KENTUCKY GEOLOGICAL SURVEY

UNIVERSITY OF KENTUCKY
LEXINGTON, KENTUCKY

WALLACE W. HAGAN
Director and State Geologist

SERIES X
1967

PUMPING TEST OF AN EOCENE AQUIFER NEAR MAYFIELD, KENTUCKY

J. H. Morgan

U. S. Geological Survey

Prepared by the United States Geological Survey
in cooperation with the Kentucky Geological Survey

INFORMATION CIRCULAR 15

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LETTER OF TRANSMITTAL

July 25, 1967

Dr. A. D. Albright
Mr. James Y. McDonald
University of Kentucky

Gentlemen:

Knowledge of the characteristics of a ground-water reservoir in the Jackson Purchase region, as determined by a specific analytical method, should prove of value to those industries interested in the development of new water reservoirs in this region.

This information circular illustrates the application of such a method to an aquifer near Mayfield, Kentucky, and we anticipate that it will prove useful to those interested in sources of underground water supplies.

Sincerely,

Wallace W. Hagan

WALLACE W. HAGAN
Director and State Geologist
Kentucky Geological Survey

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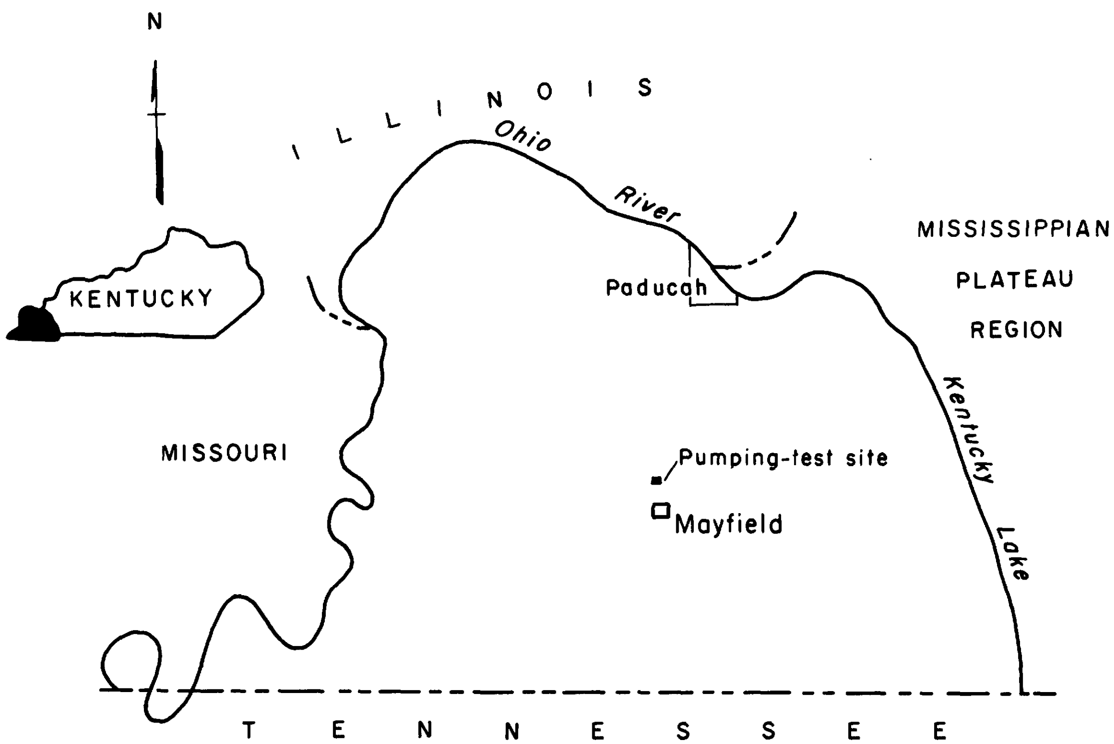

Figure 1. Index map of the Jackson Purchase region in western Kentucky showing pumping-test site near Mayfield, Ky.

PUMPING TEST OF AN EOCENE AQUIFER NEAR MAYFIELD, KENTUCKY

J. H. Morgan

ABSTRACT

In the past few years it has been realized that a refined quantitative appraisal is needed concerning the available ground-water resources of the Jackson Purchase region of Kentucky and their management. This report is concerned with a brief description and practical application of one of the analytical methods used in the quantitative appraisal of a 250-foot-thick Eocene aquifer near Mayfield, Kentucky. The effects of pumping a well at a constant rate of 96 gpm (gallons per minute) for about 24 hours were recorded at three nearby wells and the results used to compute the coefficients of transmissibility and storage of the aquifer. The Jacob method of analysis gave average values of 300,000 gallons per day per foot for the transmissibility and 0.0002 for the storage. These results indicate that the water is under artesian conditions and that the aquifer is not receiving any significant amount of downward recharge in the immediate area of the test site. Most recharge takes place laterally.

INTRODUCTION

An aquifer test was made during March 1960 by the personnel of the Ground Water Branch (now Water Resources Division), U. S. Geological Survey, using wells at the General Tire and Rubber Co. near Mayfield in western Kentucky. The test was under the field supervision of Messrs. E. A. Bell and T. W. Lambert. The purpose of the test was to determine the rate of movement of the ground water and the amount of ground water in storage in an Eocene aquifer in the area. It is part of a larger investigation of the ground-water resources of the Jackson Purchase region, Kentucky, conducted cooperatively by the University of Kentucky, Kentucky Geological Survey, Dr. W. W. Hagan, Director and State Geologist, and the U. S. Geological Survey, Water Resources Division.

The test was made possible through the courtesy of General Tire and Rubber Co., through Edward S. Brown, Plant Engineer, who permitted use of the wells for test purposes.

