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**GROUND WATER IN THE ANIMAS, PLAYAS  
HACHITA, AND SAN LUIS BASINS  
NEW MEXICO**

**BY**

**A. T. SCHWENNESEN**

**WITH ANALYSES OF WATER AND SOIL**

**BY**

**R. F. HARE**

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**Prepared in cooperation with**

**THE NEW MEXICO AGRICULTURAL EXPERIMENT STATION**



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# GROUND WATER IN THE ANIMAS, PLAYAS, HACHITA, AND SAN LUIS BASINS, NEW MEXICO.

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By A. T. SCHWENNESEN.

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## INTRODUCTION.

### PURPOSE OF INVESTIGATION.

Every traveler on either of the southern transcontinental railroads is doubtless impressed as he speeds across southern Arizona and New Mexico by the vastness of the upland plains. If he passes through this region during or soon after the short rainy season of summer or early fall, when the range grasses are at their best, he may wonder at the scarcity of farms in a region that is apparently so inviting to agriculture. The luxuriance of the forage grasses seems to belie the reputed aridity of the climate.

In this region nature has for centuries been at work evolving certain types of drought-resisting and quick-growing plants suited to the climate. Perhaps the most valuable of the native forage plants are the so-called "grama grasses," some varieties of which mature in six weeks from the time the seed is sprouted. These desert grasses have made the region a great and valuable cattle range, but to the extent that it remains a cattle range it yields only a very small income to the acre. Only as the soil can be made productive when cultivated can the region provide permanent homes for a considerable population. The dry farmer and the irrigation farmer are working hand in hand, the one to perfect valuable drought-resistant and quick-maturing crops and to develop methods of farming by which the natural moisture in the ground may be conserved and used to the best advantage, the other to make up the deficiency in precipitation by utilizing surface and ground waters for irrigation.

During the last decade popular attention has been focused on the great irrigation works undertaken by the United States Reclamation Service, whereby surface waters that formerly ran to waste are stored and used in agriculture. The Salt River project in Arizona and the Rio Grande project in New Mexico are the greatest undertakings of this kind that have been completed in this region, both in respect to the amount of land irrigated and the magnitude of the engineering problems involved. The Yuma, Carlsbad, and Hondo are other large



projects undertaken by the United States Reclamation Service in these States. These projects, which involve expenditures of millions of dollars and require years for their execution, could not for a long time have been financed by private capital. By providing water for irrigation for hundreds of thousands of acres of desert land they make possible thousands of new homes. However, after developments of this kind have been carried to their utmost limits there will still remain immense areas of unreclaimed arable land. Other means will be found for making parts of these remaining areas productive, one of the most promising of which is irrigation with water pumped from wells.

Water is found at many places in the alluvium of the valleys and plains of the Southwest. Even the most forbidding and barren desert wastes may be underlain by water-bearing deposits. The perfection of internal-combustion engines and centrifugal pumps within recent years insures the success of irrigation with ground water in many districts. These districts are, however, limited by certain physical conditions, such as the quantity and quality of the water and the depth to the water table. At present it does not generally pay to pump water for ordinary field crops from a greater depth than 50 feet, but the cost of pumping is constantly being reduced as pumping machinery is improved, so that irrigation with ground water is now practicable in areas that a few years ago were beyond the limits of economical service.

The development of supplies of ground water for irrigation is largely a matter for individual enterprise. Each landowner may own his irrigation system independent of his neighbors. The units may be as large or as small as is desired and still each may be complete in itself. This feature makes it possible to reclaim with ground water many small isolated areas in which irrigation with surface water is not practicable.

The use of ground water in the vicinity of Deming, in the Mimbres Valley, N. Mex.,<sup>1</sup> is being watched with great interest by irrigationists of the Southwest, and the success so far attained there has undoubtedly given impetus to similar use in other parts of the State. The lessons learned there in regard to the mechanics of pumping and methods of agriculture will go far toward determining the practicability of using ground water for irrigation in the less developed areas.

Southern Grant County contains large tracts of potentially fertile soil that have hitherto been utilized only for grazing. It has no available supply of surface water for irrigation, and its rainfall is too meager and irregular to warrant the expectation that settlers there can make a livelihood exclusively by dry farming. In several areas,

<sup>1</sup> Darton, N. H., Underground water of Luna County, N. Mex.: U. S. Geol. Survey Water-Supply Paper 346, pp. 25-40, 1914.

however, there is shallow ground water that could be recovered by pumping.

Recognizing the great need for more definite information in regard to the quantity and quality of this ground water, its depth beneath the surface, and its economic availability for irrigation, a ground-water survey of southern Grant County was undertaken in August, 1913, by the United States Geological Survey in cooperation with the New Mexico Agricultural Experiment Station. The field survey was made by A. T. Schwennesen, under the direction of O. E. Meinzer, both of the Geological Survey. George E. Martin, who was employed as driver and general assistant in the field, rendered efficient service. The chemical analyses of the water and of the water-soluble constituents of the soil were made in the laboratory of the experiment station under the direction of R. F. Hare. The report was prepared chiefly by Mr. Schwennesen, but Dr. Hare contributed the part of the text describing the methods used in making the analyses of soil and water.

#### GEOGRAPHIC SKETCH.

The area considered in this paper is in the southwest corner of New Mexico and comprises about 3,600 square miles. It includes four closed drainage basins—the Animas, Playas, Hachita, and San Luis—in so far as they lie within the United States. It occupies nearly all of Grant County between the Mexican boundary and latitude  $32^{\circ} 30'$  north except that part which is in the San Simon Valley.<sup>1</sup> (See fig. 1.)

The major features of the area are three nearly parallel, northward-trending mountain chains and intervening plains or valleys. The bounding ranges are not continuous, and at some places it is possible to travel from one valley to another without crossing the ranges, although many low and easily accessible passes usually provide the most direct routes. Where the mountain ranges are absent the valleys merge into one another, the drainage divides being very low and inconspicuous, so that these valleys form in reality one great plain. Owing to this merging of the valleys much confusion has arisen as to their names. The terms used by the earliest explorers were broad and indefinite, but as the country is becoming better known more specific names are required.

The western mountain chain consists of the Guadalupe and Peloncillo ranges; the central chain consists of the San Luis, Animas, and Pyramid ranges; and the eastern chain comprises the Dog Mountains, the Hatchet and Hachita ranges, and the Coyote and Quartzite hills. Still farther east are several detached groups of hills or

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<sup>1</sup> U. S. Geol. Survey Water-Supply Paper 425, pp. 1-35, 1917 (Water-Supply Paper 425-A).

mountains, the largest of which are the Apache or Doyle Hills and the Little Burro Mountains.

The region between the Peloncillo Range and the Animas and Pyramid ranges, extending from a low divide 9 miles north of the

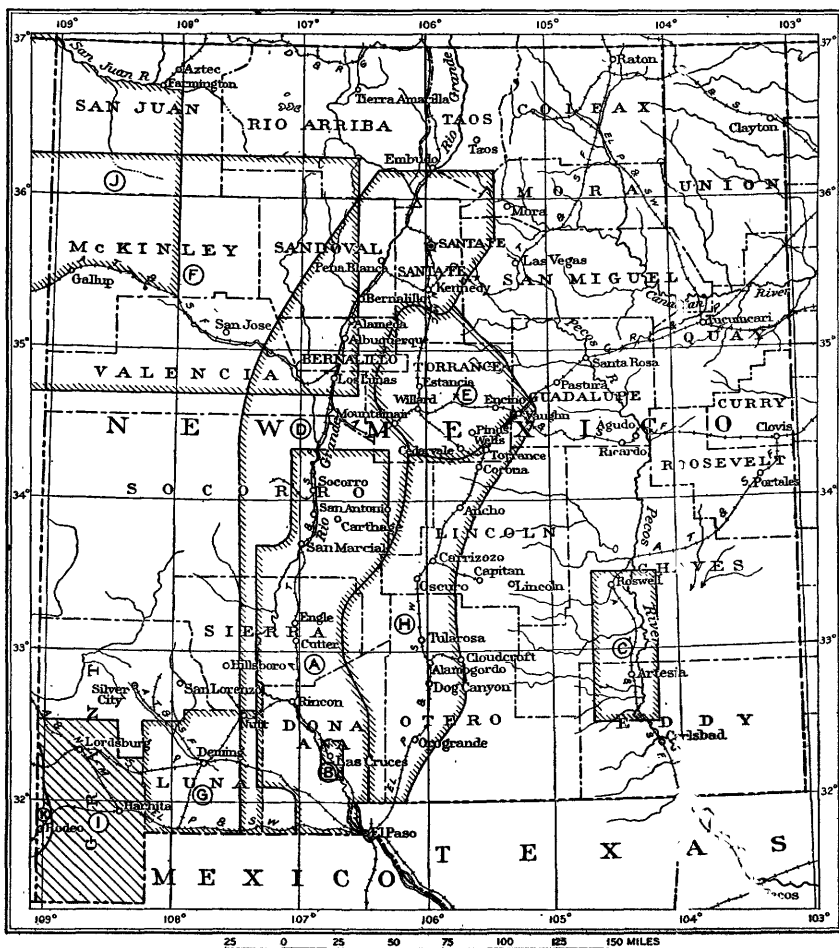


FIGURE 1.—Index map of New Mexico showing areas covered by this report and by other reports of the United States Geological Survey dealing with ground water. A, Water-Supply Paper 123; B, Water-Supply Paper 141; C, Water-Supply Paper 158; D, Water-Supply Paper 188; E, Water-Supply Paper 275; F, Bulletin 435; G, Water-Supply Paper 345-C and Bulletin 618; H, Water-Supply Paper 343; I, Water-Supply Paper 422 (the present paper); J, Water-Supply Paper 380; K, Water-Supply Paper 425-A.

Mexican border to the Gila River divide, is known as Animas Valley. The plain between the Animas Valley and the Mexican boundary is known as San Luis Valley. The part of Animas Valley south of the El Paso & Southwestern Railroad is called Upper Animas Valley, to distinguish it from Lower Animas Valley, which lies north

of the railroad. There is a marked difference in topography between the upper and lower valleys. Upper Animas Valley, from the head of Animas Creek to a point within 4 miles of Animas station, is well drained through a definite axial streamway that leads northward and discharges into the lower valley. Lower Animas Valley, on the other hand, has a broad and nearly level floor and no definite drainage lines. The flood waters discharged from the upper valley and from the gullies that head in the mountains on both sides spread in thin sheets over the valley floor or find their way through broad, shallow draws to the alkali flat that occupies the center of the lower valley.

At the time of the Wheeler survey, in the early seventies, all the plains country north of the Arizona & New Mexico Railway was called the Gila Plains, and the country farther south was known as the Valle de las Pláyas, meaning valley of the strands, because in different parts of the area there are alkali flats that become lakes in the rainy season. The name Valle de las Playas, or Playas Valley, has been retained but is now applied only to the valley which is bounded on the west by the San Luis and Animas ranges and on the east by the Hatchet and Hachita ranges and which extends from the Quartzite Hills and the south end of the Pyramid Range to the Mexican border.

Playas Valley is separated into an upper and a lower part by a low divide that extends diagonally across the valley from the base of the hills east of Mount Gillespie to Hatchet Gap. Lower Playas Valley lies in a small closed basin whose flood waters drain into Playas Lake, a barren alkali flat that occupies a depression in the center of the valley. Upper Playas Valley drains northward and eastward through Hatchet Gap.

To the region which is bounded on the west by the Hatchet and Hachita ranges and on the east by the Apache Hills and the group of hills north of the El Paso & Southwestern Railroad and which extends from Black Mountain to the Mexican boundary the name Hachita Valley is sometimes applied. A narrow but definite "draw," or dry streamway, extends along the axis of the valley from Black Mountain to the vicinity of Hatchet Gap and thence southwestward to the international boundary. At Hatchet Gap this draw receives the flood waters from Upper Playas Valley.

The plain lying north of Black Mountain and bounded on the northeast by the Little Burro Mountains and on the southwest by the Coyote Hills, Quartzite Hills, and Pyramid Range may for convenience be called Lordsburg Valley. The primary drainage line in this valley leads northwestward, parallel to the Arizona & New Mexico Railway, from Black Mountain to Lordsburg, and thence

westward around the upper end of the Pyramid Range into the alkali flat, or "dry lake," of Lower Animas Valley.

Upper Animas, Lower Animas, and Lordsburg valleys therefore lie in the Animas drainage basin, San Luis Valley is in the San Luis drainage basin, Lower Playas Valley is in the Playas drainage basin, and Upper Playas and Hachita valleys are in the Hachita drainage basin.

