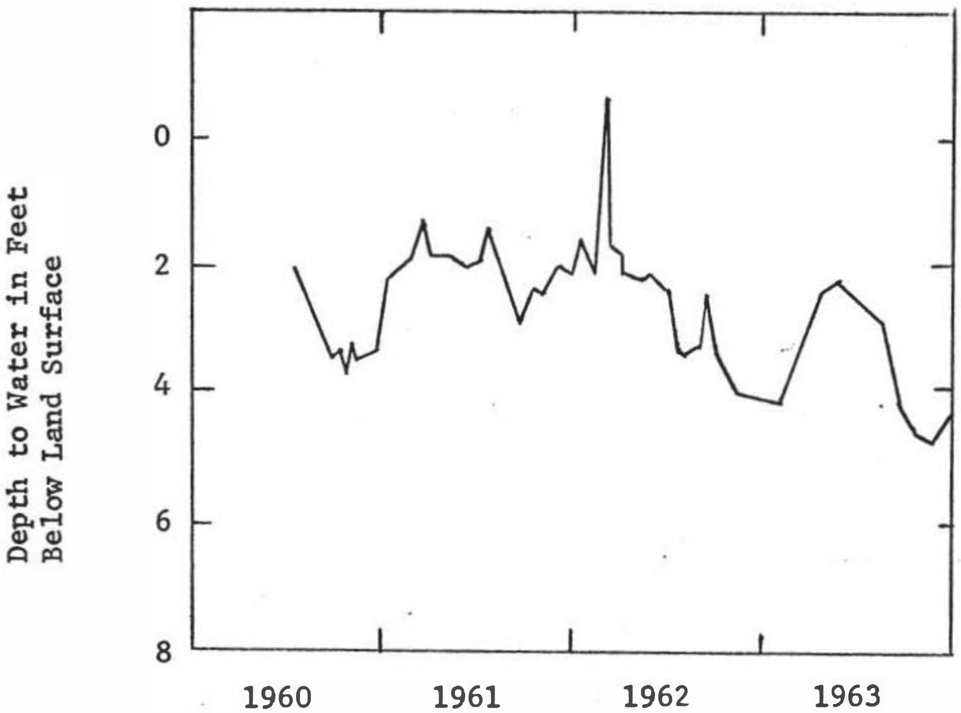
The log indicates that water-bearing strata does not exist in thick layers directly under Lerna. Although a meager supply of twenty-five to thirty gph can be obtained from the sand lens, production diminishes to zero during the drier half of the year. Lerna receives its municipal supply from bedrock wells. Presently, three of the wells are finished at depths of 125, 135, and 130 feet. The fourth well taps the thin sand lens at about forty feet below the surface. Other drift wells in the area do show some promise. Wells in all directions indicate varying yields of from one to twenty gpm. Well COL 11N8E 10.2b taps a thick sand aquifer at 700 feet above sea level which is seventeen feet thick. The yield is reported to be twenty gpm. Under extended pumpage, this well could yield over 10,000 gpd, and might be utilized by Lerna as a water source in case of emergency.

A well four miles southeast of Lerna has been studied for four years by the State Water Survey.[54] The following chart records the

[54]Walton, W. C., and Csallany, S., Op. Cit., p. 48; and Russell, R. R., "Water Levels in Illinois Through 1961," Illinois State Water Survey Report of Investigation 45, (Urbana: Department of Registration and Education, 1963), p. 39.

changing water level in the well during the four year period.

COL 11N9E 19.5g Water Levels, 1960-1963



Lincoln Log Cabin State Park - The glacial drift at the park consists of drift sheets from two distinct ages. Depth to the bedrock varies from about 135 to 165 feet, depending on the surface drilling site. The Illinoian drift sheet probably occupies the basal fifty to 100 feet of unconsolidated material, and is composed of a tight, pebbly clay of insufficient permeability to yield groundwater to a small diameter drilled well.[55] Any sand or gravel layers in this drift section would be thin, and areally limited in extent.

On the other hand, the Wisconsinan drift comprising the upper

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[55]Foster, John W., "Geological Report on the Groundwater Resources at Lincoln Log Cabin State Park About Eight Miles South of Charleston, Coles County, Sec. 21, T. 11 N., R. 9 E.," Illinois State Geological Survey Groundwater Report, (Unpublished), 1951

fifty to 100 feet of unconsolidated material is believed to contain greater amounts of sand and gravel, principally concentrated in the basal portion of the mantle. A well drilled in the northwest quarter of Sec. 21, T. 11 N., R. 9 E., encountered a five foot bed of sand at 120 to 125 feet or at about 565 to 570 feet above sea level. No yield has been reported. One-half mile west of the park, a well encountered another formation, seven feet thick at that location, at about 660 feet above sea level. The well produces five gpm. In 1937, an electrical resistivity survey conducted in the vicinity of the caretaker's cottage failed to indicate a suitable aquifer. It appears from available information that Lincoln Log Cabin State Park will be unable to supply itself with the desired quantity of groundwater from drift wells.

Oakland - The city of Oakland lies at an elevation of 656 feet, and is underlain by generally less than fifty feet of unconsolidated glacial drift. The drift thickens in all directions but remains essentially less than 100 feet thick in the surrounding area.

Log of Well COL 14N11E 19.7h

Description	Thickness (Feet)	Depth (Feet)
Soil	3	3
Clay	13	16
Muddy Gravel	8	24
Blue Clay	8	32
Mud Sand (Gas)	4	36
Blue, Green Sand	18	54
Gray Sand	18	72
White Sand	8	80
Bedrock (Shale)	1	81

The log reveals an excellent aquifer in the eastern portion of Oakland where the drift attains a thickness of eighty feet. An eight foot layer of clean white sand is overlain by thirty-six feet of slightly less porous and permeable sand. Methane gas was discovered at thirty-two feet, rendering the water undrinkable at that level. The aquifer may be tapped at 570 feet above sea level, and yields thirty gpm. Although this well alone is theoretically capable of pumping over 40,000 gpd, a surface reservoir, Lake Oakland, supplies the city with water. While the city is underlain by a good groundwater aquifer, the demand for water in this part of the county exceeds the amount that can be supplied from glacial drift.

Charleston - The city of Charleston is underlain by generally less than fifty feet of unconsolidated material. Very limited thicknesses of sand and gravel are present, and in most areas, the yield from shallow, dug wells is only one to three gpm. In two locations, four miles southeast, and two and one-half miles east of Charleston, the drift has been eroded to reveal outcrops of various units of Pennsylvanian age rock. Due to the difficulty of obtaining adequate pumpage from groundwater sources, Charleston has relied on its surface reservoir, Lake Charleston, for over twenty years. It now appears that this structure is incapable of meeting the increasing demand for water as a new multipurpose reservoir, Lincoln Lake, is being constructed for use in the next few years. While the ability of drift wells to supply groundwater in the vicinity of Charleston is poor, it remains possible that other aquifers might be used.

Fluvial Aquifers

This type of aquifer owes its origin to the eroding and transporting powers of the Embarras, Kaskaskia, and Little Wabash Rivers. Other significant fluvial aquifers may exist in the smaller creeks in the study area. There are two hydrologic areas along these rivers that will consistently yield water to wells - the flats or floodplains, and the alluvial terraces along either side (which usually make up the river bluffs when present).

The Embarras River flats one mile east of Rardin contain thicknesses of sand that exceed sixty feet. The flats would be self-recharging, and probably capable of between twenty-five and fifty gpm. However, the yields have not been verified along this section of the Embarras. Another possibility for a water supply in northern Coles County might be the terrace gravels along the river. Two areas of interest to Rardin appear to be the east half of Sec. 34, and the west half of Sec. 35, T. 14 N., R. 10 E. A total of twenty-eight sites exist along the Embarras that are either capable of development or worthy of prespecting as aquifers.[56]

The Little Wabash River provides both surface and groundwater in the southeast portion of the county. The surface elevation of the river drops from 695 feet in Sec. 28, T. 12 N., R. 7 E., to about 630 feet at the Coles-Cumberland border in Sec. 19, T. 11 N., R. 7 E. Fifty-seven well logs around Lake Paradise and along the upper course of the river indicate a widespread aquifer in the area. Streaks of gravel are encountered between thirty and seventy feet below the drift, and vary in thickness from a few feet to forty feet in Sec. 33, T. 12 N., R. 7 E.[57] Wells bordering Lake Paradise are usually shallower, averaging twenty-five feet in depth, with yields varying between five and eight gpm, and increasing in a southerly direction. Most of the drift wells around the lake appear to be finished in the gravel strata between twenty-five and thirty feet below the land surface. To the north along the river, most

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[56]Illinois State Geological Survey, Road Material Supplies Map, 1930.

[57]Gries, J. P., "Memorandum Report on the Groundwater Possibilities on the Northwest Bank of Lake Mattoon," Illinois State Geological Survey Groundwater Report, (Unpublished), 1936.

are finished in the lower sand and gravel layer indicated below.