LOCATION AND GEOLOGIC SETTING

The General Tire and Rubber Co. property is located in Graves County about 3 miles north of the town of Mayfield on U. S. Highway 45 in the Jackson Purchase region in western Kentucky (Fig. 1). The region lies within the northernmost extension of the Mississippi Embayment and is underlain by unconsolidated sediments ranging from the Cretaceous to the Tertiary in age. The principal water-bearing formation at Mayfield is of Eocene age and consists of interlaminated beds of sand and clay. The beds of sand contain large amounts of ground water, some of which is confined in the lower part of the formation by beds of clay. These sediments of Eocene age are about 250 feet thick at the test site and are overlain by 30 feet of Recent alluvium (see Fig. 2). They evidently were washed into the area from the east and were deposited in channels eroded in the underlying deposits.

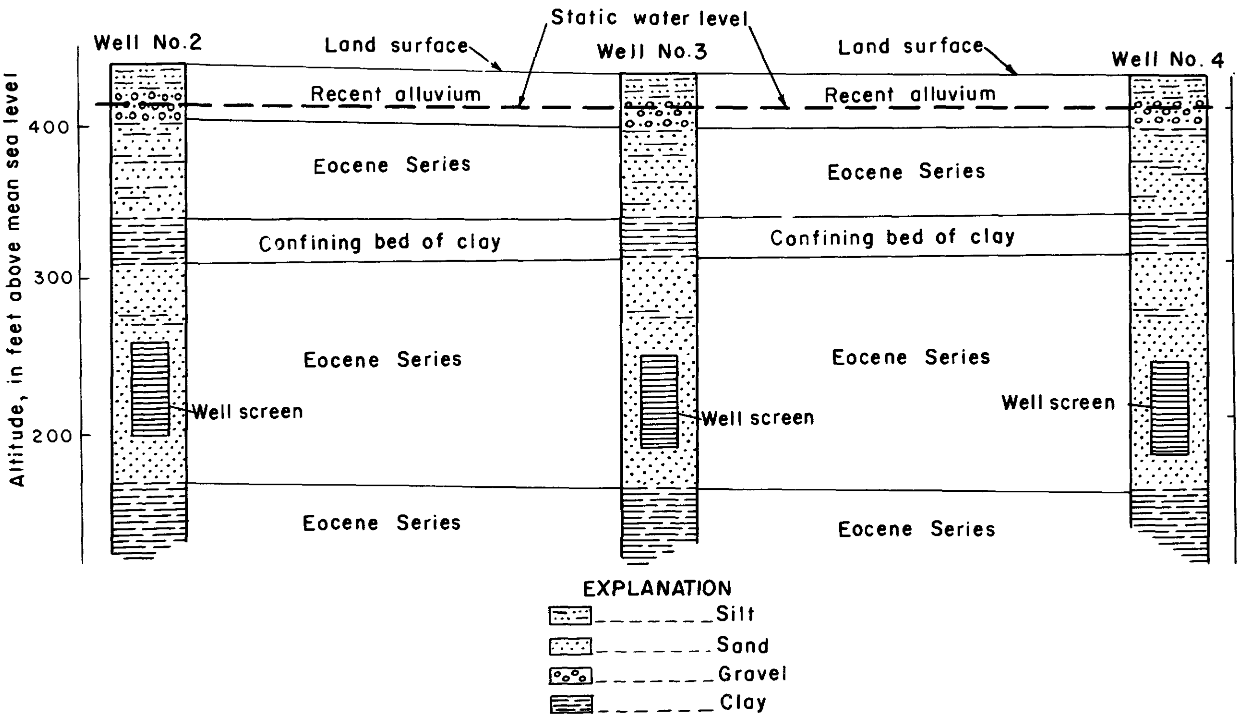

Figure 2. Generalized stratigraphic section and position of well screen for wells used in the Eocene aquifer test near Mayfield, Ky.

