

KANSAS GEOLOGICAL SURVEY OPEN-FILE REPORT 71-2

GROUND WATER IN HASKELL COUNTY, SOUTHWESTERN KANSAS

By

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For publication in the
U.S. Geological Survey
Hydrologic Investigations Atlas Series

Prepared in cooperation with the
State Geological Survey of Kansas
Kansas State Department of Health
Kansas State Board of Agriculture

1971

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GENERAL GEOLOGY AND HYDROLOGY

Unconsolidated Deposits

Tertiary and Quaternary deposits underlie all Haskell County and range in thickness from about 300 feet in the northeast corner to about 600 feet in the central part (surficial geologic map).

Figure 1 near here. Caption on following page.

The Ogallala Formation of Pliocene age, which does not crop out, overlies older consolidated rocks at depth. The Ogallala consists of individual and admixed layers of stream-deposited clay, silt, sand, and gravel. Calcium carbonate commonly forms caliche in the clay and silt deposits, and cements the sand and gravel into "mortar beds."

Figure 1.--Map showing surficial geology and thickness of unconsolidated deposits.

Undifferentiated Pleistocene deposits crop out along the walls of the Cimarron River valley. They overlies the Ogallala Formation in much of the county, but also are in contact with older consolidated rocks where the Ogallala was removed by Pleistocene erosion. These Pleistocene sediments consist of sand and gravel deposited in major channels, and clay, silt, and sand deposited on a flood plain. Because the lithology and hydrology of the Pliocene and Pleistocene deposits are similar, differentiation of the geologic units in the subsurface is impracticable.

Loess of late Pleistocene age underlies most of the county and the soil formed on the loess is ideally suited for farming. Dune sand of late Pleistocene age underlies part of the northern township of the county and is suitable for rangeland or irrigation by sprinkler systems. Quaternary alluvium, which consists of coarse-grained deposits of late Pleistocene age overlain by fine-grained deposits of Holocene age, underlies the flood plain of the Cimarron River.

Bedrock Formations

Consolidated rocks (referred to as bedrock), which underlie the unconsolidated Tertiary and Quaternary deposits, range in age from Permian to Cretaceous, as shown on the bedrock geologic map.

Figure 2 near here. Caption on following page.

Contours of the bedrock surface indicate that a broad drainage system developed in central Haskell County, was joined by an eastward-trending channel from Grant County, and flowed out of the county at the southeast corner. Two deeply incised channels trend southeastward across the northeast and southwest corners of the county.

In the southeast and southwest corners of the county, the bedrock surface is eroded on undifferentiated Upper Permian rocks. The bedrock surface in the rest of the county is formed successively on undifferentiated Upper Jurassic rocks, undifferentiated Lower Cretaceous rocks, and the Upper Cretaceous Graneros Shale. These rocks subcrop in normal stratigraphic position from the oldest to the youngest as the altitude of the bedrock surface rises northward. The dip of the bedrock formations is northeastward.

Figure 2.--Map showing bedrock geology and configuration of the bedrock surface.

Sandstone Aquifer

The sandstone aquifer is defined here to include the Upper Jurassic and Lower Cretaceous rocks in Haskell County. The Upper Jurassic rocks consist mostly of shale, with a silty sandstone unit near the base. The Lower Cretaceous rocks consist of sandstone interbedded with shale. The lithology of these formations differs within short distances and individual units are difficult to trace. Because of the varied lithology, the entire section is defined as an aquifer although only part of this unit yields water to wells. The sandstones commonly yield less than 300 gpm (gallons per minute), but uncemented zones may yield more than 1,000 gpm to wells.

The thickness of the sandstone aquifer (map) ranges from zero in

Figure 3 near here. Caption on following page.

the southern part of the county (where the formations have been removed by erosion) to more than 400 feet in the northeast corner. This aquifer directly underlies the unconsolidated deposits, except in the northeast corner where it is covered by a thin layer of Graneros Shale, which is not known to yield water to wells. Thus, contours showing thickness of unconsolidated deposits (surficial geologic map) mainly indicate the depth to the top of the sandstone aquifer, which ranges from about 300 to 600 feet below land surface. The sandstone aquifer is underlain by Permian rocks (red beds), which are not a source of potable water. Thus, the Permian surface represents the maximum depth of test drilling for water wells. The depth to the top of Permian rocks at any location in Haskell County can be estimated by adding the thickness of unconsolidated deposits to the thickness of the sandstone aquifer.

Figure 3.--Map showing thickness of sandstone aquifer.

Relation of Stratigraphy and Hydrology

A generalized block diagram illustrates the relation of water levels

Figure 4 near here. Caption on following page.

in 1970 to the thickness of unconsolidated deposits and the relation of the bedrock surface to the underlying bedrock units. The upper block relates the water table to the land surface (depth to water) and the thickness of the water-bearing materials in the Tertiary and Quaternary deposits. The lower block shows the geology and configuration of the bedrock surface, and relates the sandstone aquifer to the other bedrock units.

Figure 4.--Generalized block diagram.

Electric Logging

Electric logs, used in conjunction with drillers' logs, are useful in defining potential water-yielding zones. The generalized electric log relates depth below land surface with the electrical properties of the

Figure 5 near here. Caption on following page.

strata penetrated in a typical drill hole in Haskell County. Variations in response of the spontaneous potential and resistivity curves aid in determining the thickness of lithologic units and the relative permeability of the materials. The generalized section showing the thickness, lithology,

Table 1 near here.

and water-yielding potential of the geologic units discussed in this report can be used in conjunction with the generalized electric log to visualize the probable type of response for each lithologic unit.