Log of Well COL 11N7E 4.5d

Description	Thickness (Feet)	Depth (Feet)
No Samples	5	5
Till, orange, calcareous	5	10
No Samples	5	15
Till, Gray, much sand and gravel	5	20
Till, calcareous, orange	5	25
Gravel, coarse, dirty	5	30
Till, calcareous, gray	15	45
Sand, fine to coarse, gravelly, clean	10	55

The Kaskaskia River affords the best location for a groundwater supply for the Cook's Mill area. While upland surface aquifers reportedly yield from one to eight gpm, wells on the Kaskaskia flats yield twenty gpm. Three miles upstream at COL 14N7E 26.1c, production tests on the well indicate dependable yields of 100 gpm. However, the cost of treating and transmitting this water to Cook's Mill would probably be restrictive.

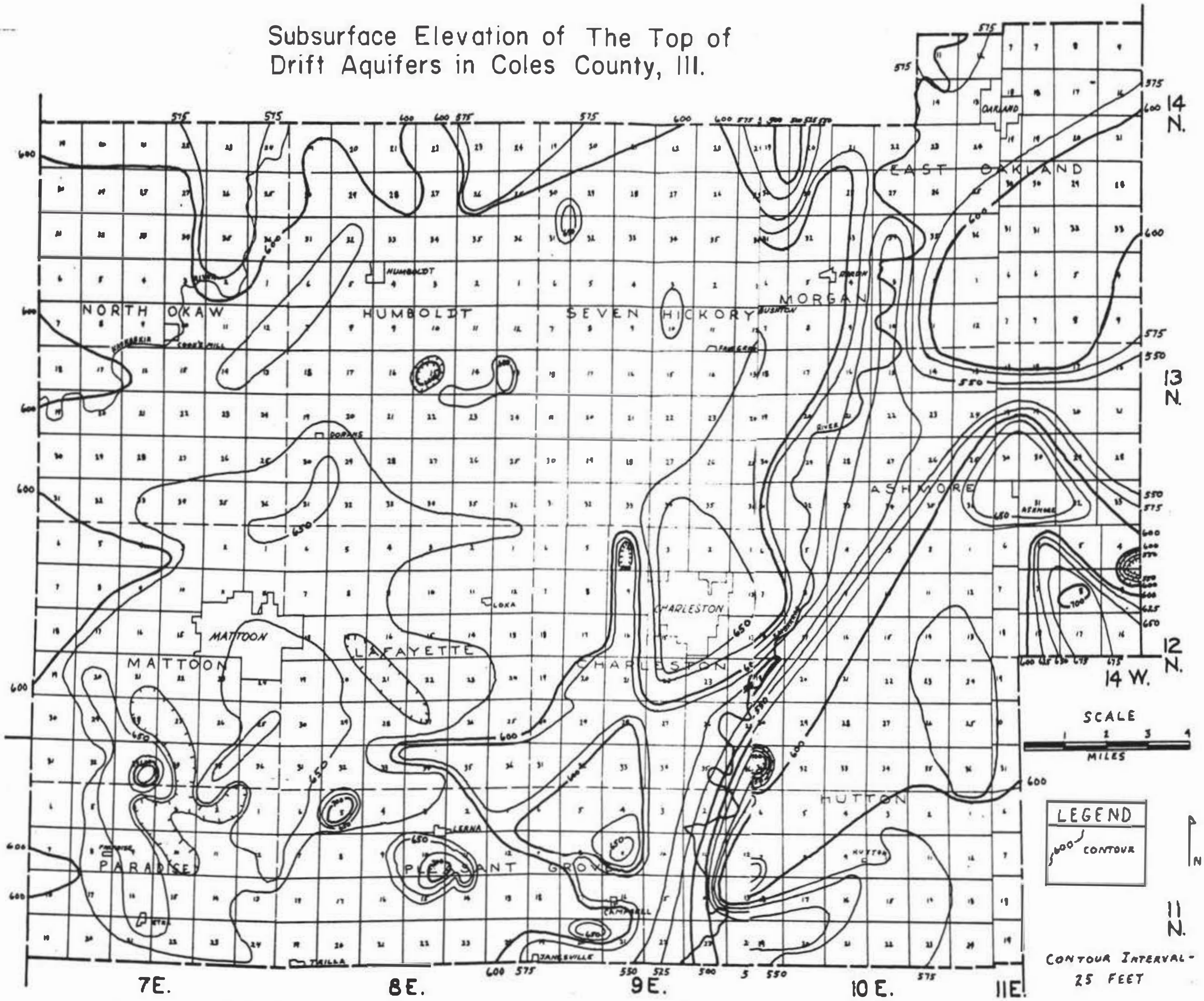
In summary, fluvial aquifers will provide more water, without the threat of going dry in the summer, than the upland surface aquifers. However, chemical tests prove that less treatment is necessary for the natural filtered groundwater from drift wells. Until cities upstream of Coles County stop dumping raw sewage into the Embarras and Kaskaskia Rivers, treatment costs will remain high for the municipalities downstream. Each of the four types of aquifers located in Coles County provides adequate production for domestic or farm use, but lacks the areal extent to be of great significance. In order of their potential production rates, they are: (1) Upland Surface, (2) Fluvial, (3) Shelbyville Fan-Complex, and (4) Buried Bedrock Valleys. Stratigraphically, they are most commonly encountered at the base of Wisconsinan material, but may be found at any elevation above the bedrock. In dozens of cases, two or more water-bearing layers exist at one site. However, the lower formation generally produces the most water since percolation due to gravity forces water to the lowest level possible. Most aquifers are two or more feet thick, but porosity and permeability are of more importance than thickness.

The distribution of the aquifers is widespread with some type represented in nearly every square mile in the county. The buried valley aquifers occur where the ancient rivers incised themselves into the bed-rock, while the fluvial type occurs within the present river systems. Several well logs studied failed to suggest any water-bearing formations in the drift while others found great thicknesses of sand and gravel.

The well logs on file in the State Water and Geological Surveys were carefully screened before data were used. There are no water well logs prior to 1900, and only a handful up to 1930. Unreliable drilling firms failed to submit logs as required by the Illinois Water Well Construction Act of 1965. Most of those submitted were incompletely filled out, usually failing to show the well yield. In many cases, the driller failed to describe the glacial drift layers drilled through, or to provide samples to the Geological Survey for description. Yield figures shown on most logs do not represent the maximum production capable for the well. (If a farm's demand is three gpm, why install a pump capable of fifty gpm?) Little information was obtained from oil well logs, since the Pleistocene material is not important to the well driller. However, the logs did provide figures on depth to bedrock. This figure, being the thickness of glacial drift, was noted and evaluated.

From the information collected, two significant maps were produced. The surface elevation of known aquifers (Fig. 3-5), and well

Subsurface Elevation of The Top of Drift Aquifers in Coles County, Ill.



Source – Illinois Geological and Water Survey, Logsf Water Wells

Fig. 3-5

5/71 jdh

yields at known locations, (Fig. 3-6) were plotted. It is hoped that these two maps will provide simple, yet practical information to farmers, industries, and the general population of Coles County. The State Geological Survey conducts, free of charge, electrical resistivity surveys to help communities or individuals locate possible aquifers. Further test drilling would provide accurate information concerning yields. Until such field work is conducted in the most likely areas of the county, the true potential of Coles County's drift aquifers shall remain cloudy.

Well Mechanics

Perhaps the most important consideration of a well, besides the cost, is the expected yield. Just as water yields vary from place to place due to hydrologic conditions, different amounts of water are demanded for various uses. Requirements in Coles County range from farms that generally need two to five gpm to small municipalities whose requirements may exceed fifty gpm. The exact yield of a well depends upon the factors of porosity and permeability of the surrounding material, the specific retention to the grains,[58] the rated capacity of the pump, the screen size, the diameter of the casing, etc. Together, these factors constitute the variables that determine recharge rates. The recharge rate ultimately determines maximum capacity, and the long term production capability of the well.

In most cases, when a well is being pumped, the water table directly below the well lowers. This lowering, called "drawdown" assumes