#### HISTORICAL SKETCH.

From the time of Coronado's memorable expedition in 1540-1542 up to the time of the Mexican war of independence, in 1811-1821, the Spaniards made numerous expeditions from Mexico into the region that now comprises Arizona and New Mexico. Most of these expeditions gained entrance to the country west of the Sierra Madre through the Santa Cruz Valley and to the country east of these mountains through the Rio Grande valley.

Southern Grant County contained none of that ancient civilization for which the early explorers were always in search, and it therefore offered almost no attraction either to the adventure in search of treasure or to the friars in search of new fields for missionary work. It is recorded that the Santa Rita mines were worked by the Spaniards in the eighteenth century, but otherwise Grant County does not figure in the early history.

Before the American occupation, in 1846, this territory was under Spanish and Mexican rule. By the treaty of Guadalupe Hidalgo, in 1848, the international boundary west of the Rio Grande was fixed at 31° 54' 40" north latitude as far west as meridian 109° 37' west longitude, and thence on that meridian north to the Pío Santo Domingo (San Simon Creek).<sup>1</sup> This left the southern part of the area described in this report still under Mexican rule. In 1853, through the Gadsden purchase, the boundary line was fixed in its present position. In 1868 Grant County was organized out of territory taken from Dona Ana County. In 1901 a part of the territory belonging to Grant County was taken to form part of Luna County, and the present boundaries of Grant County were established.

The first authentic account of any journey through this region is contained in the report of Lieut. Col. P. St. George Cooke,<sup>2</sup> who with the "Mormon battalion" started from Santa Fe in October, 1846, to find an easy and direct wagon route from the Rio Grande to the Pacific. By taking a more southerly course he expected to escape many of the difficulties experienced by Gen. Kearney, who followed the Gila route earlier in the year. In this expectation he was not disappointed, for, aside from inconveniences due to occasional scarcity

<sup>1</sup> Bancroft, H. H., *History of Arizona and New Mexico*, vol. 17, pp. 471-472, San Francisco, 1889.

<sup>2</sup> Notes of a military reconnaissance from Fort Leavenworth in Missouri to San Diego in California: 30th Cong., 1st sess., H. Doc. 41, pp. 553-555.

of water, his party suffered no unusual hardships, and on the whole he seems to have been well satisfied with the results of his journey. As nearly as can be determined from his map and description, his course led to Ojo de Vaca (Cow Spring), in the northwestern corner of Luna County, and thence across the plain north of Hachita, through one of the passes near the north end of the Hachita Range, across Playas Lake in the vicinity of the Whitmire ranch, through Whitmire Pass into Animas Valley, up Animas Valley to the present Mexican boundary, and thence across the Guadalupe Range, near the southwestern corner of the State. The party had some difficulty in crossing this range with their wagons and they spent several days in constructing a road. The lower passes to the north, discovered several years later by Lieut. Parke, were not known to Cooke at this time, for in speaking of the southern pass he says:

This is called the Pass of Guadalupe, and this is the only one for many hundreds of miles to the south by which the broken descent from the great table-land of Mexico can be made by wagons, and rarely by pack mules. I hold it to be a question whether the same difficult formation does not extend north, at least to the Gila. If it is so, my road is probably the nearest and best route. But if the prairie to the north is open to the San Pedro and water can be found, that improvement will make my road not only a good but a direct one from the Rio Grande to the Pacific.

In 1853 the War Department detailed Lieut. John G. Parke to make explorations and surveys for a railroad from the Mississippi to the Pacific Ocean. This expedition explored the route now followed by the Southern Pacific Railroad, namely, from Steins Pass northeastward across the Lower Animas Valley, around the north end of the Pyramid Range, and thence southeastward along the base of the broad slope of the Little Burro Mountains.<sup>1</sup>

In 1873 G. K. Gilbert, in connection with the Wheeler survey,<sup>2</sup> made observations on the geology in the region previously reconnoitered by Lieut. Parke's party. His notes deal particularly with the geology of the Peloncillo Range north of Gabilan Peak, the Virginia (Ralston) mining district at the northeast end of the Pyramid Range, and parts of the Little Burro Mountains. Oscar Loew,<sup>3</sup> connected with the expedition in the capacity of mineralogic assistant, made observations on the soil, vegetation, and water supply of the region with a view to ascertaining its agricultural possibilities.

#### INDUSTRIES AND POPULATION.

Two transcontinental railroad lines—the Southern Pacific and the El Paso & Southwestern—cross the area, and a branch line—the Arizona & New Mexico—extends northwestward through the area

<sup>1</sup> Explorations and surveys for a railroad from Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War, 1853-1856, vol. 7, 1857.

<sup>2</sup> U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 513-515, 1875.

<sup>3</sup> Idem, pp. 578-579.

and connects the two main lines with the Clifton and Morenci mining districts, in eastern Arizona.

In 1910, according to the United States census, Grant County had 14,813 inhabitants. As nearly as can be determined, hardly more than one-fifth of these—about 3,000—lived in the area considered in this report. Most of the inhabitants of this area are whites, the Mexicans being found only in the towns and at the small stations along the railroads, where they are employed mainly as section hands. The farmers and stockmen are practically all white and are chiefly native Americans, the foreign-born whites being confined almost exclusively to the towns and mining districts.

Lordsburg, the largest town, is in the north-central part of the area, at the junction of the Southern Pacific and Arizona & New Mexico railroads. It is supported largely by the silver and copper mines of the Virginia and Pyramid mining districts, which are a few miles south, in the Pyramid Range, and by business incident to railroad maintenance, but it is also a supply and shipping point for the cattle ranches of an extensive range country and for the farms in Lower Animas Valley. Its population in 1910 was 1,323.

Hachita, the second town in population, is in the upper part of Hachita Valley, at the point where the Arizona & New Mexico Railway connects with the main line of the El Paso & Southwestern Co. The town is supported almost entirely by trade from the cattle ranches and farms of Hachita, Playas, and Upper Animas valleys to the south and west, but during the last few years it has also been the supply point for a number of army camps along the Mexican border. The population in 1910 was 628.

Smaller settlements, having post offices and stores, are Separ and Steins, on the Southern Pacific Railroad, and Animas and Playas on the El Paso & Southwestern Railroad.

The chief industries of southern Grant County are mining, stock raising, and agriculture. Most of the mining activity is near Lordsburg, in the northern part of the Pyramid Range. Prospecting was begun here in 1870, and active mining was started in the early eighties, about the time the Southern Pacific Railroad was being built. Mines have also been worked from time to time, with varying degrees of success, at Gold Hill, in the Little Burro Mountains, at Sylvanite and Old Hachita, in the Hachita Range, at Steins Pass and Granite Gap, in the Peloncillo Range, at Gillespie, in the Animas Range, and at several points in the Apache Hills.<sup>1</sup>

Stock raising is at present the leading industry and will without doubt continue to be important. In the last few years the public lands in the valleys, upon the rich grama grasses of which the cattle-

<sup>1</sup> Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., *The ore deposits of New Mexico*: U. S. Geol. Survey Prof. Paper 68, pp. 295-348, 1910.

men depended for their summer range, have to a great extent been occupied and fenced by settlers. This change has been a severe blow to the large cattle companies and will probably result in a reconstruction of the stock-raising industry.

Agriculture in southern Grant County is still very much in the experimental stage. The conditions that must be met are severe. If the new settlers succeed it will probably be by combining stock raising on a small scale with dry farming and ground-water irrigation. They should have small herds of cattle to which unmarketable farm products may be fed, and which may range on the large upland areas of nonagricultural land that provide excellent pasturage during certain seasons of the year. In regions remote from markets and where transportation rates are high, stock raising in connection with farming is especially desirable.

#### AGRICULTURAL POSSIBILITIES.

The following greatly abbreviated quotation from an article by R. H. Forbes, relating to the possibilities of agriculture in Sulphur Spring Valley, Ariz., previously published by the United States Geological Survey,<sup>1</sup> is given here because it is believed to apply in general to the conditions in southern Grant County and to contain advice that will be helpful to the settlers in that county:

#### WATER SUPPLIES.

With reference to its use in agriculture, the water supply may be divided into direct rainfall, flood-water run-off, and ground water. The rainfall is sometimes adequate for the production of crops by ordinary methods of farming and at other times entirely inadequate. In average years, however, the summer rains, from July 1 to October 1, are adequate for the production of certain crops. The winter rainfall is much less valuable, but by suitable methods of conservation may be made to contribute to the raising of crops.

The flood water from heavy rains in the mountains is often of great benefit to the adjacent country. By means of ditches this flood water may be intercepted and carried onto cultivated land for future use in growing crops. This form of water supply, however, like rainfall, is intermittent and uncertain and must be supplemented by some more certain supply in order to be made useful.

The ground waters, where within economical reach of pumping, constitute a supplementary supply of great future value.

Several more or less successful methods of farming have been adopted. Among these are so-called dry farming, flood-water farming, farming by irrigation with pumped water, combinations of dry farming and flood-water farming, dry farming and supplementary irrigation with pumped water, and farming with the ranging of cattle where the land is yet unoccupied.

*Dry farming.*—Dry farming is uncertain because of the varying rainfall from year to year and because of the possible bad distribution of a rainfall which, if timely, would be adequate for the production of crops. Dry farming consists essentially in the stor-

<sup>1</sup> Meinzer, O. E., Kelton, F. C., and Forbes, R. H., Geology and water resources of Sulphur Spring Valley, Ariz., with a section on agriculture: U. S. Geol. Survey Water-Supply Paper 320, pp. 214-223, 1913.



age of moisture in the soil and its subsequent utilization by crops. The irregularity of the rainfall may easily interfere with a carefully planned program of operations, and the winds, the exceedingly dry air, and the heat of summer all produce excessive evaporation of moisture and necessitate unusual vigilance and care in maintaining the soil mulch to conserve the rainfall, even temporarily. Good equipment and efficient organization are consequently necessary for carrying on farming punctually and in the proper way. In spite of these difficulties, however, part crops of corn, sorghum, milo maize, and beans were grown on the dry farm of the Arizona experiment station southwest of McNeal during the somewhat unfavorable seasons of 1909 and 1910, on rainfall only, conserved by dry-farming methods of cultivation. Beans produced an encouraging crop, and considerable yields of corn and sorghum were also obtained.

Ranchers have also produced promising crops of beans, sorghum, corn, broom corn, milo, and Kafir. These preliminary results indicate that dry farming alone has a distinct but limited utility in the region, which, however, can undoubtedly be greatly increased by the use of supplementary water.

*Flood-water farming.*—Flood-water farming, which is immediately consequent upon rainfall, is practiced to some extent in the southwestern part of the United States and adjacent parts of Mexico. The Papago Indians, especially, are very skillful in diverting storm waters at advantageous points by crude ditches which lead the water upon subjacent tracts of level land. At the beginning of the summer rains these Indians make preparation for planting and cultivating their summer crops by breaking the fallow ground left after harvesting the preceding crops. In the loose soil thus prepared the rainfall and the diverted storm waters are accumulated. In it corn, beans, melons, pumpkins, squashes, martynias, and sorghum mature rapidly under the influence of the warm summer season, the moisture in the soil, and usually the continued rains and floods of the summer. The Papago Indians are particularly successful in cultivating their own quick-growing, drought-resistant varieties of corn and beans and rarely fail to obtain satisfactory returns from their work.

Winter crops of wheat and barley are usually less satisfactory, for the winter rains are less adequate and the winter run-off is less abundant than the storms and run-off of summer. In some winters, however, fairly satisfactory crops of wheat are matured by the Indians.

Following the example of agricultural tribes of the Southwest, the Mexicans, and to some extent the Americans also, are utilizing storm-water run-off, supplemented in many places with additional irrigating supplies. By combining the use of flood waters with the thorough cultivation incident to methods of dry farming, considerable though not always certain returns are realized.

In some places it is also possible to supplement rainfall and flood waters with stored water impounded behind low and inexpensive embankments thrown up at advantageous points across washes and swales leading from the mountains, from which most of the water supply comes.

*Supplementary irrigation with pumped water.*—Unlike rain and flood waters, which are intermittent and uncertain, the ground waters, which may be economically reached under certain areas, are permanent and certainly obtainable and may be used to supplement the cheaper supplies, thus assuring crop returns to the farmer.

Stored ground waters will, indeed, take the place of the reservoir waters available in certain other agricultural valleys. In some localities where water of desirable quality comes very near the surface it may be found possible to develop and use ground waters according to ordinary methods of irrigation. Where pumping from any depth is required, however, the cost of this form of water supply renders desirable the use of as little pumped water as possible. To be most effective, it should be applied only when the starting or saving of a crop renders its use especially advantageous or necessary. The summer growing season, for instance, beginning with the summer rains in July and ending with the early frosts, is in some years too short to mature

satisfactorily corn, sorghum, Kafir corn, and certain other forage and vegetable crops. These crops can be started well in advance of the summer rains by running pumped water down the planting furrows, then cultivating thoroughly to conserve moisture, and sowing seed in the moist soil. Crops thus planted will come on rapidly while the soil holds moisture and will then be carried along by the summer rains, which begin about the 1st of July. If the rains are timely and the soil is thoroughly cultivated after each rain, no further irrigation will be necessary, and fairly satisfactory crops can be had.

