SOIL SURVEY OF THE LOWER ARKANSAS VALLEY, COLORADO.

By MACY H. LAPHAM and PARTY.

LOCATION AND BOUNDARIES OF THE AREA.

The Lower Arkansas Valley area lies in southeastern Colorado. It embraces large areas of land in Otero, Bent, and Prowers counties and is traversed from west to east by the Arkansas River. This stream, one of the few which rise in the mountains of the Rocky Mountain system and, flowing eastward, break through the Great Plains, is of great importance to this section of the State as a source of water supply for irrigation purposes.

This area is one of the most important agricultural sections of the State and is watered by some of the most extensive storage reservoir and canal systems of the arid West. Its soils are famed for their fertility, and the Arkansas Valley is known for its stock-feeding industries and for its production of alfalfa, sugar beets, melons, fruits, honey, vegetables, and other staple articles of food.
The area surveyed has an extent of 945 square miles. For its western boundary the township line 6 miles west of the city of Rockyford, in Otero County, was chosen. From this point the area extends eastward about 100 miles to the Colorado-Kansas State line. Its breadth from north to south varies from 6 to 20 miles, embracing all of the land of the valley bottoms and extending out on the plains to the limits of irrigation.

For convenience the map of the area is published in four sheets, named, from west to east, the Rockyford, Las Animas, Lamar, and Holly sheets.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The early history of this region opens with the exploration of the "Great American Desert," a vast area of land extending westward across the continent from the borders of the semiarid belt. Of indefinite boundaries, this unknown tract has gradually shrunk in extent under the aggressive campaign of the pioneer plainsman until the name by which it was once known has become almost obsolete.

In the early thirties a few venturesome trappers and traders found trading with the friendly Indian tribes for beaver and other pelts profitable and erected temporary headquarters or forts in which they could defend themselves from thieving or murderous bands of savages.

With the further exploration and settlement of the West came the prairie schooner of the pioneer and the armed wagon train of the freighter. Each wagon was generally hauled by from 10 to 12 mules, horses, or oxen, and at night patrols were established to provide against a possible attack by Indians. With immigration from the Eastern and Middle States and the establishment of stage lines bands of outlaws also infested the region.

In 1847 the famous Santa Fe stage line was established, which followed the Santa Fe trail from Independence, Mo., to Santa Fe, N. Mex. Following the discovery of gold on the Pacific coast, this travel was greatly augmented by the freight and prospectors' wagon trains and by the establishment of military posts throughout the West. Many of the towns in the area surveyed were at one time important stations on this stage route.

There are records of the growing of isolated patches of grain and vegetables by the aid of irrigation in the Arkansas Valley as far back as 1854. Grazing was for many years, however, the only important form of agricultural industry practiced, some of the most valuable lands being held in large tracts as grants.

With the encroachment of the settlers and the disappearance of the buffalo before the attacks of the pelt hunters the plains Indians became jealous and more troublesome. At last their depredations assumed such proportions that Colonel Chivington, in command of a Colorado regi-
ment, was sent to punish those who had treacherously taken the war-
path while pretending to be upon friendly terms with the whites. At
Big Sandy Creek, in Kiowa County, some 25 miles north of Lamar, he
met and defeated the allied bands, after which there was no more
trouble from Indians upon the plains of Colorado.

Following the construction of the Santa Fe Railway, which displaced
the stage coach, the settlement of the region was more rapid, and prac-
tical farming began to receive some attention. With the settlement
of the Middle West immigration had gradually pushed the domains of
the practice of dry farming westward. There came a time, however,
when its borders could not be further extended with safety. The
gently undulating or level lands of the Great Plains, by reason of their
easily tillable condition and fertile soil, had always proven very
alluring to the home seeker. With an occasional season or two of
abundant rainfall the tide of immigration rapidly extended into the
subhumid belt. The recurrence of seasons of drought, however,
always rapidly depopulated these sections, leaving only deserted
buildings, abandoned towns, and an occasional broken-down fence as
evidences of their former occupation.

Such has been the case in the eastern portion of the Arkansas
Valley in Colorado, but to a much less extent than in the more
easterly States. Throughout the greater portion of the area, how­
ever, the aid of irrigation has always been recognized as necessary to
the successful practice of agriculture.

About 1872 the construction of the Rockyford Canal, the first large
irrigation system, was begun. Those engaged in grazing soon learned
the value of alfalfa as supplementary to the range in the fattening of
cattle, sheep, and swine. This has brought about the evolution of
the range steer from the wild, long-horned, angular cattle fitted for
market entirely upon the range, to the more stocky modern breeds of
the alfalfa districts. Alfalfa grows luxuriantly and also finds a ready
sale as hay, being shipped in large quantities.

The construction of the Fort Lyon Canal, the largest in the area,
was begun about 1884 and was supplemented and followed by several
other systems. When the practice of irrigation had been established,
the introduction of grains, fruits, and vegetables followed, although
alfalfa continued to be and is yet the staple crop.

Several years ago it was noticed that melons, planted for home use,
acquired an especially fine flavor. This led first to their production
for local markets and gradually to the introduction of the industry
upon a large scale to supply the markets of the East.

Experiments also proved the success of the growing of sugar beets
upon the soils of the valley. Through the efforts of the pioneer
settlers some of the land was divided and settled in small tracts.
These people then, through cooperation with business men, succeeded
in interesting capital, and the American Sugar Beet Factory was erected at Rockyford. With this came rapid development of a more intensive system of agriculture, the establishment of truck farming, and the growing of tomatoes and beans for canning purposes. Fruit growing also has recently become a flourishing and important industry.

**CLIMATE.**

The climate of this district is essentially arid. This condition is a direct result of topographic and atmospheric features and is characteristic of nearly all the western half of the continent, excepting only the mountain regions. The winds, descending to the plains on the eastern side of the mountains, have already been robbed of their moisture. As they reach the plains they are warmed and their capacity for moisture is increased. This condition is generally accompanied by cloudless skies, low relative humidity, high temperatures, and frequently by vigorous wind movement, all of which serve to increase evaporation from the fields and rapidly dwindling streams. These conditions of an abundance of sunshine, dry and pure air, and cool nights are, however, extremely healthful, and the climate of the Arkansas Valley is especially beneficial in cases of pulmonary complaints.

The annual rainfall of this region shows considerable variation in amount from year to year. Series of seasons of a more abundant precipitation sometimes follow those of drought. This has at times given rise to the theory that a permanent climatic change in favor of greater rainfall was taking place over the Great Plains, caused by a more complete settlement and cultivation of the prairie lands. However, by a study of observations covering long periods of time this theory is readily disproved.

During the winter and early spring westerly cyclonic storms occasionally occur. Such disturbances are generally preceded and followed by several hours or days of cloudiness and high winds, with precipitation taking place usually as a gentle rain, lasting two or three days. Rains so falling soak into the soil and do the greatest possible amount of good. In the summer months long-continued rains rarely occur. Local showers, often accompanied by wind and dust storms, thunder, lightning, and hail, are, however, not infrequent. They often assume the proportions of cloudbursts, especially in the vicinity of the foothills and mountains. The water thus falling runs off rapidly, frequently sweeping down the streams and arroyos and causing considerable destruction of property, and is of but little aid in supplying the soil with needed moisture. While not always of a violent nature, the summer showers are so local in character as to be productive of but little good, covering very small areas and often recurring at a given place only at long intervals.
The winters are short and generally mild, sometimes interfering but little with farm labor. Occasionally, however, the cold becomes severe. Such periods are of short duration and are soon followed by mild weather.

During the summer the days are frequently hot, the temperature for the warmest periods ranging from 90° to 105° F. With favorable moisture conditions and the usual prevalence of sunshine this insures rapid plant growth. The nights are generally cool and pleasant, and periods of cool days frequently occur.

The following tables, taken from records of Weather Bureau stations at Rockyford, Las Animas, and Lamar, show the normal monthly and annual precipitation and dates of killing frosts:

<table>
<thead>
<tr>
<th>Month</th>
<th>Rockyford</th>
<th>Las Animas</th>
<th>Lamar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°F</td>
<td>Inches</td>
<td>°F</td>
</tr>
<tr>
<td>January</td>
<td>27.9</td>
<td>0.46</td>
<td>35.6</td>
</tr>
<tr>
<td>February</td>
<td>30.2</td>
<td>0.40</td>
<td>31.6</td>
</tr>
<tr>
<td>March</td>
<td>39.5</td>
<td>0.58</td>
<td>40.6</td>
</tr>
<tr>
<td>April</td>
<td>51.9</td>
<td>1.34</td>
<td>51.4</td>
</tr>
<tr>
<td>May</td>
<td>60.8</td>
<td>2.06</td>
<td>62.0</td>
</tr>
<tr>
<td>June</td>
<td>70.5</td>
<td>1.31</td>
<td>72.6</td>
</tr>
<tr>
<td>July</td>
<td>74.3</td>
<td>3.50</td>
<td>77.2</td>
</tr>
<tr>
<td>August</td>
<td>73.9</td>
<td>1.44</td>
<td>74.9</td>
</tr>
<tr>
<td>September</td>
<td>65.4</td>
<td>0.74</td>
<td>65.6</td>
</tr>
<tr>
<td>October</td>
<td>52.8</td>
<td>0.87</td>
<td>62.8</td>
</tr>
<tr>
<td>November</td>
<td>39.0</td>
<td>0.42</td>
<td>37.6</td>
</tr>
<tr>
<td>December</td>
<td>31.1</td>
<td>0.59</td>
<td>29.3</td>
</tr>
<tr>
<td>Year</td>
<td>51.4</td>
<td>13.71</td>
<td>52.6</td>
</tr>
</tbody>
</table>

**Dates of killing frosts.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Rockyford</th>
<th>Las Animas</th>
<th>Lamar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Last in spring.</td>
<td>First in fall.</td>
<td>Last in spring.</td>
</tr>
<tr>
<td>1893</td>
<td>May 8</td>
<td>Oct. 2</td>
<td>May 16</td>
</tr>
<tr>
<td>1894</td>
<td>May 1</td>
<td>Sept. 24</td>
<td>May 2</td>
</tr>
<tr>
<td>1895</td>
<td>May 11</td>
<td>Sept. 22</td>
<td>May 19</td>
</tr>
<tr>
<td>1896</td>
<td>Apr. 29</td>
<td>Oct. 29</td>
<td>Sept. 29</td>
</tr>
<tr>
<td>1897</td>
<td>Apr. 28</td>
<td>Sept. 13</td>
<td>May 11</td>
</tr>
<tr>
<td>1898</td>
<td>May 4</td>
<td>Oct. 5</td>
<td>May 1</td>
</tr>
<tr>
<td>1900</td>
<td>Apr. 12</td>
<td>Sept. 29</td>
<td>Apr. 13</td>
</tr>
</tbody>
</table>

This region is marked by a generally low relative humidity. The contrast between the sensible and instrumental temperatures is striking. Owing to the dry atmosphere the cold waves of the winter lose their severity, and the intense sunshine and heat of summer lack the
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Oppressiveness so often experienced in the Eastern States. Sunstrokes and heat prostrations are almost unknown, and in the shade it is comfortable even at a temperature of 105°.

The almost entire absence of cloudiness during the winter and the only occasionally cloudy weather during the summer form the most notable and distinctive climatic features of southern and eastern Colorado. The abundance of sunshine is of great value as affecting the health of the inhabitants and in assuring the rapid and continuous growth of crops.

Fogs are of very rare occurrence in the Arkansas Valley. Generally brisk winds are, however, a distinctive climatic feature of this region. The topography and vegetation of the plains offer but little resistance to a free wind movement, and during the spring months the winds are brisk and are sometimes violent and accompanied by dust storms. Any considerable amount of damage is, however, rarely done. With the approach of the summer months the winds moderate, although they usually blow more or less throughout this season of the year. For short periods during the warmest weather the winds sometimes become intensely hot and dry during their passage over the prairies.

PHYSIOGRAPHY AND GEOLOGY.

The area surveyed falls into two distinct physiographic divisions—the Arkansas Valley proper and the uplands.

The uplands consist of a succession of smooth, even, gently undulating prairies characteristic of the Great Plains. In places erosion has resulted in the degradation and removal of portions of the original material, giving rise to prominent bluff and terrace lines, often cleft by arroyos having vertical sides and traversed by streams of a more or less intermittent flow. The vegetation of these uplands consists of the short and scanty but highly nutritious buffalo grass, bunch grasses, sage bush, "soap weed," and a great variety of small flowering annuals.

The soils are generally deep, but outcrops of the underlying rocks are abundant along the bluffs and terraces.

The general slope of the plains is from the northwest to the southeast, the elevation ranging from almost 3,400 feet at the eastern boundary of the area to about 4,400 feet at the highest point near the western boundary.

Farther back from the valleys the slopes become less accentuated and drainage is less efficient. Here the rainfall is largely absorbed by the soil or accumulates in broad, shallow depressions, forming lakes of an intermittent character, often connected into groups or chains. Such natural depressions, if favorably situated, have become of great importance to this area as possible sites for water-storage reservoirs.
In desert regions a large amount of material is torn loose and swept away by the mountain streams, augmented by cloudbursts and storms of great intensity and short duration, and carried to the more gentle slopes below. Owing to decrease of velocity or to the absorption of the water by the porous and thirsty soil, the material is here spread outward and deposited in fanlike sheets bordering the mountain ranges. With changes in level due to uplifts and depressions of the earth's crust or to the cutting down or building up of the stream channels, the stream beds are continually shifting and the débris apron—a broad, extensive sheet of stream-borne material formed by the coalescing of many smaller fans—is the result. These shifting streams give rise to what is known as the phenomenon of laced drainage, resulting in a mass of interlaced and interbedded deposits of material of varying degrees of fineness, ranging from coarse gravel and boulders to silt and clay. In this manner at least the greater part of the Great Plains has been built up, the mountain foot slopes in this case being very extensive and complex.

Occupying the subhumid belt of the Great Plains and constituting a distinct physiographic feature are the high plains, or that portion of the original foot slope still unscored by erosion. The surface is here nearly a dead level and the soil is closely carpeted by a fine turf, the bunch grasses found farther west having disappeared. These plains have practically no drainage, the precipitation being absorbed by the soil. The depth of the débris apron is here greatest, being upward of 500 feet. Only a limited proportion of the uplands of the eastern part of the area surveyed fall under this subdivision, the great body of the high plains lying east of the Colorado-Kansas State line.

The Arkansas Valley proper forms a trough from 2 to 5 miles wide and in the area surveyed from 100 to 300 feet deep, carved out of the Great Plains by the Arkansas River during recent geologic time.

Prominent bluff lines mark the borders of the valley through much of the area, as in the vicinity of Lajunta. At other points more gradual slopes prevail, with minor terraces of gravels, sands, and heavy silt and clay deposits, each terrace being the remnant of an ancient river flood plain. The waters of the streams of the area carry much fine sediment and, in periods of flood, material of a coarser nature. This has resulted in the deposition of much material upon the eroded surface of the valley trough.