Figure 5.--Generalized electric log of typical drill hole.

Table 1.--Generalized section of geologic units and water-yielding characteristics.

Note: The classification and nomenclature of the stratigraphic units used in this report are those of the U.S. Geological Survey and differ somewhat from those of the State Geological Survey of Kansas.

Sys-tem	Series	Stratigraphic unit	Thickness, feet	Physical character	Water supply
Quaternary	Holocene and Pleistocene	Alluvium	0-60	Clay, silt, and sand of Holocene age overlying sand, gravel, and cobbles of late Pleistocene age. Occurs in the Cimarron River valley, and underlies about 1 percent of the county.	A potential aquifer, untested in Haskell County. May yield 50 to 300 gpm (gallons per minute) to wells.
	Pleistocene	Dune sand	0-75	Fine to medium quartzose sand with lesser amounts of clay, silt, and coarse sand formed into small hills and mounds by wind action. Located principally in the northern part of the county, and underlies about 7 percent of the county.	Lies above the water table, and does not yield water to wells.
		Loess	0-30	Wind-blown silt underlies about 91 percent of the county.	
		Undifferentiated deposits	250-550	Medium to very coarse sand and gravel interbedded with clay, silt, and fine sand; contains caliche and "mortar beds." Exposed along the Cimarron River valley where it underlies about 1 percent of the county.	The sand and gravel beds are the principal water-yielding deposits in the county. Yields to irrigation wells range from 500 to more than 2,500 gpm.
Tertiary	Pliocene	Ogallala Formation	0-300	Poorly sorted clay, silt, sand, and gravel; contains caliche and "mortar beds."	
Cretaceous	Upper Cretaceous	Graneros Shale	0-30	Dark-gray calcareous shale interbedded with black noncalcareous shale.	Not known to yield water to wells in Haskell County.
	Lower Cretaceous	Undifferentiated rocks	0-260	Yellow, brown, and gray fine- to medium-grained sandstone; interbedded with varicolored shale and dark-gray to black shale.	The sandstones within the unit commonly yield 30 to 300 gpm to wells. Yields of more than 1,000 gpm are reported in a few areas.
Jurassic	Upper Jurassic	Undifferentiated rocks	0-160	Dark-gray noncalcareous shale; interbedded with grayish-green and bluish-green calcareous shale. Contains very fine to medium-grained silty sandstone at the base.	
Permian	Upper Permian	Undifferentiated rocks	200-400	Red shale, sandstone, sandy shale, and anhydrite.	Yields no potable water to wells in Haskell County.

HYDROLOGY OF UNCONSOLIDATED AQUIFER

Occurrence and Thickness

Unconsolidated alluvial deposits of Tertiary and Quaternary age are the principal aquifer in most of Haskell County. These deposits consist of lenses of clay, silt, sand, and gravel that affect the water-yielding capacity and degree of confinement (artesian pressure) within the aquifer.

Ground-water movement is east-southeastward, as shown by the water-level contours on the hydrologic map. Water enters the aquifer by under-

Figure 6(A) near here. Caption on following page.

flow from the west and north, by infiltration of precipitation on the county, by percolation of water applied for irrigation, and by infiltration from the Cimarron River. Ground water is discharged primarily by pumping from wells, and by underflow to the southeast. The closely spaced water-level contours in the northwestern part of the county indicate restricted ground-water flow, probably due to a greater percentage of clayey deposits than elsewhere.

Figure 6.--~~Hydrology~~ Hydrology map showing water-level contours, saturated thickness, and location of large-capacity wells (January 1970).

The thickness of saturated deposits, shown by pattern on the hydrologic map, ranges from about 250 to 400 feet with an average thickness in

Figure 6(B) near here. Caption on following page.

the county of 330 feet. Many irrigation wells do not penetrate the total saturated thickness, but penetrate only enough water-yielding material to satisfy the production requirements of the irrigator. As shown on the hydrologic map, about 500 wells, most of which were used for irrigation, were in use in January 1970.

Aquifer Characteristics

The principal characteristics of an aquifer are its ability to store and transmit water. The ability to store water is expressed by the storage coefficient, and the ability to transmit water is expressed by the transmissivity.

The storage coefficient is a measure of the volume of water that an aquifer releases from or takes into storage from 1 square foot of the aquifer surface per foot of water-level change. If water in the aquifer is unconfined, the storage coefficient approaches the value obtained from gravity drainage of the interstices in the dewatered part of the aquifer.

Transmissivity is the rate at which water is transmitted through a column of the aquifer 1 foot wide under a hydraulic gradient of 1 foot per foot. Hydraulic conductivity is defined as the volume of water, in cubic feet per day, that passes through 1 square foot of the aquifer under a hydraulic gradient of 1 foot per foot. Hydraulic conductivity, as used in this study, is transmissivity divided by the thickness of water-yielding materials.

Figure 6.--Map showing water-level contours, saturated thickness, and location of large-capacity wells (January 1970).

Part (B) saturated thickness.

The transmissivity and storage coefficient can be determined by several types of aquifer-test analyses using the discharge of a well and the related changes of water levels in the pumped well and in nearby observation wells. During this investigation five aquifer tests were made to determine the aquifer characteristics. Data from these tests are tabulated in the summary of aquifer tests. Storage coefficients that range from 0.15

Table 2 near here.

to 0.22 indicate unconfined conditions in the principal water-yielding deposits. A storage coefficient of 0.01 reflects the influence of semi-confinement in the water-yielding deposits at that site.

