PREPARED IN COOPERATION WITH THE
STATE GEOLOGICAL SURVEY OF KANSAS
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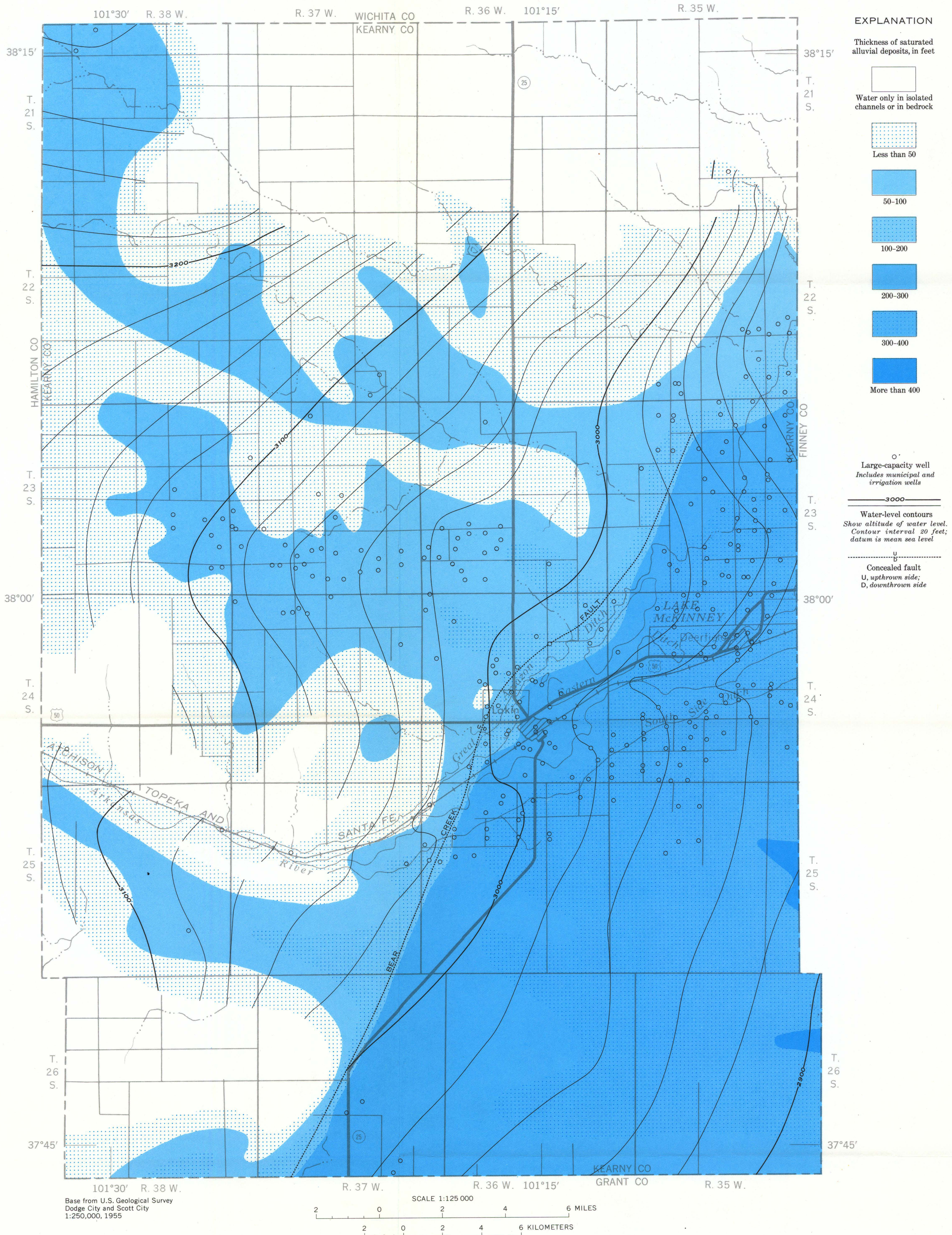
KANSAS STATE BOARD OF AGRICULTURE

HYDROLOGY OF THE ALLUVIAL AQUIFER



HYDROLOGIC MAP

HYDROLOGY OF THE ALLUVIAL AQUIFER

OCCURRENCE AND AVAILABILITY OF GROUND WATER

The Tertiary and Quaternary deposits are hydrologically connected and are considered as one aquifer. Because these deposits consist of alternating lenses of fine- and coarse-grained alluvial sediments, ground-water movement is retarded vertically and laterally. Thus, the water-yielding capacity of the aquifer differs from one area to another, and the water may be semiconfined (semiartesian) or unconfined.

