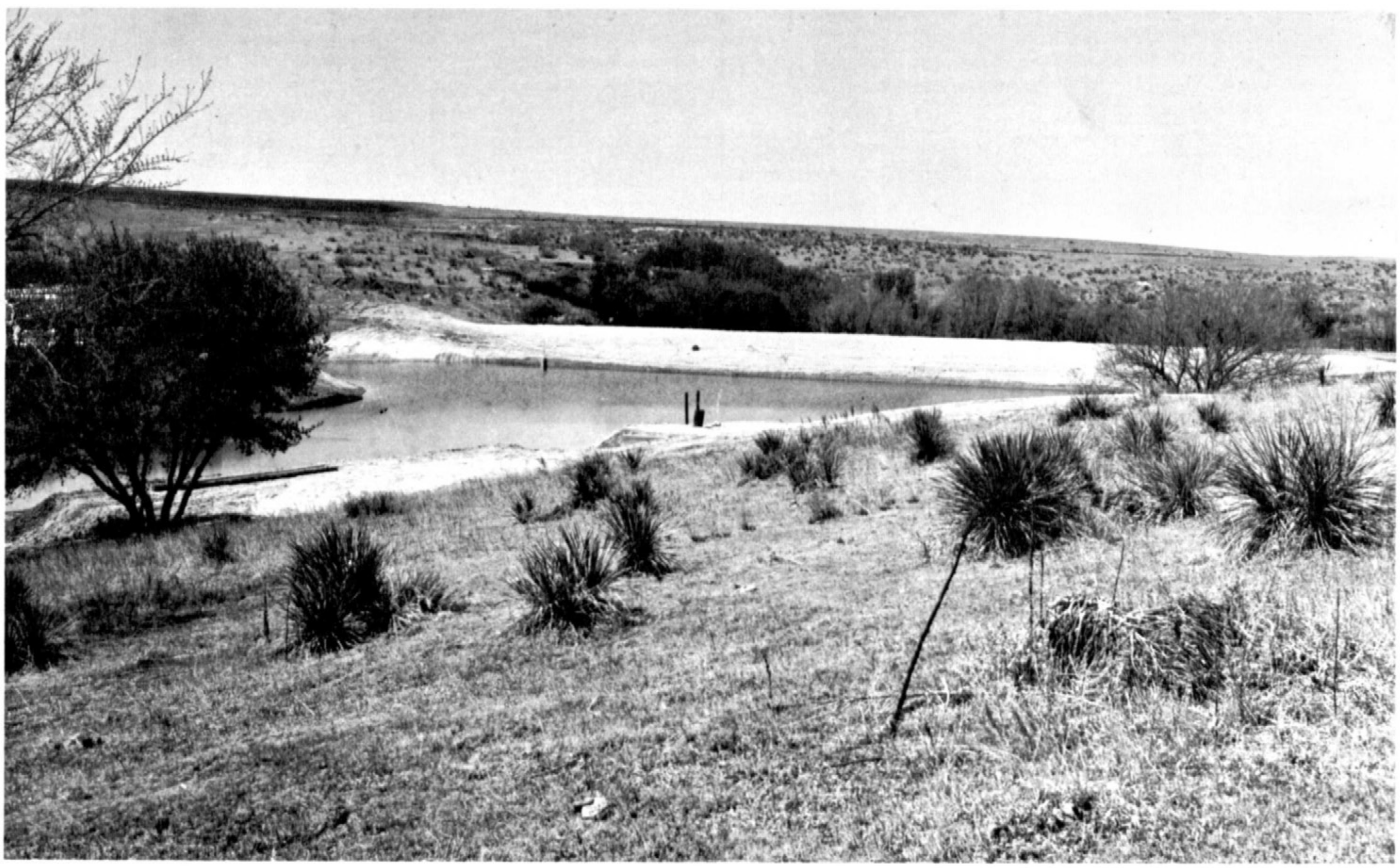
Series 1959, No. 35

Issued July 1964

SOIL SURVEY

Logan County, Kansas



UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service
in cooperation with
KANSAS AGRICULTURAL EXPERIMENT STATION

HOW TO USE THE SOIL SURVEY REPORT

THIS SOIL SURVEY of Logan County, Kans., will serve several groups of readers. It will help farmers in planning the kind of management that will protect their soils and provide good yields; assist engineers in selecting sites for roads, buildings, ponds, and other structures; aid foresters in managing woodland; and add to our knowledge of soil science.

Locating soils

Use the index to map sheets at the back of this report to locate areas on the large map. The index is a small map of the county on which numbered rectangles have been drawn to show where each sheet of the large map is located. When the correct sheet of the large map has been found, it will be seen that boundaries of the soils are outlined, and that there is a symbol for each kind of soil. All areas marked with the same symbol are the same kind of soil, wherever they occur on the map. The symbol is inside the area if there is enough room; otherwise, it is outside the area and a pointer shows where the symbol belongs.

Finding information

This report contains sections that will interest different groups of readers, as well as some sections that may be of interest to all.

Farmers and those who work with farmers can learn about the soils in the section "Descriptions of the Soils" and then turn to the section "Use and Management of Soils." In this way, they first identify the soils on their farm and then learn how these soils can be managed and what yields can be expected. The "Guide to Mapping Units, Capability Units, Range Sites, and Windbreak Suitability Groups" at the back of the report will simplify use of the map and the report. This guide lists each soil and land type mapped in the county, and the page where each is described. It also lists, for each soil and land type, the capability unit, range site, and windbreak suitability group, and the pages where each of these is described.

Persons interested in windbreaks can refer to the section "Woodland and Windbreaks." In that section the soils in the county are grouped according to their suitability for windbreaks, and factors affecting their management are explained.

Engineers will want to refer to the section "Engineering Uses of Soils." Tables in that section show characteristics of the soils that affect engineering.

Scientists and others who are interested will find information about how soils were formed and how they were classified in the section "Formation, Morphology, and Classification of Soils."

Students, teachers, and other users will find information about soils and their management in various parts of the report, depending on their particular interest.

Newcomers in Logan County will be especially interested in the section "General Soil Map," where broad patterns of soils are described. They may also be interested in the section "Additional Facts About the County," which gives general information about the county.

* * * * *

Fieldwork for this survey was completed in 1959. Unless otherwise indicated, all statements in the report refer to conditions in the county at that time. The soil survey of Logan County was made as part of the technical assistance furnished by the Soil Conservation Service to the Logan County Soil and Water Conservation District.

Cover picture: A farm pond provides water for livestock and for recreational facilities.

U.S. GOVERNMENT PRINTING OFFICE: 1964

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402

Contents

Series 1959, No. 35

Issued July 1964

SOIL SURVEY OF LOGAN COUNTY, KANSAS

BY ELBERT L. BELL, CLARENCE M. CALL, JAMES S. HAGIHARA, AND LYLE D. LINNELL, SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE IN COOPERATION WITH THE KANSAS AGRICULTURAL EXPERIMENT STATION

LOGAN COUNTY is in northwestern Kansas. It is in the second tier of counties from Colorado and in the third tier from Nebraska (fig. 1). The county has an area of 1,073 square miles. Russell Springs, the county seat, is near the center of the county. Oakley and Winona are the principal trading centers.

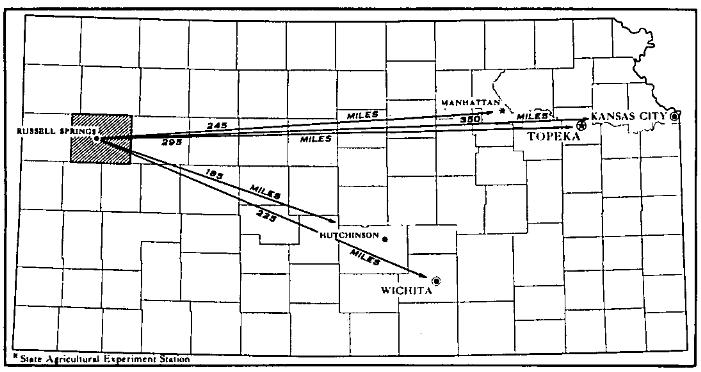


Figure 1.—**Location of Logan County in Kansas.**

The climate of the county is transitional to semiarid. The lack of rainfall has caused many of the soils to have a layer where lime has accumulated.

This is primarily an agricultural county. Wheat and grain sorghum, grown under dryland farming, are the main crops. Producing beef cattle is the major livestock enterprise, but during favorable years large flocks of sheep are moved into the county to graze the residues from winter wheat and grain sorghum.

Physiography, Relief, and Drainage

Logan County lies entirely within the Great Plains physiographic province. Only the northeastern one-third, the southwestern corner, and a narrow strip along the southern side of the county, however, consist of nearly featureless plains like those that lie to the north and to the south. The rest of the county is made up of sloping, dissected plains that are interrupted by narrow strips of rough, broken grassland adjacent to the major streams (fig. 2).

The nearly level or gently sloping tablelands, which are used for crops, are mainly in the northeastern one-third of the county. Many small, undrained, shallow depressions, called lagoons or buffalo wallows, are in those areas. The depressions range from 100 feet in diameter to several acres in size. After heavy rains, runoff collects in them and forms temporary lakes. The water is shallow, and it generally evaporates or seeps into the ground within a few weeks.

In many places between the tablelands and the flood plains of the Smoky Hill River are dissected, flat areas that slope gently toward the axis of the main valley of the river. These areas are separated from the tablelands by a steeper slope along the margin of the tablelands, and they are separated from the valley by the bluffs along the sides of the valley. The flat areas are absent over a wide area because of erosion caused by floodwaters of the minor tributaries. These tributaries are separated from one another by steep valley slopes and by rolling divides that form the large area of grassland. The areas of rolling grassland and cultivated divides are wider north of the Smoky Hill River, Chalk Creek, and Twin Butte Creek than south of those streams. Large upland depressions, ranging from 40 to 200 acres in size, are an unusual feature of the relief. They are surrounded by level benches and by moderately to strongly sloping uplands.

Cliffs and buttes of rock of the Smoky Hill chalk formation are along the valley slopes. In places they are dissected by deep, narrow canyons and pinnacles. In the southeastern part of the county, erosion has cut deep valleys into the Ogallala formation, and the cemented rocks from the Ogallala beds form vertical cliffs (*7*).[1]

The largest stream in Logan County is the Smoky Hill River. It enters the county near the middle of the western side and emerges 6 miles north of the southeastern corner. The stream has a west-to-east gradient of approximately 14 feet per mile. It drops from an elevation of 3,150 feet at the western side of the county to about 2,580 feet in the southeastern corner. The flood plain of the Smoky Hill River is flat, and in much of it the soils are sandy. In some places, through the deposition of sediment, bars have been built and the stream has developed an intricate network of interlacing channels. The maximum width of the channel is a quarter of a mile.

[1] Italicized numbers in parentheses refer to Literature Cited, p. 75.

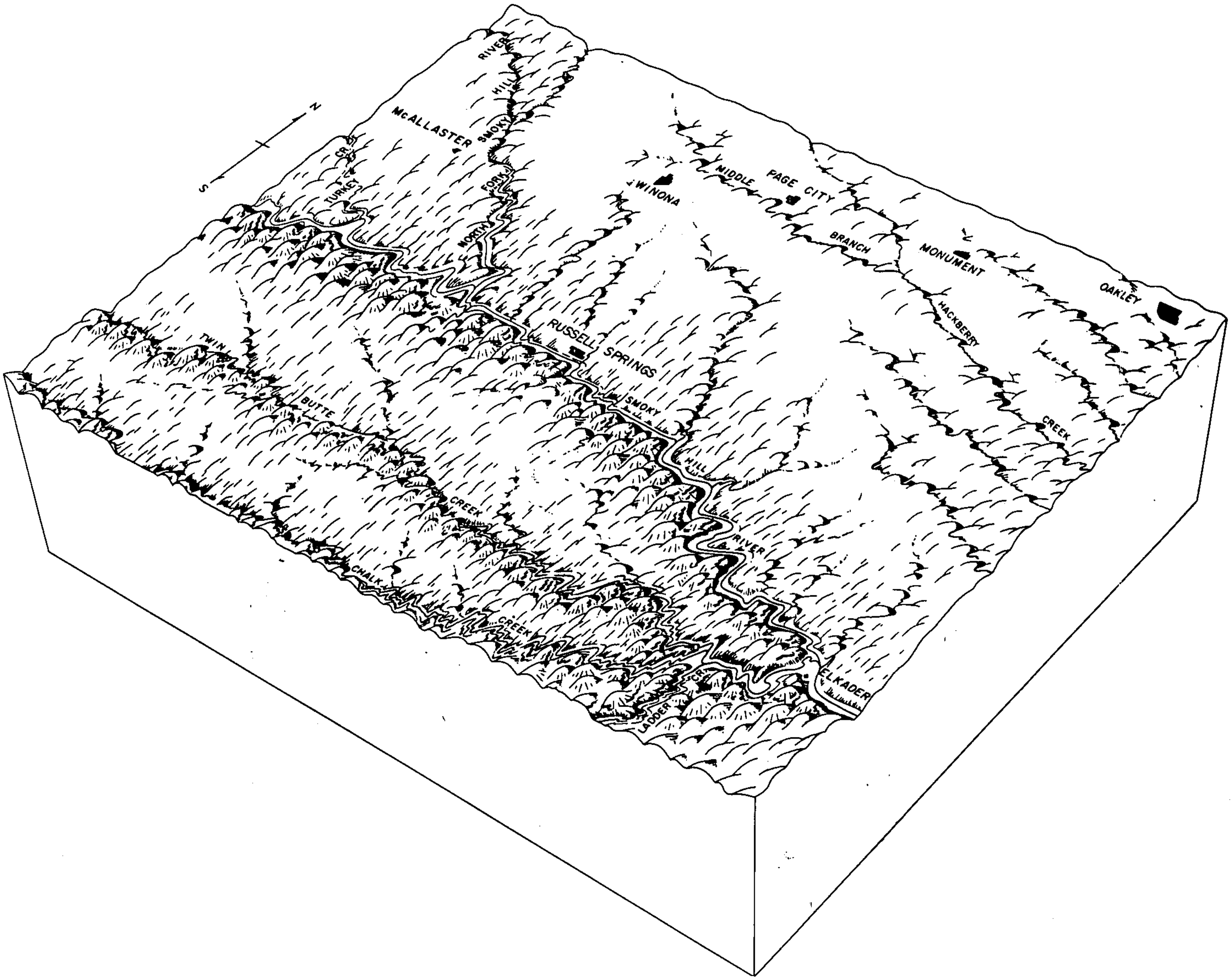


Figure 2.—Sketch of Logan County showing relief and drainage.

The main tributaries of the Smoky Hill River are the North Fork, and Twin Butte, Chalk, and Ladder Creeks. The North, South, and Middle Branches of Hackberry Creek originate within Logan County and join the Smoky Hill River farther to the east.

Climate [2]

Logan County has a dry, subhumid climate (*14*). The county is in the central High Plains midway between the drainage basins of the Republican and Arkansas Rivers. It is also near the headwaters of the Smoky Hill River. Because this county is 200 miles east of the Rocky Mountains, it is in the rain shadow of those mountains. It is also west of the general northward flow of moisture-laden air from the Gulf and receives little precipitation from that source. Therefore, the productivity of the soils is limited by inadequate moisture.

The climate of the area is reflected in the native vegetation. The treeless plains and short grasses are evidence of the prevailing marginal precipitation. Along the water courses, however, there is a greater variety of vegetation. The broad, rolling prairies are particularly well suited to grazing, but the soils are also well suited to the growing of wheat and grain sorghum.

This county has a wide daily and annual range of temperature and precipitation. The high altitude and dry air are conducive to rapid radiational cooling at night. This rapid cooling and the warming on sunny days produce a wide daily range in temperature. In addition, the open plains permit the invasion of cold northern air, which causes even greater variation in the temperature from season to season and from year to year. Illustrative of the great variation in temperature and precipitation

[2] By A. D. ROBB, State climatologist, U.S. Weather Bureau, Topeka, Kans.

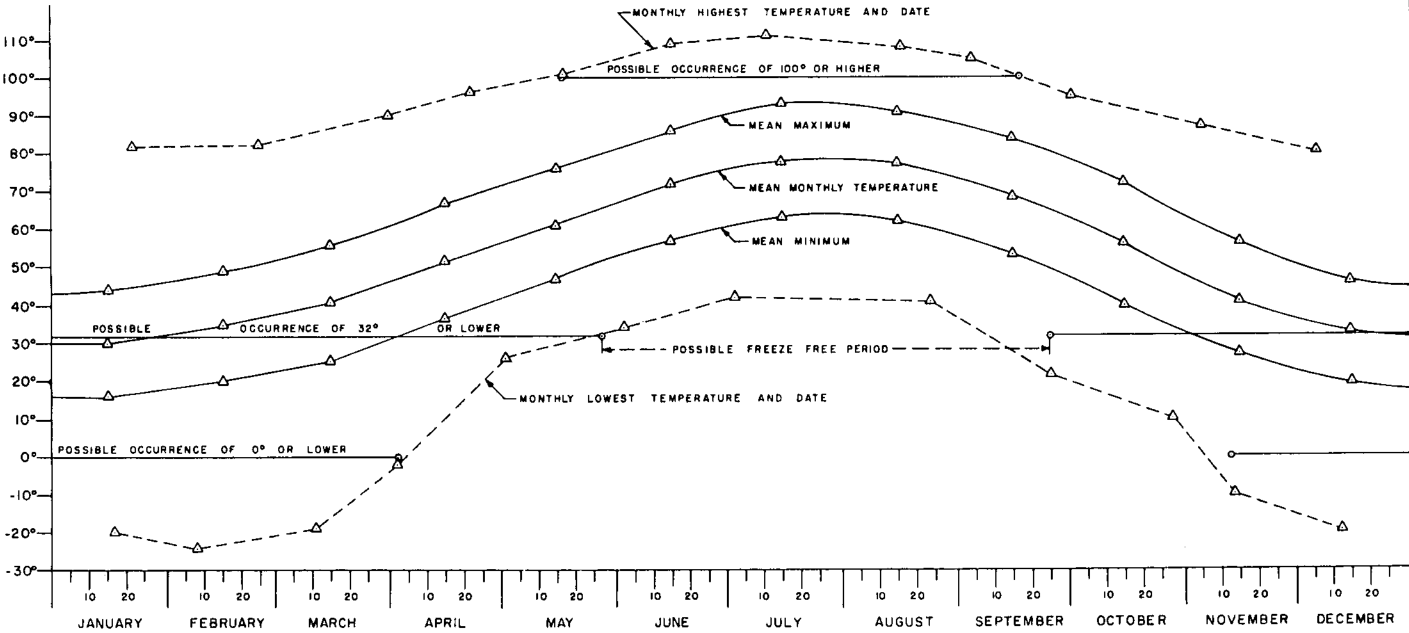


***Figure 3.*—Means and extremes of temperature at Oakley, Kans., for the period 1920 to 1961.**

are the long periods of comparatively cool weather, when there is an increase in precipitation, and the warmer periods, when there are droughts.

Spring and fall are marked by noticeable changes in weather. In fall each succeeding cold spell is a little more severe than the last. The sunshine of Indian summer finally gives way to low clouds and light, slow-falling rain or snow. Spring brings a waning of the cold spells and more showers, which are followed by summer thunderstorms.

Figure 3 shows the average (mean) temperature and the extremes in temperature for Logan County for the period 1920 to 1961. It shows the mean maximum, the mean minimum, and the mean monthly temperatures; the extremes for each month; the approximate time of occurrence of extremely high and extremely low temperatures; and the possible freeze-free period. An interesting fact is that the freeze-free period nearly coincides with the period when temperatures of 100° F. are most likely to occur. The extremes of high temperature occur near the crest of the mean maximum curve, but extreme cold is likely to occur a month or so after the curve showing the mean minimum temperature has begun to rise. This figure also shows a much wider range of temperature in the cold part of the year than in the warmer part.

An indication of the temperatures that are more likely to be experienced than the absolute extremes or means is given in table 1. Table 1 shows that a temperature of 104° or higher is probable on at least 4 days in July and 4 days in August in about 2 years in 10. The coldest day on record was 24° below zero, reached in February 1933, but the occurrence of at least 4 days in February when the temperature is 5° or lower is probable only twice in 10 years.

The warmest month for which there is a record at Oakley was July 1934, when the mean temperature was 84.2° On 20 days in that month, the temperature reached 100° or higher. As a result, the average maximum temperature for that month was 100.8°, the highest for any month on record and the only month in which the average maximum temperature was 100° or higher. In 1938, the mean temperature in both July and August was 80° or higher. That was the only time on record when there were 2 successive months when the average temperature was that high.

At the opposite extreme, January 1940 was the coldest month on record. Snow covered the ground during the entire month. On 11 days the minimum temperature was zero or lower, and on only 8 days did the temperature rise above freezing. The most prolonged cold periods on record occurred in December 1924 when the mean temperature was 21.3°, and in January 1925 when the mean temperature was 22.2°. From November 15 through March 1, a temperature of 32° or lower can be expected each night. Records show few minimum readings above freezing during that period.

In only one summer, that of 1941, in the period 1920 through 1961 have records failed to show a maximum temperature as high as 100°. Also, only one winter on record, that of 1944–45, passed without a temperature of zero or lower.

Table 2 gives the probabilities of the last freezing temperature in spring and the first in fall. Freezing temperatures are not a serious hazard in this area, because most locally grown crops are acclimated to the area. A hard freeze in spring, however, at the time the wheat is in boot or as late as the flowering stage will keep the kernels of wheat from forming. Also, if the soil remains cold and wet in spring, so that the growing season is shorter than normal, grain sorghum is likely not to mature before October 10, the average date of the first freeze in fall. According to records, the earliest freeze in fall was September 25 (*3*). A temperature of 32° or lower was recorded on that date in 1912, in 1926, and in 1961.

TABLE 1.—*Temperature and precipitation at Oakley, Logan County, Kans.*

Month	Temperature				Precipitation				
	Average daily maximum [1]	Average daily minimum [1]	Two years in 10 will have at least 4 days with— Maximum temperature equal to or higher than [2]—	Two years in 10 will have at least 4 days with— Minimum temperature equal to or lower than [2]—	Average monthly total [1]	One year in 10 will have— Monthly totals less than [1]—	One year in 10 will have— Monthly totals more than [1]—	Days when snow cover is 1 inch or more thick [3]	Average depth of snow on days with snow cover [3]
	°F.	*°F.*	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*	*Number*	*Inches*
January	43. 7	16. 1	62	−5	0. 48	(4)	1. 08	6	2. 9
February	48. 6	19. 9	68	5	. 57	0. 09	1. 20	4	2. 1
March	55. 4	25. 4	77	7	1. 29	. 27	2. 61	6	4. 5
April	67. 0	36. 6	85	22	1. 92	. 49	3. 65	3	2. 4
May	75. 7	46. 8	90	35	3. 00	1. 03	5. 34	0	0
June	86. 2	57. 3	102	45	3. 26	. 64	6. 14	0	0
July	92. 9	62. 7	104	55	2. 95	. 97	5. 51	0	0
August	91. 5	61. 7	104	53	2. 66	1. 15	5. 05	0	0
September	83. 5	52. 3	100	41	1. 46	. 29	3. 12	0	0
October	72. 1	40. 3	89	29	1. 38	. 20	3. 02	1	3. 0
November	55. 5	27. 2	74	10	. 73	. 01	1. 80	4	2. 6
December	45. 9	19. 5	65	7	. 52	. 05	1. 11	7	2. 9
Year	68. 2	38. 8	[5] 105	[6] −11	20. 22	[7] 13. 21	[3] 28. 12	31	2. 9

[1] Data for period 1920 to 1961.
[2] Data for period 1936 to 1961.
[3] Data for period 1922 to 1954.
[4] Trace.
[5] Average annual highest maximum.
[6] Average annual lowest minimum.
[7] Annual values less or more than.

The small amount and the uncertainty of its occurrence are the dominant characteristics of the precipitation in this area. Consequently, the production of crops is affected by lack of moisture. The average monthly precipitation ranges from a minimum of 0.48 inch in January to a maximum of 3.26 inches in June.

TABLE 2.—*Probabilities of last freezing temperatures in spring and first in fall in Logan County, Kans.*

[All data from Oakley, Logan County, Kans., for years 1920 to 1958]

Probability	Dates for given probability and temperature				
	16° F. or lower	20° F. or lower	24° F. or lower	28° F. or lower	32° F. or lower
Spring:					
1 year in 10 later than.	Apr. 12	Apr. 16	Apr. 22	May 5	May 20.
2 years in 10 later than.	Apr. 6	Apr. 11	Apr. 17	Apr. 30	May 15.
5 years in 10 later than.	Mar. 25	Mar. 31	Apr. 8	Apr. 19	May 5.
Fall:					
1 year in 10 earlier than.	Oct. 26	Oct. 22	Oct. 14	Oct. 6	Sept. 26.
2 years in 10 earlier than.	Nov. 1	Oct. 27	Oct. 18	Oct. 11	Sept. 30.
5 years in 10 earlier than.	Nov. 14	Nov. 7	Oct. 28	Oct. 20	Oct. 11.

As shown in table 1, one January in 10 can be expected to have no more than a trace of precipitation, and about one January in 10 will have an inch or more. August, which is usually considered to be hot and dry, has received at least 0.77 inch of rain each year since 1920. Only one August in 10 is likely to have less than 1.15 inches and more than 5.05 inches.

Heavy downpours that last as long as 24 hours result from the convective type of thunderstorms that occur in summer. Although these storms do not occur frequently, they need to be considered in the economy of the area as both an advantage and a disadvantage. Such rains provide moisture for crops and break droughts, but they may also damage crops. The largest amount of rainfall on record for a 24-hour period is 4.52 inches, which occurred on April 18, 1942. The largest amount of rainfall in 24 hours has exceeded 1 inch during the months of May, June, and July in only about half the years on record. All months, however, have had at least one storm in which 1 inch or more of rain fell in 24 hours.

Table 3 gives the amount of rainfall, lasting for a specified length of time from 30 minutes to 24 hours, that can be expected once in the return periods indicated. At least once a year, four-fifths of an inch of rain may be expected to fall during a 30-minute period, but only once in 100 years is it likely that as much as 2.7 inches will fall during a period of 30 minutes. The amount of rain that is likely to fall in 12 hours ranges from 1.6 inches once a year to 4 inches once in 25 years, or to a possible 5.1 inches once in 100 years (*16*).

TABLE 3.—*Amount of rainfall of stated duration to be expected once in the specified number of years at Oakley, Logan County, Kans.*

Duration	Return period of—						
	1 year	2 years	5 years	10 years	25 years	50 years	100 years
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
30 minutes	0. 8	1. 1	1. 5	1. 8	2. 1	2. 4	2. 7
1 hour	1. 1	1. 4	1. 9	2. 3	2. 7	3. 1	3. 5
2 hours	1. 2	1. 6	2. 1	2. 6	3. 0	3. 4	3. 8
3 hours	1. 3	1. 7	2. 2	2. 7	3. 1	3. 6	4. 0
6 hours	1. 5	1. 8	2. 5	3. 0	3. 5	4. 0	4. 5
12 hours	1. 6	2. 1	2. 8	3. 4	4. 0	4. 5	5. 1
24 hours	1. 8	2. 3	3. 1	3. 6	4. 2	5. 0	5. 5

Agriculturally, most interest centers in the amount of precipitation that occurs during the growing season. In Logan County the average amount of precipitation for the period from April through September is 15.25 inches. (See table 1.) The yearly average is 20.22 inches, and approximately three-fourths of this annual precipitation falls during one-half of the year. In 1946, the distribution of precipitation between the growing season and the entire year was more nearly equal than in any other year on record. Of the annual total of 34.49 inches, 18.01 inches fell from April through September and 16.48 inches fell during the other 6 months. This was the result of a wet October and of above-normal precipitation in March and November.

Figure 4 shows the comparison of the annual precipitation and the growing-season precipitation for Logan County for the years 1910 to 1961. One of the most noticeable facts shown in this figure is that years of comparatively high rainfall recur occasionally—on an average of about 1 year in 8. Two prolonged dry periods, one lasting 4 years and the other lasting 5, have been recorded since 1910. Three periods of above-normal precipitation during the growing season, two lasting 4 years and one lasting 6 years, have also been recorded since 1910.

The yield per acre of grain sorghum shows a direct relationship to the total amount of rainfall received in

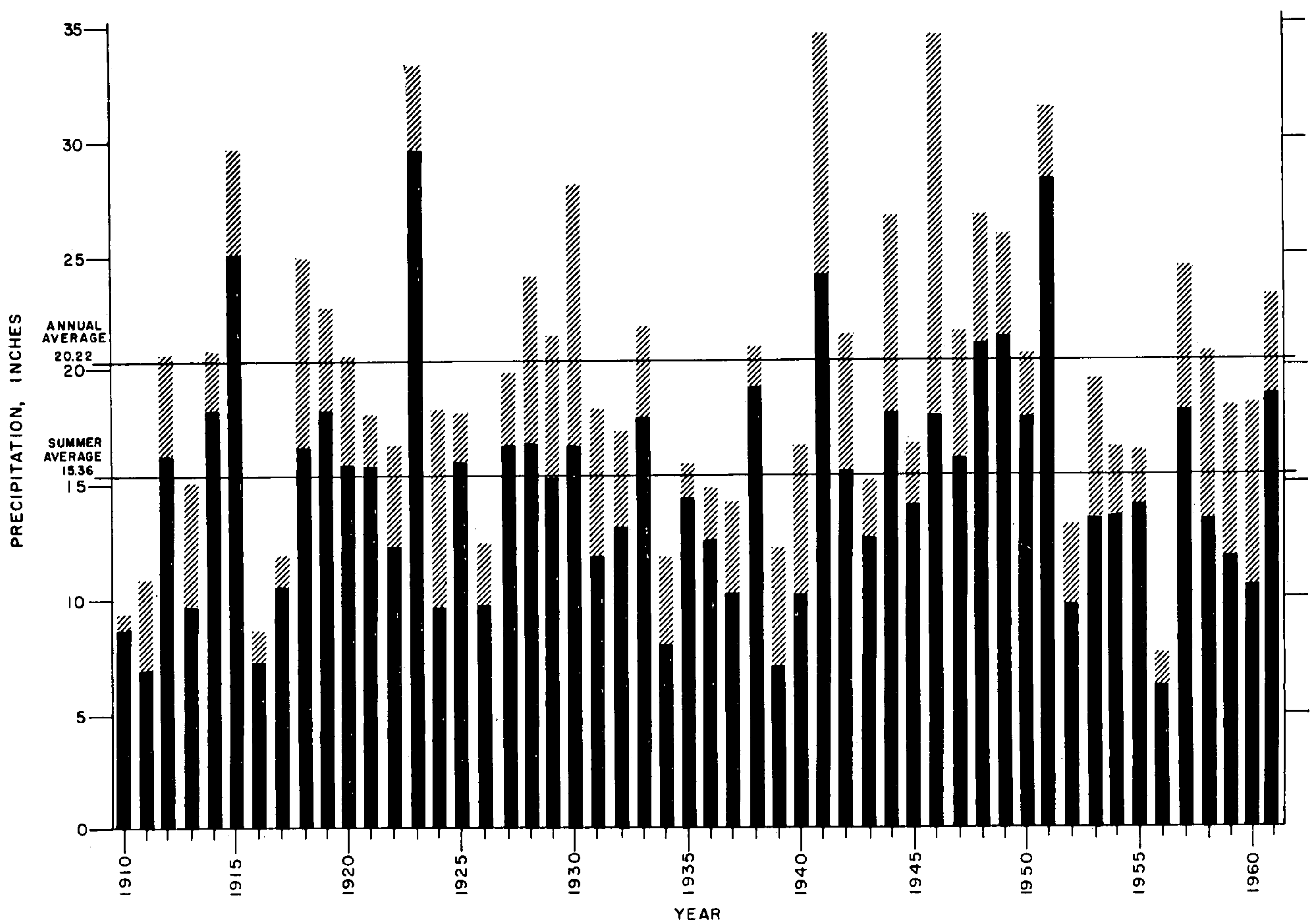


Figure 4.—Annual precipitation and precipitation during the growing season according to records at Russell Springs for the period 1910 to 1919 and at Oakley for the period 1920 to 1961. The solid part of each bar shows the amount of precipitation during the growing season, or from April through September; the hatching shows the amount of precipitation received from October through March.

TABLE 4.—*Ten driest years on record and the amount of precipitation for each month in each year at Russell Springs from 1910 to 1919 and at Oakley from 1920 to 1961*

Month	1956	1916	1910	1911	1934	1917	1939	1926	1952	1937
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	0.43	0.40	[1] 0.35	0.27	(2)	0.27	0.59	0.28	0.15	0.80
February	.36	(2)	[1] .20	1.32	1.76	.20	.93	.05	.36	.29
March	.30	(2)	0	0	.72	.60	2.60	.77	1.74	.47
April	.27	1.18	[1] .47	1.51	.17	1.08	.96	1.12	3.08	.52
May	.94	1.70	[1] 2.30	.77	2.44	2.03	1.22	1.65	1.24	1.03
June	.55	1.89	.37	1.02	2.11	.89	2.74	2.15	.91	3.14
July	2.60	.21	1.44	2.12	.67	3.11	.36	2.07	2.26	2.57
August	1.80	1.81	3.24	1.12	1.55	2.39	1.28	1.92	1.74	1.86
September	.02	.65	1.05	.57	1.15	1.13	.57	.88	.49	1.06
October	.29	.50	(2)	1.05	.30	.05	0	.35	.02	2.28
November	.19	(2)	.06	.07	.84	.12	0	.85	.87	.02
December	.05	.50	.04	1.15	.05	.15	1.01	.40	.35	.30
Year	7.80	8.84	9.52	10.97	11.76	12.02	12.26	12.49	13.21	14.34

[1] Estimated.
[2] Trace.

summer. Other factors affect the yield, of course, such as the abundance or lack of soil moisture at seeding time, the rate of seeding, the timeliness of rainfall, and the cultivation practices. During the 25 years from 1937 to 1961, when the total amount of rainfall from April to September was less than 12 inches, the average yield of grain per acre was only 10.5 bushels.[3] According to the same records, an increase of 50 percent in the total amount of rainfall resulted in an increase of approximately 50 percent in the yield. From records of rainfall for 1910 to 1961, it appears that the amount of rainfall was not great enough in about one-fourth of the summers for a yield of 10 bushels per acre to be obtained. These facts emphasize the need for further improvement in the varieties grown and in the tillage methods used. Improved varieties and better tillage methods will decrease the chance of a crop failure when the total amount of precipitation in summer is less than 12 inches.

[3] From records of the Statistical Reporting Service of the U.S. Department of Agriculture.

Dry, hot weather is the greatest deterrent to good growth of crops. In nearly every summer there is one period of at least 30 days with less than 0.25 inch of precipitation on any 1 day. Such dry periods have continued as long as 63 consecutive days (*5*). Table 4 gives the 10 driest years on record and the amount of precipitation for each. The figures were taken from records kept at Russell Springs for the period 1910 to 1919, and from records kept at Oakley for the period 1920 to 1961.

Figure 5 shows the probability, in percent, of receiving 0.02, 0.20, 0.60, 1.00, or 2.00 inches or more of precipitation in a 7-day period. The time when there is the greatest chance of receiving 0.02 inch of rain during a 7-day period, an 85-percent chance, occurs about the last part of May or in the first week of June. The least likely time is about mid-January. A weekly total of 0.60 inch or more is probable less than half the time during the first 2 weeks in June; it is not probable in weeks 45 and 46 in January. The probability of receiving as much as 2 inches of rain in 7 days is between 5 and 10

TABLE 5.—*Ten wettest years on record and the amount of precipitation for each month in each year at Russell Springs from 1910 to 1919 and at Oakley from 1920 to 1961*

Month	1941	1946	1923	1951	1915	1930	1948	1944	1949	1918
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	1.01	0.12	(1)	0.68	0.55	0.48	0.30	2.47	0.38	0.30
February	.67	.10	0.15	1.03	.80	.36	.91	.79	.37	.70
March	.68	3.59	.70	.39	[2] 1.54	.03	2.59	2.61	2.28	1.90
April	4.16	.52	2.91	1.46	[2] 3.20	2.84	.49	7.35	1.36	1.51
May	4.08	4.57	6.88	5.64	[2] 5.00	4.36	1.68	2.63	5.19	3.74
June	6.14	5.66	5.60	11.48	3.40	2.33	8.38	2.86	5.69	2.20
July	9.83	4.20	6.76	5.66	4.73	2.67	3.76	3.54	3.73	2.98
August	.92	.78	5.05	1.35	6.97	3.55	5.29	1.15	5.04	4.99
September	3.96	2.28	2.45	2.68	1.74	.91	1.39	.57	.18	1.21
October	1.33	9.02	2.46	.65	1.17	8.69	.40	.62	1.42	1.41
November	.25	3.65	.13	.27	.19	1.75	[2] 1.25	1.80	.01	.35
December	1.60	(1)	.20	.15	.45	.15	.37	.30	.29	3.70
Year	34.63	34.49	33.29	31.44	29.74	28.12	26.81	26.69	25.94	24.99

[1] Trace.
[2] Estimated.

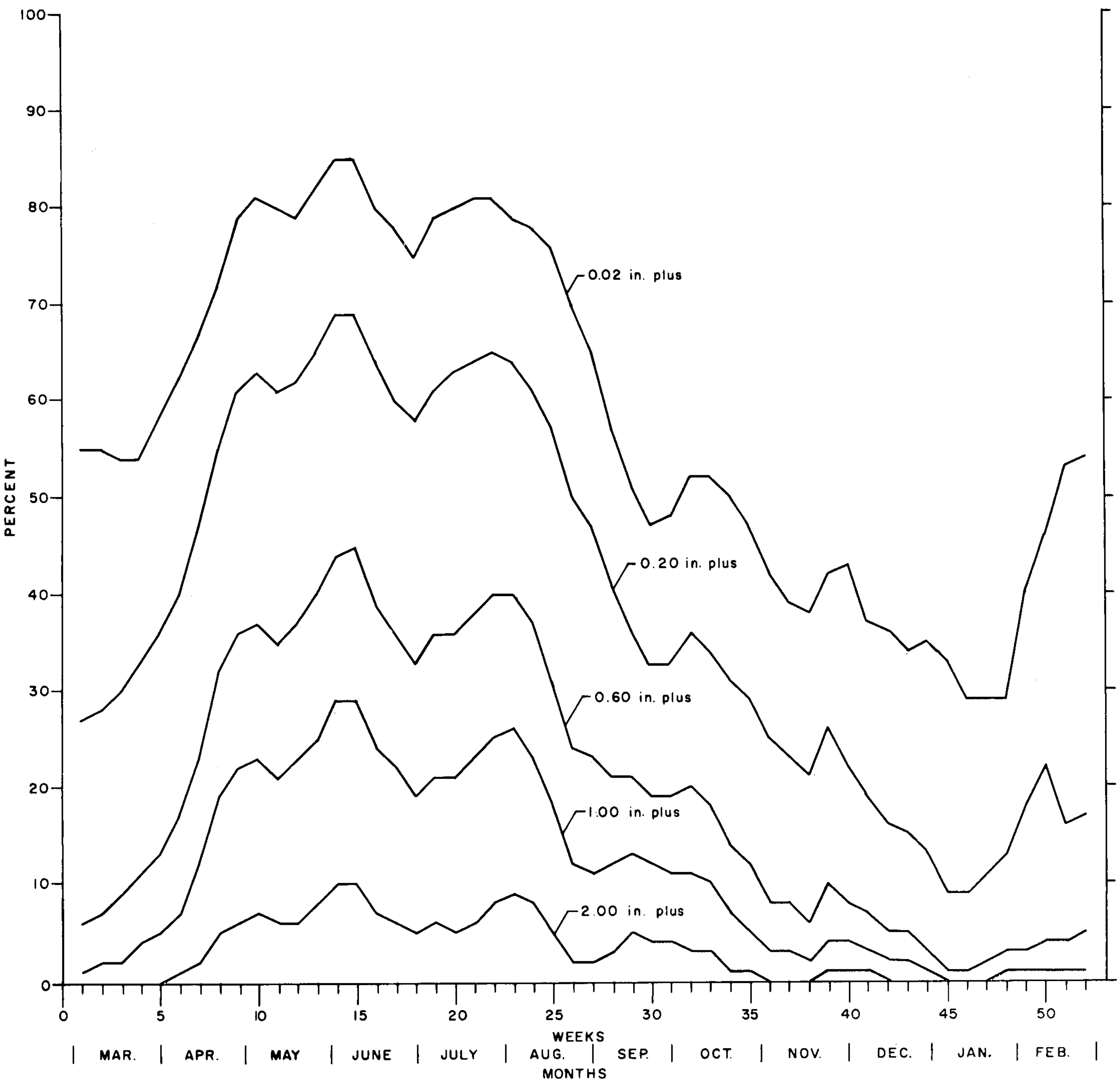


Figure 5.—**Probability, expressed in percent, of receiving 0.02, 0.20, 0.60, 1.00, or 2.00 inches or more of precipitation in a 7-day period at Oakley, Kans. The data were taken from records at Healy, Kans., for the period 1901 to 1954.**

percent during the period from mid-April to mid-August.[4]

Table 5 shows the 10 wettest years and the amount of precipitation in each year. The data were recorded at Russell Springs from 1910 to 1919 and at Oakley from 1920 to 1961.

Snowfall is probably the most variable of all weather elements in this area. Approximately 5 inches of snow has fallen during each of three winters, and almost nine times that much has fallen in four winters. In the winter of 1944–45, the total amount of snowfall was 35 inches, but there was only 5 inches in the following winter.

The snow that falls in Logan County is generally light and fluffy, and it drifts easily. Therefore, the small

[4] BARK, L. DEAN. CHANCES OF PRECIPITATION IN KANSAS. Kansas Agricultural Experiment Station Bulletin [in press 1962].

684–986—64——2

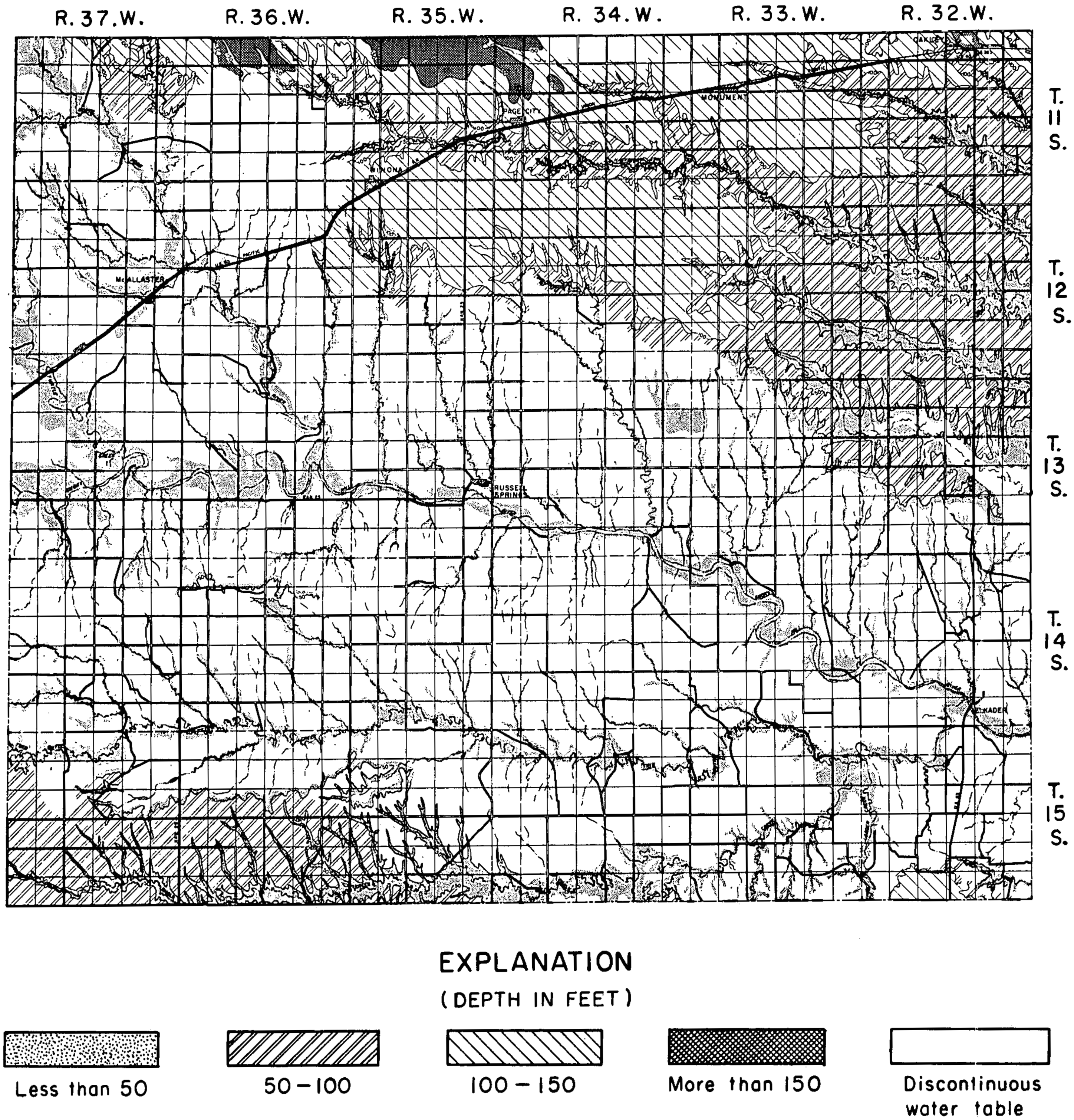


Figure 6.—**Map of Logan County showing depth to water.**

amount of precipitation furnished by snow is of little benefit to crops. Blizzards and drifting snow are serious hazards in winter.

