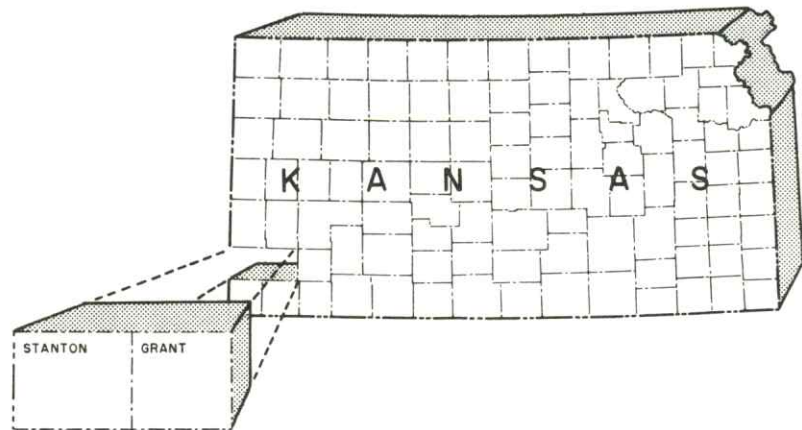


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Water-Level Changes in Grant and Stanton Counties, Kansas, 1939-1968

By John D. Winslow, Harold E. McGovern,
and Harris L. Mackey



State Geological Survey
The University of Kansas
Lawrence, Kansas

1968

Special Distribution Publication 37

STATE GEOLOGICAL SURVEY OF KANSAS

Frank C. Foley, Director



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Prepared as part of the cooperative ground-water program in Kansas conducted by the United States Geological Survey, the State Geological Survey of Kansas, the Division of Water Resources of the Kansas State Board of Agriculture, and the Environmental Health Services of the Kansas State Department of Health.

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WATER-LEVEL CHANGES IN GRANT AND STANTON COUNTIES, KANSAS, 1939-1968¹

by

John D. Winslow², Harold E. McGovern², and Harris L. Mackey³

INTRODUCTION

Water levels continued to decline in Grant and Stanton Counties as a result of increasing use of ground water for irrigation. The magnitude of this decline has differed from year to year in response to changing climatic conditions and irrigation practices. The general trend, however, indicates that the withdrawals have resulted in a progressive reduction of ground water in storage.

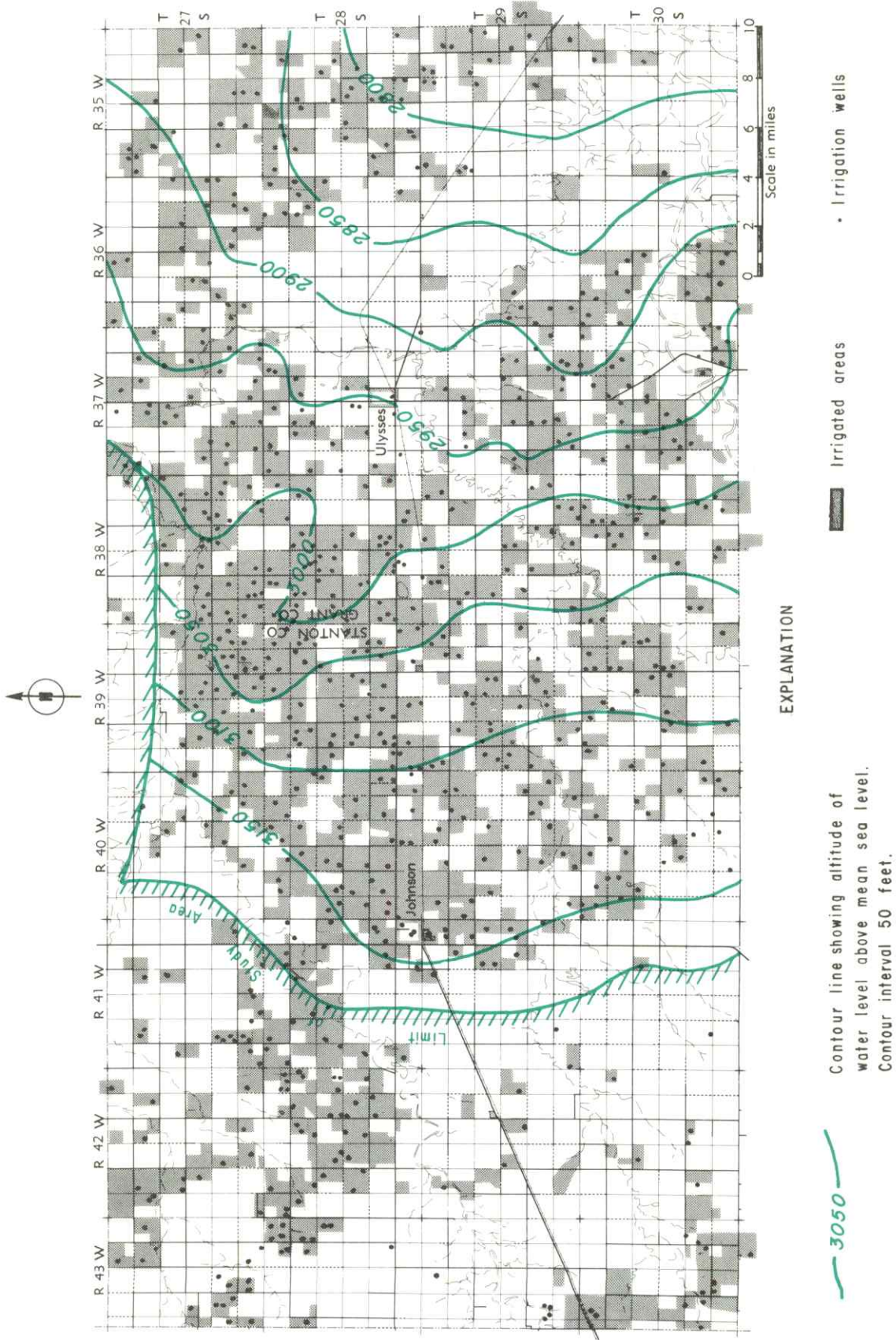
The purpose of this publication, the third in a series of short reports on the subject, is to present the pertinent data collected and to analyze the water-level fluctuations since 1939. The data shown in the graphs and illustrations indicate the seriousness of the water-supply problem. These data also provide a preview of conditions that may develop in other areas of western Kansas as use of ground water for irrigation expands.