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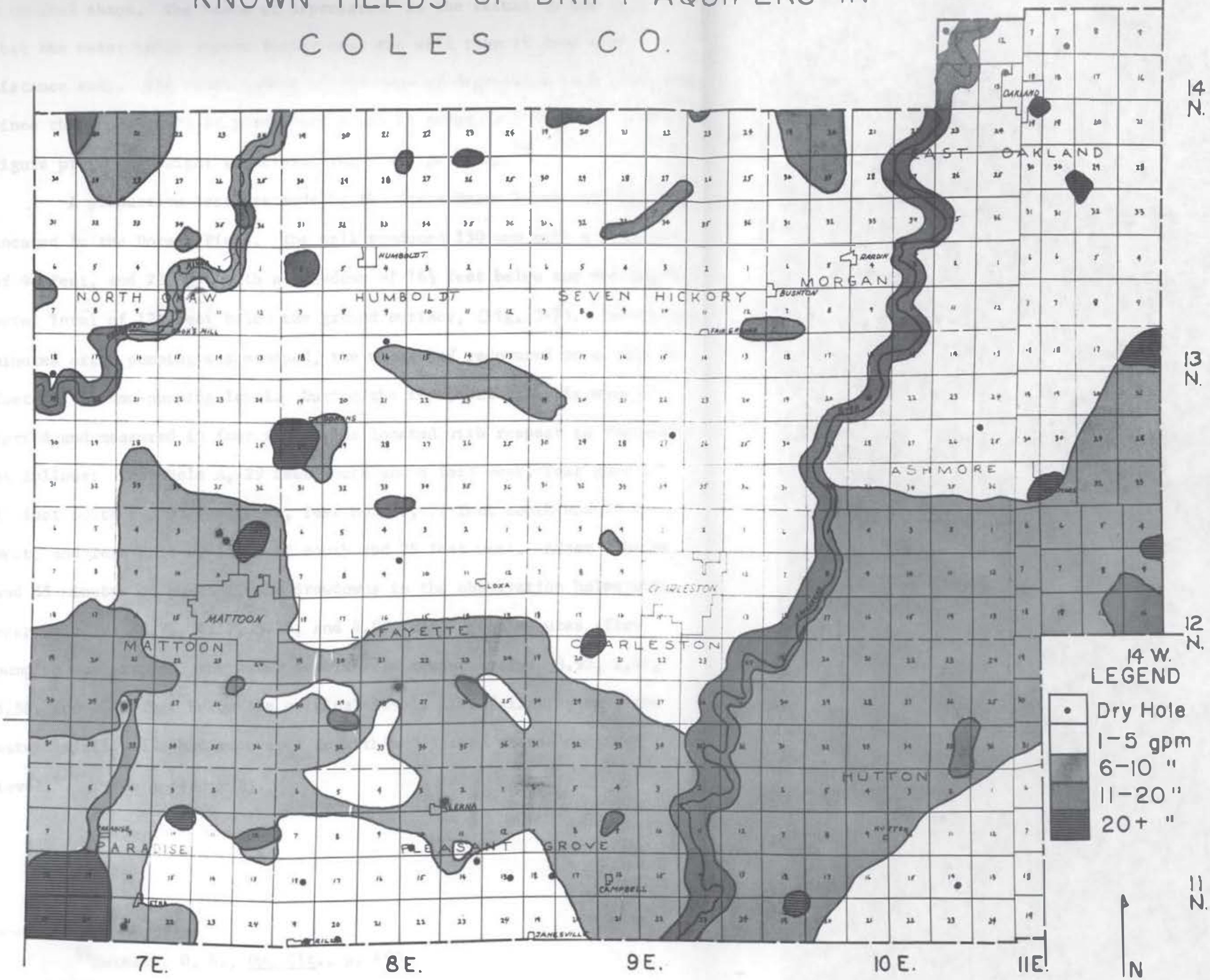
[58]Specific retention is defined as the percentage of water held in the aquifer by capillary attraction that cannot be pumped out. It varies from about five to forty percent of the total water volume.

KNOWN YIELDS OF DRIFT AQUIFERS IN COLES CO.



Source- Illinois State Geological and Water Surveys, Logs of Water Wells

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FIG. 3-6

a conical shape. The "cone of depression" is the result of the fact that the water table lowers faster near the well than it does some distance away. The exact nature of the cone of depression is significant, since the coefficient of permeability can be determined from it. This figure provides insight in determining recharge rates.[59]

A production test was made by the State Water Survey on Well 1A, located in the Dorans Field. The well produced 150 gpm with a drawdown of 9½ feet, and 235 gpm with a drawdown of 16½ feet below the non-pumping water level of 17½ feet below the ground surface, (Fig. 3-7). Twenty-one minutes after pumping was stopped, the water had recovered to within 2½ feet of the non-pumping level. During the test, water levels were observed and measured in four test holes located with respect to the well as follows: Test Hole A, 29 feet south and 8 feet west, Test Hole B, 29 feet south and 32 feet west, Test Hole C, 71 feet south and 25 feet west, and Test Hole D, 157 feet south and 25 feet west. After 7 hours and 55 minutes of pumping, the drawdowns in the observation holes were respectively: 6.75, 6.17, 5.25, and 4.00 feet. Nine minutes after pumping was stopped, the water levels were respectively: 3.92, 2.42, 2.58, and 2.42 feet below the original level. The following day, the water in all wells had recovered to within 3 inches of the original level.[60] (See Appendix B).

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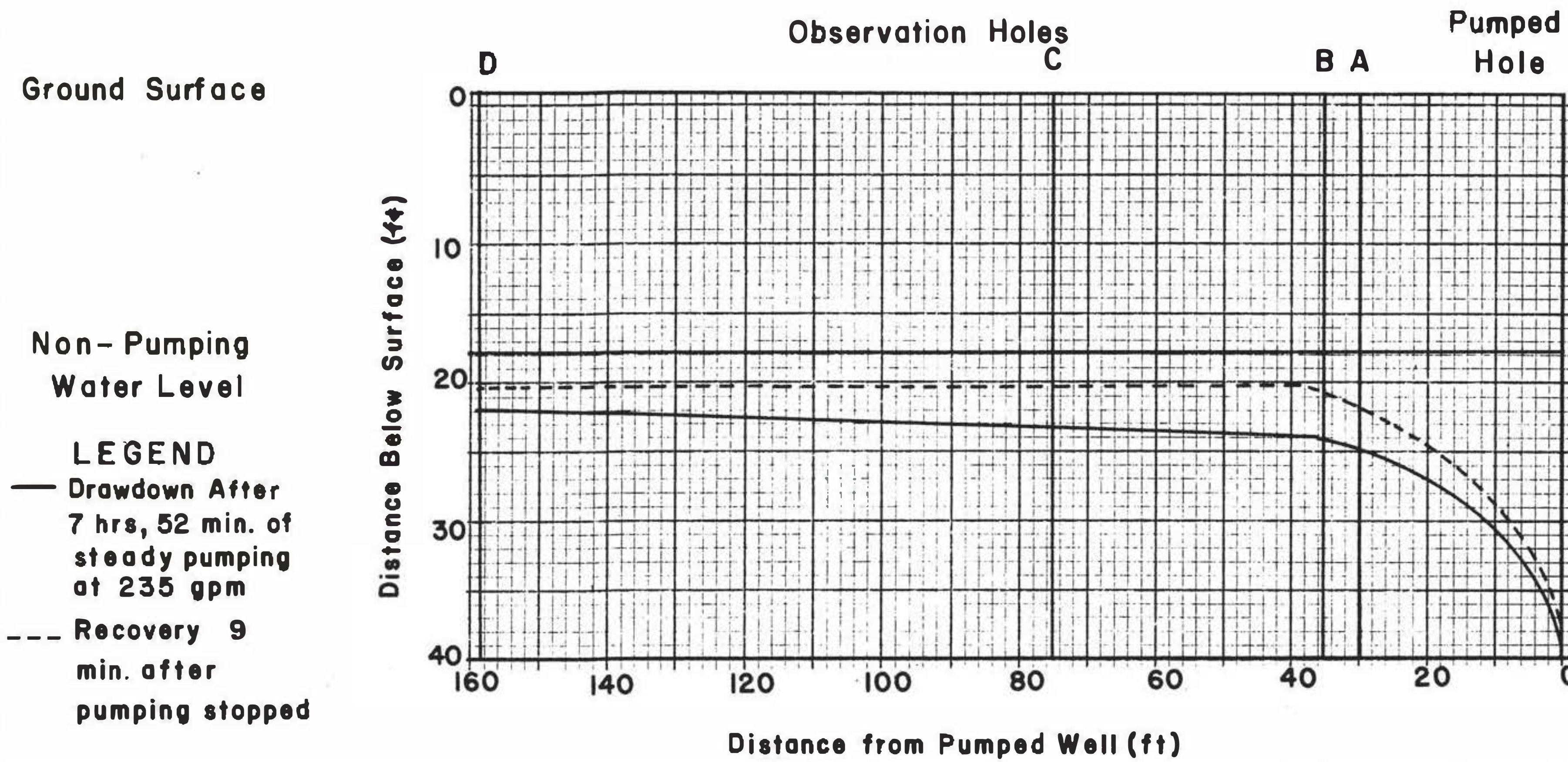
[59]Meinzer, O. E., Op. Cit., p. 460.

[60]Hanson, Ross, Op. Cit., p. Mattoon - 4.



Drawdown Test On Well COL 13N8E-30.5d

Source-Hanson (1948)

5/71 jdh

FIG. 3-7

CHAPTER 4

WATER SOURCES: PROJECTIONS AND ECONOMICS

While the purpose of this paper is an analysis of Pleistocene groundwater resources, it is recognized that most of the population centers in Coles County require more water than can be supplied by drift aquifers. Normally, the difference is supplied by a surface reservoir, but at some locations, bedrock aquifers or other sources are utilized. This chapter examines the various water sources to determine to what extent each type meets the present and projected water requirements of Coles County. An estimate has been made to predict water requirements in Illinois fifty years from now,[61] however, this paper projects water needs for domestic, municipal, and industrial use over the next ten years. The cost of drift wells, as well as alternative water sources, shall be presented.

Present and Projected Demands

Mattoon - The city of Mattoon receives 100 per cent of its treated water from Lake Paradise, a surface reservoir about six miles south of the city. According to the Office Manager[62] at Mattoon's Water Department, 825 million gallons were pumped during the preceeding year, or about

[61] Illinois Technical Advisory Committee on Water Resources, Water For Illinois - A Plan For Action, (Springfield: Department of Business and Economic Development, 1967), p. 135.