In this area winds blow almost constantly. They were once used to furnish power for windmills and, later, to supply power for wind chargers for lighting individual homes. The prevailing direction of the wind is southerly, especially in the warm months. The monthly average velocity ranges from about 12 miles per hour late in summer to 16 or 17 miles per hour in spring. Severe winds are mainly from the northwest and range from 50 to 75 miles per hour.

Hailstones are dreaded in this area. Hailstones that are driven by high winds and that range from the size of a pea to that of a marble can devastate a crop in a few minutes. Hailstones the size of a golfball or baseball have at times damaged buildings and killed livestock.

Duststorms, or black blizzards, that occur in extreme and prolonged dry weather are a hazard. Keeping a cover crop on the soils at all times and using proper methods of tillage are necessary to prevent soil erosion as the result of wind. Tornadoes occur occasionally when summer thunderstorms develop.

Water Supply

The ground-water supply for both domestic and agricultural use is limited in Logan County. Figure 6, furnished by the State Geological Survey of Kansas, shows the depth to water and the areas where there is a discontinuous water table.

The Ogallala formation is the main source of water pumped from wells, but water can be obtained from it only in the northern and extreme southern parts of the county. This formation yields water of good quality for domestic use and for use by livestock.

The Niobrara formation and Pierre shale underlie the drainage area of the Smoky Hill River. These two formations are a poor source of ground water. Water from the Niobrara formation contains a high concentration of dissolved sulfates and other solids (7). Normally, it is undesirable for domestic use, although it is generally satisfactory for livestock. Many farmers in the central and southern parts of the county, which are underlain by the Niobrara formation and Pierre shale, haul water for domestic use and store it in cisterns. In those parts of the county, lack of good-quality water for domestic use is the primary factor that limits agricultural development and that is largely responsible for the sparse population.

An abundant supply of water is available in areas adjacent to the Smoky Hill River and along the larger tributaries of that river. In the areas adjacent to the Smoky Hill River, however, there are only a few irrigation wells because the soils are not well suited to irrigation.

General Soil Map

After study of the soils in a locality and the way they are arranged, it is possible to make a general map that shows several main patterns of soils, called soil associations. Such a map is the colored general soil map in the back of this report. Each association, as a rule, contains a few major soils and several minor soils, in a pattern that is characteristic although not strictly uniform.

The soils within any one association are likely to differ from each other in some or in many properties; for example, slope, depth, stoniness, or natural drainage. Thus, the general soil map shows, not the kind of soil at any particular place, but several different patterns of soils. Each pattern, furthermore, contains several kinds of soils.

Each soil association is named for the major soil series in it, but, as already noted, soils of other series may also be present. The major soils of one soil association may also be present in another association, but in a different pattern.

The general map showing patterns of soils is useful to people who want a general idea of the soils, who want to compare different parts of a county, or who want to know the possible location of good-sized areas suitable for a certain kind of farming or other land use.

1. Ulysses-Colby Association

Sloping soils of loessal uplands

This soil association is on uplands north of the Smoky Hill River and on divides between the main tributaries south of that river. The soils were formed in loessal deposits. The texture of their surface layer is silt loam. In general, these soils are not darkened with organic matter to so great a depth as the soils of the Keith-Ulysses association. They also have steeper slopes of

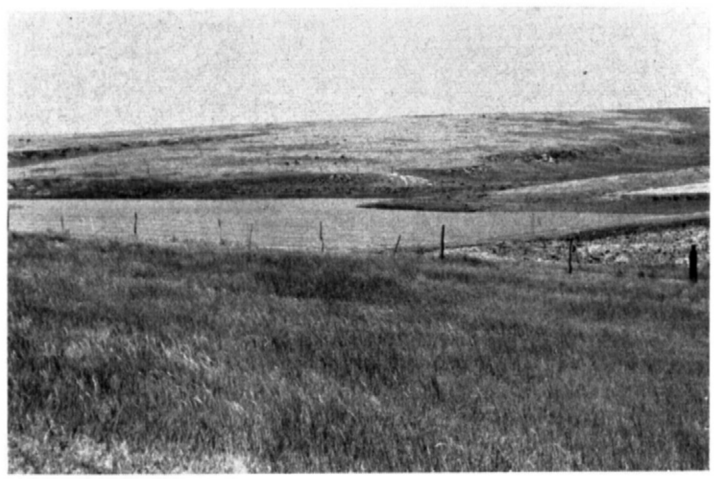


***Figure 7.*—A pond used for watering livestock that graze on the soils of the Ulysses-Colby association. The more steeply sloping areas are made up of Colby soils. Ulysses soils are on the divide in the background.**

3 to 15 percent. This association makes up 47 percent of the total area of the county.

The Ulysses soils are dark colored and are gently sloping. These soils overlie deep, calcareous, loessal material. They are productive of the commonly grown crops if they are protected from erosion by wind and water.

The Colby soils are lighter colored than the Ulysses soils and have steeper slopes. They are not well suited to cultivation.

About 45 percent of the Ulysses-Colby association is cultivated, and the rest is used for range. Wind and water erosion need to be controlled on the gently sloping areas used for crops. The steeper slopes should be reseeded to native grasses. Developing the water resources in this association helps in managing the areas used for range (fig. 7).

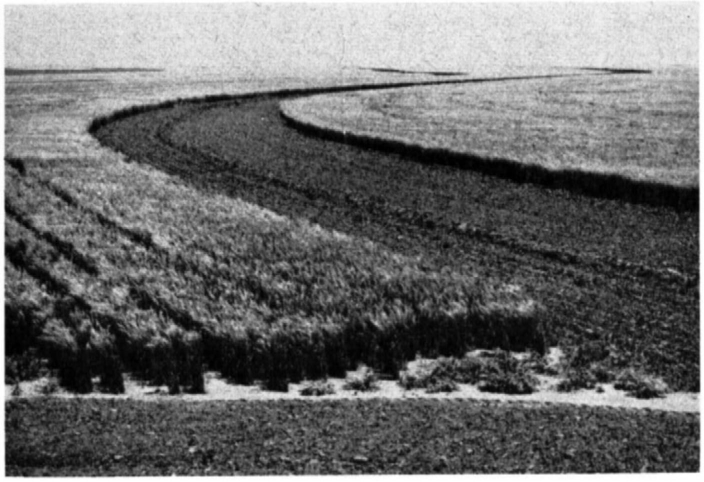


Figure 8.—**Wheat growing in strips in a field of Keith silt loam within the Keith-Ulysses association. Between the strips of wheat, the soil has been left fallow and will be used later for grain sorghum.**

2. Keith-Ulysses Association

Nearly level and gently sloping soils of loessal tablelands

This association is made up of nearly level and gently sloping areas mainly on the tablelands in the northeastern one-third of the county. The soils were formed in deep deposits of loess. They occupy approximately 31 percent of the county.

The Keith soils are nearly level or gently sloping, and they are dark colored to a depth of 15 to 24 inches. Their subsoil is silty clay loam. The Keith soils are productive of the crops commonly grown in the county.

The Ulysses soils are in the narrow drainageways that dissect areas of this association. They are dark colored to a depth of 7 to 15 inches, and their subsoil is limy silty clay loam. Except in areas that are steep and eroded, the Ulysses soils are productive of the crops that are commonly grown.

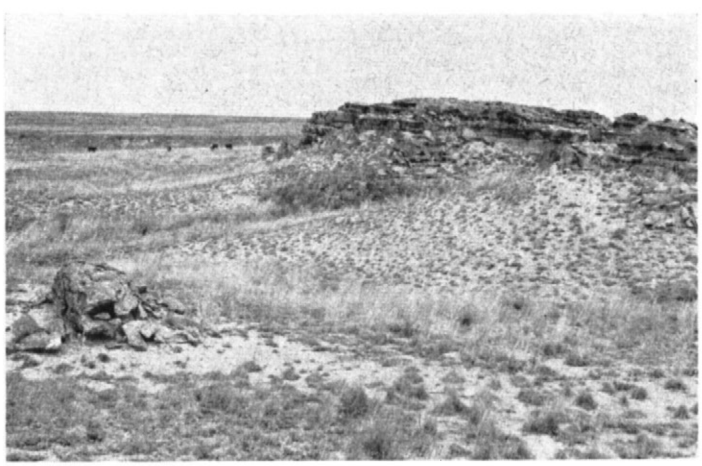


Figure 9.—**A rough, broken area in the Colby-Minnequa-Penrose association. Penrose soils are in the foreground, and Colby soils are above the rock escarpments in the background.**

Most of this association is cultivated, and winter wheat and grain sorghum are the principal crops (fig. 8). Conserving moisture and protecting the soils from wind erosion are the major conservation problems.

3. Colby-Minnequa-Penrose Association

Soils of rough, broken areas that are crossed by side drains, along the south side of the Smoky Hill River and Butte Creek.

This association is made up of rough, broken areas, mainly in the southern half of the county. The areas are crossed by the larger side drains of the county and are south of the main tributaries of the Smoky Hill River and Butte Creek. There are escarpments of bare rock within the areas (fig. 9). This association occupies only 7 percent of the county.

The Colby soils have smoother slopes than the soils in other parts of the association. The mantle of loess is thicker in these smoother areas than in the rest of the association. These soils have a thin, light-colored surface layer. They are not well suited to cultivation.

The Minnequa and Penrose soils are in areas where the Niobrara formation outcrops; they were formed in material weathered from that formation. The Minnequa soils have a thin, calcareous surface layer that overlies a deep, chalky subsoil. They are low in fertility and are not well suited to cultivation. The Penrose soils are shallow over chalk rock; outcrops of rock are scattered throughout the areas.

This association is economically important only for range. Good range management and development of water resources are needed in the areas.

4. Lismas-Colby-Gravelly Broken Land Association

Soils in broken areas of shale, gravel, and loess along tributaries of the Smoky Hill River

This association is in the western part of the county along the tributaries of the Smoky Hill River. In at least 90 percent of the association, the slope is greater than 5 percent. About 6 percent of the county is in this association.

The Lismas soils are shallow and clayey, and they overlie shale. They are strongly sloping and are in rough, broken areas. Bare outcrops of raw shale are common.

The Colby soils are on the crest of narrow divides where a mantle of loess remains. Their surface layer is thin and light colored, and they are not well suited to cultivation.

Gravelly broken land is on knolls. It consists of mixed silt, sand, and gravel over outcrops of Pierre shale.

Only about 10 percent of this association is cultivated. The rest is rough and broken and is suitable only for range. The steeper areas used for crops should be reseeded to permanent vegetation. The water resources also need to be developed, and good range management should be used.

5. Penrose-Colby-Loamy Broken Land Association

Soils in broken areas of chalk rock, sand, and loess along tributaries of the Smoky Hill River

This association is mainly between Russell Springs and the eastern boundary of the county. The soils are in broken areas of entrenched tributaries and bluffs north of the valley of the Smoky Hill River. They are shallow over chalk rock, and there are many scattered outcrops of bare rock. The slopes are between 5 and 20 percent. This association makes up 4 percent of the county.

The Penrose soils are in broken areas of entrenched drains or in outcrops on the bluffs. They are shallow over chalk rock, and the areas contain scattered outcrops of bedrock.

The Colby soils are in areas where the mantle of loess remains on the narrow ridges between the tributaries. They have a thin, light-colored surface layer and overlie loessal parent material that is deep and calcareous.

Loamy broken land consists of a mixture of loamy material of weathered Smoky Hill chalk rock, loess, and outwash sand. It is in entrenched drains north of the Smoky Hill River and north of the north fork of that river.

The soils in this association are generally not suited to cultivation. The steeper areas that have been used for crops should be seeded to permanent vegetation. The water resources also need to be developed, and good range management should be used.

6. Bridgeport-Lincoln-Las Animas Association

Nearly level soils on flood plains and terraces

This association occurs throughout the county in the valleys of the major streams. The soils are on nearly level flood plains and on low terraces and alluvial fans in the valleys. The association makes up only 3 percent of the county.

The Bridgeport soils are deep and medium textured. They are on low stream terraces adjacent to the walls of the valleys. These soils are cultivated more extensively than the other soils formed in alluvium in this county.

The Lincoln soils are in low, frequently flooded areas along the channel of the Smoky Hill River. They are too coarse textured to be suitable for cultivation.

The Las Animas soils are moderately coarse textured, and they are generally in areas between the Lincoln and Bridgeport soils. Most of the acreage of Las Animas soils is used for range.

Within this association, some of the minor soils formed in alluvium are the soils of the Las, Likes, and Volin series.

Although the soils in most of this association are not cultivated, the areas are used for grazing and as a source of water for the adjoining large tracts of rangeland. Some alfalfa is grown on the cultivated soils, and there are scattered stands of trees on the flood plains.

7. Potter-Ulysses Association

Stony soils in rough, broken areas

This association is mainly in the extreme southern part of the county, south of Chalk Creek, where the Ogallala formation outcrops. The soils in the association have slopes of 3 to 45 percent. The association comprises only 2 percent of the county.

The Potter soils are shallow over bedrock of caliche and cemented sand. There are outcrops within the areas, and these appear as rimrock or as steep, broken, bare escarpments.

The Ulysses soils have a dark-colored surface layer and overlie deep, calcareous, loessal material. In the areas below the rimrock, along drainageways and on the narrow ridges, the Ulysses soils are in the same general areas as the Potter soils. Some areas of the Ulysses soils could be cultivated, but they are within areas that are too steep or inaccessible to be used for crops.

This association is almost entirely in range. Good range management and development of water are needed in the areas.

How Soils Are Named, Mapped, and Classified

Soil scientists made this survey to learn what kinds of soils are in Logan County, where they are located, and how they can be used.

They went into the county knowing they likely would find many soils they had already seen, and perhaps some they had not. As they traveled over the county, they observed steepness, length, and shape of slopes; size and speed of streams; kinds of native plants or crops; kinds of rock; and many facts about the soils. They dug or bored many holes to expose soil profiles. A profile is the sequence of natural layers, or horizons, in a soil; it extends from the surface down to the rock material that has not been changed much by leaching or by the roots of plants.

The soil scientists made comparisons among the profiles they studied, and they compared these profiles with those in counties nearby and in places more distant. They classified and named the soils according to uniform procedures. To use this report efficiently, it is necessary to know the kinds of groupings most used in a local soil classification.

Soils that have profiles almost alike make up a soil series. Except for different texture in the surface layer, all the soils of one series have major horizons that are similar in thickness, arrangement, and other important characteristics. Each soil series is named for a town or other geographic feature near the place where a soil of that series was first observed and mapped. Colby and Elkader, for example, are the names of two soil series. All the soils in the United States having the same series name are essentially alike in natural characteristics.

A soil series contains soils that differ in the texture of their surface layer. According to such differences, separations called soil types are made. Within a series, all the soils having a surface layer of the same texture belong to one soil type. For example, Colby silt loam is a soil type in the Colby series. Thus, the texture of the surface layer is apparent from the name of the soil type.

Some soil types vary so much in slope, degree of erosion, number and size of stones, or some other feature affecting their use that practical suggestions about their management could not be made if they were shown on the soil map as one unit. Such soil types are divided into soil phases. The name of a soil phase indicates a feature that affects management. For example, Colby silt loam, 3 to 5 percent slopes, is one of several phases of Colby silt loam, a soil type that ranges from nearly level to steep.

After a fairly detailed guide for classifying and naming the soils had been worked out, the soil scientists drew soil boundaries on aerial photographs. They used photographs for their base map because these show woodland, buildings, field borders, trees, and similar details that greatly help in drawing boundaries accurately. The soil map in the back of this report was prepared from the aerial photographs.

The areas shown on a soil map are called mapping units. On most maps detailed enough to be useful in planning management of farms and fields, a mapping unit is nearly equivalent to a soil type or a phase of a soil type. It is not exactly equivalent, because it is not practical to show on such a map all the small, scattered bits of soil of some other kind that have been seen within an area that is dominantly of a recognized soil type or soil phase.

In preparing some detailed maps, the soil scientist has a problem of delineating areas where different kinds of soils are so intricately mixed, and so small in size, that it is not practical to show them separately on the map. Therefore, he shows this mixture of soils as one mapping unit and calls it a soil complex. Ordinarily, a soil complex is named for the major soil series in it, for example, Ulysses-Colby silt loams. Also, in most mapping, there are areas to be shown that are so rocky, so shallow, or so frequently worked by wind and water that they cannot be called soils. These areas are shown on a soil map like other mapping units, but they are given descriptive names, such as Active dunes or Gravelly broken land, and are called land types rather than soils.

Only part of the soil survey was done when the soil scientist had named and described the soil series and mapping units, and had shown the location of the mapping units on the soil map. The mass of detailed information he had recorded then needed to be presented in different ways for different groups of users, among them farmers, managers of windbreaks and rangeland, and engineers.

To do this efficiently, he had to consult with persons in other fields of work and jointly prepare with them groupings that would be of practical value to different users. Such groupings are the capability classes, subclasses, and units, designed primarily for those interested in producing the short-lived crops and tame pasture; range sites, for those using large tracts of native grass; windbreak suitability groups, for those who need to plant windbreaks; and the classifications used by engineers who build highways or structures to conserve soil and water.

Descriptions of the Soils

The soils mapped in Logan County are described in this section, and the main facts about each are given. The capability unit, range site, and windbreak suitability group, described in other sections of this report, are indicated for each soil. A more detailed description of a profile considered to be typical of each series is given in the section "Detailed Descriptions of the Soil Series."

Color, texture, structure, and consistence are all used to distinguish between the layers, or horizons, of a soil. The color of the surface layer is generally related to the amount of organic matter in that layer. The darker the surface layer, as a rule, the more organic matter it contains. Streaks and spots of gray, yellow, and brown in the lower layers generally indicate poor drainage and poor aeration.

Soil texture refers to the relative proportions of sand, silt, and clay that make up the soil mass. In the field, texture is determined by feel, but some samples are also analyzed in the laboratory.

Structure refers to the arrangement of the soil particles in a single mass or cluster to form the natural aggregates in the soil. It is described to indicate strength or grade (*weak*, *moderate*, or *strong*); size (*very fine*, *fine*, *medium*, *coarse*, or *very coarse*); and shape (*platy*, *prismatic*, *columnar*, *blocky*, *subangular blocky*, *granular*, or *crumb*). In a soil that lacks structure, the soil material is described as massive if it is coherent and as single grain if it is not coherent.

Consistence is determined by feel. It is gaged by determining the resistance of the aggregates to pressure.

Other terms used to describe the soils, particularly the more technical terms, are defined in the Glossary at the back of this report.

Table 6 gives the acreage of each mapping unit and its proportionate extent. The location and distribution of each of the mapping units are shown on the soil map at the back of the report. The "Guide to Mapping Units, Capability Units, Range Sites, and Windbreak Suitability Groups," also at the back of the report, lists the mapping symbol for each mapping unit and the page where that mapping unit is described. In addition, it lists for each mapping unit the capability unit, range site, and windbreak suitability group and the page where each is described.

Active dunes (Ad).—This miscellaneous land type consists of hills, ridges, and cone-shaped dunes of fine, actively shifting sand. There is no definable soil profile. The development of a soil profile is prevented by the continual movement of the sand. The areas become larger as the sand continues to drift. (Capability unit VIIe-1; Choppy Sands range site.)

Alluvial land (An).—This miscellaneous land type consists of dark-colored, moderately coarse textured and medium-textured soils of the flood plains. It is in the narrow valleys of drainageways in the uplands, and it is bordered on both sides by strongly sloping, nonarable soils.

Cultivating Alluvial land is not practical, because of the frequent flooding and the meandering channels in the areas. This land type is very productive of grass. Both mid and tall prairie grasses grow on it if the areas are not overgrazed. (Capability unit VIw-1; Loamy Lowland range site; Lowland windbreak suitability group.)

Badland (Bl).—This miscellaneous land type is made up of nearly bare geologic material of the Niobrara formation. The relief is rough and broken, and there are many escarpments, pinnacles, and vertical-walled canyons. The

TABLE 6.—*Approximate acreage and proportionate extent of the soils*

Soil	Area	Extent
	Acres	*Percent*
Active dunes	124	(1)
Alluvial land	7, 485	1. 1
Badland	2, 151	. 3
Bridgeport loam	11, 941	1. 7
Bridgeport silt loam, strongly calcareous variant	2, 613	. 4
Colby silt loam, 3 to 5 percent slopes	1, 509	. 2
Colby silt loam, 5 to 15 percent slopes	68, 094	9. 9
Dwyer loamy fine sand	1, 464	. 2
Elkader silt loam, 0 to 1 percent slopes	1, 179	. 2
Elkader silt loam, 1 to 3 percent slopes	5, 053	. 7
Elkader silt loam, 3 to 5 percent slopes	8, 652	1. 3
Elkader silt loam, 5 to 15 percent slopes	9, 861	1. 4
Gravelly broken land	3, 398	. 5
Keith silt loam, 0 to 1 percent slopes	133, 583	19. 5
Keith silt loam, 1 to 3 percent slopes	12, 303	1. 8
Las loam, moderately deep	2, 282	. 3
Las Animas sandy loam	2, 054	. 3
Likes loamy fine sand	541	. 1
Lincoln soils	2, 360	. 3
Lismas clay	10, 673	1. 6
Loamy broken land	10, 121	1. 5
Lofton silty clay loam	913	. 1
Lubbock silt loam	1, 393	. 2
Manter fine sandy loam, 1 to 3 percent slopes	1, 097	. 2
Manter fine sandy loam, 3 to 5 percent slopes	509	. 1
Minnequa silt loam	7, 195	1. 1
Minnequa-Penrose silt loams	16, 775	2. 4
Otero fine sandy loam	3, 539	. 5
Potter soils	8, 539	1. 2
Promise clay, 0 to 1 percent slopes	1, 005	. 1
Promise clay, 1 to 3 percent slopes	790	. 1
Promise clay, 3 to 5 percent slopes	533	. 1
Randall clay	1, 088	. 2
Richfield silt loam, 0 to 1 percent slopes	11, 313	1. 6
Ulysses silt loam, 0 to 1 percent slopes	97, 193	14. 2
Ulysses silt loam, 1 to 3 percent slopes	148, 072	21. 6
Ulysses silt loam, 3 to 5 percent slopes	43, 954	6. 4
Ulysses silt loam, 5 to 15 percent slopes	25, 924	3. 8
Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded	8, 380	1. 2
Ulysses-Colby silt loams, 5 to 15 percent slopes, eroded	2, 520	. 4
Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes	1, 356	. 2
Volin silt loam	3, 677	. 5
Volin-slickspot complex	329	. 1
Wet alluvial land	263	(1)
Subtotal	683, 798	99. 6
Smoky Hill River	2, 922	. 4
Total	686, 720	100. 0

[1] Less than 0.1 percent.

areas are difficult to cross and offer only limited accessibility to livestock.

Vegetation covers less than 10 percent of this land type. It generally grows on the smoother borders and isolated patches within the rough areas. (Capability unit VIIIs–1.)

Bridgeport Series

Deep, calcareous, medium-textured soils make up the Bridgeport series. The soils formed in valley sediments and in sediments of alluvial fans along the major streams.

In a typical profile the surface layer is 18 inches of grayish-brown, friable loam. It has weak, fine, granular structure and is calcareous. The subsoil is 52 inches of light grayish-brown, soft loam that is structureless. It is calcareous and contains a few clusters of soft lime and gypsum crystals in the lower part. The soil material in the lower 10 inches is stratified sandy loam and clay loam that is transitional to the substratum. The substratum is a deep deposit of sand and gravel, consisting of valley alluvium.

The surface layer of the Bridgeport soils ranges from 10 to 20 inches in thickness. It is generally calcareous to the surface, but it is noncalcareous to a depth of 10 inches in some places. The soil layers are generally uniform in texture, but there may be stratifications of sandy loam in any layer. The material in the substratum ranges from sand and gravel to loam and silt loam. If a water table is present, it is at a depth of 6 to 20 feet.

The Bridgeport soils are deeper over sand than the Las soils. They are also better drained and occupy higher positions in the valley.

The Bridgeport soils are moderately permeable, have a high water-holding capacity, and release moisture to plants readily. These soils are only moderately well supplied with organic matter. Because they are calcareous, iron chlorosis may affect sorghum grown on them. Alfalfa can be grown successfully in areas where there is an effective water table, that is, a water table that can be reached by the roots of some kinds of plants.

These are among the most extensive and productive of all the soils formed in alluvium in this county. They are used for all the different cultivated crops commonly grown. Large areas, however, remain in native grass as a part of ranching units. The native vegetation is short and mid prairie grasses.

Bridgeport loam (Bp) is nearly level. It is on alluvial fans and in valleys along the major streams and tributaries throughout the county.

The surface layer is calcareous loam, and the subsoil is also loam. The subsoil extends downward to a depth of 5 feet or more before grading to sand of the valley alluvium. In areas where there is a water table, the water table stands at a depth of 6 to 20 feet. This soil is easy to till.

Mapped with this soil are areas of Volin silt loam. These included areas are too small to be mapped separately. (Capability unit IIc–1; Loamy Upland range site; Upland windbreak suitability group.)

Bridgeport Series, Strongly Calcareous Variant

The soils of this variant from the normal Bridgeport series are deep, light colored, calcareous, and medium textured. They were formed on the flood plains of streams that derive their sediments from chalk rock of the Niobrara formation.

In a typical profile the surface layer is 6 inches of grayish-brown, calcareous, friable silt loam that has weak, fine, granular structure. It grades to the subsoil through a transitional layer that is 14 inches thick. This transitional layer is light yellowish-brown, friable silty clay loam that has moderate, fine and medium, granular structure. It contains a large amount of lime.

The subsoil is deep, soft silt loam that is structureless. It, too, contains a large amount of lime.

The surface layer ranges from 4 to 8 inches in thickness. The color of the subsoil ranges from brown to yellow, and the texture, from heavy silt loam to light silty clay loam. Only slight stratification of sandy loam and clay loam occurs in the subsoil. The water table is below a depth of 10 feet in those areas where there is a water table.

The soils of the Bridgeport series, strongly calcareous variant, have a lighter colored surface layer than the Volin soils, and their subsoil contains more lime. They have a thicker surface layer than the Minnequa soils, and they are on the flood plains of streams.

The strongly calcareous variants from the Bridgeport series are well drained and are moderately permeable. Their subsoil has a high water-holding capacity, and it releases moisture readily to plants. The soils are subject to occasional flooding. They are only moderately well supplied with organic matter. Sorghum is not suited to these soils, because of the high content of lime. Alfalfa can be grown successfully in areas where there is an effective water table.

These soils are not extensive in this county. Most of the acreage remains in native grass as a part of large ranching units. The native vegetation is mainly western wheatgrass, but some short grasses and inland saltgrass grow on the soils.

Bridgeport silt loam, strongly calcareous variant (Bv), is on the nearly level flood plains of Twin Butte Creek in the south-central part of the country.

The surface layer is 6 inches of calcareous, grayish-brown silt loam that is easy to till. The subsoil is yellowish silty clay loam that contains a large amount of lime. This soil is well drained, but it is susceptible to occasional flooding. The water table is below a depth of 10 feet in areas where there is a water table.

Mapped with this soil are a few areas of Bridgeport loam. (Capability unit IVs-3; Loamy Lowland range site; Chalky windbreak suitability group.)

Colby Series

Soils of the Colby series are deep, light colored, medium textured, and calcareous. They were formed in deep deposits of loess on moderately to strongly sloping uplands.

In a typical profile the surface layer is 5 inches of grayish-brown, friable silt loam. It has weak, fine, granular structure and is calcareous. The surface layer grades to the parent material through a transitional layer that is 19 inches thick. This layer is pale-brown, friable silt loam that is calcareous and has a few spots of lime. The parent material is deep loess of very pale brown, soft, calcareous silt loam.

The surface layer of the Colby soils ranges from 4 to 6 inches in thickness. The color ranges from grayish brown in areas of sod that have not been cultivated to pale brown in cultivated areas. The lower part of the surface layer is slightly calcareous in the areas under sod.

The Colby soils have not been darkened by organic matter to so great a depth as the soils of the Ulysses series. Their parent material contains less lime than that of the Minnequa soils.

The Colby soils are permeable, have a high water-holding capacity, and release moisture readily to plants. When they are cultivated, the soil material in their surface layer soon becomes mixed with that in the calcareous subsurface layer. The soil has little or no structure to prevent surface sealing and excessive runoff during heavy rains. Emergency tillage is only moderately effective for controlling wind erosion.

The Colby soils are used mainly for range. Fringe areas and some larger tracts, however, are used to grow small grains. If sorghum is grown, iron chlorosis is a serious problem. The native vegetation is mainly short grasses, but side-oats grama and little bluestem are mixed with the short grasses on the steeper slopes.

Figure 10.—**A profile of Colby silt loam on a slope of 6 percent. The surface layer is thin and is darkened with organic matter.**

Colby silt loam, 3 to 5 percent slopes (Cc), is on uplands between the entrenched drainageways and the tablelands. Its texture is silt loam throughout the profile. The surface layer is grayish brown and is 5 inches thick. The parent material is loess of pale brown or very pale brown, friable, calcareous silt loam.

Mapped with this soil are areas of Ulysses silt loam, 1 to 3 percent slopes. The included areas are too small to be mapped separately. (Capability unit IVe–2; Loamy Upland range site; Upland windbreak suitability group.)

Colby silt loam, 5 to 15 percent slopes (Cd), is in drainageways in the southern and western parts of the county. This soil has a texture of silt loam throughout the profile, and it is calcareous throughout. The surface layer is grayish brown and is 4 inches thick (fig. 10). The parent material is loess of very pale brown, friable, calcareous silt loam. There are a few scattered, vertical escarpments, or cat-steps, in the areas. These range from 4 to 12 inches in height. The parent material of unweathered loess is exposed on the surface of the escarpment.

Mapped with this soil are areas of Alluvial land. These areas are too small to be mapped separately. (Capability unit VIe–4; Limy Upland range site; Upland windbreak suitability group.)

Dwyer Series

Soils of the Dwyer series are deep, coarse textured, and calcareous. They were formed in calcareous sands reworked by wind and are in areas of low, hummocky relief.

The surface layer, in a typical profile, is 5 inches of brown, soft loamy fine sand that forms slightly coherent clods or consists of single grains of sand. This layer has very weak, fine, granular structure and is calcareous. It grades to the parent material through a transitional layer that is 7 inches thick. The transitional layer is light yellowish-brown, loose, calcareous fine sand that is structureless. The parent material is deep, very pale brown, loose, single grain, calcareous sand.

These soils have a thin layer of sandy loam on the surface in areas adjacent to finer textured soils. The depth to which they are darkened by organic matter ranges from 8 to 16 inches.

The Dwyer soils are coarser textured throughout than the Otero and Manter soils. Permeability is very rapid in the Dwyer soils. These soils absorb water rapidly, but the sand is low in water-holding capacity.

The Dwyer soils are not extensive in this county, and all of the acreage is used for range. The native vegetation is mainly mid and tall prairie grasses, but there is some sand sagebrush.

Dwyer loamy fine sand (Dw) is in areas of low, hummocky relief where the sides of the hummocks have slopes of 3 to 8 percent. It is south of the Smoky Hill River, above the flood plain.

The surface layer is loamy fine sand that is subject to severe wind erosion if it is not protected by vegetation. It is darkened with organic matter to a depth of only 12 inches (fig. 11). The parent material is deep fine sand that has a low water-holding capacity.

Mapped with this soil are areas of Otero fine sandy loam that are between the hummocks and near the outer margins of the Dwyer soil. The included areas are too small to be mapped separately. (Capability unit VIe–2; Sands range site.)

Figure 11.—**A profile of Dwyer loamy fine sand. Its sandy texture makes this soil low in water-holding capacity.**

Elkader Series

The soils of the Elkader series are deep, calcareous, and medium textured. They were formed in thin deposits of loess over sediments weathered from chalk rock. These soils are nearly level to strongly sloping and are on the uplands.

The surface layer, in a typical profile, is 15 inches of dark grayish-brown, friable silt loam. It has moderate, fine and medium, granular structure and is calcareous. A transitional layer that is 8 inches thick lies between the surface layer and the parent material. This layer is brown, slightly hard silt loam that has weak, fine, granular structure. It is strongly calcareous and contains a few fine grains of chalk rock. The parent material is deep, olive-yellow, slightly hard light silty clay loam that is structureless. It contains a large amount of lime and has fragments of chalk rock scattered throughout.

The surface layer of the Elkader soils ranges from 8 to 20 inches in thickness. Fragments of chalk rock commonly occur within the uppermost 3 feet of soil material. The Elkader soils are dominantly medium textured, but they are moderately fine textured in some places.

The surface layer of the Elkader soils is calcareous, and their parent material contains more lime than that of the Ulysses soils. Their surface layer is thicker than that of the Minnequa soils.

The Elkader soils are moderately permeable and have a high water-holding capacity. The large amount of lime in their profile causes severe iron chlorosis in sorghum grown on them. If these soils are cultivated, the surface seals over and runoff is excessive. The soils are highly susceptible to erosion by wind and water.

Most of the acreage of Elkader soils remains in native grass, but some areas are cultivated. Yields of sorghum are generally low. Wheat, barley, and other cereal grains are more tolerant than sorghum of the large amount of lime in the soils, and moderate yields of these crops are obtained.

Elkader silt loam, 0 to 1 percent slopes (Ea), is nearly level and is below the steeper Elkader silt loams. The surface layer of this soil is somewhat darker, thicker, and less limy than that of the other Elkader silt loams. Most of this soil is in large pastures of native grass.

Mapped with this soil are areas of Elkader silt loam, 1 to 3 percent slopes. The included areas are too small to be mapped separately. (Capability unit IIc–1; Loamy Upland range site; Chalky windbreak suitability group.)

Elkader silt loam, 1 to 3 percent slopes (Eb), is gently sloping and is on the uplands in the southern part of the county. The surface layer is 18 inches thick and is calcareous. The parent material contains a large amount of lime and grains or chips of chalk rock. The soil is used for range and for field crops.

Mapped with this soil are areas of Elkader silt loam, 3 to 5 percent slopes, and of a Minnequa silt loam. These included areas are too small to be mapped separately. (Capability unit IIIe–1; Limy Upland range site; Chalky windbreak suitability group.)

Elkader silt loam, 3 to 5 percent slopes (Ec), is moderately sloping and is on the uplands in the southern part of the county. The surface layer is 15 inches of calcareous silt loam. It contains only a moderate amount of organic matter. The parent material is yellowish, friable silt loam and contains a large amount of lime and small chips of chalk rock. Most of this soil remains in native grass. Yields of cultivated crops are generally low.

Mapped with this soil are areas of Elkader silt loam, 1 to 3 percent slopes, and of Minnequa silt loam. The included areas are too small to be mapped separately. (Capability unit IVe–2; Limy Upland range site; Chalky windbreak suitability group.)

Elkader silt loam, 5 to 15 percent slopes (Ed), is on the uplands in the southern part of the county. The surface layer is 13 inches of calcareous silt loam. It contains only a moderate amount of organic matter. The parent material is yellowish, friable silt loam that contains a large amount of lime and chips of chalk rock. Because this soil is steep and calcareous, it is not suited to cultivation. Most of the acreage is in native grass.

Mapped with this soil are small areas of Elkader silt loam, 3 to 5 percent slopes, and of Minnequa-Penrose silt loams. These included areas are too small to be mapped separately. (Capability unit VIe–4; Limy Upland range site; Chalky windbreak suitability group.)

Gravelly Broken Land (Gr)

Gravelly broken land is a miscellaneous land type that occurs as steep, broken slopes and hummocks. The areas are below the summit of the tablelands and along the sides of large drainageways. The texture of the soil material is variable in these areas. Near the surface, the soil material is moderately coarse textured or coarse textured. Sand and gravel are at a depth of 4 to 10 inches, and water-rounded pebbles, as large as 3 inches in diameter, are scattered on the surface.

The soil material in this land type takes up water rapidly, but it is low in water-holding capacity. Mid and tall prairie grasses grow on the areas, and sage and small soapweed are also common. (Capability unit VIIs–3; Gravelly Hills range site.)

Keith Series

Soils of the Keith series are deep, dark, and medium textured. They were formed in deep loess on the nearly level and gently sloping tablelands.

In a typical profile the surface layer is 11 inches of very dark grayish-brown, friable silt loam that has moderate, medium, granular structure and is noncalcareous. The subsoil is 11 inches of dark grayish-brown light silty clay loam that has weak, subangular blocky structure and is also noncalcareous. The subsoil grades to the parent material through a transitional layer that is 12 inches thick. This transitional layer is pale-brown, slightly hard silt loam that has weak, subangular blocky structure. It is calcareous and contains a few white spots of soft lime. The parent material is deep, very pale brown, soft silt loam. It has no observable structure and is calcareous.

The surface layer of the Keith soils ranges from 6 to 16 inches in thickness. The subsoil ranges from 9 to 18 inches in thickness and from 15 to 25 inches in depth to free lime.

The Keith soils are darkened with organic matter to a depth greater than in the associated Ulysses soils, and they are noncalcareous. They have weaker structure and less clay in the subsoil than the Richfield soils.

The Keith soils are moderately permeable, have a high water-holding capacity, and release moisture readily to plants. They are well supplied with organic matter and have a high level of fertility. Iron chlorosis is no problem if sorghum is grown on them. If emergency tillage is necessary, these soils tend to form clods strong enough to help check wind erosion.

The Keith soils are productive. Winter wheat, barley, and grain sorghum are the main crops grown on them. Short grasses are the dominant native vegetation, but some western wheatgrass grows in slight depressions and in flat areas.

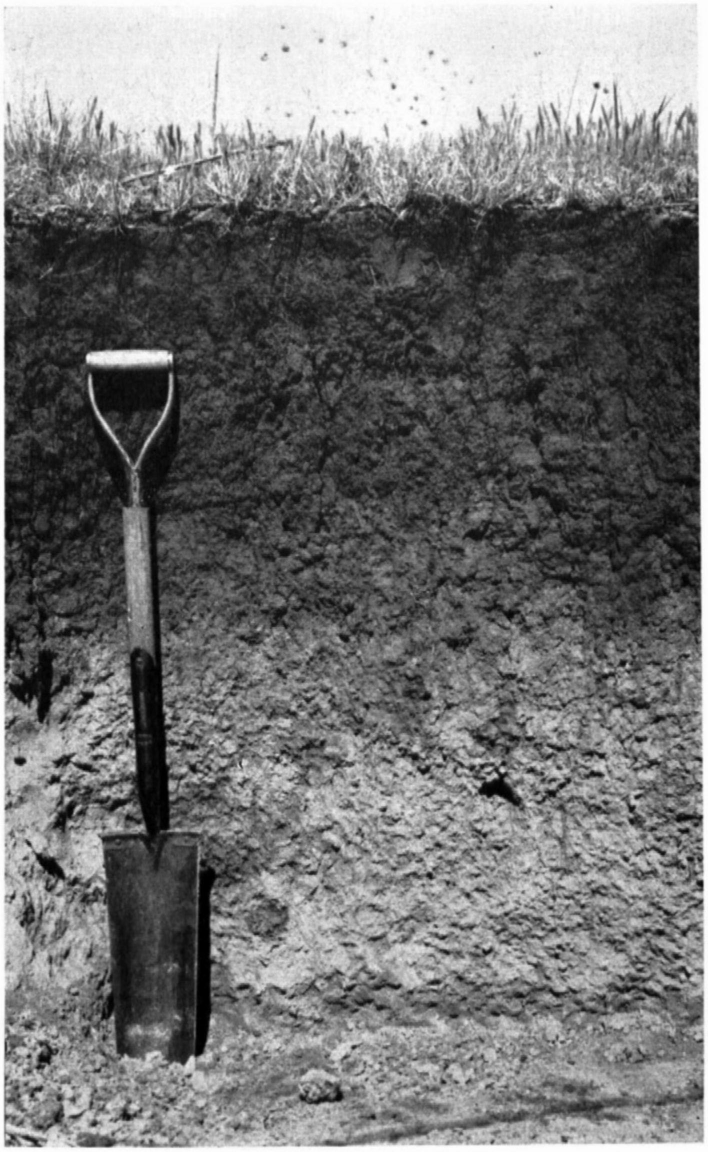


Figure 12.—A profile of nearly level Keith silt loam showing the depth to which the Keith soils are darkened with organic matter.

Keith silt loam, 0 to 1 percent slopes (Ka), is on nearly level tablelands. It is mainly in the northern part of the county, but, to a lesser extent, it is in the southwestern part. The surface layer is 11 inches thick. The subsoil is 22 inches thick and is calcareous at a depth of 20 inches (fig. 12).

Mapped with this soil are areas of Keith silt loam, 1 to 3 percent slopes, and of Lofton silty clay loam. The included areas are too small to be mapped separately. (Capability unit IIc-1; Loamy Upland range site; Upland windbreak suitability group.)

Keith silt loam, 1 to 3 percent slopes (Kb), is in the northeastern part of the county. In the areas where it occurs, the slopes are long. They are more than one-half mile long in many places.

The profile of this soil is similar to that of Keith silt loam, 0 to 1 percent slopes, but the surface layer is only about 6 inches thick, and the subsoil is 9 inches thick. Depth to free lime ranges from 15 to 18 inches. The soil contains less clay than Keith silt loam, 0 to 1 percent slopes, and it has weaker structure in the subsoil.

Mapped with this soil are areas of Keith silt loam, 0 to 1 percent slopes, and of Ulysses silt loam, 1 to 3 percent slopes. The included areas are too small to be mapped separately. (Capability unit IIe-1; Loamy Upland range site; Upland windbreak suitability group.)

Las Series

The Las series consists of medium-textured and moderately fine textured, moderately deep, stratified soils of the flood plains. These soils are imperfectly drained, and they formed in mixed valley sediments.

In a typical profile the surface layer is 8 inches of grayish-brown, calcareous, friable loam that has weak, fine, granular structure. The subsoil is 24 inches of light grayish-brown, hard clay loam that is structureless. The subsoil is calcareous and has reddish-brown stains at a depth of 28 inches. The substratum consists of deep deposits of sand and gravel of the valley alluvium.

The surface layer and subsoil range from 20 to 36 inches in thickness and are underlain by sand and gravel. The water table is normally 4 to 8 feet below the surface, but it may rise to within 2 feet of the surface during periods of above-average rainfall. The Las soils are in positions similar to those occupied by the Las Animas soils. They have a finer textured surface layer and subsoil than those soils.

The Las soils are imperfectly drained, have moderate permeability, and are limited in water-holding capacity. The water table is generally beneficial to alfalfa, and, in some seasons, it benefits other crops. These soils are droughty during prolonged dry periods when the water table falls below the root zone. Flooding does not seriously damage the soils, but it may damage a growing crop. These soils are only moderately productive of the commonly grown crops.

The Las soils are extensive in this county, and they are generally a part of a large ranching unit. Most of the acreage is in native grass.

Las loam, moderately deep (Lb), is on the nearly level, low flood plains of the Smoky Hill River. Its surface layer is 8 inches of calcareous loam. The subsoil, a mixed and stratified clay loam and sandy loam, is underlain by sand at a depth of 20 to 36 inches. The water table in this soil is generally more beneficial than harmful to crops. Soluble salts accumulate in this soil, but they usually do not seriously affect crops.

Mapped with this soil are minor areas of Wet alluvial land and a few areas of Las Animas sandy loam that are too small to be mapped separately. (Capability unit IVw-2; Loamy Lowland range site; Lowland windbreak suitability group.)

Las Animas Series

The Las Animas series is made up of moderately coarse textured, moderately deep, stratified soils formed in alluvium. The soils are imperfectly drained and were formed in mixed sediments on low flood plains.