In the winter growing season, also, fall crops of wheat and barley may be started by similar supplemental irrigation and brought up in time to utilize winter rainfall and be well advanced toward maturity by April. The scant rainfall of the spring months, however, is usually insufficient to mature grain crops, and a second supplemental irrigation is necessary. The use of supplemental pumped water is much less practicable with winter than with summer crops because of the greater amount of supplementary water required.

The use of supplemental pumped water is, however, not limited to the exigencies of planting and maturing a crop. By maintaining surface tilth in the form of a deep mulch according to the methods used in dry-farming, pumped water, like rainfall or storm-water run-off, may for a season be stored and conserved in the soil. At the dry farm near McNeal, Ariz., water has been thus stored and utilized with conspicuous benefit to crops six months after pumping, thus making it practicable to utilize the output of small plants for the storage of soil water. To do this, the ground should be irrigated through furrows as rapidly as the pumping plant will supply the water. These furrows should then be cultivated level and the mulch maintained as in dry farming. Beginning, say, on the 1st of January, the farmer can thus store water in his fields for four months, until danger of late frosts is over, and can then plant his crops on accumulated soil moisture to be supplemented by summer rains, and the crop can usually be brought to completion without further help from the pumping plant. The experiments near McNeal have shown that about 4 inches deep of water, or about one-tenth the amount required under ordinary irrigation in southern Arizona, applied in this way, is sufficient to assure a crop. Moreover, the continuous use of a pumping plant through several months is more economical, considering investment, interest, and depreciation, than the temporary use of such a plant only at critical times in the growth of the crop. Used continuously in this manner a pumping plant may be made to carry the crops, not on a few acres only, but on as many acres as can be supplied by the plant with water a few inches deep during several months of the year.

*Stock raising in connection with farming.*—The areas within which methods of dry farming, supplemented by the use of pumped water, are now possible are limited to those intermediate elevations where good soil is underlain by ground water within economical pumping distance. At higher elevations there are large areas of good land which is capable of supporting an abundant growth of native grasses but under which the water lies too deep for present economical pumping. It is not at all unlikely, therefore, that some of these lands that lie near areas where dry farming with supplemental pumped water can be undertaken with a fair certainty of success may be used for grazing cattle in connection with the dry farming on the neighboring lands. This cultivable area should be made to act as a balance wheel for the grazing areas. By means of rainfall, flood waters, and, when necessary, supplemental pumped water, crops of sorghum, Kafir corn, milo maize, and quick-growing varieties of Indian corn, and even alfalfa, may be grown and cured for use as forage in times of drought, when the open range fails. Such supplies of forage will serve to tide over range animals, especially during the dry months of April, May, and June, when feed is most likely to be scant and when, in some years, many cattle have starved. The losses of cattle from starvation sometimes reaching 50 per cent or more, may in this

manner, to a considerable extent, be prevented. By such a plan not only is productiveness insured for the cultivated areas, but use is made of large additional grazing areas.

It is not at all unlikely that the use of silos may become a feature of the agriculture of the region. During the winter and spring, when frosts and dry weather curtail the supply of green feed, a supply of fresh forage would be of great value to stock-growing industries. In French North Africa, in a semiarid region similar to southern Arizona, silos are successfully employed to preserve forage for use at times when green material is not available. With the aid of these silos dairying is carried on and cattle are fattened.

In this connection it is interesting to note the manner in which the Papago stockmen of extreme southwestern Arizona adapt themselves to the arid conditions there. About July 1, at the beginning of the summer rainy season, when surface flood waters may be impounded in the valley bottom lands, these people, with their cattle, horses, and agricultural implements, move from the mountains to the valleys and remain there, grazing their cattle on summer grasses and planting quick-growing crops on soil soaked with flood waters and occasionally moistened with rain. In the fall as the rains fail and the supplies of water impounded for domestic use disappear, the Indians go back to their villages in the adjacent foothills, where their cattle range through the winter on the summer growth of wild hay and are watered from their owner's wells. In this way, by spending half the year in the mountains and half in the valleys, these Indians live well in a region where white men, with methods unadapted to it, have repeatedly failed to establish themselves. The peculiar merit of the Indian method is that it shifts the cattle from mountains to valleys and from valleys to mountains each year, so that at no time are the ranges seriously overgrazed, as are the fixed watering places and grazing grounds commonly maintained by American stockmen.

## PHYSIOGRAPHY AND DRAINAGE.

### MOUNTAINS.

#### GENERAL FEATURES.

About 1,100 square miles, or nearly one-third of southern Grant County, is occupied by mountains. Three narrow, sharply marked, parallel mountain chains cross it from north to south, a zone of minor relief extends along its eastern margin, and numerous isolated buttes are scattered through it. (See map, Pl. I, in pocket.)

#### WESTERN CHAIN.

The Guadalupe and Peloncillo ranges form a mountain chain that extends uninterruptedly from the Mexican border to Gila River and forms a connecting link between the great mountain system of the central plateau of Mexico and that of the plateau of northern New Mexico and Arizona.

From the Mexican boundary this chain extends due north for 20 miles along the Arizona-New Mexico boundary; thence it swings eastward into New Mexico and extends northward and northwestward

for 45 miles to Steins Peak, where it crosses the State line. In Arizona the same chain continues northwestward to the canyon of Gila River and beyond into the complex mountain system of central Arizona. Along the Mexican border the chain is 12 miles wide. Toward the north it gradually narrows and in the vicinity of Granite Gap and Cowboy Pass it is less than a mile wide. Farther north it gradually becomes broader and in Arizona, south of Gila River, it is about 20 miles wide.

Several sharp conical peaks, such as Steins Peak, near the State line, about 7 miles north of the Southern Pacific Railroad, Granite Peak, 8 miles south of the Southern Pacific Railroad, Peloncillo Peak, 17 miles south of the El Paso & Southwestern Railroad, and Cloverdale Peak, 10 miles north of the international boundary, stand out prominently and form well-known land marks.

The chain consists of several more or less distinct parts. South of Cloverdale Creek it goes by the name Guadalupe Range, being considered part of the range of that name in Mexico. Between Cloverdale Creek and Antelope Gap, which is occupied by the El Paso & Southwestern Railroad, it is well developed and has no local name other than the Peloncillo Range; between this gap and Steins Pass, which is occupied by the Southern Pacific Railroad, the range is very narrow, scarcely 2 miles in average width. For a distance of 4 miles south from Granite Gap it is represented by a single sharp, low ridge less than three-fourths of a mile wide. Granite Gap and Cowboy Pass are both traversed by wagon roads and afford easy routes between Animas and San Simon valleys. The section between Antelope Gap and Steins Peak is locally called Steins Peak Range, but according to the best usage the name Peloncillo Range applies to all the chain north of the Guadalupe Range.

The average elevation of the Peloncillo Range is about 5,500 feet above sea level—1,500 feet above Animas Valley, on the east, and nearly 2,000 feet above San Simon Valley, on the west. Its west side is in most places much steeper than its east side. The general relief of the range is not great, but the steepness of the mountain slopes, which rise sheer from the plains, and the ruggedness of the bare rock masses, with their sharp outlines produced by erosion, give an exaggerated effect of loftiness, especially in its northern part where vegetation is very scanty. South of the El Paso & Southwestern Railroad the ruggedness is somewhat subdued by forests and foothills. Here the summits and higher slopes are covered with a fair growth of conifers, and the foothills and upper parts of the valley slopes support oaks and junipers. Most of that part of the range which lies south of Peloncillo Mountain is included in the Chiricahua National Forest.

## CENTRAL CHAIN.

*General features.*—Fifteen miles east of the Peloncillo Range a prominent mountain chain extends from the Mexican border northward to the Southern Pacific Railroad. This chain is composed of two parts separated by a wide gap through which the El Paso & Southwestern Railroad passes. The southern part is in the form of a rough triangle that has its apex at the north and that expands gradually to a width of about 12 miles along the Mexican boundary. It comprises the Animas Range, which lies north of the San Luis Pass, and the San Luis Range, which lies south of the pass, extends into Mexico, and connects with the Sierra Madre, a lofty and extensive mountain system lying between the States of Chihuahua and Sonora.

The northern part, which lies between the two railroads and is characterized by a number of conical peaks resembling pyramids, is known as the Pyramid Range. It lies along the same structural axis as the southern ranges and at one time was probably connected with them by a low ridge, which is now partly buried by detrital accumulations, but the highest points of which still appear as low buttes and ridges in the gap.

*San Luis and Animas ranges.*—The Animas Range culminates in a sharp crest which runs close to the east edge of the Animas Valley and extends from San Luis Pass northward to Animas Peak, where it reaches its greatest height at an elevation of about 8,800 feet, thence northeastward to Mount Gillespie, and thence again northward, gradually diminishing in height. At San Luis Pass the crest is broken at an elevation of about 5,600 feet, but it is continued southward in the San Luis Range, close to the bordering valley.

Both the Animas and San Luis ranges present bold, nearly unbroken west fronts. South of Mount Gillespie the Animas Range descends gradually toward the east, forming a plateau 8 or 10 miles wide, but on the east side of this plateau there is a sudden descent of 500 or 600 feet into Playas Valley. North of Mount Gillespie the range narrows to a width of about 3 miles.

Considerable timber grows on the crests and higher slopes of the San Luis and Animas ranges, especially in the region about Animas Mountain, and most of this timbered land has been included in the Chiricahua National Forest. E. A. Mearns<sup>1</sup> notes three forest zones on Animas Peak. At the summit is a zone of quaking aspen (*Populus tremuloides*) and Gambel oak (*Quercus gambelii*), lower a zone of Douglas spruce (*Pseudotsuga mucronata*) and Mexican white pine (*Pinus strobiformis*), and still lower a zone of bull pine (*Pinus ponderosa*). Mearns fixes the timber line of the mountains at 5,250

<sup>1</sup> Mearns, E. A., Mammals of the Mexican boundary of the United States: U. S. Nat. Mus. Bull. 56, pt. 1, pp. 91-92, 1907.

feet. Along the base, in the vicinity of springs and along the lower ends of the canyons, there are small groves of oaks and junipers.

*Pyramid Range.*—The Pyramid Range occupies the center of a great plain north of the El Paso & Southwestern Railroad. Except for a very small area in the southeast, which drains into Lower Playas Valley, it lies wholly within the closed Animas drainage basin. It extends northward, is about 21 miles long, 8 miles in maximum width, and covers about 80 square miles. The highest points are Big Pyramid Mountain, in the north-central part of the range, about 5,900 feet above sea level, and Little Pyramid Mountain, in the south-central part, about 5,700 feet above sea level. The jumble of naked peaks and ridges with sharp jagged outlines and scant timber gives this range the uninviting appearance of the typical desert range. In the low hills at the north end of the range is the Lordsburg mining district, which, both in persistence and in total production, is the most important district in southern Grant County.

#### EASTERN CHAIN.

*General features.*—About 15 miles from the central chain, parallel to it in the south but slightly approaching it toward the north, is the easternmost of the three principal mountain chains. Like the other two it is an extension from a larger system south of the international boundary. It consists of three groups lying along the same line and separated only by narrow gaps. The southern group, consisting of the Dog Mountains (Sierra del Perro in Mexico) and the Hatchet Range, extends from the Mexican boundary 25 miles northward to Hatchet Gap. The middle group, consisting of the Fachita Range, extends 16 miles northward from Hatchet Gap to the gap through which the El Paso & Southwestern Railroad passes. The northern and smallest group, consisting of the Coyote and Quartzite hills, lies north of the railroad and is about 9 miles long.

The Hatchet Range and that part of the Dog Mountains in the United States occupy a triangular area, whose apex is at the north end of the Hatchet Range and whose base at the international boundary is about 15 miles wide. This area comprises approximately 180 square miles.

*Dog Mountains.*—The Dog Mountains were not visited in the course of this investigation, but Mearns<sup>1</sup> describes them as exceedingly rugged, particularly on the east side, where they are furrowed by jagged canyons with precipitous sides abounding in caves. The highest point of the range is Emory Peak, which has an elevation of 6,129 feet. The ridges making up the mountain aggregate trend in general northwestward. The range is sparsely wooded, checker-

<sup>1</sup> Mearns, E. A., op. cit., pp. 87-88.

bark juniper crowning the summits and oaks, sycamores, walnuts, and mulberries growing at lower elevations.