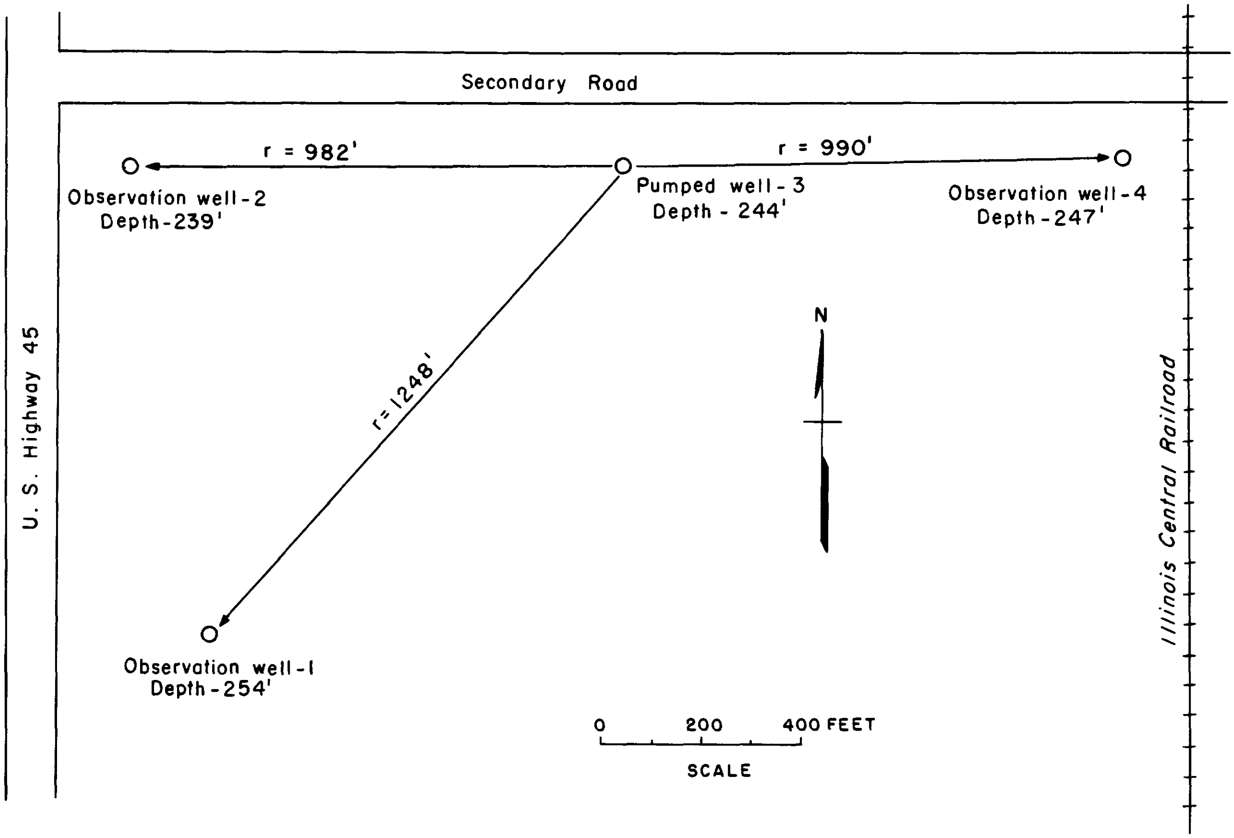

Figure 3. Map showing location of wells and their relationship in the Eocene aquifer test near Mayfield, Ky.

AQUIFER TEST

Description of Wells

Four closely spaced industrial wells were used in the aquifer test (Fig. 3). The wells range in depth between 239 and 254 feet, are 16 inches in diameter, and are equipped with 10-inch I.D. well screens that are 60 feet in length and placed at a depth of 180-240 feet in a bed of medium- to coarse-grained sand. The sand is overlain by a bed of clay about 25 or 30 feet thick. A gravel envelope was placed opposite the screens. The static water level is 20 feet below land surface or 160 feet above the top of the well screens and corresponds very closely to the unconfined water level in the shallow wells in the immediate area (Fig. 2).

Procedure

The effects of pumping one well (well 3) were measured in three observation wells by the means of continuous recording instruments. The pumping was started at 1540 Central Standard time on March 19, 1960, and was continued at a constant rate of about 96 gpm for 1475 minutes until 1615 Central Standard time on March 20. The water level in the observation wells showed a relatively rapid drawdown during the first 4 hours but declined only slightly during the remainder of the test. The measurements of the drawdown in the pumped well were made manually at frequent intervals during the test and are used to compute the specific capacity of the well. After pumping ceased, recovery measurements were continued in the pumped well for about 2 hours.

Several days prior to the aquifer test, a microbarograph was installed at the test site to measure the changes in atmospheric pressure in the area. The record of the microbarograph, converted to feet of water, was compared to the hydrograph of one of the wells for a period of several days when the wells were not affected by pumping. The comparison shown on Figure 4, indicated that for every unit increase in the atmospheric pressure, the static water level in the wells declined an equal amount. The barometric efficiency of the wells is equal to the change in the static water level divided by the change in barometric pressure for the same period of time. On Figure 4, the barometric efficiency is equal to a-b divided by c-d, or 90/91, indicating an efficiency of about 100 percent. Because the observed drawdown in the wells during the aquifer test was in part due to the change in atmospheric pressure, the drawdown data were corrected for the influence of the changing pressure shown in Figure 5. Application of the correction decreased the drawdown by as much as 0.29 foot during one period of the test.

Analysis and Interpretation

The coefficients of transmissibility (T) and storage (S) are the major hydraulic properties of an aquifer. The coefficient of transmissibility is defined as the rate of flow of water, at the prevailing temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide and extending the full saturated height of the aquifer under a hydraulic gradient of 1 foot drop in head in a 1-foot flow distance. The coefficient of storage is the volume of water that can be released or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The value of an aquifer depends on these two inherent properties: its ability to store and its ability to transmit water.