The direction of ground-water movement is eastward, as shown by the gradient on the hydrologic map. Water enters the aquifer by underflow from the west and northwest, by infiltration from the Arkansas River, by precipitation, and by infiltration from irrigation. Water is discharged by underflow to the east and southeast, by evapotranspiration where the water table is shallow, and by pumping from wells. Also shown on this map is the location of all irrigation and municipal wells in January 1968 that yielded more than 300 gpm (gallons per minute). In the dune-sand area and the western part of the Arkansas River valley, large areas exist where irrigation supplies are available but have not been developed.

The thickness of the saturated material, shown on the hydrologic map, represents the depth from the water level (January 1968) to the bedrock surface. This water-level surface reflects an unconfined condition in some areas and a semiconfined condition in other areas. The thickness of saturated material ranges from a few feet to more than 400 feet, with a significant increase occurring east of the fault.

Although the lithology of the Tertiary and Quaternary deposits differs from one area to another, there is a general relationship between thickness of saturated material and well yield. An analysis of sample logs, drillers' logs, well yields, aquifer tests, and drillers' well-performance tests indicates that the aquifer may be subdivided into three general areas of similar characteristics. The relationship between potential well yield and thickness of saturated material for areas A, B, and C is shown on the accompanying graph. The mean curve and the probable range, drawn on the basis of aquifer-test and well-performance-test data, show the magnitude of yield that may be obtained from a specific saturated thickness in each of the areas. However, the yield of an individual well depends on the method of well construction and intensity of well development in the surrounding area (mutual well interference), as well as the lithology of the sediments at the well site.

The hydrologic characteristics and comparative yields of the aquifer in the three areas are shown in the summary tables; the comparative lithologic and hydrologic characteristics are discussed in the following paragraphs.

In the summary tables of aquifer and well-performance tests, the effective thickness is considered as the part of the saturated material that apparently would yield most of the water. The values of effective thickness are assigned on the basis of the driller's log, general information on lithology of the area, and general information on the yield of other wells in the area. Permeability of the material is the capability to transmit water through a cross-sectional area of 1 square foot of the aquifer at unit gradient; vertical permeability is the capability to transmit water through a horizontal section of 1 square foot in a semiconfining bed at unit gradient. Transmissibility is the capability to transmit water through a vertical strip of the aquifer 1 foot wide at unit gradient. The storage coefficient is a measure of the volume of water removed from a unit cross section of the aquifer for each unit of water decline. The storage coefficient in the unconfined aquifer ranges from 0.1 to 0.15. In the semiconfined aquifer the coefficient ranges from 0.001 to 0.0001. To make the test results comparable, values for specific capacity (gallons per minute per foot of drawdown) and potential yield were determined for an assumed drawdown in the pumped well of 70 percent of the effective thickness. Actual drawdown will differ with well efficiency, irrigation requirements, and other factors.

The map showing the potential ground-water yield to wells was drawn by comparing values shown on the map of saturated thickness with the mean curve value for each hydrologic area, as shown on the graph. Because wells normally are designed on the basis of irrigation requirements and pump efficiency rather than aquifer efficiency, the estimated values are useful chiefly as a general guide in planning. Test drilling is recommended to insure the best location for a large-capacity well.