From Canyon City to the Kansas line the Arkansas River has a total fall of 1,975 feet, or an average of 9 feet per mile. From Lajunta to the Kansas line the average fall is 7.3 feet per mile. This, with the generally smooth and slightly sloping condition of the valley terraces and of much of the uplands, offers favorable conditions for irrigation.

The important tributaries of the Arkansas rising in the mountains are Fountain Creek and St. Charles Huervano, Apishapa, and Purga-
toire rivers, the latter discharging its waters into the trunk stream in
the vicinity of Las Animas, being the only one entering the Arkansas
within the limits of the area surveyed. Many other streams, as the
Horse, Adobe, Timpas, and Big Sandy creeks, receiving their water
supply from the springs and uncertain storms of the plains, form less
important tributaries. Many of these smaller streams flow through
narrow valleys or draws, into which the irrigating systems of the main
valley are extended.

Changes in level, in combination with the fluctuation in river flow,
have produced many alternating periods of erosion and deposition of
material in the history of the valley.

The larger streams are bordered with a heavy growth of cottonwood,
the trees sometimes attaining a large size. The lighter soils are cov-
ered with the vegetation of the upland sands and sandy loams, while
the grasses of the heavier soils and occasional patches of "greasewood"
are the characteristic vegetation of the heavier bottom lands.

The physiography of the valleys, as well as that of the uplands, has
in many respects been modified by wind action.

The rock series of the district consist of alternating beds of sand-
stone, limestone, and shales of marine origin and of the Cretaceous
period. These beds vary greatly in thickness and are generally nearly
horizontal, inclining slightly to the eastward at about the slope of the
plains. In many places the general structure and occurrence of the
rocks have been greatly modified and complicated by local faulting
and bending of the strata.

The rocks of the softer series erode easily, and under the agencies
of frost, wind, and atmospheric waters rapidly crumble into the soils
of the area, the silty and fine sandy loams predominating. Soluble
mineral salts are readily leached from these rock outcrops and added
to the soils below.

Underlying the Cretaceous rocks are found those of the Jura-Trias,
consisting of sandstone, limestone, conglomerate, shale, and gypsum.
They are usually of brilliant reddish colors and close texture.

The rock series of the Cretaceous system found in this area are
classed under three well-recognized groups.

The Dakota group is the lowest of the series, consisting chiefly of
light gray or buff-colored sandstone, sometimes dark brown or choco-
late on weathered surfaces, with occasional brilliant or orange colors
in the lower beds. Beds of gray arenaceous shales, containing par-
ticles of carbonized vegetable tissue, alternate with the sandstone
layers. The Dakota sandstones vary much in texture, the lower beds
being of a more porous nature. This rock furnishes an abundance of
excellent building stone and is also important as the source of artesian
water throughout the area. It outcrops a few miles east of Las Ani-
mas, forming prominent bluffs on each side of the river. The thick-
ness of this group varies, but averages from 200 to 250 feet.
FIG. 1.—A FIELD OF SUGAR BEETS, ONE OF THE IMPORTANT CROPS OF THE ARKANSAS VALLEY.

FIG. 2.—ALFALFA STACKS AFTER THE SECOND CUTTING OF THE CROP, LOWER ARKANSAS VALLEY.

This is one of the industries which has been remarkably successful in the Arkansas Valley.
A field of cantaloupes, the growing of which has been remarkably successful in the Arkansas Valley.
The Benton group rests upon the upper members of the Dakota. In general character it is a highly laminated gray shale, streaked with black bands. Calcareous concretions, weathering to brilliant orange in color, and fossil oysters and other bivalves frequently occur. It is divided near the middle by strata of limestone only a few inches in thickness, weathering into vertical parallel chips and separated from each other by beds of shale. The upper members of this group sometimes assume the characteristics of a sandstone or a purplish limestone containing fossil shells. The whole system is quite regular and from 400 to 450 feet thick. It outcrops and forms prominent bluffs from a point near Lajunta to Las Animas.

The Niobrara group lies above the Benton and consists of two distinct formations—the Timpas, or lower formation, and the Apishapa. The Timpas formation is about 175 feet thick and consists of a series of limestone and calcareous shales. The limestone beds have a thickness of from a few inches to 3 or 4 feet, are white or slightly yellowish in color, of a compact texture, and weather into sharp angular flakes or chips. Fossil oysters and other bivalves are abundant. This formation borders the valley eastward from Timpas Creek until the rocks drop off into those of the Benton group. It is exposed in prominent bluffs on each side of the river at Lajunta.

The Apishapa formation rests upon the Timpas, and consists of laminated dark gray shales weathering to light yellow. Small veins and flakes of gypsum are abundant throughout this formation. Large rounded boulders, like calcareous concretions, containing large checks filled with calcite and barite crystals, frequently occur. This formation crops out throughout the area eastward from Timpas Creek, and has a maximum thickness of about 500 feet.

The Tertiary deposits are of a more recent date, overlying the Cretaceous rocks and making up the unconsolidated material of the debris apron of the Great Plains. In texture the material grades from clays and fine silts to the coarse, loose upland sands and coarse gravels, and is from 50 to 200 feet in thickness. The sands are chiefly of granitic origin, consisting of quartz and felspathic fragments, and the particles are quite well rounded and abraded. Heavy deposits of coarse, well-rounded gravel are numerous, being most abundant along eroded bluff and terrace lines. This material is derived from the harder rocks of the Rocky Mountains, consisting largely of the rocks of the granite series. Fragments of volcanic origin also occasionally appear. At certain places, particularly where the Tertiary rests upon the Cretaceous, the gravels and sands are often cemented by calcareous material into a hardpan or conglomerate several inches in thickness and known as the "mortar beds." These are often cross bedded and are thought to mark former levels of the water table, the cementing material being precipitated from solution by atmospheric agencies.

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The terrace sands and gravels of the valley are quite similar in character to those of the uplands, but less extensive. The recent deposits consist largely of fine sand and silts, vast quantities of which are carried by the Arkansas River in times of flood.

SOILS.

The soils of the Lower Arkansas Valley area, through their relation to geologic and physiographic features, fall into two natural divisions, the soils of the plains and the soils of the valley. In places, however, the soils of the two divisions are separable only upon lines of arbitrary classification.

In general the soils of this area are marked by complexity of structure and mode of occurrence, by the prevalence of small areas, a rapid and widespread variation from type to type, and an apparent disregard of physiographic influences in the arrangement and position of types. The deposits of sands, gravels, and clays are intricately mixed, forming very confusing conditions in soil study. This complex arrangement exists both in the soils of the upland plains and in those of the valley.

With the exception of the coarser and lighter deposits, the soils of the Arkansas Valley area are well provided with plant food, both mineral and organic. The occurrence of lime in the soils is marked and the valuable mineral nitrates are abundant. The moisture-retaining properties of the lands of this area also greatly enhance their value for agricultural purposes.

### Areas of different soils.

<table>
<thead>
<tr>
<th>Soil</th>
<th>Rocky Ford sheet</th>
<th>Las Animas sheet</th>
<th>Lamar sheet</th>
<th>Holly sheet</th>
<th>Total area</th>
<th>Proportional extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresno fine sandy loam</td>
<td>56,384</td>
<td>13,652</td>
<td>94,720</td>
<td>71,562</td>
<td>236,288</td>
<td>39.1</td>
</tr>
<tr>
<td>Maricopa sandy loam</td>
<td>63,424</td>
<td>39,104</td>
<td>15,872</td>
<td>37,696</td>
<td>156,096</td>
<td>25.8</td>
</tr>
<tr>
<td>Fresno sand</td>
<td>14,592</td>
<td>12,800</td>
<td>13,056</td>
<td>55,222</td>
<td>95,680</td>
<td>15.8</td>
</tr>
<tr>
<td>Santiago silt loam</td>
<td>6,784</td>
<td>8,640</td>
<td>12,608</td>
<td>9,728</td>
<td>37,760</td>
<td>6.2</td>
</tr>
<tr>
<td>Maricopa sandy adobe</td>
<td>13,888</td>
<td>13,056</td>
<td>9,280</td>
<td>1,024</td>
<td>37,248</td>
<td>6.2</td>
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<td>Maricopa sand</td>
<td>11,264</td>
<td>896</td>
<td>822</td>
<td>2,16</td>
<td>14,208</td>
<td>2.1</td>
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<tr>
<td>Riverwash</td>
<td>2,432</td>
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<td>3,008</td>
<td>4,096</td>
<td>12,800</td>
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<tr>
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<td>1,280</td>
<td>960</td>
<td>1,344</td>
<td>2,368</td>
<td>5,952</td>
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<tr>
<td>San Joaquin black adobe</td>
<td>1,216</td>
<td>2,240</td>
<td>640</td>
<td>4,096</td>
<td>4,096</td>
<td>.7</td>
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<tr>
<td>Dunesand</td>
<td>2,368</td>
<td>384</td>
<td>576</td>
<td>3,328</td>
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<tr>
<td>Maricopa clay loam</td>
<td>320</td>
<td>512</td>
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<td>882</td>
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<tr>
<td>Swamp</td>
<td>256</td>
<td>384</td>
<td></td>
<td>640</td>
<td>640</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>171,840</strong></td>
<td><strong>96,900</strong></td>
<td><strong>132,640</strong></td>
<td><strong>188,888</strong></td>
<td><strong>604,288</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Fresno sand.**

The Fresno sand is typically a coarse, loose, incoherent sand, 6 feet or more in depth. It is underlain at varying depths by the heavier loams, sandy adobe, or shale or sandstone rocks. In color it is white,
or of a yellowish or slightly reddish tint, the latter due to the prevalence of feldspathic fragments, which, with quartz, form the chief mineral constituents. It usually breaks down into a loose mulch upon being turned up by the plow, containing but little clay and rarely forming clods. Occasionally, however, it assumes a sticky nature, although containing but little silt or clay, and bakes upon being puddled and exposed to the sun.

The following table gives mechanical analyses of soil and subsoil of this type:

**Mechanical analyses of Fresno sand.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality</th>
<th>Description</th>
<th>Organic matter</th>
<th>Gravel, 2 to 1 mm.</th>
<th>Coarse sand, 1 to 0.5 mm.</th>
<th>Medium sand, 0.5 to 0.06 mm.</th>
<th>Fine sand, 0.06 to 0.01 mm.</th>
<th>Very fine sand, 0.01 to 0.005 mm.</th>
<th>Silty, 0.005 to 0.0001 mm.</th>
<th>Clay, 0.0001 to 0.00001 mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7944</td>
<td>Sec. 32, T. 22 S., R. 56 W.</td>
<td>Coarse reddish sand, 0 to 12 inches.</td>
<td>.50</td>
<td>0.64</td>
<td>14.30</td>
<td>25.90</td>
<td>37.66</td>
<td>13.80</td>
<td>2.28</td>
<td>5.50</td>
</tr>
<tr>
<td>7942</td>
<td>Sec. 21, T. 23 S., R. 55 W.</td>
<td>Coarse granitic sand, 0 to 72 inches.</td>
<td>.64</td>
<td>1.14</td>
<td>7.50</td>
<td>15.72</td>
<td>34.66</td>
<td>21.02</td>
<td>21.00</td>
<td>21.02</td>
</tr>
<tr>
<td>7943</td>
<td>Sec. 3, T. 22 S., R. 56 W.</td>
<td>Coarse sand, 0 to 18 inches.</td>
<td>.81</td>
<td>1.90</td>
<td>9.14</td>
<td>12.76</td>
<td>27.92</td>
<td>14.82</td>
<td>23.62</td>
<td>23.62</td>
</tr>
<tr>
<td>7945</td>
<td>Subsoil of 7944....</td>
<td>Coarse reddish sand, 12 to 72 inches.</td>
<td>.12</td>
<td>.80</td>
<td>12.54</td>
<td>26.00</td>
<td>36.00</td>
<td>14.82</td>
<td>21.00</td>
<td>21.00</td>
</tr>
</tbody>
</table>

This soil varies somewhat in texture, physical condition, and physiographic position, a valley phase which is somewhat coarser in texture and frequently gravelly occurring upon the terraces of the bottoms.

The typical upland Fresno sand occurs generally in relatively large areas, often covering several square miles of uniform texture, and is the most easily recognized type of the area. In the valley the areas are usually small. The occurrence of gravel in this soil is seldom conspicuous except in the vicinity of eroded bluffs and outcrops of the Dakota sandstones eastward from the Purgatoire River, and in the valley phase.

The Fresno sand forms the greater proportion of the upland sand areas of the Great Plains of southeastern Colorado. It generally occurs upon the higher slopes and ridges or along the domelike elevations of the plains, sometimes dipping into the depressions. It usually grades rapidly into the Maricopa sand, Dunesand, Maricopa sandy loam, or the Fresno fine sandy loam. Outcrops of the underlying rocks seldom occur in areas of this soil.

The native vegetation consists of sage, "soap weed," and sunflowers, with many small flowering annuals and occasional patches of buffalo or other nutritious grasses.
The open, porous nature of this soil allows of the rapid absorption and percolation of water and the establishment of excellent natural drainage conditions. In the larger areas there is but little run-off, nearly all the rainfall being absorbed.

The Fresno sand is made up of the more resistant particles of the rocks of the Rocky Mountains, deposited by the interlacing streams of the formative period of the Great Plains. The action of wind has since played an important part in distributing and modifying the texture and arrangement of the sands.

Small mica plates frequently occur in the soil, but the presence of this mineral is not conspicuous. No injurious quantities of alkali are found in the soil, except in depressions in the valley areas or where the seepage waters have come to the surface.

Considering its open, porous texture, it retains moisture well and contains a good supply of mineral and organic plant food. For heavy cropping, however, it is inferior to the heavier soils unless well supplied with moisture and with an abundance of organic and mineral fertilizers. But a small proportion of the upland Fresno sand is under cultivation, the most of it lying above the canal systems of the plains and much of it being public land and devoted to grazing. Native range grasses grow quickly upon this soil when once started and provided with the necessary moisture, furnishing good pasture. Much of the land, however, is of so loose a character as to be inferior to the heavier lands for grazing purposes, sage being in many places the only vegetation. This is the case particularly south of the Arkansas River. Upon cultivated portions alfalfa, grains, corn, melons, and fruit—consisting of peaches, apples, small stone fruits, and grapes—do well if well irrigated and supplied with plant food by stable manure or green manuring. (See Pl. XLV.) In the valley areas sugar beets are also grown, in addition to the foregoing crops, and fair yields are secured.

DUNESAND.

The Dunesand occurs upon the Las Animas, Lamar, and Holly sheets, occupying usually the higher elevations of the lands surveyed upon the plains of the south side and grading into Fresno sand.

The areas are very uniform in texture and general character. Gravel occurs only in insignificant amounts.