[62] Interview, Michael Smyser, Mattoon Water Department Office Manager, May 27, 1971; and Ernie Lorenz, Mattoon Water Commissioner, May 27, 1971.

2.25 million gallons per day. However, this amount is not all used in Mattoon. Humboldt receives treated water, and Neoga (about fifteen miles south of Mattoon, in Cumberland County) receives raw water which is treated at their own expense. Excluding water pumped elsewhere, Mattoon's consumption averages 121 gallons per capita per day (gpcd). Of this amount, approximately forty-five per cent or 640,000 gallons per day are consumed by industries within the city. The demand for water in Mattoon far exceeded the amount that could be supplied from drift wells, hence, Lakes Paradise and Mattoon were constructed for municipal and industrial use. The newer lake is six times larger than the older, and is pumped only to maintain the water level in Lake Paradise. Since its construction in 1961, this water source has yet to be tapped. The total pumpage of the Dorans Field has recently been shifted from Humboldt to a large printing company four miles north of Mattoon. The plant's total consumption is unknown, as the engineering section refused to discuss the matter.

The future water requirements of Mattoon are expected to increase, at an increasing rate. Per capita consumption drops from 121 gallons per person per day in Mattoon, the most industrial city in Coles County to thirty-eight in Ashmore, with little industry. According to Harry Grafton, County Clerk, Mattoon lost 442 people down from 19,138 in 1960 to 18,696 in 1970. All previous periods from 1860 to 1960 have registered increases in population and steady economic growth. The last ten year period is expected to reverse itself and continue growing through at least 1986.[63] The major factors for Mattoon's steady growth have been its location at the junction of the Illinois Central and Norfolk and Western Railroads, and its various industries. In addition, a new educational center, Lake Land Junior College, has been built

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[63]Victor Gruen Associates, Mattoon General Plan, (Limited Publication), 1968, p. 25.

just south of Mattoon. It has shown continuous growth, doubling its enrollment each year for four years. A recreation center has been proposed for Coles County around the Lincoln Reservoir. If the proposed National Recreation Area becomes a reality, significant population increases might occur in Mattoon as well as in the county.

One factor which may be detrimental to the growth of Mattoon is the current problem of upgrading the sewer system to meet minimum anti-pollution requirements as dictated by the Environmental Protection Agency of Illinois. This has forced the city to prevent any new industry or individual house to connect onto the presently overloaded sewer system for waste disposal. This situation shall remain until the upgrading has been completed, effectively preventing any new industrial or residential growth. The city is financially incapable of meeting this deadline, and the long range effects of the sewer problem may last for years. New industries may elect to avoid the issue completely by using alternate disposal systems, especially septic systems. With the various parameters in mind, the author predicts a ten year increase in water consumption of fifty per cent. Plans have been made for even greater demands. Current construction at the treatment facility shall increase its capacity from two and one-half to five and one-half million gallons per day. This increase should guarantee Mattoon's population a more than adequate water supply for years to come.

Charleston - As of May 27, 1971, Charleston's water department reported monthly metered pumpage at 39.7 million gallons, or about 1.32 million gallons per day.[64] Forty per cent of the total pumped was consumed by either commercial or industrial sources, with Eastern Illinois University receiving eighty per cent of all industrial-commercial water. At present,

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[64]Interview, E. J. Haire, Charleston City Clerk, May 28, 1971.

Charleston receives all of its water from Lake Charleston, about four miles southeast of the city.

The projected water requirements of Charleston are based largely on projected population figures. During the period 1960 to 1970, an apparent sixty per cent increase in population occurred in Charleston. Actually, the increase was due to a change in census regulations which included more categories of students in attendance at EIU in 1970 than in 1960. This accounts for at least fifty per cent of the "additional" population. While Eastern Illinois University has grown considerably, its growth may be stopped completely in two years. The Higher Board of Governors of state colleges and universities has limited enrollments in their Master Plan, effective in 1973. Since the university is a prime factor for Charleston's growth, enrollment restrictions may slow down the growth rate.

Charleston has been faced with severe water problems for several years. As a result of studies conducted to alleviate the past water problems of Charleston, the Lincoln Reservoir has been proposed. It has three purposes, flood control, water supply, and recreation. It is expected to supply Charleston with the estimated 1.4 million gallons per day currently received from Lake Charleston, plus an additional twelve million gallons per day will be available for purchase from the state, if needed. Since an average of less than two million gallons per day is presently used, the reservoir should be capable of meeting Charleston's demands throughout the planned economic life of the reservoir.

Oakland - The present metered pumpage at Oakland, Illinois, is 85,000 gallons per day. While the total pumpage has decreased five per cent over the last ten years, the population has increased nine per cent. Per capita consumption has dropped during this period from ninety-six to fifty-five.[65] Presently, Oakland is searching for an alternate water source to pump water to keep up the lake level. Geologic tests in the vicinity of Lake Oakland have failed to locate a suitable aquifer. An electric resistivity survey has been requested by the water commissioner, Martin Kite.

In light of the present water problems, no substantial increase in population is projected, and therefore no large increase in water requirements is predicted. In this section of Coles County, the drift well will be the most reliable source of water in the near future. After the Lincoln Reservoir is constructed, Oakland should have little difficulty obtaining water from the seasonal pool about one mile to the west. Water consumption in 1980 is estimated to be near 110,000 gallons per day.

Ashmore - A public water supply was installed in Ashmore in 1955. By 1960, the average daily total pumpage had risen to 22,000 gallons per day. The water system provided service for ninety-five per cent of Ashmore's population of 1,079. By 1971, pumpage had nearly doubled to an estimated 40,000 gallons per day,[66] but the population had decreased to 1,036. Per capita consumption increased from twenty to thirty-eight over a sixteen year period. The village has witnessed the construction of a new housing development, but the population should remain stable until 1980. If the current trend prevails, a loss could occur. There is no problem meeting projected water requirements in Ashmore due to its location near the Buried Embarras Valley. If necessary, the present well system could provide over 100,000 gallons per day.

Lerna - A public water supply was installed in 1959. With a population of 296 in 1960, metered pumpage showed an average of 4,500 gallons

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[65]Csallany, S., "Relationship Between Water Use and Population in the Embarras River Basin, Illinois," Journal of the American Water Works Association, 1965, p. 393.

[66]Interview, Riley Comstock, Ashmore Water Commissioner, May 31, 1971.

per day pumped, for a per capita consumption rate of thirty gpcd. There are presently a total of four wells in the water supply system, with plans to add one more. Estimated daily pumpage for the present was 11,200 gallons per day for the 288 residents. While no major increase is predicted for Lerna, the thin and discontinuous aquifers in the vicinity make the future possibilities for developing a dependable supply rather poor. The topography does not lend itself to the construction of an impounded pond.

Tri-County Water District - At present, an attempt is being made by a handful of enterprising Mattoon residents to develop a private water district in the vicinity of the Coles, Cumberland, Shelby County borders. The district would serve the residents of Lakes Paradise, Mattoon, the villages of Etna, Paradise, and selected sites within the region. When a sufficient demand has been established, the district will probably rely on the gravels of the Shelbyville Fan-Complex to provide water. No shortage of water is predicted in this region of Coles County.

The following table compares water consumption at different population centers in Coles County, and reflects changes in per capita daily consumption during the period 1960 to 1970.

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[67]Interview, Ted Gwin, Lerna Commissioner of Public Works, June 3, 1971.

TABLE 4

WATER CONSUMPTION FOR SELECTED LOCATIONS IN COLES COUNTY

City	Total Pumpage (mgd)	Per Cent Treated	Per Cent Industrial[a]	Sources	Gpcd[b] 1960[c]	1970
1. Mattoon	2.25	35	45	Lake Paradise Lake Mattoon Dorans Field	81	121
2. Charleston	1.32	28	42	L. Charleston	88	75
3. Oakland	.08	100	5	L. Oakland	96	55
4. Ashmore	.04	100	0[d]	Wells	20	38
5. Lerna	.01	100	0[d]	Wells	30	39

[a]Includes all services other than residential

[b]Gallons per capita per day

[c]Csallany, (1965)

[d]No differentiation made between residential, commercial, or industrial.

Cost of Water Supply Systems

The type of water source that will best meet the demands of a farm, small municipality, or large city depends upon the hydrologic conditions in the area. Occasionally, ideal groundwater resources are available, but due to cost cannot be developed. Since cost often determines feasibility, the Illinois State Water Survey has conducted a series of studies to make optimum use of Illinois groundwater resources. Various studies have shed light on the costs of wells, reservoirs, and pumping, transmitting, and treating water. This section presents cost indices provided by the Water Survey, to aid in rapidly and accurately estimating the total or monthly cost of a water supply system. The cost of wells, reservoirs, pumping, transmission, and treatment shall be discussed.