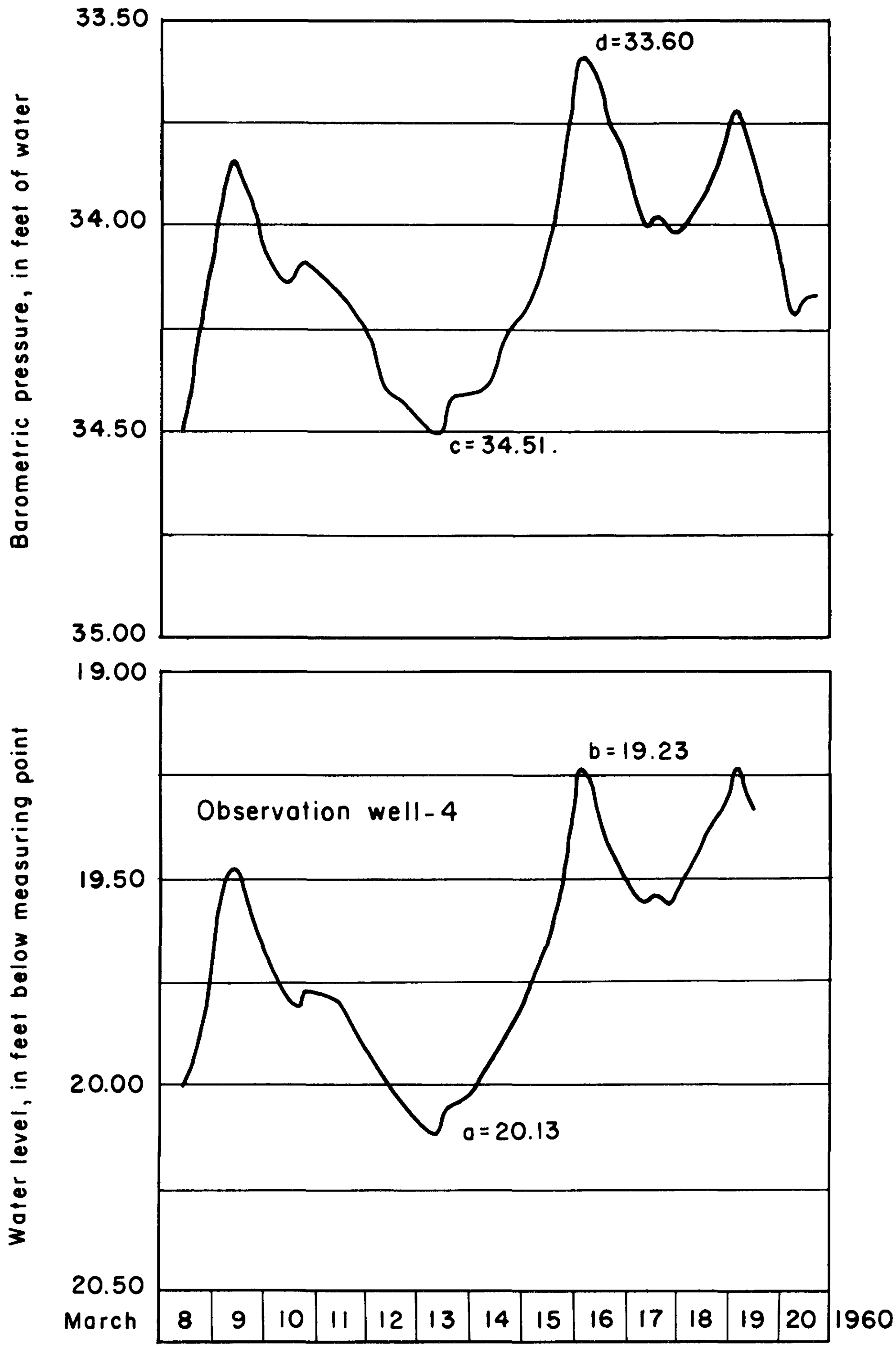

Figure 4. Graphs showing relationship between barometric pressure and water level in well 4 used in aquifer test near Mayfield, Ky.

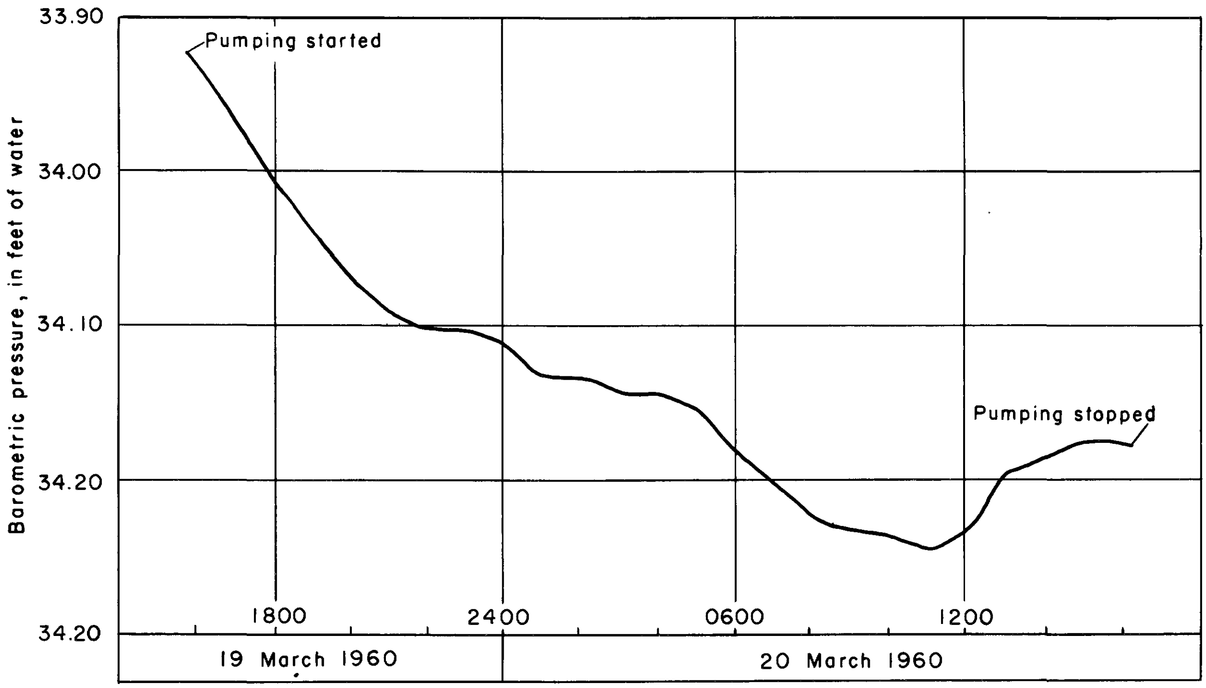

Figure 5. Graph showing change in barometric pressure used to compute adjusted drawdown of water level during period of aquifer test near Mayfield, Ky.

The method selected to determine the hydraulic properties depends largely on the geohydrologic conditions at the test site. The choice of the method involves several assumptions: (a) the aquifer is homogeneous, isotropic, and of infinite areal extent; (b) the discharging well penetrates and receives water from the full saturated thickness of the aquifer; (c) the coefficient of transmissibility is constant at all times and at all places; (d) pumping has continued at a uniform rate for the hydraulic system to reach a steady state; and (e) the flow is laminar. The Jacob method of analysis was selected because the time-drawdown graph (the plot of the drawdown of the water level, s, on an arithmetic scale versus the elapsed pumping time, t, on the logarithmic scale) produced a straight line when the values of t became large and the hydraulic system had apparently approximated a steady state. The values for T and S, using this method, are given on Figures 6 through 9. The values for T average close to 300,000 gallons per day per foot, which means that in one day, 300,000 gallons of water can move through each vertical strip of the aquifer 1 foot wide extending the full thickness of the aquifer. The values for S average 0.0002 and indicate artesian conditions.

The Jacob method of determining the hydraulic properties of an aquifer is described in detail in U. S. Geological Survey Water-Supply Paper 1536-E, entitled, "Theory of Aquifer Tests," by J. G. Ferris, D. B. Knowles, R. H. Brown, and R. W. Stallman, 1962.