In a typical profile the surface layer is 6 inches of grayish-brown, very friable sandy loam that has weak, fine, granular structure and is calcareous. The subsoil is 29 inches of light grayish-brown, slightly hard sandy loam that is calcareous. It has weak, fine, granular structure and is stratified with sandy clay loam. The lower 6 inches is transitional to the substratum. The transitional layer is loose loamy fine sand that is calcareous and is mottled with rust-colored stains. The substratum consists of sand and gravel of the valley alluvium.

The Las Animas soils have a surface layer and subsoil that range from 20 to 36 inches in thickness over sand and gravel. The subsoil is commonly stratified with loamy sand and sandy clay loam. In places below a depth of 2 feet, these soils have reddish-brown stains, which indicate a fluctuating water table.

The Las Animas soils are similar to the Las soils, but their texture is coarser throughout. They are somewhat finer textured and deeper than the Lincoln soils.

The Las Animas soils are imperfectly drained, have slow to rapid permeability, and are limited in water-holding capacity. In wet seasons the water table is normally beneficial to alfalfa and to other crops. The soils are droughty during prolonged dry periods, when the water table falls below the root zone of cultivated crops. Flooding does not seriously damage the soils, but it may destroy growing crops. The soils are fairly low in productivity.

The Las Animas soils are extensive in this county; most of their acreage is used for range. The native vegetation is mainly mid and tall grasses, but there is some sand sagebrush.

Las Animas sandy loam (Ld) is nearly level and is on slightly undulating flood plains in the valley of the Smoky Hill River. The surface layer is calcareous sandy loam that has weak, fine, granular structure. The subsoil is mixed and stratified sandy loam, and it overlies sand at a depth of 20 to 36 inches. The water table is more beneficial than harmful to crops.

Mapped with this soil are a few areas of Lincoln soils. (Capability unit IVw–2; Sandy Lowland range site; Lowland windbreak suitability group.)

Likes Series

The soils of the Likes series are deep, light colored, and coarse textured. They are on alluvial fans where drains from the uplands empty onto low terraces.

In a typical profile the surface layer is 12 inches of grayish-brown, soft loamy fine sand that has weak, fine, granular structure and is calcareous. The subsoil is 38 inches of light brownish-gray, noncoherent loamy sand. The material in the subsoil is structureless (single grain), and it is calcareous. The substratum is deep, loose calcareous sand.

The surface layer of the Likes soils ranges from 7 to 14 inches in thickness. Depth to the substratum is 36 to 50 inches. These soils are calcareous throughout. In places the subsoil contains thin layers, or lenses, of sand and sandy loam.

The Likes soils are coarser textured than the Las Animas soils, and they are deeper over sand. They also occupy higher positions in the valley.

The Likes soils have rapid permeability and a low water-holding capacity. Their subsoil is droughty, and the loamy fine sand in their surface layer is susceptible to wind erosion if the soils are cultivated.

The Likes soils are not extensive in this county; they are used for range. The native vegetation is mainly mid and tall prairie grasses, but it includes sand sagebrush, small soapweed, and pricklypear.

Likes loamy fine sand (Lk) is on smooth and slightly undulating alluvial fans and on low terraces along the Smoky Hill River. It has slopes of no more than 2 percent.

The surface layer is loamy fine sand that is darkened with organic matter to a depth of 12 inches. Below the surface layer is the subsoil, which is mainly loamy sand but contains some thin layers of sandy loam and sand. The subsoil is underlain by sand at a depth of 36 to 50 inches. This soil is calcareous throughout. (Capability unit VIe–2; Sands range site.)

Lincoln Series

Shallow, mixed and stratified, coarse-textured soils formed in alluvium make up the Lincoln series. The soils are on low flood plains and are subject to frequent flooding.

In a typical profile the surface layer is 10 inches of grayish-brown, loose loamy sand that is structureless and calcareous. The substratum lies directly beneath the surface layer. It consists of stratified sand and gravel of valley alluvium.

The surface layer of the Lincoln soils ranges from 7 to 15 inches in thickness. In some areas 4 to 6 inches of loam has been deposited on the surface.

The Lincoln soils are shallower and coarser textured than the Las Animas soils.

The Lincoln soils are droughty and are frequently damaged by recurring floods. The water table stands at a depth of 4 to 6 feet.

The Lincoln soils are extensive in this county. They are used exclusively for range, but the yields of forage are generally low. The vegetation is a sparse covering of short grasses and annual weeds. In places a large amount of the ground cover is sand sagebrush.

Lincoln soils (Ll) consists of nearly level soils of flood plains. The soils are adjacent to the channels of the major streams in the county.

The surface layer is mixed loamy sand, less than 15 inches thick. The substratum lies directly beneath the surface layer and consists of sand and gravel. The soils are frequently damaged by recurring floods. The water table normally occurs at a depth of 4 to 6 feet.

Mapped with Lincoln soils are areas of Las Animas sandy loam. The included areas are too small to be mapped separately. (Capability unit VIIw–1.)

Lismas Series

The Lismas series consists of shallow, fine-textured soils. The soils were formed from noncalcareous shale of the Pierre formation. They are strongly sloping and are in rough, broken areas of the uplands.

In a typical profile the surface layer is 2 inches of grayish-brown, very hard silty clay. It has moderate, fine and medium, granular structure and is noncalcareous. The transitional layer to the parent material is 10 inches thick. It is dark-gray, noncalcareous, extremely hard clay and shaly clay that is mottled with yellowish brown. The soil material in that layer breaks to irregular blocks. The parent material is massive gray shale that is impervious to water and air.

The Lismas soils range from 6 to 12 inches in depth over shale. Outcrops of raw shale are common. The soils are on long, dissected bluffs and in narrow, steep, entrenched drainageways. The Lismas soils are finer textured than the Potter soils. They are noncalcareous.

The Lismas soils have very slow permeability and rapid runoff. The water-holding capacity is low because the soils are shallow. These soils are droughty.

The Lismas soils are used for range. The native vegetation is mainly a sparse covering of blue grama, but inland saltgrass grows on the knolls where the soil material is shallowest. Western wheatgrass is dominant on the areas where vegetation is the thickest.

Lismas clay (Lm) occurs in the vicinity of McAllaster. It is on bluffs in the uplands adjacent to the North Fork of the Smoky Hill River (fig. 13), but it is also in entrenched drainageways in the western part of the county. Some areas are on the south side of the Smoky Hill River and Twin Butte Creek.

This strongly sloping soil consists of 12 inches of dark-gray clay over raw shale. In places there is crystalline gypsum in this soil.

Mapped with this soil are areas of Promise clay, 3 to 5 percent slopes. The included areas are too small to be mapped separately. (Capability unit VIIs–2; Shale Breaks range site.)

Loamy broken land (Ln) consists of soil material that is too mixed and too variable to separate into soil types. The soil material is medium textured and varies greatly in depth. The areas are mainly in entrenched drainageways on the north side of the Smoky Hill River and along its north fork. A few areas are also on the south side of these streams. The relief is strongly sloping and broken, and there are bare outcrops of shale and chalk rock. The shallow soil material occurs where the Niobrara and Pierre formations outcrop. The deeper soil material is of mixed origin and is below and between the outcrops. Discontinuous bands and pockets of sand and gravel lie above the outcrops. Loamy broken land is used mainly for range, but the smoother borders are cultivated occasionally. Good yields of forage from the short and mid prairie grasses are obtained. (Capability unit VIIs–1; Breaks range site.)

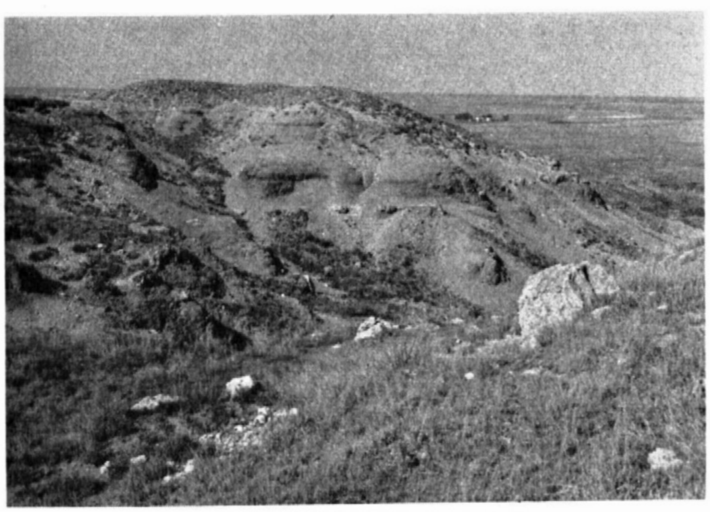


***Figure 13.*—An area of Lismas clay and outcrops of Pierre shale. Remnants of the Ogallala formation can be seen overlying the shale.**

Lofton Series

Dark-colored, moderately fine textured, imperfectly drained soils that are in small basins or lagoons in the uplands make up the Lofton series. These soils are in round, slightly depressed areas that are lower than the surrounding soils on the nearly level tablelands.

In a typical profile the surface layer is 8 inches of dark-gray, hard heavy silty clay loam that has strong, fine, granular structure. The subsoil is 22 inches of gray, very hard clay that has strong, subangular blocky structure and is mottled with yellowish brown and reddish brown. The subsoil grades to the parent material through a transitional layer that is 15 inches thick. This transitional layer is brownish-gray, slightly hard silty clay loam that has weak, medium, subangular blocky structure. The parent material is deep, light-gray, calcareous, soft silt loam that is structureless. The depth to free lime in the Lofton soils ranges from 40 to 72 inches.

The Lofton soils have a lighter textured surface layer and a less compact subsoil than the Randall soils. They are in small basins within areas of soils of the tablelands.

The Lofton soils have very slow permeability. They are poorly drained internally because of the inadequate surface drainage, which causes them to be flooded for long periods. The subsoil holds large amounts of moisture but releases it slowly to plants. These soils tend to be droughty for crops grown in summer if drainage is provided to remove the excess surface water.

These soils are not extensive, but they occur in scattered areas throughout the county. Their use conforms to the land use of surrounding soils; most of the acreage is cultivated. These soils are under water too often to permit the growth of permanent grasses.

Lofton silty clay loam (Lo) is in small, shallow basins within the flat tablelands of the county. The areas are locally called lagoons or buffalo wallows. Their size ranges from 100 feet in diameter to as large as 16 acres, but the average size is approximately 6 to 8 acres.

The surface layer, a silty clay loam, is hard to work and dries out slowly. The clay subsoil takes water slowly. Loess of soft, friable, calcareous silt loam is the parent material. Free lime is at a depth of 40 to 72 inches. (Capability unit IVw–1; Loamy Upland range site.)

Lubbock Series

The soils of the Lubbock series are dark colored and medium textured. They were formed in alluvial sediments from loessal uplands. These soils are on benches that receive additional water from the adjoining uplands.

In a typical profile the surface layer is 12 inches of dark grayish-brown, friable silt loam that has weak, fine, granular structure. The subsoil is 16 inches of dark grayish-brown, very hard silty clay loam that has moderate, fine and medium, subangular blocky structure. The subsoil is calcareous at a depth of 18 inches. A transitional layer lies between the subsoil and the parent material. This layer is 18 inches of very pale brown, calcareous, hard silty clay loam that has weak, medium, subangular blocky structure. The parent material is deep, very pale brown, calcareous, slightly hard light silty clay loam that is structureless.

The Lubbock soils are generally noncalcareous to a depth of 16 to 38 inches. In places the soil material is calcareous at the surface because recent sediments have recharged it with free lime. The Lubbock soils have a lighter textured, more permeable subsoil than the Lofton soils.

The subsoil of the Lubbock soils is slowly permeable. The soils have a high water-holding capacity and occupy a favorable position, where they receive additional water from the adjoining uplands. They are well supplied with organic matter and are high in natural fertility. Erosion control is not a major problem.

These soils are not extensive in this county, but they are among the most productive cultivated soils of the uplands. The native vegetation is mid prairie grasses; western wheatgrass is dominant.

Lubbock silt loam (Lu) is nearly level and occurs on benches around areas of Randall clay. It receives additional water from the adjoining uplands.

The surface layer is dark-colored silt loam that is well supplied with organic matter and is easy to work. The subsoil is silty clay loam that has moderate, fine and medium, subangular blocky structure. It is slowly permeable and has a high water-holding capacity. The parent material is calcareous light silty clay loam.

Mapped with this soil are small areas of Lofton silty clay loam that occur where the Lubbock soil grades to the Randall soil. (Capability unit IIc–2; Loamy Lowland range site; Lowland windbreak suitability group.)

Manter Series

Deep, dark-colored, moderately coarse textured soils that were formed in deposits of calcareous sand make up the Manter series. These soils are on long ridges in the uplands.

In a typical profile the surface layer is 6 inches of dark grayish-brown, soft fine sandy loam that has weak, granular structure. The subsoil is 20 inches of dark grayish-brown, soft sandy loam that has weak, fine, granular structure. The parent material is deep, brown, calcareous, soft sandy loam that is structureless.

The surface layer ranges from 6 to 10 inches in thickness, and the subsoil, from 12 to 20 inches. Depth to free lime ranges from 18 to 30 inches. The more sloping areas of Manter soils generally do not have a well-defined soil structure.

These soils are darkened with organic matter and are leached of lime to a greater depth than the Otero soils. They are finer textured than the soils of the Dwyer series.

The Manter soils are rapidly permeable and have limited water-holding capacity. The sandy loam in the subsoil stores a moderate amount of water and releases it readily to plants. The surface layer absorbs most of the rainfall. The soil is subject to wind erosion if the surface is bare.

The Manter soils are used for both range and field crops. Some fields of Manter fine sandy loam that were broken from sod by early settlers have since been abandoned because wind erosion could not be controlled. Under good management, however, the Manter soils are productive and dependable. The native vegetation is mainly mid and tall prairie grasses, but some sand sagebrush and small soapweed grow on these soils.

Manter fine sandy loam, 1 to 3 percent slopes (Mh), is gently sloping and is on long, narrow upland ridges south of the valley of the Smoky Hill River.

The surface layer is dark grayish-brown, friable fine sandy loam. The subsoil is noncalcareous sandy loam. This soil is noncalcareous and is darkened with organic matter to a depth of 20 inches or more. It is used for both range and field crops.

Mapped with this soil are areas of Otero fine sandy loam and Ulysses silt loam, 1 to 3 percent slopes, that are too small to be mapped separately. (Capability unit IIIe–2; Sandy range site; Upland windbreak suitability group.)

Manter fine sandy loam, 3 to 5 percent slopes (Mk), is on ridges south of the valley of the Smoky Hill River. The ridges resemble hummocks.

The surface layer is dark grayish brown and is 6 inches thick. It is friable and noncalcareous, and it has weak, granular structure. Between the surface layer and the parent material is a transitional layer. This transitional layer consists of noncalcareous, friable sandy loam that has no observable structure. The soil material is calcareous at a depth of 16 to 26 inches. Most of this soil is in range, and only small areas are cultivated.

Mapped with this soil are small areas of Manter fine sandy loam, 1 to 3 percent slopes, and of Dwyer loamy fine sand. The included areas are too small to be mapped separately. (Capability unit IVe–1; Sandy range site; Upland windbreak suitability group.)

Minnequa Series

Soils of the Minnequa series are deep, medium textured, and strongly calcareous. They were formed in chalky, weathered sediments from the Niobrara formation. These soils are on alluvial fans below outcrops of the Niobrara formation.

In a typical profile the surface layer is only 3 inches thick. It is grayish brown, friable, and strongly calcareous, and its structure is weak, fine, and granular. The surface layer grades through a transitional layer that is 7 inches thick to the parent material. This transitional layer is light yellowish-brown, friable light silty clay loam that has weak, granular structure. It contains a large amount of lime and a few grains of chalk rock. The parent material is deep, pale-yellow, soft silt loam that is structureless. It contains a large amount of lime and has fragments of chalk rock throughout.

The surface layer of the Minnequa soils ranges from 2 to 6 inches in thickness. In many places it lies directly over the parent material, and there is no transitional layer between. The parent material ranges from 5 to 8 feet in depth over consolidated chalk rock. Fragments and grains of chalk rock are common throughout the profile.

These soils contain more lime than the Colby soils, and their parent material is more yellowish. Their surface layer is thinner than that of the Elkader soils, and chalky material is nearer the surface.

The Minnequa soils are permeable. The yields of cultivated crops are low because of the thin surface layer and the high content of lime.

The Minnequa soils are used for range. Some areas have been broken for cultivation, but they were abandoned after a few years. Good yields of forage from the native grass are obtained. The native vegetation is short and mid prairie grasses.

Minnequa silt loam (Mn) is on alluvial fans below outcrops of chalk rock in the southern part of the county. It has slopes of 1 to 5 percent.

Figure 14.—**A profile of Minnequa silt loam showing the thin, dark surface layer and the particles of chalk rock in the soil material.**

The surface layer is 3 inches of grayish-brown, calcareous silt loam. In some places there is a transitional layer of silty clay loam that is about 7 inches thick. Beneath the surface layer is the chalky parent material of yellowish silt loam or light silty clay loam (fig. 14).

Mapped with this soil are small areas of Elkader silt loam, 1 to 3 percent slopes. Outcrops of chalk rock are shown by standard symbols. (Capability unit VIs-1; Chalk Flats range site; Chalky windbreak suitability group.)

Minnequa-Penrose silt loams (Mp) is in the southern part of the county. The soils are mapped as a complex because the areas are so intermixed that it was not practical to map the soils separately. Most areas consist of about 60 percent Minnequa silt loam, 35 percent Penrose silt loam, and 5 percent Badland. The soils are strongly sloping. The Minnequa and Penrose soils are described under the Minnequa and Penrose series.

These soils take up water readily, but they have a limited water-holding capacity. Runoff is excessive. The soils have a high content of lime throughout.

The topography and the depth of these soils limit their use to range. The soils are productive when used as range. Short and mid prairie grasses are the native vegetation. (Capability unit VIIs-1; Chalk Flats and Breaks range sites.)

Otero Series

Soils of the Otero series are moderately coarse textured and calcareous. They were formed in deposits of sandy material that had been reworked by wind and water. The soils are on low, hummocky ridges and on the side slopes of drainageways.

In a typical profile the surface layer is 6 inches of grayish-brown, soft fine sandy loam that has weak, fine and medium, granular structure and is calcareous. The transitional layer is light-gray, soft sandy loam that is coherent but is structureless. It is calcareous and is 12 inches thick. The parent material is deep, light-gray, loose loamy sand that is calcareous.

The surface layer of the Otero soils ranges from 4 to 6 inches in thickness. The depth of darkening with organic matter ranges from 4 to 14 inches. The texture of the surface layer ranges from light loam to light sandy loam, but it is fine sandy loam in most places. The Otero soils in some places are on strongly sloping single slopes that lead to U-shaped drainageways. In other places the slopes are irregular and resemble dunes.

The Otero soils are not darkened with organic matter to so great a depth as the Manter soils, and their surface layer is calcareous. They are somewhat finer textured than the Dwyer soils and are deeper over loose sand.

The Otero soils have rapid permeability and a limited water-holding capacity. They store moderate amounts of moisture and release it readily to plants. The low content of organic matter, the weak structure, and the calcareous material in the surface layer make these soils subject to severe wind erosion if they are cultivated.

The Otero soils are not extensive in this county. They are used mainly for range, but some small marginal areas are cultivated. The native vegetation is mainly short and mid prairie grasses, but there is some sage and little soapweed.

Otero fine sandy loam (Ot) is moderately to strongly sloping and is on irregular and hummocky ridges and knolls. It is mainly in the southern part of the county, adjacent to the valley of the Smoky Hill River.

The surface layer is calcareous fine sandy loam that is darkened with organic matter to a depth of 6 inches. The parent material is calcareous sandy loam that grades to loamy sand at a depth of 36 to 60 inches.

Mapped with this soil are areas of Dwyer loamy fine sand that occur near the summit and on the shoulders of the long ridges. Areas of Manter fine sandy loam, 1 to 3 percent slopes, are in depressions at the base of steep slopes. These included areas are too small to be mapped separately. (Capability unit VIe-3; Sandy range site; Upland windbreak suitability group.)

Penrose Series

The Penrose series is made up of shallow, medium-textured, calcareous soils. The soils were formed in limy shale and chalk rock of the Niobrara formation. They are strongly sloping and are on broken areas in the uplands.

***Figure 15.*—A profile of Penrose silt loam showing the weakly consolidated chalk rock on which this shallow soil was formed.**

In a typical profile the surface layer is 7 inches of grayish-brown, friable silt loam that has weak, fine, granular structure and is calcareous. The material in the surface layer grades to the parent material through a transitional layer that is 5 inches thick. The parent material is at a depth of 12 inches. The transitional layer consists of soft, pale-yellow silt loam. It has no natural soil structure, is strongly calcareous, and contains chips of chalk rock. In most places weakly consolidated chalk rock is at a depth of 12 inches, but it is at a depth as great as 15 inches in some places. In other places it outcrops at the surface (fig. 15).

The Penrose soils in Logan County are a component of the Minnequa-Penrose complex. This complex is described under the Minnequa series.

Potter Series

Shallow soils in rough, broken areas make up the Potter series. The soils were formed in material weathered from caliche and cemented sandstone of the Ogallala formation.

***Figure 16.*—A profile typical of the Potter soils. These soils are underlain by caliche.**

In a typical profile the surface layer is 5 inches of calcareous, dark grayish-brown, friable loam that has weak, fine, granular structure. A transitional layer, 7 inches thick, lies below the surface layer. It consists of light grayish-brown, hard loam and contains some fragments of caliche and gravel. This transitional layer has weak, medium, granular structure and is calcareous. Directly beneath the transitional layer is the hard caliche parent material. This underlying bedrock is fractured and has many cracks and crevices that grass roots penetrate.

The principal variation in soils of the Potter series is the depth to bedrock. The texture of the surface layer ranges from loam to gravelly sandy loam. In places there is a thin veneer of gravel on the surface or within the surface layer. The parent material of the Potter soils is harder and more resistant to geologic erosion than that of the Penrose soils.

The Potter soils have a low water-holding capacity. Runoff is excessive.

These soils are used for range. Where the range is well managed, good yields of forage are obtained from the mid and tall prairie grasses.

Potter soils (Po) consist of rough, broken areas in the southeastern part of the county. The slopes in these areas range from 20 to 45 percent.

In a typical profile the surface layer is 5 inches of dark grayish-brown, friable loam that is calcareous and has weak, fine, granular structure. The depth to caliche is 12 inches. The transitional layer is light grayish-brown loam that contains some fragments of caliche and gravel. It has weak, medium, granular structure and is calcareous (fig. 16). Bare outcrops of caliche rimrock are characteristic of these soils. The area in which the soils occur is not too steep for grazing animals but is difficult to traverse by automobile.

Mapped with these soils are areas of Ulysses silt loam, 5 to 15 percent slopes. (Capability unit VIIs–1; Breaks range site.)

Promise Series

Soils of the Promise series are deep, dark colored, and fine textured. They occur below outcrops of Pierre shale. The soils were formed in fine-textured sediments that have washed from the shale.

In a typical profile the surface layer is 8 inches of grayish-brown, very hard silty clay that has moderate, medium, granular structure and is weakly calcareous. The layer that is transitional to the parent material is 12 inches of light yellowish-brown, calcareous, very hard clay that has weak, fine and medium, granular structure. The parent material is deep, pale-yellow, very hard clay that is structureless. It is calcareous and is mottled with whitish crystals of gypsum.

The surface layer of the Promise soils ranges from 7 to 10 inches in thickness, and the parent material ranges from 4 to 8 feet. In places the soils are underlain by shale below a depth of 5 feet. There is considerable variation in the amount of crystalline gypsum that occurs in the soils from one place to another.

The Promise soils are finer textured, much more difficult to till, and more droughty than the Ulysses soils. They are deeper and produce higher forage yields of native grasses than the associated Lismas soils.

Moisture enters and passes down through the Promise soils very slowly. The soils have a high water-holding capacity, but they release moisture slowly to plants. The clay surface layer seals over rapidly during rains and causes excessive runoff. The soils are difficult to till and are somewhat droughty for crops grown in summer. Iron chlorosis is common if sorghum is grown on the areas.

These soils are not extensive in the county. They are used chiefly for range, but some small areas are cultivated. Winter cereal grains are the best crops to grow on these soils. Yields of cultivated crops are low, and crop failures are frequent. The native vegetation is mainly short grasses, but there is some western wheatgrass and inland saltgrass.

Promise clay, 0 to 1 percent slopes (Pr), is on alluvial fans on the south side of the Smoky Hill River. It is in the western part of the county.

The surface layer is 7 inches of calcareous clay that has weak, fine, granular structure. The material in the surface layer grades through a transitional layer that is 13 inches thick to the parent material, which is at a depth of 20 inches. This transitional layer is calcareous clay that has weak, medium, subangular blocky structure. The parent material is deep, calcareous clay, and it contains varying amounts of gypsum.

Mapped with this soil are areas of 'Promise clay, 1 to 3 percent slopes. (Capability unit IVs–1; Clay Upland range site.)

Promise clay, 1 to 3 percent slopes (Ps), is on the uplands in the northwestern part of the county. Its surface layer is 6 inches of grayish-brown clay that is calcareous. The parent material is heavy clay and contains variable amounts of gypsum. This soil is underlain by raw, unweathered shale at a debth of 5 to 8 feet.

Mapped with this soil are small areas of Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes. (Capability unit IVe–3; Clay Upland range site.)

Promise clay, 3 to 5 percent slopes (Pt), is on the uplands. It has a surface layer of grayish-brown clay that is 5 inches thick. The parent material is heavy clay that contains variable amounts of gypsum. This soil is underlain by raw, unweathered shale at a depth of 4 to 6 feet.

Mapped with this soil are a few scattered knolls of Lismas clay that are too small to be mapped separately. (Capability unit VIe–5; Clay Upland range site.)

Randall Series

The Randall series consists of dark-colored, fine-textured, very poorly drained soils. These soils are on the floor of large intermittent lakes.

In a typical profile the surface layer is 28 inches of dark-gray, extremely hard clay that has weak, fine, granular structure in the upper part. The lower 16 inches has only a weak suggestion of a subangular blocky structure. A transitional layer, which is 20 inches thick, lies between the surface layer and the parent material. This transitional layer is gray, extremely hard and compact clay. It is calcareous and is mottled with a few rust-colored stains. The parent material is deep, gray, extremely hard and compact clay. This layer is calcareous, and it has a few fine threads and spots of lime.

The surface layer of the Randall soils ranges from 20 to 30 inches in thickness, depending upon the size of the depression. The soils are generally noncalcareous to a depth of 3 feet, except where runoff from the loessal uplands has recharged the immediate surface layer with free lime. Some gypsum occurs in these soils in areas where water drains from Pierre shale.

These soils have a subsoil that is dense and takes in water very slowly. The soils are very poorly drained internally because of inadequate surface drainage. Ponded water often stands on them for long periods.

The acreage of Randall soils in this county is small. No attempt is made to cultivate these soils. They produce only annual weeds. During wet seasons, they provide a resting place for migratory waterfowl and offer excellent hunting to sportsmen.

Randall clay (Ra) is on the floor of large intermittent lakes that are surrounded by nearly level benches of Lubbock soils. The areas are scattered throughout the central and northwestern parts of the county. Runoff from large areas of adjoining uplands collects and remains ponded on this soil, which has no natural outlet.

The surface layer is dark-colored clay that dries out very slowly. The subsoil is heavy, dense clay that absorbs water slowly. All other features of Randall clay are similar to those described for the Randall series. (Capability unit VIw-2.)

Richfield Series

Soils of the Richfield series are deep and dark colored, and they have a moderately fine textured subsoil. These soils were formed in deep loess on the nearly level tablelands.

The surface layer, in a typical profile, is 5 inches of dark grayish-brown, friable silt loam that has a moderate, medium, granular structure and is noncalcareous. The subsoil is 13 inches of dark grayish-brown, hard silty clay loam that has moderate, fine and medium, subangular blocky structure and is also noncalcareous. The subsoil grades to the parent material through a transitional layer that is 20 inches thick. The transitional layer is light-gray, calcareous, friable silt loam that has weak, medium, subangular blocky structure. A few fine streaks and spots of soft lime are in this layer. The parent material is deep, light-gray, calcareous, soft silt loam that is structureless.

The surface layer of the Richfield soils ranges from 4 to 7 inches in thickness. The subsoil is 6 to 15 inches thick and has moderate to strong, fine and medium, subangular blocky structure. Free lime is within 10 to 22 inches of the surface.

These soils have a finer textured subsoil than the Ulysses soils, and their structure is more strongly developed. They have a thinner surface layer and a finer textured subsoil than the Keith soils, and they are somewhat shallower over free lime.

The Richfield soils have moderately slow permeability and a high water-holding capacity. They release moisture readily to plants. These soils are well supplied with organic matter and are high in fertility. Iron chlorosis of sorghum is not a problem. The soils have a strong enough structure so that clods form when emergency tillage is necessary to check wind erosion.

For the most part, these soils are cultivated. Winter wheat, barley, and grain sorghum are the main crops grown. Short grasses are the dominant native vegetation, but some western wheatgrass grows on these soils.

Richfield silt loam, 0 to 1 percent slopes (Rc), is on tablelands in the southwestern part of the county. The surface layer is 6 inches of dark grayish-brown silt loam that has granular structure. The subsoil is silty clay loam that has moderate, medium, subangular blocky structure. The subsoil grades to friable, light-colored, calcareous parent material at a depth of 10 to 22 inches.

Mapped with this soil are areas of Ulysses silt loam, 0 to 1 percent slopes, and Keith silt loam, 0 to 1 percent slopes. The included areas are too small to be mapped separately. (Capability unit IIc-1; Loamy Upland range site; Upland windbreak suitability group.)

Ulysses Series

The Ulysses series consists of deep, dark-colored soils that are medium textured. The soils were formed in deep loess on nearly level to strongly sloping uplands.

In a typical profile the surface layer is 7 inches of dark grayish-brown, friable silt loam that has weak, fine, granular structure and is noncalcareous. The subsoil is 7 inches of grayish-brown, calcareous, hard light silty clay loam that has weak, medium, subangular blocky structure. The subsoil grades to the parent material through a transitional layer that is 11 inches thick. This transitional layer is light-gray, soft silt loam that has no definite structure. It is calcareous and contains a few spots of soft lime. The parent material is deep, light-gray, soft silt loam that is calcareous.

The surface layer of the Ulysses soils ranges from 5 to 12 inches in thickness. On the nearly level areas, the subsoil is more pronounced than in the other areas. The more sloping Ulysses soils have a surface layer that changes gradually to the parent material. Under native grass, the surface layer contains no free lime. In most cultivated areas it is calcareous. The subsoil ranges from 6 to 8 inches in thickness. It is friable, has blocky structure, and is generally calcareous.

These soils are darkened with organic matter to a depth greater than the Colby soils and to a depth not so great as the Keith soils. Unlike the Colby soils, they have a surface layer that is noncalcareous.

The Ulysses soils are moderately permeable, have a high water-holding capacity, and release moisture readily to plants. The weak structure of the surface layer causes the surface to seal over during heavy rains. This causes excessive runoff. In most places the structure is strong enough for emergency tillage to be effective in checking wind erosion. In places iron chlorosis is a problem on these soils.

These are the most extensive soils of the uplands in the county. The more sloping Ulysses soils are used for range. Winter wheat, barley, and sorghum are grown on the less sloping areas. The native vegetation is short grasses.

Ulysses silt loam, 0 to 1 percent slopes (Ua), is on the tablelands in the southern and western parts of the county. The surface layer is silt loam that is 7 inches thick. The subsoil is light silty clay loam that has weak, medium, subangular blocky structure. It grades to the light-gray parent material, which is at a depth of 10 to 15 inches. The soil is generally noncalcareous to a depth of 6 to 10 inches.

Mapped with this soil are areas of Ulysses silt loam, 1 to 3 percent slopes, that are on small knolls. The included areas are too small to be mapped separately. (Capability unit IIc-1; Loamy Upland range site; Upland windbreak suitability group.)

Ulysses silt loam, 1 to 3 percent slopes (Ub), is on the uplands throughout the county. It is not darkened with organic matter to so great a depth as Ulysses silt loam, 0 to 1 percent slopes. The surface layer is friable silt loam that ranges from 7 to 12 inches in thickness. This soil generally lacks the texture of light silty clay loam and the subangular blocky structure below the surface layer that is typical in Ulysses silt loam, 0 to 1 percent slopes. In most places the surface layer is calcareous, and iron chlorosis is a common problem if sorghum is grown.

Some areas of Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded, are mapped with this soil. Small areas of the included soils are so eroded that the light-colored parent material is exposed. The included areas are too small to be mapped separately. (Capability unit IIIe–1; Loamy Upland range site; Upland windbreak suitability group.)

Ulysses silt loam, 3 to 5 percent slopes (Uc), is on slightly convex slopes throughout the county. Most of the acreage is in native grass. This soil has a texture of silt loam throughout the profile and is darkened with organic matter to a depth of 7 to 12 inches (fig. 17).

***Figure 17.*—A profile of a Ulysses silt loam on a slope of 4 percent.**

The plow layer is calcareous. Iron chlorosis is common if sorghum is grown. This soil has weak structure. In many places clods will not form if emergency tillage becomes necessary to protect the areas from wind erosion.

In cultivated areas small, light-colored patches are common where the soil is eroded. Areas larger than 5 acres have been shown on the map as Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded. The smaller areas are mapped with this soil because they are too small to be mapped separately. (Capability unit IVe–2; Loamy Upland range site; Upland windbreak suitability group.)

Ulysses silt loam, 5 to 15 percent slopes (Ud), is on uplands in the eastern and southern parts of the county. This soil has a texture of silt loam throughout the profile, and it is darkened with organic matter to a depth of 7 to 10 inches. If this soil is cultivated, the surface layer is soon lost through erosion. Then, the light-colored, calcareous parent material is at the surface. Most of the acreage of this soil is in native grass.

Mapped with this soil are less sloping Ulysses soils on narrow ridges or divides. The areas of included soils are too narrow or too small to be of agricultural importance. (Capability unit VIe–1; Loamy Upland range site; Upland windbreak suitability group.)

Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded (Ul), is a complex that consists of areas of Ulysses and Colby silt loams. The areas are so intermixed that it is impractical to map them separately. Each of these soils is described under the particular series.

Ulysses silt loam makes up 40 to 80 percent of the mapping unit, and Colby silt loam makes up 20 to 60 percent. Most of the Colby soil was Ulysses silt loam before it was thinned by erosion. The Ulysses-Colby silt loams are in the same areas as Ulysses silt loam, 3 to 5 percent slopes.

Erosion has been extensive on Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded. Thirty percent or more of the acreage is so eroded that the light-colored parent material is exposed. The surface seals over readily, and runoff is excessive. The structure in the plow layer is weak. Therefore, clods may not form if emergency tillage becomes necessary to protect the soils against wind erosion. (Capability unit IVe–2; Limy Upland range site; Upland windbreak suitability group.)

Ulysses-Colby silt loams, 5 to 15 percent slopes, eroded (Um), is in positions similar to those occupied by Ulysses silt loam, 5 to 15 percent slopes. As a result of cultivation, the thin surface layer on more than 30 percent of the acreage has been lost through erosion and the light-colored, calcareous parent material is now at the surface. Erosion is difficult to control on these soils, and the hazard of further erosion is severe. The productivity of the soils has thus been lowered by erosion. (Capability unit VIe–4; Limy Upland range site; Upland windbreak suitability group.)

Ulysses Series, Heavy Textured Variant

These variants from the normal Ulysses series are deep, moderately fine textured, and calcareous. They are on the uplands and were formed in local deposits of loess from Pierre shale.

In a typical profile the surface layer is 6 inches of grayish-brown, calcareous, hard silty clay loam that has weak, fine and medium, granular structure. It grades to the parent material through a transitional layer that is 10 inches thick. This transitional layer is grayish-brown, calcareous, hard heavy silty clay loam that has weak, fine and medium, granular and weak, medium and coarse, subangular blocky structure. The parent material is deep, light grayish-brown, hard heavy silty clay loam that is structureless. This material is calcareous and contains clusters of whitish crystalline gypsum.

The surface layer of the Ulysses heavy textured variants is thinner than that in the profile described as typical of the series, and the parent material contains less clay in areas where these soils grade to the adjoining Ulysses silt loams.

The heavy textured variants of the Ulysses series are finer textured throughout and are more difficult to till than the Ulysses silt loams. They are calcareous throughout and lack the structural development that is typical of the subsoil in the Richfield soils.

Moisture enters and penetrates slowly the heavy textured variants of the Ulysses soils. These soils have a high water-holding capacity and release the stored moisture slowly to plants. They are moderately well supplied with organic matter and are calcareous throughout. Iron chlorosis is a problem if sorghum is grown.

These soils are used mainly for range, and only the fringe areas are cultivated. Winter wheat and barley are the common crops grown. The native vegetation is mainly western wheatgrass, but there are some short grasses.

Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes (Uh), is on the uplands in the vicinity of McAllaster. It is inextensive in this county. The surface layer is 6 inches of grayish-brown, calcareous silty clay loam that is difficult to till. The subsoil is calcareous heavy silty clay loam that has weak, medium, subangular blocky structure in the upper part. There are some whitish seams or clusters of crystalline gypsum below the surface layer.

Mapped with this soil are areas of Ulysses silt loam, 1 to 3 percent slopes. (Capability unit IIIe-1; Clay Upland range site; Upland windbreak suitability group.)

Volin Series

The Volin series consists of deep, dark-colored, moderately fine textured soils. These soils were formed in valley sediments along the major streams in the county.

In a typical profile the surface layer is 16 inches of very dark grayish-brown, friable silt loam that has moderate, fine, granular structure and is noncalcareous. The layer that is transitional to the parent material is 24 inches thick. It is dark grayish-brown, calcareous, hard silty clay loam that has moderate, medium, subangular blocky structure. The parent material is deep, light brownish-gray, soft silt loam that is structureless and calcareous.

The surface layer ranges from 12 to 18 inches in thickness. Buried soil layers are common, but they do not occur in all areas of the Volin soils. These soils do not have significant layers of different texture. They are generally noncalcareous to a depth of at least 16 inches. In some areas there is a water table at a depth of 6 to 20 feet.

The surface layer of these soils is darker colored than that of the Bridgeport soils, and it is noncalcareous. The Volin soils have thicker soil layers and better drainage than the Las soils.

The Volin soils are permeable, have a high water-holding capacity, and release moisture readily to plants. They are high in natural fertility, and they are suited to a number of different crops. Iron chlorosis does not affect sorghum that is grown on them. Alfalfa can be grown successfully where the Volin soils are underlain by an effective water table.

The total acreage of Volin soils in this county is small. These soils are the most productive of the soils formed in alluvium, and nearly all of their acreage is cultivated. The native vegetation is mid and tall prairie grasses.

Volin silt loam (Vl) is nearly level and is on low terraces and in valleys along the major streams. If a water table is present, it is at a depth below 6 feet.

The surface layer is friable, noncalcareous silt loam that is 16 inches thick. It is well supplied with organic matter. The subsoil is calcareous silty clay loam that grades to more friable silt loam at a depth of 30 to 40 inches.

Mapped with this soil are a few areas of Bridgeport loam. (Capability unit IIc-2; Loamy Lowland range site; Lowland windbreak suitability group.)

Volin-slickspot complex (Vs) is in the east-central part of the county on a low, nearly level terrace that adjoins Plum Creek. The soil pattern within the areas is so variable and intermixed that it is not practical to map the soils separately. About 60 percent of the complex is Volin silt loam, 25 percent is a bare slickspot soil, and the rest is a soil that has characteristics intermediate between those of the Volin soil and the slickspot soil. The slickspot soil occurs throughout areas of the Volin soil. It is in circular spots 5 to 40 feet in diameter and in long, narrow strips. In places these strips are only 3 to 15 feet wide, but they are 50 to 800 feet long.

The profile of the Volin soil is described under the Volin series. The uppermost 1 inch of the slickspot soil is gray silty clay loam. The surface layer is crusted. It is massive and breaks, under considerable pressure, to medium and coarse blocks. Immediately below this crusted surface layer is 4 inches of very dark grayish-brown silty clay loam. This layer is also massive and hard. The next layer is 5 inches of dark grayish-brown, noncalcareous silty clay loam that has weak, medium and coarse, angular blocky structure. The layer below is 16 inches of grayish-brown, calcareous silty clay loam that contains many distinct mottles of crystalline salts. The parent material is deep, brownish-gray, calcareous silt loam that is structureless. It contains a few fine nests and streaks of crystalline salts.

The principal variation in areas of the Volin-slickspot complex is in the depth to the concentration of salts, which is reflected in the composition of the vegetation. The depth to the salts ranges from 10 inches in the slickspot soil to 24 inches in the areas where there is a thicker cover of vegetation.

The soil material in this complex has slow or impeded permeability. The slickspot soil is bare, is extremely hard, and has a crust on the surface. The Volin soil is productive.

All of the Volin-slickspot complex remains in native grass. Cultivating it is difficult because of the areas of hard, crusty slickspot soil that occur throughout the complex. The Volin soil supports good stands of mid and tall grasses, the slickspot soil is bare, and the intermediate areas support nearly pure stands of inland saltgrass. (Capability unit IVs–2; Loamy Lowland range site.)

Wet Alluvial Land (Wa)

Wet alluvial land consists of dark-colored, poorly drained alluvial sediments that range from loamy fine sand to clay loam. These areas are too mixed and too stratified with different textures to be classified as a soil type. They occur on the flood plains of the larger streams. The water table normally stands within 2 to 4 feet of the surface, but it rises to the surface in some areas during periods of above-average rainfall. This land type is slightly or moderately saline.

Wet alluvial land occupies only a small acreage in this county. Nearly all of it is in range. (Capability unit Vw–1; Saline Subirrigated range site.)

Use and Management of Soils

This section first describes some basic practices of management for soils used for cultivated crops. Then the system of capability grouping is defined and the use and management of the soils in each capability unit are discussed. Following this are estimated average acre yields of wheat and grain sorghum, obtained under customary management and under improved management. Finally, the use and management of the soils for range, windbreaks, and engineering are discussed.

Management of Soils Used for Cultivated Crops

In cultivating the soils of Logan County, it is necessary to use a system of soil management that includes the following: (1) Maintaining good soil tilth, (2) conserving moisture and controlling erosion, (3) keeping an adequate supply of available plant nutrients in the soils, (4) using a proper sequence of crops, (5) controlling weeds, and (6) controlling plant diseases and insects.

Soil tilth.—Good soil tilth refers to the condition of the soil that makes the soil easy to till and readily permeable to water, air, and roots. Many of the soils of this county once had good tilth. Their surface layer had granular structure, but in many places this granular structure has since been weakened or destroyed by cultivation. As a result, the present plow layer is more compact and less permeable to water and air than the original one, and now many of these soils are said to have poor tilth.

Desirable tilth is generally associated with soils that contain a fairly large amount of organic matter. Erosion removes the soil layer that contains the most organic matter and that has the most strongly developed granular structure. Using a cropping system and management practices that do not return crop residues to the soils also causes a noticeable decrease in the amount of organic matter in the surface layer. The decrease in organic matter and the associated destruction of the granular structure in the surface layer are detrimental to the tilth of the soil.

In many places cultivated loams and silt loams contain a tillage pan, which causes tilth to be poor. This tillage pan is a thin, compacted layer just below the plow layer. It reduces the intake of water and air, and in some areas it restricts the development of roots. The formation of a pan usually can be avoided by varying the depth of each tillage operation. Avoiding tillage when the surface layer is wet, as well as avoiding unnecessary tillage and excessive traffic with heavy farm machinery, help to prevent tillage pans from forming.

Soils that have free lime in the plow layer may be friable, but the structure of the plow layer is somewhat unstable. Such soils are more susceptible to surface crusting and to erosion than are other soils and are likely to develop poor tilth.

Conserving moisture and controlling erosion.—Logan County is located within the High Plains, a section that has received considerable attention because of the erosion of the soils by wind. In this county, however, water erosion on sloping cropland has been equally responsible for the depletion of soil resources. The conservation of moisture is of first importance to farmers who produce crops by using dryland farming methods. The principles and methods of conserving moisture are so closely related to those of controlling erosion that the two cannot be discussed separately without repetition.

The first principle for conserving moisture and controlling erosion is to maintain a continuous cover of vegetation on the surface. This vegetation can be in the form of a growing crop or it can consist of the residues of a mature crop. It breaks the impact of raindrops, catches snow during winter, improves the tilth of the soils and the intake of water, and reduces erosion. Stripcropping, either on the contour or at right angles to the direction of prevailing winds, is an effective way of catching snow (fig. 18), reducing runoff, and protecting the soils against wind erosion. Stubble mulching, leaving crop residues on the surface, and cover cropping are all practices that improve the tilth of the soils and reduce erosion.