Domestic Wells

In Coles County, the vast majority of wells are hand dug, lined with brick, and average five feet in diameter. Most are at least fifty years old, and some date to 1822 when the county was first settled. Today, the majority of these wells have either been abandoned, or plugged and replaced. The cost of these wells included the cost of the pump and the bricks, plus many hours of labor. Presently there are several types of wells supplying water for domestic use. Basically, they may be classified as to depth or width. Shallow wells with large diameters, normally twenty-four or thirty-six inches, are the most common, while small diameter wells of four to six inches often extend several hundred feet into glacial drift, or bedrock. While costs vary according to type of well, a direct correlation exists between cost and depth of well. Gibb has supplied the formula W. C. = K + Cd where

W. C. = Well cost, in 1969 dollars
K = Fixed cost
C = Cost/Foot of well
d = Depth of well in feet

This formula has proven to be accurate within eighty per cent confidence limits for a given depth, size, and type of well. In most cases, any discrepancy may be partly attributed to the varying costs of well drillers in different parts of the state.

Large diameter augered wells are used throughout the study area, but are concentrated on the upland surface where thin stringers of sand and gravel are encountered at relatively shallow depths. The average augered well in Coles County is approximately thirty feet deep. The yield ranges from three to five gpm, and the well relies on its storage and seepage capabilities to meet peak demand periods. Correlation coefficients of 0.999 and 0.957 have been found for the depth-cost relationships for the twenty-four and thirty-six inch diameter wells, respectively.[68] The cost-foot estimate is shown in Table 5.

Drilled sand and gravel wells are also represented in Coles County. They are concentrated in areas of thicker drift, especially along the crest of the Shelbyville Morainal System. This type of well is normally constructed by rotary or cable tool drilling, and varies in width from four to six inches. Although the yields range from five to ten gpm, in many cases the reported yields reflect the installed pump capacity and are not necessarily the production capability of the aquifer tapped. Correlation coefficients of 0.981, 0.827, and 0.947 were obtained for the depth-cost relationships developed for the four, five, and six inch diameter wells, respectively.[69]

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[68] Gibb, James P., "Cost of Domestic Wells and Water Treatment in Illinois," Illinois State Water Survey Circular 104, (Urbana: Department of Registration and Education, 1971), p. 5.

[69] Gibb, James P., Ibid, p. 7.

Lastly, in areas where unconsolidated glacial material is missing or too thin to tap as an aquifer, bedrock wells have been drilled. This type of well is scattered throughout the county, and is finished in Pennsylvanian sandstone, limestone, and dolomite. In most cases, water below 300 feet is too highly mineralized for consumption. Bedrock wells are more expensive than the same diameter drift wells due to the installation of an outside casing to seal out any formations subject to caving. In Coles County, relatively few wells extend into the bedrock. However, the wells vary in depth from forty to over 400 feet. Correlation coefficients for this type of well were 0.972, 0.868, and 0.896 for four, five, and six inch wells.[70]

TABLE 5

AVERAGE COST OF DOMESTIC WELLS IN ILLINOIS

Type	Diameter	Depth in Feet					
		20	30	40	50	60	70
Augered	24"	$200	290	380	460	540	630
	36"	$270	370	500	600	720	850
		50	100	150	200	250	300
Drilled Sand and Gravel	4"	$380	580	800	980	1180	1420
	5"	$440	620	820	980	1140	1330
	6"	$680	1000	1340	1670	2000	2350
		50	100	150	200	300	350
Drilled Bedrock	4"	$	430	620	800	1070	
		$	480	720	950	1410	1640
		$350	540	580	1000	1460	1700

Source: Gibb (1971)

[70]Gibb, James P., Ibid, p. 9.

Municipal and Industrial Wells

Municipal and industrial well demands are much greater than domestic requirements. Yields of 100 gpm and higher are desirable. To achieve larger amounts of water, a more powerful pump and a different type well construction is used. Well diameters used in Illinois are reflected below.

Pumping Rate Desired (gpm)	Diameter of Well (Inches)
125	6
300	8
600	10
1200	12
2000	14
3000	16

Gibb and Sanderson have furnished the formula - $W.C. = Kd^n$, where

W.C. = Well cost, in 1966 dollars
K = Fixed cost
d = Depth of well in feet
n = Slopes of the best fit line, or average figure of data available

Two types of wells have supplied various municipalities in the study area. They are the tubular, and the gravel packed sand and gravel wells. The tubular wells range in depth from forty to over 200 feet, have screen diameters from six to twelve inches, screen lengths from ten to thirty feet and installed pump capacities from twenty to 400 gpm. Correlation coefficients of 0.957, 0.976 were obtained for the six to ten inch diameter and twelve to fifteen inch diameter wells, respectively.[71] Cost estimates for the various types of municipal and industrial wells are given in Table 6.

In addition to the initial construction cost of the well is the cost of the pumping system. These data include the installed cost of the pump, pitless adapter unit, pressure tank, and associated piping and wiring.

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[71]Gibb, James P., and Sanderson, E. W., Op. Cit., p. 5.

TABLE 6

AVERAGE COST OF MUNICIPAL AND INDUSTRIAL WELLS IN ILLINOIS

Type	Diameter	Depth in Feet						
		50	75	100	1 25	150	175	200
Tubular	6-10"	$2600	2900	3200	3400	3550	3750	3950
	12-15"	$3700	4300	4700	5250	5450	5800	6200
Gravel Packed Sand and Gravel	16-20"	$3400	3900	4500	4900	5200	5600	5900
	36-42"	$8700	11250	13750	15000	16500	17900	19500
Source: Gibb, Sanderson (1969)								

The large variation in domestic well prices found by the Illinois State Water Survey was due largely to variations in pump capacity. For the purposes of meaningful presentation, all systems equipped with ten gpm pumps were selected for further analysis. The final set of pumping system cost data represent the consumer cost of 1) a 10 gpm submersible pump, 2) pitless adapter unit, 3) an adequately sized pressure tank, and 4) the necessary piping and wiring to deliver water to the house. Fifty per cent of the selected systems had costs between 400 and 680 dollars, with an average cost of about 585 dollars per domestic well. The total range was from 300 to 1500 dollars.[72]

For a more meaningful estimate, the monthly cost of wells and pumping systems is given in Table 7. The cost is obtained by amortizing the initial costs of the well and pumping systems over the expected life span of each unit, an annual maintenance expense of ten dollars, plus an interest rate of eight per cent. The well and pump life span are figured at twenty and ten years respectively. Therefore, payment is based on costs

[72]Gibb, James P., Op. Cit., p. 11.

over a twenty year period at eight per cent.

TABLE 7

MONTHLY COST OF WELLS AND PUMPING SYSTEMS

Initial Well Cost	Initial Pumping System Cost					
	300	400	500	600	700	800
$400	$ 8.00	9.00	10.50	11.70	13.00	14.00
$800	$11.00	12.20	13.80	15.00	16.10	17.60
$1200	$15.30	15.80	17.00	18.20	19.30	20.60
$1600	$17.80	19.00	20.30	21.50	23.00	24.00
$2000	$21.20	22.20	23.70	25.00	26.00	27.10
$2400	$24.80	25.80	27.00	28.20	29.40	30.60

Source: Gibb (1971)

Cost of Reservoirs

Dawes and Wathne[73] arrived at a determination of reservoir cost to be used as a tool for the development, use, and management of water resources in Illinois. One such reservoir, the Lincoln Reservoir, has been proposed with construction due to begin within two or three years. A total of thirteen potential reservoir sites have been proposed in Coles County,[74] so a method of cost estimation is essential. Dawes and Wathne present the formula, $P_c = 9161\ S^{0.54} + 0.49\ S^{0.87}\ K$ where

P_c = Total project cost in dollars
S = Reservoir storage capacity in acre-feet
K = Land cost expressed in dollars per acre

This type of estimate does not take the place of detailed engineering

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[73] Dawes, J. H., and Wathne, Magne, Op. Cit., p. 1.

[74] Dawes, J. H., and Terstriep, M. L., "Potential Surface Water Reservoirs of South-Central Illinois," Illinois State Water Survey Report of Investigation 54, (Urbana: Department of Registration and Education, 1966), pp. 32-35.

studies, but can be used for screening alternative water sources. The project cost for the proposed Lincoln Reservoir has been estimated at 50,000,000 dollars.

In any cost comparison analysis between domestic or municipal wells and reservoirs, several factors need consideration. In general, municipal well water is less costly than domestic well water. Both of these sources are generally more expensive than water provided by a reservoir. Depending on the diameter, depth, and pump, a domestic well at the lower end of the general price range can compete with a reservoir. However, costs at the upper end of the price range may be four times the lower limit. In conclusion, due largely to economies of scale, water provided by surface reservoirs is less expensive than well water.

Costs of Pumping Water

The determination of the cost of pumping water must include the following components: 1) the quantity of flow required, 2) the total pumping head, 3) the wire to water efficiency, and 4) the unit cost of power. Ackermann[75], Chief of the Illinois State Water Survey, has furnished the basic formula Kw-hr = $1.88 \times 10^{-4} Q_1 ht/E_0$ where

Kw-hr = Amount of power required in kilowatt-hours
Q_1 = Flow of water desired, in gallons per minute
E_0 = Wire to water efficiency, in per cent
h = Total pumping head, in feet
t = Time, in hours

Since it is assumed that one Kw-hr equals approximately one cent, the cost will vary inversely with the wire to water efficiency of the well. (The more efficient the well, the less expensive it is to operate). For the average domestic well requiring less than ten gallons per minute, the cost of pumping water would be only about fifty cents per month for the electricity.