Potential Yield to Wells

Analysis of drillers' well-performance tests from a sampling of 125 of the existing irrigation wells indicates a general correlation between percent penetration of total saturated thickness, effective thickness (water-yielding material, in both feet and percent) of total saturated deposits, and calculated specific capacity of the well (in gallons per minute per foot of drawdown). The summary table of well-performance tests lists these

Table 3 near here.

factors by townships.

Table 2.--Summary of aquifer tests.

Well location	Effective thickness (feet)	Hydraulic conductivity (ft per day)	Transmissivity (ft ² per day)	Storage coefficient
SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec.31, T.26 S., R.32 W. (Finney County)	139	87	12,000	0.22
NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec.2, T.28 S., R.31 W.	155	220	35,000	.20
SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec.16, T.27 S., R.34 W.	142	180	26,000	.18
NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec.18, T.28 S., R.32 W.	200	200	40,000	.15
NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec.28, T.27 S., R.34 W.	130	70	9,000	.01

Table 3.--Summary of well-performance tests of producing wells.

Township and range	Percentage penetration of saturated deposit	<u>Effective thickness</u>		Specific capacity (gpm per ft drawdown)
		(percent)	(feet)	
27 S., 31 W.	26-77 51 avg.	46-92 75 avg.	61-226 122 avg.	30-105 72 avg.
27 S., 32 W.	28-100 68 avg.	42-96 70 avg.	84-231 154 avg.	33-123 78 avg.
27 S., 33 W.	29-75 55 avg.	39-94 70 avg.	89-242 148 avg.	30-121 84 avg.
27 S., 34 W.	39-100 64 avg.	41-75 65 avg.	82-146 118 avg.	30-77 54 avg.
28 S., 31 W.	33-100 62 avg.	43-100 66 avg.	93-180 143 avg.	26-135 65 avg.
28 S., 32 W.	66-100 83 avg.	43-78 52 avg.	112-200 147 avg.	29-125 59 avg.
28 S., 33 W.	88-100 98 avg.	39-50 45 avg.	151-177 164 avg.	16-65 41 avg.
28 S., 34 W.	48-100 81 avg.	44-75 57 avg.	108-159 132 avg.	32-46 41 avg.
29 S., 31 W.	35-100 73 avg.	32-92 70 avg.	80-218 149 avg.	40-104 72 avg.
29 S., 32 W.	53-80 66 avg.	33-93 67 avg.	80-168 145 avg.	31-53 39 avg.
29 S., 33 W.	50-100 73 avg.	34-58 47 avg.	103-142 116 avg.	37-53 46 avg.

Table 3.--Summary of well-performance tests of producing wells--continued.

Township and range	Percentage penetration of saturated deposit	<u>Effective thickness</u>		Specific capacity (gpm per ft drawdown)
		(percent)	(feet)	
29 S., 34 W.	60-100 93 avg.	32-79 47 avg.	100-168 122 avg.	28-120 56 avg.
30 S., 31 W.	62-80 70 avg.	39-81 56 avg.	75-170 125 avg.	50-100 69 avg.
30 S., 32 W.	57-100 79 avg.	29-80 58 avg.	114-189 140 avg.	20-67 49 avg.
30 S., 33 W.	58-100 71 avg.	51-69 61 avg.	117-134 126 avg.	41-70 56 avg.
30 S., 34 W.	85-100 91 avg.	37-70 56 avg.	100-170 140 avg.	62-92 74 avg.

Percentage penetration is calculated from the ratio of saturated materials penetrated by an irrigation well to the total saturated thickness of aquifer at that site. The effective thickness is that part of the saturated material that yields most of the water to the well. Specific capacity, as determined from drillers' tests, is the ability of the well to obtain water from the aquifer when the well is pumped at a rate sufficient to produce a drawdown equivalent to 70 percent of the effective thickness.

The specific capacities of wells penetrating coarse-grained deposits greatly exceed those of wells penetrating fine-grained deposits.

In areas of loose coarse-grained deposits in the upper part of the aquifer many wells with a low percent penetration obtain large yields, whereas in areas of fine-grained material wells must penetrate most of the aquifer to obtain a yield adequate for irrigation.

Data from the summary table of well-performance tests were used in preparation of the potential yield map. The map shows that well yields

Figure 7 near here. Caption on following page.

of 1,000 to 2,500 gpm are available everywhere in the county if the full saturated thickness of the unconsolidated deposits is penetrated. Locally, however, test drilling may be required to locate a thickness of water-yielding material adequate for such large yields. The map also shows that well yields of 500 to 2,500 gpm are available from depths of 200 feet or less in the northern and eastern parts of the county.

Figure 7.--Map showing potential yield to wells.

Water-Level Changes

Ground-water withdrawals for irrigation have removed water from storage and caused a decline in water levels. Changes in water level reflect the response of the aquifer to changes in recharge and discharge rates. To evaluate the water-level change in the unconsolidated aquifer, data collected during 1941 (McLaughlin, 1946) are compared with measurements made in 1970. Ground-water pumpage prior to 1941 was insignificant and the measurements made in 1941 are considered to be representative of equilibrium conditions (recharge equal to discharge). Water levels in 1970 were measured in January when the effects of seasonal pumping are at a minimum.

Water-level declines from 1941 to 1970 (map of water-level decline) range from less than 10 feet to more than 30 feet, with an average decline

Figure 8 near here. Caption on following page.

of 15 feet. The greatest decline is in T.28 S., R.34 W., where recharge by lateral flow into the area of pumping is retarded by clayey deposits to the northwest.

Figure 8.--Map showing water-level decline, 1941-70.