The data presented were collected as part of the cooperative program of ground-water investigations of Kansas being conducted by the U.S. Geological Survey, the State Geological Survey of Kansas, the Division of Water Resources of the Kansas State Board of Agriculture, and the Environmental Health Services of the Kansas Department of Health. The nomenclature and classification of the geologic units

¹ *Publication authorized by the Director, U.S. Geological Survey.*

² *Water Resources Division, U.S. Geological Survey.*

³ *Division of Water Resources, Kansas State Board of Agriculture.*



EXPLANATION

— 3050 —
 Contour line showing altitude of
 water level above mean sea level.
 Contour interval 50 feet.

■ Irrigated areas

• Irrigation wells

Figure 1.--Location of irrigation wells, irrigated areas, and water-level contours as of January 1, 1968. (Modified after Fader and others, 1964.)

described in this report are those of the State Geological Survey of Kansas, which differ somewhat from usage adopted by the U.S. Geological Survey.

DEVELOPMENT OF WATER USE

In 1940, approximately 15 irrigation wells were in use in Grant and Stanton Counties. The number of wells increased to about 550 by December 1963 and to about 850 by December 1967. The drought between 1953 and 1956 was a significant factor contributing to the great increase in irrigation in the area because it pointed out the economic advantages of irrigation farming.

The location of wells and the areas of irrigation in Grant and Stanton Counties are shown in figure 1. This map was modified from a similar map by Fader and others (1964) to include current data (January 1, 1968) in the water-rights file of the Division of Water Resources of the Kansas State Board of Agriculture. The irrigated areas listed on water rights were 263,000 acres as of January 1, 1968, an increase of about 48,000 acres since January 1965 (fig. 2). The authorized annual water use for the two-county area was 564,000 acre-feet as of January 1968, an increase of more than 104,000 acre-feet since January 1965.

WATER-BEARING FORMATIONS

The principal water-bearing formations in Grant and Stanton Counties are the alluvial deposits of Tertiary and Quaternary age and the sandstones of Jurassic(?) and Cretaceous age. Table 1 shows the geologic formations and their water-bearing properties. The general relation of geologic units in the subsurface is illustrated by the geologic section on the back cover of the report. A detailed description of the geology may be found in reports by Latta (1941), McLaughlin (1946), and Fader and others (1964).