In texture, color, depth, mineral and chemical composition, and drainage features it is similar to the Fresno sand, being formed from the latter by the strong prevailing northwest winds, which have heaped the loose Fresno sand, not well protected by vegetation, into lines of shifting sand dunes from 6 to 20 feet high. The surfaces of the dunes are often barren and scored by wind ripples.

All of the areas of Dunesand lie above the irrigating canals and, owing to their uneven nature and loose structure, could not be irri-
A YOUNG ORCHARD ON THE FRESNO SAND, LOWER ARKANSAS VALLEY.
gated if a water supply were available. They are uninhabited and used only as range land. The vegetation, consisting chiefly of sage, is of but little value for grazing purposes.

MARICOPA SAND.

In texture, color, mineral and chemical composition, and physical properties the Maricopa sand is identical with the Fresno sand. It is, however, a much shallower deposit. In typical profile it is 3 feet in depth, underlain by a sandy loam, frequently grading to a sandy adobe, the materials in both cases being similar to those forming the Maricopa sandy loam and the Maricopa sandy adobe. It differs, then, from the Fresno sand in this heavier material occurring at an average depth of 3 feet, which in the Eastern States would not be a sufficient basis for a new type, but which in this Western area would have an effect upon the water supply in the soil, particularly under irrigation.

The Maricopa sand occupies the higher slopes and levels of the plains upon each side of the river, frequently bordering the deeper deposits of the Fresno sand. The largest areas of this type occur in the vicinity of the Holbrook reservoir and to the eastward. The areas are generally small, and there is usually but little variation in texture, although in certain local places, as in the Fresno sand, the soil has a peculiar sticky property. Small gravel areas frequently occur within the boundaries of this soil type, especially in the vicinity of terrace lines and along outcrops of the underlying rocks. With the exception of the Dakota sandstones, however, there are few rock outcrops in the Maricopa sand. This soil type grades into the Maricopa sandy loam and the Fresno sand, the native vegetation being similar to that on the latter.

As in the Fresno sand, the loose, open texture of the Maricopa sand results in excellent natural drainage and the ready absorption of the spring rains and local showers of the summer months. Owing to the heavier subsoil, it is superior to the Fresno sand in its power to retain moisture and when irrigated suffers less loss from seepage.

The origin and mode of formation of the Maricopa sand is the same as that of the Fresno sand, it being simply a shallower deposit of the same material. In its distribution it also owes much to wind movement, which has played an important part in forming the deposits from the neighboring Fresno sand.

Like the other upland sands of the plains this soil is free from alkali in injurious amounts.

The greater part of this soil type lies above the irrigating systems of the area and is devoted to grazing. Upon irrigated tracts, however, this soil is superior to the deeper sands for agricultural purposes. Alfalfa is the prevailing crop, yielding well under proper irrigation.
With the aid of an occasional intelligent application of green or stable manure and a sufficient supply of water this soil should produce fair crops of alfalfa, grain—including corn and sorghum—and sugar beets. It is best adapted, however, to tomatoes, melons, and truck and to the growing of crops requiring a light, warm soil to insure an early and rapid growth. Fruit—consisting of peaches, apples, cherries, plums, grapes, and small fruits—would probably do well and become a profitable line with favorable markets. Frequent and intelligent cultivation is most important with lands of this texture in order to properly conserve the supply of moisture.

**MARICOPA SANDY LOAM.**

The Maricopa sandy loam, like the Fresno sand, occurs both upon the upland plains and in the valley bottoms.

In its typical upland phase it occurs as a coarse, slightly reddish or yellowish sandy loam. In depth the soil varies, but the average profile gives about 18 inches of sandy loam underlain by sandy adobe. In local areas the texture assumes a fine, silty character, tenacious when wet, and grading into the finer and heavier soils of the area. In other places the soil becomes much deeper and more open in texture, approaching the Fresno sand. Such phases frequently occur in the uplands, but more often upon the valley floor.

A peculiar phase of the Maricopa sandy loam occurs as a reddish, coarse, sandy loam, very compact, crumbling only upon considerable pressure, and checking upon puddling and exposure to the sun and air. This phase occurs in many local areas resembling the Maricopa sandy adobe, into which it often quickly grades.

This type covers a large proportion of the uplands upon each side of the valley. The most extensive areas, however, occur upon the plains of the north side of the western part of the area. The areas are usually large, although often much complicated and cut by narrow strips and small bodies of the adjacent soil types, particularly those of the upland sands and the Maricopa sandy adobe.

The occurrence of local gravel beds in soils of this type is very noticeable. Gravel often occurs in moderate amounts throughout the subsoils of the uplands. Along the eroded edges of the valley walls this gravel seems to have been washed out and concentrated into beds bordering the bluffs and terrace lines. These gravel beds where exposed at the surface are often very narrow, being only a few rods wide, but forming a very prominent physiographic feature. The rock fragments are generally well rounded and often coated with a thin incrustation of lime, especially in the vicinity of the “mortar beds” previously mentioned. These gravel-bordered terraces of the Maricopa sandy loam are of but little agricultural value, the gravel being present in such quantities as to interfere with cultivation of the lands
and varying from the size of a pea to 4 or 6 inches in diameter. The position of these gravel-capped bluff lines is shown upon the soil maps. As the soils recede from the terraces the occurrence of the heavy gravel quickly becomes less marked or entirely disappears. A moderate quantity of gravel of the smaller-sized fragments, however, often covers considerable areas of this soil, both upon the plains and in the valley.

The upland phase of the Maricopa sandy loam generally occurs upon the higher and intermediate slopes of the Great Plains, occasionally extending into the draws and local depressions. In certain parts of the area, particularly south of Rockyford and northward from Lajunta, it is cut by rugged bluffs, terraces, gravel beds, and rock outcrops of the Apishapa and Timpas formations, which frequently cap the summits of the mesas and higher terraces of the area.

The native vegetation of the Maricopa sandy loam consists of buffalo grass and bunch grasses, with the sage, "soap weed," and vegetation of the lighter upland soils in less proportions.

This soil absorbs moisture readily, and owing to its physical structure, usual protection of vegetation, and a thin mulch of wind-blown sand which often covers it, possesses pronounced moisture-retaining properties. The heavier subsoil also plays an important part in maintaining a long-continued supply of moisture to the looser soil above. The compact structure of the subsoil also retards the movement of seepage water from the irrigating canals and ditches.

The natural drainage is good, and the soils are little damaged by seepage waters except when occurring in the draws of the plains and in local depressions of the valley bottoms adjacent to canals and heavily irrigated lands of a loose structure.

The upland Maricopa sandy loam, like the upland sands, owes its origin to the ancient débris-bearing streams of the foot slopes of the Rocky Mountains. These deposits, bearing a somewhat larger percentage of fine material than the sands, have since been greatly modified by stream wash from higher elevations and by intermixture with fine wind-blown material.

The proportion of mica mingled with the quartz and feldspar of this soil is noticeable. The soil contains a moderate but not large amount of organic matter, lime, and the other elements necessary to the growth of plants. It contains an injurious amount of alkali salts only where subjected to the seepage and leaching from the alkali-bearing rocks and soils of surrounding higher elevations. The heavier subsoil, however, sometimes contains a relatively large amount of alkali, and in such places irrigation should be practiced with care. This matter will be treated in a separate chapter.

All but a small proportion of the upland Maricopa sandy loam lying on the south side of the valley is devoted to grazing, the greater part
consisting of high, rolling land lying above the canal systems. Large areas of this soil type similarly situated, shown upon the Rockyford sheet, extend westward from Holbrook Lake along the north side. Northeast from Holbrook Lake, and extending nearly to Horse Creek, about half of this soil is irrigated, producing excellent crops of alfalfa and sugar beets, wheat, oats, sorghum, and other staple crops of the section. The raising of watermelons, cantaloupes, apples, peaches, and small fruits is also becoming an important and profitable industry. Large and valuable cultivated areas of this soil type occur also upon the other sheets of the area surveyed.

These areas of Maricopa sandy loam, being easily cultivated and producing abundant yields under favorable conditions, are among the most valuable lands in the area surveyed. This soil is well adapted to melons, sugar beets, alfalfa, tomatoes, and truck crops, and the gradual extension of an intensive system of agriculture over such lands seems to be in progress.

In the valley phase the color sometimes becomes of a grayish tint and the texture coarse. When less than 6 feet in depth it is generally underlain by material similar to Fresno sand, Riverwash, or occasionally the heavier types of the valley bottoms. The areas of the valley phase are usually small and much interlaced with river sands and soils of the heavier bottoms. Quite large and uniform areas, however, occur in the vicinity of and northeast from Rockyford and in various portions of the valley bottoms throughout the area. The areas usually occur as slightly sloping elevations or narrow streaks cutting the adjacent soils of the valley terraces.

In the case of the valley phase the formation of this soil is due rather to the more recent deposits of the Arkansas River, the material being originally derived in part from the quartz and feldspar bearing rocks of the mountains and in part from the heavier alluvial deposits of the upper valleys.

The crops grown are similar to, and the yields compare favorably with, those of the upland soil. Owing to its deeper nature and looser texture, however, it usually requires a more frequent irrigation and thorough cultivation in order to guard against excessive losses from evaporation.

The table on the following page gives the results of mechanical analyses of the Maricopa sandy loam.
The Maricopa sandy adobe is one of the most important of the upland soils, and, like the Maricopa sandy loam, is subject to variation in texture, physiographic position, and physical properties. In typical section it consists of a yellowish-brown or reddish sandy adobe, the sand occurring in considerable proportions and being rather coarse in texture. It is usually 6 feet or more in depth and quite uniform in character throughout this profile.

In occasional small and generally oval-shaped areas and fingers the Maricopa sandy adobe sometimes assumes the characteristics of a clay loam, the adobe structure being in this case less marked and the sand normally present giving way in large part to a larger proportion of silt and clay. The color becomes of a brownish or dark-gray tint, and the soil grades into the silt loam and clay loams of the bottoms. Bodies of the typical Maricopa sandy adobe occur throughout the area surveyed. It is, however, a distinctively upland type and is rarely found upon the uplands of the south side. The areas vary in extent from a few acres to several square miles. They are usually quite irregular in outline and extend as long, narrow fingers through the adjoining areas of Fresno fine sandy loam and Maricopa sandy loam. Unlike the adjacent types, these areas are seldom gravelly, gravel occurring only in small proportions and consisting of fine, angular limestone or shale fragments.

The Maricopa sandy adobe generally occupies the lower levels and draws of the plains. Long, narrow, areas frequently follow the course

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality.</th>
<th>Description.</th>
<th>Organic matter.</th>
<th>Gravel, 2 to 1 mm.</th>
<th>Coarse sand, 1 to 0.5 mm.</th>
<th>Medium sand, 0.5 to 0.25 mm.</th>
<th>Fine sand, 0.25 to 0.1 mm.</th>
<th>Very fine sand, 0.1 to 0.06 mm.</th>
<th>Silt, 0.06 to 0.006 mm.</th>
<th>Clay, 0.006 to 0.001 mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7956</td>
<td>Sec. 5, T. 23 S., R. 56 W.</td>
<td>Gravelly sandy loam, 0 to 10 inches.</td>
<td>0.16</td>
<td>7.64</td>
<td>19.32</td>
<td>20.74</td>
<td>12.38</td>
<td>8.94</td>
<td>7.68</td>
<td></td>
</tr>
<tr>
<td>7950</td>
<td>Sec. 8, T. 23 S., R. 55 W.</td>
<td>Sandy loam, 0 to 18 inches.</td>
<td>0.10</td>
<td>6.40</td>
<td>15.20</td>
<td>17.52</td>
<td>12.08</td>
<td>9.54</td>
<td>9.24</td>
<td></td>
</tr>
<tr>
<td>7951</td>
<td>Sec. 5, T. 22 S., R. 56 W.</td>
<td>Coarse sandy loam, 0 to 12 inches.</td>
<td>0.07</td>
<td>4.20</td>
<td>9.74</td>
<td>25.72</td>
<td>31.78</td>
<td>14.44</td>
<td>13.02</td>
<td></td>
</tr>
<tr>
<td>7952</td>
<td>Sec. 2, T. 22 S., R. 56 W.</td>
<td>Coarse brownish sandy loam, 0 to 24 inches.</td>
<td>0.73</td>
<td>0.94</td>
<td>9.52</td>
<td>24.82</td>
<td>21.24</td>
<td>20.32</td>
<td>19.28</td>
<td></td>
</tr>
<tr>
<td>7953</td>
<td>Subsoil of 7952</td>
<td>Sandy loam, 24 to 72 inches.</td>
<td>0.49</td>
<td>3.34</td>
<td>9.52</td>
<td>24.82</td>
<td>21.24</td>
<td>20.32</td>
<td>19.28</td>
<td></td>
</tr>
<tr>
<td>7954</td>
<td>Subsoil of 7950</td>
<td>Sandy loam, 18 to 24 inches.</td>
<td>0.26</td>
<td>1.00</td>
<td>3.14</td>
<td>21.64</td>
<td>25.92</td>
<td>29.52</td>
<td>20.96</td>
<td></td>
</tr>
<tr>
<td>7957</td>
<td>Sec. 2, T. 23 S., R. 56 W.</td>
<td>Sandy loam, 6 to 10 feet.</td>
<td>0.13</td>
<td>1.60</td>
<td>2.20</td>
<td>10.90</td>
<td>13.10</td>
<td>37.00</td>
<td>34.82</td>
<td></td>
</tr>
</tbody>
</table>
of arroyos and drainage basins, and small areas sometimes occur near eroded rock outcrops upon higher terraces.

The areas are unmarked by prominent bluffs or terrace lines and rock outcrops, and the surface is generally smooth and covered with the buffalo grass of the plains. Areas of the clay loam phase of the soil occur in local depressions and drainage basins upon the Great Plains, or frequently as long, narrow fingers bordering the courses of arroyos and minor stream channels. The surface is generally level and devoid of gravel in noticeable quantities. The vegetation usually consists of the bunch grasses and buffalo grass of the plains.

In many local areas, especially where the Maricopa sandy adobe grades into the Fresno fine sandy loam, the coarse sand is wanting and the soil assumes a fine, loamy character. The adobe structure is, however, retained. The color is somewhat lighter and sometimes of a yellowish tint.

Areas of this character often occur in the neighborhood of the disintegrating Cretaceous rocks and upon the higher terraces and slopes of the plains. In this phase the frequent occurrence of fine, angular gravel, white in color and consisting of fragments of shale and limestone rock, is characteristic.

The weathering of the Cretaceous rocks in place seems to have been an important factor in the origin of this phase of the Maricopa sandy adobe, although it has been greatly modified by subsequent stream wash and wind action.