Irrigation Development

The period from June 28, 1945 (effective date of the Kansas Water Appropriation Act), through 1952 was one of little irrigation development. Development proceeded from 1953 through 1969 at an average rate of about 30 applications per year to appropriate water. Data on the number of applications to appropriate ground water and the number of square miles under application, as shown on the graph, are from the records of the Division of

Figure 9 near here. Caption on following page.

Water Resources of the Kansas State Board of Agriculture. The cumulative number of applications to appropriate ground water differs from the number of wells in use in January 1970 because the wells may not be completed in the year the applications were filed.

Note to be placed on sheet 2 of Hydrologic Investigations Atlas: Additional information on drillers' logs and well production is available in the office of the U. S. Geological Survey, Garden City, Kans., and may be examined there.

Figure 9.--Graph showing cumulative number of applications to appropriate ground water and area under application.

CHEMICAL QUALITY OF GROUND WATER

Water in the unconsolidated aquifer is a calcium bicarbonate type and is suitable for domestic, stock, and irrigation use. The water, which generally has a hardness of 150 to 280 mg/l (milligrams per liter), is classed as hard to very hard. Hardness of water is classified by the U.S. Geological Survey as follows: 0-60 mg/l, soft; 61-120 mg/l, moderately hard; 121-180 mg/l, hard; and more than 180 mg/l, very hard.

The selected chemical analyses table indicates that depth generally

Table 4 near here.

has little effect on water quality where the unconsolidated deposits are underlain by Jurassic or Cretaceous rocks. The higher sulfate concentration in water from wells in the southern part of the county indicates that the water in the lower part of the unconsolidated aquifer has dissolved gypsum that was derived from Permian rocks.

Table 4.--Selected chemical analyses.
 [Chemical constituents in milligrams per liter.
 Analyses by Kansas State Department of Health]

Date sampled	Depth (feet)	Tem- pera- ture (°C)	Dis- solved solids	Silica (SiO ₂)	Iron (Fe)	Man- gan- ese (Mn)	Cal- cium (Ca)	Mag- ne- sium (Mg)	Sodium and potas- sium (Na+K)	Bicar- bon- ate (HCO ₃)	Sul- fate (SO ₄)	Chlo- ride (Cl)	Fluo- ride (F)	Ni- trate (NO ₃)	Hardness	
															Total	Non- car- bon- ate
W. 8-05-64	200	16.0	199	17	0.00	0.00	47	7.6	13	176	12	9.0	0.2	6.6	150	4
W. 5-03-66	360	17.0	265	17	.00	.00	50	10	29	198	44	11	.9	6.2	170	4
W. 4-03-70	590	17.0	245	18	.09	.00	43	11	27	185	36	8.0	.6	6.2	150	0
W. 5-03-66	415	17.5	482	28	.00	.00	70	26	52	212	167	20	1.0	13	280	110
W. 7-30-69	532	17.5	465	25	.13	.00	62	30	46	210	154	20	1.1	9.7	280	110

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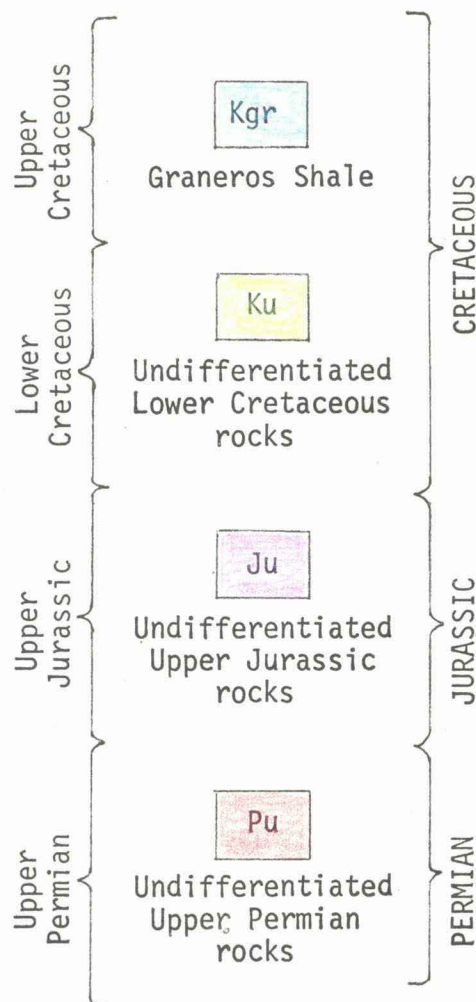
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EXPLANATION



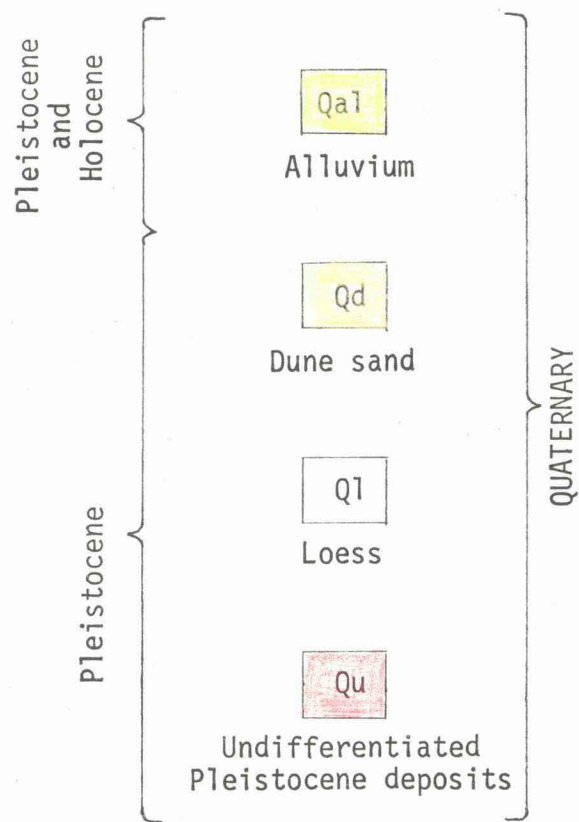
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Bedrock contour.
Shows altitude of
bedrock surface

