Some Characteristics of the Pullman Soils on the Amarillo Experiment Station

TEXAS AGRICULTURAL EXPERIMENT STATION
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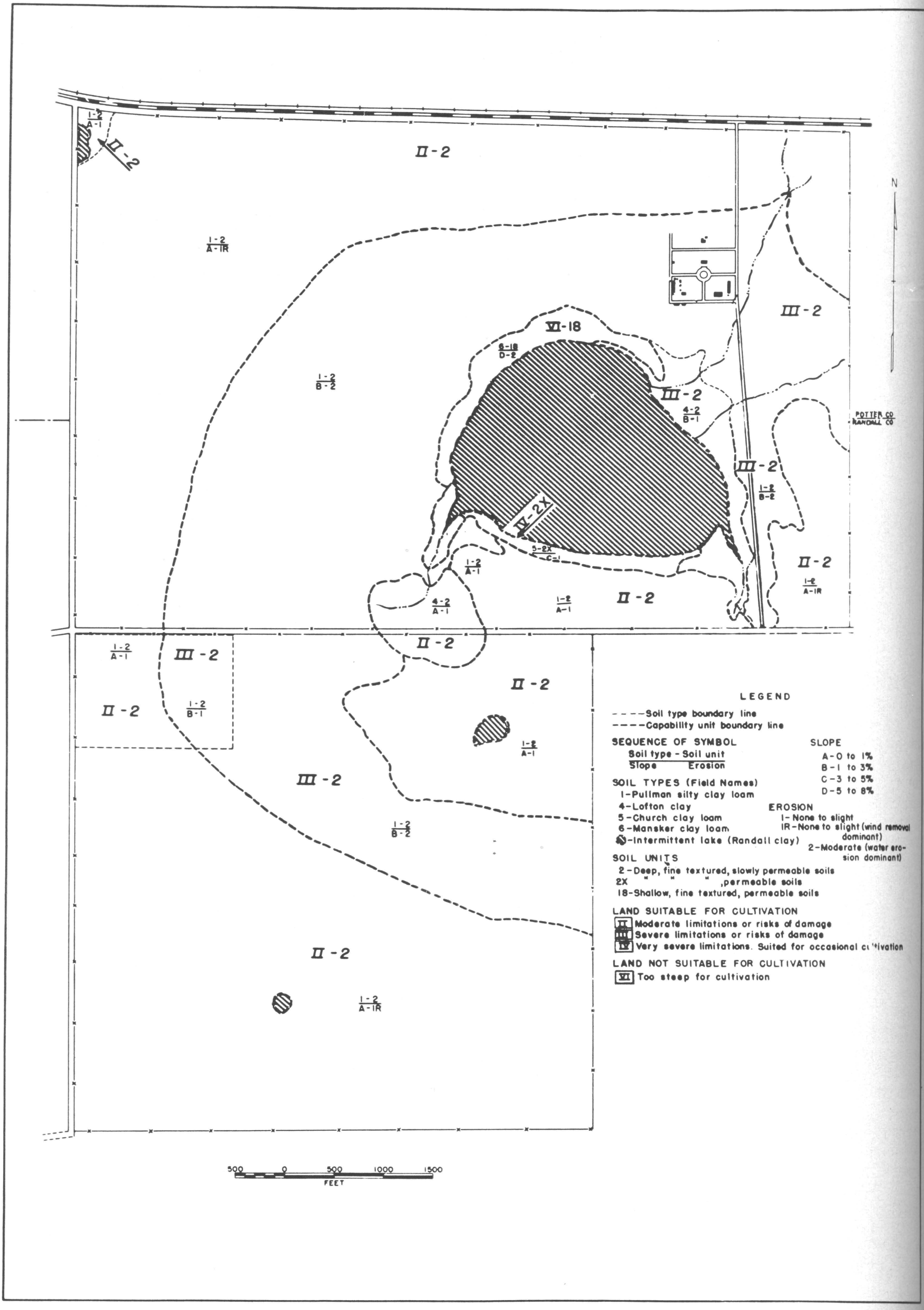

Figure 1. Soils and capability units, Amarillo Experiment Station.

Some Characteristics of the Pullman Soils on the Amarillo Experiment Station

James R. Coover, C. E. Van Doren and Charles J. Whitfield*

THE SOILS on the Amarillo Experiment Station are representative of the some 12,000,000 acres of "hardlands" on the High Plains between Lubbock, Texas, and Clovis, New Mexico, on the south, and Guymon, Oklahoma, on the north. Pullman soils, which are deep and slowly permeable, generally prevail throughout this vast area of relatively uniform soil. They occupy more than 75 percent of the surface and probably about 90 percent of the cropland. The Amarillo station is near the center of these "hardlands" and largely of Pullman silty clay loam.

The soil studies on the station began in 1937 and are concentrated on the Pullman soil. All experimental plots and land in cultivation are of this soil. It is deep, fine textured and slowly permeable. The farm planning conservation survey symbol for this soil is 2-HP.

THE AMARILLO STATION

The Amarillo Experiment Station is located in Potter and Randall counties, 14 miles west of Amarillo, Texas, on U. S. Highway 66. The elevation is 3,825 feet above sea level; the growing season is 196 days; the 14-year annual precipitation averages 18.60 inches; the mean annual temperature is 57° F., and it is not unusual in the spring to have wind velocities of 30 to 35 miles per hour at a height of 2-½ feet above the ground. Climatological data for the period 1939-52 are presented in Appendix A.

The surface of the High Plains is nearly level, except for the numerous enclosed flat bottomed depressions, the low parts of which are occupied by intermittent lakes or playas. These depressions reach a maximum size of several square miles. Most of those larger than 100 acres consist of three parts: (1) a central low flat, occupied by an intermittent lake bed (Randall soils) constituting from one-fourth to one-half of the total area of the depression; (2) a surrounding concentric poorly-drained flat usually known as "second bottom" (Lofton soils); and (3) an outer surrounding slope from one-eighth to one-fourth mile wide, with a slope usually from 1 to 3 percent. Mansker, Zita or Pullman soils of shallow development are usually found on these slopes.