*Hatchet Range.*—North of the Dog Mountains the topography presents a marked change. The more or less scattered ridges, which appear inconspicuous in the aggregate, give way to a single dominating ridge—the Hatchet Range. At the north end of this range, where the base is narrow, the mass rises over 4,000 feet above the plain in great vertical cliffs, some of which are at least 1,000 feet from base to top. This part of the Hatchet Range is by far the most striking and conspicuous feature in this whole region. Big Hatchet Mountain, the main peak, about 5 miles south of Hatchet Gap, rises about 8,400 feet above sea level. In the clear atmosphere it can be distinguished for remarkably long distances, and as a landmark even Animas Peak, although overtopping it by 400 feet, is far less conspicuous.

Some timber is found in the Hatchet Mountains. A zone of piñon pine occupies the upper half of the slopes and a number of checkerboard junipers stand at the summit. At the base there are a few red junipers.<sup>1</sup>

*Hachita Range.*—The Hachita (Spanish, “little hatchet”) Range extends from Hatchet Gap to the El Paso & Southwestern Railroad. Its length is about 15 miles and its maximum width a little over 5 miles. It reaches its greatest height in twin peaks that stand a short distance south of the center of the area covered by the range. The northernmost and highest of these peaks, known as Hachita or Little Hatchet Peak, rises about 6,500 feet above sea level. The range is compact and rugged, and is characterized by sharp peaks and ridges and rocky, bare, precipitous slopes.

*Coyote and Quartzite hills.*—North of the Hachita Range, and separated from it by the gap traversed by the El Paso & Southwestern Railroad, are the Coyote and Quartzite hills. The Coyote Hills trend northwestward and are separated by a low pass from the Quartzite Hills, on the north, which trend eastward. The Coyote Hills are marked by a persistent ridge on the south and west that culminates in Coyote Peak and faces Playas Valley in a short, precipitous slope. The Quartzite Hills consist of a single ridge, about 5 miles long, which extends eastward along the fifth standard parallel south. Although probably not rising more than 500 feet above the plain, this ridge is rather conspicuous on account of numerous small juniper trees along its crest and flanks.

#### APACHE (DOYLE) HILLS.

Six miles east of the Hachita Range, on the east side of the Hachita Valley, are the Apache Hills, locally also known as the Doyle Hills.

<sup>1</sup> Mearns, E. A., op. cit.

They consist of a tangled group of bare rounded hills with a maximum relief of perhaps 1,000 feet. They extend eastward into Mexico, where they are known as the Sierra Rica.

About  $3\frac{1}{2}$  miles north of the Apache Hills, on the north side of the El Paso & Southwestern Railroad, is a similar group of small bare hills. On the south they end in a flat-topped block with a straight vertical scarp facing the railroad. On the north they end in a westward-trending ridge eroded into numerous rounded and conical peaks. The maximum relief of this group of hills is probably not more than 500 or 600 feet.

#### LITTLE BURRO MOUNTAINS.

In the northeastern part of the area is a compact little group of mountains known as the Little Burro Mountains. They are connected at the north with the Big Burro Mountains. Their maximum elevation is somewhat less than 7,000 feet above sea level and not more than 2,500 feet above the general level of the adjacent plain. A rather remarkable feature in connection with this range is the immense accumulation of rock waste that is piled against its southwestern flank and that stretches in a broad, sweeping slope from a zone far up on the side of the range nearly to the Southern Pacific Railroad. This accumulation seems to be greatly out of proportion to the mass and the elevation of the range. The range contains some timber and is included in the Gila National Forest.

#### VALLEYS OR PLAINS.

##### GENERAL FEATURES.

About two-thirds of the surface of southern Grant County consists of intermontane plains or valleys which in general appear smooth and nearly level, though they include some very irregular tracts and, as they slope gently in the same direction for many miles, have differences in elevation of hundreds of feet. The surfaces of these plains or valleys have, for the most part, been constructed by the aggradational work of the storm waters. They consist chiefly of stream-built slopes that extend from the mountain borders to the lowest depressions in the basins. The gradients of these slopes are regular and gentle and decrease gradually with increase of distance from the mountains, thus producing concave or somewhat saucer-shaped land forms. In the depressions—the bottoms of the saucers—the flood waters that are not otherwise dissipated come to rest and produce nearly level surfaces, which, if well developed, form alkali flats, or playas, such as the Animas and Playas basins. (See Pl. I, in pocket.) The flats are in sharp contrast to the slopes and they cover much smaller areas.



The monotonous expanses comprising the stream-built slopes are modified in southern Grant County by (1) ancient shore features, (2) erosion features, (3) sand dunes, and (4) lava beds.

#### ALKALI FLATS OR PLAYAS.

Alkali flats, or playas, are features distinctive of the closed drainage basins of the arid West. They occupy the lowest parts of the basins. In southern Grant County alkali flats occur in Lower Animas, Lower Playas, and Lordsburg valleys. (See Pl. I, in pocket.) After heavy rains they may be covered by sheets of water, seldom more than a few inches in depth but often several square miles in extent. These shallow sheets of water soon evaporate, and on evaporation deposit their dissolved mineral matter and the fine clayey material which they hold in suspension, thus in time forming surfaces that are smooth and nearly level. When dry these surfaces are generally checkered with innumerable small sun cracks, are mottled with black, brown, and white alkali stains, and are so hard that the wheels of a heavily laden wagon hardly leave an impression. The flats are devoid of vegetation except for scattered bunches of alkali-resistant weeds and grasses, found chiefly along the margins. (See Pls. III, A, and VI, B, p. 76.)

When flooded the playas perform some of the functions of ordinary lakes. Along their edges shore features, such as pebbly beaches, beach ridges, sand bars, spits extending out from the shore, and sand dunes on the sides opposite the prevailing winds may be reproduced in miniature.

#### ANCIENT SHORE FEATURES.

There were at one time many lakes in the interior drainage basins of the Western States. A few of the largest basins still contain remnants of these ancient lakes, such as Great Salt Lake, in Utah, and Carson and Pyramid lakes, in Nevada, but the lakes in most of the smaller basins are represented only by alkali flats, which may become submerged during the rainy seasons.

The largest of these ancient bodies of water were Lake Bonneville, described by Gilbert,<sup>1</sup> and Lake Lahontan, described by Russell.<sup>2</sup> They have shrunk to comparatively insignificant dimensions but have left abundant evidence of their former size in wave-cut cliffs and terraces, beach ridges, sand bars, spits, deltas, and various other shore features. Topographic features that are smaller but no less characteristic of landlocked bodies of water occur in the Estancia

<sup>1</sup> Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, 1890.

<sup>2</sup> Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, 1885.



A. LOWER PLAYAS VALLEY, SHOWING PLAYAS LAKE; HACHITA RANGE IN BACKGROUND.



B. TYPICAL VEGETATION OF SAND-DUNE AREA IN LOWER ANIMAS VALLEY.



A. BEACH DEPOSITS IN LOWER ANIMAS VALLEY, SHOWING HORIZONTAL BEDDING.



B. CENTRAL PLAIN OF UPPER PLAYAS VALLEY IN VICINITY OF OJO DE LAS CIENEGAS.

and Encino valleys,<sup>1</sup> in New Mexico, and in the Sulphur Spring Valley,<sup>2</sup> in Arizona.

In southern Grant County there were at least three ancient lakes—one in Lower Animas Valley, one in San Luis Valley, and one in Lower Playas Valley—and a fourth lake probably existed in Hachita Valley but almost wholly in Mexican territory. As these lakes were comparatively small and shallow their shore features are not large, and as the features were formed in unconsolidated valley fill they were easily eradicated by erosion. Consequently the record of the Grant County lakes is comparatively incomplete. Certain features however, such as beaches, terraces, and embankments are preserved as distinct landmarks on the otherwise nearly featureless plains, and by the aid of these it is possible to trace the areas covered by the lakes.

These ancient lakes are described in detail on pages 86-87, 100-104, 108, and 120, and the location of the shore features is shown on the map (Pl. I, in pocket).

#### EROSION FEATURES.

In most parts of southern Grant County the flood waters are still depositing and building up the alluvial slopes, but in some places, chiefly in Upper Animas Valley and in Hachita Valley, the smooth alluvial slopes are being dissected by erosion into innumerable gullies. (See Pl. I.) The erosion cycle thus begun is probably the result of the climatic changes indicated by the ancient shore features, for these climatic changes involved changes both in the transporting power and in the base-levels of the streams, thus necessarily disturbing the aggradational adjustments. The erosion features and their causes are more fully discussed on pages 31-33.

#### SAND DUNES.

There are three principal sand-dune areas in southern Grant County, situated respectively in Lower Animas, Lower Playas, and San Luis valleys. (See Pl. I.) They are on the northeast or leeward sides of the three ancient lake beds and probably owe their existence to the former presence of these lakes. They are described on page 35.

#### LAVA BEDS.

Lava beds that are geologically of recent origin are found in several places in southern Grant County. The principal lava bed in the valley areas is in the Animas basin, west of Animas station. (See Pl. I.) It is described on pages 35-36.

<sup>1</sup> Meinzer, O. E., *Geology and water resources of Estancia Valley, N. Mex.*: U. S. Geol. Survey Water-Supply Paper 275, pp. 18-23, 1911.

<sup>2</sup> Meinzer, O. E., Kelton, F. C., and Forbes, R. H., *Geology and water resources of Sulphur Spring Valley, Ariz.*: U. S. Geol. Survey Water-Supply Paper 320, pp. 34-38, 1913.

## GEOLOGY.

## PRE-QUATERNARY ROCKS.

In the study of the water resources of this region particular attention was given to the unconsolidated sediments that fill the valleys and contain nearly all the water that exists in the region. No attempt was made to map the geology of the mountain areas. A general knowledge of the distribution and character of the rocks and of the geologic structure was, however, obtained, as these are important in their bearing on the character of the valley sediments, which are derived from the rocks, and on the configuration of the rock floor of the valleys, on which the sediments have been deposited. The following brief account of the rock geology is based on the fragmentary knowledge obtained from previous reconnaissance work and on the few observations made during the present investigation.

Pre-Cambrian rocks are known only in the northeastern part of the area, where they form the core of the Little Burro Mountains and comprise gneiss and schist intruded by bodies of granite and by dikes of pegmatite and diabase. Carboniferous and probably other Paleozoic limestones, sandstones, and quartzites outcrop in many parts of the region, including the Peloncillo, Animas, San Luis, and Hatchet ranges and Apache Hills. Cretaceous rocks have not been definitely identified in this region but may be represented in dark-gray fire clay mined in the Peloncillo Range 2 miles south of Pratt, in a series of hard sandstones and shales outcropping on the north slope of Hachita Peak, and in a series of thin-bedded shales and limestones overlying Carboniferous limestones in the Hachita Range north of Livermore Spring. So far as known, there are no sedimentary rocks of Tertiary age in the area except possibly in the Guadalupe Range, where Mearns<sup>1</sup> reports a deposit containing many Tertiary fossils. Igneous rocks and breccias of probable Tertiary age occur extensively throughout the region. They vary greatly in texture and composition but fine-grained acidic rocks predominate.

Except for some general observations made in 1853 by Thomas Antisell<sup>2</sup> at the time of the Mississippi River-Pacific Ocean railroad survey, by Gilbert<sup>3</sup> in connection with the survey west of the one-hundredth meridian in 1873, and by L. C. Graton and Waldemar Lindgren<sup>4</sup> in 1905 during cursory visits to the mining districts in the northern part of the range, no geologic work has been done in the Peloncillo Range. The core of the range is formed of granitic

<sup>1</sup> Mearns, E. A., Mammals of the Mexican boundary of the United States: U. S. Nat. Mus. Bull. 56, pt. 1, p. 94, 1907.

<sup>2</sup> Explorations and surveys for a railroad from the Mississippi River to the Pacific Ocean, 1853-1856, vol. 7, pt. 2, pp. 152-153, 1857.

<sup>3</sup> Gilbert, G. K., U. S. Geol. and Geol. Surveys W. 100th Mer. Rept., vol. 3, p. 513, 1875.

<sup>4</sup> Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 329-332, 1910.

and porphyritic igneous rocks intruded into sedimentary rocks largely of Paleozoic age. In regard to the structure and general disposition of the rocks Gilbert<sup>1</sup> says:

At Peloncillo Peak Antisell noted only volcanic rocks, but at Gavilan Peak, 10 miles beyond, the sedimentaries are once more exposed. They comprise limestones and sandstones, and are probably of the Paleozoic series observed in the Chiricahui Range. Carboniferous fossils were seen in their débris. The strata dip at a high angle toward both flanks of the range, and upon their upturned edges rests the granite which constitutes the peak. The circumstances admit of no question that the granite in this case is eruptive and was extruded after or during the disturbance of the Paleozoic strata. The limestones, at their contact with the granite, are converted to white, coarsely crystalline marble; and the same metamorphism is to be seen along the margin of a heavy dike of granite in the vicinity. The granite is fine grained, and consists chiefly of quartz and albite. Its body is traversed in one place by a dike of quartz porphyry.