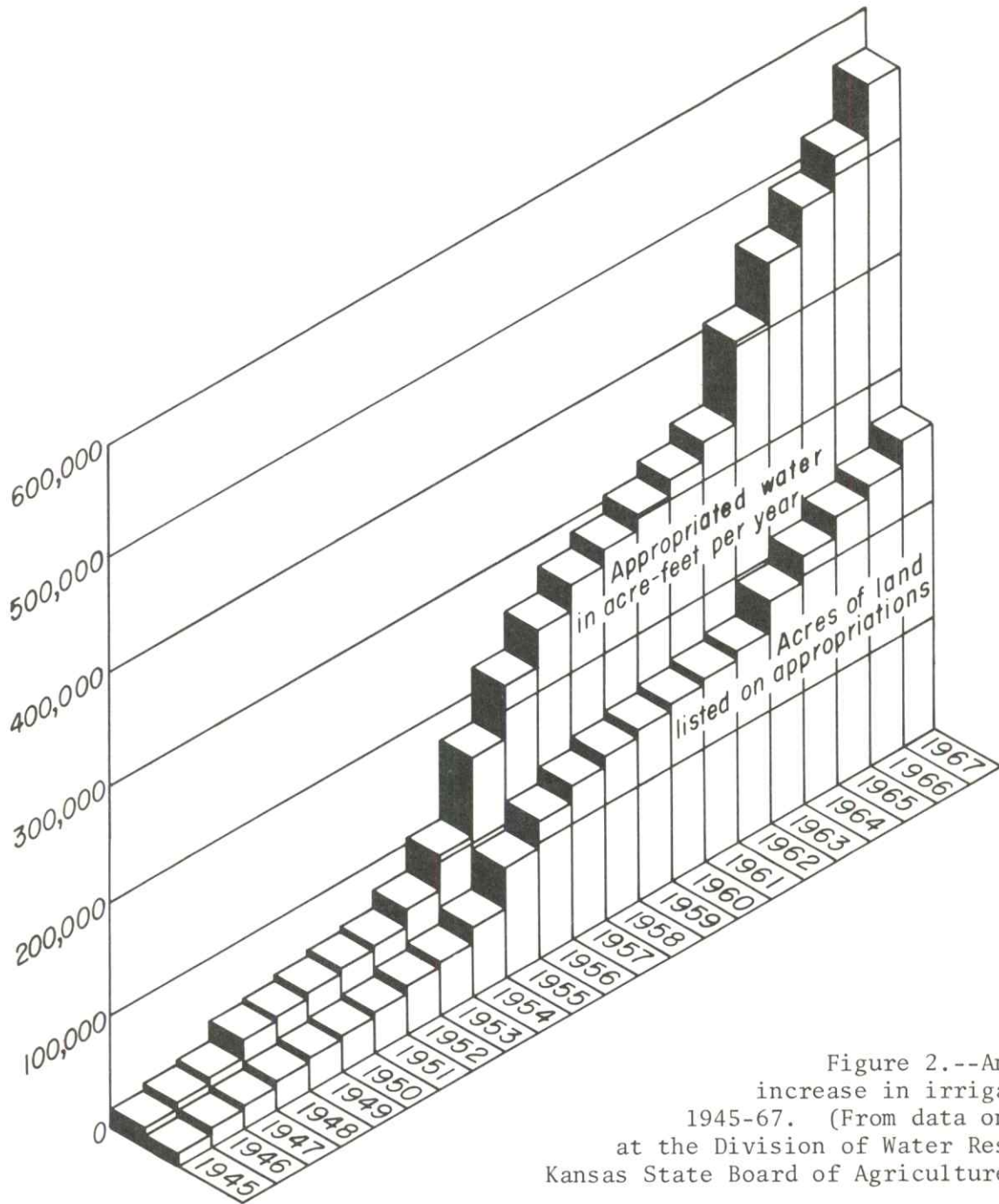


Figure 2.--Annual increase in irrigation, 1945-67. (From data on file at the Division of Water Resources, Kansas State Board of Agriculture.)

The Tertiary and Quaternary deposits, which consist of interbedded clay, silt, sand, and gravel, form the principal aquifer, or water-yielding formation, in the

Table 1.--Geologic formations and their water-bearing properties (after Fader and others, 1964).

System	Series	Stage	Stratigraphic unit	Thickness, feet	Character	Water supply
Quaternary	Pleistocene	Wisconsinan	Undifferentiated eolian and alluvial deposits	0 to 270+ _—	Soil, loess, dune sand, alluvium on surface. Clay, silt, sand, and gravel in subsurface.	Where saturated, known to yield as much as 750 gpm from sand and gravel; higher yields may be possible. (Most deposits lie above water table and yield no water to wells.)
		Sangamonian Illinoian	Undifferentiated alluvial deposits	0 to 300+ _—	Coarse sand and gravel deposits in channel fill; silt, fine sand, and clay in backwater and interstream deposits.	Wells screened only in lower Pleistocene(?) deposits yield as much as 2,000 gpm.
Tertiary	Pliocene	Yarmouthian	Undifferentiated alluvial deposits	0 to 200+ _—	Silt, clay, sand, and gravel. (Sand and gravel lenses may contain large amounts of inter-bedded silt and clay.)	Yields up to 1,000 gpm obtained in areas of coarse channel-fill deposits.
		Kansan Aftonian Nebraskan	Dakota Formation (L.? Cret.)	0 to 135+ _—	Fine- to medium-grained sandstone with shale beds.	Yields small supplies of water for stock and domestic wells. Yields water to multiple aquifer irrigation wells.
Cretaceous	Lower	(disconformity)	Kiowa Shale	0 to 150+ _—	Gray to black silty shale; may contain some thin sandstone beds.	Yields little or no water to wells.
		(disconformity)	Cheyenne Sandstone	0 to 120+ _—	White to yellow fine to coarse quartzose sandstone.	Yields as much as 500 gpm possible. Yields water to multiple-aquifer irrigation wells.
Jurassic(?)	Upper	(disconformity)	Unnamed deposits	0 to 130+ _—	Fine- to medium-grained quartzose sandstone. Contains red sandstone and siltstone.	Yields as much as 1,000 gpm reported. Yields water to multiple-aquifer wells.
			Big Basin Formation	160+ _—	Dark-red mudstone and orange-red siltstone beds.	No information available.

two-county area. In these deposits, beds consisting chiefly of sand and gravel yield moderate to large quantities of water to wells. Beds consisting chiefly of clay and silt contain water but drain so slowly that little water is yielded to wells.