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Table 1. Extent and capability classes of the soils on the Amarillo Station

Soil	Capability Class	Acres
Deep, fine textured, slowly permeable soils of the High Plains. (2-HP)		
Pullman silty clay loam		
On slopes less than 1%	II	914
On slopes of 1 to 3%	III	515
Total Pullman		1429
Lofton clay		
On slopes less than 1%	II	21
On slopes of 1 to 3%	III	21
Total Lofton		42
Total 2 H-P		1471
Deep, fine textured, moderately permeable soils of the High Plains. (2X-HP)		
Church clay loam (on slopes of 3 to 5%)	IV	13
Shallow, fine textured, moderately permeable soil of the High Plains. (18-HP)		
Mansker clay loam (on slopes of 5 to 8%)	VI	17
Intermittent lakes		
Randal clay		115
Total area of station		1,616

SOIL PROFILE DESCRIPTION

A description of a representative profile of Pullman on the Amarillo Station is presented in Appendix B.

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The cultivated land on the station is Pullman silty clay loam and totals 578 acres. In 429 acres of this area, the slope is less than 1 percent and the capability class is II; the other 149 acres have slopes between 1 and 3 percent and are capability class III. Erosion has been slight on the slopes of less than 1 percent, and slight to moderate on those of 1 to 3 percent. Excepting small areas in station headquarters and roads, pasture occupies the remainder and totals approximately 1,020 acres.

MECHANICAL ANALYSIS

The mechanical analysis of a typical Pullman silty clay loam soil under native grass is given in Table 2. Samples for this mechanical analysis were taken from the same locations as the profile described in Appendix B. The soil type name for the Pullman soils on this station is taken from the Soil Survey of Potter County, published in 1929.[1]

Table 2. **Mechanical analysis, reaction and organic matter, Pullman silty clay loam, native grass pasture, Amarillo station**

Depth	Mechanical analysis[1]			Reaction	Organic matter
	Sand	Silt	Clay		
Inches				pH	%
0 - 1½	29.0	52.0	19.0	6.5	3.41
1½ - 5	35.8	37.0	27.2	6.4	2.22
5 - 13	27.0	27.8	45.2	6.8	1.68
13 - 18	25.2	32.0	42.8	7.5	0.94
18 - 30	26.8	31.0	42.2	7.7	0.46
30 - 41	32.8	34.0	33.2	7.7	0.33
41 - 62	28.5	32.5	39.0	7.4	0.17
62 - 80	29.6	29.6	40.8		0.13

[1]This mechanical analysis was made in 1938.

REACTION

The pH of a typical Pullman profile was determined with a Hellige glass electrode. The soil paste had a 2½ to 1 soil-water ratio, Table 2.

These values are in good agreement with measurements made using indicators. The Soil Survey of Potter County stated that the pH of a typical Pullman silty clay loam surface soil was about 6.5.

Depth of Caliche

The depth to the caliche layer, as determined by borings, of the Pullman soils on slopes of less than 1 percent varied from 60 inches to 72 inches. On slopes from 1 to 3 percent the depth to caliche ranged from 26 to 40 inches.

[1]Soil Survey of Potter County, Texas. E. H. Templin, Texas Agricultural Experiment Station, and A. E. Shearin, U. S. Department of Agriculture.

ORGANIC MATTER AND NITROGEN

Studies were made of organic matter and nitrogen levels on the samples taken in connection with the 1947 soil survey. These levels indicate the amount of organic matter and nitrogen present before cultivation or erosion occurred, except for the 0 to 1½-inch depth, which represents an accumulation of recent wind blown material, Table 2.

Information concerning the influence of land use and treatment on soil organic matter was gathered from crop rotation and tillage plots on the station. Organic matter content was studied in 1942, at the time the plots were established, and in 1949 after the plots had been in operation for 8 years. The Walkely-Black method was used for organic matter determinations.

On the rotation plots seeded to grass, the organic matter content of the top 6 inches of soil averaged 2.38 percent in 1942 and 2.34 percent in 1949. Apparently reseeding the land to grass served to maintain the organic matter content of the soil but did not increase it in 6 years.

On another series of plots, tillage by one-waying was compared with sub-surface tillage for raising wheat. The original organic matter content of the plots averaged 2.45 percent in 1942. By 1949, the organic matter content had dropped to 1.92 percent on one-wayed fallow, to 2.14 percent on subtilled continuous wheat, Table 3. The practice of raising continuous wheat was slightly less destructive of soil organic matter than raising wheat on fallow. Differences developing during the 8-year period, however, were too small to be of statistical significance, except in the case of subtilled continuous wheat compared with one-wayed wheat on fallow.

Table 3. **Average percent organic matter at the 0 to 6-inch level under various cropping and tillage practices, Amarillo station**

	Wheat - clean fallow One-way Plow	Wheat - early fallow Sub-surface tillage	Continuous wheat One-way Plow	Continuous wheat Sub-surface tillage
1942	2.45[1]	2.45[1]	2.45[1]	2.45[1]
1949	1.92	2.03	2.10	2.14
Least significant mean difference (5 percent level)				.138

[1]At the time these studies were started, organic matter determinations on these plots averaged 2.45 percent, varying from 2.38 to 2.54 percent.

Table 4 shows the organic matter and nitrogen status of plots receiving various treatments.