Contour interval 50 feet
Datum is mean sea level

EXPLANATION



Contact

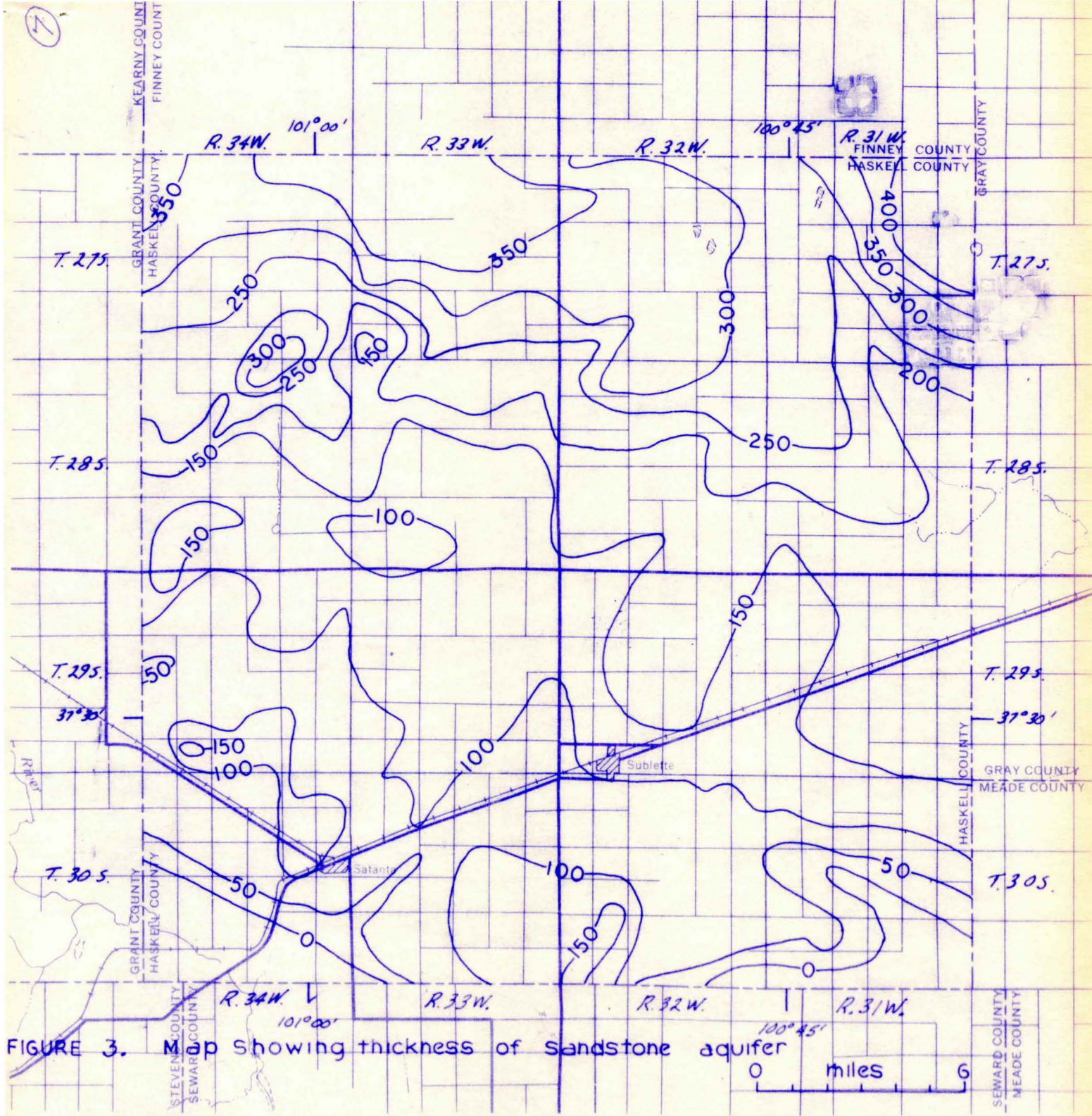
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Line of equal thickness
of unconsolidated deposits
Interval 50 feet