Several major water-bearing zones in the sand and gravel aquifer underlie a large part of Grant and Stanton Counties. The water customarily used for domestic and stock supplies is withdrawn from a shallow unconfined zone that underlies much of the area. Most of the irrigation wells in the area obtain water from wells screened in one or more of the deeper artesian zones in the Tertiary and Quaternary deposits. These deep zones are classified as artesian because water will rise in a well above the top of the water-yielding deposits. Characteristically, the water level in an artesian well will decline rapidly when it is pumped. The maximum reported yield of a well penetrating these deposits is 2,700 gpm (gallons per minute).

The Jurassic(?) and Cretaceous formations, which yield moderate to large quantities of water, collectively form the second most productive aquifer in Grant and Stanton Counties. These formations consist of four major lithologic units (see table 1). The Kiowa Shale and the Dakota Formation of Lower Cretaceous age generally are composed of sandy shale interbedded with fine-grained sandstone. The Kiowa, which in this area consists predominantly of shale and sandy shale, yields little or no water to wells. The Dakota consists of sandy shale interbedded with fine- to medium-grained sandstone that yields enough water for domestic and stock supplies. The unnamed deposits of Jurassic(?) age and the Cheyenne Sandstone of Lower Cretaceous age are composed chiefly of fine- to coarse-grained sandstone. Yields of as much as 1,000 gpm have been reported from these rocks, but the average yield probably is less than 500 gpm. In some areas, yields have been increased significantly by screening wells in both the sandstone and the overlying sand and gravel.

DECLINE OF WATER LEVELS

Well records in the two-county area show that the development of ground-water irrigation has been accompanied by a marked decline in water levels. In order to evaluate this decline, water levels have been measured annually and further studies are in progress.

In 1958, a review of the geohydrology of Grant and Stanton Counties (Fader and others, 1964) was initiated to learn the effects of increased ground-water withdrawals. Measurements made during the course of the study revealed that water levels had declined significantly between 1939 and 1960. Similar measurements have been made each January since 1963 to monitor the decline.

Information concerning water-level changes in the Tertiary and Quaternary deposits has been published in short reports by Winslow and others in 1964 and by Nuzman and Meyer in 1965. These reports showed the areal extent and the progressive rate of water-level declines compared to the increasing growth of ground-water appropriations.

In order to compare changing ground-water conditions in the Tertiary and Quaternary deposits, the present report and the previous reports have related the annual water-level measurements to water-level data collected during the period 1939-42. Because the total ground-water pumpage in the period 1939-42 was relatively insignificant, the water-level data are considered to be representative of an equilibrium condition (recharge approximately equal to discharge). The progressive changes in water level in the principal aquifer through January 1968 are listed in table 2 and shown graphically in figure 3.

The net change in water levels from the 1939-42 base period to January 1968 is shown in figure 4. Continued observation of well data from the Tertiary and Quaternary deposits revealed that water levels in the shallow zone of the sand and gravel