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[75]Ackermann, William C., Op. Cit., p. 2, (#9).

Water Transmission Costs

This section presents transmission costs for municipal-industrial requirements only. Normally domestic wells are located close to the house, and the cost of pipe has been accounted for in the cost of the pumping system figure. The cost figures for this section concern the cost of water transmission lines of known diameters. As used here, construction cost covers pipe cost, transportation, installation, valves, and other appurtenances that are integral parts of a transmission line. Costs of right-of-way must be added to arrive at a project cost. Ackermann has presented the following formula[76] $C_p = 2.16\ (1.28)\ D^{1.2} + k\ (c)$ where

C_p = Total project cost for a transmission line
D = Pipe diameter in inches
k = Unit cost of land, easements, or right-of-way
c = Units of land necessary
1.28 = Correction factor to include 84.1 per cent of sampled data

TABLE 8

UNIT CONSTRUCTION COST FOR TRANSMISSION LINES

Diameter in inches	Cost Per Mile
5	$11,000
10	35,000
20	77,000
30	130,000
40	190,000
50	240,000

Water Treatment Costs

Desirable water for general domestic use should contain no objectionable or dangerous concentrations of minerals or gases and should be of safe sanitary quality. However, objectionable concentrations of hardness forming minerals and iron are common throughout Coles County.

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[76]Ackermann, William C., Op. Cit., p. 2, (#7).

In the past, tolerance rather than treatment has been the general rule, but today an increasing number of private water supply systems are being equipped with treatment units to soften the water, remove its iron, and chlorinate where necessary. The following table gives a summary of costs of a typical domestic water supply in Illinois. The initial costs of the well, the pumping system, and treatment are included.

TABLE 9

MONTHLY COSTS OF A TYPICAL DOMESTIC WATER SUPPLY IN ILLINOIS[77]

Monthly Consumption (1,000 gals)	Raw	Treatment* Soften	+ Remove Iron	+ Chlorinate
0	$11.00	13.80	18.50	21.60
2	$11.20	14.30	20.00	22.80
4	$11.35	15.00	21.75	24.40
6	$11.50	15.70	23.00	25.90
8	$11.65	16.20	24.20	27.20
10	$11.75	16.90	25.80	28.90
12	$11.80	17.40	27.10	30.00
14	$11.85	18.00	28.30	31.00

* Based on a 100 foot deep, four inch sand and gravel well (1969 costs)

Cost figures and indices for various water sources in Coles County have been found through personal interviews and graphical models developed and adjusted by the Water Survey staff. The following table gives the cost of 1,000 gallons of water at selected sites in Coles County.

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[77]Ackermann, William C., Op. Cit., Fig. 4, (#11), and Gibb, James P., Op. Cit., p. 23.

TABLE 10

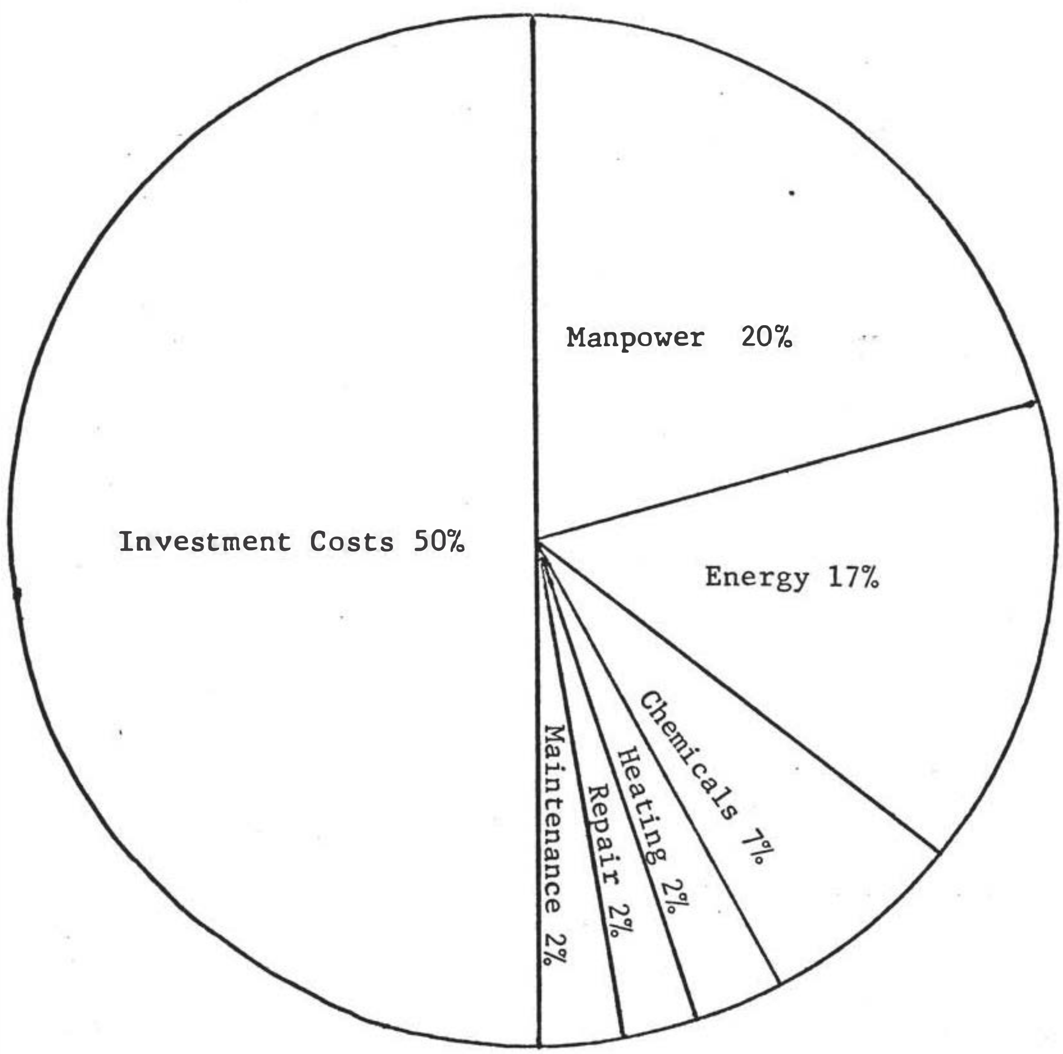
MONTHLY COST OF WATER AT SELECTED SITES IN COLES COUNTY

Site	Cost*	Type of Supply
1. Mattoon	$1.44	M
2. Charleston	1.40	M
3. Oakland	2.25	M
4. Humboldt	1.94	M
5. Ashmore	2.00	M
6. Cook's Mill	4.55	D
7. Fairgrange	5.11	D
8. Lerna	2.25	M
9. Paradise	4.88	D
10. Lincoln Log Cabin State Pk	5.20	D
11. Janesville	4.22	D
12. Coles County Airport	4.82	D

*Based upon following data: 1) Family of six, 2) Per capita consumption of fifty gpcd, 3) Treated for iron removal, chlorinated, and softened, 4) Well life of twenty years, pumping system life of ten years, 5) Eight per cent interest, and 6) Municipal cost includes cost of water and sewer plus a utility tax averaged between the six municipal supplies.

The following graphical model, Figure 4-1, gives the major costs which determine the total cost of one gallon of water in Illinois. Based upon empirical and theoretical research, it can be seen that water costs vary greatly from place to place within Coles County. Some of the sources of greatest variation include type of water source required, depth of well, quantity of water demanded, quantity of treatment necessary, and variations in cost of the drilling contractor. As a general statement one might conclude that the cost of water is more expensive when produced from wells rather than reservoirs. In any case, it is recommended that the various parameters of water supply be thoroughly studied to arrive at an accurate cost estimate.

MAJOR COST OF ONE GALLON OF WATER RELATED TO ITS CONSTITUENTS



Source: Ackermann (1968) Plus insurance and taxes

Fig. 4-1

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS OF STUDY

This chapter presents a summary of the paper, conclusions drawn from the synthesis of previous chapters, and recommends courses of action to alleviate future groundwater problems. Many of the findings are depicted in Figure 3-6. The salient feature of groundwater in Coles County appears to be one of uneveness of distribution.

The purpose of this paper was to examine Pleistocene aquifers to determine the potential groundwater supply available for municipal, industrial, and rural use. Approximately 450 well logs on file at the Illinois State Water Survey and the Illinois State Geological Survey were consulted and correlated to locate major and minor formations of water-bearing sand and gravel. Two additional sources of major importance were Horberg's map Bedrock Surface of Illinois and Piskin's map Thickness of Glacial Drift in Illinois. It is recognized that areas of thicker drift are more likely to contain substantial formations of sand and gravel, hence, a base map was constructed using data from the above sources shown in relation to topographic elevations due to moraines.

Four different types of Pleistocene aquifers were found to exist in Coles County. In order of potential importance they are 1) buried bedrock valleys, 2) Shelbyville Fan-Complex, 3) fluvial, and 4) upland surface. Their horizontal distribution is illustrated in Figure 3-1. Major aquifers were discovered at two levels in the glacial drift. In most cases, the normal location was in the basal portions of the Illinoian drift just above the bedrock. However, in some cases, adequate aquifers were encountered between the Wisconsinan and Illinoian drift sheets in the Sangamon interglacial material (Fig. 2-2).