The loss of organic matter from continuous row crops is striking. In general, the loss of

Table 4. **Soil nitrogen and organic matter as affected by treatment, Pullman silty clay loam (soil unit 2-HP), Amarillo station**

Plot[1]	Land use 1949	Organic matter		Total nitrogen %		C-N ratio		Pounds N per 6" acre
		0-3"	3-6"	0-3"	3-6"	0-3"	3-6"	
I-1	Native buffalo-blue grama grass	3.05	2.27	.147	.109	12.0	12.1	2540
G-1	Continuous wheat	1.99	1.93	.117	.110	9.9	10.2	2265
G-1	Continuous sorghum	1.66	1.68	.108	.103	8.9	9.5	2055
A-1&7	Wheat on crested wheatgrass sod, plowed out in 1948	2.17	2.17	.117	.113	10.7	11.2	2031
A-3&8	Fallow in rotation	1.92	1.92	.112	.108	9.9	10.4	2308
A-2&5	Sorghum in rotation	1.87	1.91	.118	.112	9.2	9.9	2282
A-4&6	Crested wheat, seeded 1947-48	1.99	1.98	.118	.108	9.8	10.6	2488

[1]The I-1 plot is in native grass. It has never been cultivated, but did receive approximately 1½ inches of accumulation as a result of wind erosion during the 1930's. The G-1 plots have been in continuous wheat or continuous sorghum since 1942, and are located on a field broken out of sod in 1927. The A plots are located on a field broken out in 1917, and the various treatments were started in 1942.

carbon with cultivation is greater than the loss of nitrogen, and a lower C-N ratio results with cultivation. The C-N ratio appears to be a little wider from 3 to 6 inches than in the 0 to 3-inch zone. About a third or fourth of the nitrogen in the entire profile appears to be in the top 6 inches.

VOLUME WEIGHTS

Volume weight studies of the Pullman silty clay loam soil were made by the paraffin clod method, using oven dry clods, Table 5. The values obtained do not represent field conditions, as an unknown quantity of shrinkage occurs between field moisture conditions and oven drying. Volume weight of oven dry clods was determined primarily in an effort to measure changes in soil physical conditions as affected by treatment.

Table 5. **Typical volume weights found by paraffin clod method on Pullman silty clay loam soils, soil unit 2, Amarillo station**

Depth in inches	Volume weight[1]
0 - 12	1.50
12 - 18	1.76
18 - 30	1.77
30 - 41	1.73
41 - 62	1.75

[1] These values are given only as a basis for comparison of the density of oven dry natural aggregates or clods at different depths in the profile. They do not represent volume weights at field moisture conditions.

Volume weights of oven dry clods were determined in 1949 on some grass and rotation plots in an effort to determine the influence of treatment on tillage compaction, Table 6. It was assumed that if differences in density of clods were found after oven drying, that these differences also existed in the field. The results were similar for each soil layer sampled on all plot treatments, with the exception of the 0 to 3-inch zone. Plots that had been in grass 6 years and then returned to a wheat-sorghum-fallow rotation showed a lower volume weight in the 0 to 3-inch soil layer. All other plots were similar in volume weight for the 0 to 3-inch depth.

Field observations indicate that effective aeration of the subsoil for most crops depends on shrinkage of the natural aggregates. Roots follow the cleavage planes of these aggregates. Studies of pore space and aeration based on oven dry clods or natural aggregates would not give a true picture of amounts of soil air available for plant roots in the Pullman silty clay loam soil.

Volume weights under field moisture conditions have not been studied at the station. When studies of shrinkage characteristics and percent moisture values found are considered, it is obvious that the values shown are too high to represent field conditions.

AGGREGATION

The effect of treatment on aggregation was measured by the wet sieving procedure, in which the sample was sieved for 30 minutes with about 36 oscillations per minute.

Studies were made to measure the effect of grasses in the rotation on aggregation, as well as the effects of other treatments, Table 6. All aggregation studies were made on fields of capability unit II - 2-HP, Pullman silty clay loam, on slopes of less than 1 percent, slight erosion.

Additional aggregation measurements were made in mid-September 1950. The procedure was altered in that the sieving time was reduced to 10 minutes, and the original sample was selected from soil granules 2 to 4 mm. in diameter. This might be called an aggregate stability test. Results are shown in Table 7.

The residual effect of grass is shown in the 0 to 3-inch zone of plots A-1 and A-7. Very erratic results were obtained in the 3 to 6-inch layer, possibly due to localized compaction. Below 6 inches, the aggregation was similar for all plots in sorghum, with or without a past history in grass. The plots in fallow were less well aggregated than the sorghum plots.

SOIL-WATER RELATIONSHIPS

Permanent Wilting Point

Permanent wilting point studies on Pullman silty clay loam soils were made in the greenhouse, using dwarf sunflowers. Wilting point values by depths are shown in Table 8.

During the prolonged drouth of 1940, moisture values were determined under various cover conditions on Pullman silty clay loam soils on the station. These values are presented in Table 9.

Table 6. **Physical properties of Pullman silty clay loam soil as affected by treatment, Amarillo station**

Plot	Land use 1949	Aggregation % over ½ mm summer 1949				Volume weight[1] summer 1949			
		0-3″	3-6″	6-9″	9-12″	0-3″	3-6″	6-9″	9-12″
I-1	Native buffalo-blue grama grass	26.9	37.2	48.9	43.7	1.41	1.52	1.75	1.80
I-2	Western wheatgrass, seeded 1943	21.0	28.0	42.0	40.7	1.46	1.49	1.75	1.78
I-4	Crested wheat, seeded 1944	18.7	33.4	38.3	42.3	1.41	1.51	1.65	1.72
G-1	Continuous wheat	7.3	23.6	34.9	36.7	1.41	1.53	1.68	1.76
G-1	Continuous sorghum	3.6	6.7	10.9	28.2	1.38	1.48	1.62	1.79
A-1&7	Wheat on crested wheatgrass sod, plowed out in 1948	10.5	19.7	43.7	43.6	1.24	1.42	1.70	1.76
A-3&8	Fallow in rotation	5.1	10.0	15.2	21.2	1.45	1.64	1.80	1.88
A-2&5	Sorghum in rotation	5.6	5.4	11.4	21.5	1.42	1.50	1.68	1.90
A-4	Crested wheat, seeded 1948	8.0	37.5	47.8	35.0	1.38	1.64	1.75	1.75

[1]Volume weights were measured primarily to see if there was a compact zone due to tillage. Apparently there has been no increase in density due to tillage.

Note: The A plots are located in a field which was originally put in cultivation in 1917. Plots A-1 and A-7 had been in crested wheatgrass for 6 years, 1942-48. The I-2 and I-4 plots were first put in cultivation in 1930. The G-1 plots are located in a field which was originally put in cultivation in 1927, and had been in continuous wheat or continuous sorghum for 8 years prior to 1949.