At the north end of the Animas Range bluish-gray limestones with inclusions of siliceous material resembling the limestone of the Hatchet Range were noted at several places. Along the road leading through the San Luis Pass volcanic rocks in great profusion were noted. The San Luis Range, farther south, is stated by Mearns<sup>2</sup> to be composed largely of calcareous rock.

The Pyramid Range consists chiefly or entirely of volcanic rocks. Thomas Antisell<sup>3</sup> thought that it was similar in structure to the Peloncillo Range, but he does not mention finding any sedimentary rocks. G. K. Gilbert<sup>4</sup> found only volcanic rocks. Likewise Graton,<sup>5</sup> in examining the Lordsburg mining district, found only volcanic rocks, a diorite porphyry being the most prevalent, and he mentions andesite as making up the bulk of the rocks farther south in the range.

The Hatchet Range is similar to the Animas and Hachita ranges in consisting of tilted and faulted Paleozoic limestone, probable Cretaceous shale and sandstone, and intrusive granite and porphyry. One of the peaks examined at the north end of the range consists wholly of massive bluish-gray limestone containing many inclusions of siliceous material. Several small buttes in the gap to the north consist of the same rock, in places intruded by a lava and metamorphosed to marble.

Several mountain blocks north of Alamo Hueco are tilted toward the northeast and have scarps facing southwest, thus trending in the same direction as the ridges in the Dog Mountains. Many of the limestone cliffs in the vicinity of Hatchet Mountain also face

<sup>1</sup> U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, p. 514, 1875.

<sup>2</sup> Mearns, E. A., op. cit., p. 90.

<sup>3</sup> Antisell, Thomas, Explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean, 1853-1856, vol. 7, pp. 152-153, 1857.

<sup>4</sup> Op. cit., pp. 514-515.

<sup>5</sup> Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 63, pp. 332-335, 1910.

southwest. This structure probably indicates faulting along north-west-southeast lines.

Geologically the Hachita Range is related to the Hatchet and Animas ranges.<sup>1</sup> In the Eureka mining district, in the northern part of the range, near the site of the old town of Hachita, the rocks are mainly limestones (probably Paleozoic), cut by abundant sheets and dikes of a quartzose porphyry.<sup>2</sup>

In the Sylvanite district,<sup>3</sup> which extends from Livermore Spring to Granite Gap, a thick series of thin-bedded quartzites, dark shales, limestones, and dolomites of Paleozoic or younger age are found. These rocks dip to the southwest, are considerably faulted, and have been intruded by porphyry of several types. In the region north of Livermore Spring limestone, probably Carboniferous, is overlain by a series of thin-bedded shales and limestone, probably of Cretaceous age. South of Sylvanite the Hachita Range consists mainly of sedimentary rocks dipping toward the southwest and intruded by dikes and sheets of porphyry. Near Granite Gap the rocks, which consist of thin-bedded shale, quartzite, and granite, have been considerably disturbed by faulting.

The Apache Hills appear to consist chiefly of a quartz-bearing porphyry.<sup>4</sup> In the foothills on the southwest, along the Hachita road, there are outcrops of bluish-gray limestones with gentle dip, evidently belonging to the Paleozoic system. The Apache mine, 2 miles south of the corner made by the international boundary line, is on the contact of the limestone with the porphyry. The group of small hills about  $3\frac{1}{2}$  miles north of the Apache Hills, on the north side of the El Paso & Southwestern Railroad, consist of dark volcanic rock.

Geologically<sup>5</sup> the Little Burro Mountains are related to the Big Burro Mountains to the north, being composed chiefly of pre-Cambrian gneiss and schist cut by rather fine grained granites and by dikes of pegmatite and diabase.

#### QUATERNARY DEPOSITS.

##### ORIGIN AND DISTRIBUTION.

The most widespread formation and the most important with respect to water supplies is the valley fill, which underlies more than two-thirds of the area. Classified according to origin the valley fill comprises four kinds of deposits, which, named in the order of

<sup>1</sup> Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 295, 1910.

<sup>2</sup> Idem, p. 336.

<sup>3</sup> Idem, pp. 339-340.

<sup>4</sup> Idem, pp. 343-344.

<sup>5</sup> Idem, pp. 326-327.

their importance, are as follows: (1) Stream deposits, including gravel, sand, and clay derived from the older rocks of the mountains, carried down, and spread over the valleys by torrential streams; (2) lake deposits, including gravel, sand, and clay laid down in bodies of water that formerly existed in the lowest parts of the valleys or in the thin sheets of water that temporarily cover the alkali flats at the present time; (3) wind deposits, consisting chiefly of sand along the shores of ancient lakes; and (4) lavas, mostly basalt, spread over the unconsolidated material in the valleys and over the older rocks in the mountains.

#### STREAM DEPOSITS.

*Origin.*—The transportation and sorting of rock waste from the mountains and its deposition on adjacent land surfaces is one of the most common and elemental of geologic processes. In arid and semiarid regions it is also one of the most important. Deposits owing their origin to this process cover about three-fifths of the surface of the area under discussion. As soon as a land surface is exposed to the atmosphere the process of weathering begins. Under the action of various agencies the rocks are disintegrated and broken into fragments of all sizes, from huge boulders to impalpable clay. The streams remove this rock waste.

The fundamental factors of the mechanics of erosion, transportation, and deposition by streams are (1) the grade of the streamways, (2) the volume of water, (3) the character of the streamways or of the surfaces over which the streams flow, and (4) the character of the sediments transported. Within the mountain areas the streams are usually confined to narrow channels with steep gradients and hence are so swift that they sweep everything before them. As they emerge into the valleys their channels decrease in slope and widen out, and the underlying material is so porous that it absorbs the water rapidly. Hence deposition of material takes place, producing the alluvial fans or detrital slopes that constitute one of the most characteristic features of the deserts of the Southwest.

*Character.*—The material forming the alluvial slopes is roughly arranged in zones or belts extending parallel to the mountain borders and at right angles to the courses of the streams. The coarsest material, consisting largely of boulders and large rock fragments, is in a zone along the edge of the mountains, with zones of successively finer materials down the slopes toward the centers of the valleys.

Because of the uniformity with which the gradient changes on the stream-built slopes the transition from material of one class to that of another is very gradual and the boundaries between the zones are indefinite. As seen on the surface the material making up any



particular zone is, because of imperfect sorting of the material, not homogeneous. Although the upper zone may contain a preponderance of coarse gravel it may also contain large quantities of sand and clay.

In vertical section the material may be even less homogeneous. The cause of this may be best illustrated by considering the processes of slope building at the mouth of any canyon that discharges flood waters on the plain. In a large flood boulders may be carried far out into the valley and deposited on top of the fine sediments laid down by a previous smaller flood. In the lower stages following the crest of this flood and in succeeding smaller floods sand and clay may, in turn, be deposited over the coarse material. Moreover, the main streamways, in which the coarsest gravel is deposited, are continually shifting their positions on the alluvial fans, as a result of which coarse materials become interbedded with fine sediments. A canyon having a large catchment area may, by reason of its larger volume of water, be carrying coarse material far from the mountain base while a neighboring smaller canyon is depositing fine material comparatively close to the mountains. As the cone at the mouth of the larger canyon is built up it expands laterally, the coarser sediments of its upper slopes blending with and overlapping the finer sediments of the lower slopes of its smaller neighbor. The continuous alluvial slopes extending along the fronts of the ranges are the result of the coalescing of innumerable fans. Every opening in the mountain wall, whether it is a large canyon or a small gully, is furnishing material for its own individual fan, which overlaps or blends with its neighbor.

The breaking down of the rocks forming the mountains and the deposition of the débris in the valley troughs has been going on for a long time and is the chief geologic process taking place in this region at the present time. Most of the sediments underlying the valleys described in this report are believed to lie where they were originally deposited by the streams, although some rehandling has taken place in the lakes that formerly occupied parts of the valleys, on the slopes now being extensively eroded, as in Upper Animas Valley, and in many places where the wind has been more or less effective.

*Correlation.*—The valley fill of southern Grant County can be correlated with the Gila conglomerate first described by Gilbert<sup>1</sup> from sections exposed along the gorges of the upper Gila and its tributaries. Gilbert assigns these beds to the Quaternary and states that they are continuous with the gravels which occupy the mountain troughs and floor the plains of the region bordering the Gila. This relation is well shown in the northwestern part of the

<sup>1</sup> Gilbert, G. K., U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 540-541, 1875.

area, where the detrital plain stretches toward the south and east between the several ranges and toward the north to Gila River, where underlying deposits are exposed. From Summit station, near the northwestern corner of the area, the Arizona & New Mexico Railway descends along a large gully or canyon to the Gila, and in this gully the beds underlying the plain are exposed, a section 330 feet thick having been measured between Summit and Thomson station.

Along Gila River the Quaternary deposits, after a long period of accumulation, have been extensively eroded, the general dissection according to Gilbert<sup>1</sup> amounting to more than 1,000 feet. Up to the present time the dissection has taken place mainly along the Gila and its principal tributaries and has not been carried very far back from these main drainage lines. If, however, the conditions remain for a long enough time as they are at present the filled valleys farther from the Gila will eventually also become deeply dissected. It is not difficult to conceive of the gullies which head at the divide between the Animas and Gila drainage basins working headward, draining the Animas basin into Gila River, and causing extensive dissection of the Animas and Lordsburg valleys.

*Thickness.*—On account of the unevenness of the rock floor on which the stream deposits rest the depth of these deposits varies greatly in different parts of the area. That the original rock surface was very irregular is suggested by the numerous buttes and hills in the valleys, some of them far from the mountains, representing protuberances of the rock floor above the sea of sediments. There are probably many other high places on the rock floor which do not project above the surface but which come near it and are covered by only a thin layer of sediments. In general the sediments are thickest in the parts of the valleys farthest from the mountains.

At different points wells have been put down to considerable depths without reaching bedrock. In San Luis Valley,  $4\frac{1}{2}$  miles north of the Mexican boundary (well 181, Pl. II), the Victoria Land & Cattle Co. is said to have drilled a well 500 feet deep without striking bedrock. At the XT ranch (well 160), in Upper Animas Valley, a 305-foot well was drilled with the same result. The Southern Pacific Railroad wells at the pumping plant 2 miles east of Lordsburg (well 22) go down over 300 feet and end in sediments. At Separ the railroad company has two wells (No. 5) over 600 feet deep, which do not reach bedrock. In Playas Valley west of Hatchet Gap the Winkler well (No. 264) reaches a depth of 836 feet without striking bedrock. Many other wells throughout the area end in unconsolidated sediments at depths of 200 feet or more.

<sup>1</sup> Gilbert, G. K., U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol 3, pp. 540-541, 1875.

## LAKE DEPOSITS.

*Stratified lake beds.*—As far as can be determined from the logs of drilled wells, the interbedded clay, sand, and gravel encountered at shallow depths in the areas formerly occupied by permanent lakes in the Upper and Lower Animas and Lower Playas valleys differ little in composition from ordinary stream-laid deposits. As the lake beds have not been dissected no opportunity is offered for observing them in place. The homogeneity of the material in certain beds indicates that it has undergone a more thorough and selective grading than it would have received under ordinary conditions of stream deposition. Beds that are distinctive in one well may, however, pinch out or grade into different material so as not to be recognizable in a well only a short distance away. The top 10 or 20 feet of clay and sand encountered in all the wells on the ancient lake beds is more homogeneous than the deeper material and represents the last layer deposited on the floor of the lakes. It may in fact represent the total deposition during the lake epoch indicated by the existing shore features, and the deeper sediments may be ordinary stream deposits.

On the alkali flats sediments are at present being deposited from flood waters during the intermittent periods of submergence. The heavier particles settle soon after they reach the flats, but the material held in solution and much of the fine materials in suspension are deposited only when the water evaporates, and they form layers of exceedingly dense alkali-impregnated clay.

In the Sulphur Spring Valley in Arizona<sup>1</sup> and in the San Simon Valley<sup>2</sup> thick beds of homogeneous clay, thought to be lake beds, are buried beneath stream deposits. In Grant County none of the wells that have been drilled show conditions comparable to these, and there is nothing in the arrangement and character of the deeper beds to indicate that they were not laid down by streams. Considerable thicknesses of clay were penetrated in some of the wells, but this clay is generally mixed with boulders and gritty material such as is commonly found in stream-deposited clays.