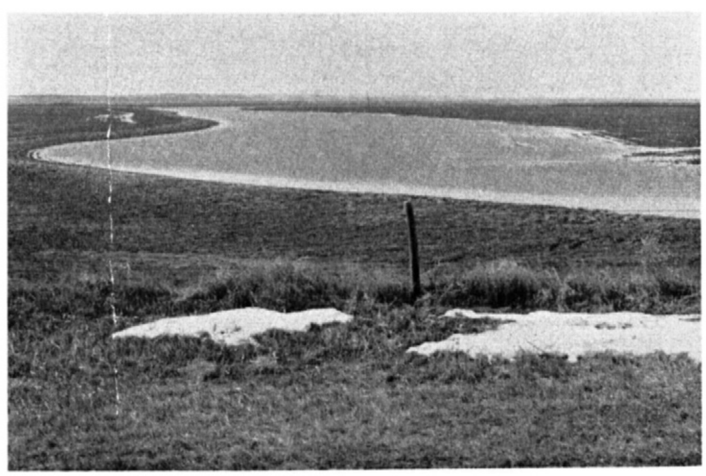


Figure 18.—A field where water from snowmelt has accumulated. The field has been terraced and cultivated on the contour to reduce runoff and to conserve moisture.

Figure 19.—**Standing wheat stubble, which catches snow and keeps it from drifting. The snow adds moisture to the soils for future crops.**

Stubble mulch catches snow, which adds moisture to the soils (fig. 19). Seeding grass waterways on sloping land or on slowly permeable soils facilitates terracing and contour farming. Controlling grazing of growing crops or crop residues assures that an adequate cover of vegetation will be kept on the surface of the soils.

Summer fallowing is a practice that keeps the land free of growing vegetation during one crop season so that soil moisture will be stored for crops grown the following year. This practice should be supported with stubble mulching to reduce erosion.

Constructing level terraces on deep, permeable soils is a practice that intercepts runoff, conserves moisture, and reduces water erosion. Contour farming is used in conjunction with the terraces (fig. 20). Farming on the contour also reduces runoff, conserves moisture, and reduces water erosion.

Other management practices that help to conserve moisture are controlling weeds, growing adapted crops that make efficient use of stored moisture, and seeding at the proper rate and at a time when the supply of available soil moisture is most favorable for the germination of the seed and the growth of the crop.

During prolonged droughts, cultivated land may become bare of any vegetation because of conditions beyond the control of the farmer. When cultivated land is bare and is subject to wind erosion, the farmer can roughen the surface of the soil with tillage tools. Surface roughening brings to the surface aggregates and clods that resist the force of the wind and that trap drifting soil material. If this practice fails to control wind erosion, the only alternative left is to wait until enough moisture has accumulated to allow a cover crop to germinate. A cover crop provides a protective cover that prevents erosion. It may have to be grown without any expected harvest of forage or grain.

Adequate supply of available plant nutrients.—Low fertility is generally not considered a problem in dryland farming in this county. The response of crops to applications of fertilizer depends largely upon the amount of available moisture. Results of soil tests in the county and field trials at other locations indicate that the soils contain abundant potassium. The supply of available phosphorus is low in the Bridgeport silt loam, strongly calcareous variant, and in the Elkader and Minnequa soils.

If soils contain free lime in the plow layer, sorghum grown on them is likely to be affected by iron chlorosis, sometimes referred to as lime-induced chlorosis. When this happens, the foliage turns yellow, the plants lack vigor, and the sorghum is unproductive.

Crops used for dryland farming are more likely to give response to nitrogen fertilizer than to other kinds of fertilizer. The availability of the nitrogen, however, is related to the amount of organic matter in the soils. Crops grown on sandy soils and on eroded silt loams may respond to nitrogen fertilizer in years when moisture is adequate. If the soils are used alternately for wheat and fallow, enough nitrogen generally accumulates during the fallow period to meet the needs of the crop that follows.

Sequence of crops.—The climate in Logan County restricts the choice of crops that can be grown under dryland farming. Winter wheat is well adapted because it usually matures before the hottest part of summer. Winter barley, however, which requires a growing season similar to that needed for wheat, is susceptible to winterkilling. Nevertheless, it is sometimes preferred over sorghum if the sorghum must be used in a fallow, wheat, sorghum sequence. Sorghum withstands dry periods and resumes growth after rains. It yields more if its growth is not interrupted by drought, but it is not a total failure in years when dry spells occur.

Alfalfa is grown on a small acreage of soils formed in alluvium in the larger valleys in the county. The alfalfa must be grown in areas where there is a water table to supply moisture to the roots.

Some common cropping sequences used in the county are alternate wheat and fallow; alternate sorghum and fallow; fallow, wheat, and sorghum; and fallow, wheat, fallow, and sorghum.

Controlling weeds.—In this county the importance of conserving moisture makes the control of weeds an essential part of soil management. Storing moisture in

Figure 20.—**Aerial view of a field that is terraced and has been cultivated on the contour. Alternate strips of summer fallow and a growing crop are shown in the foreground. The level terraces hold water on the land.**

the soils is the primary purpose of summer fallowing. Satisfactory control of weeds is important to the success of this practice. When a field is to be summer fallowed, growth of volunteer grain is stopped by using appropriate subsurface tillage as early as practicable after the grain germinates.

Weeds that grow excessively in areas of cultivated crops compete for moisture that would otherwise be available to the crop. In addition to tillage, chemical weedkillers have been developed that are effective in controlling weeds.

Controlling plant diseases and insects.—Damage to crops by plant diseases and insects can be reduced by using an alternating sequence of crops, timely tillage, and proper seeding dates. Using insecticides and resistant varieties of crops also help to prevent damage from insects and disease.

Capability groups of soils

The capability classification is a grouping of soils that shows, in a general way, how suitable the soils are for most kinds of farming. It is a practical grouping based on the limitations of the soils, the risk of damage when they are used, and the way they respond to treatment.

In this system all the kinds of soil are grouped at three levels, the capability class, subclass, and unit.

The eight capability classes in the broadest grouping are designated by Roman numerals I through VIII. In class I are the soils that have few limitations, the widest range of use, and the least risk of damage when they are used. There are no soils of class I in Logan County. The soils in the other classes have progressively greater natural limitations. In class VIII are soils and landforms so rough, shallow, or otherwise limited that they do not produce worthwhile yields of crops, forage, or wood products.

The subclasses indicate major kinds of limitations within the classes. Within most of the classes, there can be as many as four subclasses. The subclass is indicated by adding a small letter, *e*, *w*, *s*, or *c*, to the class numeral, for example, IIe. The letter *e* shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; *w* means that water in or on the soil will interfere with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c*, used in only some parts of the country, indicates that the chief limitation is a climate that is too cold or too dry.

In class I there are no subclasses, because the soils of this class have few or no limitations. Class V can contain, at the most, only subclasses *w*, *s*, and *c* because the soils in it have little or no susceptibility to erosion but have other limitations that limit their use largely to pasture, range, woodland, or wildlife.

Within the subclasses are the capability units, groups of soils enough alike to be suited to the same crops and pasture plants, to require similar management, and to have similar productivity and other responses to management. Thus, the capability unit is a convenient grouping for making many statements about management of soils. Capability units are generally identified by numbers assigned locally, for example, IIe-1 or IIIe-2.

Soils are classified in capability classes, subclasses, and units in accordance with the degree and kind of their permanent limitations; but without consideration of major and generally expensive landforming that would change the slope, depth, or other characteristics of the soil; and without consideration of possible but unlikely major reclamation projects.

The eight classes in the capability system, and the subclasses and units in this county, are described in the list that follows.

Class I. Soils that have few limitations that restrict their use (none in Logan County).

Class II. Soils that have some limitations that reduce the choice of plants or that require moderate conservation practices.

- Subclass IIe. Soils subject to moderate erosion if they are not protected.
  - Unit IIe-1.—Deep, dark silt loam that is gently sloping.
- Subclass IIc. Soils that are limited by lack of moisture.
  - Unit IIc-1.—Deep, dark, nearly level soils that are mainly silt loams.
  - Unit IIc-2.—Deep, well-drained silt loams that are nearly level and that receive additional moisture.

Class III. Soils that have severe limitations that reduce the choice of plants, that require special conservation practices, or both.

- Subclass IIIe. Soils subject to severe erosion if they are cultivated and not protected.
  - Unit IIIe-1.—Deep, dark silt loams and silty clay loams that are gently sloping.
  - Unit IIIe-2.—Deep, dark fine sandy loam that is gently sloping.

Class IV. Soils that have very severe limitations that restrict the choice of plants, that require very careful management, or both.

- Subclass IVe. Soils subject to very severe erosion if they are cultivated and not protected.
  - Unit IVe-1.—Deep, dark fine sandy loam that is moderately sloping.
  - Unit IVe-2.—Deep, moderately dark silt loams that are moderately sloping.
  - Unit IVe-3.—Deep, moderately dark clay that is gently sloping.
- Subclass IVw. Soils that have very severe limitations for cultivation because of excess water.
  - Unit IVw-1.—Deep, poorly drained silty clay loam that is in depressions.
  - Unit IVw-2.—Moderately deep, moderately dark, imperfectly drained loam and sandy loam.
- Subclass IVs. Soils that have very severe limitations because they are strongly calcareous, alkaline, or have a tight clay subsoil within the root zone.
  - Unit IVs-1.—Deep, moderately dark, nearly level soil that has a subsoil of tight clay.
  - Unit IVs-2.—Deep, dark silt loam that contains slickspots.
  - Unit IVs-3.—Deep, light-colored, well-drained soil that has a strongly calcareous subsoil.

Class V. Soils not likely to erode that have other limitations, impractical to remove, that limit their use largely to pasture or range, woodland, or wildlife food and cover.
  Subclass Vw. Soils too wet for cultivation; drainage or protection not feasible.
    Unit Vw-1.—Deep, dark, saline clay loam that is poorly drained.

Class VI. Soils that have severe limitations that make them generally unsuitable for cultivation and that limit their use largely to pasture or range, woodland, or wildlife food and cover.
  Subclass VIe. Soils severely limited, chiefly by risk of erosion, if protective cover is not maintained.
    Unit VIe-1.—Deep, moderately steep silt loam.
    Unit VIe-2.—Deep loamy fine sands that are nearly level or hummocky.
    Unit VIe-3.—Deep fine sandy loam that is hummocky.
    Unit VIe-4.—Deep, calcareous silt loams that are strongly sloping.
    Unit VIe-5.—Deep, moderately sloping clay.
  Subclass VIw. Soils severely limited by excess water and generally unsuitable for cultivation.
    Unit VIw-1.—Deep, loamy alluvial land that is frequently flooded.
    Unit VIw-2.—Deep, poorly drained clay on the floors of large intermittent lakes.
  Subclass VIs. Soils generally unsuitable for cultivation and severely limited by low fertility.
    Unit VIs-1.—Deep silt loam that is highly calcareous.

Class VII. Soils that have very severe limitations that make them unsuitable for cultivation, and that restrict their use largely to grazing, woodland, or wildlife.
  Subclass VIIe. Soils very severely limited, chiefly by risk of erosion if protective cover is not maintained.
    Unit VIIe-1.—Deep sands that have active blowouts.
  Subclass VIIw. Soils very severely limited by excess water.
    Unit VIIw-1.—Shallow loamy sand from alluvial material; subject to frequent flooding.
  Subclass VIIs. Soils very severely limited by a shallow root zone, low moisture-holding capacity, or both.
    Unit VIIs-1.—Shallow, loamy, strongly sloping, and broken soils.
    Unit VIIs-2.—Shallow clay that is strongly sloping.
    Unit VIIs-3.—Deep, gravelly, steep soil material.

Class VIII. Soils and landforms that have limitations that preclude their use for commercial production of plants, and that restrict their use to recreation, wildlife, water supply, or esthetic purposes.
  Subclass VIIIs. Rock or soil materials that have little potential for production of vegetation.
    Unit VIIIs-1.—Badland.

Management of soils by capability units

In this section each capability unit is described and the soils in it are listed. Suggestions are given on how to use and manage the soils of each unit.

CAPABILITY UNIT IIe-1

Only one soil—Keith silt loam, 1 to 3 percent slopes (Kb)—is in this capability unit. This soil is deep, dark, and gently sloping. It is among the most productive soils of the uplands in the county. This soil is easy to till and is well supplied with organic matter. Crops respond well if it is summer fallowed. Because the slopes are long, control of water erosion is needed. The soil is subject to wind erosion if it is not protected by a cover of vegetation.

All dryland crops grown in this county are adapted to this soil. The most common crops are wheat, barley, and sorghum grown for forage or grain.

The common cropping system is one in which a small grain is alternated with fallow. During years when the moisture in the soil is above average in spring, sorghum can be grown after a small grain in a continuous cropping sequence.

Terracing and contour farming conserve moisture and help to prevent water erosion. The tilth of the soil and the intake of moisture are improved and erosion is reduced by proper management of the crop residues.

CAPABILITY UNIT IIc-1

This capability unit consists mainly of deep, dark silt loams that are nearly level. The following soils are in this unit:

Bridgeport loam (Bp).
Elkader silt loam, 0 to 1 percent slopes (Ea).
Keith silt loam, 0 to 1 percent slopes (Ka).
Richfield silt loam, 0 to 1 percent slopes (Rc).
Ulysses silt loam, 0 to 1 percent slopes (Ua).

All of the soils in this capability unit, except Bridgeport loam, are well supplied with organic matter. The surface layer of the Bridgeport and Elkader soils is calcareous. As a result, small sorghum plants may be damaged by iron chlorosis if they are grown on those soils. The plants generally recover their color and mature, however, except when there is an unusually dry growing season. All of the soils in this unit are easy to till. They have a subsoil of loam to silty clay loam. Their subsoil has a high moisture-storing capacity, which enables crops to respond well after the soils are summer fallowed. Conservation of moisture and control of wind erosion are needed on all of these soils to assure economical production of crops.

Wheat and barley are well adapted to all of these soils. Sorghum is better adapted to the Keith, Richfield, and Ulysses soils than to the Bridgeport and Elkader. Good yields of alfalfa are obtained on the Bridgeport soil in areas where there is an effective water table.

A cropping system of small grains alternated with fallow is best suited to the soils in this unit. Sorghum grown for forage or grain can be grown after a small grain during years when the soil moisture is above average in spring. Alfalfa generally remains on the Bridgeport soil until the stand thins. Then one or two crops of a small grain are grown before returning the soils to alfalfa.

Practices to conserve moisture are needed. Good management of crop residues improves soil tilth, increases the intake of water, and reduces erosion. Optional practices, which require on-site determination, are terracing and contour farming. These practices conserve moisture and reduce erosion. Wind stripcropping is another desirable practice to use in the control of wind erosion.

CAPABILITY UNIT IIc-2

The soils in this unit are deep, dark, well-drained silt loams that are nearly level. The following soils are in this capability unit:

Lubbock silt loam (Lu).
Volin silt loam (Vl).

These soils are very fertile and are readily permeable to roots, air, and moisture. Runoff and a water table supply them with additional moisture. These are among the most productive soils in the county, but controlling wind erosion, conserving moisture, and maintaining good soil tilth are problems.

High yields of all the crops commonly grown in the county are obtained. Alfalfa is grown on the Volin soil in areas where there is a water table.

The Lubbock soil occurs only in small areas and is generally cropped in the same sequence as the soils on the adjoining uplands. Small grains or sorghum are sometimes grown year after year on the larger areas of the Lubbock soil. Alfalfa is normally grown on the Volin soil until the stand becomes thin. The soil is then cropped to small grains or sorghum before returning it to alfalfa.

Managing crop residues properly on the soils of this capability unit improves soil tilth and the intake of water. It also reduces erosion.

CAPABILITY UNIT IIIe-1

This capability unit is made up of deep, dark, gently sloping silt loams and silty clay loam. The following soils are in this unit:

Elkader silt loam, 1 to 3 percent slopes (Eb).
Ulysses silt loam, 1 to 3 percent slopes (Ub).
Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes (Uh).

These soils are moderately well supplied with organic matter. The Elkader soil and the Ulysses silty clay loam have a calcareous surface layer, and in many places the surface layer of the Ulysses silt loam is calcareous. Iron chlorosis may affect small sorghum plants grown on these soils, but the plants generally recover their color, except in an unusually dry growing season. The Elkader soil and the Ulysses silt loam are friable and are readily permeable to moisture, air, and roots. The Ulysses silty clay loam is more difficult to till than the other soils, and it is somewhat slowly permeable to moisture, air, and roots. It also tends to be droughty for crops that grow in summer. The soils of this unit are subject to erosion by both wind and water. It is necessary that moisture be conserved if they are to be used profitably to grow crops.

The Ulysses silt loam is suitable for all of the crops commonly grown in the county. The Elkader soil and the Ulysses silty clay loam are more suitable for winter wheat and barley than for other crops.

A cropping system of small grains alternated with fallow is used on the soils in this unit. On the Ulysses silt loam, sorghum can be grown after a small grain in years when there is above-average moisture in the soil at seeding time.

These soils need terracing and contour farming to conserve moisture and to reduce erosion. Managing the crop residues properly improves the tilth of the soils, increases the intake of water, and reduces erosion. Contour stripcropping helps to control wind erosion.

CAPABILITY UNIT IIIe-2

Only one soil—Manter fine sandy loam, 1 to 3 percent slopes (Mh)—is in this capability unit. This soil is deep, dark, and gently sloping. It is easy to till and is well supplied with organic matter. The surface layer absorbs most of the rainfall, and there is little runoff. This soil is subject to wind erosion when the surface is bare.

The ease with which moisture enters this soil and is released to plants makes it possible to use a cropping system in which crops are grown every year. Moderate yields, on the average, can be depended upon under such a system. Wheat, barley, and grain sorghum are the crops generally grown. Small grains are subject to wind erosion late in winter and early in spring. Therefore, most farmers grow small grains on the medium-textured soils and sorghum on this soil.

A suitable cropping system is one in which small grains or sorghum are grown year after year. A protective cover that consists of a growing crop or of residues of a mature crop should be kept on the surface at all times. Proper management of the crop residues improves the tilth of the soils, increases the intake of water, and reduces erosion. Wind stripcropping, in which a small grain and sorghum are grown in alternate strips, reduces soil blowing and damage to growing crops. This soil responds to nitrogen fertilizer during years when moisture in the soil is above average.

CAPABILITY UNIT IVe-1

Only one soil—Manter fine sandy loam, 3 to 5 percent slopes (Mk)—is in this capability unit. This deep, dark, moderately sloping soil is easy to till and is moderately well supplied with organic matter. Both the surface layer and subsoil have a texture of fine sandy loam. As a result, practically all the rainfall is absorbed and released readily to plants. The structure of the surface layer is too weak for clods to form when emergency tillage is used to check wind erosion. On the small knolls and narrow ridges that occur throughout areas of this soil, wind erosion is likely to be severe.

Because of the ease with which moisture enters this soil and is released to plants, crops can be grown year after year. Moderate yields of grain sorghum are obtained, but small grains are susceptible to damage as the result of severe wind erosion late in winter and early in spring.

This soil is best suited to native grasses for range. If it is cultivated, a cropping system of grain sorghum grown year after year is suitable. Sorghum grown for forage does not leave enough cover to protect the soil during the critical period when wind erosion is most serious. Small grains can be grown if good management of the residues is practiced.

684-986—64——3

If this soil is cultivated, managing the crop residues is important because the residues reduce erosion and improve soil tilth. Wind stripcropping, in which a small grain and grain sorghum are grown in alternate strips, reduces soil blowing and damage to growing crops. The soil responds to nitrogen fertilizer during years when soil moisture is above average. During prolonged droughts, a cover crop may have to be planted, without any expected harvest of forage or grain, to provide a protective cover for the soils.

CAPABILITY UNIT IVe-2

The soils in this capability unit are deep, moderately dark silt loams that are moderately sloping. The following soils are in this unit:

Colby silt loam, 3 to 5 percent slopes (Cc).
Elkader silt loam, 3 to 5 percent slopes (Ec).
Ulysses silt loam, 3 to 5 percent slopes (Uc).
Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded (Ul).

These soils are friable and easy to till, but they have a calcareous plow layer. Their subsoil is silt loam that is high in moisture-holding capacity. Crops respond well if these soils are summer fallowed. The large amount of lime in the surface layer causes surface sealing and excessive runoff during rains. These soils are subject to severe erosion by wind and water. During prolonged droughts, when the surface is bare, the soil structure is too weak to furnish stable clods if emergency tillage is used. Iron chlorosis severely affects sorghum.

Under good mangement, moderate yields of wheat and barley are obtained. Sorghum generally does not give profitable returns.

These soils are best suited to native grasses for range. If the soils are cultivated, a cropping system in which small grains are alternated with fallow is suitable. Sorghum should not be planted on the Colby and Elkader soils. It should be grown on the Ulysses soils only when no better soils are available to ranchers for growing feed crops.

Terracing and contour farming reduce erosion and conserve moisture in cultivated areas. Proper management of the crop residues during the fallow period improves soil tilth, increases the intake of water, and reduces erosion. Contour stripcropping in areas where sorghum is grown reduces soil blowing and damage to the growing crop. During prolonged droughts, a cover crop may have to be planted, without any expected harvest of forage or grain, to provide a protective cover. Grassed waterways need to be seeded in areas where gradient terraces are planned and no native grass outlets are available.

CAPABILITY UNIT IVe-3

The only soil in this capability unit—Promise clay, 1 to 3 percent slopes (Ps)—is deep, moderately dark, and gently sloping. It is difficult to till and contains only a moderate amount of organic matter. The plow layer is calcareous. Water enters and moves downward slowly through this soil. The clayey surface layer seals over readily during rains. As a result, excessive runoff is caused. The subsoil is high in moisture-holding capacity, but it releases the moisture slowly to growing plants. The soil is droughty for crops grown in summer. Iron chlorosis, a result of the large amount of lime in the surface soil, retards the growth of sorghum. This soil is subject to moderate erosion by wind and water.

Yields of cultivated crops are low, and crop failures are frequent. Winter wheat and barley, which mature before summer droughts occur, are best adapted to this soil. The soil is too droughty for sorghum, except in years of above-average rainfall. It is best suited to native grasses for range. If the soil is cultivated, a cropping system in which small grains are alternated with fallow is suitable.

Terracing and contour farming reduce erosion and conserve moisture for crops. Proper management of the crop residues during the fallow period improves soil tilth, increases the intake of water, and reduces erosion. Additional protection from wind erosion is obtained by the use of contour stripcropping. Grassed waterways should be established in areas where gradient terraces are planned and no native grass outlets are available. During prolonged droughts, a cover crop should be planted, without any expected harvest of forage or grain, to provide a protective cover for the soil.

CAPABILITY UNIT IVw-1

Lofton silty clay loam (Lo) is the only soil in this capability unit. It is deep, dark, and imperfectly drained, and it is in depressions or small basins throughout the nearly level tablelands of the county. The subsoil takes up water very slowly, and the surface is frequently ponded. The soil is generally too wet to till at seeding time, and crops that are seeded are often drowned before they mature. If this soil is drained, it tends to be droughty for crops grown in summer. The soil is subject to wind erosion when it is dry and not protected by a cover of plants.

This soil is used and managed about the same as the surrounding soils. Most of the acreage is used for cultivated crops, mainly wheat, barley, and sorghum. Emergency tillage may be necessary to control wind erosion during dry years when the surface is bare.

CAPABILITY UNIT IVw-2

This capability unit consists of moderately deep, moderately dark, imperfectly drained soils that have a surface layer of loam or sandy loam. The soils are nearly level. The following are in this unit:

Las loam, moderately deep (Lb).
Las Animas sandy loam (Ld).

These soils are underlain by sand and gravel at a depth of 20 to 36 inches. The water table is normally at a depth of 4 to 8 feet, but it rises to within 2 feet of the surface in spring and in seasons of above-average rainfall. This fluctuating water table is beneficial to alfalfa, and, in wetter seasons, it is beneficial to cultivated crops. During prolonged dry periods when the water table falls below the root zone, cultivated crops are likely to be damaged because of the low water-holding capacity of the soils. Crops may also be damaged by flooding. The Las Animas soil is subject to wind erosion when it is bare.

Alfalfa and grain sorghum are the crops commonly grown on the soils of this capability unit. Small grains are subject to damaging overflow that usually occurs in spring.

These soils are best suited to native grasses for range. The cropping system in areas that are cultivated is one in which alfalfa or grain sorghum is grown year after year. When the stand of alfalfa becomes thin, sorghum or a small grain can be grown for 1 year to provide a protective cover for reseeding to alfalfa.

When alfalfa is not grown, managing the crop residues properly reduces erosion, conserves moisture, and improves soil tilth.

CAPABILITY UNIT IVs-1

Only one soil—Promise clay, 0 to 1 percent slopes (Pr)—is in this capability unit. This soil is deep and moderately dark, and it has a subsoil of tight clay. It is difficult to till. The supply of organic matter is only moderate, and the plow layer is calcareous. Water enters and moves through the soil slowly. The clay subsoil has a high moisture-holding capacity, but it releases the moisture slowly to growing plants. This slow release of the subsoil moisture causes the soil to be droughty for crops grown in summer. Iron chlorosis, a result of the large amount of lime in the surface layer, retards the growth of sorghum. This soil is subject to moderate wind erosion.

Yields of cultivated crops are low. Moderate yields of alfalfa are obtained in areas where there is a water table. Winter wheat and barley are better adapted to this soil than other crops because they mature before the droughts come in summer. Except in years of above-average rainfall, this soil is too droughty for sorghum.

This soil is best suited to native grasses for range. A cropping system of small grains alternated with fallow is suitable if the soil is cultivated. If alfalfa is grown, it generally remains on the soil until the stand becomes thin. Then one or two crops of a small grain are grown before returning the soil to alfalfa.

Proper management of the crop residues is important in cultivated areas. It improves soil tilth, increases the intake of water, and reduces erosion. Additional protection from wind erosion can be provided by wind stripcropping. During prolonged droughts, a cover crop may have to be planted, without any expected harvest of forage or grain, to provide a protective cover for the soils.

CAPABILITY UNIT IVs-2

Only Volin-slickspot complex (Vs) is in this capability unit. About 60 percent of the acreage consists of a Volin soil, which is a deep, dark, friable silt loam. About 25 percent consists of a slickspot soil, which has a surface layer that is crusted with alkali and is very hard when dry. The remaining 15 percent consists of a soil that has characteristics intermediate between those of the Volin soil and the slickspot soil. The slickspot soil occurs throughout the areas of Volin soil in circular spots and in long, narrow strips. It supports little or no vegetation.

All of the acreage is in native grass, to which the soils are best suited. Proper management of grazing is needed to maintain a vigorous stand of grass that will provide forage and help protect the soils.

The soils of this complex can be cultivated if necessary, but the slickspot soil is unproductive and is difficult to till. If the soils are cultivated, a cropping system in which a small grain or grain sorghum is grown year after year is best suited. Managing the crop residues properly improves soil tilth, increases the intake of water, and helps to prevent soil blowing. Wind stripcropping also helps to reduce soil blowing and damage to growing crops.

CAPABILITY UNIT IVs-3

Only Bridgeport silt loam, strongly calcareous variant (Bv), is in this capability unit. This soil is deep, light colored, well drained, and nearly level. Its surface layer and subsoil are calcareous. The surface layer has weak, granular structure, and it is relatively low in organic matter. The subsoil is silt loam and contains a large amount of lime. The soil is subject to occasional flooding, and in some places it has a deep water table. It is also subject to erosion by wind if it is not protected by a cover of plants.

Alfalfa grows well in areas where there is a water table. Wheat and barley are commonly grown, and rye is grown occasionally for pasture. Sorghum is not adapted to this soil, because of the high content of lime.

This soil is best suited to native grasses for range. If the soil is cultivated, a cropping system in which a small grain or alfalfa is grown continuously is suitable. When the stand of alfalfa becomes thin, a small grain can be grown for 1 or 2 years before reseeding to alfalfa.

Proper management of the crop residues improves soil tilth and the intake of water. It also helps to control erosion in cultivated areas.

CAPABILITY UNIT Vw-1

Only Wet alluvial land (Wa) is in this capability unit. It consists of deep, dark, saline clay loam that is poorly drained. This land type is nearly level and is on low flood plains along the Smoky Hill River. If it is cultivated, a spotty or poor stand of crops is obtained. The growth of the plants is stunted, and crops generally fail to mature. This land type has a high water table, and it is too wet and saline to be suitable for cultivation. Overgrazing of the native grasses results in a nearly pure stand of inland saltgrass.

This land type is best suited to grass. Range seeding will return cultivated areas to their natural vegetation so that they can be used for range. Interseeding improves poor to fair range. Proper range use and deferred grazing are practices that maintain and improve the natural vegetation. Salting and fencing are management practices that help facilitate proper use of the range. More information about the management of this land type is given under the Saline Subirrigated range site in the section "Management of Rangeland."

CAPABILITY UNIT VIe-1

Ulysses silt loam, 5 to 15 percent slopes (Ud), is the only soil in this capability unit. This deep, moderately steep soil is on the uplands in the eastern and southern parts of the county. It is too sloping and susceptible to erosion to be suitable for cultivation.

This soil is best suited to grass. Range seeding will return cultivated areas to their natural vegetation. The natural vegetation can be maintained and improved by proper use of the range and by deferred grazing. Fencing and salting are management practices used to facilitate proper use of the range, and some areas need water development. More information about managing this soil is given under the Loamy Upland range site in the section "Management of Rangeland."

CAPABILITY UNIT VIe-2

This capability unit consists of deep loamy fine sands that are nearly level or hummocky. The following soils are in this unit:

Dwyer loamy fine sand (Dw).
Likes loamy fine sand (Lk).

These soils are on alluvial fans and low hummocks above the flood plain on the south side of the Smoky Hill River. They are coarse textured and are too susceptible to erosion to be suitable for cultivation. The soils are used entirely for range.

These soils are better suited to grass than to crops that require cultivation. Interseeding improves poor to fair range. Deferred grazing and proper use of the range will maintain and improve the natural vegetation. Salting and fencing are management practices that help facilitate proper range use. Mechanical and chemical means of controlling sand sagebrush can be practiced if extreme care is used to avoid exposing these soils to severe wind erosion. More information about the management of these soils is given under the Sands range site in the section "Management of Rangeland."

CAPABILITY UNIT VIe-3

Otero fine sandy loam (Ot), the only soil in this capability unit, is deep and moderately coarse textured. It is moderately to strongly sloping and is on irregular and hummocky ridges and knolls. Most of the acreage is used for range, and only small areas are cultivated.

This soil is better suited to grass than to crops that require cultivation. Range seeding will return cultivated areas to their natural vegetation. Interseeding improves poor to fair range. The natural vegetation can be maintained or improved by proper use of the range and by deferred grazing. Fencing and salting are management practices that facilitate proper use of the range. Chemical or mechanical means of controlling sand sagebrush can be used. More information about the management of this soil is given under the Sandy range site in the section "Management of Rangeland."

CAPABILITY UNIT VIe-4

The soils of this capability unit are deep, calcareous silt loams that are strongly sloping. The following soils are in this unit:

Colby silt loam, 5 to 15 percent slopes (Cd).
Elkader silt loam, 5 to 15 percent slopes (Ed).
Ulysses-Colby silt loams, 5 to 15 percent slopes, eroded (Um).

These soils occur throughout the county. They are too sloping and susceptible to erosion to be suitable for cultivation, but most of the eroded areas are still cultivated.

These soils are best suited to grass. Range seeding will return them to their natural vegetation. The natural vegetation can be maintained or improved by proper use of the range and by deferred grazing. Fencing and salting are practices that facilitate proper use of the range. Some areas of these soils require water development before proper range use can be attained. More information about the management of these soils is given under the Limy Upland range site in the section "Management of Rangeland."

CAPABILITY UNIT VIe-5

Promise clay, 3 to 5 percent slopes (Pt), is the only soil in this capability unit. This moderately sloping soil is in the northwestern part of the county. It is practically all in native grass, except for a few marginal areas. The soil is too susceptible to erosion and too droughty to be suitable for cultivation.

This soil is better suited to grass than to cultivated crops. Range seeding returns cultivated areas to their natural vegetation. The natural vegetation can be maintained or improved by the proper use of the range and by deferred grazing. Fencing and salting are management practices used to facilitate proper range use. More information about the management of this soil is given under the Clay Upland range site in the section "Management of Rangeland."

CAPABILITY UNIT VIw-1

Alluvial land (An) is the only land type in this capability unit. It consists of deep, loamy soil material and is frequently flooded. This land type occurs throughout the county. It is on the narrow floors of drainageways in the uplands. Cultivating it is not practical, because of the meandering channels and the frequent flooding.

This land is best suited to grass. It is used entirely for range. Deferred grazing and proper use of the range are practices that maintain and improve the natural vegetation. More information about management is given under the Loamy Lowland range site in the section "Management of Rangeland."

CAPABILITY UNIT VIw-2

Randall clay (Ra) is the only soil in this capability unit. It is on the floors of large intermittent lakes that are scattered throughout the central and northwestern parts of the county.

This soil is poorly drained and is ponded with water too often to be well suited to the growing of cultivated crops year after year. It is also poorly suited to native grasses, and seems best suited as a habitat for wildlife.

Developing wetlands by providing permanent water and islands within the impounded areas improves the habitat for wildlife. Food of high quality is provided by planting shrubs or other plants that provide food adjacent to the areas of wetland that are developed. Cover also should be provided for wildlife.

CAPABILITY UNIT VIs-1

The only soil in this capability unit—Minnequa silt loam (Mn)—is deep, highly calcareous, and gently to moderately sloping. It is on alluvial fans below outcrops of chalk rock in the southern part of the county. Most of the acreage is in native grasses. Some areas were once broken for cultivation, but they were abandoned after a few years. The soil is too calcareous and too low in fertility to be suitable for cultivated crops.

This soil is best suited to grass. Range seeding will return cultivated areas to their natural vegetation. Interseeding is a practice that improves poor to fair range. The natural vegetation can be maintained or improved by proper use of the range and by deferred grazing. Fencing and salting are management practices used to facilitate proper use of the range, but some areas also require water development. More information about managing this soil is given under the Chalk Flats range site in the section "Management of Rangeland."

CAPABILITY UNIT VIIe-1

The only land type in this capability unit is Active dunes (Ad). It consists of deep, unstabilized, bare and shifting sands that have active blowouts. These areas are too susceptible to wind erosion to be suitable for cultivation.

This land type is better suited to grass than to cultivated crops. The dunes must be stabilized and seeded if the areas are to be returned to their natural vegetation. Proper range use and deferred grazing maintain and improve the natural vegetation. Fencing is a management practice that facilitates proper use of the range. More information about managing this land is given under the Choppy Sands range site in the section "Management of Rangeland."

CAPABILITY UNIT VIIw-1

Only Lincoln soils (Ll) is in this capability unit. The soils consist of loamy sand from alluvial material. They are nearly level and are on low flood plains adjacent to the channels of the major streams in the county. The soils are too shallow and are damaged too frequently by flooding to be suitable for cultivation. Wind erosion is a hazard.

These soils are best suited to grass. The vegetation is in a constant state of change because of frequent flooding. Generally, grazing must be controlled so as to maintain the existing vegetation, but management requirements vary according to the location. Therefore, these soils have not been assigned a range site for management purposes. Information about the use and management of the soils may be obtained from a local representative of the Soil Conservation Service.

CAPABILITY UNIT VIIs-1

In this capability unit are shallow, loamy, strongly sloping, and broken soils. The following soils are in this unit:

Loamy broken land (Ln).
Minnequa-Penrose silt loams (Mp).
Potter soils (Po).

These soils are mainly in areas of rough, broken relief throughout the county, but some areas are on tablelands in the northeastern part. The soils are too shallow for cultivated crops and are used for range.

These soils are best suited to grass. The natural vegetation can be maintained and improved by proper use of the range and by deferred grazing. Fencing and salting are management practices that facilitate proper range use, but some areas also need water development for proper use of the range. More information about managing these soils is given under the Chalk Flats and Breaks range sites in the section "Management of Rangeland."

CAPABILITY UNIT VIIs-2

Lismas clay (Lm) is the only soil in this capability unit. It is shallow and is strongly sloping. This soil is in areas of rough, broken relief in the western part of the county. It is too shallow to be suitable for cultivation and is used entirely for range.

This soil is best suited to grass. Deferred grazing and proper use of the range are practices that maintain and improve the natural vegetation. Water development, fencing, and salting are practices that also help to obtain proper use of the range. More information about the management of this soil is given under the Shale Breaks range site in the section "Management of Rangeland."

CAPABILITY UNIT VIIs-3

Only one land type—Gravelly broken land (Gr)—is in this capability unit. This land type consists of coarse-textured material that occurs in areas that are steep, broken, and hummocky. It is used entirely for range.

This land is better suited to grass than to cultivated crops. Proper use of the range and deferred grazing are practices that maintain and improve the natural vegetation, and fencing also facilitates proper use of the range. More information about managing this land is given under the Gravelly Hills range site in the section "Management of Rangeland."

CAPABILITY UNIT VIIIs-1

Badland (Bl) is the only land type in this capability unit. It consists of nearly bare geologic material. It is in areas of rough, broken relief where there are many vertical-walled canyons, escarpments, and pinnacles.

Badland has no agricultural use. The vegetation on the areas is sparse and covers less than 10 percent of the acreage.

Estimated yields

Table 7 gives the estimated average yields of wheat and grain sorghum grown on the arable soils of Logan County under two defined levels of management. The estimates are based mainly on information gathered through interviews with farmers, agricultural workers, and others who have observed yields. They indicate the relative productivity of each soil shown on the soil map.

Yields in columns A are to be expected under average management. They are obtained by many farmers in the county. Average management does not include the use of a suitable cropping system, terracing, cultivating on the contour, stubble mulching, and other good farming practices. Yields in columns B are those to be expected under improved management, or when a suitable cropping system, terracing, contour farming, stubble mulching, and other good cultural practices are followed. Yields higher than those given in columns B are not uncommon and can be obtained under good management in years when soil moisture is above average. Yields may change greatly in the future as new plant varieties and cultural practices are developed and as additional plant diseases and insects appear.

TABLE 7.—*Estimated average acre yields of seeded wheat and grain sorghum grown on the arable soils under two levels of management*

[Columns A show yields to be expected under average management, and columns B show yields to be expected under improved management]

Soil	Wheat [1]		Grain sorghum	
	A	B	A	B
	Bu.	*Bu.*	*Bu.*	*Bu.*
Bridgeport loam	14.0	18.0	13.5	17.0
Bridgeport silt loam, strongly calcareous variant [2]	7.0	9.0	(3)	(3)
Elkader silt loam, 0 to 1 percent slopes	14.0	18.0	13.5	17.0
Elkader silt loam, 1 to 3 percent slopes	11.0	15.0	(3)	(3)
Elkader silt loam, 3 to 5 percent slopes	10.5	14.0	(3)	(3)
Keith silt loam, 0 to 1 percent slopes	17.0	21.0	15.0	19.0
Keith silt loam, 1 to 3 percent slopes	16.0	21.0	14.0	19.0
Las Animas sandy loam [2]	(4)	(4)	10.0	12.5
Las loam, moderately deep [2]	(4)	(4)	11.0	13.5
Lofton silty clay loam	6.0	12.0	7.0	14.0
Lubbock silt loam	22.5	27.5	22.5	28.0
Manter fine sandy loam, 1 to 3 percent slopes [2]	10.0	14.0	15.0	19.0
Manter fine sandy loam, 3 to 5 percent slopes [2]	(4)	(4)	13.5	17.0
Promise clay, 0 to 1 percent slopes	9.0	11.0	7.5	9.0
Promise clay, 1 to 3 percent slopes	7.5	10.0	6.0	8.0
Richfield silt loam, 0 to 1 percent slopes	15.0	19.0	15.0	18.0
Ulysses silt loam, 0 to 1 percent slopes	14.5	19.0	14.5	18.0
Ulysses silt loam, 1 to 3 percent slopes	12.0	16.0	12.5	14.5
Ulysses silt loam, 3 to 5 percent slopes	11.0	15.0	10.5	13.5
Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes	13.0	17.0	11.5	15.0
Volin silt loam	22.0	27.0	22.0	27.5
Volin-slickspot complex	11.0	14.0	11.5	14.5

[1] Except where indicated, the wheat yields given reflect the general use of summer fallow.
[2] Summer fallowing is not practical or is not practiced on this soil. Yield estimates are for continuous cropping.
[3] The soil is not suited to grain sorghum.
[4] Little or no wheat is grown.

Management of Rangeland [5]

The raising of livestock in Logan County is second in importance only to the growing of field crops. The success of this enterprise depends largely on the way ranchers and owners of grassland manage the forage on the range.

Rangeland makes up about 50 percent of the acreage in the county. Generally, the areas of rangeland are not suitable for cultivation. The most important of these range areas is in the southern part of the county. It includes the breaks along the Smoky Hill River, Twin Butte Creek, and Chalk Creek. Other valuable grazing areas are adjacent to the North Fork of the Smoky Hill River.

[5] By H. RAY BROWN, range conservationist, Soil Conservation Service.

Principles of range management

High yields of forage are obtained on the range, and soil, water, and plants are conserved, by maintaining range that is already in good or excellent condition and by improving range that has been depleted. These things are accomplished by managing grazing to encourage the more desirable native forage plants so that they will replace the less desirable ones. Storage of food, development of leaves, growth of roots, formation of flower stalks, production of seed, and regrowth of forage are essential processes in the growth of grass. Grazing must allow for these natural processes of growth if maximum yields of forage and gains in weight and in number of animals are to be maintained.

Livestock graze selectively. They constantly seek out the palatable and nutritious plants. If grazing use is not regulated carefully, the better plants are gradually eliminated. Less desirable plants can then increase. If heavy grazing pressure is continued, even the second-choice plants, or increasers, are gradually thinned out or eliminated and undesirable weeds or invaders take their place.

Research and the experience of ranchers have shown that if only about half the yearly volume of grass produced is grazed, damage to the better plants is minimized and the range can improve up to its maximum production. The forage left on the ground serves as a mulch that encourages the rapid intake of water. It also stops snow where it falls so that the water from snowmelt soaks into the soil for later use. The more water stored in the soil, the better the growth of grass for grazing. Overgrazed grass cannot reach deep moisture, because not enough green shoots are left to provide the food needed for good root growth.

Grass is one of the best kinds of cover for preventing erosion. A good growth of grass protects the soil from wind and water. If grasses are vigorous, the better grasses can crowd out weeds, which means that range in a low state of productivity will improve. Grasses are also able to store food for quick growth after droughts and in spring. Plenty of grass also provides a reserve of feed for the dry spells that otherwise might force the stockman to sell his animals at a loss.

Sound range management requires that the stocking rate be adjusted from season to season as the range improves or as fluctuations in the amount of precipitation make adjustment necessary. During periods of prolonged dry weather, the stocking rate should be reduced below the rate that is normal for the particular site. In wet years the stocking rate may be increased to slightly above the rate normal for the site. Reserve pastures or other feed should be provided for use during droughts or other periods when the production of forage is curtailed. This permits the proper degree of use of range forage at all times.

In addition to maintaining reserves of forage and feed, it is desirable to maintain flexibility in the numbers of livestock. This can be done by keeping stock that is readily salable, such as stocker steers, during periods of high production of forage. The steers can be sold when yields of forage are low.

Range sites and condition classes

Different kinds of range produce different kinds and amounts of forage. If the operator of a range is to manage his rangeland properly, he needs to know the different kinds of land or range sites in his holdings and the plants each site is capable of producing. He is then able to determine what his range can be expected to produce in different seasons and under different degrees of grazing use.

A range site is a kind of rangeland in which the soil, climate, and topography are enough alike to produce a distinct kind of climax vegetation. Differences between sites are best distinguished by measurable differences in the kind or amount of climax vegetation. A significant difference is one that is great enough to require different grazing practices or other management practices to maintain and improve the present vegetation.

Climax vegetation is the combination of plants that grew originally on a given site. The most productive combination of forage plants on the range is generally the climax type of vegetation. Grazing is managed to attain or maintain excellent range condition, using the climax vegetation as a gage.

Range condition is the present state of the vegetation in relation to the highest stage of plant growth the site can support. It is determined by computing the percentage of the present vegetation in relation to the climax vegetation for the site. Changes in range condition are caused primarily by the degree of use or the kind of use of the rangeland. The effects of grazing become more apparent during periods of drought. Four range condition classes are defined. A range in excellent condition has from 76 to 100 percent of the vegetation that is characteristic of the climax vegetation on the same site; one in good condition, 51 to 75 percent; one in fair condition, 26 to 50 percent; and one in poor condition, less than 26 percent.