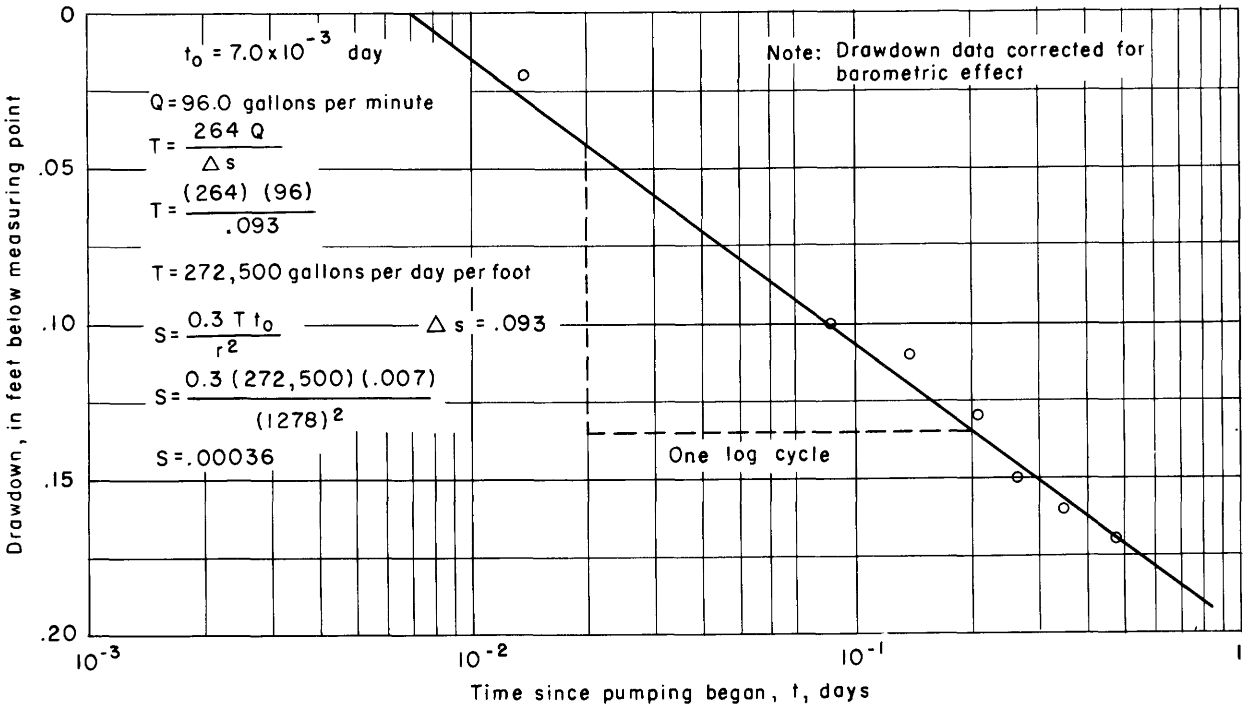

Figure 6. Time-drawdown graph for well 1.

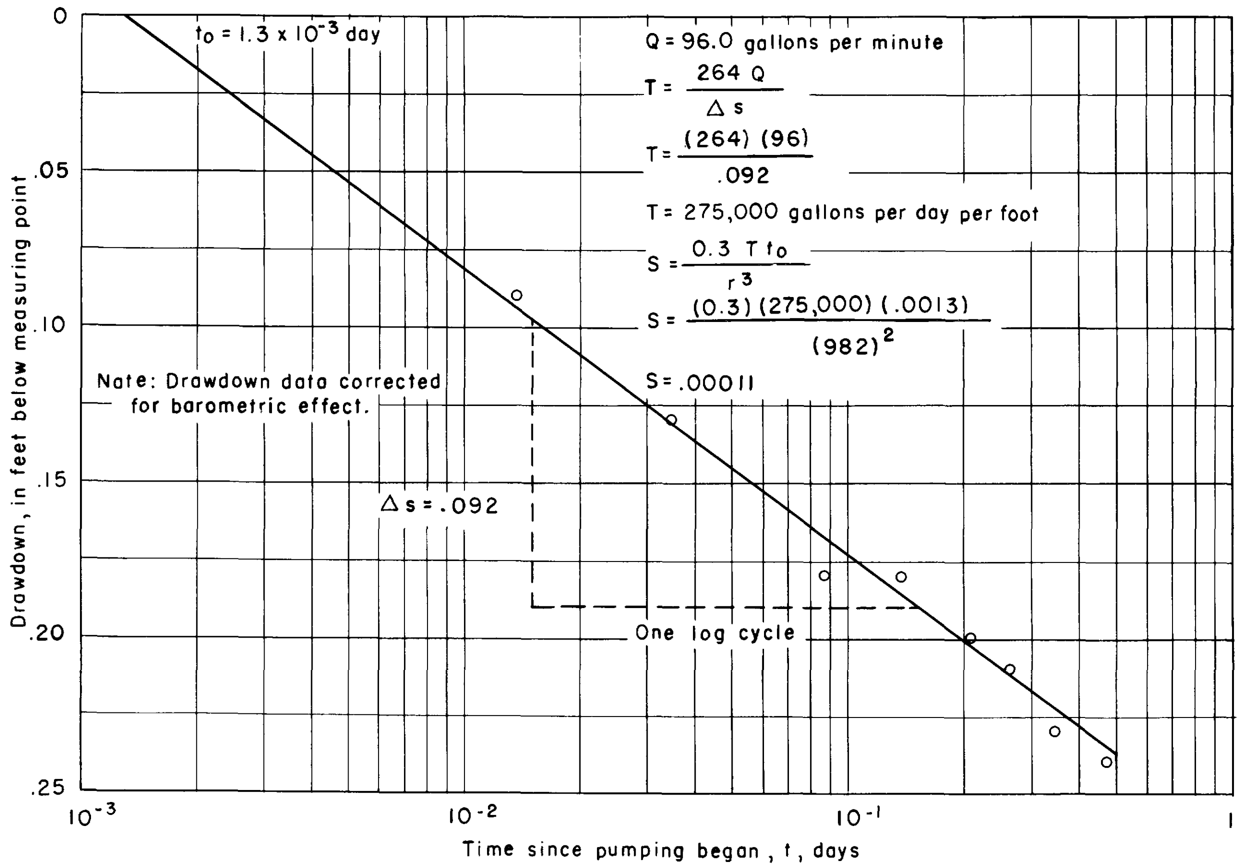

Figure 7. Time-drawdown graph for well 2.