*Beach deposits.*—The beaches and beach ridges along the shores of the ancient lakes are built of gravel and coarse sand. The pebbles and sand grains are all waterworn, and many of the pebbles are flattened, evidently through attrition by wave action. An excellent longitudinal section of a beach ridge is exposed in a gravel pit south of the railroad  $2\frac{1}{2}$  miles west of Steins, in the southwest corner of sec. 6, T. 24 S., R. 20 W., from which the Southern Pacific Co. formerly dug material for track ballast. The material consists chiefly of clean, well-sorted, horizontally bedded sand and gravel. (See Pl. IV, A; also pp. 86-88.)

<sup>1</sup> Meinzer, O. E., Kelton, F. C., and Forbes, R. H., Geology and water resources of Sulphur Spring Valley, Ariz.: U. S. Geol. Survey Water-Supply Paper 320, pp. 57-62, 1913.

<sup>2</sup> Idem, p. 128.

## WIND DEPOSITS.

Deposits formed by the wind are found for the most part in three localities—in Lower Animas Valley (chiefly Tps. 21 and 22 S., Rs. 19 and 20 W.), in San Luis Valley (T. 33 S., R. 20 W.), and in Lower Playas Valley (Tps. 27 and 28 S., R. 17 W.). These deposits (see Pl. I, in pocket) consist principally of loose, shifting sands piled into low hills and ridges.

In Lower Animas Valley the sand dunes cover an area of about 30 square miles lying north and east of the alkali flats and of the shore line of the ancient lake. They consist principally of a medium-grained clean arkose sand of a prevailing gray color with a slight reddish tinge imparted by the presence of red feldspar grains. The average thickness of the deposit for several miles back from the old shore line is about 50 or 60 feet, the maximum thickness in some places being perhaps 100 feet. Toward the edges the sand sheet thins out gradually and merges into the plain. Sand and clay, evidently deposited in their present position by the wind, are found along the northeastern border of the large alkali flat in Lower Animas Valley and on the east sides of the Lordsburg playas.

In San Luis Valley a deposit of wind-blown sand forms a belt of low dunes about  $2\frac{1}{2}$  miles long and half a mile wide along the northeast shore of the ancient lake. The sand is piled up on the beach ridge and on the lower ground back of the ridge and on top of the ridge attains a maximum thickness of 30 or 40 feet.

In Playas Valley wind deposits occupy a strip about half a mile wide, extending for 6 miles along the eastern edge of the northern part of the alkali flat. They consist chiefly of gray sand piled in low dunes back of the shore line of ancient Playas Lake.

It is significant that all the larger sand deposits are along the northeast sides of the ancient lakes, leeward of the prevailing winds. The deposits probably accumulated at the time the ancient lakes existed, as sand dunes are common features in similar locations along the shores of modern lakes and seas.

## LAVA BEDS.

The only volcanic rocks known to have been directly involved in the recent geologic history of the valleys are flows of basalt. They rest upon the Quaternary sediments and are the youngest igneous rocks in southern Grant County.

The largest and most important lava flow of this kind is in Animas Valley. (See Pl. I, in pocket, and pp. 85–86.) Fresh surfaces of the basalt are predominantly of a dull black color, although locally they are reddish brown or blue gray. Weathered surfaces of the rock in place are mostly brown. Soils derived from it are brown with a distinct reddish tinge. In texture the basalt is fine grained, sometimes very compact but usually vesicular. Evidently the lava

was poured out in a comparatively thin sheet. The surface of the lava sheet is now 15 to 45 feet higher than the surrounding plain, but this does not represent its whole thickness, for in many places the plain has been built up around it so as to partly submerge it in valley sediments. Some idea of the thickness of the lava and its relation to the valley fill may be gained from the following log of a well in a small draw within the lava sheet 2 miles southeast of Pratt:

*Log of well (No. 109) belonging to Ben Pague, in the SW.  $\frac{1}{4}$  sec. 26, T. 27 S., R. 20 W.*

[Log furnished by owner.]

	Thickness.	Depth.
	<i>Feet.</i>	<i>Feet.</i>
Soil.....	30	30
"Malpais" (basalt).....	12	42
Hard reddish baked sediments.....	18	60
Clay and gravel.....	77	137

The well log shows the bottom of the lava to be 42 feet below the surface of the plain at this place, and the general surface of the lava sheet bordering the draw is about 20 feet above the plain; consequently the total thickness of the lava bed in this region must be about 60 feet. In some places where the lava fills sags in the original surface upon which it was poured the thickness is probably greater. The 30-foot layer of soil above the lava represents sedimentation since the lava was extruded. The deposition of so much sediment probably required a long time according to human units; but the relation of the lava to the valley fill and the fact that weathering has produced relatively small effects on the lava show that geologically the lava flow is very young.

Basaltic lava similar in character to that in Animas Valley occurs as a large flat-topped block extending parallel to and facing the El Paso & Southwestern Railroad 2 miles east of Hachita. The small group of hills culminating in Secho Mountain, 2 miles northeast of Summit station, consists of lava of similar character. As these lava beds, however, do not occur in such definite relationship to the Quaternary sediments as those of Animas Valley their age is not so certain.

#### CLIMATE.

#### PRECIPITATION.

*Records.*—Records of precipitation have been obtained by the United States Weather Bureau at Lordsburg since 1882 and at Hachita, Pratt, and Rodeo since 1909. According to these records the average annual precipitation at Lordsburg during 33 years from 1882 to 1914 is 9.23 inches. During the 5 years that records have been obtained at Hachita the precipitation has been nearly the same there as at Lordsburg, the annual average at Hachita during that time being 12.29 inches, as against 12.41 inches at Lordsburg.

The records at the other stations are so incomplete that they are of little value. In round numbers, 10 inches may be taken as the average annual precipitation, at least in the northern half of the area. The monthly and yearly records for Lordsburg, Hachita, Pratt, and Rodeo are given in the following table:

*Precipitation in southern Grant County, N. Mex.*

**Lordsburg.**

[Elevation, 4,245 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1882	0.95	0.35	0.38	0.00	0.59	0.68	1.32	3.12	0.00	0.00	1.20	0.28	8.74
1883	.33	.37	.00	.00	.00	.00	1.00	3.45	.11	.56	.40	.28	6.42
1884	.80	.13	1.20	.20	Trace	.00	2.20	1.30	2.35	2.55	.00	1.48	12.19
1885	.00	.20	.40	Trace	.40	.39	1.75	.35	.05	.20	.55	.70	3.99
1886	.00	.33	.00	.00	.00	.00	1.54	1.65	1.17	.17	.20	.00	5.06
1887	.00	.12	.00	.00	.10	.30	3.17	2.67	1.31	.00	.32	.70	8.69
1888	.44	.10	.88	.00	.00	.28	2.97	.84	.76	2.14	1.50	.90	10.83
1889	4.07	.45	.10	.20	.00	.25	1.70	1.28	1.76	.41	.02	.10	10.34
1890	.92	.05	.00	.13	.00	.43	3.11	3.69	1.90	.26	.60	1.88	12.95
1891	.10	1.52	.65	.00	1.01	.00	.00	1.10	.88	.00	.60	.40	5.66
1892	.50	1.01	.92	.71	.00	.00	.05	.20	.05	.69	.00	.00	4.13
1893	Trace	.90	1.00	.00	1.96	Trace	.90	2.58	2.15	.00	.00	.05	9.32
1894	.70	.50	.20	.00	.00	.00	.89	4.30	.10	.90	.00	Trace	7.59
1895	.20	.00	Trace	.00	.40	.40	1.22	.45	.84	.40	1.38	.10	5.39
1896	Trace	Trace	.48	.00	.20	.40	1.91	2.34	1.51	6.46	.20	.15	13.15
1897	1.21	.20	.12	.00	.00	.00	3.95	1.25	4.50	1.75	.00	.18	12.58
1898	.50	.00	.75	.16	.00	.33	2.33	.17	.16	.00	.60	.66	5.68
1899	.33	.08	.18	.04	.00	.70	2.62	.50	1.18	.00	.10	Trace	5.73
1900	.24	.10	1.25	.49	.00	.00	.38	1.95	2.71	.12	.45	.00	6.99
1901	.40	.50	.20	.13	Trace	.00	2.30	.95	.00	2.17	.76	Trace	7.41
1902	Trace	.10	Trace	.00	.00	.20	.85	2.55	.40	.13	.52	1.12	5.87
1903	.00	Trace	.90	.00	.27	.58	.45	.70	.93	.00	.00	.20	4.04
1904	.14	.16	.23	.00	.04	.38	1.09	1.12	3.09	.69	.55	1.20	8.70
1905	1.57	3.35	3.24	1.27	.12	.56	2.10	.92	2.59	.32	2.93	.50	19.50
1906	.15	1.07	.07	.07	Trace	.00	1.67	1.80	.02	.00	1.31	3.43	9.58
1907	2.52	.51	.00	.27	.60	Trace	2.20	4.05	Trace	1.20	.80	.00	12.15
1908	1.75	.71	.34	.68	.20	.00	1.61	.97	.65	.10	.35	1.30	8.66
1909	Trace	.20	1.30	.00	.00	.05	4.22	2.36	.95	.70	.00	.40	10.18
1910	.48	.00	.00	.02	.42	.60	2.09	.87	Trace	.00	.26	.00	4.76
1911	.64	.95	.26	.83	.0	1.31	2.46	.50	.68	1.60	.0	2.60	11.73
1912	Trace	1.15	2.14	.07	.06	.51	4.19	2.14	.0	1.07	.18	2.64	14.15
1913	1.00	2.43	.51	.35	Trace	.28	.43	.38	1.70	.30	3.89	.45	11.69
1914	.88	.62	.45	.00	1.17	.93	2.63	4.06	1.00	2.81	.69	4.40	19.70
Mean	.63	.55	.55	.17	.23	.28	1.83	1.69	1.07	.84	.60	.70	9.23

**Hachita.**

[Elevation, 4,504 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1909							1.91	4.77	0.26	0.53	0.00	0.91	-----
1910	0.15	0.14	0.36	Trace	0.00	0.45	.97	1.26	.61	Trace	.30	.14	4.38
1911	.65	.76	.13	0.27	Trace	1.42	4.74	.98	1.93	1.27	.19	.82	13.21
1912	.0	.45	1.50	.69	0.15	Trace	3.25	4.46	.0	1.10	.08	3.67	15.35
1913	.52	1.44	.29	.20	.20	.36	1.22	1.95	1.92	.10	2.26	.83	11.29
1914	.20	Trace	.05	.00	.06	3.77	6.29	1.34	1.26	1.59	.33	2.33	17.21
Mean	.30	.56	.48	.23	.08	1.20	3.29	2.00	1.14	.81	.63	1.56	12.28

**Pratt.**

[Elevation, 4,415 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1909							0.56	4.73	1.53	0.00	Trace	0.18	-----
1910	Trace	Trace	.0	.0	.0	0.77	3.79	.99	.20	.0	0.50	.0	6.25
1911	0.80	1.62	.0	0.45	.0	1.55	2.76	1.33	1.38	1.40	.18	2.07	13.54
1912	.0	.58	1.00	.04	.0	.48	1.56	2.73	1.20	.75	.28	.93	9.55
1913	.50	2.45	.15	.20	Trace	.04	3.41	2.17	.63	.08	2.88	.90	13.41
1914	.85	.00											-----
Mean	.33	1.16	.29	.17	.0	.71	2.88	1.81	.85	.56	.96	.98	10.70

• Interpolated.

*Precipitation in southern Grant County, N. Mex.—Continued.***Rodeo.**

[Elevation, 4,118 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1909.....							3.28	2.59	1.20	Trace	0.08	0.75	.....
1910.....	0.18	0	0.19	0.10	0.06	1.29	3.26	.58	.18	0	.79	0	6.63
1911.....	1.02	1.58	.28	Trace	Trace	1.24	3.47	1.81	.85	0.90	0	1.91	13.06
1912.....	0	.30	1.79	0	0	a.50	1.50	2.23	.10	.77	.28	1.04	8.51
1913.....	.53	1.15	Trace	.23	a 0	.00	.80	1.62	2.37	.26	a1.50	.95	9.41
1914.....	.50	.10	.93	Trace	.24	.48	a4.50	1.60	2.40	3.60	1.06	5.43	20.84
Mean.....	.43	.63	.64	.07	.08	.75	2.26	1.57	1.18	1.11	.53	2.44	11.69

a Interpolated.