The general areas of similar hydrologic characteristics in the Tertiary and Quaternary deposits are described as follows:

AREA A.—The shallow unconfined aquifer in the Arkansas River valley. The deposits generally consist of coarse- to very coarse-grained sediments containing a few thin beds of fine-grained sediments. The effective thickness and total thickness of saturated material are almost equal. Water in the aquifer is unconfined (as indicated by the storage coefficient of 0.14), and the permeability is high. The yield to wells per foot of saturation is large, whereas drawdown and pump lift are small. Yields from individual wells may be as much as 2,400 gpm; some battery-well systems have produced more than 4,000 gpm.

AREA B.—The deep unconfined aquifer beneath the upland in the north-central and southwestern parts of the county. The deposits generally consist of stratified fine- to coarse-grained sediments. The effective thickness is slightly less than the total thickness of saturated material, the water in the aquifer usually is unconfined (as indicated by the storage coefficient of 0.11), and the permeability is moderate by comparison with Area A. Thus, a greater saturated thickness is required in Area B than in Area A to produce a comparable yield. Usually, a thickness of more than 50 feet of saturated material is required to insure a dependable irrigation supply. The depth to water ranges from 50 to 200 feet, and pumping lifts of 150 to 300 feet are required for a large-capacity well.

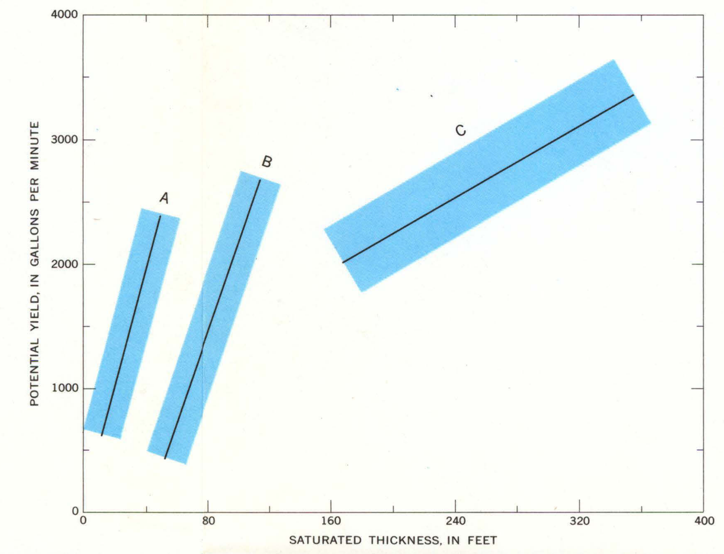
AREA C.—The deep semiconfined aquifer east of the fault. The deposits consist of stratified fine- and coarse-grained sediments commonly interbedded with thick layers of fine-grained sediments. The effective thickness differs from area to area, but averages 68 percent of the total saturated thickness. Water contained in the coarse-grained sediments at depth usually is semiconfined (as indicated by the storage coefficient of 0.0006). Permeability of the water-yielding zones is nearly equal to that of the stratified deposits in Area B. Vertical permeabilities determined by aquifer tests indicate that leakage is significant; thus, a considerable volume of water is transmitted through the fine-grained deposits from the shallow unconfined aquifer to the principal water-yielding zones. Because the aquifer is semiconfined, water levels will decline rapidly during pumping and recover rapidly when pumping ceases. Therefore, a much greater saturated thickness is required in Area C than in Area B to produce a comparable yield. As the saturated thickness in Area C exceeds 175 feet, the mean curve on the graph indicates a potential yield of more than 2,000 gpm. Although an adequate yield for irrigation should be available in Area C, test drilling may be desirable to assure a supply and to obtain the greatest yield for the least amount of pumping lift.

The pattern in Area C shows the approximate location of the shallow unconfined aquifer in the Arkansas River valley, which is not included in the determination of potential yield. Owing to the very high concentrations of dissolved solids in the water from the shallow aquifer, wells located in this part of the Arkansas River valley commonly are constructed to retard inflow from the upper zone. Aquifer-test data and water-quality data indicate that yields from the underlying semiconfined aquifer are significantly increased by downward leakage.

AREA D.—Little or no yield from the alluvial deposits except in isolated channels.