EXPLANATION

300

Line of equal
thickness of
sandstone aquifer
Interval 50 feet



Base by U.S. Geological Survey, 1955

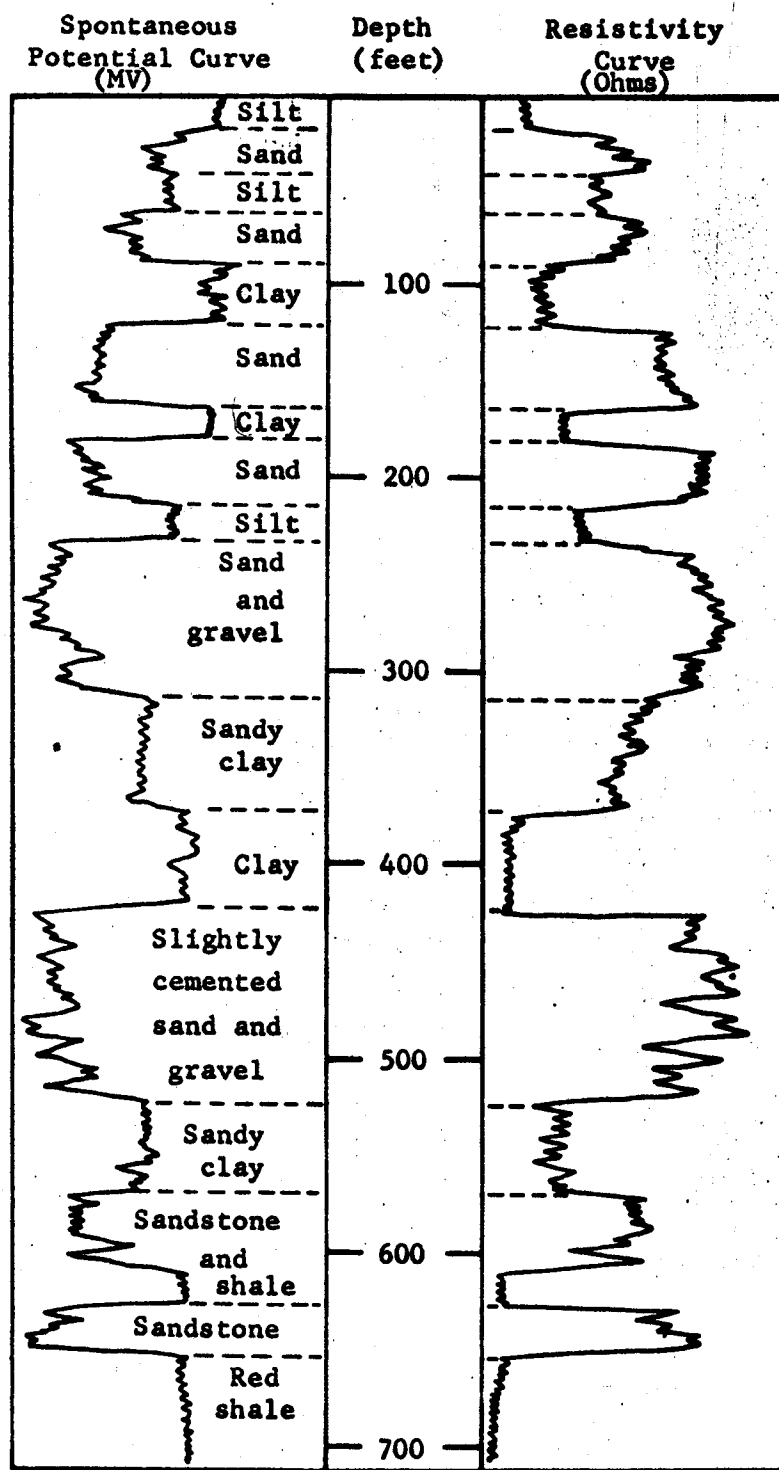
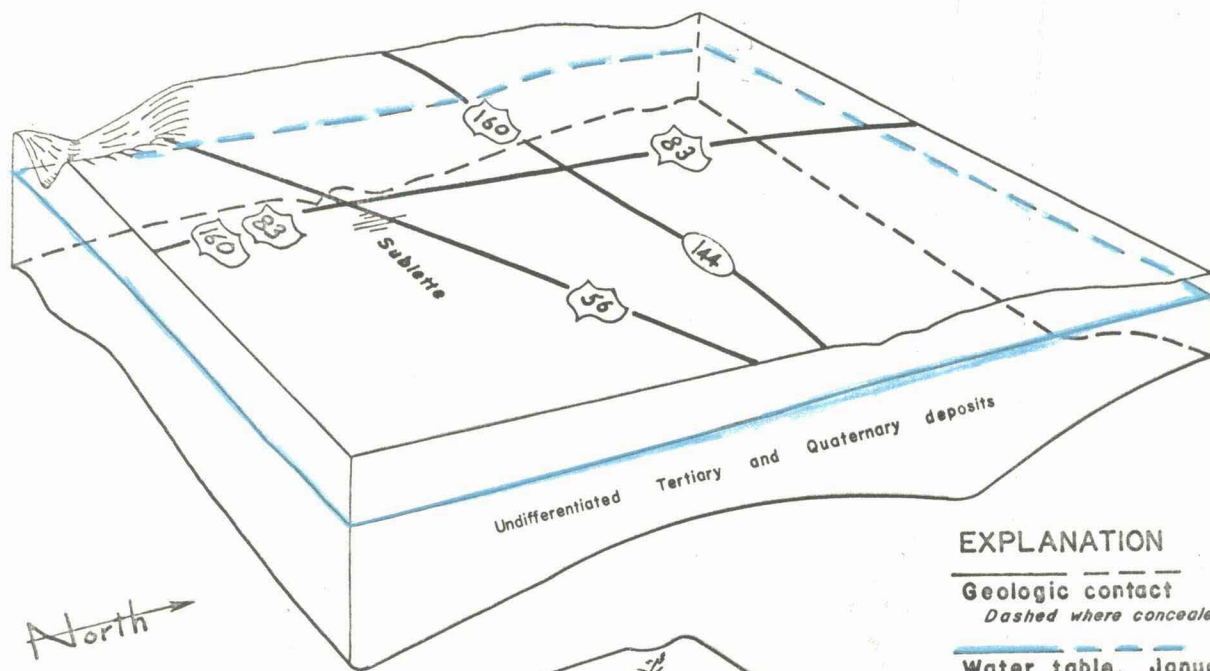


Figure 5--Generalized electric log of typical drill hole.