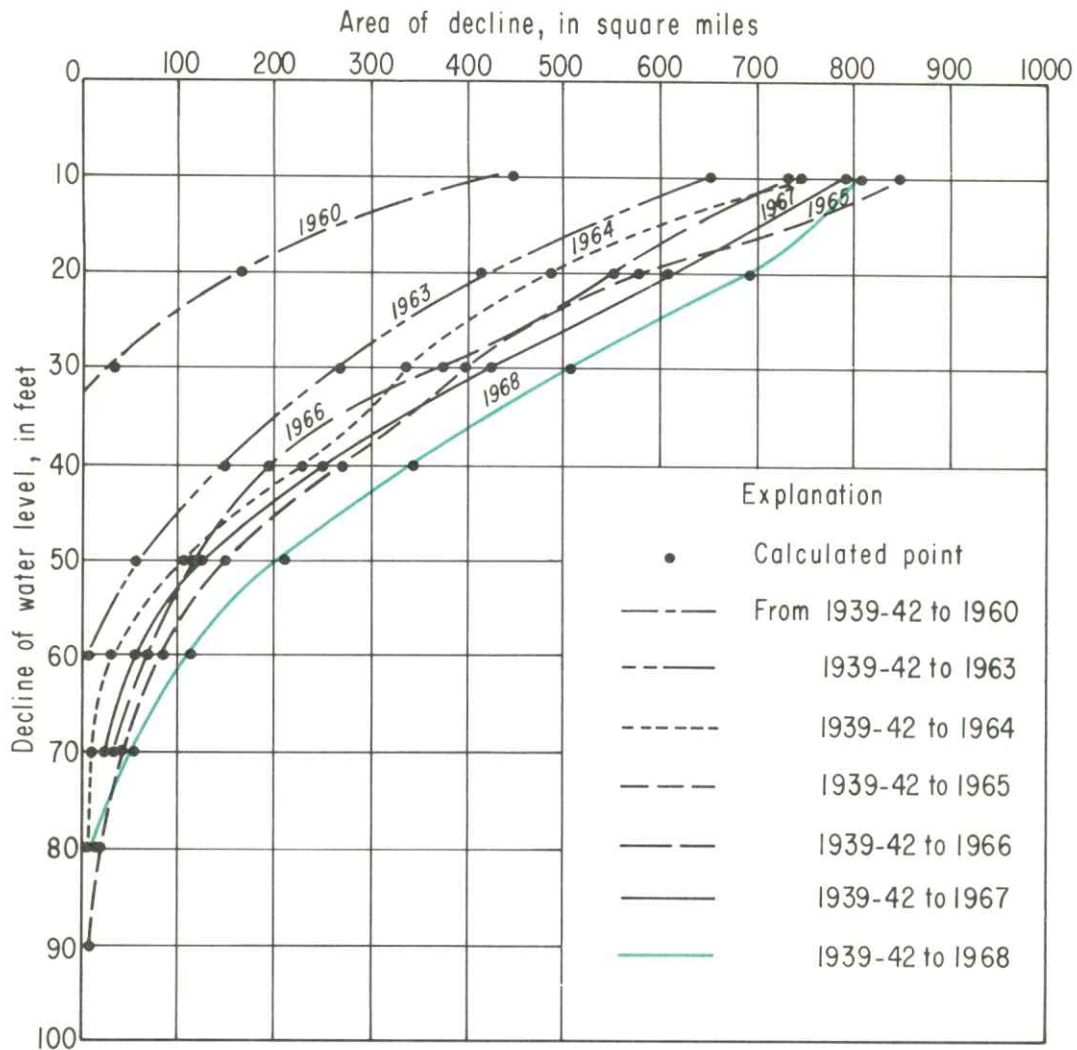


Figure 3.--Areal decline of water levels in the Tertiary and Quaternary deposits (modified after Fader and others, 1964).

aquifer occurred at shallower depths and have declined at a slower rate than water levels in the deeper zones of the aquifer. Therefore, it is evident that water-level measurements in the shallow zone and the deep zones are not comparable. Because most of the ground water used for irrigation is pumped from the deeper zones in the sand and gravel aquifer, only the measurements that reflect changes in these deeper zones were used in the compilation of figure 4. In the previous short reports describing declining water levels in Grant and Stanton Counties (Winslow and others, 1964;

Table 2.--Areal decline of water levels in Tertiary and Quaternary deposits.

Time interval 1939-42 to January of year shown	Area, in square miles, in which water levels declined								
	10 ft.	20 ft.	30 ft.	40 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.
1960	444	164	36	--	--	--	--	--	--
1963	656	414	264	147	55	--	--	--	--
1964	742	484	340	228	108	30	16	6	--
1965	848	580	398	269	148	80	40	20	11
1966	738	559	375	195	116	66	26	--	--
1967	791	608	423	249	124	61	21	--	--
1968	812	694	504	344	206	116	49	16	--

Nuzman and Meyer, 1965), water-level data from a number of wells penetrating only the shallow zone were included in estimating the decline. By using in this report water-level data only from wells that are screened in the major producing deeper zones, the progressive decline of water levels appears to be slightly less in most areas than reported in previous reports. This fact, however, does not detract from the ground-water depletion problem that overpumpage of ground water in the area is creating.

Water levels fluctuate during the year in response to the intensity and duration of pumping. As the total ground-water pumpage increases through the irrigation season, water levels progressively decline, especially in areas where the wells are closely spaced. The water levels in some pumping wells during dry years have been lowered as much as 250 feet below water levels in the 1939-42 reference period. As pumping diminishes during the winter season, water levels in the aquifer rise, reflecting a leveling-off trend and inflow of water from surrounding, less heavily pumped areas. The magnitude of this rise is greatly influenced by the length of time