Summary of aquifer tests

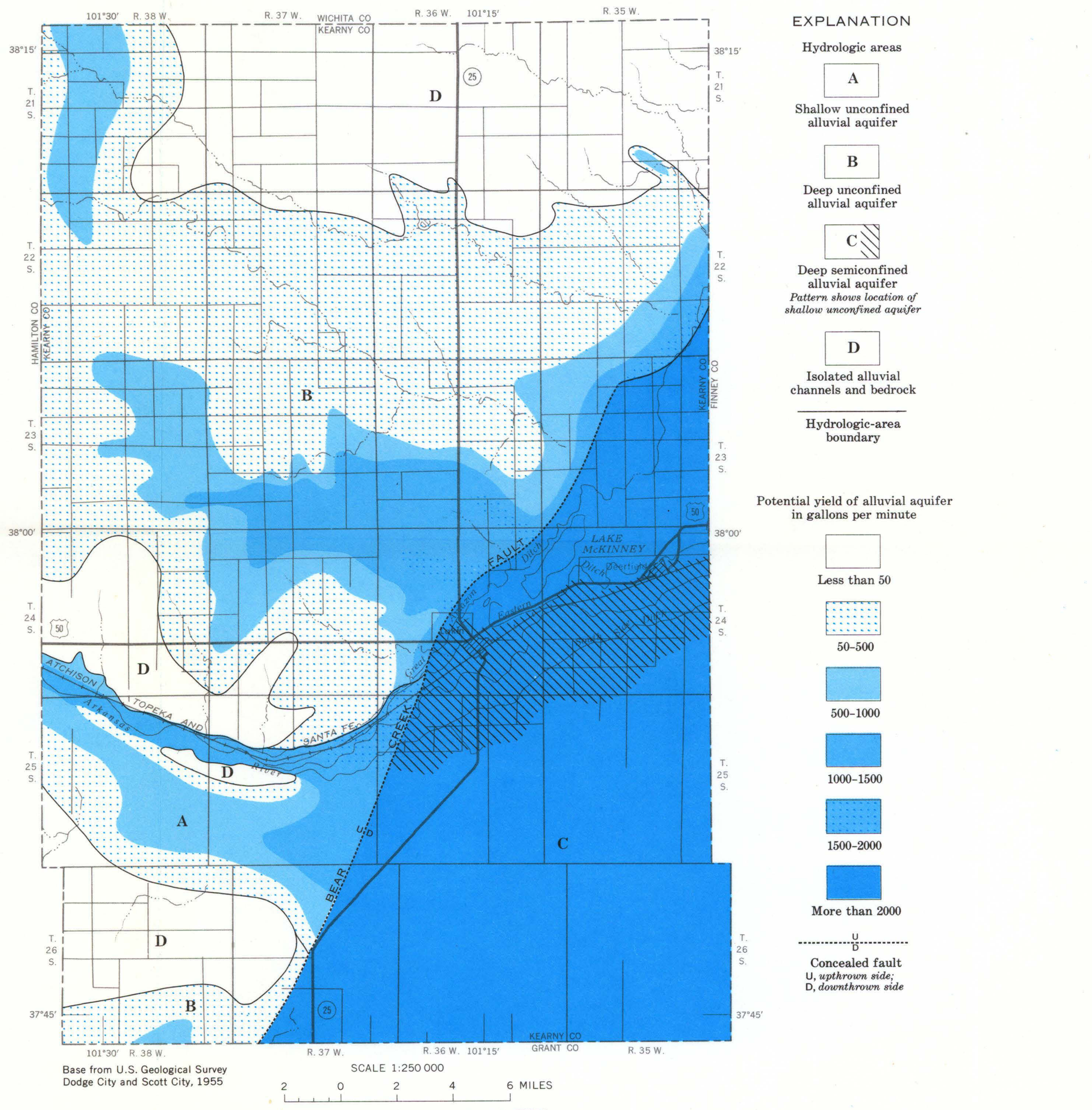
Hydrologic area	Well location	Effective thickness (feet)	Permeability (gpd/sq ft)	Transmissibility (gpd/ft)	Storage coefficient	Vertical permeability (gpd/sq ft)
A	NW¼SW¼SW¼ sec. 35, T. 24 S., R. 39 W. (Hamilton County)	42	3,800	162,000	0.14	----------
B	NE¼NE¼NW¼ sec. 36, T. 23 S., R. 37 W.	76	300	25,000	.11	----------
C	SE¼SE¼SE¼ sec. 21, T. 26 S., R. 37 W.	180	260	47,000	.0006	0.03
A–C	SW¼SW¼NE¼ sec. 18, T. 25 S., R. 36 W.	136	1,440	196,000	.06	7.00