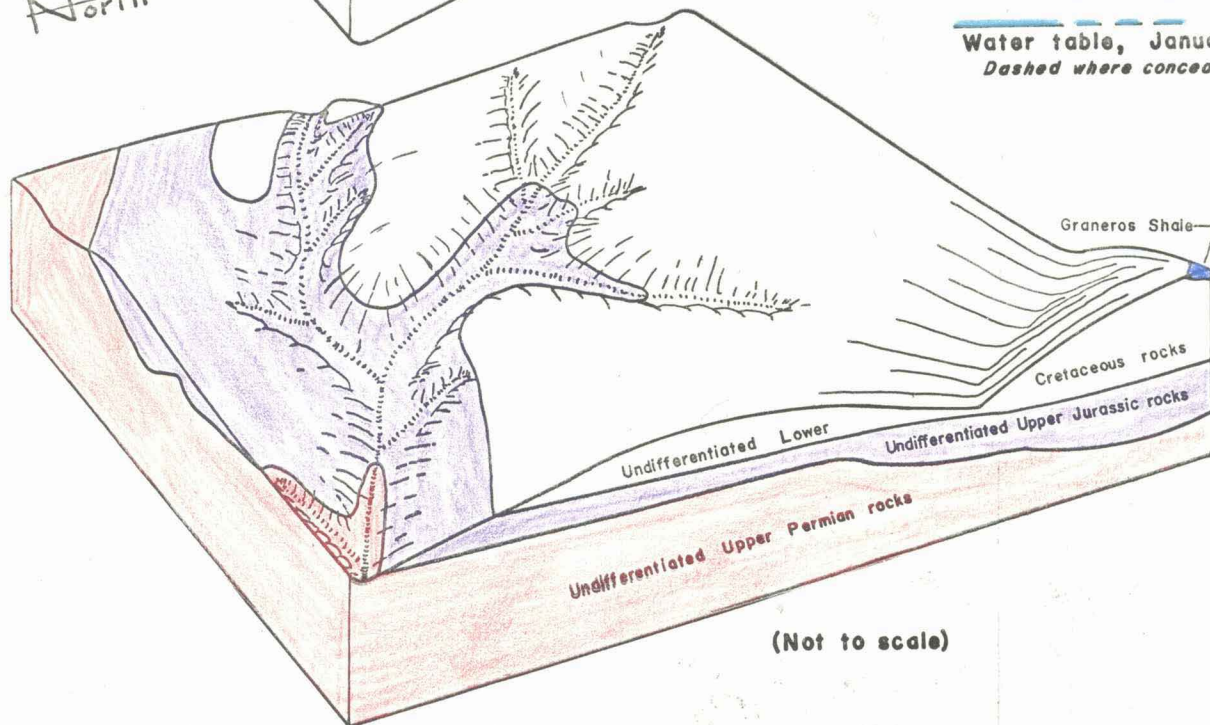
EXPLANATION

Geologic contact

Dashed where concealed

Water table, January 1970

Dashed where concealed



1 ms -- Water table line to be published in blue.

Figure 4. Generalized Block diagram

EXPLANATION

①

Large-capacity well
(more than 300 gpm);
includes municipal
and irrigation wells

2750

Water-level contours
Show altitude of water level
Contour interval 10 feet
Datum is mean sea level