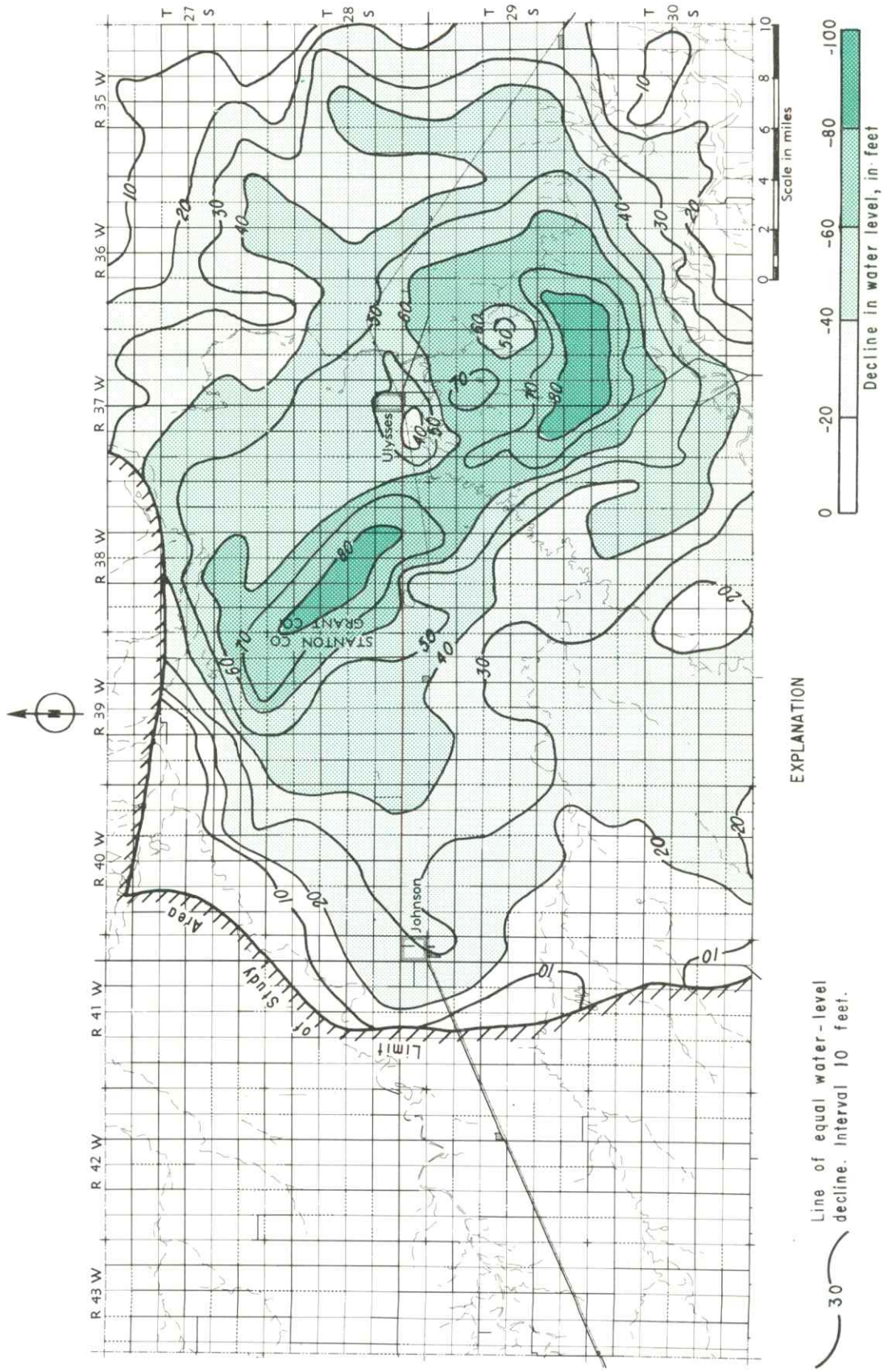


Figure 4.--Water-level declines in Tertiary and Quaternary deposits from 1939-42 to January 1968.

that pumping is reduced. This pattern of cyclic fluctuations is illustrated by the hydrographs in figure 5.

Each year is different with respect to the variety and acreage of crops grown and the amount and distribution of precipitation during the irrigation season. Thus, the annual rate of pumping will vary in response to climatic conditions and irrigation practices. The resulting water-level decline may appear to be great during one year and small during another year. The general trend is downward, however, because the amount of water pumped exceeds the amount of water recharged to the aquifer. The measurements made during January best serve to indicate the net annual decline of water levels.

ANALYSIS OF HISTORIC TRENDS

A relationship is evident between declining water levels in the Tertiary and Quaternary deposits and increasing ground-water pumpage. The exact nature of this relationship is obscure because the controlling factors are both variable and complex. However, some meaningful conclusions can be drawn from an analysis of the trends that have developed.

All the available data indicate that the saturated part of the Tertiary and Quaternary deposits (the zone from the shallow water table to the underlying bedrock) functions as a single hydrologic unit. A variety of geologic and hydrologic conditions exists within this unit that locally affects ground-water movement with respect to time. These conditions are related to the three general zones: the shallow zone of the sand and gravel aquifer, the intermediate clay and silt zones, and the deep zones of the sand and gravel aquifer. Water levels in the shallow zone respond slowly to seasonal changes because the water is unconfined and the annual pumpage is relatively small. Water levels in the deep zones fluctuate greatly because the water