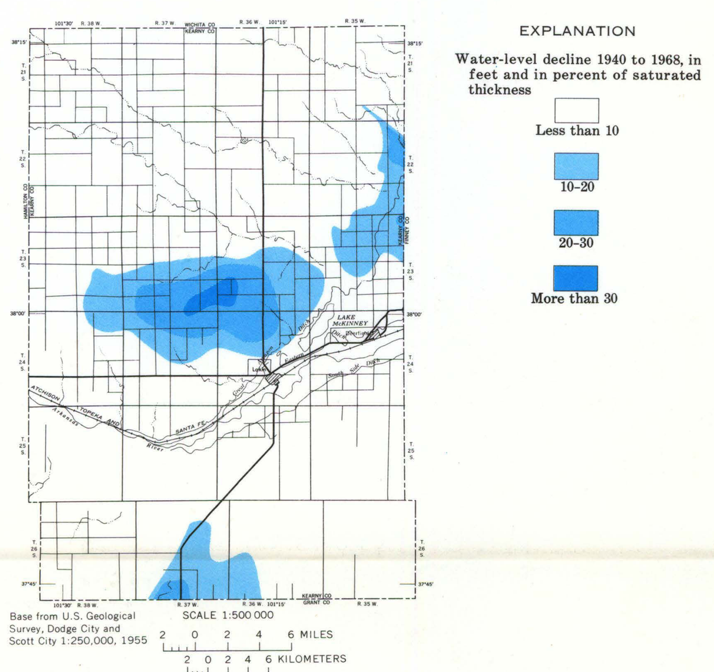
GRAPH SHOWING RELATION OF POTENTIAL WELL YIELD TO SATURATED THICKNESS IN HYDROLOGIC AREAS A, B, AND C

Summary of well-performance tests

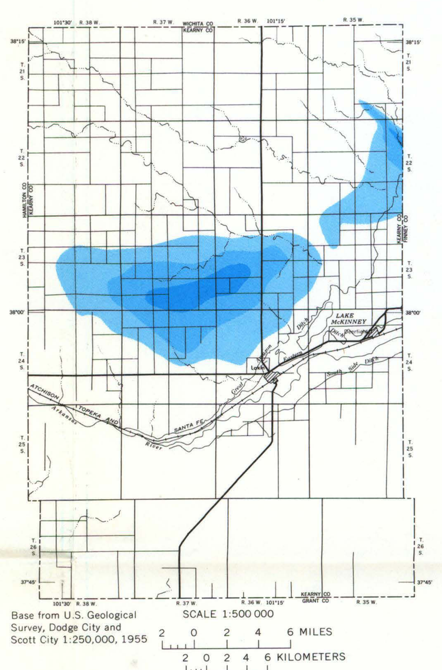
Hydrologic area	Description	Saturated thickness (feet)	Effective thickness (feet)	Effective thickness ÷ Saturated thickness (percent)	Aquifer potential	
					Yield (gpm)	Specific capacity (gpm/ft)
A	Shallow unconfined aquifer	10–50 34 avg	10–45 32 avg	97	650–2,400 1,650 avg	68–85 76 avg
B	Deep unconfined aquifer	50–125 74 avg	50–115 71 avg	96	450–2,900 1,400 avg	12–35 26 avg
C	Deep semi-confined aquifer	175–377 292 avg	140–256 200 avg	68	2,100–3,800 2,600 avg	17–23 21 avg