Man relied on dug wells for his water supply for over one hundred years in the study area. As his demand for water increased, various methods of well construction were used to meet his requirements. In the county, some dug wells are still used that were built in the Nineteenth Century. However, most of these structures have been replaced by augered or drilled wells ranging in width from four inches to two feet, and in depth from fifteen to over 400 feet. Yields vary accordingly, with production ranging from one to over 100 gallons per minute.

Due to the variation in distribution and quality of the four types of aquifers, several villages within the study area are unable to develop dependable water supplies from the drift aquifers. These villages are forced to consider alternate sources - impounded ponds, lakes, and wells drilled into the Pennsylvanian bedrock. At least two areas exist in the county in which preliminary tests indicate substantial thicknesses of sand and gravel. Further exploration is necessary to locate and confirm the formations.

It has been discovered that an adequate water supply can be obtained from drift wells over much of the study area. This is not true of the three largest cities in the county. Increasing per capita consumption, driven upward by industrial requirements, has forced a change from drift wells to alternate water sources. In all but ideal hydrologic conditions, a dependable water supply can be obtained more cheaply from a surface reservoir than from developed Pleistocene aquifers.[78]

The problem of cost is discussed in the preceeding chapter, but

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[78]<u>Supra,</u> p. 72.

must be reviewed here. All matters of choice involving municipal or private water supply systems are not made blindly; rather the cost of each becomes the primary aspect in the decision making process. The question is reduced to one of feasibility. In Coles County, every decision concerning water supplies is influenced by cost. It is cheaper to buy water from existing surface reservoirs than it is to develop a high capacity well. This is partly due to special rates granted to major consumers by the various water departments. In light of the trend for per capita consumption to continue increasing, this author sees the role and importance of drift wells relegated to emergency use only for the cities of Coles County. However, consumption rates have not increased significantly in the rural areas of the county. In many cases, the same well has been used for fifty or more years. Rural consumption has been rather stable, with usage estimated at fifty gallons per person per day.[79]

The fact that two glacial drift sheets exist in the county is significant. Approximately half of all the developed aquifers in the study area are upland surface type in sands and gravels of Sangamon age; that is, located stratigraphically between the Illinoian and Wisconsinan layers. In places where the Wisconsinan material has been eroded or never deposited, a valuable potential aquifer site does not exist. This factor is largely responsible for the difficulty encountered at Lerna in finding water-bearing strata within the residual clay deposits. This also holds true for nearly all of Cumberland County and many other locations to the south.

Recommendations

As the field research was being conducted, it became readily apparent

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[79]Division of Sanitary Engineering, "Pond Water Treatment", State of Illinois Circular No. N820, (Springfield: Department of Public Health, n.d.), p. 5.

that the majority of water well logs were of limited use. Some failed to describe the formations drilled through, or forgot to locate the well site accurately within a section. Almost all failed to record the elevation, while most ignored the pumping test data. Since these data provided the only information available in much of the county, a greater effort must be made to assure accurate and complete preparation of well logs. The following suggestions are recommended.

1) A standard form should be used by both the Illinois State Water Survey and the Illinois State Geological Survey.

2) The property owner should be recorded on the well log. Such information can be obtained from Plat maps,[80] and the County Clerk and Recorder's Office.

3) Accurate description of formation passed through, giving exact thickness of each layer, is essential for correlation and evaluation. Standardized terminology and tests could be worked out by the Illinois State Water Survey in conjunction with the Illinois State Geological Survey for distribution to licensed water well contractors.

4) The recording of elevation at the well site should be made by the driller with the use of an altimeter rather than estimating from a topographic map, and entered on the log.

5) Each log should show either graphically (p. 27) or by the standard section, township, range method the exact location of the well. Subsequent nearby wells should be numbered (Well No. 2, etc.).

6) That section of the Water Survey logs pertaining to pumping data should include information on the capacity of the testing pump, screen size, and duration of test.

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[80]Rockford Map Publishers, Inc., Triennial Atlas and Plat Book - Coles County, Illinois, (Rockford, Illinois: Limited Publication, 1971).

7) A well log should be completed and filed at each survey office for every well drilled in the state. One method of insuring the accurate preparation of water well logs would be to continue licensing water well contractors. Those drillers who fail to submit logs should have their license revoked after adequate warning. Legislation should be passed making it illegal to drill a water well without a license.

8) Extensive geophysical research needs to be conducted in those areas known to be potentially favorable for groundwater, and those areas where water shortages are critical. (The Lerna water department cannot insure adequate fire protection for any of its residents.) In Coles County, electrical resistivity surveys are recommended in the vicinity of Oakland, Lerna, Humboldt, Cook's Mill, Fairgrange, Bushton, and Rardin. Each village has indicated, by correspondence to the state surveys, water supply difficulties. These difficulties will become more severe with time. Further testing by geophysical methods is recommended in two of the county's buried valleys, the Middletown and the Embarras. The surveys are conducted under the direction of competent geologists from the Geological Survey. They are available on a first come - first served basis, free of charge, to any individual or municipality in the state. In addition, once substantial sand and gravel aquifers are located by the resistivity survey, secondary drilling should be conducted to confirm the aquifer, and establish its yield.

9) Another necessary item is an appeal to the concerned population of the county to prevent groundwater pollution by whatever means available. Many contaminants are being piped into the state's waterways. An area of major concern where the pollution of groundwater is highly possible is on the Embarras River near the Charleston Stone Company. At this location, creviced limestone outcrops at the surface and is bissected by the channel of

the Embarras. This situation is known to be highly prone to contamination.[81] Without an effort to correct this situation now, the county's most valuable natural resource will be rendered useless, and treatment costs shall continue rising.

10) The final recommendation of this paper is an analysis of the Buried Embarras Valley as a potential source (along with the present Lake Charleston) for Charleston's water supply. Most parameters indicate a slowing of the population growth rate in Charleston and a subsequent tapering off in the projected water demands.[82] If this situation exists, and available data indicates that it does, the proposed Lincoln Reservoir may not be feasible as an economical water source, at the predicted cost of 50,000,000 dollars.[83] This author recommends an impartial committee of area residents and consultants make such a determination of economic feasibility.

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[81]Walker, William H., Op. Cit., p. 3.

[82]Supra, p. 62.

[83]Authors estimate based upon data presented in League of Women Voters, Charleston, Illinois, "Some Aspects of Flood Control and Water Supply in the Embarras River Basin," (Unpublished Mimeographed Report, 1970), p. 11.

APPENDIX A

LIST OF WATER WELL LOGS IN COLES COUNTY

Location		Thickness(Ft)	Sub-Surface Elev.	Yield(gpm)
T11N, R7E				
1.	1.7f	10	660	
2.	2.2a	11	660	6
3.	2.2h	5	616	6
4.	2.6c	19	653	17
5.	2.7b	14	630	120
6.	2.7f	20	660	120
7.	2.8b	11	635	
8.	3.2a	15	640	120
9.	3.2b	10	640	120
10.	3.7g	6	657	10
11.	4.2d	4	620	5
12.	Average of 57 wells around lake, aver. 620-625, 4-6 ft. thick, 3-8 gpm.			
13.	5.2h	6	660	4
14.	6.7h	4	620	10
15.	8.6c	8	640	12
16.	8.7b	17	590	30
17.	9.6d (1)	5	660	
18.	9.6d (2)	6	658	
19.	9.6e (1)	5	655	
20.	9.6e (2)	9	681	
21.	9.7e	10	655	
22.	10.4c	Dry Hole		
23.	10.4d	Dry Hole		
24.	10.2f	Dry Hole		
25.	10.3c	2	610	
26.	10.3g (1)	5	598	
27.	10.3g (2)	6	603	15
28.	10.4h	7	593	
29.	10.5g	9	644	25
30.	12.7g	3	660	5
31.	12.8d	6	630	15
32.	Average of 49 wells in SW Field, aver. 555, 15 ft. thick, 30 gpm.			
33.	21.3h	6	650	
34.	21.6b	Dry Hole		
35.	22.4e	13	635	9
36.	24.8b	2	647	

Location		Thickness (Ft)	Sub-Surface Elev.	Yield
T11N, R8E				
37.	3.1a	Dry Hole		
38.	3.5e	17	630	8
39.	4.3c	4	640	
40.	5.5f	2	700	3
41.	5.2c	5	640	6
42.	6.4e	11	650	5
43.	7.4d	3	620	
44.	7.8c	10	670	12
45.	10.3a	17	700	20
46.	10.5d	7	650	
47.	10.7a	Dry Hole		
48.	12.2h	4	620	4
49.	12.4g	1	590	
50.	12.7c	7	620	10
51.	13.4f	Dry Hole		
52.	14.2g	Dry Hole		
53.	14.3g	2	625	
54.	14.5g	4	681	1
55.	14.8g	4	640	6
56.	15.4e	2	690	
57.	18.2f	Dry Hole		
58.	19.3a	Dry Hole		
59.	20.6a	Dry Hole		
60.	8.4e T11N, R9E	13	560	
61.	9.5f (1)	9	630	2
62.	9.5f (2)	10	635	15
63.	10.5b	27	570	12
64.	17.3f	25	555	8
65.	17.1c	2	609	3
66.	18.1d	Dry Hole		
67.	19.6a	20	560	3
68.	20.4f	7	660	5
69.	1.5g T11N, R10E	2	640	
70.	2.4h	20	580	20
71.	10.5h	20	560	7
72.	10.8f	9	595	8
73.	14.3b	Dry Hole		
74.	14.3c	3	520	
75.	14.4d	25	601	
76.	18.8h	13	660	5
77.	19.1a	38	575	5
78.	19.1h	8	500	20
79.	20.4d	9	515	6
80.	1.7e T12N, R7E	6	640	30
81.	Average of 69 wells, aver. 10 feet deep in sand, yield 10 gpm.			
82.	1.7h	5	650	
83.	2.4c	Dry Hole		
84.	2.5d	Dry Hole		
85.	9.1h	4	600	
86.	9.4d	5	625	5
87.	15.5e	3	625	1
88.	16.6d	17	635	13