EXPLANATION

—300—
Line of equal
saturated thickness

THICKNESS OF SATURATED ALLUVIAL DEPOSITS, IN FEET



Less than 250



250-300



300-350



350-400



More than 400

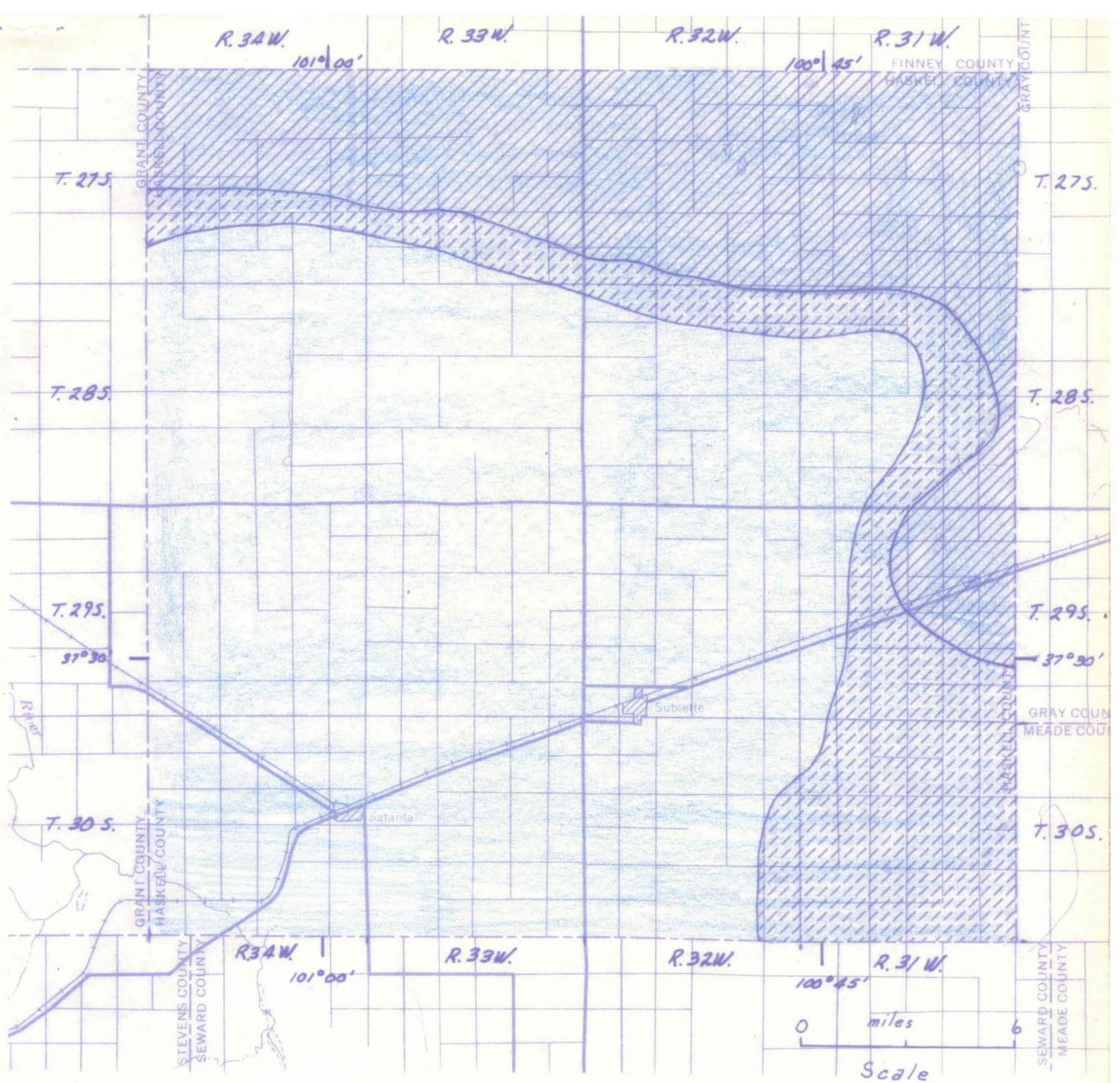


Figure 7. Map showing potential yield to wells

Base by U. S. Geological Survey, 1956

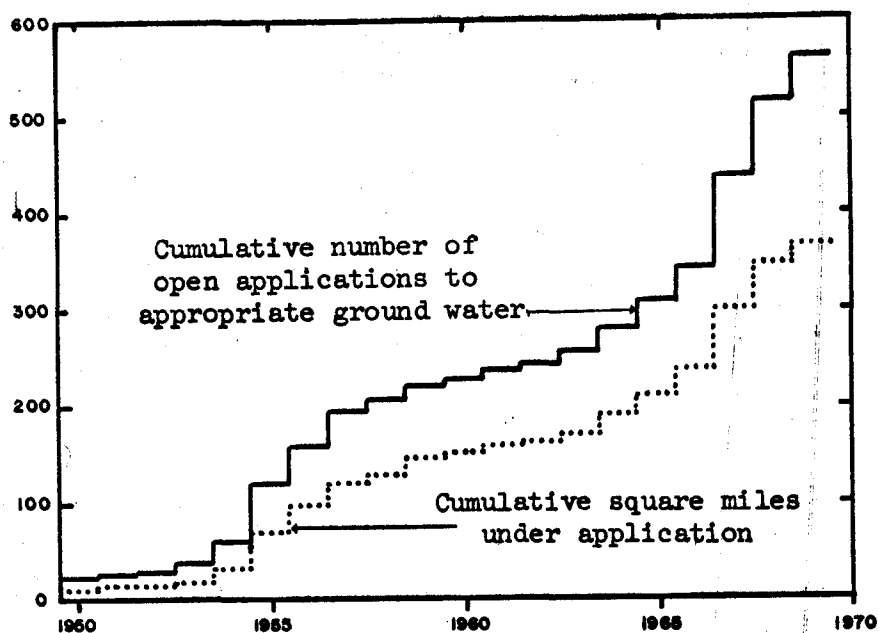


Figure 9. -- Cumulative number of applications to appropriate ground-water and area under application.

EXPLANATION

Water-level decline,
in feet



Less than 10



10-20



20-30



More than 30

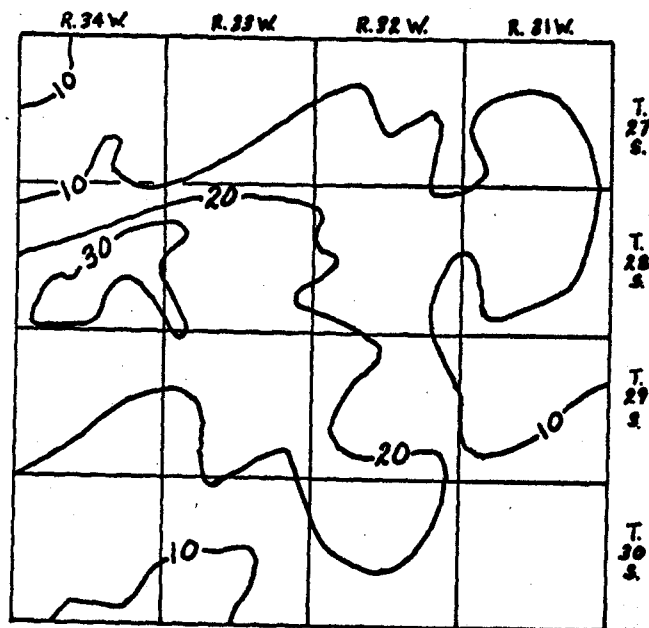


Figure 8.--Water-level decline, 1941-1970

0 6 miles
Scale 1:500,000