*Fluctuations from year to year.*—The fluctuation in precipitation from year to year at any one station is great. This is well shown by figure 2, which represents the annual precipitation at Lordsburg. The wettest years on record are 1905, when the precipitation

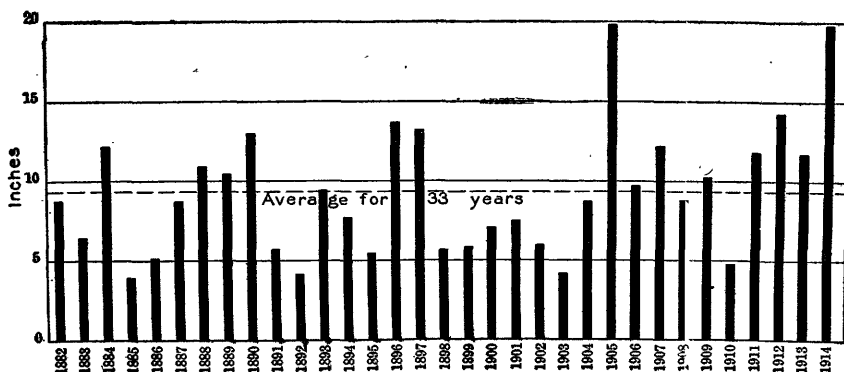


FIGURE 2.—Diagram showing annual precipitation at Lordsburg.

amounted to 19.50 inches, and 1914, when it amounted to 19.70 inches, in both years more than twice the average amount. The other extreme is represented by 3.99 inches in 1885, 4.13 inches in 1892, and 4.04 inches in 1903, when less than half the average amount of rain fell. In 15 years out of the 33 the precipitation equaled or exceeded the average, 9.23 inches, and for 18 years it fell below the average. It is interesting to note, however, that during the 10-year period beginning and ending with the excessively wet years 1905 and 1914 the average annual precipitation was 12.19 inches and in only two years was the precipitation less than the long-term average. The diagram (fig. 2) also shows that the wet and dry years usually occur in groups.

*Seasonal distribution.*—The precipitation occurs principally during two seasons of the year, a primary maximum occurring during the months of July to September, inclusive, and a secondary maximum during the cold months of the year.<sup>1</sup>

<sup>1</sup> Summary of the climatological data for the United States, sec. 3, pp. 21-22, U. S. Weather Bureau, 1908.

Figure 3, showing the actual and average monthly precipitation at the several stations in the area, brings out this fact clearly. The following table gives average precipitation, in inches, and the per-

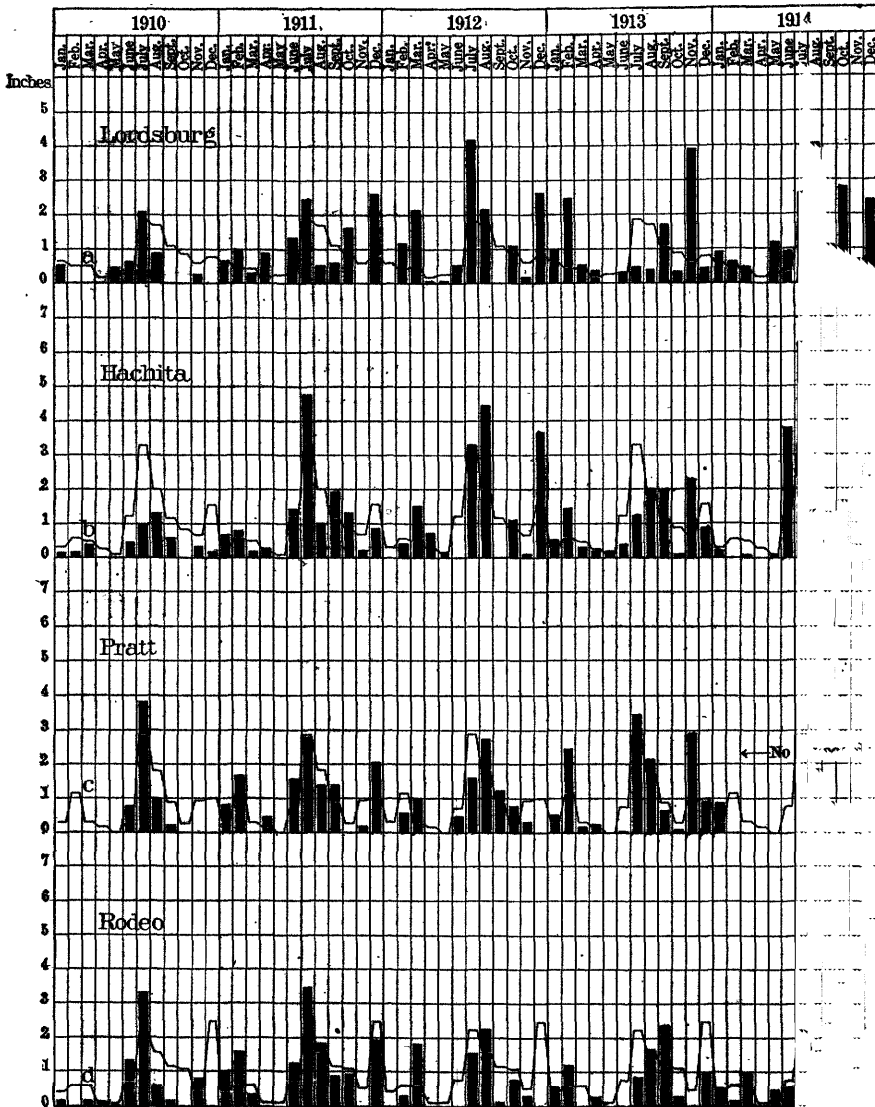


FIGURE 3.—Diagram showing actual and average monthly precipitation in southern Grant County, 1910-1914. The curves a, b, c, d represent the average precipitation for the five years

centage of the total precipitation for each month of the year, calculated from the records at Lordsburg for a period of 33 years, given on page 37.



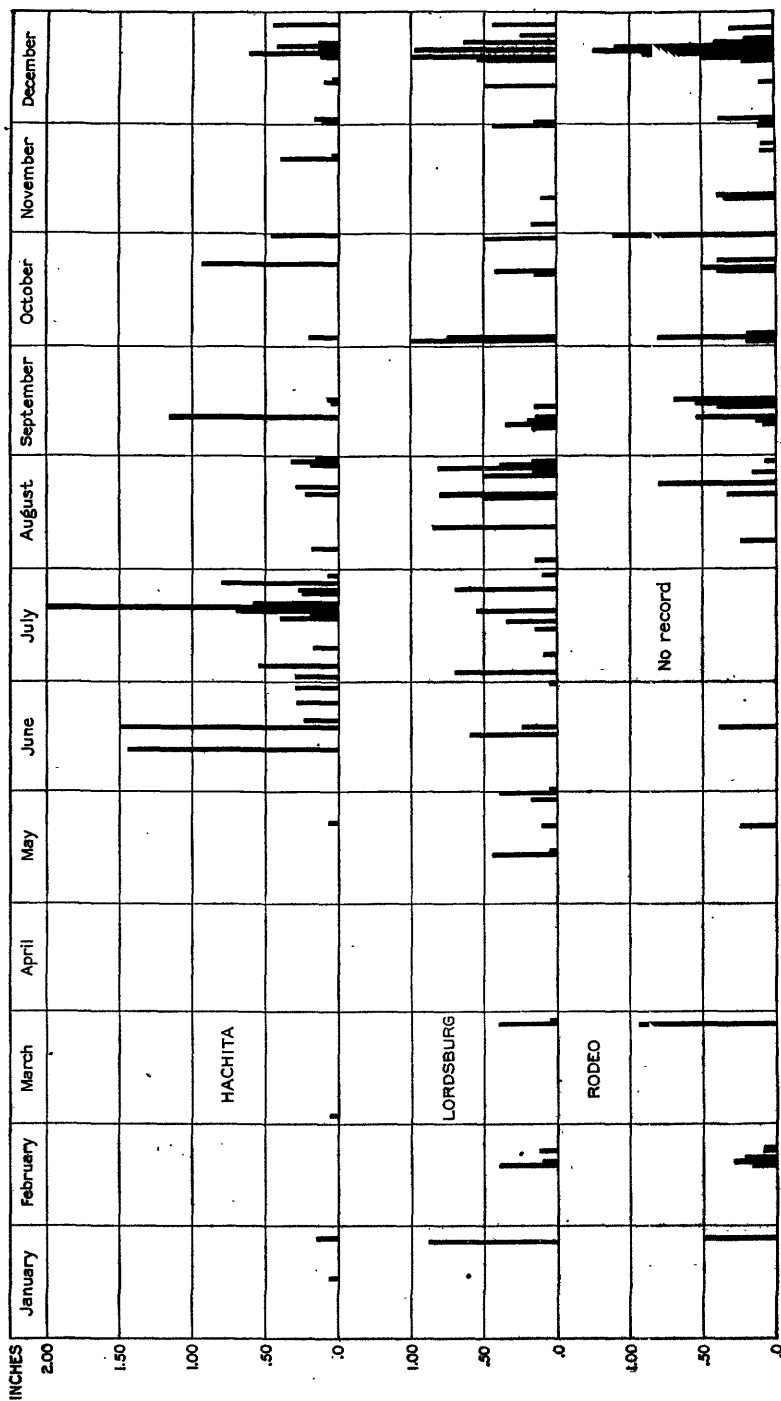


FIGURE 4.—Diagram showing daily precipitation in southern Grant County in 1914.

*Monthly and seasonal distribution of precipitation at Lordsburg, N. Mex.*

Month.	Average pre- cipitation in inches.	Per cent of total pre- cipitation.	Month.	Average pre- cipitation in inches.	Per cent of total pre- cipitation.
January.....	0.63	7	July.....	1.83	20
February.....	.55	6.19	August.....	1.69	18.50
March.....	.55	6	September.....	1.07	12
April.....	.17	2	October.....	.84	9
May.....	.23	2.7	November.....	.60	6.24
June.....	.28	3	December.....	.79	9

The heaviest rains usually fall in July and August in thunderstorms of short duration. Figure 4, showing the daily precipitation for 1914 at several stations in southern Grant County, gives a good idea of the magnitude of some of the storms during the summer. At Hachita, for instance, 2 inches of rain—nearly 10 per cent of the total precipitation for the year—fell on July 21. On June 11 and June 17 the precipitation was 1.45 and 1.50 inches, respectively, each more than  $8\frac{1}{2}$  per cent of the annual precipitation. The three days mentioned therefore contributed 29 per cent, or nearly one-third, of the total precipitation for that year.

*Regional distribution.*—The local character of the rains is also shown by figure 4. Lordsburg, a little more than 30 miles north-east of Hachita, received no rain on the dates mentioned above, in spite of the fact that the country is open and that there are no considerable mountain ranges intervening between the two places to intercept the moisture-laden winds.

According to the United States Weather Bureau:<sup>1</sup>

While the rains of summer are local in character and generally traceable to the influence of the mountains interposing their masses to the free passage of the rain-bearing winds, the precipitation of winter is the result of general storm movements over the district, induced by the low areas that develop over the Gulf of California and the lower Colorado Valley, the greater part of the moisture from which, however, is deposited in regions far to the eastward. During the winter months the moisture at the higher elevations [as in southern Grant County] is precipitated as snow.

**TEMPERATURE.**

The daily range in temperature is large. In summer months the heat during the day is sometimes great, but the nights are usually comfortable. In June, July, and August the thermometer frequently rises above 100° F., but the dryness of the air and the rapid evaporation of the moisture from the body eliminate to a large extent the inconveniences and dangers of high temperatures so common in more humid climates.

<sup>1</sup> Summary of the climatological data for the United States: U. S. Weather Bureau Bull., sec. 3, pp. 21-22, 1912.