Owing to the compact structure of the Maricopa sandy adobe, water is less freely absorbed and the run-off is relatively greater than with the Maricopa sandy loam. The water-holding capacity and drought-resisting properties under proper and sufficient cultivation are, however, marked. While in its natural condition, with the exception of a few local drainage basins, the drainage is good, many low-lying areas have been damaged by seepage from heavy and frequent irrigation upon surrounding higher levels. Percolation in a soil of this structure takes place slowly, and the removal of seepage and drainage waters must be aided by artificial drainage in order to bring such lands to a state of full productivity.

The sand occurring in the Maricopa sandy adobe seems to be similar in mineral character to that of the other sandy soils of the uplands and was undoubtedly derived from these other soils. The finer sediments have been derived by stream wash from the surrounding uplands and by disintegration of the Cretaceous rocks, particularly the shales. These mixed sediments have been laid down by streams and surface drainage, resulting from heavy rains, in the depressions and lower levels of the plains. In some places sedimentation may have taken place from temporary lakes or stagnant water. The addition of wind-blown material, ranging from fine dust to sand, to these deposits seems
to have played a less important part in the formation of the soil than in some of the other types.

The sand of the Maricopa sandy adobe consists mainly of well-abraded quartz and feldspathic fragments. Gypsum is very abundant throughout the soil section, occurring as partly disintegrated crystals and flakes, often very nearly pure and imparting a mealy character to the soil. This constituent seems to have been derived largely from decomposition of the shales, but may in part be due to desiccation of concentrated solutions. Lime is usually present in large amounts, and the soil is generally well provided with plant food, although sometimes rather deficient in organic matter.

Like all true adobes, this soil is characterized by its stickiness when wet, its lightness in weight, and its tendency to crack into a system of small, roughly cubical blocks upon exposure to the sun after subjecton to heavy rains or puddling. With proper cultivation the structure assumes a looser character and the soil partakes of the nature of a sandy loam. It possesses marked moisture-retaining properties when well handled, and forms an important and valuable soil in the Lower Arkansas Valley area.

The Maricopa sandy adobe is not only relatively rich in the valuable mineral elements, but it also contains a considerable amount of the injurious alkali salts. In its normal condition these are, however, not in a concentrated form and occur only in the subsoil. While a large amount of alkali may be present in this soil, it may be so uniformly distributed and occur at such depths as not to impair the growth of shallow-rooted crops. Such lands have been farmed in this area for years with good profit and no damage from accumulation of the alkali salts within the root zone of crops. With too frequent or excessive use of irrigating waters, however, or with seepage from adjacent canal systems, the underlying alkali salts are sure sooner or later to make their appearance at the surface in a more concentrated form. Many small areas of this land have already been damaged in this manner. For such lands the establishment of thorough artificial drainage, coupled with the judicious use of irrigating waters, is the only remedy.

A considerable proportion of this land is unirrigated and uncultivated by reason of its position. Such areas are devoted to grazing. While good yields of sorghum, corn, wheat, and oats are produced upon the areas of the Maricopa sandy adobe under irrigation, the raising of alfalfa for hay and seed is the principal interest. Excellent yields are obtained, and this line of agricultural industry is a very important and profitable one.

The Maricopa sandy adobe is well adapted to the raising of hay, grains, and all crops of this section requiring a moderately strong, heavy soil. Sugar beets should do well with thorough preparation of the land and careful cultivation.
The following table gives mechanical analyses of typical samples of the soil and subsoil of this type:

**Mechanical analyses of Maricopa sandy adobe.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality.</th>
<th>Description.</th>
<th>Calcareous mater.</th>
<th>Gravel, 2 to 1 mm.</th>
<th>Coarse sand, 0.5 to 0.65 mm.</th>
<th>Medium sand, 0.25 to 0.5 mm.</th>
<th>Fine sand, 0.05 to 0.14 mm.</th>
<th>Very fine sand, 0.006 to 0.05 mm.</th>
<th>Silt, 0.006 to 0.0006 mm.</th>
<th>Clay, 0.0006 to 0.0001 mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7948</td>
<td>Sec. 3, T. 23 S., R. 55 W.</td>
<td>Sandy loam, 0 to 12 inches.</td>
<td>P. ct.</td>
<td>1.26</td>
<td>0.30</td>
<td>1.98</td>
<td>4.02</td>
<td>26.78</td>
<td>27.32</td>
<td>24.04</td>
</tr>
<tr>
<td>7946</td>
<td>Sec. 6, T. 23 S., R. 55 W.</td>
<td>Loam, 0 to 12 inches.</td>
<td>P. ct.</td>
<td>.90</td>
<td>.80</td>
<td>2.04</td>
<td>5.64</td>
<td>22.34</td>
<td>23.76</td>
<td>29.54</td>
</tr>
<tr>
<td>7949</td>
<td>Subsoil of 7948</td>
<td>Sandy loam, 12 to 72 inches.</td>
<td>P. ct.</td>
<td>.41</td>
<td>.10</td>
<td>1.88</td>
<td>2.20</td>
<td>26.00</td>
<td>21.42</td>
<td>24.36</td>
</tr>
<tr>
<td>7947</td>
<td>Subsoil of 7946</td>
<td>Sticky yellowish loam, 12 to 72 inches.</td>
<td>P. ct.</td>
<td>.25</td>
<td>.62</td>
<td>2.10</td>
<td>5.44</td>
<td>19.64</td>
<td>22.20</td>
<td>24.20</td>
</tr>
</tbody>
</table>

**MARICOPA CLAY LOAM.**

The Maricopa clay loam is a very heavy, tenacious clay loam of a dark-brown color, 6 feet or more in depth.

This type occurs only as small areas in the Rockyford, Lamar, and Holly sheets, occupying the lower bottoms of small valleys or recent lake beds. The surface is generally level and unbroken by terraces, rock outcrops, or the occurrence of gravel in noticeable amounts. The native vegetation consists mainly of the bunch grasses and other plants of the heavy bottom lands.

This soil is often subject to the accumulation of seepage waters from the soils of open, porous texture surrounding it, and, owing to its level surface and close, compact nature, the natural drainage is poor. The damage resulting from seepage waters upon the area of this soil near Taylor Lake, shown in the Rockyford sheet, has reached alarming proportions, and a thorough artificial drainage of this land is necessary in order to render it capable of profitable cultivation.

The Maricopa clay loam is made up of the finer sediments washed from the surrounding uplands and probably deposited in still water.

The presence of gypsum in this soil is often very marked, occurring throughout the soil in small granules and flakes to an undetermined depth. The necessary mineral and vegetable plant food is also provided in abundance, and the soil would possess excellent moisture-retaining properties if well drained and properly cultivated. It is, however, very sticky when wet, and dries and bakes badly upon exposure after puddling. Nearly all this body of land has been seriously damaged by the accumulation of alkali salts resulting from the alkaline
seepage waters of the adjoining lands of higher level. Owing to the close texture of the soil, such salts are removed with difficulty, and a thorough drainage of the land is a necessary preliminary step in its reclamation.

Owing to the presence of the injurious alkali salts, much of this land, at present occupied by a few hardy, alkali-resistant grasses and plants, is used as pasture. In local spots it is barren of vegetation, and, generally, its value for grazing purposes is only nominal.

With thorough drainage and the reclamation of this land by removal of seepage waters and the alkali salts, good crops of alfalfa, sorghum, corn, small grain, and other crops adapted to heavy lands should be grown. During the process of reclamation sorghum and beets would probably prove the crops most beneficial to the soil and most profitable.

The following table shows the texture of the soil and subsoil of this type:

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality</th>
<th>Description</th>
<th>Organic matter</th>
<th>Gravel, 2 to 1 mm.</th>
<th>Coarse sand, 1 to 0.5 mm.</th>
<th>Medium sand, 0.5 to 0.25 mm.</th>
<th>Fine sand, 0.25 to 0.1 mm.</th>
<th>Very fine sand, 0.1 to 0.006 mm.</th>
<th>Silt, 0.006 to 0.0001 mm.</th>
<th>Clay, 0.0001 and under</th>
</tr>
</thead>
<tbody>
<tr>
<td>7968</td>
<td>Sec. 3, T. 23 S., R. 55 W.</td>
<td>Heavy, sticky clay loam, 0 to 12 inches.</td>
<td>0.36</td>
<td>0.36</td>
<td>4.08</td>
<td>5.60</td>
<td>11.50</td>
<td>9.54</td>
<td>37.64</td>
<td>31.24</td>
</tr>
<tr>
<td>7969</td>
<td>Subsoil of 7968.</td>
<td>Clay loam, 12 to 72 inches.</td>
<td>0.32</td>
<td>0.10</td>
<td>0.86</td>
<td>0.72</td>
<td>6.62</td>
<td>8.84</td>
<td>53.42</td>
<td>29.44</td>
</tr>
</tbody>
</table>

The Fresno fine sandy loam is a soil of very fine sandy or silty texture, slightly yellowish in color, and typically 6 feet or more in depth. It is usually quite sticky when wet, bakes slightly during dry weather, and possesses a marked adobe structure. When subjected to stream erosion it washes easily, cleaving vertically into deep arroyos and cuts. Occasionally it is underlain at from 3 to 6 feet by a coarse yellowish sand or sandy clay, but usually it is very uniform in structure and texture to a considerable depth, often extending with but little variation to bed rock.

In the depressions a higher percentage of silt frequently occurs and the soil becomes slightly darker in color, owing to the greater proportion of organic matter.

A valley phase of the Fresno fine sandy loam, which is of alluvial origin, differs from the typical Fresno fine sandy loam in its texture, darker color, lack of uniformity, and position. In this phase the heavy
percentage of silt is often largely replaced by fine sand. The color frequently becomes of a dark brown, and in depth the soil varies from a few inches to several feet. Like the other soils of the valley bottoms it is usually underlain by the interlaced and lenticular patches of other soils of recent alluvial origin. It is almost all under cultivation, absorbs water readily, is generally free from alkali, and produces the staple crops profitably.

This soil occurs both upon the uplands and upon the upper terraces of the valley bottoms. A much less important phase also occurs in the valley bottoms, usually in close proximity to stream channels.

In the western part of the area the Fresno fine sandy loam occurs only upon the higher terraces and slopes of the valley floor. In the eastern part of the Rockyford sheet it disappears from the valley and makes its appearance upon the uplands. It becomes quite a prevailing and uniform soil type in the vicinity of Lajunta, and the soil areas become more extensive progressively through the Las Animas, Lamar, and Holly sheets to the Kansas State line.

Gravel frequently occurs in the upland areas of this soil type. The fragments are usually small, shaly, or angular in shape. The gravelly areas usually occupy the higher elevations, or occur in the vicinity of outcropping ledges of the Cretaceous limestones and shales from which they are derived. The smooth waterworn pebbles found in abundance in the Maricopa sandy loam rarely occur. Upon the higher slopes the soil areas generally grade into the Maricopa sandy loam and in the depressions into the Maricopa sandy adobe, the Santiago silt loam, or the minor soil types of the bottoms.

In the extreme western part of the area surveyed the bodies of the Fresno fine sandy loam occur upon the gently sloping borders of the valley floor. The surface is smooth and nearly level, but of sufficient inclination toward the valley trough to afford effective drainage.

In the eastern part of the Rockyford sheet and throughout the other three sheets of the area the soil usually occupies the higher and intermediate slopes of the plains, frequently extending into the draws and lower depressions. The soil surface is unusually smooth, of gentle slope, and occasionally broken by outcrops of the Cretaceous limestones and shales. Deep, vertically eroded arroyos sometimes occur.

The native vegetation consists of buffalo grass, sometimes accompanied by the Indian soap weed and other plants of the plains.

With the exception of a small proportion of this soil type lying along the natural draws and drainage depressions, the bodies of the Fresno fine sandy loam are well drained and admirably situated for irrigation. The soil is of a marked close texture, however, and absorbs water somewhat slowly. A large proportion of the rainfall is lost by surface drainage. When once thoroughly wet, however, it retains moisture well. It possesses marked capillary power.
The drainage of the seepage draws and depressions mentioned must be aided by artificial means to render such lands capable of cultivation and to prevent serious damage or ruin from the accumulation of an excess of the alkali salts. The location of such depressions may be ascertained by a comparison of the soil map (to be found in the accompanying portfolio) and the alkali and ground-water maps, colored Pls. XLV to LIII.

In the origin of this soil the weathering of the Cretaceous limestones and shales appears to have been an important factor. With the progressive weathering of the parent rocks this decomposed material has been transported by local drainage streams to the lower levels. Considerable modification by stream wash and wind action has subsequently taken place.

Mica usually occurs in small but noticeable quantities. Lime is generally present in relatively large proportions, and gypsum is usually quite abundant. Occasionally gypsum occurs in small pockets in this soil in a nearly pure form, imparting to the soil a granular structure, crumbling readily to a powdery or pasty mass. Considerable quantities of the alkali salts are also present, but these are usually found in injurious amounts only in the lower depths of the subsoil and do not impair the agricultural value of the soil, except along terrace edges and in the lower depressions, where the alkali is brought to the surface by seepage waters resulting from excessive irrigation, canal seepage, and imperfect drainage.

The Fresno fine sandy loam is relatively rich in plant food, although sometimes somewhat deficient in organic matter. The results of mechanical analyses are given in the following table:

**Mechanical analyses of Fresno fine sandy loam.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality.</th>
<th>Description.</th>
<th>Organic matter</th>
<th>Gravel, 2 to 1 mm.</th>
<th>Coarse sand, 1 to 0.5 mm</th>
<th>Medium sand, 0.5 to 0.1 mm</th>
<th>Fine sand, 0.1 to 0.05 mm</th>
<th>Very fine sand, 0.05 to 0.001 mm</th>
<th>Silt, 0.05 to 0.001 mm</th>
<th>Clay, 0.001 to 0.0001 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>7964</td>
<td>Sec. 9, T. 28 S, R. 56 W.</td>
<td>Fine sandy loam to sandy loam, 0 to 12 inches.</td>
<td><strong>P. ct.</strong></td>
<td><strong>P. ct.</strong></td>
<td><strong>P. ct.</strong></td>
<td><strong>P. ct.</strong></td>
<td><strong>P. ct.</strong></td>
<td><strong>P. ct.</strong></td>
<td><strong>P. ct.</strong></td>
<td><strong>P. ct.</strong></td>
</tr>
<tr>
<td>7962</td>
<td>Sec. 18, T. 24 S, R. 56 W.</td>
<td>Fine sandy loam, 0 to 12 inches.</td>
<td>.91</td>
<td>.10</td>
<td>1.10</td>
<td>2.16</td>
<td>8.26</td>
<td>19.02</td>
<td>56.46</td>
<td>12.78</td>
</tr>
<tr>
<td>7963</td>
<td>Subsoil of 7962.</td>
<td>Yellowish, micaceous fine sandy loam, 12 to 72 inches.</td>
<td>.36</td>
<td>.08</td>
<td>.40</td>
<td>1.14</td>
<td>4.86</td>
<td>13.78</td>
<td>66.86</td>
<td>12.66</td>
</tr>
<tr>
<td>7965</td>
<td>Subsoil of 7964.</td>
<td>Sandy loam to fine sandy loam, 12 to 72 inches.</td>
<td>.47</td>
<td>.90</td>
<td>.50</td>
<td>1.18</td>
<td>6.14</td>
<td>33.48</td>
<td>39.54</td>
<td>19.02</td>
</tr>
</tbody>
</table>
The Fresno fine sandy loam is one of the most valuable soils of the Arkansas Valley area. In the eastern part of the area, however, owing to the present insufficiency of the water supply, a large proportion of the land is unirrigated and is devoted to grazing. The most of it is capable of cultivation and with the increase and perfecting of the means for storing the flood waters will undoubtedly be gradually brought under cultivation.