Descriptions of range sites

The dominant range sites in Logan County are Loamy Upland, Limy Upland, and Breaks. The Loamy Upland range site makes up nearly 75 percent of the rangeland in the county; the Limy Upland site, about 12 percent; and the Breaks site, about 5 percent. Chalk Flats, Choppy Sands, Clay Upland, Gravelly Hills, Loamy Lowland, Saline Subirrigated, Sands, Sandy, Sandy Lowland, and Shale Breaks make up the rest of the acreage.

Lincoln soils, Randall clay, and Badland are not suited to range and have therefore not been placed in a range site. The mapping unit of Lincoln soils is adjacent to the major streams in the county. The Lincoln soils are frequently flooded, and the floodwaters cause scouring and leave deposits of silt. As a result, the kind of vegetation changes frequently. Runoff from large areas of adjoining uplands collects on Randall clay. This soil is covered by water too frequently and remains under water too long for permanent grasses to become established. Badland consists of nearly bare geologic material. The areas of Badland are difficult to cross and offer only limited access to livestock. The vegetation is sparse and covers only about 10 percent of the acreage.

BREAKS

In this site are loamy soils that are shallow to deep. The soils have a weakly developed profile and formed in partly weathered chalk rock, caliche, and shale. They are strongly sloping to steep. Bare geologic formations outcrop in places. The following soils are in this range site:

Loamy broken land (Ln).
Minnequa-Penrose silt loams (Mp) (Penrose soils only).
Potter soils (Po).

The climax plant cover is a mixture of decreaser plants, such as little bluestem, side-oats grama, and forbs. These plants make up as much as 60 percent of the vegetation, and other perennial grasses, forbs, and annuals account for the rest. The dominant increasers are blue grama, sand dropseed, forbs, and buffalograss. Blue grama and forbs are the main increasers under grazing pressure. Side-oats grama, blue grama, and little bluestem are the key grasses under the present grazing use. Common invaders are annuals, broom snakeweed, and ring muhly. The estimated yield of air-dry herbage for this site in excellent condition is 1,250 to 2,000 pounds per acre.

CHALK FLATS

The soils in this range site are on alluvial fans and colluvial slopes, below areas where unweathered rocks of the Niobrara formation are exposed. The soils are gently sloping. Their surface layer is only 1 to 4 inches thick, and the boundary between the surface layer and the substratum is abrupt. The substratum consists of loamy to silty, highly calcareous, recently deposited, unweathered sediments from weathered chalk beds. These soils absorb moisture readily, and they have a high water-holding capacity. The following soils are in this site:

Minnequa silt loam (Mn).
Minnequa-Penrose silt loams (Mp) (Minnequa soils only).

The climax plant cover is a mixture of side-oats grama, little bluestem, big bluestem, switchgrass, and other decreaser grasses. These decreasers make up as much as 60 percent of the climax vegetation (fig. 21). Common

Figure 21.—Chalk Flats range site. To the right of the fence, the range is in excellent condition; to the left, it is in fair condition.

increasers are buffalograss, inland saltgrass, sand dropseed, blue grama, western wheatgrass, and forbs. Annual plants are the principal invaders. The estimated yield of air-dry herbage for this site in excellent condition is 2,000 to 2,500 pounds per acre.

CHOPPY SANDS

Only Active dunes (Ad) is in this range site. It consists of deep sands on hummocks and dunes. The sands absorb water rapidly, but they store little of it. Blowouts are numerous on this site.

The climax plant cover is a mixture of sand bluestem, switchgrass, little bluestem, side-oats grama, and other decreaser grasses. These grasses make up as much as 60 percent of the climax vegetation, and other perennial forbs and grasses account for the rest. The dominant increaser grasses include sand dropseed and sand paspalum. The principal woody plant increaser is sand sagebrush. Common invaders are false buffalograss, annuals, and purple sandgrass. The estimated yield of air-dry herbage for this site in excellent condition is 1,250 to 1,750 pounds per acre.

CLAY UPLAND

This site consists of deep, calcareous soils that have a surface layer and subsoil of silty clay loam to clay. The soils are nearly level to moderately sloping and are on alluvial fans and on uplands. Their subsoil is slowly permeable and releases moisture slowly to plants. The soils in this site are more droughty than those in the Loamy Upland range site. The following soils are in this range site:

Promise clay, 0 to 1 percent slopes (Pr).
Promise clay, 1 to 3 percent slopes (Ps).
Promise clay, 3 to 5 percent slopes (Pt).
Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes (Uh).

The climax plant cover is a mixture of such decreaser plants as western wheatgrass, side-oats grama, and forbs. Buffalograss and western ragweed are the main increasers under grazing pressure. After the areas have been grazed heavily for a number of years, buffalograss makes up as much as 60 percent or more of the plant cover in some areas. Blue grama and buffalograss are the key grasses in most areas under present grazing use. Common pricklypear, wavyleaf thistle, and annuals are the common invaders. The estimated yield of air-dry herbage, when the site is in excellent condition, is 750 to 1,500 pounds per acre.

GRAVELLY HILLS

This range site is made up of Gravelly broken land (Gr). The areas are strongly sloping and contain broken hummocks. They lie below the summit of the tablelands and on the sides of large drainageways. The texture of the soil material varies from place to place. It is moderately coarse or coarse textured near the surface. Sand and gravel are at a depth of 4 to 10 inches. Water-rounded pebbles 3 inches in diameter are scattered over the surface. The soil material in these areas takes up water rapidly, but it is low in water-holding capacity.

The climax cover is a mixture of decreaser grasses, such as little bluestem, side-oats grama, and tall dropseed, with smaller amounts of switchgrass and big bluestem. These climax grasses make up as much as 60 percent of the climax vegetation. The rest is made up of increasers, chiefly blue grama, hairy grama, sand dropseed, buffalograss, sand sagebrush, and small soapweed. Common invaders are perennial three-awn, windmillgrass, and sixweeks fescue. The estimated yield of air-dry herbage, when this site is in excellent condition, is 1,500 to 2,000 pounds per acre.

LIMY UPLAND

The soils in this range site are deep, calcareous silt loams. They have a thin, calcareous surface layer that overlies calcareous parent material. These soils are sloping and are on eroded uplands. The following soils are in this site:

Colby silt loam, 5 to 15 percent slopes (Cd).
Elkader silt loam, 1 to 3 percent slopes (Eb).
Elkader silt loam, 3 to 5 percent slopes (Ec).
Elkader silt loam, 5 to 15 percent slopes (Ed).
Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded (Ul).
Ulysses-Colby silt loams, 5 to 15 percent slopes, eroded (Um).

The principal climax grasses are side-oats grama, little bluestem, western wheatgrass, and forbs, but there are small amounts of big bluestem and switchgrass. Blue grama and broom snakeweed are the main increasers under grazing pressure. Side-oats grama and blue grama are the key forage grasses under present grazing use, but there is some little bluestem. Windmillgrass, tumblegrass, and other annual and perennial plants are common invaders. The estimated yield of air-dry herbage on this site in excellent condition is 1,800 to 2,200 pounds per acre.

LOAMY LOWLAND

The soils of this range site are mainly nearly level loams or silt loams on lowlands. These soils receive additional water from flooding or from runoff from higher areas. In places the water table is high enough to reach the root zone, but it is not the dominant factor that controls the growth of plants on this site. The following soils are in this site:

Alluvial land (An).
Bridgeport silt loam, strongly calcareous variant (Bv).
Las loam, moderately deep (Lb).
Lubbock silt loam (Lu).
Volin silt loam (Vl).
Volin-slickspot complex (Vs).

The climax plant cover is a mixture of such decreaser grasses as switchgrass, side-oats grama, big bluestem, Canada wildrye, and little bluestem. These grasses make up as much as 60 percent of the climax vegetation, and other perennial forbs and grasses make up the rest. The dominant increaser plants are western wheatgrass, blue grama, buffalograss, and forbs. Western wheatgrass is the main increaser under grazing pressure. Woolly verbena, western ironweed, and other annual and perennial plants are common invaders. The estimated yield of air-dry herbage, when the site is in excellent condition, is 3,000 to 4,000 pounds per acre.

LOAMY UPLAND

This site contains deep soils that have a surface layer and subsoil of loam to silty clay loam. The soils are nearly level to strongly sloping and are on uplands. They are permeable, have a high water-holding capacity,

Figure 22.—**A view of the Loamy Upland range site. The cage is used to obtain information about the production of the principal climax grasses.**

and release moisture readily to plants. Lofton silty clay loam is included in this range site only because the areas are small and scattered. This soil is in small, shallow basins within areas of flat tablelands. The following soils are in this range site:

Bridgeport loam (Bp).
Colby silt loam, 3 to 5 percent slopes (Cc).
Elkader silt loam, 0 to 1 percent slopes (Ea).
Keith silt loam, 0 to 1 percent slopes (Ka).
Keith silt loam, 1 to 3 percent slopes (Kb).
Lofton silty clay loam (Lo).
Richfield silt loam, 0 to 1 percent slopes (Rc).
Ulysses silt loam, 0 to 1 percent slopes (Ua).
Ulysses silt loam, 1 to 3 percent slopes (Ub).
Ulysses silt loam, 3 to 5 percent slopes (Uc).
Ulysses silt loam, 5 to 15 percent slopes (Ud).

The principal climax grasses are blue grama, buffalograss, western wheatgrass, side-oats grama, and little bluestem (fig. 22). Buffalograss is the main increaser under grazing pressure. Blue grama and buffalograss are the key grasses under the present grazing use. Annuals are the principal invaders, but in droughty years common pricklypear is also a common invader. The estimated yield of air-dry herbage is 1,250 to 2,000 pounds per acre when the site is in excellent condition.

SALINE SUBIRRIGATED

Wet alluvial land (Wa) makes up this range site. It is a mixture of soil material that ranges from loamy fine sand to clay loam. This land type contains concentrations of salts that affect the kinds and amounts of vegetation produced. It is nearly level and is on flood plains, where it receives additional moisture from a water table that is near the surface.

The climax plant cover is a mixture of alkali cordgrass, western wheatgrass, switchgrass, side-oats grama, Canada wildrye, forbs, and other decreaser plants. The principal increasers are inland saltgrass, sedges, and forbs. Common invaders are alkali muhly, western ragweed, foxtail barley, and tamarisk. Inland saltgrass is the main increaser under grazing pressure. The estimated yield of air-dry herbage is 6,000 to 8,000 pounds per acre when the site is in excellent condition.

684-986—64——4

SANDS

This site consists of soils that have a surface layer of loamy fine sand and a subsoil of loamy sand or sand. These soils take up water rapidly, but they are low in moisture-holding capacity. Most of the annual precipitation enters the soils and is used by plants. The following soils are in this range site:

Dwyer loamy fine sand (Dw).
Likes loamy fine sand (Lk).

The climax plant cover is a mixture of sand bluestem, little bluestem, switchgrass, side-oats grama, and other decreaser grasses. These climax grasses make up as much as 65 percent of the climax cover. Perennial forbs and other grasses account for the rest. The dominant increaser grasses are blue grama, sand dropseed, and sand paspalum, and the principal woody increaser is sand sagebrush. Common invaders are false buffalograss, tumblegrass, purple sandgrass, and red lovegrass. The estimated yield of air-dry herbage, when the site is in excellent condition, is 2,000 to 2,500 pounds per acre.

SANDY

This range site consists of deep, gently sloping to strongly sloping soils of the uplands. Their surface layer is fine sandy loam, and it overlies sandy loam. These soils take up water readily, store a moderate amount of it, and release it readily to plants. The following soils are in this range site:

Manter fine sandy loam, 1 to 3 percent slopes (Mh).
Manter fine sandy loam, 3 to 5 percent slopes (Mk).
Otero fine sandy loam (Ot).

The climax cover is a mixture of such decreaser grasses as sand bluestem, little bluestem, switchgrass, and side-oats grama. These climax grasses make up as much as 55 percent of the climax vegetation. Perennial forbs and other grasses account for the remainder. The dominant increaser grasses are blue grama, sand dropseed, buffalograss, and sand paspalum. The dominant woody increasers are sand sagebrush and small soapweed. Common invaders are annuals, windmillgrass, tumblegrass, and sixweeks fescue. The estimated yield of air-dry herbage for the site in excellent condition is 1,500 to 2,000 pounds per acre.

SANDY LOWLAND

The only soil in this range site—Las Animas sandy loam (Ld)—is moderately deep and is on lowlands. It receives additional moisture from flooding; therefore, plants on this site make extra growth. In places the water table is high enough to reach the root zone, but it is not the dominant factor in controlling the growth of the plants.

The climax plant cover is a mixture of such decreaser grasses as sand bluestem, switchgrass, little bluestem, and side-oats grama. These grasses make up as much as 60 percent of the climax vegetation. Other perennial forbs and grasses account for the remainder. The dominant increaser plants are blue grama, sand dropseed, perennial three-awn, sedges, and forbs. Sand sagebrush is the main woody increaser. Common invaders are annuals, windmillgrass, and tumblegrass. The estimated yield of air-dry herbage is 3,000 to 4,000 pounds per acre when the site is in excellent condition.

SHALE BREAKS

Lismas clay (Lm) makes up this range site. This soil is shallow and formed in material weathered from noncalcareous shale of the Pierre formation. Bare outcrops of unweathered shale are common in the areas. The soil is strongly sloping and is in rough, broken areas of the uplands. It is low in moisture-supplying capacity.

The climax plant cover is mainly a mixture of such decreaser grasses as western wheatgrass and side-oats grama, but there are small amounts of little bluestem and switchgrass. Dominant increaser plants are blue grama, buffalograss, inland saltgrass, and forbs. Annuals and common pricklypear are the principal invaders. Blue grama, inland saltgrass, and forbs are the main increasers under grazing pressure. The estimated yield of air-dry herbage for the site in excellent condition is 800 to 1,200 pounds per acre.

Practices of range management

Proper range use and deferred grazing are practices that are applicable on all rangeland, regardless of other practices used. They cost little and improve the range. Other practices that improve the range and that make livestock easier to control are range seeding, developing proper watering places, constructing fences, placing salt in areas where it will encourage uniform grazing, and controlling undesirable plants.

1. *Proper range use* consists of grazing rangeland at a rate that will keep reserves of carbohydrates in the plants and that will maintain enough vigorous plants to provide adequate cover to conserve soil and water. At the same time, proper range use keeps the most desirable vegetation on the site or improves the quality of the vegetation that has deteriorated. This practice applies to native range used for winter grazing, as well as to range used for year-long grazing or for summer grazing.
2. *Deferred grazing* is postponing or delaying grazing on a given area of range during any growth period of the year. All livestock is kept off the range while it is rested. This practice increases the vigor of the forage plants. In favorable years this practice permits the desirable plants to reproduce naturally by seed. It also allows a reserve of forage to be built up for fall and winter grazing and is a means of building up a reserve of forage for emergency use.

   In Logan County the maximum improvement in range is obtained by resting the range for an entire growing season, or at least until after the seed has matured. One area is rested each year until all the areas in the range have been rested for one growing season. While one area is rested, care needs to be taken to keep other areas from being overstocked. If individual areas of range are overstocked, the range will not benefit as a whole, even though part is rested.
3. *Range seeding* consists of establishing native grasses and forbs on a given range. The area to be seeded should have a climate and soils that will support range. Also the plants need to be adapted to the climate and soils. This insures that the supply of forage can be maintained with no care other than the proper management of grazing.

   A mixture of species that are dominant in the climax vegetation on the particular site should be seeded. The seed of the native grasses to be planted ought to have originated from an area as near as feasible to the area to be seeded. Generally, the origin of the seed should be no farther away than 250 to 400 miles south or 100 to 150 miles north of the area to be seeded. In addition, it should not be from an area where the elevation is more than about 1,500 feet higher than that of the area where the seed is to be used. The seed ought to originate west of the belt where the average amount of rainfall is 34 inches.

   Interseeding to improve range in poor to fair condition may be used on range sites where it is not feasible to grow a cover. Interseeding may also be used in areas where using a one-way plow for preparing the seedbed is hazardous because of erosion by wind and water. When seeding cultivated land or rangeland that has been plowed for seeding, first grow sorghum to provide a stubble mulch into which plantings can be made. This type of cover protects the soils from erosion, provides a firm seedbed, helps control competition from weeds and helps retain moisture in the upper layer of the soil. When reseeding native rangeland that has been used for cultivated crops, the area should be planted to a cultivated crop at least one season before planting sorghum so as to provide a stubble mulch. The planting of a cover crop on land just plowed out of sod and seeded to grass has not been successful, because of competition from undesirable forbs and grasses.

   Newly seeded areas should not be grazed until the stand is well established. Proper range use needs to be practiced after the grass is ready for grazing.
4. *Water developments* need to be distributed over the entire range, if feasible, so that livestock do not have to travel far to obtain water. Good distribution of watering places is of great help in achieving uniform grazing on the range. Wells, springs, live water in streams, ponds, and dugouts supply water for livestock. In many areas water must be hauled. The characteristics of each range determine which type of water development is most practical to use. Water developments should not be placed in areas of Choppy Sands range site, because of the hazard of wind erosion.
5. *Fences* need to be constructed to provide for good management of livestock and range. This can mean separating different areas of range on the basis of seasonal use. In some places different range sites are fenced separately. This is done when the areas differ greatly and are of large enough size for fencing to be practical.
6. *Salting* is necessary on rangeland to supplement the native forage on the range. Proper distribu-

tion of salt is used to improve the distribution of grazing and to obtain greater uniformity of range use. Placing salt on the Sands and Choppy Sands range sites ought to be avoided to eliminate the hazard of wind erosion. Do not place salt near ponds or other bodies of water.

7. *Control of undesirable plants* through chemical or mechanical means may be needed in some areas. It permits the forage on the range to improve and also makes livestock easier to handle. In this county sand sagebrush is the major plant that needs to be controlled. The sand sagebrush will not keep desirable vegetation from being improved, however, unless it makes up 25 percent or more of the total plant composition and unless there are six or more plants per square rod. Undesirable plants should not be controlled on areas of fine sand or duneland or on other areas where severe erosion might result from the loss of a brushy cover. Defer grazing for at least the first growing season after an area has been treated to control undesirable plants. The range can be grazed moderately during the second year. Continue to practice proper range management to maintain a vigorous, high-producing stand of grass.

To summarize, livestock management that achieves high production and conserves the resources of the range includes—

1. A feed and forage program that provides available range forage and also concentrates, tame and native hay, silage, and tame pastures to keep livestock in good condition throughout the year. During emergencies, the use of reserved roughage for feed and the deferred grazing of native pastures will indirectly conserve the plant cover, soil, and water. Shortages of feed can be avoided by storing for future use the surplus produced in years of high yields. Reserves of feed may be stored in stacks, shocks, bales, sheds, or silos.
2. A breeding program that provides for the type of livestock most suitable for the range and for the ranching system. It must also be suitable for the climate of the area, as well as for the economic conditions that exist.
3. Culling nonproductive animals from the herd. This can mean an overall increase in the salable product and can contribute greatly to range management.

Woodland and Windbreaks [6]

The native trees and shrubs of Logan County grow in scattered stands in local areas of subirrigated flood plains along the major watercourses. The dominant species are plains cottonwood, black willow, sandbar willow, American plum, and western chokecherry.

On the breaks of the Ogallala formation in the eastern and southern parts of the county, there is an occasional hackberry tree. Some aromatic sumac and flowering currant grow on outcrops of caliche of the same formation.

The native trees and shrubs provide some protection for livestock, as well as food and cover for wildlife. They also help stabilize the banks of streams. Most of the stands adjoin rangeland. The areas are grazed, which limits natural reproduction.

Windbreaks

Windbreaks of trees and shrubs, which help protect farmsteads and feedlots from the effects of wind and water erosion, have been established successfully in some areas (fig. 23). The windbreaks trap snow, and they provide cover for game and songbirds of the uplands. They also add color and contrast to the landscape.

Successful plantings require that the site be prepared properly, that adapted species of trees and shrubs be selected, and that the areas be cultivated to control weeds. If it is practical to do so, the trees and shrubs should be planted on the contour to conserve moisture and to reduce soil erosion. Any extra water that can be provided by irrigation or by diversion of runoff from other areas to the windbreak site will be beneficial. Livestock must be excluded from the plantings to prevent damage to trees and shrubs.

Some of the soils in this county are not suitable for windbreak plantings, because of unfavorable characteristics, susceptibility to erosion, or unfavorable relief or position. The soil types that are suitable for windbreaks have been placed in the three suitability groups shown in the following list:

Upland windbreak suitability group:

Bridgeport loam.
Colby silt loam.
Keith silt loam.
Manter fine sandy loam.
Otero fine sandy loam.
Richfield silt loam.
Ulysses silt loam.
Ulysses silty clay loam, heavy textured variant.
Ulysses-Colby silt loams, eroded.

Lowland windbreak suitability group:

Alluvial land.
Las loam, moderately deep.
Las Animas sandy loam.
Lubbock silt loam.
Volin silt loam.

Figure 23.—**A windbreak that is 5 years old on an area of Keith silt loam.**

[6] By Julius H. Mai, area conservationist, Soil Conservation Service.

TABLE 8. —*Trees and shrubs suitable for windbreaks, and estimated height attained in 10 years*

Adapted trees and shrubs	Windbreak suitability groups [1]		
	Upland	Lowland	Chalky
	Feet	*Feet*	*Feet*
American plum	8	10	([2])
Aromatic sumac	5	6	4
Austrian pine	8	10	8
Black walnut	([2])	10	([2])
Boxelder	16	18	([2])
Buffaloberry	8	10	8
Bur oak	6	8	([2])
Cotoneaster	5	6	([2])
Cottonwood	([2])	28	([2])
Eastern redcedar	10	12	6
Greenash	([2])	15	([2])
Hackberry	14	18	12
Honeylocust	16	20	16
Mulberry	10	15	([2])
Osage-orange	8	10	([2])
Ponderosa pine	8	10	([2])
Russian-olive	12	15	12
Siberian elm (Chinese)	20	25	20
Tamarisk	10	16	10
Western chokecherry	8	10	([2])

[1] See listing of soil types grouped by windbreak suitability groups.
[2] Species not adapted.

Chalky windbreak suitability group:

Bridgeport silt loam, strongly calcareous variant.
Elkader silt loam.
Minnequa silt loam.

The trees and shrubs suitable for windbreaks on soils in the windbreak suitability groups are shown in table 8, and their estimated height attained in 10 years is indicated. In general, it is estimated that for the first 10 years redcedar and pine generally grow about 1 foot each year; broadleaf trees, 1 to 2 feet; and shrubs, between ½ and 1 foot. Information on planning and managing windbreaks can be obtained from a local representative of the Soil Conservation Service or from the county agent.

Engineering Uses of Soils [7]

Soil material is frequently used in construction, or it influences the behavior of other material used in a structure. For example, it may be the major material used for constructing dams made of earthfill or used in roadbeds for highways. Likewise, it is a major material used for construction when it is used as a bearing material to support a heavy concrete structure, such as a large grain elevator. The suitability of a soil for construction depends on certain inherent soil qualities. These qualities, frequently referred to as engineering properties, include shear strength, permeability, texture, plasticity, consolidation potential, and reaction.

[7] Prepared with the assistance of HUBBARD, Y. COTT, civil engineer, Soil Conservation Service, Hays, Kans. Other assistance was given by personnel of the Kansas State Highway Department, under a cooperative agreement with the U.S. Department of Commerce, Bureau of Public Roads.

Soil material is a heterogeneous mixture of mineral particles that vary widely in size, shape, and composition. Seldom are two individual soil samples identical in all details. They can, however, usually be classified into one of several groups according to their general inherent properties. A broad understanding of the characteristics of a soil and knowledge of its behavior when used as construction material prove helpful to the classifier.

The information in this report can be used by engineers to—

1. Make soil and land use studies that will aid in selecting and developing industrial, business, residential, and recreational sites.
2. Make preliminary estimates of the engineering properties of soils that will help in planning agricultural drainage, farm ponds, terraces, waterways, dikes, diversions, and irrigation systems.
3. Make preliminary evaluations of soil and ground conditions that will aid in selecting locations for highways and airports and in planning detailed investigations of selected locations.
4. Locate probable sources of gravel, sand, and other construction material.
5. Correlate performance of engineering structures with soil mapping units, and thus develop information that will be useful in designing and maintaining the structures.
6. Determine the suitability of soils for cross-country movement of vehicles and construction equipment.
7. Supplement information obtained from other published maps, reports, and aerial photographs for the purpose of making maps and reports that will be more useful to engineers.
8. Develop other preliminary estimates for construction purposes pertaining to the particular area.

It is not intended that this report will eliminate the need for detailed investigation at the site and proper classification of material proposed for construction use. Information in the report should prove useful, however, in planning such detailed studies.

Some of the terms used by the soil scientist may be unfamiliar to the engineer, and other terms may have a special meaning in soil science. These terms are defined in the Glossary at the back of the report.

Engineering classification systems

Agricultural scientists of the U.S. Department of Agriculture classify soils according to texture, color, and structure. This system is useful only as the initial step in making engineering classifications of soils. The engineering properties of a soil must be determined or estimated after the initial classification has been made. Two systems are used by engineers for classifying soils. These are the systems used by the American Association of State Highway Officials (AASHO) and the Unified system. These systems are explained briefly in the following paragraphs. The explanations are taken largely from the PCA Soil Primer (*13*).

The AASHO (*1*) system is based on actual performance of material used as a base for roads and highways. In this system all the soils are classified in seven groups. The soils most suitable for road subgrade are classed A–1, and the soils least suitable are classed as A–7.

Within rather broad limits, soils are classified numerically between these two extremes, according to their load-carrying ability. Three of the seven basic groups may also be divided into subgroups to designate within-group variations. Within each group, the relative engineering value of the soil material is indicated by a group index number, which is shown in parentheses following the group classification. Group indexes range from 0 for the best material to 20 for the poorest. Increasing values of group indexes denote decreasing load-carrying capacity.

In the AASHO system the soil materials may be further divided into the following two major groups: (1) Granular materials in which 35 percent or less of the material passes a 200-mesh sieve, and (2) silt-clay materials in which more than 35 percent of the material passes a 200-mesh sieve. The silty part of the silt-clay materials has a plasticity index of 10 or less, and the clayey material has a plasticity index greater than 10. The plasticity index refers to the numerical difference between the liquid limit and the plastic limit. The liquid limit is the moisture content, expressed as a percent of the ovendry weight of the soil, at which the soil material passes from a plastic to a liquid state. The plastic limit is the moisture content, expressed as a percent of the ovendry weight of the soil, at which the soil material passes from a semisolid to a plastic state.

In the Unified system (*17*) the soils are grouped on the basis of their texture and plasticity, as well as on their performance when used as material for engineering structures. The soil materials are identified as coarse grained, which are gravels (G) and sands (S); fine grained, which are silts (M) and clays (C); and highly organic (Pt). There are no highly organic soils in Logan County.

Under the Unified system, clean sands are identified by the symbols SW or SP; sands with fines of silt and clay are identified by the symbols SM and SC; silts and clays that have a low liquid limit are identified by the symbols ML and CL; and silts and clays that have a high liquid limit are identified by the symbols MH and CH.

After an engineer has been trained and has obtained experience, he can make approximate classification of soils, based on visual field inspection and observation. Exact classification, however, must be based on review and application of complete laboratory analysis data. Field classifications are useful in determining when and upon which soils laboratory analyses should be made.

Engineering interpretations of the soils

The engineer should know the properties of the soils that affect their use for engineering purposes. He should also know the in-place condition of the soils at the site where construction is planned. The soil map and this soil survey report will aid him in making a preliminary evaluation of the in-place condition of the soils and their use for various engineering purposes, and help him plan a soils investigation program to evaluate these factors precisely.

Tables 9 and 10 give a summary of data from tests made on a modal profile for several soils in the county. A modal profile is the one most typical of the soil as it occurs in the county. The data furnished in table 9 show the results of tests made by the State Highway Commission of Kansas in accordance with standard procedures of the American Association of State Highway Officials. Table 10 gives the results of tests made by a graduate student of the Department of Agronomy of Kansas State University.

Table 11 gives a brief description of all the soils mapped in Logan County and the estimated physical properties that are significant when the soils are used for construction material. The estimates are based on the laboratory data given in tables 9 and 10, on actual field observations, and on general knowledge of the soils in the county. Table 11 also gives the textural classification of the U.S. Department of Agriculture, estimates of the Unified classification, and estimates of the classification used by the American Association of State Highway Officials. In addition, the grain size, permeability, available water capacity, and shrink-swell potential are estimated. In table 11 the description of the soil properties is based on a single typical profile for each soil mapped. The soil profile is divided into layers significant in engineering, according to the depth, in inches, from the surface. A more complete description of each profile can be found in the section "Formation, Morphology, and Classification of Soils."

The percentage of soil material passing through sieves of various sizes was estimated on the basis of test data for the soils in Logan County and on similar test data available for the same soil types in other areas. These data help in classifying the soils.

In the column showing permeability, the rate at which moisture moves downward in the soil is estimated. The rate is expressed in inches per hour.

Available water capacity, described in inches per inch of soil depth, refers to the approximate amount of capillary water in the soil when the soil is wet to field capacity. When the soil is air dry, the amount of water indicated will wet the soil material described to a depth of 1 inch without deeper penetration.

The shrink-swell potential is an indication of the volume change to be expected with changes in content of moisture. Soils that contain a large amount of clay have a high shrink-swell potential, and those that contain a large amount of sand have a low shrink-swell potential.

The reaction for the soils of Logan County is not given in table 11, but it ranges from neutral to moderately alkaline, or in pH values, from 7.0 to 8.5.

Table 12 shows specific characteristics of the soils that affect their use for engineering purposes. Efforts were made to list all the features that adversely affect the use of the soils. Generally, only the most significant favorable features are mentioned. Soils that are not listed in table 12 are considered to be unsuitable for any of the engineering uses listed.

The suitability of the soil material for road subgrade and road fill depends largely on the texture of the soil material and its natural water content. Highly plastic soil material is rated as poor for road subgrade and poor or fair for road fill, depending on its natural water content and the ability to handle, dry, and compact the soil material. Highly erodible soils, such as silts and fine sands, are difficult to compact, and they require moderately gentle slopes and a cover of fast-growing vegetation. For these reasons they are rated as fair for road subgrade and as poor to fair for road fill.

TABLE 9.—*Engineering test data for soil samples*

Soil name and location	Parent material	SCS sample No.	Depth	Horizon	Moisture-density [2]	
					Maximum dry density	Optimum moisture
		S-59-Kans-	Inches		Lb. per cu. ft.	Percent
Keith silt loam:						
328 feet W. and 94 feet S. of the NE. corner of sec. 23, T. 12 S., R. 34 W. (modal profile).	Sanborn loess.	55-1-1	0-11	Ap and A1	97	20
		55-1-2	15-24	B21	101	19
		55-1-3	24-33	B22	99	21
		55-1-4	61-76	C	102	20
547 feet S. and 278 feet E. of NW. corner of sec. 36, T. 11 S., R. 35 W. (modal profile).	Sanborn loess.	55-4-1	0-11	Ap and A1	99	20
		55-4-2	16-22	B21	101	19
		55-4-3	22-32	B22	102	18
		55-4-4	53-70	C	103	18
Minnequa silt loam:						
0.25 mile N. of the SW. corner of sec. 6, T. 15 S., R. 35 W. (modal profile).	Alluvial-colluvial deposit (Smoky Hill chalk).	55-5-1	0-3	A1	92	19
		55-5-2	3-62	C1, C2, C3	97	22
700 feet N. of the SE. corner of sec. 32, T. 14 S., R. 35 W. (modal profile).	Alluvial-colluvial deposit (Smoky Hill chalk).	55-6-1	0-3	A1	86	24
		55-6-2	15-42	C	102	20
Ulysses silt loam:						
1,580 feet W. and 86 feet S. of NE. corner of sec. 6, T. 13 S., R. 34 W.	Sanborn loess.	55-2-1	0-8	A1	101	19
		55-2-2	8-18	AC	100	20
		55-2-3	18-60	C	101	21
1,580 feet E. and 72 feet N. of the SW. corner of sec. 36, T. 12 S., R. 35 W.	Sanborn loess.	55-3-1	0-8	A1	100	18
		55-3-2	8-19	AC	98	21
		55-3-3	19-60	C	102	20

[1] Tests performed by the State Highway Commission of Kansas under a cooperative agreement with the U.S. Department of Commerce, Bureau of Public Roads, in accordance with standard procedures of the American Association of State Highway Officials (AASHO), except as noted below.

[2] Based on AASHO Designation: T 99-57, Moisture-Density Relations of Soils Using a 5.5-pound Rammer and a 12-Inch Drop, with the following variations: (1) All material is ovendried at a temperature of 230° F., (2) all material is crushed in a laboratory crusher after drying, and (3) no time is allowed for dispersion of moisture after mixing with soil material.

[3] Mechanical analyses according to the AASHO Designation T 88, with the following variations: (1) All material is ovendried at a temperature of 230° F. and crushed in a laboratory crusher, (2) the sample is not soaked prior to dispersion, (3) sodium silicate is used as a dispersing agent, and (4) dispersing time is established by using half the plasticity index value in minutes, with a maximum of 15 minutes and a minimum of 1 minute. Results by this procedure frequently may differ somewhat from results that would have been obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHO procedure, the fine material is anlayzed

taken from six profiles in Logan County, Kans.[1]

Mechanical analysis [3]: Percentage passing seive— No. 10 (2.0 mm.)	Mechanical analysis [3]: Percentage passing seive— No. 40 (0.42 mm.)	Mechanical analysis [3]: Percentage passing seive— No. 200 (0.074 mm.)	Percentage smaller than— 0.05 mm.	Percentage smaller than— 0.02 mm.	Percentage smaller than— 0.005 mm.	Percentage smaller than— 0.002 mm.	Liquid limit	Plasticity index	Classification: AASHO [4]	Classification: Unified [5]
100	100	98	88	52	27	17	37	12	A-6(9)	ML-CL.
100	100	99	90	58	33	23	40	19	A-6(12)	CL.
100	100	99	91	47	27	20	40	17	A-6(11)	CL.
100	100	97	85	40	16	11	32	8	A-4(8)	ML-CL.
100	100	98	86	44	18	12	37	14	A-6(10)	ML-CL.
100	100	99	92	57	29	20	38	16	A-6(10)	CL.
100	100	99	90	54	27	18	38	15	A-6(10)	ML-CL.
100	100	98	87	41	17	11	32	9	A-4(8)	ML-CL.
100	94	85	74	49	25	15	39	8	A-4(8)	ML.
100	96	76	78	43	(6)	(6)	35	9	A-4(8)	ML-CL.
100	98	93	81	52	28	17	43	13	A-7-5(10)	ML.
100	98	88	79	60	36	24	35	13	A-6(9)	ML-CL.
100	100	98	88	49	23	14	37	14	A-6(10)	ML-CL.
100	100	99	91	49	24	16	38	14	A-6(10)	ML-CL.
100	100	100	93	47	20	14	35	10	A-4(8)	ML-CL.
100	100	98	86	44	18	12	35	12	A-6(9)	ML-CL.
100	100	98	91	51	22	14	38	13	A-6(9)	ML-CL.
100	100	100	89	48	20	12	32	7	A-4(8)	ML-CL.

by the hydrometer method and the various grain-size fractions are calculated on the basis of all the material, including that coarser than 2 millimeters in diameter. In the SCS soil survey procedure, the fine material is analyzed by the pipette method and the material coarser than 2 millimeters in diameter is excluded from calculations of grain-size fractions. The mechanical analyses used in this table are not suitable for use in naming textural classes for soils.

[4] AASHO Designation: M 145-49, based on Standard Specifications for Highway Materials and Methods of Sampling and Testing (Pt. 1, Ed. 8). The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes.

[5] Based on the Unified Soil Classification System, Tech. Memo. No. 3-357, v. 1, Waterways Expt. Sta. Corps of Engin., March 1953. Soil Conservation Service and Bureau of Public Roads have agreed to consider that all soils having plasticity indexes within 2 points from A-line to be given a borderline classification. Examples of borderline classifications obtained by this use are GM-GC, SM-SC, ML-CL, and MH-CH.

[6] Hydrometer analysis could not be performed, because of the presence of calcium carbonate.

TABLE 10.—*Engineering test data for soil samples*

Soil name and location	Parent material	Depth	Horizon
Bridgeport loam:		*Inches*	
100 feet N. of established trail through cultivated field on quarter line between the SW¼ and SE¼ sec. 22, T. 13 S., R. 35 W. Approximately ½ mile SW. of Russell Springs.	Alluvium	0–18	Alp, A1
		18–36	C1
		40–46	C2
Colby silt loam:			
300 feet S. of center of sec. 25, T. 14 S., R. 34 W	Sanborn loess	0–5	A1
		12–24	AC
		25–36	C
Dwyer loamy fine sand:			
0.2 mile S. of bridge across Smoky Hill River and 100 feet W. in SE¼ sec. 1, T. 14 S., R. 34 W.	Eolian sands from Pleistocene deposits.	0–5	A1
		5–12	AC
		12–24	C
Likes loamy fine sand:			
300 feet S. of the S. end of bridge across Smoky Hill River and 0.35 mile E. in NW¼ sec. 26, T. 13 S., R. 35 W.	Alluvium	0–12	A1
		12–30	AC
		50–60	C
Lofton silty clay loam:			
580 feet N. and 475 feet E. of S. quarter corner sec. 1, T. 12 S., R. 34 W.	Loessal sediments	0–5	Ap
		8–17	B21
		43–55	BC
Manter fine sandy loam:			
0.4 mile S. and 100 feet W. of NE. corner of sec. 7, R. 14 S., R. 36 W.	Eolian sediments from Pleistocene deposits and Ogallala formation.	0–6	A1
		6–14	A3
		26–36	C
Promise clay:			
0.2 mile E. and 0.2 mile N. of SW. corner of sec. 18, T. 12 S., R. 36 W.	Alluvium and colluvium from Pierre shale.	0–8	Alp, A1
		8–20	AC
		25–35	C
Richfield silt loam:			
0.15 mile S. and 500 feet E. of NW. corner of sec. 18, T. 15 S., R. 37 W.	Sanborn loess	0–5	Alp
		5–18	B1, B2
		27–36	Cca

[1] Tests by Richard Dale Davis, Department of Agronomy, Kansas State University.

[2] Tests performed and calculated in accordance with standard procedures of American Society for Testing Materials, ASTM Designation: D1140–54.

[3] Tests based on tentative method for grain-size analysis, ASTM Designation: D422–54T, with the following exceptions: (a) a water bath or constant room temperature were not employed; the relatively small temperature variations were compensated for by use of a correction factor as given by Bouyoucos; and (b) rather than correcting the samples for hygroscopic water, the samples were oven dried.

taken from eight profiles in Logan County, Kans.[1]

Water content at saturation	Mechanical analysis: Percentage passing sieve[2]— No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)	Percentage smaller than 0.02 mm.[3]	Liquid limit[4]	Plasticity index	Classification: AASHO[5]	Unified[6]
Percent								
30	95	92	73	29	27	5	A-4(7)	ML-CL.
44	100	100	95	52	36	16	A-6(10)	CL.
38	100	100	86	45	33	13	A-6(9)	CL.
39	100	100	95	30	31	7	A-4(8)	ML-CL.
34	100	100	75	46	30	15	A-6(10)	CL.
36	100	100	81	38	31	15	A-6(10)	CL.
29	100	99	60	16	17	0	A-4(5)	ML.
19	100	100	5	2	(7)	0	A-1b(0)	SP-SM.
19	100	100	9	2	(7)	0	A-3(0)	SP-SM.
15	99	98	10	17	(7)	0	A-2-4(0)	SM.
15	99	99	17	5	(7)	0	A-2-4(0)	SM.
18	94	93	3	2	(7)	0	A-3(0)	SP.
48	100	100	99	60	32	10	A-4(8)	ML-CL.
55	100	100	99	73	54	33	A-7-6(20)	CH.
49	100	100	99	64	42	21	A-7-6(13)	CL.
18	100	100	37	12	23	4	A-4(0)	SC-SM.
20	100	100	34	12	24	5	A-2-4(0)	SC-SM.
22	100	100	40	14	20	1	A-4(1)	SM.
43	100	100	79	69	52	31	A-7-6(19)	CH.
43	100	100	81	66	53	32	A-7-6(19)	CH.
47	100	100	85	74	47	25	A-7-6(15)	CL.
43	100	100	99	52	31	10	A-4(8)	ML-CL.
45	100	100	99	50	37	15	A-6(10)	CL.
45	100	100	99	54	38	16	A-6(10)	CL.

[4] Test based on tentative method of test for liquid limit, ASTM Designation: D423-54T, mechanical method, with the following variation: After initially mixing each soil with water, the mixture was allowed to stand for approximately 30 minutes over water in a closed dessicator before testing.

[5] AASHO Designation: M145-49, based on Standard Specifications for Highway Materials and Methods of Sampling and Testing (pt. 1, Ed. 8). The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes.

[6] Based on the Unified Soil Classification System, Tech. Memo. No. 3-357, v. 1, Waterways Expt. Sta., Corps of Engin., March 1953.

[7] Nonplastic soils.