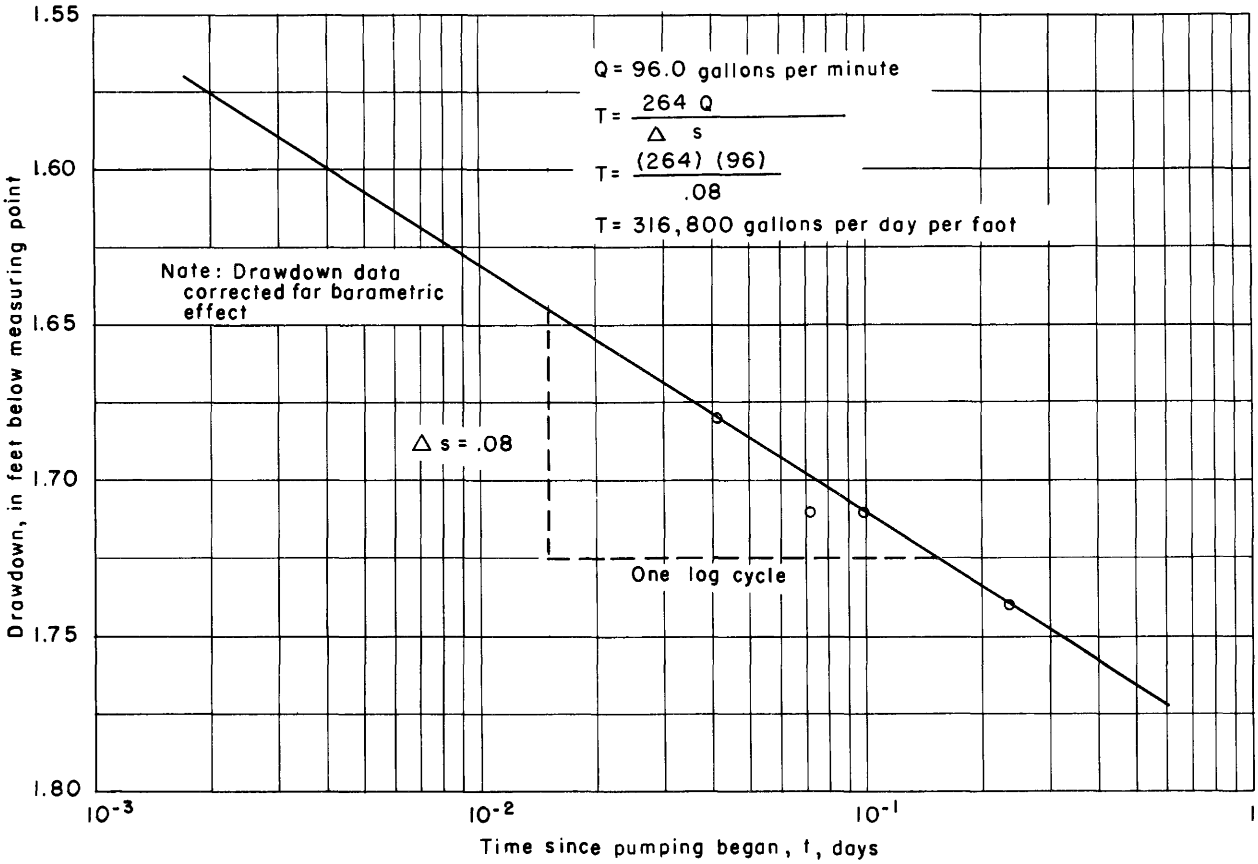

Figure 8. Time-drawdown graph for well 3.

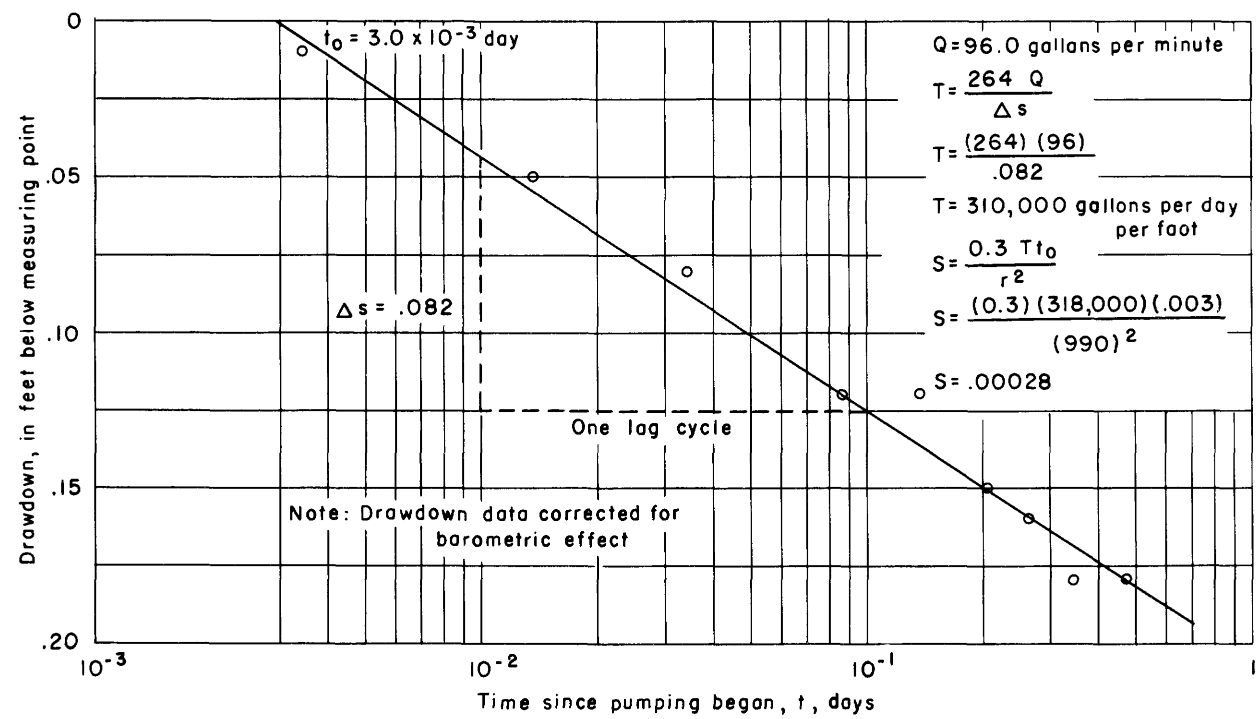

Figure 9. Time-drawdown graph for well 4.