Table 7. Aggregation of some plots in fallow and in grain sorghum, September 1950, Amarillo station. Average percent of soil in the form of aggregates over ½ mm. in size after sieving

Depth, inches	Field G-12, sorghum	Field A-8, fallow after wheat[1]	Plot A-7 sorghum (old grass plot)	Plot G-1, Continuous sorghum	Plot A-1, sorghum (old grass plot)	Field A-2, fallow after sorghum	L.S.D. 5%	L.S.D. 1%
0-3	5.5	5.1	12.1	4.7	9.5	3.9	2.30	3.11
3-6	19.8	11.8	19.6	11.3	18.9	12.3	8.84	12.00
6-9	31.7	22.8	27.8	29.4	33.7	18.6	7.05	9.55
9-12	33.4	25.3	30.9	35.3	33.7	21.0	6.47	8.76

[1]Seeded to wheat fall of 1949. Wheat died. Fallowed after June 12.

The soils appeared to be very uniform, but some physical differences not apparent in field observation may have existed. Although the moisture values under different cover conditions varied, they do not necessarily indicate the variance in ability of different crops to extract moisture from the soil. Their primary significance is in the moisture deficiencies indicated in the first foot. The low moisture values in the first foot of the pasture soil indicate the amount of rainfall needed to be effective during such conditions of drouth. If the value of 14.0 percent is correct for the wilting point of the first foot of a Pullman silty clay loam soil, then a 6.5 percent moisture deficiency existed, which would have to be met merely to bring the first foot back up to the wilting point. This is equivalent to approximately one inch of moisture.

Table 8. Field capacity and permanent wilting point for Pullman silty clay loam soils on the Amarillo station

Depth	Field capacity[1]	Wilting point
Feet	Percent	Percent
0-1	31.0	14.0
1-2	25.1	14.1
2-3	23.9	13.9
3-4	22.7	13.8

[1]Values from soil moisture tests in the field.

Table 9. Moisture values found in September 1940, after[1] prolonged dry weather, Pullman silty clay loam soils, Amarillo station

Depth	Wheat	Sorghum	Pasture	Weeds
	Percent	Percent	Percent	Percent
0-6″	5.3	6.2	4.1	6.2
6-12″	10.5	13.0	9.0	11.2
1-2′	12.6	12.8	10.0	13.2
2-3′	12.0	11.7	10.4	12.6
3-4′	12.5	12.6	11.0	13.7
4-5′	13.1	14.2	11.0	15.2

[1]At the time samples were taken, all the annual vegetation appeared dead, and the perennial native grasses were dormant. Observations in 1941 showed that a large number of the grass plants died as a result of the drouth of 1940.

Field Capacity

Critical study of field capacities of Pullman silty clay loam soil have not been made by station personnel. However, a study of an exploratory nature was made in the fall of 1941 to gain some knowledge of these values.

In November 1941, soil moisture was found to a depth of 8 feet or more on nearly level slopes. Rainfall for the preceding 13 months had totaled 35.63 inches. Total rainfall for the 4 months prior to the study had been 18.89 inches. During this 4-month period, no living vegetation had been present on the sites sampled. Soil moisture samples were taken in November 1941, and the percentage of soil moisture was determined. At the time of sampling, the fields were in a condition to be worked, and wheat was being drilled on the field at the time of sampling.

For all practical purposes, the soil to a depth of 4 feet was considered to be at field capacity. Normally, under dryland conditions, this moisture level to a depth of 4 feet is not found. The values found are given in Table 8 as field capacity.

Total Available Moisture

Under conditions found in the field in November 1941, following a period of precipitation totaling 35.63 inches in the preceding 13 months, the moisture stored in the first 4 feet could be calculated to total approximately 7.9 inches, using the moisture values given in Table 8 and an assumed volume weight of 1.4.

Soil moisture values such as were found during November 1941, rarely occur under dryland conditions on Pullman silty clay loam soils. These moisture values indicate conditions which should exist under irrigation when deep penetration of irrigation water is achieved.

INFILTRATION AND RUNOFF STUDIES

During the last part of November 1951, a series of runoff studies were made on the Amarillo station, using the infiltrometer developed at the Albuquerque Soil Conservation Service regional office.

This equipment applies water to a plot 51 inches by 6 feet, using 6 spray nozzles with a uniform pressure of 35 pounds. A rain gauge is used on the plot for measuring the amount of rain applied. The pressure for applying the water is furnished by a pump from the power takeoff on a pickup truck. Water is applied at the rate of 3.0 to 3.50 inches per hour for a 42-minute period, both on an initial dry run and on a wet run after a delay of 24 hours. Rainfall and

Table 10. Infiltration and runoff, 1951, Pullman silty clay loam soil, Amarillo station

Plot treatment	Runs	Total water applied	Runoff	Infiltration
		Inches	Inches	Inches
Fallow—one-wayed in a wheat-fallow-wheat rotation	Dry	2.34	1.30	1.04
	Wet	2.29	1.63	0.66
Early fallow—stubble mulch in a wheat-fallow-wheat rotation	Dry	2.24	0.23	2.01
	Wet	2.44	0.60	1.84
Delayed fallow—stubble mulch in a wheat-fallow-wheat rotation	Dry	2.43	0.21	2.22
	Wet	2.45	1.28	1.17
Fallow after sorghum in a wheat-sorghum-fallow-grass rotation	Dry	2.26	1.08	1.18
	Wet	2.47	1.93	0.54
Native grass—good cover, heavily grazed	Dry	2.29	0.86	1.43
	Wet	2.21	1.24	0.97
Native grass—good cover, conservatively grazed	Dry	2.00	0.07	1.93
	Wet	2.18	0.54	1.64

Table 11. Total available calcium, magnesium, sodium and potassium; and sodium and potassium in the saturation extract, Pullman silty clay loam profile, Amarillo station

Horizon (approx)[1]	Depth, inches	Exchange capacity ME.	Total available bases, ME.				Bases in saturation extract, ME.	
			Sodium	Potassium	Calcium	Magnesium	Sodium	Potassium
A_w	0-1½	16.1	.11	1.56	8.0	6.2	.05	.07
A_1	1½-5	16.9	.22	.83	8.8	6.8	.07	.02
B_{2-1}	5-13	23.9	.81	1.51	18.8	8.3	.20	.03
B_{2-2}	13-18	21.7	1.08	1.32	18.8	9.2	.19	.02
B_{ca}	18-30	20.0	1.36	1.10	18.0	7.4	.49	.03
....	30-41	18.2	1.34	.83	17.5	7.0	.56	.03
....	41-62	19.3	1.56	1.04	20.0	6.2	.69	.03
....	62-80	18.3	1.30	.88	20.4	5.4	.60	.02

[1]Sampling depths correspond only approximately with the horizon designations given in the soil profile descriptions. Designation for the lower depths is not definitely known.

runoff readings are taken every 6 minutes. Infiltration refers to the measured differences between the water applied and the runoff.