Upon the irrigated areas large crops of alfalfa, wheat, oats, corn, sorghum, melons, sugar beets, sweet potatoes, fruits, and all staple as well as special crops of the region are successfully grown.

This soil is especially adapted to the raising of sugar beets, alfalfa, grains, and melons. Fruits, especially apples, cherries, plums, and peaches, do well when properly cultivated and protected by windbreaks. The growing of tomatoes and truck crops for local market and canning purposes could be made a profitable industry.

The soil is easily tilled and with proper and thorough cultivation and irrigation may be brought to and maintained at a high state of fertility and productiveness.

Riverwash.

Riverwash varies in texture from fine micaceous sand to coarse sand and gravel, with which waterworn bowlders are frequently mingled. The sand is usually of a white or reddish color and is often drifted about by the winds.

In typical section this deposit is 6 feet or more in depth, the depth being usually greater, except where the bed rocks of the Cretaceous Period outcrop or appear near the surface.

Riverwash, as its name implies, occupies the present or former channels of the Arkansas River and its larger tributaries. It thus occurs as a body from one-eighth to one-fourth mile or more in width, extending throughout the area surveyed, with occasional smaller branches following the course of tributary streams.

Riverwash is usually separated from the bordering soils by well-defined boundaries or terrace lines, but it sometimes grades into the stream-deposited bodies of Fresno fine sand and Fresno sand. It is found only in the bottoms of the valley trough and is with few exceptions devoid of vegetation, only a few weeds and willows finding here and there favorable conditions for growth.

Its mineral constituents are mainly fragments of quartz and feldspar mingled with the finer silt sediments, the whole being deposited from the waters of the valley streams when heavily laden with sediments at times of flood. The deposits are continually shifting and rearranging themselves with every alternating flood, and the stream beds frequently fill with quicksand, rendering fording dangerous or impossible. Riverwash is not only deficient in organic matter and the valuable mineral soil constituents, as well as lacking the proper physical
texture, but it is submerged with every passing flood. Hence it is uncultivated and of no agricultural value.

FRESNO FINE SAND.

The Fresno fine sand is a grayish or yellowish micaceous fine sand, varying in depth from a few inches to several feet. It usually occurs as shallow deposits about 18 inches in depth, underlain by coarse sand and gravel or occasionally by the finer and heavier river silts. The areas are often cut by narrow streaks and local patches of waterworn gravel, Fresno sand, Riverwash, and silt deposits, too small to be indicated upon the maps.

The areas of this soil type are generally small in extent, consisting of long, narrow strips adjacent to present or recent stream channels. The soil usually grades into the recent sands and loams of the river bottoms.

The Fresno fine sand usually occurs upon the lower terraces of the Arkansas River and its principal tributaries. The terrace lines are usually well marked, and the surface is generally level or slightly pitted by stream action. A heavy growth of sunflowers and of the less desirable cocklebur, sand bur, and other weeds of the lighter soils frequently cover the areas of this soil type, while in many places the soil supports quite a vigorous growth of cottonwood, some of the trees reaching a considerable size.

The deposits of the Fresno fine sand are usually but slightly elevated above the stream channels and the present water table. The soil is subject to very rapid percolation, however, and when not influenced by seepage from surrounding higher lands or by a water table lying very near the surface requires abundant irrigation during the growing season for vigorous crop growth. Some of the lower areas, however, require drainage for the removal of surplus seepage or overflow waters. The areas are subject to frequent and sudden overflows in times of floods.

The materials of the Fresno fine sand come partly from the mica-bearing rocks of the Rocky Mountains and partly from the finer sands of the river bottoms and stream channels. This material has been deposited in recent times from the moderately slack waters of the streams in flood. More recent modification by wind action has since taken place in many of these soil areas.

The presence of a large amount of mica is a distinctive feature of this soil type, imparting a peculiar mealy and greasy feel to the soil when rubbed between the fingers. Large quantities of this material are deposited upon the lower terraces with every passing flood. The soil is somewhat deficient in both organic and mineral plant food, and this deficiency should be supplied by artificial means for the practice of successful agriculture.
Normally the soil is free from alkali salts in injurious quantities. In a few cases, however, where small areas are subject to seepage from higher levels, the alkali salts have accumulated at the surface in injurious quantities. Owing to the generally pervious nature of the soil, however, this trouble can generally be remedied by artificial drainage, where sufficient fall can be obtained for the establishment of a drainage system.

The areas of Fresno fine sand are generally reserved for pasture, although occasionally small crops of alfalfa and other staples of the area are grown.

With artificial drainage, the application of stable or green manures, and intelligent cultivation and irrigation fair crops of alfalfa, grain, sweet potatoes, and melons should be produced. These areas are, however, generally subject to overflow during flood periods, and in their present condition are of but little value for other agricultural purposes than grazing. A part of the overflowed lands might be reclaimed by a system of protecting dikes, but, owing to expense of construction and possibility of destruction by floods, this can hardly be recommended under the present agricultural conditions.

**SANTIAGO SILT LOAM.**

The Santiago silt loam is a heavy brownish silt loam, typically 6 feet in depth, but sometimes only 3 feet, or even less. It is exceedingly tenacious when wet and possesses a marked adobe structure, baking and cracking by intersecting checks upon exposure to dry weather.

The shallower deposits of this soil formation are underlain, usually at about 3 feet, by material similar to San Joaquin black adobe or the Fresno sand and sometimes, when adjacent to stream channels, to the Fresno fine sand.

This soil type is the most extensive type of the lower bottoms. It usually occurs in quite large areas of irregular outline, but occupying the lower lands adjacent to the main streams of the area. These soil areas are somewhat more extensive and uniform in the eastern than in the western part of the area. The soil is quite uniform in texture and structure, but often grades quickly into the other soils of the bottoms and is greatly cut and marked with irregular patches and streaks of the Fresno sand, Maricopa sandy loam, Fresno fine sand, and other adjacent soils. These bodies are generally too small to be indicated upon the soil maps, but are often present to such extent as to influence the productivity and agricultural value of such lands.

The typical soil is quite easily recognized by its position, heavy, sticky nature, and adobe structure, being commonly called adobe in this locality.

Waterworn gravel rarely occurs, except occasionally in the subsoil. Frequently very fine, angular chips and fragments of the Cretaceous rocks appear upon the surface.
The Santiago silt loam is found only in the valley bottoms, lower stream terraces, and a few of the local depressions and draws. The areas are often separated from the adjacent soils by light terrace lines of recent river formation. The surface is usually level, and the areas are unmarked by outcrops or other topographic features.

The native vegetation consists principally of the bunch grasses, buffalo grass, and plants of the heavier soils, with occasional patches of sunflowers, cockleburs, and other weeds of rank growth. In the western part of the area surveyed this soil type is sometimes covered with extensive and vigorous growths of "greasewood."

The following table gives the mechanical analyses of the soil and subsoil of this type:

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality</th>
<th>Description</th>
<th>Organic matter</th>
<th>Gravel, 2 to 1 mm.</th>
<th>Coarse sand, 1 to 0.5 mm.</th>
<th>Medium sand, 0.5 to 0.25 mm.</th>
<th>Fine sand, 0.25 to 0.1 mm.</th>
<th>Very fine sand, 0.1 to 0.05 mm.</th>
<th>Silt, 0.06 to 0.005 mm.</th>
<th>Clay, 0.005 to 0.001 mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7966</td>
<td>Sec. 32, T. 23 S., R. 56 W.</td>
<td>Heavy silty loam, 0 to 12 inches</td>
<td>1.87</td>
<td>0.00</td>
<td>0.32</td>
<td>0.62</td>
<td>6.08</td>
<td>39.34</td>
<td>39.94</td>
<td>13.60</td>
</tr>
<tr>
<td>7968</td>
<td>NE. corner sec. 1, T. 22 S., R. 57 W.</td>
<td>Brownish heavy silty loam, 0 to 24 inches</td>
<td>.94</td>
<td>.84</td>
<td>2.23</td>
<td>2.32</td>
<td>7.88</td>
<td>11.38</td>
<td>30.50</td>
<td>44.62</td>
</tr>
<tr>
<td>7967</td>
<td>Subsoil of 7966</td>
<td>Heavy silty loam, 12 to 72 inches</td>
<td>.72</td>
<td>.00</td>
<td>.18</td>
<td>.18</td>
<td>2.68</td>
<td>34.46</td>
<td>46.76</td>
<td>15.60</td>
</tr>
</tbody>
</table>

Owing to the large proportion of the finer sediments in this soil and to its close texture and impervious structure, percolation and drainage take place slowly. Small areas lying near stream channels are sometimes subject to overflow during freshets. With this exception the greater part of these lands are normally free from water in excess of the amount required by crops, except during periods of heavy rains.

With the extension of irrigation, however, and the formation of resulting seepage springs along terrace lines, the drainage of the lower areas of these lands has become very imperfect. This is true especially of the deeper deposits or those underlain by heavy clay loam. The location of such areas is shown upon the accompanying groundwater maps. The establishment of a thorough system of drainage, preferably by use of tile, is the only means of effectively correcting this evil.

The Santiago silt loam is of alluvial origin, the material being derived by the scouring of the streams along their upper courses. The waters of the Arkansas River and its tributaries are very muddy during flood time, often containing by analysis over 3 per cent of silt. This is deposited in large quantities along the flood plains during high water.
The Santiago silt loam is rich in both mineral and organic plant foods. Gypsum and lime often occur in abundance, especially in the subsoils of the deeper deposits. These are also often accompanied by relatively large quantities, often amounting to over 1 per cent, of the injurious alkali salts. In the deeper deposits and those not affected by seepage waters or by long-continued irrigation these alkali salts remain in the subsoil and do not greatly affect the native vegetation. These conditions now exist upon large areas of the land covering the western part of the Rockyford sheet.

With insufficient drainage the alkali has in many places appeared at the surface and greatly impaired the land for agricultural uses. In the eastern part of the area surveyed large areas of the Santiago silt loam have a slight accumulation of alkali upon the surface. While in its present condition it has the appearance of containing large amounts of alkali, there is really less proportionally than upon the “greasewood” covered lands of the upper valley.

With proper cultivation this soil should retain moisture well, and should possess valuable capillary properties. Upon exposure during the summer, however, it becomes compact and bakes badly, becoming very hard and dry even with the water table from 3 to 6 feet below the surface. This condition is found throughout the greater proportion of the eastern part of the valley.

A large proportion of the Santiago silt loam bottoms is devoted only to grazing. This is the case especially where the lands have been damaged by alkali or seepage water, and in the eastern sheets, where the water supply is limited.

In the western part of the Rockyford sheet and in the vicinity of the towns throughout the valley valuable and productive farms and ranches are located upon this soil type. The most important crops are alfalfa, sugar beets, the grains, and melons. Excellent yields of these crops are produced during favorable seasons.

This soil is especially adapted to the production of alfalfa hay and seed and sugar beets. Owing to its heavy and somewhat refractory nature, thorough, deep, and frequent cultivation is imperative. These lands, when properly handled, rank with the most valuable beet lands of the valley. Under the same conditions of cultivation and handling, the soil is well suited to the production of watermelons and cantaloupes. This soil is not so well adapted to fruit growing as the lighter types, although apples do well.

SAN JOAQUIN BLACK ADOBE.

The San Joaquin black adobe is a very heavy black clay loam, typically about 3 feet in depth. It is usually underlain by river-deposited sands and silts. The soil is very stiff and tenacious when wet and when dry cracks upon exposed surfaces and assumes an adobe struc-
SOIL SURVEY OF LOWER ARKANSAS VALLEY, COLORADO. 757
ture. It greatly resembles the typical heavy adobes of the Pacific coast.

This is one of the least extensive and important soil types in the area. It occurs in small patches or streaks in the bottoms throughout the area surveyed. It is easily recognized by its position, vegetation, heavy, tenacious nature, and adobe structure. No gravel occurs in this soil type.

The San Joaquin black adobe occurs in local drainage depressions and slough bottoms of the lower valley terraces. The surface is generally smooth and below the level of the surrounding country. The areas are unmarked by rock outcrops, bluffs, or terrace lines. The native vegetation consists of buffalo grass, the common weeds of the heavier soils, and, more often, slough grass and rushes.

The most of the areas of this soil type are poorly drained, the water table being close to or at the surface. The soil is of a very close, heavy texture and percolation and natural drainage takes place very slowly. Many of the small areas in the heavily irrigated sections of the survey have been greatly damaged by seepage waters.

This soil is of alluvial origin, resulting from the sedimentary deposits of ponded streams, small local lakes, and sloughs. These deposits have since been modified by puddling, maceration, and the incorporation of organic matter.

The San Joaquin black adobe in poorly drained areas usually contains sufficient quantities of the alkali salts to impair its agricultural value. Thorough drainage and careful cultivation of these lands are necessary to render them productive.

Owing to position and deficient drainage, but very little of this land is under cultivation. Upon a few of the better drained areas the crops of the heavy silt loam are produced, with fair yields during favorable seasons.

This soil, when thoroughly drained, is best adapted to the growing of sugar beets and alfalfa. (See Pl. XLIII, fig. 1.)

The following table shows the texture of soil and subsoil of this type:

*Mechanical analyses of San Joaquin black adobe.*

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality</th>
<th>Description</th>
<th>Organic matter</th>
<th>Coarse sand</th>
<th>Medium sand</th>
<th>Fine sand</th>
<th>Very fine sand</th>
<th>Silts</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>P. ct.</td>
<td>0.2 to 1 mm.</td>
<td>0.05 to 0.25 mm.</td>
<td>0.025 to 0.05 mm.</td>
<td>0.006 to 0.025 mm.</td>
<td>0.0006 to 0.006 mm.</td>
<td>0.0006 mm.</td>
</tr>
<tr>
<td>7960</td>
<td>Sec. 6, T. 23 S., R. 56 W.</td>
<td>Heavy black clay loam, 0 to 12 inches.</td>
<td>2.61</td>
<td>0.16</td>
<td>0.24</td>
<td>1.16</td>
<td>3.64</td>
<td>47.68</td>
<td>46.80</td>
</tr>
<tr>
<td>7961</td>
<td>Subsoil of 7960</td>
<td>Heavy clay loam, 12 to 48 inches.</td>
<td>1.82</td>
<td>.84</td>
<td>.82</td>
<td>.46</td>
<td>1.54</td>
<td>4.84</td>
<td>52.20</td>
</tr>
</tbody>
</table>
WATER SUPPLY FOR IRRIGATION.