TABLE 11.—*Brief description of the soils*

Map symbol	Soil	Description of soil and site	Depth from surface
			Inches
Ad	Active dunes.	Actively shifting sand in which there is no definable soil profile	0 to 60
An	Alluvial land.	Stratified loamy and sandy alluvial soil material in narrow valleys of upland drainageways; subject to occasional flooding and deposition.	([1])
Bl	Badland.	Bare geologic formations with little or no natural soil material	([1])
Bp	Bridgeport loam.	Loamy soil material 5 to 20 feet thick; in places a water table is at a depth of 6 to 20 feet; on nearly level alluvial fans; subject to flooding in places.	0 to 60
Bv	Bridgeport silt loam, strongly calcareous variant.	Consists of 6 inches of silt loam surface soil over 5 to 10 feet of silt loam; strongly calcareous; alluvial sediments from Smoky Hill chalk; on nearly level flood plains; subject to occasional flooding.	0 to 6 6 to 68
Cc Cd	Colby silt loam, 3 to 5 percent slopes. Colby silt loam, 5 to 15 percent slopes.	Silt loam loess at a depth between 5 and 10 feet over loess or mixed outwash (Pleistocene) deposits; moderately to strongly sloping; on uplands.	0 to 60
Dw	Dwyer loamy fine sand.	From 5 to 20 feet of mixed fine sand deposits of outwash (Pleistocene) reworked by water, over shale and chalk rock; on low, hummocky uplands.	0 to 5 5 to 60
Ea Eb Ec Ed	Elkader silt loam, 0 to 1 percent slopes. Elkader silt loam, 1 to 3 percent slopes. Elkader silt loam, 3 to 5 percent slopes. Elkader silt loam, 5 to 15 percent slopes.	Consist of 2 feet of silt loam over 4 to 15 feet of silt loam from strongly calcareous, weathered sediments of Smoky Hill chalk; in places consolidated chalk rock or shale is within a depth of 6 to 15 feet of the surface; nearly level to strongly sloping; on uplands.	0 to 23 23 to 66
Gr	Gravelly broken land.	One-half foot of loamy sand or loamy gravel, over 5 to 10 feet of sand and gravel, with minor areas of loamy soils; pockets of gravel in places; in areas of rough, broken relief.	([1])
Ka Kb	Keith silt loam, 0 to 1 percent slopes. Keith silt loam, 1 to 3 percent slopes.	Silt loam to a depth of 1 foot, over 2 feet of light silty clay loam; underlain by 5 to 15 feet of silt loam loess; nearly level and gently sloping; on upland divides and tablelands.	0 to 11 11 to 32 32 to 70
Lb	Las loam, moderately deep.	Consists of 8 inches of loam over 18 to 24 inches of clay loam; underlain by sand and gravel; nearly level and on flood plains; subject to occasional flooding; water table fluctuates between a depth of 2 and 8 feet.	0 to 8 8 to 32 32 to 60
Ld	Las Animas sandy loam.	Between 2 and 3 feet of sandy loam over sand and gravel; in places contains thin layers or lenses of clay loam; nearly level and on flood plains, subject to occasional flooding; the water table fluctuates between a depth of 2 and 10 feet.	0 to 29 29 to 60
Lk	Likes loamy fine sand.	Loamy fine sand to a depth of 3 to 4 feet, over 5 to 10 feet of sand; on nearly level alluvial fans and low terraces.	0 to 50 50 to 60
Ll	Lincoln soils.	Loamy sand to a depth of 1 foot, over 5 to 10 feet of sand and gravel; in places contains thin layers or lenses of clay loam; nearly level and on flood plains; subject to recurrent flooding, scouring, and deposition; water table below a depth of 4 feet.	0 to 10 10 to 60
Lm	Lismas clay.	Clay to a depth of 1 foot, over shale that contains thin layers of impure gypsum; in rough, broken areas.	0 to 12
Ln	Loamy broken land.	Mixed loamy soil material that ranges from 1 to 3 feet in depth over shale or chalk rock; discontinuous pockets of sand and gravel; strongly sloping; in broken areas where there are rock outcrops.	([1])
Lo	Lofton silty clay loam.	Consists of 6 inches of silty clay loam over 3 feet of silty clay; underlain by 5 to 15 feet of silt loam loess; in shallow basins (potholes) in the uplands; frequently ponded with water.	0 to 5 5 to 43 43 to 67
Lu	Lubbock silt loam.	Silt loam to a depth of 1 foot over 2 to 3 feet of silty clay loam; underlain by 5 to 15 feet of silt loam loess; on nearly level benches that surround large basins; receives additional water from run-in.	0 to 12 12 to 46 46 to 79

See footnote at end of table.

and their estimated physical properties

Classification			Percentage passing sieve—			Permeability	Available water capacity	Shrink-swell potential
USDA texture	Unified	AASHO	No. 4	No. 10	No. 200			
						Inches per hour	*Inches per inch of soil depth*	
Fine sand	SP, SP-SM	A-2-4	100	100	0 to 10	2. 0 to 5. 0	0. 04	Low.
[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1].
[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1].
Loam	ML or CL	A-6 or A-4	100	100	70 to 85	0. 5 to 1. 0	. 18	Low to moderate.
Silt loam	ML	A-4	100	100	80 to 100	0. 2 to 0. 5	. 19	Low.
Silt loam	ML or CL	A-4	100	100	75 to 100	0. 5 to 1. 0	. 19	Low.
Silt loam	ML or CL	A-6 or A-4	100	100	70 to 100	0. 2 to 0. 5	. 19	Low to moderate.
Loamy fine sand	ML	A-4	100	100	50 to 60	1. 0 to 2. 0	. 06	Low.
Fine sand	SP, SP-SM	A-1 or A-3	100	100	0 to 10	2. 0 to 5. 0	. 04	Low.
Silt loam	ML	A-4	100	100	90 to 100	0. 2 to 0. 5	. 19	Low.
Silt loam	ML-CL	A-4	100	100	80 to 90	0. 5 to 1. 0	. 19	Low.
[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1].
Silt loam	ML-CL	A-6	100	100	95 to 100	0. 2 to 0. 5	. 19	Moderate.
Light silty clay loam.	CL	A-6	100	100	95 to 100	0. 2 to 0. 5	. 19	Moderate.
Silt loam	ML-CL	A-6 or A-4	100	100	95 to 100	0. 2 to 0. 5	. 19	Moderate.
Loam	ML-CL	A-6 or A-4	100	100	70 to 85	0. 5 to 1. 0	. 16	Low to moderate.
Clay loam	CL	A-7	95 to 100	85 to 95	85 to 95	0. 2 to 0. 5	. 18	Moderate.
Sand and gravel	SP, SP-SM	A-3	95 to 100	90 to 95	0 to 10	>5. 0	. 04	Low.
Sandy loam	SM	A-2-4	95 to 100	95 to 100	20 to 30	1. 0 to 2. 0	. 13	Low.
Sand and gravel	SP, SP-SM	A-3	95 to 100	90 to 95	0 to 10	>5. 0	. 04	Low.
Loamy sand	SM	A-2-4	100	95 to 100	15 to 25	2. 0 to 5. 0	. 05	Low.
Sand	SP, SP-SM	A-3	100	95 to 100	0 to 10	>5. 0	. 04	Low.
Loamy sand	SM	A-2-4	95 to 100	90 to 95	15 to 25	2. 0 to 5. 0	. 05	Low.
Sand and gravel	SP, SP-SM	A-3	95 to 100	90 to 95	0 to 10	>5. 0	. 04	Low.
Clay	CH	A-7	100	100	95 to 100	<0. 05	. 19	High.
[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1].
Silty clay loam	ML or CL	A-4 or A-6	100	100	95 to 100	0. 05 to 0. 2	. 20	Moderate.
Silty clay	CH	A-7-6	100	100	95 to 100	<0. 05	. 19	High.
Silty clay loam	CL	A-7-6	100	100	95 to 100	0. 2 to 0. 5	. 19	High.
Silt loam	ML-CL	A-6	100	100	95 to 100	0. 2 to 0. 5	. 19	Moderate.
Silty clay loam	CL	A-6 or A-7	100	100	95 to 100	0. 05 to 0. 2	. 20	Moderate to high.
Silt loam	ML-CL	A-6	100	100	95 to 100	0. 2 to 0. 5	. 19	Moderate.

TABLE 11.—*Brief description of the soils*

Map symbol	Soil	Description of soil and site	Depth from surface
			Inches
Mh	Manter fine sandy loam, 1 to 3 percent slopes.	Sandy loam to a depth of 5 feet underlain by 5 to 10 feet of loamy or sandy soil material; gently and moderately sloping; on long ridges in the uplands.	0 to 60
Mk	Manter fine sandy loam, 3 to 5 percent slopes.		
Mn	Minnequa silt loam.	Silt loam; weathered, raw sediments of Smoky Hill chalk rock to a depth of 5 feet; in places soft, fractured chalk rock is below a depth of 5 feet; nearly level and gently sloping alluvial and colluvial fans in uplands.	0 to 3 3 to 66
Mp	Minnequa-Penrose silt loams.	Deep and shallow, strongly sloping soils on broken uplands; the Minnequa soil is described under Minnequa silt loam; the Penrose soil consists of 1 foot of silt loam over soft, fractured chalk rock or limy shale of the Niobrara formation; outcrops of chalk rock are common.	0 to 12
Ot	Otero fine sandy loam.	From 3 to 5 feet of sandy loam over loamy sand that in places contains a small amount of gravel; on moderately and strongly irregular ridges and knolls that resemble hummocks.	0 to 38 38 to 60
Po	Potter soils.	Loamy soil material to a depth of 1 foot over thick beds of caliche and cemented sandstone of the Ogallala formation; there are outcrops of caliche rock; in rough, broken areas in the uplands.	0 to 12
Pr	Promise clay, 0 to 1 percent slopes.	Clay that extends to a depth of 5 to 10 feet over shale; in places very thin layers of impure gypsum occur in the shale; on nearly level to moderately sloping alluvial fans and slopes in the uplands; in places rock outcrops or bedrock are at a depth of 15 feet or less.	0 to 60
Ps	Promise clay, 1 to 3 percent slopes.		
Pt	Promise clay, 3 to 5 percent slopes.		
Ra	Randall clay.	From 6 to 8 feet of clay over silt loam loess; in large depressions, basins, or intermittent lakes that lack a surface outlet; occasionally ponded with water.	0 to 64
Rc	Richfield silt loam, 0 to 1 percent slopes.	One-half foot of silt loam over 1 foot of silty clay loam subsoil; underlain by 10 to 15 feet of silt loam loess; nearly level; on tablelands.	0 to 5 5 to 18 18 to 60
Ua	Ulysses silt loam, 0 to 1 percent slopes.	Consist of 1 foot to 2 feet of silt loam, slightly altered by soil-forming processes, over 5 to 15 feet of silt loam loess; nearly level to strongly sloping; on uplands.	0 to 60
Ub	Ulysses silt loam, 1 to 3 percent slopes.		
Uc	Ulysses silt loam, 3 to 5 percent slopes.		
Ud	Ulysses silt loam, 5 to 15 percent slopes.		
Ul	Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded.		
Um	Ulysses-Colby silt loams, 5 to 15 percent slopes, eroded.		
Uh	Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes.	From 5 to 8 feet of heavy silty clay loam underlain by shale or silt loam loess; in places the shale contains thin layers of impure gypsum; gently sloping; on uplands; in places outcrops or bedrock are at a depth of less than 15 feet.	0 to 60
Vl	Volin silt loam.	Silt loam to a depth of 1 foot over 2 to 3 feet of light silty clay loam underlain by 5 to 20 feet of silt loam; in places sand and gravel are at a depth below 8 feet; a water table is generally at a depth of 8 to 20 feet on nearly level alluvial fans and low terraces.	0 to 16 16 to 40 40 to 60
Vs	Volin-slickspot complex.	About 60 percent of this soil complex consists of Volin silt loam; 25 percent, of a slickspot soil; and 15 percent, of a soil that has characteristics intermediate between those of the Volin soil and the slickspot soil; the Volin soil is described under Volin silt loam. The slickspot soil consists of 6 inches of dark, very hard, dispersed silty clay loam over 2 feet of partly dispersed silty clay loam that is underlain by 5 to 20 feet of silt loam; on low terraces.	0 to 6 6 to 26 26 to 60
Wa	Wet alluvial land.	Between 3 and 4 feet of clay loam over sand and gravel; poorly drained and has a permanent water table within a depth of 2 to 4 feet from the surface; on low flood plains subject to occasional flooding; slight to moderate salinity.	0 to 40 40 to 60

[1] Too variable to be characterized accurately for engineering interpretations.

and their estimated physical properties—Continued

Classification			Percentage passing sieve—			Permeability	Available water capacity	Shrink-swell potential
USDA texture	Unified	AASHO	No. 4	No. 10	No. 200			
						Inches per hour	*Inches per inch of soil depth*	
Sandy loam	SC-SM	A-2 or A-4	100	95 to 100	25 to 40	0.5 to 1.0	0.13	Low.
Silt loam	ML	A-4	100	100	80 to 90	0.5 to 1.0	.19	Low.
Silt loam	ML-CL	A-4	100	100	80 to 90	0.5 to 1.0	.19	Low.
Silt loam	ML	A-4	100	95 to 100	80 to 90	0.2 to 0.5	.19	Low.
Sandy loam	SM	A-2-4	100	90 to 100	20 to 35	1.0 to 2.0	.13	Low.
Loamy sand	SM	A-2-4	95 to 100	85 to 100	10 to 20	2.0 to 5.0	.04	Low.
Loam	CL	A-6	95 to 100	85 to 95	50 to 70	0.5 to 1.0	.16	Low to moderate.
Clay	CH	A-7-6	100	95 to 100	80 to 95	<.05	.19	High.
Clay	CH	A-7	100	100	90 to 100	<.05	.19	High.
Silt loam	ML-CL	A-4	100	100	95 to 100	0.2 to 0.5	.19	Low.
Silty clay loam	CL	A-6	100	100	95 to 100	0.2 to 0.5	.20	Moderate.
Silt loam	ML-CL	A-6 or A-4	100	100	95 to 100	0.2 to 0.5	.19	Moderate.
Silt loam	ML-CL, CL	A-6 or A-4	100	100	95 to 100	0.2 to 0.5	.19	Moderate.
Silty clay loam	CL	A-6 or A-7	100	100	95 to 100	0.05 to 0.2	.20	Moderate to high.
Silt loam	ML-CL		100	100	95 to 100	0.2 to 0.5	.19	Moderate.
Light silty clay loam.	CL		100	100	95 to 100	0.2 to 0.5	.19	Moderate.
Silt loam	ML-CL		100	100	90 to 100	0.2 to 0.5	.19	Moderate.
Silty clay loam	CL	A-6	100	100	95 to 100	<.05	.19	Moderate.
Silty clay loam	CL	A-6	100	100	90 to 100	<.05	.19	Moderate.
Silt loam	ML-CL	A-4 or A-6	100	100	90 to 100	0.2 to 0.5	.19	Moderate.
Clay loam	CL	A-6 or A-7	95 to 100	95 to 100	75 to 95	0.2 to 0.5	.18	Moderate to high.
Sand and gravel	SP, SP-SM	A-1	95 to 100	80 to 95	0 to 10	>.5	.04	Low.

TABLE 12.—*Interpretation of soil*

Soil series and map symbol	Suitability as source of—					Soil features affecting—	
	Topsoil	Sand	Gravel	Material for road fill [1]	Material for subgrade [1]	Highway location	Dikes and canals
Active dunes (Ad)	Poor	Good	Unsuitable.	Poor to fair; erodible; good if confined.	Good if confined.	Unstable slopes, because of high erodibility.	(2)
Bridgeport (Bp)	Good	Poor	Poor	Good	Fair	(3)	Deep; moderate permeability; stable.
Bridgeport, strongly calcareous variant (Bv).	Fair	Unsuitable	Unsuitable.	Fair	Poor to fair	Subject to overflow.	(2)
Colby (Cc, Cd)	Good	Unsuitable	Unsuitable.	Good	Good	(3)	Moderately erodible; low to moderate shear strength and plasticity.
Dwyer (Dw)	Poor	Good	Poor	Good if confined.	Good if confined.	Highly erodible	Unstable; very rapid permeability; highly erodible.
Elkader (Ea, Eb, Ec, Ed).	Fair	Unsuitable	Unsuitable.	Fair	Poor to fair	High content of calcium carbonate; moderately erodible.	High content of calcium carbonate; moderately erodible.
Keith (Ka, Kb)	Good	Unsuitable	Unsuitable.	Good	Fair	(3)	Low to moderate shear strength and plasticity.
Las, moderately deep (Lb).	Good	Substratum good; poorly graded; imperfectly drained.	Poor	Poor above 2½ to 3 feet; good below.	Poor to fair.	Moderately deep; subject to overflow; plastic subsoil.	Moderately well drained; moderately slow permeability; moderately deep; subject to overflow.
Las Animas (Ld)	Fair	Substratum good; poorly graded; imperfectly drained.	Poor	Good	Poor to good.	Moderately deep; subject to overflow.	Moderately deep; moderately well drained; slow to rapid permeability; subject to overflow.
Likes (Lk)	Poor	Fair in substratum.	Poor	Good	Good	Rapidly permeable; highly erodible.	Moderately stable; highly erodible; rapid permeability.
Lincoln (Ll)	Poor	Good; poorly graded; fluctuating water table.	Poor	Fair to good.	Poor to good.	Fluctuating water table; subject to flooding.	(2)

See footnotes at end of table.

properties that affect engineering

Soil features affecting—Continued					
Farm ponds		Agricultural drainage	Irrigation	Terraces and diversions	Waterways
Reservoir areas	Embankments				
(2)	(2)	(2)	(2)	(2)	(2).
(2)	(2)	Deep; well drained.	Deep; moderate permeability; high water-holding capacity.	Deep; stable; moderate permeability.	Deep; moderately erodible.
(2)	(2)	Deep; well drained; moderate permeability.	Low inherent fertility; subject to overflow.	(2)	Deep; moderately erodible.
Deep; moderate permeability.	Deep; low to moderate shear strength and plasticity.	Deep; well drained.	Deep; moderate permeability; high water-holding capacity.	Deep; moderately stable; highly erodible.	Deep; highly erodible; well drained.
Very rapid permeability and erodible.	Unstable; very rapid permeability; low plasticity.	Very rapid permeability.	Low water-holding capacity; very rapid permeability; highly erodible.	(2)	(2).
Moderately erodible.	Moderately erodible.	Well drained.	High content of calcium carbonate; moderately weak structure.	Moderately weak structure; moderately erodible.	Moderately weak structure; moderately erodible.
(2)	(2)	Deep; well drained; moderate permeability.	Deep; high water-holding capacity; moderate permeability.	Deep; highly erodible; moderately stable.	Deep; well drained; highly erodible; moderate permeability.
(2)	(2)	Imperfectly drained; fluctuating water table.	Moderately deep; moderately well drained; fluctuating water table.	(2)	Moderately deep; moderately slow permeability; moderately erodible.
(2)	(2)	Imperfectly drained; fluctuating water table.	Moderately deep; slow to rapid permeability; moderately well drained; fluctuating water table.	(2)	Moderately deep; moderately erodible; fluctuating water table.
Rapid permeability; highly erodible; low plasticity.	Highly erodible; rapid permeability; moderately stable.	Somewhat poorly drained.	Rapid permeability; low water-holding capacity; highly erodible.	(2)	Highly erodible; rapid permeability.
Very rapid permeability; highly erodible.	Very rapid permeability; highly erodible; unstable.	Fluctuating water table.	Very rapid permeability; low water-holding capacity; subject to overflow.	(2)	Highly erodible; unstable; very rapid permeability.

TABLE 12.—*Interpretation of soil properties*

Soil series and map symbol	Suitability as source of—					Soil features affecting—	
	Topsoil	Sand	Gravel	Material for road fill [1]	Material for subgrade [1]	Highway location	Dikes and canals
Lismas (Lm)	Poor	Unsuitable	Unsuitable.	Poor	Poor	Shallow; highly plastic; high shrink-swell potential.	Shallow; unstable; high shrink-swell potential; highly plastic; low shear strength.
Lofton (Lo)	Poor	Unsuitable	Unsuitable.	Poor	Poor	Highly plastic; in depressions.	High shrink-swell potential; highly plastic; low shear strength.
Lubbock (Lu)	Good	Unsuitable	Unsuitable.	Good	Fair	Subsoil has moderate to high shrink-swell potential; occasional flooding.	Moderate to high plasticity and shrink-swell potential in subsoil.
Manter (Mh, Mk)	Fair	Poor	Unsuitable.	Good	Good	Moderately erodible.	Moderately stable; rapid permeability; moderately erodible.
Minnequa (Mn, Mp)	Poor	Unsuitable	Unsuitable.	Fair	Poor to fair.	High content of calcium carbonate; highly erodible.	High content of calcium carbonate; highly erodible.
Otero (Ot)	Fair	Poor	Unsuitable.	Good	Good	Moderately erodible.	Rapid permeability; moderately erodible.
Penrose (not mapped separately in the county).	Poor	Unsuitable	Unsuitable.	Fair	Poor to fair.	Shallow; high content of calcium carbonate; highly erodible.	(2)
Potter (Po)	Poor	Poor; localized pockets of variable quality.	Poor; localized pockets of variable quality.	Good	Poor [4]	Shallow	(2)
Promise (Pr, Ps, Pt)	Poor	Unsuitable	Unsuitable.	Poor	Poor	Highly plastic; high shrink-swell potential.	Low shear strength when wet; highly plastic; high shrink-swell potential.
Randall (Ra)	Poor	Unsuitable	Unsuitable.	Poor	Poor	Highly plastic; in depressions.	Highly plastic; high shrink-swell potential; low shear strength when wet.

See footnotes at end of table.

that affect engineering—Continued

Soil features affecting—Continued					
Farm ponds		Agricultural drainage	Irrigation	Terraces and diversions	Waterways
Reservoir areas	Embankments				
Shallow	Unstable; highly plastic; high shrink-swell potential; low shear strength.	Shallow; highly plastic; very slowly permeable.	Shallow; very slow permeability; highly plastic; weak structure.	Shallow; unstable; very slow permeability; high shrink-swell potential.	Shallow; very slow permeability; weak structure.
(2)	(2)	In depressions; very slow permeability; high shrink-swell potential.	Very slow permeability; subject to flooding; high shrink-swell potential; highly plastic.	(2)	(2).
(2)	(2)	Well drained; subject to occasional flooding.	Subject to occasional flooding.	(2)	Moderate to high shrink-swell potential and plasticity in subsoil.
Rapid permeability; moderately erodible.	Rapid permeability; possibility of piping.	Well drained	Rapid permeability; limited water-holding capacity.	Rapid permeability; moderately erodible.	Moderately erodible.
Highly erodible	Highly erodible	Well drained	High content of calcium carbonate; weak structure.	Weak structure; highly erodible.	Highly erodible; weak structure.
Rapid permeability; moderately erodible.	Rapid permeability; moderately erodible.	Well drained	Rapid permeability; limited water-holding capacity; moderately erodible.	Rapid permeability; moderately erodible; weak structure.	Moderately erodible; limited water-holding capacity; weak structure.
Shallow; high content of calcium carbonate; highly erodible.	Shallow; high content of calcium carbonate; highly erodible.	Excessively drained	(2)	(2)	(2).
Shallow; possible piping.	Shallow	Excessively drained	(2)	(2)	(2).
High shrink-swell potential.	Highly plastic; low shear strength when wet; high shrink-swell potential.	Very slow permeability; highly plastic.	Very slow permeability; highly plastic.	Very slow permeability; highly plastic; high shrink-swell potential.	Very slow permeability; weak structure; highly plastic.
(2)	(2)	In depressions; very slow permeability.	Very slow permeability; subject to flooding; highly plastic; high shrink-swell potential.	(2)	(2)

TABLE 12.—*Interpretation of soil properties*

Soil series and map symbol	Suitability as source of—					Soil features affecting—	
	Topsoil	Sand	Gravel	Material for road fill [1]	Material for subgrade [1]	Highway location	Dikes and canals
Richfield (Rc)	Good	Unsuitable	Unsuitable.	Good	Fair	(3)	Low to moderate shear strength and plasticity.
Ulysses (Ua, Ub, Uc, Ud, Ul, Um).	Good	Unsuitable	Unsuitable.	Good	Fair to good.	(3)	Moderately erodible; low to moderate shear strength and plasticity.
Ulysses, heavy textured variant (Uh).	Good	Unsuitable	Unsuitable.	Fair	Poor	Moderate to high shrink-swell potential; moderate to high plasticity.	Moderate to high shrink-swell potential and plasticity.
Volin (Vl, Vs)	Good	Poor	Unsuitable.	Good	Fair	(3)	Deep; moderate permeability; stable.
Wet alluvial land (Wa).	Poor	Unsuitable in upper part; fair in substratum.	Unsuitable in upper part; poor in substratum.	Poor to a depth of 3 feet; good below.	Poor to fair.	High water table; subject to flooding.	Moderately slow permeability; moderate shrink-swell potential, stability, and plasticity.

[1] Prepared with the assistance of C. W. HECKATHORN, field soils engineer, and HERBERT E. WORLEY, soils research engineer, Kansas State Highway Commission.

[2] Practice does not apply to specified soil series.

that affect engineering—Continued

Soil features affecting—Continued					
Farm ponds		Agricultural drainage	Irrigation	Terraces and diversions	Waterways
Reservoir areas	Embankments				
(2)	(2)	Well drained	Deep; high water-holding capacity; moderately slow permeability.	Deep; friable; strong structure.	Deep; friable; strong structure.
Deep; moderate permeability.	Deep; low to moderate shear strength and plasticity.	Well drained	Deep; moderately permeable; high water-holding capacity.	Deep; moderately stable; moderately erodible.	Deep; moderately erodible.
Moderate to high shrink-swell potential and plasticity.	Moderate to high shrink-swell potential and plasticity; moderately low shear strength when wet.	Slow permeability	Slow permeability; moderately high plasticity; weak structure.	Slow permeability; moderately high plasticity and shrink-swell potential.	Slow permeability weak structure.
(2)	(2)	Deep; well drained	Deep; moderate permeability; high water-holding capacity.	Deep; stable; moderate permeability.	Deep; moderately erodible.
(2)	(2)	Seasonally high water table.	Seasonally high water table; slight to moderate salinity.	(2)	Slight to moderate salinity.

[3] No detrimental factors affecting highway location.
[4] Caliche performs poorly in subgrade under flexible surfaces but is useful for dry surfacing on local roads. It occurs in localized pockets, and its characteristics vary widely.

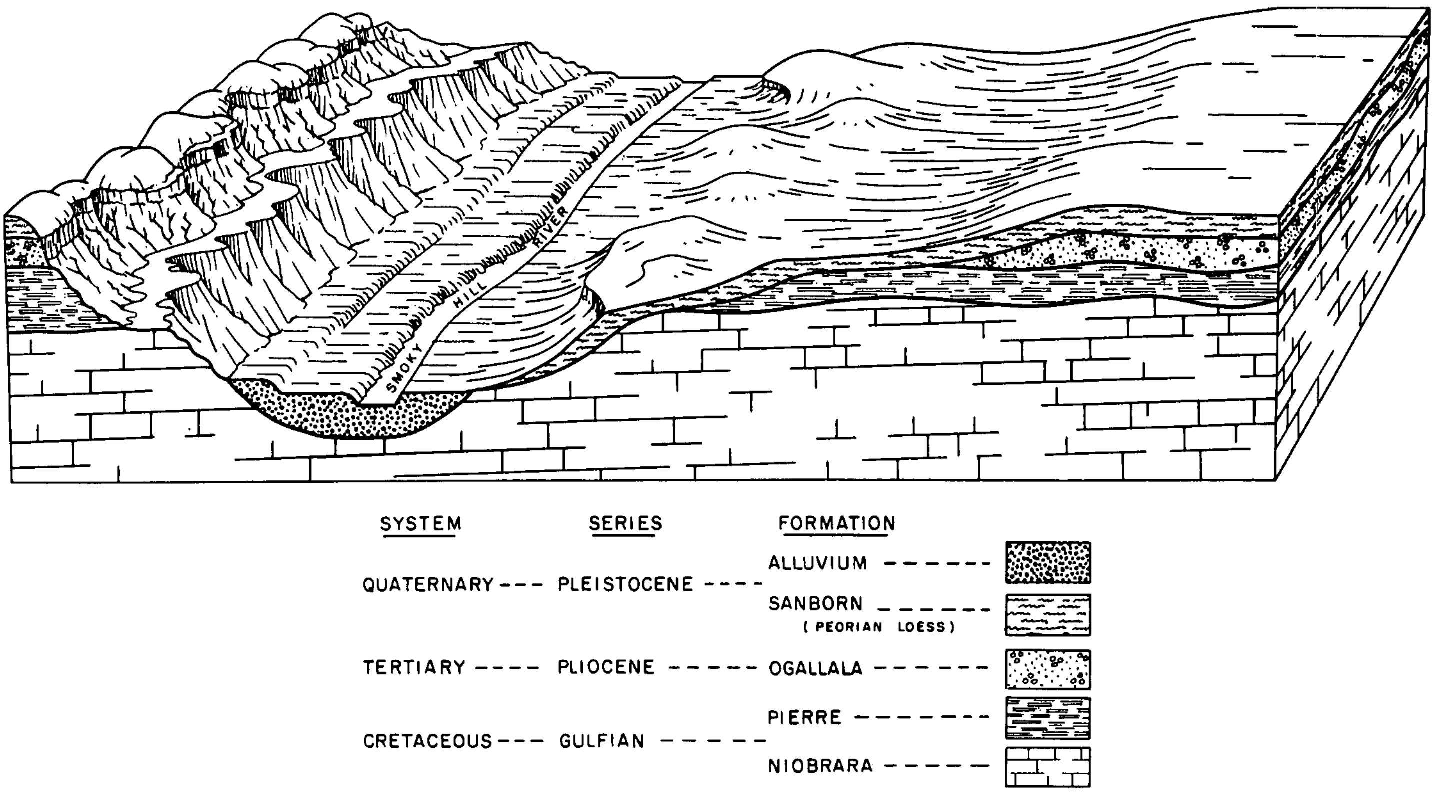


Figure 24.—Diagram of the major outcropping geologic formations of Logan County that contribute parent material for the soils.

Geology

No formations older than the Cretaceous outcrop in Logan County. Therefore, only the geology from that period to the present is discussed in this section (fig. 24).

During the latter part of the Cretaceous period, the area of this county was covered by a vast inland sea. Out of this sea was precipitated the sediment of the Niobrara formation, which underlies all of Logan County. Smoky Hill chalk is the only member of the Niobrara formation that outcrops in this county (fig. 25). The numerous fossils that have been found in the Cretaceous deposits underlying the county show that this inland sea contained abundant marine life. The deposits yield numerous remains of marine invertebrates and some well-preserved skeletons of large fishes, swimming reptiles, toothed diving birds, and flying reptiles that fell into the water and were drowned many miles from the nearest land (*10*).

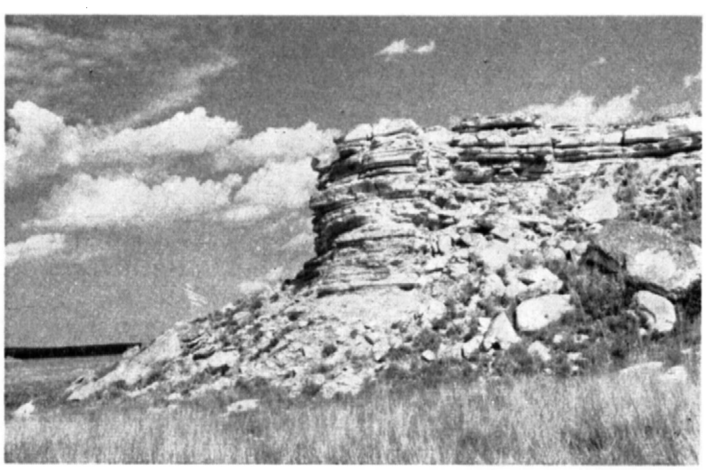


Figure 25.—Escarpment of fractured Smoky Hill chalk.

Pierre shale, a product of sedimentation in the Cretaceous sea, conformably overlies the Smoky Hill chalk (fig. 26). It can be readily distinguished from Smoky Hill chalk by its dark-gray color. The Smoky Hill chalk effervesces if dilute hydrochloric acid is added because it is almost pure calcium carbonate. Pierre shale does not effervesce if acid is added. The following gives the analysis [8] of Smoky Hill chalk:

	No. 1	*No. 2*
Moisture	0.34	0.58
Insoluble in acids (silica, lime, alumina)	.69	11.40
Alumina (little oxide of iron)	.43	.97
Ferrous carbonate	.14	2.83
Calcium carbonate	98.47	84.19
	100.07	99.97

Toward the end of the Cretaceous period, one of the major mountain-building epochs of world history affected North America. At that time, folding and faulting took place in the earth's crust, and the crust was elevated throughout the length of the Rockies from Alaska to Mexico. These events forced a retreat of the sea and started a long cycle of erosion. The deformation of the earth's crust in the Rocky Mountain region provided conditions that favored rapid erosion in some

[8] Analysis by G. E. PATRICK (*4*).

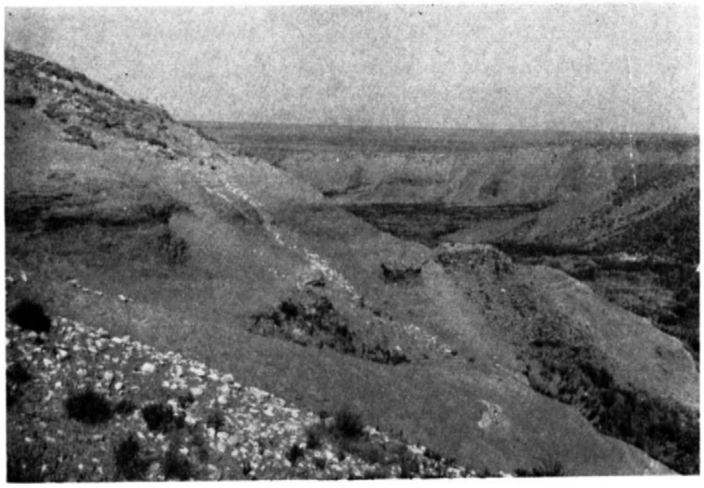


Figure 26.—**Bare outcrops of Pierre shale. Remnants of the Ogallala formation are scattered over the surface of the shale.**

areas and accelerated deposition of the products of erosion in others. As the result of the wearing away of the mountains, large quantities of gravel, sand, silt, and clay were released and were carried by streams to the adjoining plains and intermountain basins.

Since the withdrawal of the Cretaceous sea, the area has been continually above sea level. Streams flowing outward from the mountainous areas during Tertiary time carried debris eroded from the highlands. They deposited this material as a complex sequence of lenticular and sheetlike bodies of gravel, sand, silt, and clay. The surface upon which the sediments of the Ogallala formation (fig. 27) were deposited was a plain that had a topography of low relief. The deposits not only filled the shallow valleys but also spread across the divides (*6*).

This plain of aggradation completely erased all signs of the preexisting topography. Such Cretaceous strata as those of the Smoky Hill chalk, which now form prominent escarpments along the belts where the chalk outcrops, were blanketed by at least a thin veneer of Tertiary sediments (*6*).

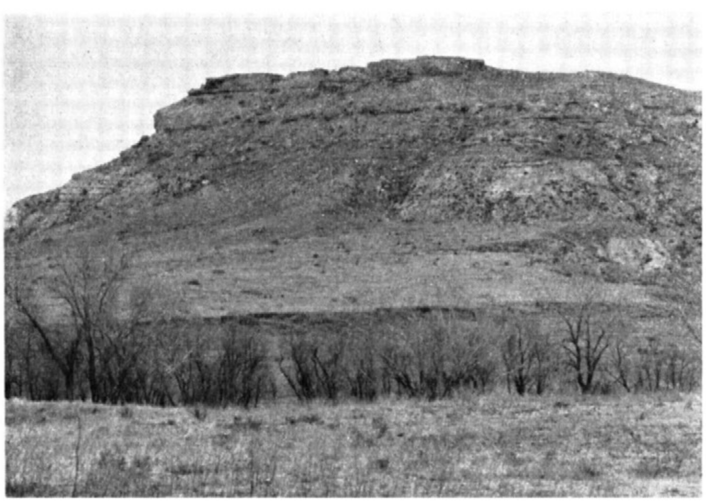


Figure 27.—**Geologic contact between the Ogallala formation and Smoky Hill chalk. In many places Pierre shale lies conformably between these two formations, but in this area it has been removed by erosion.**

An event of importance occurred in western Kansas after the sediments of the Ogallala formation were deposited. The major streams, in whatever position they happened to occupy, started to cut their channels through the former deposits. In those areas where the Ogallala formation was thin, they cut into the underlying bedrock.

Alluvial deposits began to accumulate in the valleys of the major streams in northwestern Kansas after the streams became entrenched in the Tertiary deposits. These deposits and the overlying silt or loess make up the Sanborn formation (*6*).

Late in the Quaternary period, a thick mantle of silt was spread over this region. The silt is extremely well sorted. It is generally called loess because its position on areas of the upland divides indicates it was blown to those areas by wind (*6*).

Figure 28.—**Deep Peorian loess exposed in a trench silo. This loess is the parent material of practically all of the silty soils of the uplands in the county.**

The geologic history that has been sketched explains the kinds of rocks that have been exposed in this county. The oldest rock exposed is Smoky Hill chalk, which was formed by tiny microscopic marine organisms on the floor of a Cretaceous sea. The Pierre shale, conformably overlying the Smoky Hill chalk, was a product of sedimentation in this same sea. Then the Rocky Mountain chain was uplifted, the sea retreated, and a cycle of erosion and deposition was started. The Pierre shale and Smoky Hill chalk were eroding during this time. The streams that were responsible for the erosion then shifted laterally, and the Ogallala formation, as well as the underlying formations, was cut into and began eroding. The windblown silt, commonly called Peorian loess, was then deposited.

All of these formations in Logan County have been partially removed by erosion. The parent material of the Penrose and Minnequa soils was derived as the result of the weathering of the exposed Smoky Hill chalk. The finer textured, more impervious soils, such as those of the Lismas series, occur wherever the Pierre shale outcrops. The parent material of the thin, lithosolic soils of the Potter series and that of some of the sandy soils was derived from the Ogallala formation and from the reworking of the Ogallala sand and gravel. The youngest geologic deposit, Peorian loess, is the parent material from which the Colby, Keith, and Ulysses silt loams, as well as practically all of the other silty soils of the uplands in the county, were formed (fig 28). The Ogallala formation is the major source of the underground water supply in the uplands.

Formation, Morphology, and Classification of Soils

This section is written for those who wish to gain a better understanding of Logan County soils. In it are discussed the formation, morphology, and classification of the soils. Also, the physical and chemical analyses of selected soils are described.

Factors of Soil Formation

Soil is the product of the forces of weathering and the processes of soil development that act on parent material that has been deposited or accumulated by geologic agencies. The kind of soil that is formed depends on the effect of the interaction of the five factors of soil formation—climate, plant and animal life, parent material, relief, and time. All of these factors are important, but, in different locations and under different conditions, some have more effect than others.

The five factors of soil formation are interdependent; each modifies the effect of the others. Climate and plant and animal life are the active forces that change the parent material and gradually form a soil. Parent material and relief can be considered as passive factors because they modify the effects of the active factors. Time is a relative factor, which indicates the extent to which the other factors have functioned. The interrelation of all these factors is complex. Each factor, however, is discussed independently in the following paragraphs.

Climate.—The climate of Logan County is subhumid, but it is transitional to semiarid. The average annual precipitation is only about 20 inches. The small amount of moisture limits the kinds of plants that grow on the soils. Short grasses, which require little moisture, are the principal native vegetation. The effects of climate on the morphology of soils formed in a semiarid region are somewhat weakly expressed as compared to the effects on soils formed in a humid region that has a similar temperature. The lack of rainfall has caused many of the soils to have a dark-brown surface layer and a horizon of lime accumulation. More information about the precipitation and temperature in Logan County can be found in the section "Climate," in the first part of the report.

Plant and animal life.—Of all the living organisms that function in the formation of a soil, the morphological effect of vegetation is the most easily recognized. Prairie grasses provided the organic matter that has accumulated in the soils of Logan County. This organic matter has caused the uppermost horizons to be dark.

In this county the principal soils that have well-developed soil characteristics as the result of the kind of vegetation are those of the Keith series. These soils show the effects of fairly large amounts of organic matter produced by native grasses in nearly level to gently sloping areas. The native vegetation is buffalograss and blue grama. The Keith soils are dark grayish brown to a depth of 21 inches. Below this depth the color grades from grayish brown to very pale brown as the amount of organic matter decreases.

In contrast to the Keith soils are the soils in depressions or on flood plains where moisture accumulates. The additional moisture helps produce more of the taller grasses, and consequently, more organic matter. As a result, soils formed in moist sites, such as those of the Randall series, which formed in depressions, have a thicker, darker A1 horizon than the Keith soils.

Animals are also important in the formation of a soil. Typical krotovinas, made by rodents that burrow into the soil, are common in the friable, loessal soils of the county. Occasionally, channels filled with pale-brown, loessal parent material occur throughout the darker A1 and B2 horizons.

Earthworm casts are abundant in the friable, loessal soils. The earthworms are in the surface layer only when the soil is moist, usually in spring. As summer advances and the soils become dry as a result of frequent drought, the earthworms burrow deep into the soil and are no longer in the surface layer.

Man has a great effect on the development of a soil. His management of the soil is a primary factor. Man's introduction of summer fallowing, to store moisture for crops, has disturbed the soil-moisture relationship that existed for several thousand years. Under summer fallowing, moisture is generally stored to a depth of 4 to 6 feet. This storing of moisture tends to cause more rapid development than would occur under natural conditions.

Parent material.—This is the unconsolidated mass in which soils are formed. It determines many of the morphological characteristics of the soils in their early stages of development.

About 81 percent of the acreage in this county consists of soils formed in loess of Peorian age. The unweathered loess in the C horizon of the Keith soils, for example, has many properties essential to the growth of plants. Keith silt loam would not have developed so rapidly, however, if the parent material were not easily altered by the influences of the active factors of soil formation.

Pierre shale and cemented caliche of the Ogallala formation offer a contrast to loess as parent material. These two geological formations are resistant to weathering and produce lithosolic soils by their exposure to the forces of soil formation.

The weakly consolidated Smoky Hill chalk rock of the Niobrara formation, however, is very susceptible to weathering. Geologic erosion has removed this material at a faster rate than the soil-forming processes have functioned. Soil development has failed to stabilize the soils of the landscape, and bare badlands have resulted in many areas. More information about parent material can be found in the section "Geology."

Relief.—Relief tends to modify the influences of the active factors of soil formation. Broad areas of both macrorelief and microrelief where the parent material is the same offer an excellent opportunity to observe the modifying effects of relief.

The Ulysses silt loams, formed in thick deposits of Peorian loess, are the most extensive soils in the county. The Ulysses silt loams have slopes that range from less than 1 percent to 15 percent. In the broad, nearly level areas, these soils have a thin B2 horizon; in the gently sloping areas, the B2 horizon is even thinner and is less distinct. The B2 horizon is not discernible in moderately sloping areas of these soils on narrow ridges and in strongly sloping areas on the sides of drainageways. Corresponding differences in the amount of lime accumulation and in the depth to which the soil material is darkened by organic matter occur within the Ulysses soils according to differences in slope.

The effects of microrelief can be observed within one soil type in the broad areas of nearly level tablelands. The soils in slightly concave areas or in depressions have slightly thicker horizons than those in the adjoining areas of smooth tablelands, and those in slightly convex areas or knolls have thinner horizons.

Time.—Time influences the morphological effects of the active soil-forming factors. Soils such as those of the Dwyer and Lincoln series have characteristics that group them as young soils in terms of morphological change. These soils have a surface layer that is not leached of its soluble carbonates and has no eluviated clays.

Peorian loess, the parent material of the soils that have a well-developed profile, is about 15,000 years old. From a standpoint of geology and soil formation, this is considered to be relatively young. Soils such as those of the Keith series in Logan County are therefore young in morphological advancement and are believed to be still developing.

Classification of Soils

Soils are placed in narrow classes for the organization and application of knowledge about their behavior within farms, ranches, or counties. They are placed in broad classes for study and comparison of large areas, such as continents. In the comprehensive system of soil classification followed in the United States (*2*), the soils are placed in six categories. Beginning at the top, the six categories are order, suborder, great soil group, family, series, and type.

In the highest category the soils of the whole country are grouped into three orders, whereas thousands of soil types are recognized in the lowest category. The suborder and family categories have never been fully developed and thus have been little used. Attention has been given largely to the classification of soils into soil types and series within counties or comparable areas and to the subsequent grouping of series into great soil groups and orders. Soil series and soil type are defined under the heading "How Soils Are Named, Mapped, and Classified."

In table 13 the soil series are classified by great soil groups and their important characteristics are given. Following the table is a description of a typical soil profile for each series.

The soil series of Logan County are classified into three orders, five great soil groups (*15*), and one group of intergrades. The soil series, as classified in this survey report, are based on the profile characteristics of the soils as they occur within Logan County. They may not represent the central concept of the series, but they are within the range of the series throughout its geographic occurrence.

The zonal order consists of soils that have well-developed, genetically related horizons that reflect the dominant influence of climate and plant and animal life, particularly vegetation, in their environment.

The Chestnut soils are the only zonal soils in the county. They have A1, B2, B3, or B2ca, Cca, and C horizons. They have a distinct horizon of lime accumulation below the B2 horizon. The soils of the Keith, Lofton, Lubbock, Manter, and Richfield series are Chestnut soils.

The intrazonal order comprises soils with genetically related horizons that reflect the dominant influence of a local factor of their environment, such as relief or parent material, over the influence of climate and plant and animal life in their formation.

The Grumusols are the only soils of the county in the intrazonal order. They have a thick, dark-colored A1 horizon and a clayey profile consisting of A, AC, and C horizons, but they do not have eluvial and illuvial horizons. The Promise and Randall soils are Grumusols.

The azonal order contains soils that lack distinct, genetically related horizons because of age, resistant parent material, or relief.

The Alluvial great soil group is comprised of young soils consisting of recent stream deposits that are generally stratified and show little evidence of leaching. A typical profile has A1, AC, C, or D horizons. The soils of the Bridgeport series, the strongly calcareous variant from the Bridgeport series, the moderately deep soil of the Las series, and the Las Animas, Lincoln, and Volin soils are in this great soil group. The Volin soils, as characterized in this county, show evidence of initiating horizon differentiation. They are leached of lime to a depth of 16 inches or more and have slightly more clay in the AC horizon than in the A1 and C horizons.

Chestnut soils intergrading toward Regosols are young in their stage of profile development. They are intermediate in horizon differentiation between the zonal Chestnut soils and the azonal Regosols in the same area. This is evident by the depth of darkening and by the eluviated clays below the A1 horizon. The two series that are intergrading toward Regosols are the Elkader and Ulysses.

Lithosols have a weakly developed profile and a solum that is generally less than 12 inches thick. A typical profile contains A1, AC, and Dr horizons. The Lismas, Penrose, and Potter soils are Lithosols.

Regosols are deep soils in relatively unaltered parent material, and they lack the horizon development of their associated zonal soils. Typically their profile contains A1, AC, and C horizons. There is an accumulation of organic matter in the surface layer and little or no illuviated clay below the A1 horizon. The Colby, Dwyer, Likes, Minnequa, and Otero soils and the heavy textured variant from the Ulysses series are in the Regosol great soil group.