Determinations were made on the following plots on class II-2 land: wheat-fallow-wheat rotation with one-way disc plow, stubble mulch plow and delayed fallow left undisturbed since harvest; fallow after sorghum in a wheat-sorghum-fallow-grass rotation; and native blue grama-buffalograss pasture heavily and conservatively grazed. Table 10 gives the results on the basis of total water applied.

Total infiltration in 42 minutes from the initial dry run was 2.22 inches on the delayed fallow, 1.93 inches on the native grass conservatively grazed, 1.43 inches on the native grass heavily grazed, 1.18 inches on fallow following sorghum and 1.04 inches on one-wayed fallow. The amount of infiltration was less on the wet run, with some change in the order of treatments having the highest infiltration. The largest amount was on early stubble mulch fallow with 1.84 inches, and followed by native grass conservatively grazed, 1.64 inches, delayed fallow, 1.17 inches, native grass heavily grazed, 0.97 inch, one-wayed fallow, 0.66 inch, and fallow following sorghum, 0.54 inch.

From these preliminary studies, it appears that infiltration can be increased and runoff decreased by two simple practices. The first important one is keeping residues on the surface to intercept and dissipate the energy of the raindrop and prevent sealing over of the surface of the soil. The second step would be to increase the temporary storage capacity of the soil; that is, loosen the surface to allow more pore space for free water storage. This effect was indicated in these studies when early stubble mulch fallow, which had been tilled twice with a stubble mulch sweep machine, had a higher total infiltration on the wet run than any other site. Additional temporary storage in the surface 4 to 5 inches probably accounted for the higher rate on the wet run.

Infiltration by the Ring Method

Infiltration studies were made in 1949 and 1950 using the concentric ring method. In general, the results of all these experiments indicate that the infiltration velocity at the surface of Pullman silty clay loam soils becomes constant at a rate of 0.20 to 0.4 inch per hour or less.

BASE SATURATION AND EXCHANGE CAPACITY, PULLMAN SILTY CLAY LOAM

The samples used in measuring some of the base saturation and exchange properties were obtained at the time the station was established in the fall of 1937. The soil type was classified Pullman silty clay loam, and the sampling location was described as 100′ N and 850′ E of SW corner, Sec. 178, Blk. 9, BS and F Survey. Analyses referred to are those made at the Amarillo station during 1949-50 by W. C. Johnson of the station staff.

Values for exchange capacity, total available sodium, potassium, calcium and magnesium, and sodium and potassium in the saturation extract are given in Table 11.

SOIL TEMPERATURE

Recording soil thermographs were installed at 1 and 3-foot depths in a Pullman silty clay loam soil in the fall of 1938. Cover was reseeded buffalo-blue grama grass which had made a fair cover in 1939. The 3-foot depth soil temperature measurements were discontinued in June 1940. The 1-foot depth soil temperatures are still being recorded.

The maximum, minimum and average soil temperatures at the 1-foot depth by months for 1939 are presented in Figure 2. The same readings for the 3-foot depth are shown in Figure 3. Atmospheric temperatures for 1939 at the station are presented in Figure 4. The year 1939 was fairly representative at the station in respect to climatic conditions.

PRACTICAL INTERPRETATION OF RESULTS

Physical and chemical properties of Pullman soils studied on the Amarillo station are representative for the type.

Nitrogen and organic matter levels have dropped rapidly on the plots planted to continuous row crops. The need for conservation practices which add or maintain organic matter and nitrogen is clearly indicated. This is especially true of irrigated fields farmed continuously to row crops, as well as dryland fields. Studies with legumes are in progress on the station, and grass rotations are being continued for further investigation. Subsurface tillage with wheat, in rota-