The average annual rainfall of this region is generally greater than that of most of the irrigated districts of the West. Dry farming in the Arkansas Valley area has, however, always proven a failure, and can never be recommended for this section.

An irrigation system to prove efficient must be able to supply water at all periods of the growing season whenever the lack of sufficient moisture is indicated by the growing crops. Plants abundantly supplied with water by artificial means during a part of the growing season become pitifully dependent upon such a supply, and when from sudden shortage this supply is denied them suffer accordingly. The necessity for an uninterrupted water supply in irrigated sections is thus obvious.

The State of Colorado is divided into watersheds and again into water districts, each under the charge of a water commissioner. The commissioners serve under the State engineer, an official appointed by the governor of the State. Acting upon reports from gauging stations, the water is apportioned to the different canal systems according to amount claimed and priority of claim. In case of a shortage in the supply all the systems suffer, and a rather complex scheme of loaning or exchanging water is sometimes observed among the canals of a district. This is in a measure doing away with the long-established system of dispensing water strictly according to the doctrine of prior rights, which, although it may be just, does not admit of the most efficient irrigation of the greatest area.

The larger canal systems are each under the control of a canal superintendent. The individual lateral headgates are usually kept locked down, care being taken that each patron is supplied with only such an amount of water as is due him. Under such regulations there is much less danger of immoderate irrigation and the use of excessive and injurious quantities of water than where each patron is left to help himself.

The irrigation waters of the area are supplied by the Arkansas River and its tributaries, and the permanency of water in these streams depends not so much upon the rainfall during the summer as upon the winter snows in the mountains, which slowly melt and furnish a constant supply during the growing season.

The supply is subject to great and sudden variations. Short periods of violent floods alternate with long periods of but little flow. During periods of normal flow but little water reaches the Kansas State line, practically all being taken out for irrigation purposes. The amount of the underflow is undetermined, but is undoubtedly considerable.

The canal and storage-reservoir systems of the area are very extensive. Of the canal systems of the Rockyford or most western sheet of the area, the Rockyford Canal is the oldest and one of the most important. A large share of the melon and beet lands of the valley lie under this canal. Other important systems are those of the Catlin...
Ditch and the High Line and Otero canals. Of these all but the Rockyford Canal have their headgates outside of the area surveyed. Upon the north side of the valley a large section, known as the Holbrook country, is covered by the Holbrook Canal. This is supplemented by the Reservoir Ditch from Holbrook Lake, which is supplied with water from the Holbrook Canal during flood time.

In this area, at least, the storage reservoir is a necessary adjunct to an ideal system of irrigation. By using such a reservoir, where properly constructed and where means for filling the reservoirs during flood periods can be had, a constant supply of water may be maintained during the growing season, regardless of summer droughts.

Within the remaining sheets of the area many small canals water the south side. These are usually in the vicinity of the towns and larger ranches which they water, and are generally of a more or less private nature. Taken as a whole, however, the claims and priorities of these canals are well established, and they cover a large part of the most valuable lands of the valley.

On the north side of the valley the land is covered by the Fort Lyon Canal, operated by the Fort Lyon Canal Company, and by the immense storage reservoir and canal system of the Arkansas Valley Sugar Beet and Irrigated Land Company. This latter system was constructed at a total cost of over $2,000,000 by the Great Plains Water Company, and has been recently acquired by the present owners. This company also owns the greater proportion of the land covered by its own irrigating system in the eastern part of the area surveyed. This land is now being placed on sale.

By arrangement with the Fort Lyon Canal Company the storage reservoirs are supplied with water through the Kicking Bird Canal, which is taken from the Fort Lyon Canal where the latter crosses Gageby Arroyo. There is no irrigated land in the vicinity of the reservoirs nor above the Fort Lyon Canal, the waters of the reservoirs being drawn upon only to supplement the Amity Canal through the Comanche and Pawnee canals and Big Sandy Creek. This canal, with the Buffalo Canal, is owned and controlled by the Arkansas Valley Sugar Beet and Irrigated Land Company.

This system, while of recent construction, is the largest of its kind in the country. Tables giving the capacities of both the canals and reservoirs of the system follow:

<table>
<thead>
<tr>
<th>Name</th>
<th>Water unavailable.</th>
<th>Water available.</th>
<th>Total capacity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nee Sopah</td>
<td>10,908</td>
<td>23,464.50</td>
<td>34,372.50</td>
</tr>
<tr>
<td>Nee Gonda</td>
<td>39,880</td>
<td>57,309.00</td>
<td>97,069.00</td>
</tr>
<tr>
<td>Nee Noehe</td>
<td>21,486</td>
<td>60,686.50</td>
<td>82,121.50</td>
</tr>
<tr>
<td>Nee Skab</td>
<td>9,989</td>
<td>18,279.00</td>
<td>18,279.00</td>
</tr>
<tr>
<td>Total</td>
<td>82,192</td>
<td>182,635.60</td>
<td>264,827.60</td>
</tr>
</tbody>
</table>
Considerable allowance must be made in the above figures for decrease in capacity of canals due to their filling in with silt deposits.

The system has so far proved a partial failure. The reservoirs are natural lakes or depressions lying considerably below the level of the surrounding country. Consequently a large quantity of water must be supplied to them before any of it can be taken out through the canals and made available for use. The inlet canals are deficient in carrying capacity. The headgates at river inlets sometimes become jammed with logs and flood débris, and when finally cleared the flood is often past. In case of failure to fill the reservoirs during the brief time of the freshets the system becomes useless. The loss of water by evaporation where it lies spread out over a large surface, as it does in the shallow reservoirs, is great, amounting to 6 feet or more in depth over the entire surface. The losses of water from seepage and evaporation from the longer canals are also very great.

Another defect quite common to the canal systems of the area is the matter of cheaply constructed and unstable headworks. This applies especially to the smaller and private canals. Those of the Holbrook and Fort Lyon systems are of a much more substantial and durable character. The headgates and dam of the Amity Canal have in the past given much trouble, especially during the floods of 1902. These are now, however, being replaced by quite expensive and stable structures. Many of the canals of the area have been greatly damaged at crossing points of arroyos and washes. Usually no provision is made at these local draws and drainage channels for the waters which occasionally gather from violent local showers, and these floods often wash large sections of the canals away. There is more or less loss in the capacity of the canals from rapid silting up of the channels by the muddy waters. To avoid this evil considerable fall is usually given to the canals, but even then it becomes necessary to remove the silt from the canals at frequent intervals. In some cases a foot of sediment has been known to accumulate in the canals during a single

<table>
<thead>
<tr>
<th>Name</th>
<th>Length</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort Lyon</td>
<td>118.00</td>
<td>2,090.00</td>
</tr>
<tr>
<td>Kicking Bird</td>
<td>36.50</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Satanta</td>
<td>12.50</td>
<td>300.00</td>
</tr>
<tr>
<td>Comanche</td>
<td>16.78</td>
<td>400.00</td>
</tr>
<tr>
<td>Pawnee</td>
<td>6.34</td>
<td>200.00</td>
</tr>
<tr>
<td>Amity</td>
<td>110.00</td>
<td>870.00</td>
</tr>
<tr>
<td>Buffalo</td>
<td>16.10</td>
<td>192.00</td>
</tr>
<tr>
<td>Total</td>
<td>311.22</td>
<td>5,058.00</td>
</tr>
</tbody>
</table>
season. Many of the canals abound in frequent and very sharp curves, which hasten the silting up of the channels at such points.

The Horse Creek Reservoir, supplementing the supply of the Fort Lyon Canal, is of recent construction, and no statements as to its efficiency can as yet be made.

The problem of controlling the flood waters of the Arkansas River and its tributaries is more formidable than seems to be generally appreciated by the constructing engineers; and yet, although past efforts have in a measure been disappointing, the problem is still a hopeful one.

The construction of a few flumes and cut-offs would in many cases greatly shorten the canals and save considerable loss by seepage. Thorough puddling of the canal sides and bottom during construction should be accomplished if practicable, in order to make them as impervious as possible. The necessity of a more thorough irrigation of a small amount of land, rather than the imperfect watering of large tracts, of a more durable construction of headworks and flumes, and of larger inlets to storage reservoirs, is evident. The matter of the preservation of the forests around the headwaters of the rivers is also a most important one and worthy careful consideration by legislators, since the early melting of the unprotected snows of the mountains leads to quickly passing floods and shortage of water during the later season.

Stream measurements have been taken at irregular intervals throughout the valley, but no reliable observations, continuing unbroken for considerable periods of time, are available. The Arkansas River usually has a considerable discharge during the late spring and early summer, supplied largely by the melting of the mountain snows. Of its tributaries, Purgatoire River and Horse and Adobe creeks are the most important within the area surveyed. These streams sometimes have a discharge of several thousand feet during short intervals of flood, but are normally dry or nearly so.

While an immense amount of water is supplied to the area, this is entirely inadequate for the lands under the present canals and capable of irrigation. The extension of irrigation in the Arkansas Valley area must consist of a more abundant supply to lands already covered by canals, rather than the construction of more systems. In the middle and eastern parts only a small proportion of the land capable of irrigation is now successfully cultivated.

The utilization of the Horse and Adobe creek reservoir sites, with a more thorough and careful system of storage, the necessity of which is being more fully realized, will undoubtedly greatly alleviate this condition.

The character of the irrigation waters is an interesting and important subject. All waters taken from the Arkansas River and its tribu-
Field Operations of the Bureau of Soils, 1902.

Tories during flood time are extremely muddy. An analysis of a sample of such water, with the silt which it carries, follows:

**Analysis of muddy water from Fort Lyon Canal, Las Animas, Colo.**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per 100,000.</th>
<th>Constituent</th>
<th>Parts per 100,000.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium sulphate (CaSO₄)</td>
<td>42.39</td>
<td>Sodium chloride (NaCl)</td>
<td>3.29</td>
</tr>
<tr>
<td>Magnesium sulphate (MgSO₄)</td>
<td>18.30</td>
<td>Sodium carbonate (Na₂CO₃)</td>
<td></td>
</tr>
<tr>
<td>Potassium chloride (KCl)</td>
<td>1.69</td>
<td>Sodium bicarbonate (NaHCO₃)</td>
<td>19.30</td>
</tr>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>.60</td>
<td>Total solids</td>
<td>85.60</td>
</tr>
</tbody>
</table>

The analysis of silt carried by water from Fort Lyon Canal shows the principal mineral constituents:

<table>
<thead>
<tr>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of silt in sample of water</td>
</tr>
<tr>
<td>In dry sample:</td>
</tr>
<tr>
<td>Total nitrogen (N)</td>
</tr>
<tr>
<td>Phosphoric acid (P₂O₅)</td>
</tr>
<tr>
<td>Lime (CaO)</td>
</tr>
<tr>
<td>Potash (K₂O)</td>
</tr>
</tbody>
</table>

This heavy percentage of silt, as previously stated, gives considerable trouble in rapidly silting up the canals and ditches. This is, however, not altogether a disadvantage, as it forms a more or less impermeable layer on the bottom and sides of the canals and greatly checks losses from seepage. It is due to this that the muddy waters can be carried for many miles across the loose-textured upland sands, where the clear waters from the reservoirs would be lost through seepage.

The fertilizing value of this sediment is also not to be overlooked. It is very rich in lime, and also contains considerable quantities of nitrogen, phosphoric acid, and potash, as is shown by the foregoing analysis. When several inches of this material are added to the soil in the course of a half dozen years, as often occurs, it is equal in value to many pounds of costly fertilizers. For this reason the silt-laden water of the streams is preferred by farmers to water from the storage reservoirs.

While analysis reveals the presence of a considerable quantity of soluble mineral salts in the waters, these are generally of the less harmful class. With proper cultivation and drainage no harmful results should follow their use. In the case of the reservoir waters a sensible concentration of the soluble alkali salts is sure to result from evaporation. With the full operation of the systems and proper precautions, however, it is believed this will not become a serious problem.

**UNDERGROUND AND SEEPAGE WATER.**

The source of the artesian water of the Arkansas Valley is the Dakota sandstones. These rocks outcrop over large areas in the vicinity of the mountains, where the main supply is received. In several quite extensive areas near the central part of the area surveyed the Dakota
sandstones are covered only by the upland sands. A considerable
addition to the supply may be received at these points.

As before stated, the strata of the Dakota sandstones are frequently
broken. The rock varies also from a loose and open to a more per­
fectly cemented and impervious texture. The prediction of the quan­
tity of water to be encountered at any point becomes very difficult.
Most of the town wells of the area furnish from 50 to 150 gallons per
minute at a depth of from 400 to 800 feet. It is only rarely that the
pressure is sufficient to produce a flowing well.

The character of the waters also varies considerably, all of them
being mineralized to a greater or less extent, depending upon the
quantity of infiltrating waters from the Cretaceous shales, which are
quite heavily charged with the alkali salts.

Tables showing the results of analyses of samples of the artesian
waters of the area follow:

**Analysis of artesian water, Las Animas, Colo.**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per 100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (Ca)</td>
<td>0.69</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>5.00</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>36.30</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>.80</td>
</tr>
<tr>
<td>Sulphuric acid (SO₃)</td>
<td>49.29</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>2.09</td>
</tr>
<tr>
<td>Bicarbonate acid (HCO₃)</td>
<td>54.24</td>
</tr>
<tr>
<td>Carbonic acid (CO₂)</td>
<td>2.09</td>
</tr>
</tbody>
</table>

**Conventional combinations:**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per 100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium sulphate (CaSO₄)</td>
<td>2.30</td>
</tr>
<tr>
<td>Magnesium sulphate (Mg SO₄)</td>
<td>24.71</td>
</tr>
<tr>
<td>Potassium chloride (KCl)</td>
<td>1.49</td>
</tr>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>41.40</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>2.29</td>
</tr>
<tr>
<td>Sodium bicarbonate (NaHCO₃)</td>
<td>74.71</td>
</tr>
<tr>
<td>Total solids</td>
<td>150.50</td>
</tr>
</tbody>
</table>

**Analyses of artesian water from Lamar, Lajunta, and Rockyford, Colo.**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per 1,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium chloride (LiCl)</td>
<td>Tr. 3</td>
</tr>
<tr>
<td>Potassium chloride (KCl)</td>
<td>12 13</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>55 32</td>
</tr>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>1,000 671</td>
</tr>
<tr>
<td>Magnesium sulphate (MgSO₄)</td>
<td>29</td>
</tr>
<tr>
<td>Calcium sulphate (CaSO₄)</td>
<td>1,000</td>
</tr>
<tr>
<td>Sodium nitrate (NaNO₃)</td>
<td>11 67</td>
</tr>
<tr>
<td>Sodium carbonate (Na₂CO₃)</td>
<td>73 48</td>
</tr>
<tr>
<td>Ammonium carbonate (NH₄)₂CO₃</td>
<td>72</td>
</tr>
<tr>
<td>Magnesium carbonate (MgCO₃)</td>
<td>75 43</td>
</tr>
<tr>
<td>Strontium carbonate (SrCO₃)</td>
<td>104 37</td>
</tr>
<tr>
<td>Calcium carbonate (CaCO₃)</td>
<td>184 6</td>
</tr>
<tr>
<td>Ferric carbonate (Fe₂CO₃)</td>
<td>0.2 Tr.</td>
</tr>
<tr>
<td>Manganese carbonate (MnCO₃)</td>
<td>2</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>50 12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per 1,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1,341</td>
</tr>
<tr>
<td>Sum of MgSO₄, CaSO₄, MgCO₃, and CaCO₃</td>
<td>206 80</td>
</tr>
</tbody>
</table>

---

Nearly all the towns and larger settlements of the area are supplied with the artesian water of the Dakota sandstone. With this exception, however, there are but few wells. There is no perfect artesian basin, and the possibilities of irrigating with waters of an artesian source are remote. The character of the water for this purpose is often poor, the supply insufficient to irrigate more than a few acres of truck crops, and the cost of pumping prohibitive.