Location			Thickness (Ft)	Sub-Surface Elev.	Yield (gpm)
89.	17.4d		15	635	
90.	18.5d		25	595	
91.	20.4c		2	655	
92.	21.3b		6	635	15
93.	22.4g		4	640	5
94.	22.5e		5	640	7
95.	24.3a		7	650	6
96.	24.2a		7	655	10
97.	25.2d		6	675	6
98.	25.2g		6	655	3
99.	25.8h		7	650	12
100.	26.1d		5	625	10
101.	28.3b		10	670	8
102.	28.3f		3	610	10
103.	28.6d		Dry Hole		
104.	29.6c		9	630	15
105.	30.2f		24	615	
106.	32.3e		32	610	7
107.	33.3c		61	590	12
108.	33.5e		Dry Hole		
109.	33.4g		30	670	
110.	33.7c		40	650	
111.	34.8a		3	650	5
112.	34.1a		32	620	5
113.	35.6d		5	680	
114.	1.4g	T12N, R8E	3	625	
115.	2.7a		5	605	5
116.	4.5d		5	640	15
117.	9.1h		Dry Hole		
118.	14.3f		3	615	5
119.	15.6h		14	600	16
120.	16.5h		Dry Hole		
121.	17.4a		3	620	3
122.	20.2g		5	625	5
123.	20.4a		5	640	
124.	20.6c		3	660	5
125.	21.3d		Dry Hole		
126.	23.4b		18	630	5
127.	25.3c		24	600	3
128.	25.8h		28	615	3
129.	26.2g		3	600	15
130.	28.1h		Dry Hole		
131.	28.4d		4	641	
132.	28.4g		5	615	
133.	29.3b		9	655	12
134.	29.4d		1	696	
135.	29.6f		2	695	2
136.	30.1b		7	650	10
137.	31.6c		9	655	5
138.	33.2a		7	570	8
139.	33.2h		5	650	
140.	34.2e		9	640	

Location			Thickness (Ft)	Sub-Surface Elev.	Yield
141.	4.7b	T12N, R9E	2	540	5
142.	12.7f		2	665	
143.	13.1b		12	610	
144.	16.1b		5	660	
145.	16.7d		Dry Hole		
146.	16.8g		2	560	
147.	17.2c		51	600	
148.	18.4d				1.5
149.	20.3h		12	560	50+
150.	20.5h		9	590	
151.	20.8a		3	550	
152.	21.3c		4	614	
153.	28.4d		9	610	10
154.	29.8h		9	585	
155.	1.4h	T12N, R10E	53	630	
156.	5.4c		2	530	12
157.	7.3a		3	600	4
158.	7.6e		6	625	
159.	7.5a		3	640	
160.	17.4e		3	505	
161.	18.1h		8	610	
162.	19.1g		8	430	
163.	22.2d		2	610	
164.	24.6a		4	640	
165.	27.1a		9	622	
166.	27.8a		5	620	
167.	30.6b		19	590	
168.	31.3f		5	480	
169.	31.7c		50	640	
170.	35.1h		10	635	13
171.	4.1f	T12N, R14W	28	610	
172.	4.4h			590	
173.	4.5c		7	602	
174.	5.8d		8	640	5
175.	6.4e		20	650	
176.	7.3a		60	690	
177.	8.3d		12	690	25
178.	8.5e		4	700	
179.	9.2g		145	520	20
180.	9.2f		18	638	4
181.	16.5b		3	662	15
182.	6.8a	T13N, R7E	4	620	10
183.	8.5a		7	620	20
184.	10.5e		8	620	3
185.	14.1e		6	627	3
186.	17.4c		22	589	10
187.	19.5h		Dry Hole		
188.	19.6e		2	601	18
189.	33.4a		7	630	6
190.	33.5h		7	624	6
191.	34.6c		5	632	6

Location			Thickness (Ft)	Sub-Surface Elev.	Yield
192.	1.5g	T13N, R8E	3	640	
193.	6.7d		3	630	12
194.	10.3e		5	604	
195.	13.8d		6	650	
196.	14.2d		21	615	
197.	14.3a		5	640	
198.	15.1a		4	630	5
199.	14.5d		3	620	
200.	15.8f		4	590	
201.	16.1d		9	634	5
202.	16.5g		Dry Hole		
203.	5.8a	T13N, R9E	32	605	
204.	8.1h		3	624	
205.	8.4d		Dry Hole		
206.	10.4h		15	625	
207.	11.5a		6	605	
208.	12.6a		8	631	10
209.	19.4f		4	600	5
210.	20.5e		4	615	2
211.	24.5c		8	640	
212.	33.7g		8	620	
213.	34.3b		70	671	
214.	6.2g	T13N, R10E	4	600	3
215.	7.4h		4	600	
216.	7.6a		4	625	10
217.	13.8h		4	615	
218.	14.1e		4	601	
219.	15.2h		2	600	
220.	19.7g		4	600	5
221.	25.8h		Dry Hole		
222.	36.5g		20	670	
223.	18.8a		23	580	1
224.	City of Ashmore		27	660	
225.	4.1a		Dry Hole		
226.	4.3h		3	600	5
227.	16.1h		18	585	25
228.	19.1e		60	570	
229.	19.7d		5	660	3
230.	31.4c		30	630	
231.	32.6c		60	650	
232.	19.7a	T14N, R7E	26	610	1
233.	20.5a		10	590	10
234.	20.8h		5	580	15
235.	21.2b		1	580	7
236.	25.2h		5	595	5
237.	25.7h		8	595	10
238.	26.1c		20	560	100
239.	28.8g		8	607	10
240.	29.1h		3	620	7
241.	29.8d		8	620	
242.	34.2a		7	570	10
243.	36.3c		30	605	

Location			Thickness (Ft)	Sub-Surface Elev.	Yield
244.	19.3e	T14N, R8E	Dry Hole		
245.	19.5d		4	600	3.5
246.	19.7g		4	586	3
247.	21.3g		20	600	
248.	23.6b		2	600	
249.	26.7b		42	565	
250.	26.7h		10	565	
251.	27.4a		5	600	5
252.	28.1d		29	590	2
253.	28.1h		5	595	7
254.	30.8f		5	590	4
255.	32.8f		18	602	
256.	32.8g		13	642	
257.	33.8c		3	622	
258.	20.6h	T14N, R9E	5	594	15
259.	20.2h		45	577	
260.	23.8h		3	607	5
261.	27.1d		4	620	5
262.	31.1h		1	663	4
263.	33.7e		6	600	6
264.	36.8h		3	613	4
265.	11.7f	T14N, R10E	Dry Hole		
266.	13.5e		Dry Hole		
267.	15.6c		10	550	
268.	26.4h		32	568	
269.	28.6h		9	610	
270.	29.4h		5	585	10
271.	31.2h (1)		2	580	
272.	31.2h (2)		1	490	
273.	33.2e		10	495	
274.	31.2g		10	640	
275.	34.8a		22	525	
276.	18.4a	T14N, R11W	8	570	30
277.	7.1d	T14N, R14W	Dry Hole		
278.	21.4b		10	615	
279.	29.8b		5	609	20

APPENDIX B

THIEM FORMULA FOR COEFFICIENT OF PERMEABILITY

$$P = Q \frac{(\text{Log. } r_2 - \text{Log. } r_1)}{2\pi m \, (S_1 - S_2)}$$

where

Q = Quantity of water pumped (gpm)
r_1 = Distance in feet from pumped well to observation hole A
r_2 = Distance in feet from pumped well to observation hole B
S_1 = Drawdown at r_1
S_2 = Drawdown at r_2
m = Thickness of aquifer in feet

	Log
Distance between pumped well and observation hole A = 30.2'	1.4800
Distance between pumped well and observation hole B = 35.5'	1.5502
Distance between pumped well and observation hole C = 75.5'	1.8779
Distance between pumped well and observation hole D = 159'	2.2014

$r_2 - r_1 = .0702$	$S_1 - S_2 = .58$	$m = 23.5$ feet
$r_3 - r_2 = .3277$	$S_2 - S_3 = .92$	
$r_4 - r_3 = .3235$	$S_3 - S_4 = 1.25$	$Q = 235$ gpm

Source: Meinzer, O. E., *Ibid*, p. 461.

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