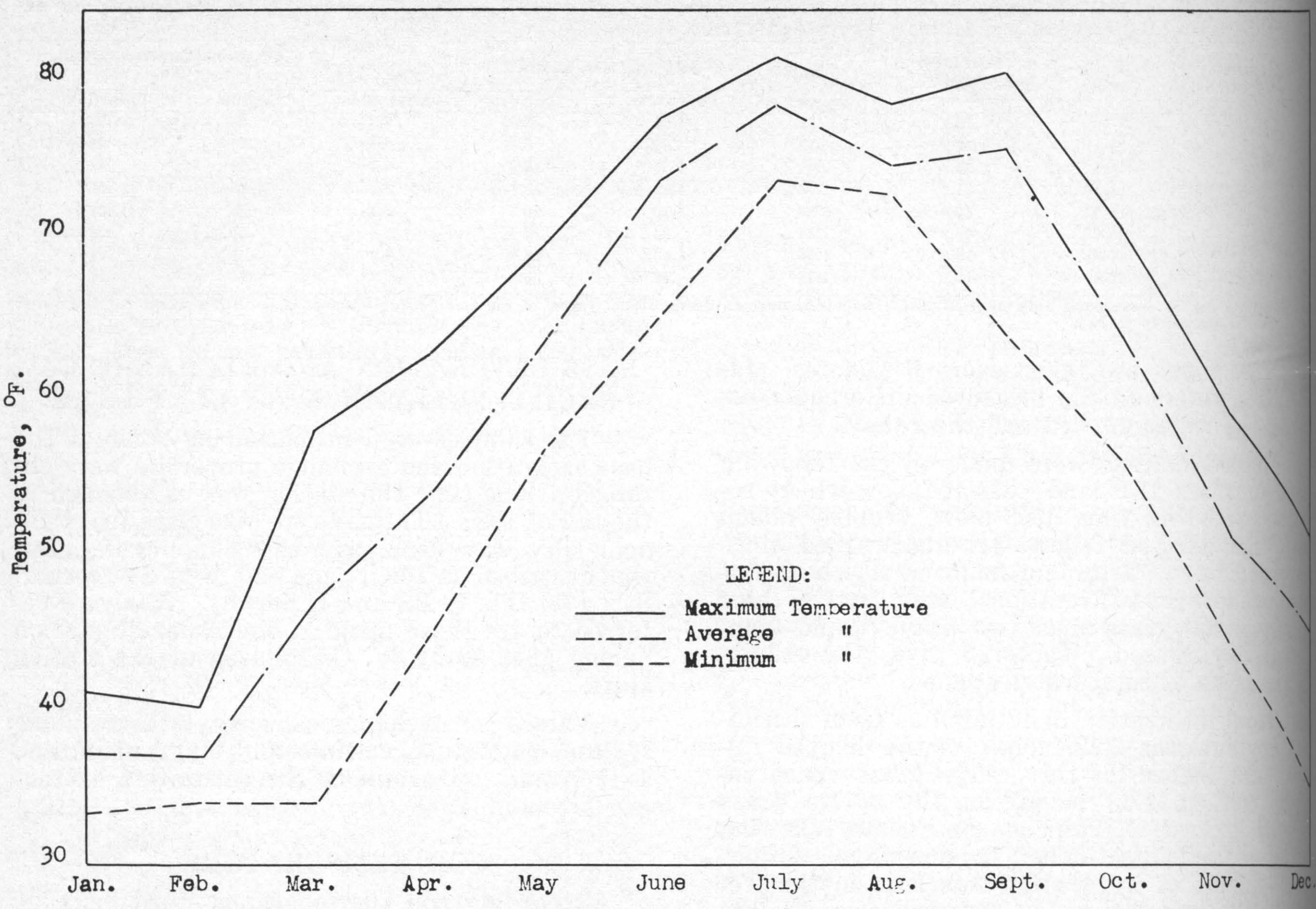

Figure 2. Soil temperatures, 1-foot depth, Pullman silty clay loam soil, 1939, Amarillo Experiment Station

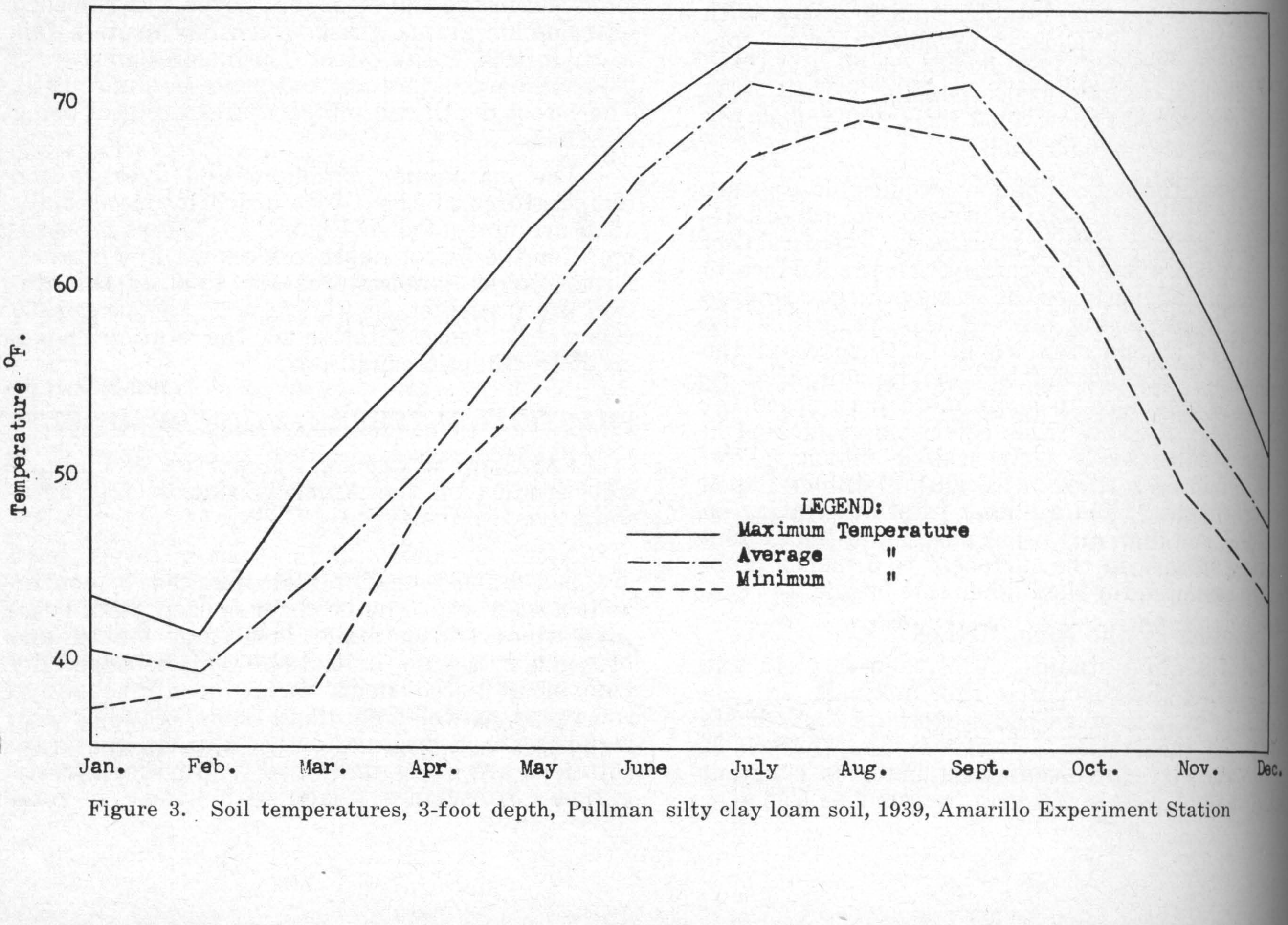

Figure 3. Soil temperatures, 3-foot depth, Pullman silty clay loam soil, 1939, Amarillo Experiment Station