Ground water consists of underground water lying much nearer the surface than artesian waters and not under a head of pressure. The zone of saturation, or the line at which the soil becomes saturated with free water, is known as the water table. When the water table is encountered by wells free water rapidly oozes out, but does not rise in the well above its source. The determining factors in the position of the water table and the amount of water are the rainfall and irrigation, the thickness and porosity of the water-bearing strata, and the position of the underlying impervious rocks and earth. The water table may or may not be parallel to the surface and often fluctuates greatly in position from season to season. This is especially true in heavily irrigated districts, in which the position of the water table is affected by seepage from irrigated lands.

Upon the uplands of the Arkansas Valley area and above the canals the water table lies at relatively great depths. Near the canals, however, and through the valley bottoms it approaches very near to the surface. Its source here is the percolating waters of the rainfall and the seepage springs and underground waters from the canals and irrigated lands. Upon the higher lands and at some distance from the canals the supply is limited. Upon the lower lands and in the vicinity of the canals the wells are usually shallow and supplied with a good flow of water.

The quality of a few of the wells which tap the springs having their source in the upland soils is good. As a whole, however, the character of the ground waters of the area is poor and often unfit for domestic use. For this purpose artesian water from the town or outlying wells, or cisterns filled from the irrigating ditches in flood time, are in general use. The surface wells are often contaminated by organic matter and surface drainage, and the waters are usually too highly charged with alkali salts to be used for drinking purposes.

While large quantities of water of this character underlie the lower lands of the area, the prospects of irrigation by pumping from this source are not encouraging. With the operation of a few pumping plants of sufficient capacity to irrigate a considerable proportion of the lands the supply would probably rapidly diminish. The character of the water is such also as to make its use dangerous. In general, any water so heavily charged with alkali salts as to be unfit for domestic use is unfit for irrigation.

The presence of large quantities of seepage water in an irrigated district is unfortunate, and the removal of such water is an important
SOIL SURVEY OF LOWER ARKANSAS VALLEY, COLORADO. 765

problem. Even its appearance in small quantities is an indication of dangerous conditions. Seepage water results either from loss of water from canal systems and storage reservoirs or from the use of large and too often unnecessary quantities of water in irrigation. The immoderate use of water has always been one of the greatest dangers of irrigated districts. The injury lies not only in the swamping of large areas of the lower lands, but also in the ruin of large tracts from the accumulation of the alkali salts at the surface.

While the damage from the accumulation of alkali and seepage waters in the Lower Arkansas Valley area is much less than in many sections of the West, it is sufficiently serious to create alarm. The position of such seepage areas may be ascertained by consulting the underground water maps (Pls. XLVI to XLIX).

Upon the uplands the seepage areas occur usually as relatively narrow strips bordering canal lines, or as broader areas occupying local depressions, flats, or draws. There is often considerable seepage on the slopes of terraces and elevations, due to the outcropping of a porous layer of soil or rock confined between relatively impervious layers.

The greatest injury has occurred, however, in the bottoms of the main valley and of the many tributary valleys extending outward from it. This is especially true of the draws along which canals extend. In the western part of the area the local depression known as Patterson Hollow is one of the worst affected areas. Eastward from this point many parts of the valley bottoms show similarly bad conditions. Springs carrying a considerable quantity of alkali-laden seepage water are frequent, and many local sloughs and bogs have been formed since the advent of irrigation. In nearly all these localities the conditions seem to be rapidly growing worse, and means should be taken at once to put a stop to the evil.

All of the seepage water contains large quantities of alkali salts, the sulphates and chlorides predominating. The extremely injurious black alkali has been detected, but exists in only very small proportions. The alkali salts in the seepage water are derived from the leaching of the Cretaceous shale rocks and adjoining soils. An analysis of a sample of this shale rock, taken near Rockyford, follows:

Chemical analysis of soluble salts in Cretaceous shale.

[Sample 6622, taken 11 miles northeast of Rockyford, Colo.]

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Per cent.</th>
<th>Constituent</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ions:</td>
<td></td>
<td>Conventional combinations:</td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>9.77</td>
<td>Calcium sulphate (CaSO₄)</td>
<td>21.80</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>2.25</td>
<td>Calcium chloride (CaCl₂)</td>
<td>9.77</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>15.03</td>
<td>Magnesium chloride (MgCl₂)</td>
<td>9.77</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>1.50</td>
<td>Potassium chloride (KCl)</td>
<td>3.00</td>
</tr>
<tr>
<td>Sulphuric acid (SO₄)</td>
<td>15.79</td>
<td>Sodium bicarbonate (NaHCO₃)</td>
<td>55.66</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>15.03</td>
<td>Total salt content</td>
<td>0.266</td>
</tr>
<tr>
<td>Bicarbonate acid (HCO₃)</td>
<td>40.63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The importance of the drainage of soils in connection with their irrigation is too often unrecognized. Its value is, however, becoming more and more evident. It offers opportunities for the regulation and solution of one of the most serious problems of the arid regions. The introduction of a thorough system of drainage in a district damaged by seepage is productive of many valuable results, chief among which are the removal of bogs and sloughs, the extension of the cultivable areas, and the production of earlier and better crops. It is the only efficient method of reclaiming alkali lands. Drainage also effects a better aeration of the soil and produces conditions favorable to the decomposition of the mineral and organic constituents of the soil, thus increasing the supply of plant nutrients. The reclamation of swamps, with the resulting improved hygienic conditions, and the improvement of the country highways, are also advantages not to be overlooked. The drainage of the seepage areas in this district is generally practicable. The work has already been started in parts of the valley, and the outlook for its extension is encouraging.

ALKALI IN SOILS.

A comparison of the alkali and underground water maps of the Lower Arkansas Valley area shows that in general the areas in which there is a concentration of 0.20 per cent or more of the alkali salts in the first 6 feet of soil coincide very closely with those in which the water table is indicated as lying 6 feet or less below the surface. This relation shows the effect of the seepage waters upon the distribution of the alkali salts in the soil and the accumulation of alkali upon the surface.

In the uplands the soils damaged by alkali occur as relatively narrow strips running parallel with the canals or as broader bodies occupying local draws, flats, or former seepage lake bottoms. A number of alkali areas of the latter class are found in the vicinity of Holbrook Lake, in the Rockyford sheet. Other areas appear in the “Big Bend country,” a large section of well-settled and valuable farming land to the northwest of Lamar, covered by the Fort Lyon Canal, and in many other similar localities. Nearly all the draws and secondary valleys have quite prominent slopes, and but little injury has been done to the land in these places, excepting long, narrow strips occupying depressions and following the axes of the valleys. The zone of injury is, however, in most cases rapidly extending upward and outward and encroaching upon the more valuable lands.

In the valley proper the damaged areas usually occur upon the heavier soils of the bottoms. The areas of the Santiago silt loam and the San Joaquin black adobe, from their heavy texture and structure and low-lying position, are most often affected. In the eastern part of
the area the greater proportion of the Santiago silt loam bottoms contains over 0.20 per cent of alkali, and is devoted mainly to pasture.

In the southern part of the Rockyford sheet several alkali areas covering creek bottoms there shown as containing from 0.20 to 1 per cent of alkali in the first 6 feet have the greater proportion of all the salts in the subsoil. The surface soil is free from alkali, or nearly so. In this condition the lands, although heavily charged with alkali, will produce good crops until the alkali of the subsoil is brought to the surface by irrigation and seepage waters.

Sodium sulphate is the prevailing alkali salt of the Lower Arkansas Valley area. This, with the other common salts of the area, is derived largely from the Cretaceous shales. Sodium chloride is second in quantity and importance, while calcium sulphate, or gypsum, and magnesium sulphate, or Epsom salts, form large proportions of the remaining alkali salts of the region. Sodium bicarbonate is generally found, often in considerable quantities, in the irrigation and seepage waters, but the extremely injurious black alkali, or sodium carbonate, does not exist in harmful quantities in either the soils or irrigation waters. This salt has been detected in solution in seepage waters of poorly drained parts of the area, where it probably owes its formation to conversion from the less injurious bicarbonate through deficient drainage, which favors this chemical reaction.

Under normal conditions the alkali salts of the Lower Arkansas Valley occur only in the subsoil, the rainfall of the region being sufficient to leach them from the immediate surface. With the progress of irrigation, however, the subsoil becomes filled with water and the water table of the lower lying lands is raised. As the irrigation and seepage waters percolate through the soil the readily soluble salts are leached away and carried to the lower lands, and there, with the evaporation of these waters, the material in solution is left upon the surface in the form of an alkali crust. The capillary power of a soil, at times of so much value as a means of supplying moisture to growing crops, may thus become a menace to agriculture by its properties of lifting large quantities of salts in solution to the surface, there to be concentrated by evaporation. This tendency should be checked by the planting of close-growing crops, such, for instance, as alfalfa, which check evaporation by shading the surface, or, better still, by the constant maintenance of a loose mulch of soil upon the surface by thorough and careful cultivation.

In the case of a soil containing alkali only in the subsoil, shallow-rooted crops may for a time be raised with safety. In case of an alkali accumulation upon the immediate surface only, as occurs in many local alkali spots of the valley bottoms, deep-rooted crops, if once started, grow with comparative luxuriance. Heavy irrigation or deep planting are sometimes resorted to as aids in securing germination, after which the plants are less susceptible to the effects of the salts.
Several methods for the reclamation and utilization of alkali lands have been tried. Prominent among these are the removal of alkali crusts by scraping, the washing away of the surface concentrations by heavy flooding, the utilization of partly unproductive lands by special cultivation of alkali-resistant crops, and the application of gypsum to the lands. All of these may, under certain conditions, be of value in aiding the removal of the alkali salts and in rendering the fields capable of cultivation, but in the reclamation of lands containing considerable quantities of alkali they are all inefficient.

The application of gypsum is beneficial, particularly in the presence of black alkali or sodium carbonate. By chemical reaction, the less injurious white alkali, or sodium sulphate, replaces the carbonate. This, however, still leaves an excess of the sulphates in the soil. As there is practically no black alkali in the area surveyed, this means of improving the condition of the alkali lands does not apply. There is, also, an abundance of gypsum at the present time in the soils of this area, and it is therefore unlikely that the black alkali will ever give any trouble.

The only method for the reclamation of alkali lands which effects a permanent reclamation is thorough drainage. Its absolute success in lowering the water table, destroying the capillary connection between the underground water and the surface, and in removing in solution large quantities of alkali salts has already been demonstrated, not only by artificial drainage systems but in nature as well. The question of the cost of a system of artificial drainage is, however, the determining factor in its utility for the purpose.

In the Lower Arkansas Valley there are many small tributary valleys or draws, previously mentioned, extending outward into the plains and traversing in many cases the alkali lands. It frequently happens that these local drainage channels are not continuous, though with but slight expense they could be made so by cutting open drainage ditches along their axes. The construction of such ditches would in itself remove a large quantity of seepage water and greatly improve the condition of neighboring lands. For the complete reclamation of the lands, however, a system of lateral drains having their outlet into the main drainage channel should be constructed.

Open lateral drains are somewhat less expensive than tile drains, considering first cost, but the former not only interfere with cultivation, but, in the Lower Arkansas Valley, require frequent cleaning and constant attention, as they fill up rapidly with tumbleweeds, which are blown about in great numbers by the winds, and so are more expensive in the end.
Several examples of tile drainage and its effects may be seen in this area at the present time. These systems have been in operation but a few months, but something of their ultimate success may already be appreciated. The most complete system at the present time is found upon the lands of the American Beet Sugar Company at Rockyford. This was laid out after a preliminary contour survey taken at 6-inch intervals. These plans are now being followed out, and up to the present time several thousand feet of tile have been laid. The tile used vary from 4 to 10 inches in diameter, and are laid at a depth of from 3 to 7 feet. Tile may be purchased delivered at Rockyford in carload lots at a cost of from 2 cents per foot for 4-inch to 7½ cents per foot for 10-inch diameters. The cost per foot of the tile laid upon these lands amounted to from 7 to 11 cents. In laying the system in this tract considerable trouble was encountered with quicksand, which frequently underlies the soils of the bottoms, often to considerable depths. This made it necessary in some cases to use sheet piling for trench curbing while the work was in progress, and to substitute sewer pipe for ordinary drainage tile to avoid displacement by the shifting sands. The sheet piling was in certain cases left in the ground. This, with the use of the sewer pipe, has greatly increased the cost of the work, but it is unlikely that such conditions will everywhere be encountered. The cost of the sewer pipe, second grade, varies from 11 cents per foot for 10-inch to 25 cents per foot for 15-inch pipe. Specially prepared paraffin paper was used to cover the upper portions of the joints in the pipe.

The results of the work have been very gratifying. After extremely heavy rains, the 10-inch tile have been observed to run full for several days. The system resulted in lowering the water table from 1 to 2 feet during the summer of 1902.

After the excess of alkali is removed from the soil, cultivation of the land should be very thorough, keeping a loose mulch of fine earth continually on the surface. Water should not be applied in quantities in excess of the actual needs of the crops. Irrigation by flooding should be generally practiced, rather than furrow irrigation.

With the partial reclamation of the lands the raising of alkali-resistant crops is recommended. Among these, sorghum and sugar beets can be grown as soon as any of the field crops, and besides will allow frequent cultivation of the soil. Later on, alfalfa, corn, and other field crops may be grown.