MAP SHOWING POTENTIAL GROUND-WATER YIELD TO WELLS



MAP SHOWING WATER-LEVEL DECLINE FROM 1940 TO 1968, IN FEET



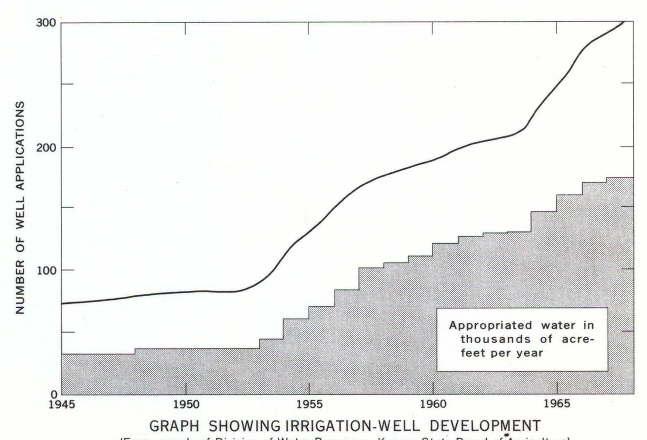
MAP SHOWING WATER-LEVEL DECLINE FROM 1940 TO 1968, IN PERCENT OF SATURATED THICKNESS

WATER-LEVEL CHANGES

The increasing use of ground water for irrigation has resulted in a decline in water levels and a gradual loss of water in storage. The magnitude of change differs from year to year and from area to area in response to climate, hydrologic conditions, and intensity of irrigation development. To determine the long-range effect of changing ground-water conditions, water-level data for 1940 (McLaughlin, 1943) are compared with water levels for 1968. Data for 1940 are representative of equilibrium conditions (recharge equal to discharge) because the annual pumpage prior to that date was relatively small. Water levels for 1968 were measured in January to minimize the effects of seasonal fluctuation resulting from changes in artesian pressure and differences in intensity and duration of pumping.

The map of water-level declines from 1940 to 1968 shows that declines ranged from zero to more than 30 feet. The greatest decline occurred in the deep unconfined aquifer in the central part of the county. Water levels are essentially unchanged in the shallow unconfined aquifer of the Arkansas River valley, where recharge is great and pumpage is small. Declines in the deep semiconfined aquifer east of the Bear Creek fault are insignificant because pumpage is small compared to the large quantity of water in storage. In one area, however, declines of 10 to 20 feet result from heavy irrigation withdrawal in adjoining Grant County.

To evaluate the effect of increasing irrigation withdrawals on ground-water storage in Kearny County (see graph of irrigation well development), the water-level decline is compared to the decline in thickness of saturated material. In the north-central part of the county, a 30-percent decline in the saturated thickness has resulted in a significant reduction in well yields. In the area east of the fault, saturated thickness is great and declines are generally less than 10 percent.



GRAPH SHOWING IRRIGATION-WELL DEVELOPMENT
(From records of Division of Water Resources, Kansas State Board of Agriculture)

SELECTED HYDROLOGIC AND WATER-QUALITY REFERENCES

Hem, J.D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p.
McLaughlin, T.G., 1943, Geology and ground-water resources of Hamilton and Kearny Counties, Kansas: Kansas Geol. Survey Bull. 49, 120 p.
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U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Pub. 956, 61 p.
Walton, W.C., 1962, Selected analytical methods for well and aquifer evaluation: Illinois Water Survey Bull. 49, 81 p.
Winslow, J.D., McGovern, H.E., and Mackey, H.L., 1968, Water-level changes in Grant and Stanton Counties, Kansas, 1939–1968: Kansas Geol. Survey Spec. Distrib. Pub. 37, 17 p.

Note. Additional information on drillers' logs and well production is available in the office of the U.S. Geological Survey, Garden City, Kansas.

CHEMICAL QUALITY OF WATER

CHEMICAL QUALITY OF GROUND WATER

Water in the alluvial aquifer may be a calcium bicarbonate or a calcium sodium sulfate type and is very hard. Water in the sandstone aquifer is a sodium bicarbonate type and is hard. The areas designated on the map and summary table are grouped according to similar hydrologic conditions in the Tertiary and Quaternary deposits. Concentrations of dissolved solids also are shown for the sandstone aquifer, which underlies the entire county. The two samples collected in Kearny County show an increase in concentration northwest from the outcrop area.