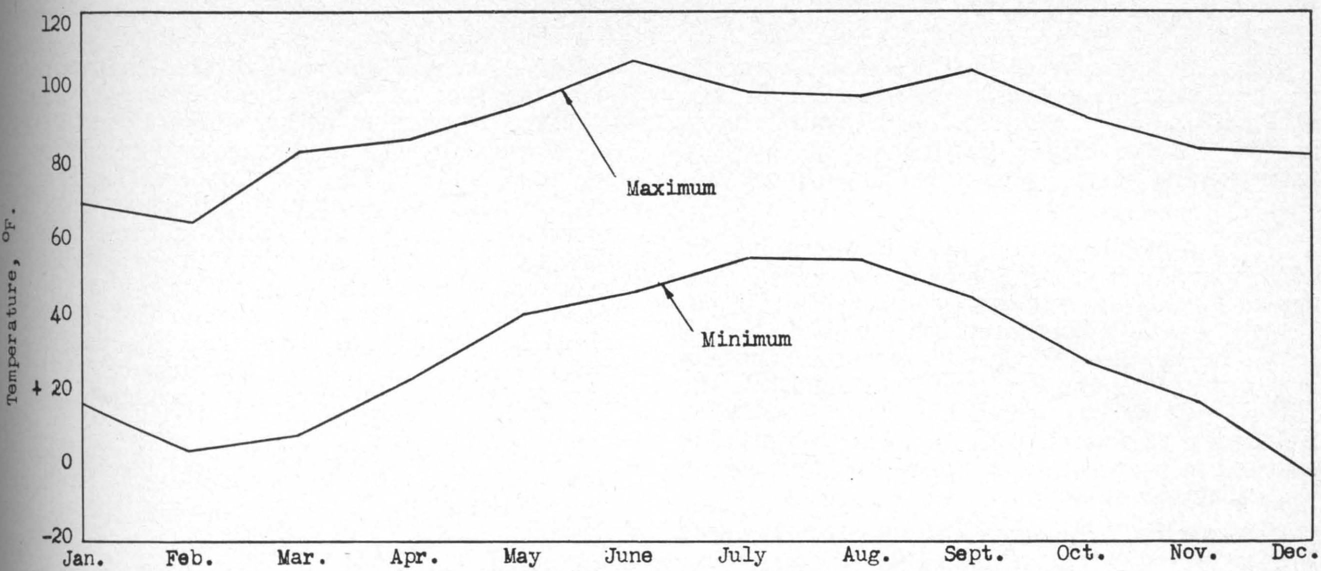

Figure 4. Atmospheric temperatures, 1939, Amarillo Experiment Station.

tion with fallow, appears to be the most conservative of organic matter and nitrogen when soil improving crops are not included in the cropping pattern.

Volume weight studies give values which can be used to compare the density of the different depths of soil in the profile. These studies have also given some clear indications of the value of grasses in rotation, in increasing the pore space and aeration of the Pullman silty clay loam soil, especially in the 0 to 3-inch zone. However, the grasses tested apparently had no effect on volume weight below 3 inches. Indications are that better results might be found in opening the tight clay subsoil if vigorous deep-rooted grasses or legumes with roots larger than 1/20 inch in diameter could be grown successfully.

Aggregation studies give indications of the benefits of grasses on soil structure. They also gave the same indications as volume weight studies of the benefits of grasses in the rotation.

Field capacity and wilting point values found for the Pullman silty clay loam can be used in soil moisture investigations. Total available moisture values give information in the design of irrigation systems and amounts of water to add to bring the soil to field capacity at different moisture levels.

Infiltration studies give a water intake rate of approximately 0.4 inch per hour, which can be used to determine time of water application in a conservation irrigation system. These studies also point to the need for deep-rooted soil improving crops for cultivated lands to improve the low infiltration rates found on these lands. Some cultivated fields were found to stop taking water completely after 200 minutes.

Base saturation and exchange capacity studies of Pullman silty clay loam indicate that it has a high capacity to store plant nutrients, and no toxic effects or plant nutrient deficiencies are indicated.

LAND EVALUATION AND CAPABILITY CLASSIFICATION

Many of the studies of Pullman silty clay loam soil at the Amarillo station give valuable assistance in its capability classification.

Some of the factors evaluated in classification of land are listed following, with their values, as applied to a soil such as Pullman silty clay loam, on slopes from 0 to 1 percent, with slight erosion from wind:

Land Characteristics

Mapping Unit 2 A 1R
Depth of surface soil and subsoil—deep (20 inches or more)
Surface texture—fine (silty clay loam)
Subsoil permeability—slow (0.2-0.8 inches per hour)
Slope—nearly level (0-1 percent)
Erosion—slight wind erosion, none to slight water erosion
Inhibitory factors—none

Interpretation of Land Characteristics

Total available moisture—high (6.88" + in 0 to 3-foot zone)
Plant-soil-moisture relationship—fair
Depth—deep
Fertility holding capacity—high
Wind erosion susceptibility—slight
Water erosion susceptibility—none (short slopes only)

These interpretations show a slight hazard from wind erosion, and a limitation of fair plant-soil moisture relationship. This Pullman silty clay loam soil (soil unit 2) on a nearly level slope with slight erosion is class II land.

On slopes of 1 to 3 percent, the same soil would have a slight wind and water erosion hazard and the limitation of fair plant-soil-moisture relationship and is class III land.

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Wendell C. Johnson, soil scientist, recently resigned, carried out most of the studies on organic matter, nitrogen, base exchange, volume weight and reaction. Other workers on soil properties whose results have been used in this report include Claude L. Fly, Soil Conservation Service, and Luther K. Eby and F. G. Ackerman, both formerly with that agency. Each of these men not only carried out phases of the investigations but prepared some of the material presented in the paper. It was primarily through the efforts of these last four technicians that this paper was made possible, and their contribution to High Plains agriculture is gratefully acknowledged.