The alkali lands of this area, when once reclaimed, become the most valuable lands of this section of the country, and in the great majority of cases there can be no doubt as to the profitableness of reclamation, even by the most expensive system of tile drainage.
AGRICULTURAL METHODS.

The agricultural methods employed in different parts of the Lower Arkansas Valley area vary widely. The agricultural lands range from those under a very intensive system of cultivation to those retained in large tracts and devoted to the growing of alfalfa, stock raising, and grazing. In general, however, the methods of cultivation and irrigation practiced in growing the general farm crops are none too careful.

The character of the irrigation depends very largely upon the supply of water available in the canals at the time irrigation is judged necessary. As in other irrigated areas, considerable waste attends the distribution of the water, and more water is often consumed than is needed by the growing crops, while subsequent cultivation is often lax. Rank growths of weeds are often observed in orchards and in fields of growing crops. In the older and more intensively cultivated portions of the valley, however, cultivation is much more thorough.

Very little commercial fertilizer is used in the area, but barnyard and sheep manure are applied to the fields and green manuring is practiced, usually with alfalfa as the crop to be turned under.

Alfalfa growing is practiced on a large scale, labor-saving machinery being brought into play wherever possible in handling the crop. The warm and generally cloudless weather of the summer season is especially favorable to its growth. The hay is ready to stack very soon after cutting. It is first raked into piles, and these are in turn carried to the stack upon "bull rakes," where it is pushed upon the stacker and lifted by horsepower and placed upon the stack. By this method there is very little hand labor employed.

Three crops of hay are usually produced during the season, the yield averaging about 5 tons per acre for the season in fairly good years. (See Pl. XLIII, Fig. 2.) This will sell for from $3 to $5 per ton in the stack, and, considering the low cost of production, the crop is a very profitable one. Alfalfa is generally irrigated once during the winter and twice during the summer. The growing of alfalfa seed is also an important industry, one crop of hay and one of seed being produced during the season.

In growing melons and sugar beets the methods followed are much more intensive. For cantaloupes the heavier sandy loams having a slight slope are preferred. The soil is often made very rich by green manuring and the application of barnyard manure, a large proportion of organic matter being of value in the production of this crop. The land is then marked out in checks, 8 feet each way for watermelons and 6 feet each way for cantaloupes, the checks then being furrowed one way. About 10 to 15 seeds are planted from 1 to 2 inches deep in hills 1 foot long at intersections of checks, the hills being elevated sufficiently to keep the surface from being flooded during irrigation,
Frequent cultivating and hoeing is necessary. At the second hoeing the hills are thinned to two plants. The vines are usually lightly irrigated once from one to three weeks after thinning. In planting, every twelfth row is left vacant for a roadway to be used in harvesting.

The cantaloupes are picked when they will slip from the vine easily and are placed in a burlap sack slung across the shoulders of the picker. The sacks are emptied into boxes or crates placed upon sleds and lined with straw or burlap to prevent bruising. Each sled is drawn by a horse to the crating shed, which consists usually of a rude framework of poles covered lightly with branches or burlap sacking. The melons are here carefully inspected and packed in crates 12 by 12 by 24 inches, each crate holding 45 melons of standard size. Perfect melons should be of proper size, shape, and weight, closely netted, with ten distinct ribs and small seed cavity, and should have a flesh of light-green color, slightly yellowish at the center.

The average yield per acre is about 80 crates, although from 150 to 200 or more crates per acre are sometimes produced. The bulk of the shipments takes place between the middle of August and the middle of October. The planting is done from the 1st to the 15th of May, about forty days being required for the melons to reach maturity after they are set on the vines. The crop is shipped through the Melon Growers' Association and commission firms. The average net receipt per crate for the season of 1902 was about $1.

The cantaloupe industry is a very profitable one for growers who live within a radius of 5 miles from a shipping point, and is capable of further extension throughout the valley. Rockyford usually ships from 400 to 500 carloads and the other towns throughout the valley from 50 to 100 carloads per season.

In sugar-beet culture there are no striking departures from the methods used in other areas. Considerable stress is laid upon the necessity for early and deep plowing and thorough preparation of the land, especially when the soil is heavy, and upon securing a smooth, even surface and fine condition of the soil before seeding. As a rule beet culture is carried on somewhat more intensively and successfully in the western than in the eastern part of the area, owing to the greater experience of the growers. The average yield in the former district during the season of 1902 was about 16 tons per acre. The lower valley lands fell considerably below this, owing to an unusual scarcity of water. The sugar content is usually about 16 per cent. The use of too much water, a frequent mistake of less experienced growers, tends to produce shallow-rooted beets of low sugar content. Insufficient and careless cultivation has the same effect.

The rows are commonly sown 18 inches apart, and to sow an acre requires from 18 to 20 pounds of seed. The beets bring an average price of about $5 per ton at the factory.
Although this is not a grain-producing country, considerable quantities of corn and winter wheat are grown throughout the middle and eastern parts of the area surveyed. Rye and barley are raised, but only to a very slight extent. Except in the area covered by the Rockyford sheet, fruit is grown only in a small way and mainly for home consumption, but this industry is capable of further extension. The planting of wind-breaks of cottonwood and mulberry about the orchards is quite general, and while these afford considerable protection from windstorms the growing fruit is sometimes badly damaged by local hailstorms. As elsewhere, frequent spraying and thorough cultivation of the orchards are important. Apples, plums, cherries, and peaches are best adapted to the soils and climate, although the latter, if unprotected, are often injured by spring and winter frosts. The soil is frequently dug away from the roots of the young bearing trees and the tree bent down and buried under straw for the winter, to protect the tender fruit buds.

Irrigation by flooding is generally practiced where alfalfa and grains are the crops grown, while the furrow method is used in the beet and melon fields. The latter method is somewhat more likely to injure lands impregnated with alkali, owing to the tendency of the salts to creep upward and accumulate upon the ridges and elevations left above the water.

In general, the rotation of crops is not followed as closely as it should be, although more scientific and exact methods of rotation and cultivation are gradually coming in with the development of the sugar-beet and melon industries.

**AGRICULTURAL CONDITIONS.**

In the more intensively cultivated parts of the area, and in those which have not been held back by restricted water supply, the farming class is generally prosperous. In the middle and eastern parts, however, where a great deal of the land is held in large tracts, where a less intensive and careful system of cultivation prevails, and where the recent unusual shortage of water for irrigating purposes has been most severely felt, the situation is less satisfactory. Many abandoned tracts marked by broken prairie sod, half-completed houses, or cistern or cellar excavations occur, from which the settlers have removed to more favorable locations in the valley or returned to the Middle States, whence the most of them came. The abandonment of the lands is largely due to ignorance of the principles of irrigation on the part of settlers. Many have carelessly taken up lands under proposed irrigation systems which, when completed, have proven inadequate to supply the entire area or have been unable to reach the more elevated lands. The establishment of the more adequate and efficient system
of water storage now being considered will greatly alleviate this condition and lead to increased prosperity of the entire area.

The farming class is largely derived from the agricultural classes of the Middle Western States. The farmhouses of the newly settled tracts are usually very simple and cheaply constructed, often consisting of rudely built temporary houses or dugouts. These are in the more prosperous districts soon replaced with more substantial and often quite pretentious buildings, frequently of brick or stone. Building stone of excellent character is obtained, at but little expense for quarrying, at many points throughout the valley.

The towns and more thickly settled districts are well provided with churches and good schools. The high schools of the valley towns are the equals of those in much larger Eastern towns. The dwellings of outlying districts are often connected with each other and with the towns by telephone lines, the top wire of farm fences being frequently used for this purpose. Free rural mail delivery is in operation over a large part of the area, and it is not an unusual thing for a farmer living 10 or more miles from town to be in immediate communication with the local markets and shipping points by telephone, and to receive his daily newspaper with almost as much dispatch and regularity as though he resided in the larger towns. This not only leads to more intelligent business methods, but does away with much of the isolation of farm life. Local government is as well organized and the laws are as well enforced as in the more thickly settled districts of the East.

A large number of the farms of the area have been bought through the agency of building and loan associations, water companies, and real-estate brokers. Much indebtedness has been incurred and heavy obligations still encumber the lands in many cases, although the more intelligently farmed districts are rapidly being cleared of debt and the intensively cultivated districts are already largely free from indebtedness.

Good alfalfa, grain, and beet lands with water rights can be bought for from $30 to $50 an acre, but as the towns are approached the value rapidly increases. Fruit, beet, and melon lands adjacent to shipping points in the western portion of the area are valued at from $100 to $200 an acre. The price of land in the middle and eastern parts of the survey is much less than in the vicinity of Rockyford, although under similar conditions of cultivation, water supply, and shipping facilities it should be equally as valuable.

Tax rates are at the present time unusually high, due largely to necessarily expensive construction of bridges throughout the valley, the wagon bridges having been destroyed frequently by floods in the past few years.

Many extensive alfalfa and stock ranches occur throughout the entire survey. These are, however, most numerous in the areas cov-
Field Operations of the Bureau of Soils, 1902.

Excluding these vast tracts, and considering separately the general farming lands, the average size of the farms is about 160 acres. In the intensively cultivated beet and melon districts the tracts are much smaller. With the growth of the intensive melon and beet culture the general tendency is toward the breaking up of the larger ranches and tracts and the substitution of smaller tracts and better methods of cultivation. The Arkansas Valley Sugar Beet and Irrigated Land Company, which is now selling large areas of land near Amity (see Holly sheet), limits the quantity which may be purchased by one person to 40 acres.

Fairly satisfactory farm labor is to be had at a cost about one-fourth or one-third more than is paid in the Middle and Eastern States. In the more mechanical operations of thinning and topping beets and similar tasks the cheaper Mexican or white labor of less responsibility is usually employed. During the recent season a large part of the labor has been cheaply and intelligently performed by Navajo Indians, imported by contract from the reservations for this purpose.

Most of the important crops have already been mentioned. Nearly all products suited to the climate of the area may be produced with success. The growing of Irish potatoes is, however, usually attended with but very poor results, the soil or climatic conditions tending to produce tops rather than tubers. Sweet potatoes yield well. The raising of watermelons for shipment and local consumption is of importance, but is less developed than the cantaloupe industry. Fruit growing is becoming an important industry in the vicinity of Lajunta and Rockyford, the fruit being of excellent quality and finding a ready market. The growing of melon and garden seeds for market is also becoming a profitable and quite extensive line of agricultural development.

Stock raising and stock feeding are very important industries of the area. Many thousand head of cattle and sheep are annually brought in from the range and fattened during the winter. A large proportion of the alfalfa hay of the district is consumed in this manner. Many feeders are now growing large quantities of sugar beets to be used in fattening both cattle and sheep, claiming greater profits than can be obtained by selling the beets to the factory. Large quantities of factory beet pulp are also consumed in feeding. It is estimated that probably 100,000 head of sheep will be fed in the area during the winter of 1902-3.

Honey of excellent quality is produced in large quantities and is shipped extensively to eastern markets, about 12½ cents per pound being obtained for the crop. Unlike the alfalfa honey of some other western districts, the product is white and commands fancy prices.

Truck farming is becoming of some importance in the vicinity of the larger towns and is capable of further extension.
No unusually serious diseases prevail among the stock of the area, and insect pests and plant diseases are not more numerous nor destructive than elsewhere. Field corn suffers considerably from the ravages of smut, and grasshoppers are at times somewhat destructive to crops, especially in the eastern part of the area.

Several noxious weeds prevail to a troublesome extent, the most common being the Russian thistle, sandbur, cocklebur, and wild sunflower.

In melon culture the rich sandy loams containing plenty of organic matter are preferred. Sugar beets usually produce heavier and richer yields upon the heavier silt-loam bottoms, provided proper precautions are taken in the preparation of the land and the subsequent cultivation. In general, however, the character of the preparation of the land, watering, and subsequent cultivation seem to be of more effect upon both the beet and melon crops than the soils upon which they are grown. (See Pl. XLIV.)

Celery of fine quality may be produced upon the loams of the bottoms if properly cared for, and it would seem that the production of this crop might become of importance. Cucumbers, squashes, pumpkins, and similar crops are said to yield enormously, and the growing of these crops, especially upon the Rockyford fine sandy loam, should become profitable could the crops be handled by canning and pickling factories. The opportunities for the growing of special crops and for diversified farming in this area are promising, and the area will likely in the future become known for other products than its melons, sugar beets, alfalfa, and honey.

The valley is traversed throughout its entire length by the Atchison, Topeka and Santa Fe Railway, which handles a very heavy passenger and freight traffic, both through and local. The early melons are shipped by express and the later by fast freight. Many thousand tons of beets are annually shipped to the Rockyford factory from loading stations along the line. The freight upon such shipments is paid by the sugar company. Freight rates are generally high, and the shipping of produce is rather expensive. Many of the heavy beet-producing districts are also at some distance from the railway, making long hauls necessary and reducing the profits of the grower.

The more thickly settled rural districts are well provided with wagon roads, which are usually kept in good condition. The almost entire absence of mud in the spring is of considerable advantage to the rural districts, as the soil when once thoroughly wet becomes very sticky, making travel very difficult.

In addition to the local markets and those of the East, to which large shipments of melons, alfalfa, and honey are made, the resort, manufacturing, and mining towns of the central part of the State furnish excellent opportunities for the sale of agricultural products.
The important towns of the area are Rockyford, Lajunta, Las Animas, Lamar, Granada, and Holly. Nearly all of these places have at some time suffered from the inflation of real-estate values by the usual boom methods, but they are now enjoying a more healthful and normal, if slower, growth.

Rockyford is the center of the cantaloupe industry, the seat of the American Beet Sugar Company's factory, having a capacity of 1,000 tons of beets daily, and an important shipping point for fat stock and other agricultural produce. The Arkansas Valley substation, a branch of the State agricultural experiment station, is also located there. The city of Lajunta is the division terminal of the Santa Fe Railway, and the seat of the company's shops. It is also the county seat of Otero County and the location of a large brick and tile plant and other industries. The other towns of the valley are important shipping points for live stock and general farm produce. Lamar supports a large flouring mill, the grain for which is, however, largely shipped in from Kansas points. Another sugar factory is needed in the eastern part of the area and will soon likely be erected at Holly or Lamar, the production of beets at present being equal to or exceeding the capacity of the Rockyford factory. Amity, upon the Holly sheet, is the seat of a rapidly growing colony and a large orphanage under the management of the Salvation Army. The sanitary conditions of these towns is generally good, although improved drainage and sewerage systems are needed in some cases.

To summarize, agriculture in parts of the area surveyed is in a flourishing condition. In other parts it has received a severe check from inadequate water supply and inefficient or careless practices. With improvement in the irrigation systems now under way and the adoption of more scientific methods of irrigation and cultivation the conditions will be much improved in the future. The Lower Arkansas Valley area offers to the careful, industrious home seeker and to the cautious investor excellent opportunities, but is not without dangers for those less conservative or intelligent and industrious.