AREA I.—The land surface is mantled by loess, and water occurs in the deep unconfined alluvial aquifer. The concentration of dissolved solids ranges from 150 to 500 mg/1 (milligrams per liter). Concentrations of more than 300 mg/1 generally are associated with areas of poor surface drainage.

AREA II.—The land surface is mantled by dune sand, and water occurs in the shallow unconfined and the deep semiconfined aquifers. Concentrations range from 150 to 300 mg/1 because infiltration of precipitation is rapid and only small amounts of soluble minerals are available in the dune sand.

AREA III.—The land surface is mantled by loess or dune sand, water occurs in the deep semiconfined alluvial aquifer, and the effects of surface water infiltration are significant. Concentrations range from 300 to 3,500 mg/1.

Infiltration of runoff through the clayey sediments along Bear Creek increases concentrations to as much as 1,500 mg/1. Infiltration from irrigation water in the loess increases concentrations to as much as 3,500 mg/1.

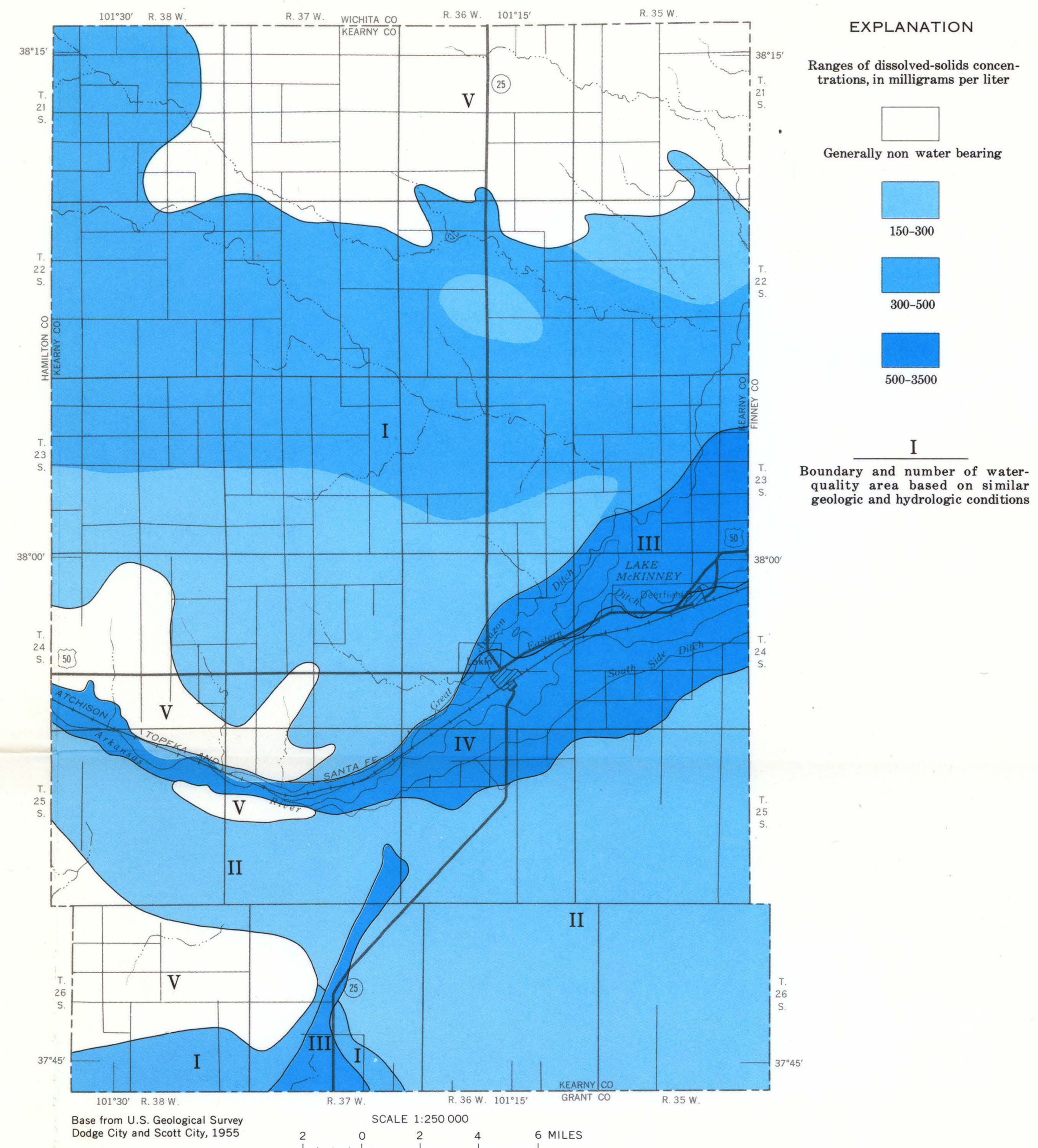
AREA IV.—The flood plain of the Arkansas River is mantled by sandy clay or silt, and water occurs in the shallow unconfined and deep semiconfined alluvial aquifers. Water in the shallow aquifer generally has a high concentration (1,000 to 3,500 mg/1) owing to infiltration of river water and evaporation from the shallow water table. Water in the semiconfined aquifer commonly has a lower concentration (300 to 1,500 mg/1) as depth increases.