The specific capacity of a well is defined as the yield of the well in gallons per minute per foot of drawdown. The specific capacity is 54.2 gallons per minute per foot of drawdown when corrected for the barometric effect and 47.5 gallons per minute per foot when not corrected for barometric effect.

CONCLUSIONS

The results of the aquifer test lend support to the following interpretation. The ground water contained in the sand beds in the lower part of the formation is evidently under artesian conditions, and the aquifer is not receiving any significant amount of downward recharge in the immediate area of the test site, although there may be some leakage of water into the aquifer through the confining beds of clay. The greater values for the coefficient of transmissibility are in an easterly direction and probably relate to the direction of sedimentation. The longitudinal axes of the sand grains are apparently aligned in this direction and impart a greater ability for the aquifer to transmit water. The amount of water in storage is considered to be large because of the low values for the coefficient of storage; however, the exact amount available depends on the areal extent of the bed of sand, which is not known. Because the sand is considered to be continuous over a large area, the aquifer should furnish large yields without any significant dewatering of the formation.

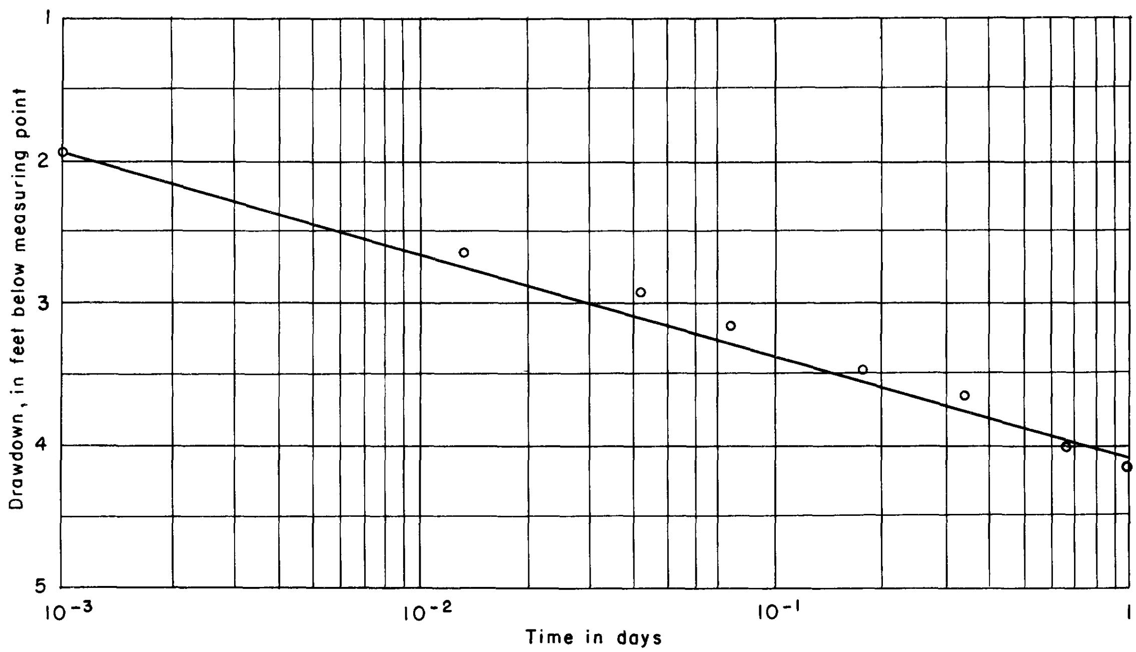

Figure 10. Theoretical drawdown in well 4 when pumping wells 1, 2, and 4 simultaneously at 100 gpm.

At present well spacings, the maximum drawdown of water level in the observation wells will be less than 0.3 foot after the first 24 hours of pumping of well 3 at 100 gpm. With only this well pumping, the rate of decline of the water level should decrease with time. An increase in the pumping rate of well 3 or the pumping of two or more wells simultaneously will alter this pattern. Doubling the pumping rate of well 3 will in effect cause an initial decline of water level of approximately 4 feet at the pumping well and approximately 0.6 foot in each of the observation wells. Pumping of wells 1, 2, and 4 simultaneously at 100 gpm will result in a maximum drawdown at well 4 of approximately 4.0 feet after 24 hours. The drawdown in the following 24-hour period would be approximately 0.4 foot at well 4 and the rate would decrease slightly thereafter. Well 3 was not included in the latter analysis to allow for maximum distance and therefore minimum interference between wells.

TABLE 1. SUMMARY OF VALUES FOR T AND S OBTAINED BY THE JACOB METHOD

Well no.	Coefficient of transmissibility (gallons per day per foot)	Coefficient of storage
1	272,500	0.00036
2	275,000	.00011
3	316,800	--
4	310,000	.00028

TABLE 2. DRAWDOWN DATA FOR WELL 1, GENERAL TIRE AND RUBBER CO., MAYFIELD, KY.