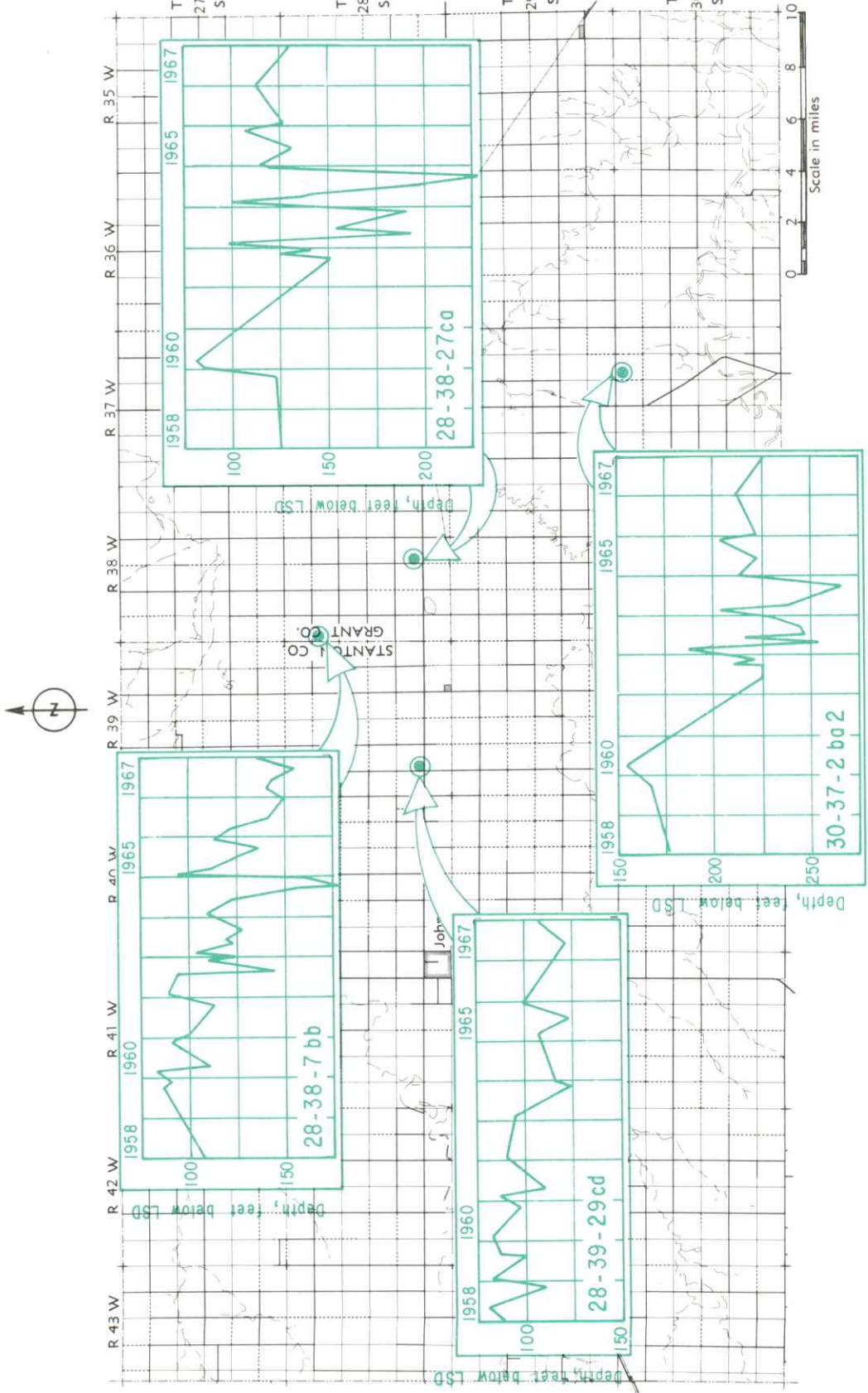


Figure 5.--Hydrographs of water levels below land surface datum (LSD) in selected wells in Tertiary and Quaternary deposits. (Modified after Broecker and Winslow, 1966.)

is generally under artesian pressure and the seasonal pumpage is large.

A review of water-level changes that have developed from 1939 to 1968 reveals some significant trends. The greatest water-level declines have occurred in the deep zones of the sand and gravel aquifer. Such declines are to be expected because these aquifers supply the major part of the ground-water pumpage. Much smaller declines have occurred in the shallow zone. However, these small declines are excessive in respect to the quantity of ground water pumped from the shallow zone. Thus, it appears that some water is draining downward through the intermediate clay and silt zones into the deep zones of the sand and gravel aquifer.

As previously stated, water movement in the deep aquifer zones responds in a manner characteristic of an artesian system. If water is draining through and from the overlying clay and silt zones, the deep zones would be considered as a "leaky artesian" system. The result is that water levels decline rapidly in response to seasonal pumping and recover slowly in response to delayed drainage. In view of geologic conditions in Grant and Stanton Counties, the rate of drainage is so slow that water levels usually do not recover from the drawdown incurred in one pumping season before the next pumping season begins. However, the January 1966 measurements, which were preceded by a year of above normal rainfall, a short pumping season, and a long recovery period, did show water levels to be above those of a year earlier over much of the area.

It is evident that water-level changes during a 1-year period are not necessarily an accurate measurement of the change in ground-water storage. An average of the annual changes recorded over a 10-year period, however, gives a reasonable approximation because the effects of drainage become nearly constant and the variations due to climatic conditions and irrigation practices are minimized. A review of the records shows that water levels in the deep water-yielding zones declined rapidly in