AREA V.—Generally non water bearing except in isolated alluvial channels.

Summary of water-quality analyses
(Chemical constituents expressed in milligrams per liter)

	Depth (feet)	Temperature (°C)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na & K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness Total	Hardness Carbonate	Hardness Noncarbonate
AREA I																	
Maximum	330	17	459	25	7.8	0.00	78	40	62	251	170	66	1.7	28	306	212	130
Minimum	65	14	201	15	.00	.00	31	14	9.2	106	23	6.0	.4	4.9	144	133	0
Average	205	16	313	20	.61	.00	48	21	33	193	78	19	1.1	11	206	163	76
AREA II																	
Maximum	171	17	258	25	4.1	0.08	64	11	18	198	62	9.0	0.7	29	193	162	43
Minimum	35	15	114	7.0	.00	.00	27	2.2	6.5	120	1.2	3.0	.2	.0	84	84	0
Average	99	16	196	19	1.1	.03	48	5.8	12	168	16	5.2	.4	10	145	132	12
AREA III																	
Maximum	400	17	1,820	21	2.7	0.18	276	105	225	361	966	133	2.5	32	986	296	773
Minimum	25	14	424	15	.00	.00	58	19	36	174	119	25	.5	2.2	281	143	95
Average	225	16	1,110	18	.33	.02	161	57	115	216	562	75	1.0	12	636	180	458
AREA IV																	
Maximum	150	16	3,350	25	4.8	0.17	417	132	470	276	1,990	170	1.6	21	1,540	226	1,310
Minimum	15	14	248	10	.00	.00	45	19	19	159	62	8.0	.4	1.2	191	130	39
Average	59	14	2,320	16	.69	.02	292	92	312	218	1,390	110	1.1	8.8	1,110	179	929
UNDIFFERENTIATED LOWER CRETACEOUS ROCKS																	
Maximum	800	18	783	18	0.17	0.00	40	26	211	202	365	36	2.4	6.3	180	180	0
Minimum	300	18	298	9.0	.12	.00	29	15	47	200	35	15	2.4	5.3	162	162	0

Hardness of water classified by U.S. Geological Survey as follows: 0–60 mg/l, soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and 180 mg/l or more, very hard.



MAP SHOWING CONCENTRATION OF DISSOLVED SOLIDS IN TERTIARY AND QUATERNARY DEPOSITS

GROUND WATER IN KEARNY COUNTY, SOUTHWESTERN KANSAS

By
E. D. Gutentağ, D. H. Lobmeyer, and H. E. McGovern

1972