Clock time	Elapsed time (minutes)	Elapsed time (days) t	Water level in well (feet below measuring point)	Drawdown (feet below measuring point)	Barometer (feet of water)	Change in barometer (feet of water)	Adjusted drawdown (feet below measuring point)
1540	pump on	--	19.86	0.00	33.93	0.00	0.00
1545	5	3.47×10^{-3}	19.87	.01	33.93	.00	.01
1600	20	1.39×10^{-2}	19.89	.03	33.94	0.01	.02
1630	50	3.47×10^{-2}	19.92	.06	33.97	.04	.02
1745	125	8.68×10^{-2}	20.03	.17	34.00	.07	.10
1900	200	1.39×10^{-1}	20.09	.23	34.05	.12	.11
2030	290	2.01×10^{-1}	20.14	.28	34.08	.15	.13
2200	380	2.64×10^{-1}	20.18	.32	34.10	.17	.15
2400	500	3.47×10^{-1}	20.20	.34	34.11	.18	.16
0300	680	4.72×10^{-1}	20.23	.37	34.13	.20	.17
0700	920	6.39×10^{-1}	20.26	.40	34.21	.28	.12
1200	1220	8.47×10^{-1}	20.29	.43	34.22	.29	.14
1615	1475	1.024	20.24	.38	34.17	.24	.14

TABLE 3. DRAWDOWN DATA FOR WELL 2, GENERAL TIRE AND RUBBER CO., MAYFIELD, KY.

Clock time	Elapsed time (minutes)	Elapsed time (days) t	Water level in well (feet below measuring point)	Drawdown (feet below measuring point)	Barometer (feet of water)	Change in barometer (feet of water)	Adjusted drawdown (feet below measuring point)
1540	pump on	--	26.16	0.00	33.93	0.00	0.00
1545	5	3.47×10^{-3}	26.17	.01	33.93	.00	.01
1600	20	1.39×10^{-2}	26.26	.10	33.94	0.01	.09
1630	50	3.47×10^{-2}	26.33	.17	33.97	.04	.13
1745	125	8.68×10^{-2}	26.41	.25	34.00	.07	.18
1900	200	1.39×10^{-1}	26.46	.30	34.05	.12	.18
2030	290	2.01×10^{-1}	26.51	.35	34.08	.15	.20
2200	380	2.62×10^{-1}	26.54	.38	34.10	.17	.21
2400	500	3.47×10^{-1}	26.57	.41	34.11	.18	.23
0300	680	4.72×10^{-1}	26.60	.44	34.13	.20	.24
0700	920	6.39×10^{-1}	26.64	.48	34.21	.28	.20
1200	1220	8.47×10^{-1}	26.68	.52	34.22	.29	.23
1615	1475	1.024	26.64	.48	34.17	.24	.24

TABLE 4. DRAWDOWN DATA FOR WELL 3, GENERAL TIRE AND RUBBER CO., MAYFIELD, KY.

Clock time	Elapsed time (minutes)	Time since pump on (days) t	Water level in well (feet below measuring point)	Drawdown (feet below measuring point)	Barometer (feet of water)	Change in barometer (feet of water)	Adjusted drawdown (feet below measuring point)
1455	--	--	23.35	0.00	00.00	0.00	0.00
1537	--	--	23.36	.00	33.92	.0	.00
1540	0	--	pump on	.00	.00	.0	.00
1545	5	$3.48x10^{-3}$	24.83	1.47	33.93	.01	1.46
1554	14	$.97x10^{-3}$	24.95	1.59	33.93	.01	1.58
1601	21	$1.46x10^{-2}$	24.98	1.62	33.94	.02	1.60
1621	41	$2.84x10^{-2}$	25.06	1.70	33.94	.02	1.68
1640	60	$4.15x10^{-2}$	25.08	1.72	33.96	.04	1.68
1656	76	$5.28x10^{-2}$	25.10	1.74	33.97	.05	1.69
1723	103	$7.16x10^{-2}$	25.13	1.77	33.98	.06	1.71
1802	142	$9.88x10^{-2}$	25.16	1.80	34.01	.09	1.71
1840	180	$1.25x10^{-1}$	25.18	1.82	34.03	.11	1.71
2111	331	$2.31x10^{-1}$	25.27	1.91	34.09	.17	1.74
2203	383	$2.66x10^{-1}$	25.30	1.94	34.10	.18	1.76
0836	1016	$7.06x10^{-1}$	25.39	2.03	34.23	.31	1.72
0928	1068	$7.42x10^{-1}$	25.41	2.05	34.23	.31	1.74
1606	1466	1.085	25.38	2.02	34.17	.25	1.77
1612	1472	1.09	25.38	2.02	34.17	.25	1.77
1615	1475	1.095	pump off				
1615.5			24.05	.69	34.17	.25	.44
1616.5			23.92	.56	34.17	.25	.31
1621			23.85	.49	34.18	.26	.23
1626			23.80	.44	34.18	.26	.18
1630			23.78	.42	34.18	.26	.16
1705			23.68	.32	34.18	.26	.06
1806			23.64	.28	34.20	.28	.00

TABLE 5. DRAWDOWN DATA FOR WELL 4, GENERAL TIRE AND RUBBER CO., MAYFIELD, KY.

Clock time	Elapsed time (minutes)	Elapsed time (days) t	Water level in well (feet below measuring point)	Drawdown (feet below measuring point)	Barometer (feet of water)	Change in barometer (feet of water)	Adjusted drawdown (feet below measuring point)
1540	pump on	--	19.33	0.00	33.93	0.00	0.00
1545	5	$3.47x10^{-3}$	19.34	0.01	33.93	.00	0.01
1600	20	$1.39x10^{-2}$	19.39	.06	33.94	0.01	.05
1630	50	$3.47x10^{-2}$	19.45	.12	33.97	.04	.08
1745	125	$8.68x10^{-2}$	19.52	.19	34.00	.07	.12
1900	200	$1.39x10^{-1}$	19.57	.24	34.05	.12	.12
2030	290	$2.01x10^{-1}$	19.63	.30	34.08	.15	.15
2200	380	$2.64x10^{-1}$	19.66	.33	34.10	.17	.16
2400	500	$3.47x10^{-1}$	19.69	.36	34.11	.18	.18
0300	680	$4.72x10^{-1}$	19.71	.38	34.13	.20	.18
0700	920	$6.39x10^{-1}$	19.74	.41	34.21	.28	.13
1200	1220	$8.47x10^{-1}$	19.78	.45	34.22	.29	.16
1615	1475	1.024	19.74	.41	34.17	.24	.17