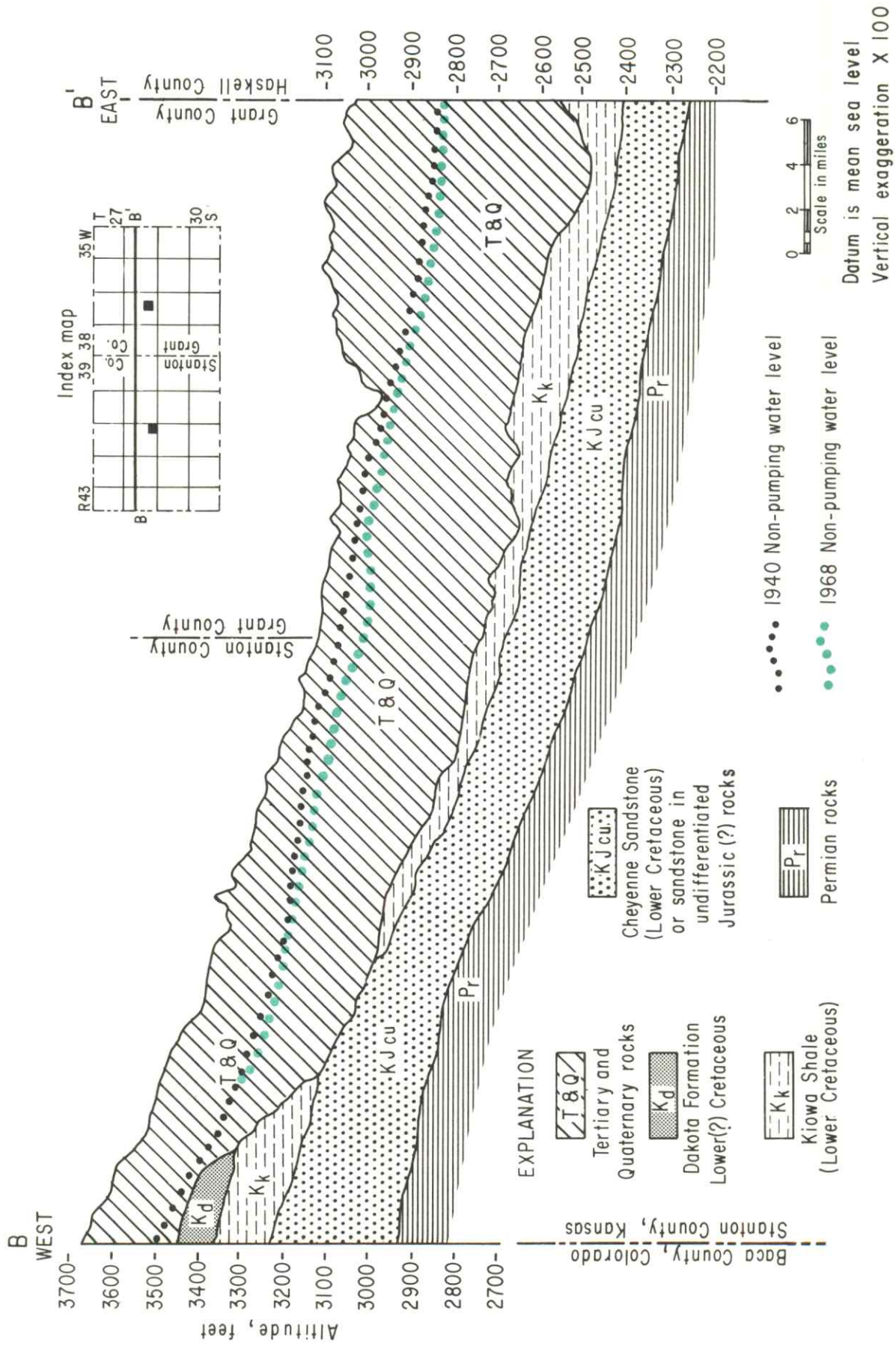
the early years of intensive irrigation development. This rapid decline essentially represents a semipermanent loss of artesian pressure. On the basis of well measurements made from 1957 to 1968 (after the initial pressure decline), the annual water-level decline for the two-county area averaged about 3 to 4 feet. This value represents the water-level decline due to the removal of ground water from storage.

Therefore, it may be concluded that recently intensified development in areas where artesian or leaky artesian conditions exist initially can expect rapid declines in water levels. Similar areas of long established development, which have already experienced appreciable declines, can expect future declines to occur at a slower rate. Naturally, if the rate of ground-water pumpage increases, water levels will decline at a greater rate.

In order to evaluate the effect on ground-water storage in Grant and Stanton Counties through January 1968, the amount of water-level decline may be compared with the thickness of saturated material. The greatest decline of about 80 feet occurs in an area near Ulysses where the saturated thickness ranges from 350 to 400 feet. The decline due to the loss of artesian pressure and the withdrawal of ground water from storage represents about a 20 percent reduction in the amount of ground water in storage as compared to the water in storage in the base period 1939-42.

REFERENCES

- Broeker, M. E., and Winslow, J. D., 1966, Ground-water levels in Kansas, 1965: Kansas Geol. Survey Bull. 184, 92 p., 15 figs.
- Fader, S. W., Gutentag, E. D., Lobmeyer, D. H., and Meyer, W. R., 1964, Geohydrology of Grant and Stanton Counties, Kansas: Kansas Geol. Survey Bull. 168, 147 p., 12 pl., 15 figs.
- Latta, B. F., 1941, Geology and ground-water resources of Stanton County, Kansas: Kansas Geol. Survey Bull. 37, 119 p., 9 pls., 6 figs.
- McLaughlin, T. G., 1946, Geology and ground-water resources of Grant, Haskell, and Stevens Counties, Kansas: Kansas Geol. Survey Bull. 61, 221 p., 12 pls., 18 figs.
- Nuzman, C. E., and Meyer, W. R., 1965, Water-level changes in Grant and Stanton Counties, Kansas, 1949-1965: Kansas Geol. Survey Spec. Distrib. Pub. 18, 12 p., 8 figs.
- Winslow, J. D., Nuzman, C. E., and Fader, S. W., 1964, Water-level changes in Grant and Stanton Counties, 1939-1964: Kansas Geol. Survey Spec. Distrib. Pub. 10, 12 p., 8 figs.



Geologic section B-B', Grant and Stanton Counties, Kansas. Line of section B-B' differs somewhat from that used in previous reports. (Modified after Fader and others, 1964.)