TABLE 13.—*Soil series classified by higher categories and factors that contributed to their morphology*

Great soil group and soil series	Position	Slope	Parent material	Color of surface layer	Dominant texture below A1 horizon	Depth of soil	Drainage class	Native vegetation
ZONAL								
		Percent				*Inches*		
Chestnut soils:								
Elkader [1]	Sloping erosional uplands.	0 to 15	Mixture of loess and weathered sediments of chalk rock.	Dark grayish brown.	Silt loam	60+	Well drained	Short grasses.
Keith	Loess-covered tablelands.	0 to 3	Peorian and Bignell loess.	Dark grayish brown.	Light silty clay loam.	60+	Well drained	Short grasses.
Lofton	Shallow depressions or basins.	0 to 1	Medium-textured loess.	Dark gray	Clay	60+	Imperfectly drained.	Generally bare.
Lubbock	Benches around basins in the uplands.	0 to 1	Medium-textured loess.	Dark grayish brown.	Silty clay loam	60+	Well drained	Mid prairie grasses.
Manter	Narrow ridges of the uplands.	1 to 5	Sandy sediments reworked by wind.	Dark grayish brown.	Sandy loam	60+	Well drained	Mid and tall prairie grasses.
Richfield	Loess-covered tablelands.	0 to 1	Peorian and Bignell loess.	Dark grayish brown.	Silty clay loam	60+	Well drained	Short grasses.
Ulysses [1]	Loess-covered tablelands and dissected uplands.	0 to 15	Peorian and Bignell loess.	Dark grayish brown.	Silt loam and light silty clay loam.	60+	Well drained	Short grasses.
INTRAZONAL								
Grumusols:								
Promise	Alluvial-colluvial fans of the uplands.	0 to 5	Fine-textured alluvium and colluvium from Pierre shale.	Grayish brown	Clay	48 to 60	Moderately well drained.	Short grasses with inland saltgrass.
Randall	Depressions or basins.	0 to 1	Fine-textured alluvium.	Dark gray	Clay	60+	Very poorly drained.	Generally bare.
AZONAL								
Alluvial soils:								
Bridgeport	Alluvial fans and valley sediments.	0 to 2	Medium-textured alluvium.	Grayish brown	Loam	48 to 60+.	Well drained	Short and mid prairie grasses.
Bridgeport, strongly calcareous variant.	Low flood plains	0 to 2	Medium-textured alluvium.	Grayish brown	Light silty clay loam.	60+	Well drained	Western wheatgrass and inland saltgrasses.
Las, moderately deep.	Low flood plains	0 to 2	Medium and moderately fine textured alluvium.	Grayish brown	Clay loam	20 to 36	Imperfectly drained.	Mid and tall prairie grasses.

684-980—64——5

Las Animas	Low flood plains	0 to 2	Moderately coarse textured alluvium.	Grayish brown	Sandy loam	20 to 36	Imperfectly drained.	Mid and tall prairie grasses.
Lincoln	Low flood plains	0 to 2	Coarse-textured alluvium.	Grayish brown	Sand and gravel.	<15	Excessively drained.	Short grasses, annual weeds, sand sagebrush.
Volin	Low terraces and valley sediments.	0 to 2	Medium-textured alluvium.	Very dark grayish brown.	Silt loam and light silty clay loam.	60+	Well drained	Mid and tall prairie grasses.
Lithosols:								
Lismas	Dissected breaks in the uplands.	6 to 25	Pierre shale	Grayish brown	Clay	<15	Excessively drained.	Short grasses and inland saltgrass.
Penrose	Eroded breaks in the uplands.	5 to 20	Smoky Hill chalk	Grayish brown	Silt loam	<15	Excessively drained.	Short and mid prairie grasses.
Potter	Dissected breaks in the uplands.	20 to 45	Caliche and cemented sandstone.	Dark grayish brown.	Loam	<15	Somewhat excessively drained.	Mid and tall prairie grasses.
Regosols:								
Colby	Dissected, loess-covered uplands.	3 to 15	Peorian and Bignell loess.	Grayish brown	Silt loam	24+	Well drained	Short grasses.
Dwyer	Low, hummocky uplands.	3 to 8	Windblown sandy deposits.	Brown	Sand	60+	Excessively drained.	Mid and tall prairie grasses.
Likes	Alluvial-colluvial fans and low terraces.	0 to 2	Coarse-textured alluvium.	Grayish brown	Loamy sand	36 to 50	Somewhat excessively drained.	Mid and tall prairie grasses.
Minnequa	Alluvial fans of the uplands.	1 to 5	Raw sediments from chalk rock.	Grayish brown	Silt loam or light silty clay loam.	60+	Well drained	Short and mid prairie grasses.
Otero	Irregular uplands	3 to 8	Moderately coarse textured, reworked Tertiary deposits.	Grayish brown	Sandy loam	36 to 60	Well drained	Mid and tall prairie grasses.
Ulysses, heavy textured variant.	Sloping uplands	1 to 3	Regional and local loess from Pierre shale.	Grayish brown	Silty clay loam	60+	Well drained	Western wheatgrass and short grasses.

[1] The Elkader and Ulysses soils are in the Chestnut great soil group but are intergrading toward Regosols.

Detailed Descriptions of the Soil Series

In this section the soil series in the county are discussed in alphabetical order. In addition, a representative profile of each series is described in detail. The great soil group is given for each series for easy cross reference to table 13.

Bridgeport series.—This series is made up of light-colored, deep, calcareous soils that are medium textured. The soils formed in alluvium and are on alluvial fans and in valleys. They are in the Alluvial great soil group. The following describes a typical profile of Bridgeport loam, 100 feet north of the southwestern corner of SE¼ sec. 22, T. 13 S., R. 35 W.:

A1p—0 to 7 inches, grayish-brown (10YR 5/2) loam, dark grayish brown (10YR 3.5/2) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist; calcareous; abrupt boundary.

A1—7 to 18 inches, grayish-brown (10YR 5/2) heavy loam, dark grayish brown (10YR 3.5/2) when moist weak, fine, granular structure; slightly hard when dry, friable when moist; calcareous; gradual boundary.

C1—18 to 40 inches, light brownish-gray (10YR 6/2.5) loam, grayish brown (10YR 4.5/2) when moist; massive (structureless), but porous; slightly hard when dry, friable when moist; calcareous; gradual boundary.

C2—40 to 60 inches, light brownish-gray (10YR 6/2.5) loam, grayish brown (10YR 4.5/2) when moist; massive (structureless), but porous; soft when dry, friable when moist; calcareous and contains a few fine crystals of $CaSO_4$ and soft concretions of $CaCO_3$; clear boundary.

Cu—60 to 70 inches, very dark grayish-brown (10YR 3/2), thin layers of sandy loam and clay loam, grayish brown (10YR 5/2) when moist; massive (structureless); slightly hard when dry, friable when moist; abrupt boundary.

D—70 to 80 inches +, fine sand of the valley fill.

The A1 horizon ranges from heavy loam to light clay loam in texture, but in most places the texture is loam. The A1 horizon ranges from 10 to 20 inches in thickness. It is dominantly calcareous to the surface, but in places it is noncalcareous to a depth of 10 inches. The C horizon is generally uniform in texture but contains thin layers of sandy loam. The profile is unmottled to a depth of 40 inches or more.

The Bridgeport soils are well drained. Both runoff and internal soil drainage are medium. In most places the water table is at a depth of 6 to 20 feet, but in some places there is no water table.

Bridgeport, strongly calcareous variant.—The strongly calcareous variants from the Bridgeport series are deep, light-colored, calcareous soils formed in alluvium. These soils are medium textured. They are on the flood plains of streams. The sediments in which they formed were derived chiefly from chalky shale and chalk rock of the Niobrara formation. These soils are in the Alluvial great soil group, but they are associated with the Chestnut soils. The following describes a typical profile of Bridgeport silt loam, strongly calcareous variant, in a cultivated field 162 feet south and 272 feet west of the southwestern corner of the concrete bridge across Twin Butte Creek, in the SE¼ sec. 2, T. 15 S., R. 35 W.:

A1—0 to 7 inches, grayish-brown (10YR 5/2) silt loam, dark grayish brown (10YR 3.5/2) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist; calcareous; abrupt boundary.

AC—7 to 21 inches, light yellowish-brown (1Y 6/3.5) light silty clay loam, light olive brown (1Y 4.5/4) when moist; moderate, fine and medium, granular structure; hard when dry, firm when moist; numerous worm casts; strongly calcareous, 15 to 25 percent $CaCO_3$, by volume; gradual boundary.

C—21 to 68 inches +, light yellowish-brown (1Y 6/3.5) heavy silt loam, light olive brown (1Y 5/5) when moist; massive (structureless); soft when dry, friable when moist; calcareous; the content of $CaCO_3$ higher than that of alluvial sediments derived from loess.

The principal variations in these soils consist of differences in the thickness of the horizons and in the colors. The A1 horizon ranges from 4 to 8 inches in thickness. Its color, when it is dry, ranges from 4.5 to 5.5 in value and from 1.5 to 2.5 in chroma in the 10YR hue. The AC and C horizons have a texture of heavy silt loam and light silty clay loam.

These soils are well drained. Runoff is slow and internal soil drainage is medium. The water table is below a depth of 10 feet, except during short periods of flooding.

Colby series.—Light-colored, medium-textured soils that are immature make up this series. The soils were formed in Peorian and Bignell loess and in other sediments similar to loess, but there is little horizon differentiation in the profile. The soils are in the Regosol great soil group. The following describes a typical profile of a Colby silt loam in an area of native short prairie grasses, on a smooth, south-facing slope of 8 percent, sec. 25, T. 14 S., R. 34 W.:

A1—0 to 5 inches, grayish-brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) when moist; weak, coarse, prismatic to weak, fine, granular structure; slightly hard when dry, friable when moist; abundant fine roots; calcareous at lower limits; clear boundary.

AC—5 to 24 inches, pale-brown (10YR 6/3) silt loam, grayish brown (10YR 5/2.5) when moist; weak, coarse, prismatic structure; slightly hard when dry, friable when moist; abundant fine roots; strongly calcareous and a few concretions of soft lime; diffuse boundary.

C—24 inches+, very pale brown (10YR 7/3) silt loam, pale brown (10YR 6/2.5) when moist; massive (structureless); soft when dry, friable when moist; strongly calcareous loess that extends to a depth of several feet.

The maximum limit of development is an A1 horizon, 4 to 6 inches thick, that has a color no darker than 10YR 5/0 when the soil is dry.

In areas of sod where the soils have never been cultivated, part or all of the A1 horizon is calcareous. Where the soil material in the upper horizons has been mixed by cultivation, the plow layer has a color value of 10YR 5.5/0 to 10YR 6/0 in places.

These soils are well drained. Runoff is moderate to rapid, and internal drainage is medium.

Dwyer series.—The soils of this series are light colored, coarse textured, and calcareous. They formed in deposits of calcareous sand that has been reworked by wind. These deposits are probably of Tertiary origin. The Dwyer soils are Regosols. The following describes a typical profile of Dwyer loamy fine sand, 0.2 mile south of the southern end of the bridge across the Smoky Hill River and 100 feet west in the SE¼ of sec. 1, T. 14 S., R. 34 W.:

A1—0 to 5 inches, brown (10YR 5/3) loamy fine sand, dark grayish brown (10YR 4/2.5) when moist; slightly coherent clods that break easily to single grains of sand and granular silt; soft when dry, loose when moist; plentiful fine roots; weakly calcareous; clear boundary.

AC—5 to 12 inches, light yellowish-brown (10YR 6/4) fine sand, yellowish brown (10YR 5.5/4) when moist; single grain (structureless); loose when moist; plentiful fine roots; calcareous; diffuse boundary.

C—12 to 60 inches, very pale brown (10YR 7/3) fine sand, pale brown (10YR 6.5/3) when moist; single grain (structureless); loose when moist; plentiful fine roots to a depth of 15 inches, decreasing to few fine roots at a depth of 20 inches; calcareous; sands extend downward below a depth of 60 inches.

The principal variation in these soils is in the depth of darkening in the A1 and AC horizons. The A1 and AC horizons range from 8 to 16 inches in thickness.

The Dwyer soils are excessively drained. Runoff is slow and internal drainage is very rapid.

Elkader series.—The soils of the Elkader series are dark, medium textured, and calcareous. Their profiles are immature. The soils were formed in a thin veneer of regional or local loess over reworked sediments of weathered chalky shale and chalk rock of the Niobrara formation. They are Chestnut soils that intergrade toward Regosols. The following describes a typical profile of an Elkader silt loam in an area of native grass 1,050 feet north and 1,680 feet west of the southeastern corner of sec. 11, T. 15 S., R. 34 W., on a smooth, north-facing slope of 4 percent:

A1—0 to 15 inches, dark grayish-brown (10YR 4/2) silt loam, dark brown (10YR 3/3) when moist; moderate, fine and medium, granular structure; slightly hard when dry, friable when moist; numerous roots; in places fine (less than 1 millimeter in diameter) grains of chalk rock are in this horizon but not at this location; common nests of worm casts; calcareous; clear boundary.

AC—15 to 23 inches, brown (10YR 5/3) silt loam, dark yellowish brown (10YR 4/4) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist; few fine roots; common nests of worm casts; few fine grains of chalk rock; strongly calcareous; gradual boundary.

C—23 to 66 inches +, pale-yellow (1Y 7/4) silt loam, olive yellow (1Y 6/6) when moist; massive (structureless); slightly hard when dry, friable when moist; few fine roots to none at a depth of 40 inches; strongly calcareous; content of $CaCO_3$ is 15 to 35 percent, by volume.

The principal variations in these soils are in the color and thickness of the horizons. The A1 horizon ranges from 8 to 20 inches in thickness. When the soil is dry, the color of the surface layer ranges from a value of 4 to 5 in the 10YR hue and from a chroma of 2 to 3. Fragments of chalk rock are common in the upper 3 feet. In places there are fragments of chalk rock, as much as 2 inches across, in the C horizon. The soils are dominantly medium textured, but in places they are moderately fine textured. A chroma of 4 or greater within a depth of less than 36 inches distinguishes these soils from those of the Ulysses series.

The Elkader soils are well drained. Runoff and internal drainage are medium.

Keith series.—Dark, medium-textured soils that were formed in calcareous loess of the tablelands make up this series. These soils have a well-developed profile. They have advanced far enough in development to have a distinct, illuviated B2 horizon. The Keith soils are in the Chestnut great soil group. The following describes a typical profile of a Keith silt loam in a cultivated field 557 feet south and 278 feet east of the northwestern corner of sec. 36, T. 11 S., R. 35 W. The soil at this site was sampled for soil characterization analysis, and the results of the analysis are shown in table 14. The sample numbers are S–57–Kans–55–2–(1–8).

A1p1—0 to 4 inches, dark grayish-brown (10YR 4/2) silt loam, very dark grayish brown (10YR 2.5/2) when moist; weak, very fine and fine, granular structure; slightly hard when dry, friable when moist; noncalcareous; abrupt, smooth boundary.

A1p2—4 to 6 inches, dark grayish-brown (10YR 4/1.5) silt loam, very dark brown (10YR 2/2) when moist; weak, thick, platy structure but breaks to fine and medium, granular structure; slightly hard when dry, friable when moist; noncalcareous; abrupt, smooth boundary.

A12—6 to 11 inches, very dark grayish-brown (10YR 3/1.5) light silty clay loam, very dark brown (10YR 2/2) when moist; moderate, medium, granular structure; slightly hard when dry, friable when moist; noncalcareous; gradual boundary.

A3—11 to 17 inches, very dark grayish-brown (10YR 3/1.5) light silty clay loam, very dark brown (10YR 2.5/2) when moist; moderate, medium, granular structure; hard when dry, friable when moist; noncalcareous; gradual boundary.

B21—17 to 21 inches, dark grayish-brown (10YR 4/2) light silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate, medium, subangular blocky structure; weak, patchy clay films; hard when dry, firm when moist; noncalcareous; gradual boundary.

B22—21 to 33 inches, grayish-brown (10YR 5.5/2) light silty clay loam, dark grayish brown (10YR 4/2) when moist; moderate, medium, subangular blocky structure; weak, patchy clay films; hard when dry, firm when moist; calcareous; gradual boundary.

B2ca—33 to 41 inches, grayish-brown (10YR 5.5/2) light silty clay loam, dark grayish brown (10YR 4/2) when moist; moderate, medium, subangular blocky structure; weak, patchy clay films; hard when dry, firm when moist; calcareous; about 2 percent, by volume, of small, soft concretions of $CaCO_3$; gradual boundary.

Cca—41 to 57 inches, light brownish-gray (10YR 6/2.5) silt loam, brown (10YR 5/3) when moist; weak, coarse, prismatic but breaks to weak, medium and coarse, subangular blocky; slightly hard when dry, friable when moist; calcareous; few, small, soft concretions and fine threads of $CaCO_3$: gradual boundary.

C—57 to 70 inches +, very pale brown (10YR 7/2.5) silt loam, brown (10YR 5/3) when moist; massive (structureless); soft when dry, very friable when moist; calcareous. (This material not sampled for laboratory analyses.)

The B horizon ranges from light to medium silty clay loam in texture and has weak to moderate, fine to medium, subangular blocky structure. Depth to lime ranges from 15 to 25 inches, but in most places lime is at a depth between 18 and 22 inches. In many places the A3 horizon is absent or is thinner than that in the profile described.

These soils are well drained. Runoff and internal drainage are medium.

Las series.—The soils of the Las series are light colored, calcareous, stratified, and medium to moderately fine textured. They are imperfectly drained, immature soils of the flood plains. They are in the Alluvial great soil group, but they are in the same general areas as the

Chestnut soils. The following describes a typical profile of Las loam, moderately deep, in a cultivated field 0.1 mile north and 390 feet east of the southwestern corner of the SE¼ sec. 23, T. 13 S., R. 35 W.:

A1—0 to 8 inches, grayish-brown (10YR 4.5/2) loam, very dark grayish brown (10YR 3.5/2) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist; calcareous; gradual boundary.

AC—8 to 32 inches, light brownish-gray (10YR 6/2) clay loam, grayish brown (10YR 5/2) when moist; weak, fine, granular structure to massive; hard when dry, firm when moist; few, fine, distinct mottles of reddish brown (5YR 4/4) at a depth of 28 inches; calcareous; grades through sandy loam to the C horizon.

C—32 to 42 inches +, alluvial sands of the valley fill.

The major variations in these soils are in the thickness of the profile, in the degree of stratification, and in the depth to the water table. In most places the A1 horizon is about 8 inches thick and the profile extends to a depth of 20 to 36 inches. Thin layers or lenses of sandy loam are common below the A1 horizon. The degree of mottling ranges from faint to distinct, and mottling occurs below a depth of 2 feet.

These soils are imperfectly drained and have a fluctuating water table. Runoff is slow and internal drainage is medium. The water table normally stands 4 to 8 feet below the surface, but it rises to within 2 feet of the surface during periods of above-average rainfall.

Las Animas series.—The soils of the Las Animas series are light colored, calcareous, and moderately coarse textured. They are moderately deep, imperfectly drained, and immature. These soils formed in stratified, sandy alluvial deposits on flood plains. They are in the Alluvial great soil group, but they are in the same general areas as the Chestnut soils. The following describes a typical profile of Las Animas sandy loam, in an area of native grass, 250 feet south and 150 feet west of the northeastern corner of sec. 18, T. 12 S., R. 36 W.:

A1—0 to 6 inches, grayish-brown (10YR 4.5/2) sandy loam, dark grayish brown (10YR 3.5/2) when moist; weak, fine, granular structure; slightly hard when dry, very friable when moist; numerous roots; calcareous clear boundary.

C1—6 to 29 inches, light brownish-gray (10YR 5.7/2) sandy loam, dark grayish brown (10YR 4/2) when moist; weak, fine, granular structure, but in places there are some single grains of sand and pebbles; slightly hard when dry, very friable when moist; few fine roots; stratified with sandy clay loam; calcareous; gradual boundary.

C2—29 to 35 inches, grayish-brown (10YR 5/2) loamy fine sand, very dark grayish brown (10YR 3/2) when moist; massive (structureless); noncoherent; mottled with few, fine, faint, rust-brown stains; calcareous; clear boundary.

D—35 to 60 inches +, fine sand and gravel of the alluvial valley fill.

The principal variations in these soils are in the depth to sand and gravel and in the degree of stratification in the profile. The depth to the sand that underlies the profile ranges from 20 to 36 inches. The profile contains common lenses of loamy sand and sandy clay loam. In places the profile is mottled below a depth of 2 feet.

These soils are imperfectly drained and have a fluctuating water table. Runoff is slow and internal drainage is medium. The water table normally stands at a depth of 4 to 10 feet, but it may rise to within 2 feet of the surface during periods of above-average rainfall.

Likes series.—The soils of the Likes series are fairly light colored, deep, coarse textured, and calcareous. Their profile is immature, and these soils were formed in coarse-textured sediments of alluvium and colluvium. They are in areas where drains from the uplands terminate on low terraces in the valleys. The source of the parent material is reworked sandy deposits of Pliocene and early Pleistocene age. These soils are in the Regosol great soil group. The following describes a typical profile of Likes loamy fine sand, in an area of native pasture, 300 feet south of the southern end of the bridge across the Smoky Hill River and 0.35 of a mile east in NW¼ sec. 26, T. 13 S., R. 35 W.:

A1—0 to 12 inches, grayish-brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) when moist; weak, fine, granular structure with few single grains; soft when dry, loose when moist; numerous roots; calcareous; gradual boundary.

AC—12 to 50 inches, light brownish-gray (10YR 6.5/2.5) loamy sand, brown (10YR 5/3) when moist; massive and single grain but has a suggestion of weak granulation in upper part; generally noncoherent; few rootlets to a depth of 36 inches; calcareous; gradual boundary.

C—50 inches +, loose, calcareous sands.

The profile extends to a depth of 36 to 50 inches. In some places it contains thin layers of sandy loam and sand, but in most places the profile is calcareous loamy sand throughout. In a few small areas, the texture of the surface layer is light sandy loam.

These soils are somewhat excessively drained because the profile is porous. Runoff is slow and internal drainage is rapid. The water table normally stands at a depth greater than 10 feet.

Lincoln series.—The Lincoln series is made up of light-colored, shallow, mixed and stratified, coarse-textured soils. The soils were formed in coarse-textured alluvium on low flood plains that are subject to recurrent flooding. They are classified as Alluvial soils, but they are in the same general areas as the Chestnut soils. The following describes a profile that is typical of Lincoln soils, 100 feet north of the low water bridge across the Smoky Hill River and 500 feet east in NW¼ sec. 19, T. 13 S., R. 36 W.:

A1—0 to 10 inches, grayish-brown (10YR 5/2) loamy sand, dark grayish brown (10YR 4/2) when moist; contains a few pockets, 1 to 2 inches in diameter, of fine, granular loam; single grain; loose when dry; few fine roots; calcareous; abrupt boundary.

C—10 to 24 inches +, stratified coarse sand and gravel of the valley fill with a few thin lenses of finer textured material.

These soils have a loam, sandy loam, or loamy sand surface layer that is underlain by loamy sand or other coarser material at a depth of 15 inches or less. Considerable stratification occurs throughout the profile. The surface layer varies in texture because the areas are covered by recent deposits of loam, sandy loam, or loamy sand that is 4 to 6 inches thick.

These soils are excessively drained. Runoff is slow and internal drainage is very rapid. The water table normally stands at a depth below 4 feet.

Lismas series.—The Lismas soils are fine textured, shallow, and noncalcareous. They formed from weathered gypsum-bearing shale of the Pierre shale formation. These soils are in strongly sloping areas or in rough, broken areas of the uplands. They are classified as Lithosols. The following describes a typical profile of Lismas clay, in an area of native grass that has not been fenced or grazed, NE¼NE¼ sec. 30, T. 12 S., R. 36 W.:

A1—0 to 2 inches, grayish-brown (1Y 4.5/1.5) clay, dark grayish brown (10YR 3.5/1.5) when moist; moderate, fine and medium, granular structure; very hard when dry, very firm when moist; plentiful roots; noncalcareous; abrupt boundary.

AC—2 to 12 inches, dark-gray (N 4.5/0) clay and shaly clay, very dark gray (N 3.5/0) when moist; moderate, fine and medium, irregular blocky structure; extremely hard when dry, extremely firm when moist; noncalcareous; common, medium, distinct, light yellowish-brown (2.5Y 6/4) mottles; clear boundary.

Dr—12 to 20 inches, gray (N 5/0, dry) massive shale with a few whitish streaks that effervesce when a 10 percent solution of HCl is added; many, coarse, prominent, whitish (N 8/0) mottles on the surface of partly weathered and fractured shale.

These soils range from 6 to 15 inches in thickness over the parent material. In some areas unaltered shale outcrops on bluffs or occurs as vertical outcrops.

These soils are excessively drained. Runoff is rapid and internal drainage is very slow.

Lofton series.—The soils of the Lofton series are dark, fine textured, and imperfectly drained. They were formed in medium-textured loess in shallow depressions within the loessal tablelands of the High Plains. These soils are in the Chestnut great soil group. The following describes a typical profile of Lofton silty clay loam, in the center of a depression in N½NW¼ sec. 11, T. 12 S., R. 34 W.:

Ap—0 to 5 inches, dark-gray (10YR 4/1) heavy silty clay loam, very dark gray (10YR 2.5/1) when moist; moderate, fine, granular structure; hard when dry, firm when moist; slightly acid; abrupt boundary.

A3—5 to 8 inches, dark-gray (10YR 4.5/1) light silty clay, very dark gray (10YR 2.5/1) when moist; strong, fine, granular structure; very hard when dry, firm when moist; distinct clay films on the surfaces of peds; common, medium, prominent mottles of reddish brown (5YR 4/3); noncalcareous; clear boundary.

B21—8 to 20 inches, gray (10YR 5/1) clay, very dark gray (10YR 3/1) when moist; strong, medium, subangular blocky structure; extremely hard when dry, extremely firm when moist; distinct clay films; common, medium, prominent mottles of reddish brown (5YR 4/3); noncalcareous; clear boundary.

B22—20 to 30 inches gray (10YR 5/1) clay, very dark gray (10YR 3/1) when moist; moderate, medium, subangular blocky structure; extremely hard when dry, extremely firm when moist; distinct clay films; few, fine, faint mottles of yellowish brown (10YR 5/4); noncalcareous; gradual boundary.

B3—30 to 43 inches, gray (10YR 5.5/1) heavy silty clay loam, very dark grayish brown (10YR 3.5/2) when moist; weak, medium and coarse, subangular blocky structure; very hard when dry, firm when moist; thin, continuous clay films; noncalcareous; gradual boundary.

BC—43 to 55 inches, light brownish-gray (10YR 6/2) light silty clay loam, dark grayish brown (10YR 4/2) when moist; weak, coarse, subangular blocky structure that approaches massive; slightly hard when dry, friable when moist; weak, patchy clay films; noncalcareous; diffuse boundary.

C—55 to 67 inches +, light-gray (10YR 7/2) silt loam, brown (10YR 5/3) when moist; massive; calcareous loess.

The areas in which these soils occur range in size from 100 feet in diameter to 16 acres, but the average size is between 6 and 8 acres. The depth to free carbonates ranges from 40 to 72 inches.

These soils are imperfectly drained. Runoff is ponded and internal drainage is very slow.

Lubbock series.—The Lubbock series consists of dark, moderately fine textured soils. These soils are on benches around basins within the uplands that have a mantle of loess. They were formed in alluvial sediments from the surrounding loessal uplands. These soils are in the Chestnut great soil group. The following describes a typical profile of Lubbock silt loam, 1,320 feet east and 1,050 feet south of the northwestern corner of sec. 6, T. 12 S., R. 36 W.:

A1—0 to 10 inches, dark grayish-brown (10YR 3.5/2) silt loam, very dark grayish brown (10YR 2.5/2) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist; noncalcareous; gradual boundary.

AB—10 to 14 inches, dark grayish-brown (10YR 3.5/2) light silty clay loam, very dark grayish brown (10YR 2.5/2) when moist; weak, medium and fine, subangular blocky structure; hard when dry, firm when moist; noncalcareous; gradual boundary.

B2—14 to 20 inches, dark grayish-brown (10YR 4/1.5) heavy silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate, medium and fine, subangular blocky structure; very hard when dry, very firm when moist; thin and continuous clay films; clear boundary.

B3—20 to 28 inches, pale-brown (10YR 6/3) heavy silty clay loam, brown (10YR 5/3) when moist; weak, coarse and medium, subangular blocky structure; very hard when dry, very firm when moist, calcareous; gradual boundary.

Cca—28 to 46 inches, very pale brown (10YR 6.5/3) silty clay loam, brown (10YR 5/3) when moist; weak, coarse, subangular blocky structure; hard when dry, firm when moist; calcareous, few fine concretions of $CaCO_3$; diffuse boundary.

C—46 to 79 inches +, very pale brown (10YR 6.5/3) light silty clay loam, brown (10YR 5/3) when dry; massive (structureless); soft when dry, friable when moist; calcareous parent material.

The texture of the B2 horizon ranges from heavy silty clay loam to light silty clay. This horizon has dominantly moderate, medium, subangular blocky structure, but there is weak, angular blocky structure in the finer textured horizons. The profile is noncalcareous to a depth of 16 to 38 inches.

These soils are well drained. Runoff and internal drainage are medium.

Manter series.—The Manter series consists of dark, moderately coarse textured soils that have a weakly developed profile. The soils were formed in reworked, calcareous deposits of sand from Tertiary and Quaternary materials on ridges of the uplands. They are in the Chestnut great soil group. The following describes a typical profile of a Manter fine sandy loam, in a cultivated field, 0.4 mile south and 100 feet west of the northeastern corner of sec. 7, T. 14 S., R. 36 W.:

A1—0 to 6 inches, dark grayish-brown (10YR 4/2) fine sandy loam, very dark grayish brown (10YR 3/2) when moist; weak, fine, granular structure; soft when dry, friable when moist; noncalcareous; gradual boundary.

A12—6 to 14 inches, dark grayish-brown (10YR 3.5/2) heavy sandy loam, very dark grayish brown (10YR 2.5/2) when moist; very weak, fine, granular structure to massive; soft when dry, friable when moist; very weak, patchy clay films; noncalcareous; gradual boundary.

AC—14 to 26 inches, dark grayish-brown (10YR 4/2) heavy sandy loam; very dark grayish brown (10YR 3.5/2) when moist; massive (structureless); soft when dry, very friable when moist; weak, patchy clay films; noncalcareous; diffuse boundary.

C—26 to 60 inches +, brown (10YR 5/3) sandy loam, dark brown (10YR 3.5/3) when moist; massive (structureless); soft when dry, very friable when moist; calcareous.

The texture of the solum ranges from heavy sandy loam to heavy loamy sand. In some places the soils have a very weak B horizon. The depth to calcareous material ranges from 18 to 30 inches, but in most places it is 20 inches.

These soils are well drained. Runoff is slow and internal drainage is rapid.

Minnequa series.—The soils of the Minnequa series are deep, medium textured, and light colored. They formed in sediments of weathered chalk rock and chalky shale of the Niobrara formation. These soils are on alluvial fans below residual outcrops of the Niobrara formation. They are in the Regosol great soil group. The following describes a typical profile of Minnequa silt loam, in a large pasture of native grass, 68 feet south and 68 feet west of the northeastern corner of sec. 5, T. 15 S., R. 35 W., on a north-facing slope of 2 percent:

A1—0 to 3 inches, grayish-brown (10YR 4.4/2) silt loam, dark grayish brown (10YR 4/2) when moist; weak, fine granular structure; slightly hard when dry, friable when moist; numerous roots; few fine (less than 1 millimeter in diameter) grains of chalk rock; calcareous; abrupt boundary.

AC—3 to 10 inches, light yellowish-brown (1Y 6/3) light silty clay loam, olive brown (1Y 4/4) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist; numerous roots; few fine (less than 1 millimeter in diameter) grains of chalk rock; calcareous; gradual boundary.

C—10 to 66 inches, pale-yellow (1Y 7/4) heavy silt loam, light olive brown (1Y 5/6) when moist; massive (structureless); soft when dry, very friable when moist; roots decrease in number with increasing depth to none at a depth of 40 inches; few fine fragments of chalk rock; strongly calcareous; content of $CaCO_3$, 25 to 50 percent, by volume.

The texture of these soils is dominantly medium, but in some places it is moderately fine. In many places the AC horizon is lacking and there is a thin A1 horizon and an abrupt boundary between it and the C horizon. Grains and fragments of chalk rock occur throughout the profile.

These soils are well drained. Runoff and internal drainage are medium. The water table is deep or there is none. The soils of this series are not flooded by any creek or river.

Otero series.—The soils of the Otero series are light colored, calcareous, and moderately coarse textured. They developed, without any significant eluviation, in reworked material of Pliocene age. These soils are on high dissected terraces adjacent to the valleys of the major streams. They are in the Regosol great soil group. The following describes a typical profile of Otero fine sandy loam, in an area of native sod 950 feet north and 100 feet east of the center of sec. 27, T. 14 S., R. 33 W.:

A1—0 to 6 inches, grayish-brown (10YR 4.5/2) fine sandy loam, very dark grayish brown (10YR 3/2) when moist; weak, fine and medium, granular structure with few, medium and coarse, single grains of sand; slightly hard when dry, friable when moist; abundant grass roots; calcareous; clear boundary.

AC—6 to 16 inches, grayish-brown (10YR 5.5/2) sandy loam, dark grayish brown (10YR 4/2) when moist; weak, fine, granular structure; soft when dry, very friable when moist; numerous fine roots; strongly calcareous; gradual boundary.

C1—16 to 38 inches, light-gray (10YR 7/2) light sandy loam, light grayish brown (10YR 6/2.5) when moist; coherent but without consistent structural form; soft when dry, very friable when moist; few fine roots; strongly calcareous; diffuse boundary.

C2—38 to 60 inches +, light-gray (10YR 7/2) loamy sand, light grayish brown (10YR 6/2.5) when moist; only slightly coherent; strongly calcareous.

The texture of the surface layer ranges from loam to light sandy loam because of the local mixing of windblown silt with the sandy material. The depth of darkening ranges from 4 to 16 inches. The soil material is generally calcareous at the surface or within 8 inches of the surface.

These soils are well drained. Runoff is slow and internal drainage is rapid.

Penrose series.—The soils of the Penrose series are light colored, shallow, and medium textured. They were formed in material weathered from weakly consolidated chalky shale and chalk rock of the Niobrara formation. These soils are in geologically eroded areas of the uplands. Their slope is 5 to 20 percent. The soils are in the Lithosol great soil group. The following describes a typical profile of Penrose silt loam, 1,800 feet south and 120 feet west of the northeastern corner of sec. 5, T. 15 S., R. 35 W.:

A1—0 to 6 inches, grayish-brown (10YR 5.5/2) silt loam, very dark grayish brown (10YR 3/2) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist; numerous roots; few fine particles of chalk rock, from 1 to 5 millimeters in diameter, scattered throughout the horizon; few small nests of worm casts; calcareous; clear boundary.

AC—6 to 12 inches, pale-yellow (1Y 7/4) silt loam, yellowish brown (10YR 5/5) when moist; weak, fine, granular structure in upper part of horizon, but grades to massive below a depth of 10 inches; soft when dry, friable when moist; roots decrease in number with increasing depth, and there are none at a depth of 15 inches; common fine fragments of chalk rock that increase in size with increasing depth until they are 15 millimeters in diameter in lower part of horizon; few small nests of worm casts in upper 4 inches; strongly calcareous; abrupt boundary.

Dr—12 inches +, weakly consolidated chalk rock.

Depth to the parent material ranges from 8 to 16 inches. Bare outcrops are common.

These soils are excessively drained. Runoff is rapid and internal drainage is medium.

Potter series.—The Potter soils are dark and shallow. They formed in material weathered from mortar beds of the Ogallala formation. These soils are in the Lithosol great soil group. The following describes a profile that is typical of Potter soils, on top of a prominent escarpment 0.1 of a mile north and 0.24 of a mile west of the southeastern corner of sec. 31, T. 15 S., R. 34 W.:

A1—0 to 5 inches, dark grayish-brown (10YR 4.5/2) loam, very dark grayish brown (10YR 3.5/2) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist; numerous fine roots; slightly calcareous; clear boundary.

AC—5 to 12 inches, light grayish-brown (10YR 6/2) loam, grayish brown (10YR 4.5/2) when moist; 10 percent of soil mass made up of gravel and fragments of caliche; weak, medium, granular structure and single grain; hard when dry, friable when moist; strongly calcareous; abrupt boundary.

Dr—12 inches +, hard caliche mortar bed several feet thick.

The principal variation in these soils is in their depth to consolidated material. The depth ranges from a thin layer of nearly bare soil material to 15 inches, but in most places it is about 12 inches. The A1 horizon ranges in texture from heavy loam to gravelly sandy loam. A thin veneer of gravel of Tertiary age is on the surface or within the profile.

These soils are somewhat excessively drained. Runoff is very rapid and internal drainage is medium.

Promise series.—The Promise series consists of deep, dark, fine-textured, calcareous soils that have no significant profile development. The soils were formed in clayey sediments on alluvial-colluvial slopes below outcrops of Pierre shale. They are clayey throughout, and they contain a moderate amount of salts below the A1 horizon. These soils are Grumusols. The following describes a typical profile of a Promise clay, in a cultivated field, 0.2 of a mile east and 0.2 of a mile north of the southwestern corner of sec. 18, T. 12 S., R. 36 W., on an east-facing slope of 2 percent:

Ap—0 to 3 inches, grayish-brown (10YR 4.5/2) clay, very dark grayish brown (10YR 3/2.5) when moist; structureless; very hard when dry, very firm when moist; slightly calcareous; abrupt boundary.

A1—3 to 8 inches, grayish-brown (10YR 4.5/2) clay, very dark grayish brown (10YR 3/2.5) when moist; moderate, medium, granular structure; very hard when dry, very firm when moist; slightly calcareous; clear boundary.

AC—8 to 20 inches, light yellowish-brown (1Y 5.5/3) clay, olive brown (1Y 4.5/4) when moist; weak, fine and medium, granular structure; very hard when dry, very firm when moist; calcareous; clear boundary.

C—20 to 60 inches +, pale-yellow (2.5Y 6.5/3) clay, light olive brown (2.5Y 5/4) when moist; massive (structureless); extremely hard when dry, extremely firm when moist; calcareous; common, medium, prominent, whitish (N 8/0) threads and nests of gypsum.

The principal variations in these soils are in the thickness of the horizons, in the depth to unweathered shale, and in the amount of gypsiferous salts within the profile. The salts do not accumulate in amounts harmful to plants, except in small, isolated areas. These areas are recognizable by the presence of inland saltgrass in the native vegetation. The A1 horizon ranges from 4 to 8 inches in thickness. The C horizon begins at a depth of 16 to 24 inches, and it extends downward to shale, which is at a depth of 4 to 8 feet.

These soils are moderately well drained. Runoff is rapid and internal drainage is very slow.

Randall series.—The soils of the Randall series are dark and clayey. They have no profile development. These soils are on the floors or beds of large, intermittent lakes, and they have no natural surface drainage. Water covers them for long periods after rainy seasons. These soils are in the Grumusol great soil group. The following describes a typical profile of Randall clay, in a large depression 800 feet south and 800 feet west of the northeastern corner of SE¼ sec. 7, T. 13 S., R. 34 W.:

A1—0 to 12 inches, dark-gray (10YR 4/1) clay, black (10YR 2/1.5) when moist; only a suggestion of weak, fine, granular structure; extremely hard when dry, very firm when moist; noncalcareous; upper 7 inches weakly calcareous because of recent recharge as the result of drainage from the uplands; gradual boundary.

A12—12 to 28 inches, dark-gray (10YR 4.5/1) clay, black (10YR 2/1.5) when moist; massive, but in places a weak suggestion of fine, subangular blocky structure; extremely hard when dry, very firm when moist; noncalcareous; gradual boundary.

AC—28 to 48 inches, gray (10YR 5/1) clay, very dark gray (10YR 3/1.5) when moist; massive (structureless); few, fine, distinct mottles of reddish brown (5YR 4/3); extremely hard when dry, very firm when moist; noncalcareous; diffuse boundary.

C—48 to 64 inches +, gray (10YR 6/1) clay, dark grayish brown (10YR 4/2) when moist; massive (structureless); extremely hard when dry, very firm when moist; calcareous; a few fine threads or soft concretions of $CaCO_3$.

The A1 and A12 horizons combined range from 20 to 30 inches in thickness. Some variation occurs in the amount of mottling in the lower horizons. Crystals of calcium sulfate, ($CaSO_4$) are in areas where water from places underlain by Pierre shale drains onto these areas. The Randall soils are generally noncalcareous to a depth of 3 feet or more, except in areas where runoff from the adjacent loessal soils has recharged the surface layer with lime.

These soils are very poorly drained. Runoff is ponded and internal drainage is very slow. Water from rainfall often collects and stands on them for several weeks at a time. In some places ground water is at a great depth, and in other places it is lacking.

Richfield series.—The Richfield soils are dark and are moderately fine textured. They formed in silty loess that mantles the flat tablelands. These soils have a well-developed profile. They are in the Chestnut great soil group. The following describes a typical profile of Richfield silt loam in a cultivated field 0.15 of a mile south and 500 feet east of the northwestern corner of sec. 18, T. 15 S., R. 37 W.:

A1p—0 to 5 inches, dark grayish-brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) when moist; compacted, and lower 1½ inches has weak, platy structure; slightly hard when dry, friable when moist; noncalcareous; abrupt boundary.

B1—5 to 11 inches, dark grayish-brown (10YR 4.5/2.5) silty clay loam, very dark grayish brown (10YR 3.5/2.5) when moist; moderate, medium, subangular blocky structure; hard when dry, firm when moist; thin, continuous clay films that do not clog the pores; noncalcareous; clear boundary.

B2—11 to 18 inches, grayish-brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3.5/2.5) when moist; compound, weak, medium, prismatic structure that breaks to moderately strong, fine and medium, subangular blocky structure; hard when dry, firm when moist; thin, continuous clay films that have open pores; lower 2 inches is calcareous; gradual boundary.

B2ca—18 to 27 inches, light brownish-gray (10YR 6/2) silt loam, dark grayish brown (10YR 4.5/2) when moist; weak, medium, subangular blocky structure; slightly hard when dry, friable when moist; few, fine, prominent, white (N 8/0) streaks and films of soft, segregated $CaCO_3$ and few, fine, distinct, very dark grayish-brown (10YR 3/2) stains made by organic matter; calcareous; gradual boundary.

Cca—27 to 38 inches, light-gray (10YR 6.5/2) silt loam, grayish brown (10YR 5/2) when moist; weak, medium, subangular blocky structure slightly hard when dry, friable when moist; common, fine, prominent, white (N 8/0) streaks and films of soft, segregated $CaCO_3$; calcareous; diffuse boundary.

C—38 to 48 inches +, light-gray (10YR 6.8/2) silt loam, grayish brown (10YR 5.5/2) when moist; massive; friable when moist; calcareous loess, probably of Peorian age.

Variations in these soils are chiefly in the thickness of the solum and in the degree of profile development. The A1 horizon ranges from 4 to 7 inches in thickness. The content of clay in the B2 horizon ranges from 34 to 38 percent by volume. The structure of the B2 horizon ranges from moderately strong, fine and medium, subangular blocky to moderate, medium, subangular blocky. The depth to lime and to the lower boundary of the B2 horizon ranges from 10 to 22 inches.

These soils are well drained. Runoff and internal drainage are medium.

Ulysses series.—The Ulysses series consists of deep, dark, medium-textured, loessal soils of the uplands. The profile of these soils is not so well developed as that of the Keith soils, but it is better developed than that of the Colby soils. The B2 horizon of the Ulysses soils contains less clay, has a weaker structure, and is more friable than that of the Richfield soils. The Ulysses series is made up of Chestnut soils that intergrade toward Regosols. The following describes a typical profile of a Ulysses slit loam, in a cultivated field 653 feet east and 233 feet south of the northwestern corner of SW¼ sec. 36, T. 12 S., R. 35 W. This site was sampled for the soil characterization analyses, shown in table 14. Its sample numbers are S–57–Kans–55–3–(1–7).

Alp—0 to 5 inches, dark grayish-brown (10YR 4/1.5) silt loam, very dark grayish brown (10YR 3/2) when moist; weak, fine and very fine, granular structure; slightly hard when dry, friable when moist; noncalcareous; abrupt, smooth boundary.

A1—5 to 7 inches, dark grayish-brown (10YR 4/2) light silty clay loam, very dark grayish-brown (10YR 3.5/2) when moist; moderate, fine, granular structure; slightly hard when dry, friable when moist; weakly calcareous; gradual boundary.

B2—7 to 14 inches, grayish-brown (10YR 5/2) light silty clay loam, very dark grayish brown (10YR 3.5/2) when moist; weak, medium, subangular blocky and moderate, fine, granular structure; weak, patchy clay films; hard when dry, firm when moist; calcareous, gradual boundary.

Bca—14 to 25 inches, light-gray (10YR 7/2) heavy silt loam, grayish brown (10YR 5.5/2.5) when moist; weak, coarse, prismatic and weak, coarse, subangular blocky structure; slightly hard when dry, friable when moist; calcareous and has fine threads of $CaCO_3$ on the surfaces of peds; gradual boundary.