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APPENDIX A

Climatological Data—1939-52, Amarillo Experiment Station

Table 12. 14-year summary of precipitation at the Amarillo station, 1939-52

Month	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	Average
January	2.36	0.15	0.03	0.11	T	0.76	0.79	0.55	0.09	0.15	1.81	T	0.58	0.43	0.56
February	0.05	0.49	0.19	0.14	0	0.73	0.16	0.10	T	2.04	0.60	0.33	0.80	0.11	0.41
March	0.09	0.09	1.81	0.43	0.05	T	0.31	0.29	0.33	0.55	0.36	0	0.76	0.73	0.41
April	1.87	0.68	1.17	4.78	0.61	1.80	0.63	0.37	1.22	0.29	2.35	0.38	0.13	2.97	1.38
May	1.17	4.15	5.66	0.20	2.90	3.02	0.36	1.03	5.64	3.32	6.69	1.12	6.25	1.40	3.06
June	4.13	1.13	4.05	1.22	2.12	3.52	1.55	2.03	2.03	2.25	3.45	5.05	3.38	2.00	2.71
July	1.42	0.24	3.06	0.58	5.26	2.66	1.30	0.30	0.84	1.88	3.18	6.99	2.46	2.64	2.34
August	2.99	0.82	3.26	3.53	1.33	3.58	2.70	1.57	1.94	5.09	1.94	2.16	2.17	2.69	2.56
September	0.11	0.55	3.43	1.68	1.15	2.68	4.44	1.44	0.26	1.18	2.51	3.93	0.98	0.33	1.76
October	1.04	0.31	9.14	4.35	0.05	0.69	0.68	7.23	0.12	0.83	1.17	0.11	1.23	0	1.92
November	0.06	3.44	0.21	0	0.18	1.22	T	0.68	0.97	2.79	0	0.02	0.28	1.04	0.78
December	0.79	0.08	0.55	1.48	3.41	1.03	0.01	0.29	0.91	0.01	0.46	0.21	0.29	0.43	0.71
Total	16.08	12.13	32.56	18.50	17.06	21.69	12.93	15.88	14.35	20.38	24.52	20.30	19.31	14.77	18.60

Table 13. 14-year summary of average monthly climatic factors, Amarillo station, 1939-52

Month	Precipitation	Air temperatures		Wind movement	Evaporation	Atmospheric humidity
		Average maximum	Average minimum			
	Inches	Degrees	Degrees	Miles per hour	Inches	Percent
January	0.56	50.1	22.7	7.0		61.1
February	0.41	56.3	26.0	7.9		59.4
March	0.41	64.1	30.2	8.8		50.0
April	1.38	72.5	40.3	8.5	8.352	50.7
May	3.06	79.6	49.7	7.6	9.645	55.8
June	2.71	88.5	59.3	7.5	11.721	52.1
July	2.34	91.1	63.3	6.3	12.279	50.8
August	2.56	90.6	62.2	6.0	11.245	49.9
September	1.76	84.6	54.8	6.8	8.703	51.3
October	1.92	74.6	44.5	6.2		51.5
November	0.78	61.5	31.0	6.4		52.4
December	0.71	53.2	25.4	6.5		59.3
Total or average	18.60	72.2	42.4	7.1	61.945	53.7

Absolute maximum temperature, 107° F. Absolute minimum temperature, 14° F.
Average date of last killing frost in the spring, April 14.
Average date of first killing frost in the fall, October 28.

APPENDIX B

Description of Pullman Silty Clay Loam

Location, approximate center of field I-1 on the Amarillo station. Native pasture of buffalo and blue grama grass. Level upland of ½ per-cent slope. Uneroded, except for approximately 1-½ inches of accumulation as a result of wind erosion during the 1930's. In 1937, the rootstocks of the grass and surface litter were covered by this deposition.

0-1½ inches. Dark brown (7.5YR 4/2; 3/2 when moist) silt loam; weakly platy; non-calcareous; contains few visible pores and few roots; represents accumulation of windblown material; grades to the horizon beneath.

1½-6 inches. Dark brown (7.5YR 4/2; 3/2 moist) silty clay loam; moderate medium granular; friable when moist; very hard when dry; non-calcareous; contains many pores smaller than ½ mm. Roots are most numerous of any horizon in the profile. This rests abruptly on the horizon beneath. A^1 horizon.

6-14. Dark brown (7.5YR 4/2; 3/2 moist) clay. Compound moderate medium blocky and weak granular; the exterior of the aggregate is shiny; firm when moist, very hard when dry; grades indistinctly to the horizon beneath. B^{2-1} horizon.

14-22 inches. Dark brown (7.5YR 4/2 3/2 moist) clay; strong medium and coarse blocky; the large blocks breaking into smaller ones, which have closely fitting faces; few visible pores; very firm when moist; very hard when dry; non-calcareous; roots are largely confined to crevices between larger blocks; grades shortly to the horizon beneath. B^{2-2} horizon.

22-38 inches. Brown (7.5YR 5/3; 4/3 moist) clay; strong medium blocky; firm when moist; very hard when dry; mildly calcareous; contains threads and small aggregates of $CaCO_3$; more porous than horizon above; grades to horizon beneath. B_{ca} horizon.

38-60 inches, plus. Reddish brown (5YR 5/4; 4/4 moist) clay loam; moderate medium blocky and weak medium granular; somewhat prismatic in lower part; relatively porous; contains threads and films of $CaCO_3$. Interior of blocks appear to be non-calcareous in upper part. Caliche was not reached at this depth. In other places, it occurs at a depth of 60 to 72 inches.[1]

[1] The horizon designation for this layer is not known. It could be designated as B_{2b}, the buried horizon of a soil developed on an older material. The parent material of the entire profile is thought to be loess. The caliche found at depths of 60 to 72 inches could be the C_{ca} horizon of the buried soil.