BC1—25 to 36 inches, light-gray (10YR 7/2.5) silt loam, brown (10YR 5/3) when moist; weak, coarse, prismatic and weak, coarse, subangular blocky structure; soft when dry, friable when moist; calcareous; gradual boundary.

BC2—36 to 48 inches, light-gray (10YR 7/2.5) silt loam, brown (10YR 5/3) when moist; weak, coarse, prismatic and weak, coarse, subangular blocky structure; soft when dry, friable when moist; calcareous; diffuse, smooth boundary.

C3—48 to 63 inches +, light-gray (10YR 7/2.5) silt loam, brown (10YR 5/3) when moist; massive (structureless); soft when dry, very friable when moist; calcareous.

When dry, these soils are dark grayish brown (10YR 4/2) or darker to a depth as great as 15 inches. The minimum limit of development is an A1 horizon, 6 to 8 inches thick, that is not lighter than grayish brown (10 YR 5/2) when the soils are dry. The A1 horizon is calcareous in cultivated areas and noncalcareous to a depth of 6 inches in areas that have not been cultivated. The content of clay in the B2 horizon does not exceed 32 percent.

These soils are well drained. Runoff is medium to rapid and internal drainage is medium.

Ulysses series, heavy textured variant.—This variant from the Ulysses series consists of light-colored, calcareous, moderately fine textured soils of the uplands. These soils have no textural horizonation. They were formed in local loess from weathered Pierre shale or from a mixture of local and regional loess. They are Regosols. The following describes a typical profile of Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes, in an unfenced area of native grass, 150 feet east and 100 feet north of the intersection of U.S. Highway No. 40 and the township road along the east side of sec. 24, T. 12 S., R. 37 W.:

A1—0 to 6 inches, grayish-brown (10YR 5.5/2) silty clay loam, dark grayish brown (10YR 3.5/2) when moist; weak, fine and medium, granular structure; hard when dry, firm when moist; numerous roots; slightly calcareous; clear boundary.

AC—6 to 16 inches, grayish-brown (10YR 5.5/2) silty clay loam, dark grayish brown (10YR 3.7/2) when moist: weak, medium and coarse, subangular blocky structure but breaks to weak, fine and medium, granular structure; very hard when dry, firm when moist; numerous roots; calcareous; gradual boundary.

C—16 to 64 inches, light grayish-brown (10YR 6.5/2) silty clay loam, grayish brown (10YR 4.5/2) when moist; common, medium, distinct, white (N 8/0) mottles of crystalline salts; massive (structureless) but has a suggestion of weak, coarse, prismatic structure formed by leader roots that have made cleavage planes in the soil mass; hard when dry, firm when moist; few roots to a depth of 40 inches; calcareous.

The A and AC horizons are thinner than those in the profile described. The C horizon also contains less clay in areas of these soils that grade to the adjoining Ulysses soils formed in Peorian loess. The content of clay in the profile is generally uniform, but it ranges from 42 percent near the source of the local loess to 35 percent at the greatest distance.

These soils are well drained. Runoff is medium; internal drainage is slow.

Volin series.—The Volin series is made up of deep, dark, medium-textured soils that were formed on low terraces and valley sediments. The soils are leached of lime to a depth of 16 inches or more. These soils are in the Alluvial great soil group but are associated with the Chestnut soils. The following describes a typical profile of Volin silt loam in a cultivated field 1,120 feet south and 100 feet west of the northeastern corner of sec. 20, T. 13 S., R. 36 W.:

A1—0 to 16 inches, very dark grayish-brown (10YR 3.5/2) silt loam, very dark brown (10YR 2.5/2) when moist; moderate, fine, granular structure; slightly hard when dry, friable when moist; noncalcareous; clear boundary.

AC—16 to 26 inches, dark grayish-brown (10YR 4/2) light silty clay loam, very dark grayish brown (10YR 3.5/2) when moist; weak, fine and medium, subangular blocky structure; hard when dry, friable when moist; upper part of horizon is noncalcareous, but lower 3 inches is slightly calcareous; gradual boundary.

A1b—26 to 40 inches, dark grayish-brown (10YR 4/2) light silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate, fine and medium, subangular blocky structure; very hard when dry, firm when moist; calcareous, few fine clusters of soft, segregated lime; gradual boundary.

C—40 to 60 inches +, light brownish-gray (10YR 6/2) heavy silt loam, grayish brown (10YR 4.5/2) when moist; massive (structureless); soft when dry, friable when moist; calcareous; a few fine clusters of segregated lime.

The horizons in this soil are not stratified. Buried horizons are common, but they are not present in all areas. No mottling occurs within the uppermost 40 inches.

These soils are well drained. Runoff and internal drainage are medium. The water table normally stands below a depth of 6 feet.

Mechanical and Chemical Analyses of Soils, and Clay Mineralogy

The data obtained by mechanical and chemical analyses for Keith silt loam and for Ulysses silt loam are given in table 14. A representative profile of each of these two soil types is described in the section "Formation, Classification, and Morphology of Soils." The data in table 14 can be used by soil scientists in classifying soils and in making interpretations concerning them.

Methods of Analyses[9]

All samples used to obtain the data in table 14 were collected from carefully selected pits. Unless otherwise noted, all laboratory analyses were made on the material that had passed a 2-millimeter sieve and are reported on an ovendry basis.

Standard methods of the Soil Survey Laboratory were used to obtain most of the data in table 14. Determinations of the amount of clay were made by using the pipette method (*8*, *9*, *11*). The reaction of the soil material in a saturated paste and of that in a 1:10 water suspension was determined by measuring with a glass electrode. The calcium carbonate equivalent was determined by measuring the volume of carbon dioxide emitted when the soil samples were treated with concentrated hydrochloric acid. Organic carbon was determined by wet combustion, using a modification of the Walkley-Black method (*12*).

To determine the extractable calcium and magnesium, the calcium was separated as calcium oxalate and the magnesium was separated as magnesium ammonium phosphate (*12*). Extractable sodium and potassium were determined on original extracts by direct distillation of absorbed ammonia (*12*). The base saturation is 100 percent in the horizons that were analyzed, but it was not determined for horizons that contain free carbonate.

Clay Mineralogy[10]

The mineralogy of the clay fraction in the profiles of the Keith and Ulysses soils was determined by X-ray diffraction, in the Geology Research Laboratory of the Kansas State Highway Commission in Manhattan. The clay less than 2 microns in diameter was removed from a dispersed suspension with a hook-type siphon. Three milliliters of the clay suspension were allowed to dry on a glass microscope slide. After they dried, the oriented clay particles gave only basal reflections in the X-ray diffraction analysis. A Geiger counter diffractometer was used. Specimens were exposed to nickel-filtered copper radiation before and after treatment with ethylene glycol.

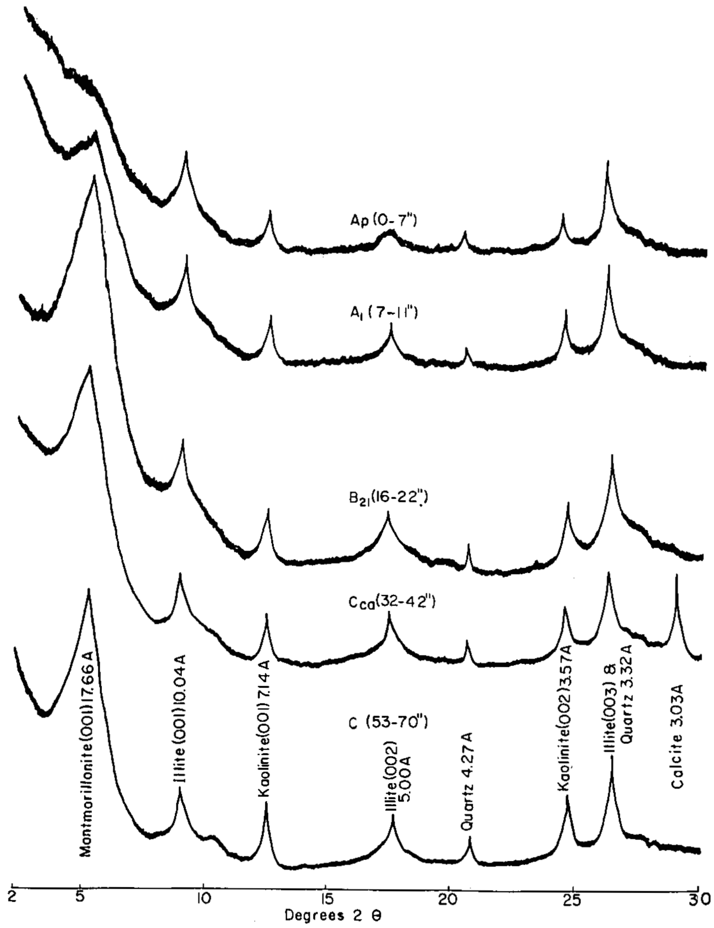


Figure 29.—**X-ray diffraction patterns of the glycolated clay fraction, less than 2 microns in diameter in a profile of the Keith soil.**

The X-ray diffraction analyses of the Keith profile are given in figure 29. The analyses of the Ulysses soil are not given, because of their similarity to those of the Keith soil. Samples of the Keith soil are from profile S–57–Kans–55–2. Those of the Ulysses soil were taken in section 6, T. 13 S., R. 34 W., a different location from that in which the profile samples for the characterization analyses were taken.

The X-ray identification of montmorillonite was based on a 12 to 14 A° basal reflection that expanded to 17.6 A° after the sample was treated with ethylene glycol. Illite was identified by the 10 A° basal reflection and by other basal reflections with a 10 A° periodicity that remained unchanged after ethylene glycol was added. The identification of kaolinite was based primarily on an integral series of orders related to a 7.1 to 7.2 A° periodicity that did not change after the ethylene glycol was added, after

[9] By members of the staff of the Soil Survey Laboratory, Soil Conservation Service, Lincoln, Nebr.

[10] By W. A. Badgley and C. F. Crumpton, research geologists, Kansas State Highway Commission.

TABLE 14.—*Chemical and mechanical analyses of two soils*

Soil, location, and sample number	Depth	Particle-size distribution			Bulk density	Moisture held			pH		$CaCO_3$ equivalent	Organic matter			Extractable cations					Cation exchange capacity (NH_4Ac)
		Clay (<0.002 mm.)	Silt (0.002 to 0.05 mm.)	Sand (0.05 to 2.0 mm.)		1/10 atmosphere	1/3 atmosphere	15 atmospheres	1:1	1:10		Organic carbon	Nitrogen	C/N ratio	Ca	Mg	H	Na	K	
Keith silt loam (NW¼SW¼ sec. 36, T. 11 S., R. 35 W.):	*Inches*	*Percent*	*Percent*	*Percent*	*Gms. per cc.*	*Percent*	*Percent*	*Percent*			*Percent*	*Percent*	*Percent*		*Meq. per 100 gm.*	*Meq. per 100 gm.*	*Meq. per 100 gm.*	*Meq. per 100 gm.*	*Meq. per 100 gm.*	*Meq. per 100 gm.*
S-57-Kans-55-2-1	0-4	24. 8	67. 1	8. 1	(1)	46. 1	26. 2	11. 4	7. 3	8. 0	(2)	1. 54	0. 143	10. 8	19. 3	3. 4	1. 2	(2)	3. 3	23. 2
S-57-Kans-55-2-2	4-6	26. 8	64. 0	9. 2	(1)	45. 8	27. 8	12. 3	7. 0	7. 6	(2)	1. 50	. 134	11. 2	18. 4	3. 4	2. 0	(2)	2. 7	23. 6
S-57-Kans-55-2-3	6-11	29. 6	60. 4	10. 0	1. 30	45. 4	29. 3	13. 4	6. 8	7. 4	(2)	1. 16	. 102	11. 4	18. 6	4. 2	2. 0	(2)	1. 8	24. 6
S-57-Kans-55-2-4	11-17	29. 3	61. 5	9. 2	(1)	44. 6	29. 4	13. 3	7. 0	7. 6	(2)	. 76	. 075	10. 0	19. 4	4. 6	1. 2	(2)	1. 4	24. 7
S-57-Kans-55-2-5	17-21	27. 2	63. 6	9. 2	(1)	40. 2	28. 4	12. 8	7. 8	8. 7	1	. 59	. 067	9. 0	(1)	(1)	(1)	(2)	1. 5	23. 8
S-57-Kans-55-2-6	21-33	29. 7	61. 9	8. 4	1. 35	41. 2	31. 0	13. 9	8. 2	9. 0	8	. 39	. 047	8. 0	(1)	(1)	(1)	0. 1	2. 1	22. 1
S-57-Kans-55-2-7	33-41	30. 4	60. 1	9. 5	(1)	42. 7	31. 3	13. 6	8. 2	9. 0	8	. 32	(2)	(1)	(1)	(1)	(1)	. 2	2. 7	23. 5
S-57-Kans-55-2-8	41-57	22. 8	65. 7	11. 5	1. 20	43. 4	28. 8	12. 0	8. 2	9. 1	8	. 21	(2)	(1)	(1)	(1)	(1)	. 3	2. 9	21. 7
Ulysses silt loam (NW¼NW¼ sec. 36, T. 12 S., R. 35 W.):																				
S-57-Kans-55-3-1	0-5	25. 1	62. 7	12. 2	(1)	42. 9	24. 5	11. 2	7. 4	8. 1	(2)	1. 35	. 136	9. 9	21. 4	3. 4	. 8	(2)	3. 2	23. 2
S-57-Kans-55-3-2	5-7	27. 9	61. 9	10. 2	(1)	39. 1	28. 6	13. 1	8. 0	8. 7	2	1. 03	. 104	9. 9	(1)	(1)	(1)	(2)	1. 6	24. 0
S-57-Kans-55-3-3	7-14	29. 8	61. 3	8. 9	1. 16	38. 4	28. 3	13. 6	8. 0	8. 7	3	. 79	. 083	10. 0	(1)	(1)	(1)	(2)	1. 2	24. 7
S-57-Kans-55-3-4	14-25	25. 9	64. 8	9. 3	(1)	40. 6	29. 4	14. 0	8. 1	8. 9	10	. 52	. 056	9. 0	(1)	(1)	(1)	. 1	1. 7	23. 1
S-57-Kans-55-3-5	25-36	21. 9	68. 1	10. 0	1. 24	43. 8	28. 9	11. 9	8. 1	9. 1	10	. 25	(2)	(1)	(1)	(1)	(1)	. 2	2. 2	22. 0
S-57-Kans-55-3-6	36-48	17. 1	71. 3	11. 6	(1)	43. 5	25. 7	10. 2	8. 3	9. 2	7	. 18	(2)	(1)	(1)	(1)	(1)	. 3	2. 2	20. 9
S-57-Kans-55-3-7	48-63+	18. 9	69. 9	11. 2	(1)	44. 2	24. 9	10. 6	8. 2	9. 1	7	. 18	(2)	(1)	(1)	(1)	(1)	. 4	2. 4	21. 0

[1] Not determined.
[2] Below minimum reportable.

heating to 400° C., or after treatment with warm hydrochloric acid.

The clay from the lowest three horizons of the Keith soil is approximately two-thirds montmorillonite, one-fourth illite, and one-tenth kaolinite, and it also contains small amounts of iron-rich chlorite, calcite, and quartz. This estimate of composition agrees with the exchange capacity determined by chemical methods. The soil material in the Ap and A1 horizons is approximately the same, but no estimate of its composition was made, because these horizons have weaker and more diffuse montmorillonitic peaks than the other horizons. This condition, which is exhibited by many of the loessal soils of the area, is attributed to less crystal structure and a greater degree of randomness of the montmorillonitic clay.

Additional Facts About the County

In this section the history and development of the county are discussed and the agriculture and wildlife are described. The statistics on agriculture are mainly from the biennial reports of the Kansas State Board of Agriculture, but they are partly from reports of the U.S. Bureau of the Census.

Settlement and Population

Before the Homestead Act of 1862 was passed, the area now occupied by Logan County was inhabited primarily by nomadic Indians. The few white people were mostly cattle ranchers who operated large ranches. At that time, the only means of transportation and communication was by stagecoach or by wagon train over the Butterfield Trail, which crossed the county on the north side of the Smoky Hill River. Remains of this trail can still be traced in the county.

During the period just after the Civil War, many of the ranchers from this area marketed their cattle by gathering them into large herds and driving them to northern markets or to the nearest railroad shipping yard. Before the Union Pacific Railroad reached Fort Wallace in 1868, many of these herds were driven through the county.

In these early days, Indian uprisings took place from time to time in this area. The last of these was the German Massacre, which occurred on September 11, 1874, 6 miles east of Russell Springs on the Butterfield Trail. After hostilities had ended, more homesteaders moved into the area. The influx of settlers, the greatest of which took place in the years 1885 and 1886, eventually brought about the end to large-scale ranching.

Most of the homesteaders were Civil War veterans and their families. These early settlers had to bring their own livestock, farming implements, and seeds with them. Because of the lack of trading centers and transportation to markets, they were forced to provide their own livelihood by growing crops and raising livestock. The 160-acre tracts provided by the Homestead Act were found to be uneconomical to operate, and many of the settlers were forced to sell their homesteads and move (fig. 30). Many of these homesteads were bought by one person. As a result, holdings became larger and livestock farming became more extensive.

Logan County was created in 1881 out of a part of Wallace County. It was originally named St. John, but the name was changed in 1885. The county government was formed in 1887 when county officers were appointed by the governor.

***Figure 30.*—An old, abandoned farmstead showing the use of Smoky Hill chalk as building stone.**

The population of the county was 3,112 in 1887. By 1900, however, it had decreased to less than half that number as the result of the severe droughts, lack of markets, and other hardships. The population then increased and has remained almost constant since 1910. In 1912, it was 4,240, and in 1960, it was 4,036. Oakley, located in the extreme northeastern corner of the county and the largest town in the county, had a population of 2,190 in 1960. The population is distributed unevenly, largely because of the location of the transportation facilities.

The Union Pacific Railroad and U.S. Highway No. 40 cross the northern part of the county from east to west. They provide direct routes to Denver, Colo., and Kansas City, Mo. U.S. Highway No. 83 and State Highway No. 25 run from north to south. There are a number of graveled and graded roads throughout the county.

The location of the railroad leaves the southern part of the county a considerable distance from an outlet to terminal markets. Agricultural products are often transported from this part of the county by way of State Highway No. 96 and the Missouri Pacific Railroad, which are located in the neighboring counties to the south.

Agriculture

Logan County is basically an agricultural county. It has no industries, but one producing oil well is located in the county. In addition, some sand and gravel for use in constructing roads are obtained from pits in the uplands and from the channel of the Smoky Hill River. Crops and livestock are the main sources of income. In 1959, the total value of farm products sold was $6,909,806, according to the U.S. Bureau of the Census.

Size and number of farms.—Until about 1927, most people believed that this area was too dry for anything but grazing. Few farmers tried to grow cultivated crops. With the coming of tractors and large-scale farming equipment, however, the more nearly level areas of deep soils around Oakley, Monument, and Page City were used for cultivated crops. Then, good yields in a few favorable years when rainfall was above average proved that wheat farming was profitable in those areas. The more progressive homesteaders purchased the land of those who had decided to move. The size of farms began to increase, until 1930 the average size of farms in the county was 1,023 acres.

In recent years there has been a change in the size of farms, in the number of farms, and in the acreage of cultivated land in the county. Because farming operations are now largely mechanized, a large investment has been made in farm machinery and there has been a trend toward larger and fewer farm units. About 26 percent of the 378 farms in the county in 1959 were less than 499 acres in size, but about 56 percent were between 500 and 1,999 acres. Most of the rest contained about 2,000 acres, but a few farms were as large as 12,000 acres.

In this county the acreage in cropland increased markedly during two different periods. The first increase was after World War I, and the second, after World War II. Because of the favorable amount of rainfall and the high prices paid for wheat during those periods, a large acreage of sod was plowed and the soils were used for cultivated crops. In 1935, a total of 261,412 acres was used for crops and 410,253 acres was in grass. In 1945, the acreage used for crops had increased to 307,515 acres and 364,150 acres was in grass. In 1955, the acreage used for crops had increased still further to 353,619 acres and only 318,046 acres was in grass.

Crops.—Table 15 gives the acreage of the principal crops grown in the county. Winter wheat and sorghum are the principal crops, but alfalfa, barley, corn, and rye are also grown. A large acreage of sorghum is grown for forage or is cut for silage and is used by farmers and ranchers to feed livestock on the farm. The implements used for seeding, tilling, and harvesting the wheat and sorghum have been adapted so that they can be used for both crops.

Livestock.—Table 16 shows the kinds and numbers of livestock in the county in stated years. Producing beef cattle is the major livestock enterprise in this county, but sheep are raised extensively. The number of sheep in the county fluctuates annually. During favorable years, large flocks of sheep are moved into the county to graze on winter wheat and on the stubble of grain sorghum.

Farm equipment.—As a result of the nearly level or gently sloping relief in this county, broad areas are favorable for the use of large farming machinery. The development of the tractor has played an important part in the agriculture of the county. Farmers were quick to make use of this source of power. The tractor enabled them to break large acreages of the native sod so that cultivated crops could be grown. Adopting summer fallowing as a dryland cropping practice made it necessary to use large tractors and other equipment for tillage and seeding. The present farming is highly mechanized and makes use of all the advances in power equipment. Each year, fleets of custom combines are moved into the county to help harvest the wheat and grain sorghum.

TABLE 15.—*Acreage of principal crops in stated years* [1]

Crop	1925	1935	1945	1955
	Acres	*Acres*	*Acres*	*Acres*
Wheat	42,368	(2)	93,000	94,000
Corn	34,586	37,684	3,000	390
Sorghum for grain	9,701	17,587	17,250	25,600
Sorghum for forage or silage	13,509	55,967	24,490	41,700
Barley	20,803	14,102	13,780	1,300
Alfalfa	2,174	1,441	580	1,770
Rye	36	(2)	630	390

[1] The acreages given in this table are for harvested acreage of the crop, not including acreage abandoned because of crop failure. The figures are from biennial reports of the Kansas State Board of Agriculture.
[2] Crop failure.

TABLE 16.—*Kinds and numbers of livestock in stated years* [1]

Livestock	1935	1945	1955
	Number	*Number*	*Number*
Horses and mules	2,889	1,480	440
Milk cows	1,580	2,350	1,440
Other cattle	12,946	23,450	29,600
Sheep and lambs	2,569	35,000	19,320
Hogs and pigs	1,347	3,200	1,200
Chickens	(2)	42,500	20,000

[1] According to biennial reports of the Kansas State Board of Agriculture.
[2] Not reported.

Farm tenancy.—Many of the owners and operators of land in this county do not live on the farms they operate. In 1960, there were 150 such absentee operators who farmed in the county. Many of these live 100 miles or more from the land they farm. They are in the county only during the time that is required to prepare the soil and seed a crop, and they may not return until harvesting time. This sometimes presents a problem during periods when there is too little plant cover on the soils to prevent wind erosion. Fields start blowing, and considerable damage may be done to growing crops before the absentee operator can be informed and his machinery mobilized to perform emergency tillage.

Irrigation.—Irrigation has not developed so extensively in Logan County as in the adjoining counties to the south and north. In 1960, approximately 1,400 acres was irrigated. A small acreage of soils on alluvium is irrigated in the valley of the Smoky Hill River. Irrigation in this valley is not likely to become extensive, however, because of the small acreage of irrigable soils. Also, the quality of the water varies in the valley alluvium.

Available ground water is limited for irrigating the soils of the uplands. Therefore, irrigation is not expected to be a significant part of the agriculture in this county.

Wildlife

The plains of western Kansas originally supported a number of large animals, such as bison, elk, deer, and antelope. Other animals were the coyote, badger, prairie dog, skunk, raccoon, and rabbit. Among the game birds were prairie chickens, quail, doves, and migratory water birds, including ducks and geese. The Indians used wild game for their food and clothing, and later the homesteader depended on wild game for his food.

Figure 31.—**Ring-necked pheasants that have found shelter at the edge of a sorghum field. This bird is hunted extensively in Logan County.**

Most kinds of wildlife that were present in the early days, except the bison, gray wolf, and elk, still live in this county. In addition, the ring-necked pheasant has been introduced into the parts of the county used for crops (fig. 31).

The large tract of rangeland that extends through the central part of the county provides a habitat for deer and antelope. The development of ponds for watering livestock and the proper use of the range will improve this rangeland for deer, antelope, prairie chickens, and quail.

Fish and other forms of wildlife provide food and recreation for farmers and ranchers. They also provide some income to the business people in the towns, who sell hunting and fishing supplies and accommodations. During the year ending July 1, 1959, 774 hunting licenses and 741 fishing licenses were sold in Logan County. Each fall many hunters from outside the county come to hunt pheasants. Ducks provide good hunting during years when the large, intermittent lakes are full of water.

Grain crops provide abundant food for pheasants. The greatest need of these birds is year-round woody and herbaceous cover in and adjacent to areas of cropland (fig. 32).

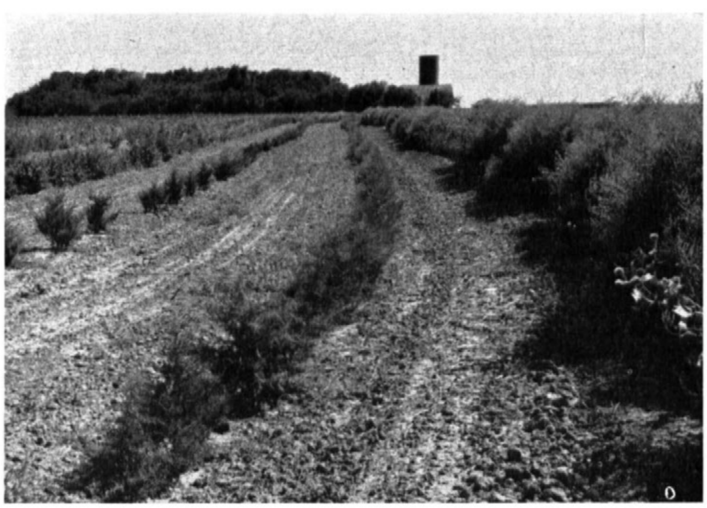


Figure 32.—**Redcedar and deciduous trees and shrubs planted on the contour to provide shelter and food for wildlife. A food planting for wildlife is on the left, and a nesting cover is on the right.**

Some fish are taken from the Smoky Hill River, but most fishing is done in ponds used to water stock and in the Logan County State Lake. Fishing can be increased if greater attention is given to the size and depth of the ponds, to stocking with the proper kinds and numbers of fish, to fertilizing, to controlling aquatic weeds, and to controlling erosion.

The Kansas Forestry, Fish, and Game Commission; the County Extension Service; and the Soil Conservation Service assist local people in developing the wildlife resources of Logan County.

Literature Cited

(1) American Association of State Highway Officials.
1961. Standard specifications for highway materials and methods of sampling and testing. Ed. 8, 2 v., illus.

(2) Baldwin, M., Kellogg, C. E., and Thorp, J.
1938. Soil classification. U.S. Dept. Agr. Ybk. 979–1001.

(3) Bark, L. Dean.
1959. When to expect late-spring and early-fall freezes in Kansas. Kans. State Univ. of Agr. and Applied Sci., Kans. Agr. Expt. Sta. Bul. 415, 23 pp., illus.

(4) Elias, Maxim H.
1931. The geology of Wallace County, Kansas. Univ. of Kans. Bul. 18: 38, 47–48.

(5) Flora, S. D.
1948. Climate of Kansas. Rept. Kans. State Bd. of Agr. 67, 320 pp., illus.

(6) Frye, John C.
1945. Geology and ground-water resources of Thomas County, Kansas. Univ. of Kans. Bul. 59: 24–25.

(7) Johnson, Carlton R.
1958. Geology and ground-water resources of Logan County, Kansas. Univ. of Kans. Bul. 129, pp. 14–15, 40, 92.

(8) Kilmer, V. J., and Alexander, L. T.
1949. Methods of making mechanical analyses of soils. Soil Sci. 68: 15–24.

(9) ———, and Mullins, J. F.
1954. Improved stirring and pipetting apparatus for mechanical analysis of soils. Soil Sci. 77: 437–441, illus.

(10) Moore, Raymond C.
1949. Introduction to historical geology. McGraw Hill Book Co. Inc., New York. 1949: 344, 411–412.

(11) Olmstead, L. B., Alexander, L. T., and Middleton, H. E.
1930. A pipette method of mechanical analysis of soils based on improved dispersion procedure. U.S. Dept. Agr. Tech. Bul. 170, 23 pp., illus.

(12) Peech, M., Alexander, L. T., Dean, L. A., and Reed, J. F.
1947. Methods of soil analysis for soil-fertility investigations. U.S. Dept. Agr. Cir. 757, 25 pp.

(13) Portland Cement Association.
1956. PCA soil primer. 86 pp., illus. Chicago.

(14) Thornthwaite, C. W.
1948. An approach toward a rational classification of climate. Geog. Rev. 38: 55–94, illus.

(15) Thorp, James, and Smith, Guy D.
1949. Higher categories of soil classification: order, suborder, and great soil groups. Soil Sci. 67 (2): 117–126.

(16) U.S. Dept. of Commerce, Weather Bureau.
1961. Rainfall frequency atlas of the United States for duration from 30 minutes to 24 hours and return periods from 1 to 100 years. Tech. Paper No. 40, 115 pp., illus.

(17) Waterways Experiment Station, Corps of Engineers.
1953. The unified soil classification system. Tech. Memo. No. 3-357. 2 v. and appendix. Rev. 1957.

Glossary

Alkali soil. A soil that has such a high content of salts, exchangeable sodium, or both, that the growth of most crops is reduced. In popular usage, saline soils are often called white alkali, and the truly alkaline soils, those that contain exchangeable sodium, are called black alkali. See also Saline soil.

Alluvial fan. A fan-shaped deposit of sand, gravel, and fine material dropped by a stream where the gradient lessens abruptly.

Alluvium. Sediments consisting of sand, silt, or clay that have been deposited by streams.

Calcareous soil. A soil that contains enough calcium carbonate, or often magnesium carbonate, that it fizzes, or forms bubbles, when treated with dilute hydrochloric acid. A soil that is alkaline in reaction because it contains free calcium carbonate.

Caliche. A cemented deposit of calcium carbonate in many soils of warm-temperate areas, as in the Southwestern States. In some places the material consists of soft, thin layers in the soil or of hard, thick beds just beneath the solum; in other places it is exposed at the surface by erosion.

Chalk rock. As used in this report, weakly consolidated rock consisting chiefly of calcium carbonate.

Clay. As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Colluvium. Mixed deposits of soil material and rock fragments, moved by creep, slide, or local wash and deposited at the base of steep slopes.

Eluviation. The movement of material from one place to another within the soil, in either true solution or colloidal suspension. Soil horizons that have lost material through eluviation are said to be eluvial; those that have received material are illuvial.

Gravelly soil material. From 15 to 50 percent of the soil material, by volume, consists of rounded or angular rock fragments that are not prominently flattened and that are as much as 3 inches in diameter.

Horizon, soil. A layer of soil, approximately parallel to the soil surface, that has characteristics produced by the soil-forming processes. Horizons are identified by letters of the alphabet, as follows:

A horizon. The horizon at the surface that has lost soluble minerals and clay through the action of percolating water, that has a dark color because of the accumulation of organic matter, or that shows evidence of both translocation of materials and accumulation of organic matter. The A horizon is a zone of accumulation, or a leached zone. It may be divided into several layers, for example, A1, A2, and A3. An Ap horizon is the part of the A horizon that has been disturbed by cultivation or wind.

B horizon. The horizon where clay or other material has accumulated, or zone of illuviation, where natural structural aggregates are present, or both. This horizon may be subdivided; for example, B1, B2, and B3.

C horizon. The material immediately under the true soil, or solum. In chemical, physical, and mineral composition, this layer is presumed to be similar to the material from which at least part of the overlying soil developed.

Illuviation. The accumulation of material in a soil horizon through the deposition of suspended material and organic matter removed from the horizons above. Because part of the fine clay in the B horizon (or subsoil) of many soils has moved into the B horizon from the A horizon above, the B horizon is called an illuvial horizon.

Krotovina. A former animal burrow in one soil horizon, which has been filled with material from another horizon.

Loess. Geological deposit consisting of fairly uniform, fine material, mostly silt, that presumably was transported by wind.

Marl. An earthy, unconsolidated deposit formed in fresh-water lakes; it consists chiefly of calcium carbonate mixed with various amounts of clay or other impurities.

Morphology, soil. The makeup of the soil, including the texture, structure, consistence, color, and other physical, chemical mineralogical, and biological properties of the various horizons that make up the soil profile.

Mottled. Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage. Descriptive terms are as follows: Abundance—*few, common,* and *many;* size—*fine, medium,* and *coarse;* and contrast—*faint, distinct,* and *prominent.* The size measurements are these: *Fine,* less than 5 millimeters (about 0.2 inch) in diameter along the greatest dimension; *medium,* ranging from 5 millimeters to 15 millimeters (about 0.2 to 0.6 inch) in diameter along the greatest dimension; and *coarse,* more than 15 millimeters (about 0.6 inch) in diameter along the greatest dimension.

Parent material. The horizon of weathered rock or partly weathered soil material from which soil has formed; horizon C in the soil profile.

Permeability, soil. The quality of a soil horizon that enables water or air to move through it. Terms used to describe permeability are as follows: *Very slow, slow, moderately slow, moderate, moderately rapid, rapid,* and *very rapid.*

Poorly graded (engineering). A term used to indicate that a soil consists of particles chiefly of the same or of very nearly the same size or diameter; having a narrow range of particle size and, thus, poor grain-size distribution. Such a soil can be increased in density only slightly by compaction.

Profile, soil. A vertical section of the soil through all its horizons and extending into the parent material. See also Horizon, soil.

Reaction, soil. The degree of acidity or alkalinity of a soil expressed in pH values. A soil that tests to pH 7.0 is precisely neutral in reaction because it is neither acid nor alkaline. In words the degree of acidity or alkalinity is expressed thus:

	pH		*pH*
Extremely acid	Below 4.5	Mildly alkaline	7.4 to 7.8
Very strongly acid	4.5 to 5.0	Moderately alkaline	7.9 to 8.4
Strongly acid	5.1 to 5.5	Strongly alkaline	8.5 to 9.0
Medium acid	5.6 to 6.0	Very strongly alakaline	9.1 and higher
Slightly acid	6.1 to 6.5		
Neutral	6.6 to 7.3		

Saline soil. A soil that contains excess soluble salts, so distributed in the profile as to interfere with the growth of most crops. A saline soil normally is friable and granular because the clay and other colloids have been flocculated, or pulled together, by the chemical action of the salts.

Sand. Individual rock or mineral fragments in soils having diameters ranging from 0.05 millimeter to 2.0 millimeters. Most sand grains consist of quartz, but they may be of any mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.

Silt. Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

Solum. The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in a mature soil consists of the A and B horizons. Generally, the characteristics of the soil material in these horizons are unlike those of the underlying parent material. The living roots and other plant and animal life characteristic of the soil are largely confined to the solum.

Structure, soil. The arrangement of primary soil particles into compound particles or clusters that are separated from adjoining aggregates and have properties unlike those of an equal mass of unaggregated primary soil particles. The principal forms of soil structure are *platy* (laminated), *prismatic* (vertical axis of aggregates longer than horizontal), *columnar* (prisms with rounded tops), *blocky* (angular or subangular), and *granular. Structureless soils* are (1) *single grain* (each grain by itself, as in dune sand) or (2) *massive* (the particles adhering together without any regular cleavage, as in many claypans and hardpans).

Subsoil. Technically, the B horizon; roughly, the part of the profile below plow depth.

Substratum. Any layer beneath the solum, or true soil; the C or D horizon.

Surface soil. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, about 5 to 8 inches in thickness. The plowed layer.

Terrace (geological). An old alluvial plain, ordinarily flat or undulating, bordering a river, a lake, or the sea. Stream terraces are frequently called *second bottoms*, as contrasted to *flood plains*, and are seldom subject to overflow. Marine terraces were deposited by the sea and are generally wide.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. (See also Clay; Sand; and Silt.) The basic textural classes, in order of increasing proportions of fine particles are as follows: Sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

Tilth, soil. The condition of the soil in terms of its relation to growing a plant or sequence of plants. A soil with good tilth is friable, porous, and has stable granular structure. A soil in poor tilth is nonfriable, hard, nonaggregated, and difficult to till.

Variant, soil. A soil having properties believed to be sufficiently different from other known soils to justify a new series name but occurring in so limited a geographic area that creation of a new series is not believed to be justified.

GUIDE TO MAPPING UNITS, CAPABILITY UNITS, RANGE SITES, AND WINDBREAK SUITABILITY GROUPS

[See table 6, p. 13, for the approximate acreage and proportionate extent of the soils; see table 7, p. 36, for estimated average acre yields. For information significant to engineering, see p. 42]

			Capability unit		*Range site*		*Windbreak suitability group*	
Mapping symbol	*Mapping unit*	*Page*	*Symbol*	*Page*	*Name*	*Page*	*Name*	*Page*
Ad	Active dunes	12	VIIe-1	35	Choppy Sands	38	(1)	
An	Alluvial land	12	VIw-1	34	Loamy Lowland	38	Lowland	41
Bl	Badland	12	VIIIs-1	35	(1)		(1)	
Bp	Bridgeport loam	13	IIc-1	30	Loamy Upland	38	Upland	41
Bv	Bridgeport silt loam, strongly calcareous variant.	14	IVs-3	33	Loamy Lowland	38	Chalky	42
Cc	Colby silt loam, 3 to 5 percent slopes	15	IVe-2	32	Loamy Upland	38	Upland	41
Cd	Colby silt loam, 5 to 15 percent slopes	15	VIe-4	34	Limy Upland	38	Upland	41
Dw	Dwyer loamy fine sand	15	VIe-2	34	Sands	39	(1)	
Ea	Elkader silt loam, 0 to 1 percent slopes	16	IIc-1	30	Loamy Upland	38	Chalky	42
Eb	Elkader silt loam, 1 to 3 percent slopes	16	IIIe-1	31	Limy Upland	38	Chalky	42
Ec	Elkader silt loam, 3 to 5 percent slopes	16	IVe-2	32	Limy Upland	38	Chalky	42
Ed	Elkader silt loam, 5 to 15 percent slopes	16	VIe-4	34	Limy Upland	38	Chalky	42
Gr	Gravelly broken land	16	VIIs-3	35	Gravelly Hills	38	(1)	
Ka	Keith silt loam, 0 to 1 percent slopes	17	IIc-1	30	Loamy Upland	38	Upland	41
Kb	Keith silt loam, 1 to 3 percent slopes	17	IIe-1	30	Loamy Upland	38	Upland	41
Lb	Las loam, moderately deep	17	IVw-2	32	Loamy Lowland	38	Lowland	41
Ld	Las Animas sandy loam	18	IVw-2	32	Sandy Lowland	39	Lowland	41
Lk	Likes loamy fine sand	18	VIe-2	34	Sands	39	(1)	
Ll	Lincoln soils	18	VIIw-1	35	(1)		(1)	
Lm	Lismas clay	19	VIIs-2	35	Shale Breaks	40	(1)	
Ln	Loamy broken land	19	VIIs-1	35	Breaks	37	(1)	
Lo	Lofton silty clay loam	19	IVw-1	32	Loamy Upland	38	(1)	
Lu	Lubbock silt loam	20	IIc-2	31	Loamy Lowland	38	Lowland	41
Mh	Manter fine sandy loam, 1 to 3 percent slopes.	20	IIIe-2	31	Sandy	39	Upland	41
Mk	Manter fine sandy loam, 3 to 5 percent slopes.	20	IVe-1	31	Sandy	39	Upland	41
Mn	Minnequa silt loam	21	VIs-1	34	Chalk Flats	37	Chalky	42
Mp	Minnequa-Penrose silt loams	21	VIIs-1	35	Chalk Flats and Breaks	37	(1)	
Ot	Otero fine sandy loam	22	VIe-3	34	Sandy	39	Upland	41
Po	Potter soils	23	VIIs-1	35	Breaks	37	(1)	
Pr	Promise clay, 0 to 1 percent slopes	23	IVs-1	33	Clay Upland	38	(1)	
Ps	Promise clay, 1 to 3 percent slopes	23	IVe-3	32	Clay Upland	38	(1)	
Pt	Promise clay, 3 to 5 percent slopes	23	VIe-5	34	Clay Upland	38	(1)	
Ra	Randall clay	24	VIw-2	34	(1)		(1)	
Rc	Richfield silt loam, 0 to 1 percent slopes	24	IIc-1	30	Loamy Upland	38	Upland	41
Ua	Ulysses silt loam, 0 to 1 percent slopes	24	IIc-1	30	Loamy Upland	38	Upland	41
Ub	Ulysses silt loam, 1 to 3 percent slopes	24	IIIe-1	31	Loamy Upland	38	Upland	41
Uc	Ulysses silt loam, 3 to 5 percent slopes	25	IVe-2	32	Loamy Upland	38	Upland	41
Ud	Ulysses silt loam, 5 to 15 percent slopes	25	VIe-1	33	Loamy Upland	38	Upland	41
Uh	Ulysses silty clay loam, heavy textured variant, 1 to 3 percent slopes.	26	IIIe-1	31	Clay Upland	38	Upland	41
Ul	Ulysses-Colby silt loams, 3 to 5 percent slopes, eroded.	25	IVe-2	32	Limy Upland	38	Upland	41
Um	Ulysses-Colby silt loams, 5 to 15 percent slopes, eroded.	25	VIe-4	34	Limy Upland	38	Upland	41
Vl	Volin silt loam	26	IIc-2	31	Loamy Lowland	38	Lowland	41
Vs	Volin-slickspot complex	26	IVs-2	33	Loamy Lowland	38	(1)	
Wa	Wet alluvial land	27	Vw-1	33	Saline Subirrigated	39	(1)	

1 This mapping unit not assigned to the particular site or group.

Accessibility Statement

This document is not accessible by screen-reader software. The Natural Resources Conservation Service (NRCS) is committed to making its information accessible to all of its customers and employees. If you are experiencing accessibility issues and need assistance, please contact our Helpdesk by phone at (800) 457-3642 or by e-mail at ServiceDesk-FTC@ftc.usda.gov. For assistance with publications that include maps, graphs, or similar forms of information, you may also wish to contact our State or local office. You can locate the correct office and phone number at http://offices.sc.egov.usda.gov/locator/app.

Nondiscrimination Statement

Nondiscrimination Policy

The U.S. Department of Agriculture (USDA) prohibits discrimination against its customers, employees, and applicants for employment on the basis of race, color, national origin, age, disability, sex, gender identity, religion, reprisal, and where applicable, political beliefs, marital status, familial or parental status, sexual orientation, whether all or part of an individual's income is derived from any public assistance program, or protected genetic information. The Department prohibits discrimination in employment or in any program or activity conducted or funded by the Department. (Not all prohibited bases apply to all programs and/or employment activities.)

To File an Employment Complaint

If you wish to file an employment complaint, you must contact your agency's EEO Counselor (http://directives.sc.egov.usda.gov/33081.wba) within 45 days of the date of the alleged discriminatory act, event, or personnel action. Additional information can be found online at http://www.ascr.usda.gov/complaint_filing_file.html.

To File a Program Complaint

If you wish to file a Civil Rights program complaint of discrimination, complete the USDA Program Discrimination Complaint Form, found online at http://www.ascr.usda.gov/complaint_filing_cust.html or at any USDA office, or call (866) 632-9992 to request the form. You may also write a letter containing all of the information requested in the form. Send your completed complaint form or letter by mail to U.S. Department of Agriculture; Director, Office of Adjudication; 1400 Independence Avenue, S.W.; Washington, D.C. 20250-9419; by fax to (202) 690-7442; or by email to program.intake@usda.gov.

Persons with Disabilities

If you are deaf, are hard of hearing, or have speech disabilities and you wish to file either an EEO or program complaint, please contact USDA through the Federal Relay Service at (800) 877-8339 or (800) 845-6136 (in Spanish).

If you have other disabilities and wish to file a program complaint, please see the contact information above. If you require alternative means of communication for program information (e.g., Braille, large print, audiotape, etc.), please contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

Supplemental Nutrition Assistance Program

For additional information dealing with Supplemental Nutrition Assistance Program (SNAP) issues, call either the USDA SNAP Hotline Number at (800) 221-5689, which is also in Spanish, or the State Information/Hotline Numbers (http://directives.sc.egov.usda.gov/33085.wba).

All Other Inquiries

For information not pertaining to civil rights, please refer to the listing of the USDA Agencies and Offices (http://directives.sc.egov.usda.gov/33086.wba).