Figure 5 shows the maximum, minimum, and mean monthly temperatures at Lordsburg during five years—1910 to 1914. The highest recorded temperature during these five years was  $106^{\circ}$  F. in

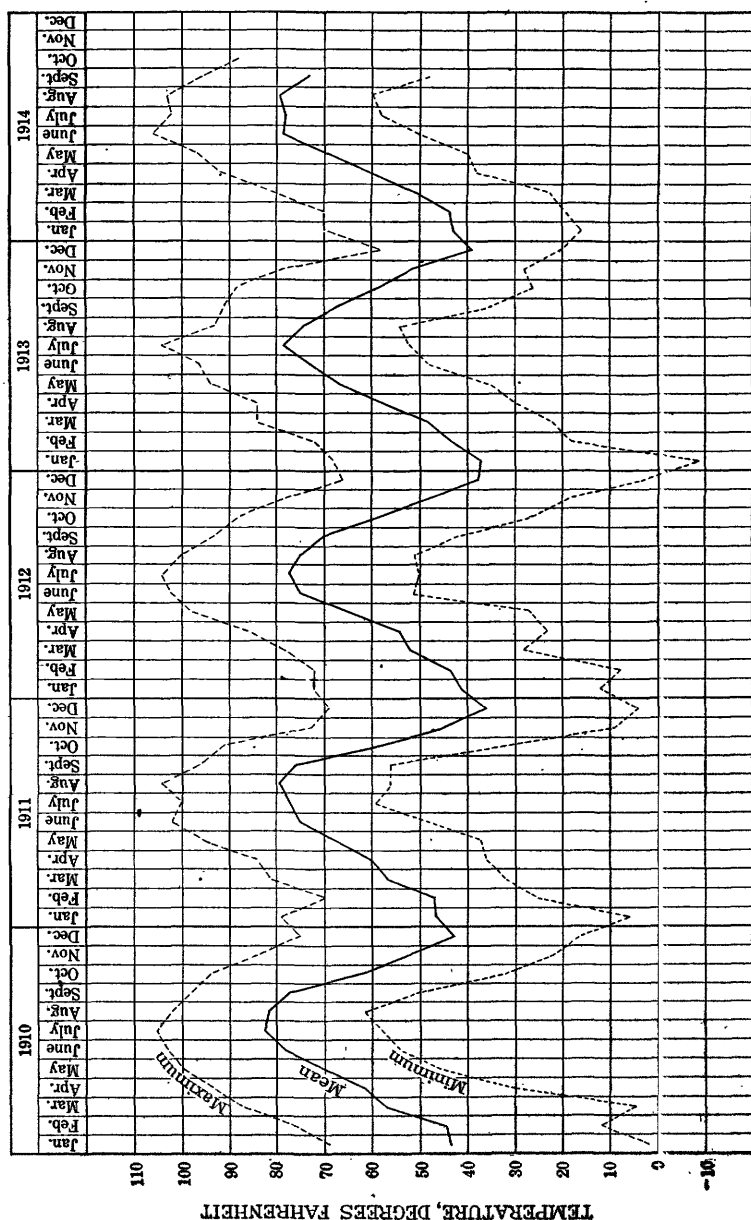


FIGURE 5.—Diagram showing maximum, minimum, and mean monthly temperatures at Lordsburg, 1910-1914.

June, 1914, and the lowest temperature was  $9^{\circ}$  below zero in January, 1913. The mean summer temperature is about  $87^{\circ}$  F. and the mean winter temperature about  $40^{\circ}$  F.

## SOIL.

## GENERAL CHARACTERISTICS.

The following statements in regard to the general characteristics of the soils of arid regions have been taken largely from Bulletin 85 of the Bureau of Soils:<sup>1</sup>

The distinguishing characteristics of arid soils are (1) a large quantity of soluble mineral matter, (2) low content of organic matter, (3) generally gray or light color, (4) deep soils with little change in character with depth, and (5) marked productiveness when irrigated. The large amount of soluble mineral matter in the soils of arid regions is due to the low precipitation. In humid climates much of the soluble matter is leached out and carried off by drainage waters, whereas under arid conditions it remains in the soil. The soils of arid regions contain less organic matter than those of humid regions. The light color of arid soils is due largely to the absence of much humus. The dry climate not only prevents the production of much humus but also causes the rapid disappearance of that which is formed. Arid soils do not as a rule change much with depth in color, texture, or productiveness. In humid regions plants do not thrive where the surface soil has been removed, but in arid regions good crops are obtained on freshly exposed material from several feet below the surface. The marked productiveness of most arid soils when irrigated is well known. It has often been pointed out that some of the earliest and most highly organized civilizations were developed in arid regions.

According to the manner of their formation, the soils of southern Grant County are mainly of three classes, (1) residual soils, (2) wind-deposited soils, and (3) alluvial soils. Residual soils are those formed in place from the disintegration of the underlying rocks. They occur principally in the mountain areas, but are found also where lava sheets (malpais) have been poured out over the valley surfaces. Soils composed of wind-deposited material are found in dune regions along the borders of some of the dry lakes and more or less in other localities. Alluvial soils, or soils formed from material brought down from the mountains and deposited by water, cover the greater part of the valley areas. They grade in texture from the coarse gravels of the upper slopes to the dense, exceedingly fine-grained clays of the alkali flats. The soils best suited for agriculture are those of an intermediate texture.

<sup>1</sup> Coffey, G. H., A study of the soils of the United States: U. S. Dept. Agr. Bur. Soils Bull. 85, pp. 38-41, 1912.

## ALKALI.

## FORMATION AND ACCUMULATION.

As rocks disintegrate to form soil various substances are freed that are readily soluble in water. Some of these substances are useful as plant food and some are harmful if present in large amounts. The commonest water-soluble constituents of the soil are the chloride, sulphate, carbonate, and bicarbonate of soda, collectively known as alkali. Quantities of the salts present in soils are carried off by water flowing over the surface and percolating through the soil. Conditions due to arid climate are said to be conducive to fertile soils in that the salts essential to plant growth are not leached out of the soil. These same conditions, on the other hand, have been the cause of the unproductiveness of certain areas, for they have allowed too great a concentration of salts injurious to plants. The comparative poverty of the soil of humid regions in soluble salts and the excess of such salts in certain soils of arid regions is directly attributable to the manner of disposal of the salts after they have been leached from the soils in which they originated. In humid regions most of the salts dissolved out of the soil are carried out through the drainage into the ocean; in arid regions they are redeposited in the soil as the waters are evaporated.

The greatest concentration naturally occurs in places where the largest amounts of water are evaporated, as in areas where the ground water is shallow and rises to the surface by capillarity and in areas where surface water collects. In many soils water will not rise by capillarity higher than 5 feet above the water table, but in some it has been known to rise as much as 10 feet.<sup>1</sup>

Except in the vicinity of springs and at a very few other places the ground water in the valleys of southern Grant County is too deep for capillary rise to the surface. Capillarity therefore can not be considered an important factor in accumulating alkali in the soil at present, but possibly some of the older buried soils have become charged with alkali by this process. Most of the alkali deposits that are now being accumulated in the low central parts of the undrained valleys are the result of the evaporation of standing surface water.

## KINDS OF ALKALI.

A distinction is usually made between the black alkali—sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) or sal soda—and the white alkalies, which are principally sodium chloride ( $\text{NaCl}$ ) or common salt, and sodium sulphate ( $\text{Na}_2\text{SO}_4$ ) or Glauber's salt. Black alkali, although it is white, is so called because of the dark color it imparts to the surface

<sup>1</sup> In experiments conducted at the California Experiment Station, Loughridge observed a maximum rise of 10.17 feet. Hilgard, E. W., Soils, p. 203, 1916.

soil and to standing water, and the dark stain is usually, though not always, an indication of its presence. A dark color may be produced by less harmful salts, and if the soil contains little humus it may not be dark even if it contains sodium carbonate. The effect of the different alkali salts on soil and vegetation and their relative harmfulness are discussed as follows by T. H. Kearney,<sup>1</sup> of the Bureau of Plant Industry:

Black alkali \* \* \* is far more injurious to plants than the white-alkali salts. It is a strong corrosive, causing the decay of plant tissue. Trees growing in black-alkali land are sometimes completely girdled at the crown through the corrosive action of the sodium carbonate. This salt also has a bad effect upon the texture of heavy soils, causing them to become puddled.

The white-alkali salts are not corrosive, but when freely taken up into the cells of the plant they cause serious disturbances in its nutrition. If present in the soil in sufficient quantity, these salts also hinder the absorption of water by the plant roots, so that even when the soil is quite wet the plants may actually be suffering from lack of water. This is doubtless one of the chief reasons why seeds germinate more slowly where alkali is present.

The chloride type of white alkali is somewhat more harmful to most crop plants than the sulphate type. The bicarbonates as such do not appear to be very injurious, but there is always danger where bicarbonates are present that black alkali will be formed by chemical action.

#### DISTRIBUTION OF ALKALI.

Samples of soil were taken at 53 localities so chosen that each sample would be representative of the soils in as large an area as possible and would furnish information as to the chemical characteristics of some of the common types of soil. The samples were obtained by boring with a soil auger. With a few exceptions borings were carried to a depth of 4 feet, two samples of soil being taken from each boring—one from the first foot and one from the last 3 feet. A chemical analysis of the water-soluble content of each sample was made in the laboratories of the New Mexico experiment station. Notes were taken in the field of the physical character of the soil and of the vegetation on the area represented by each sample. The results of the analyses, with notes on the physical character of the soil and the predominant vegetation, are given in the table on pages 144–149. The investigation was confined for the most part to the areas which show symptoms of the presence of alkali.

The results of the chemical analyses are also shown on Plate I, symbols being used to represent the different degrees of concentration of alkali, according to the classification adopted by the United States Bureau of Soils in the construction of alkali maps, which is as follows: (1) Negligible alkali—less than 0.2 per cent of total salts or less than 0.05 per cent of black alkali; (2) weak alkali—0.2 to 0.4 per cent of total salts or 0.05 to 0.1 per cent of black alkali; (3)

<sup>1</sup> The choice of crops for alkali land: U. S. Dept. Agr. Farmers' Bull. 446, pp. 8-9, 1911.

medium alkali—0.4 to 0.6 per cent of total salts or 0.1 to 0.2 per cent of black alkali; (4) strong alkali—0.6 to 1 per cent of total salts or 0.2 to 0.3 per cent of black alkali; and (5) excessive alkali—more than 1 per cent of total salts or more than 0.3 per cent of black alkali. The values used for total soluble salts (total alkali) and for sodium carbonate (black alkali) are the average amounts to the depth of the boring (usually 4 feet).

If grown on soils containing a negligible amount of alkali none of the common crops will suffer injury unless practically all the salts are concentrated near the surface. On weak-alkali soils all but the most sensitive crops will thrive. Good crops may be expected of all forage crops and of most cereals. Alfalfa, when well started, grows on land of this class, although it is sometimes difficult to get a good stand. Sugar beets, sorghum, and barley should also do well. Medium-alkali soils will not as a rule produce large yields of any of the common crops. Sorghum, sugar beets, and some varieties of oats and barley may be made to produce fair crops under ordinary conditions by careful preparation of the seed bed and washing down of the salts by heavy irrigation. For strongly alkaline soils crops with exceptional resisting qualities must be chosen. According to Dorsey<sup>1</sup> the Australian saltbush and sorghum can often be grown with profit where other crops fail. He says:

Certain saltbushes withstand large quantities of alkali. Saltbushes from Australia were introduced into California more than 20 years ago, but the most valuable species was not brought in until many years later. This is now commonly known as the Australian saltbush (*Atriplex semibaccata*), and, on account of its rank growth and ability to resist drought as well as alkali, has been somewhat extensively cultivated in California, Arizona, and New Mexico. It may be used for pasture or cut and cured as hay, yields of several tons per acre being not at all unusual.

While the cultivation of saltbushes has not perhaps been practiced long enough to make definite statements as to the future, sufficient trials have been made to prove that under certain conditions some revenue may be derived from land that would otherwise be nonproductive. On lands which will admit of other more profitable crops to be grown, sorghum ranks high as an alkali-resistant crop. At the Tulare substation the California experiment station reports sorghum growing luxuriantly in soils having a large amount of alkali, the surface often having a very dark incrustation from the black alkali. In the surface foot of soil chemical analysis revealed 0.872 per cent of total salts, a little more than half this quantity in the second foot, and slightly less quantities in the third and the fourth foot. The predominating salt was sulphate. From these results sorghum would seem to have a high tolerance for alkali salts and may be expected to grow where many other crops fail.

On the excessively alkaline soils it is hopeless to attempt the cultivation of any crop until a part of the alkali is removed.

Alkali accumulates in greatest quantity in the low central parts of the undrained valleys, where the surplus run-off collects and forms shallow lakes in the rainy season. As the fine texture of the soils

<sup>1</sup> Dorsey, C. W., Reclamation of alkali soils: U. S. Dept. Agr. Bur. Soils Bull. 34, pp. 14-19, 1906.

prevents much downward percolation most of this water evaporates and the salts which it carries are left in the soil. Where this process is repeated from year to year the soil finally becomes strongly impregnated with alkali. These areas, usually bare of native vegetation, are known throughout the Southwest as "alkali flats." In southern Grant County they form parts of Lower Animas, Lower Playas, and Lordsburg valleys. (See maps, Pls. I and II.) Stains on the surface of the alkali flats give abundant evidence of the existence of both black and white alkali in the soil, and this evidence is confirmed by analyses of the soil. Samples 8, 10, and 12, taken from the south alkali flat of the Lower Animas Valley contained, respectively, 0.908, 0.916, and 0.766 per cent of total alkali, a large part of which was black alkali. Sample 32, from the alkali flat of Lower Playas Valley, showed 1.279 per cent of total alkali, one-fourth of which was black alkali, and sample 6, from one of the small flats in the Lordsburg Valley, contained 0.632 per cent of total alkali, of which almost one-third was black alkali. (See Pl. I and Table 2.)

Soils that contain strong or excessive alkali and that are therefore generally unfit for farming are also found in certain comparatively small areas outside of the flats. They support some native vegetation, but most of it is of a type very much more resistant to alkali than any of the cultivated crops. Most of the soil of this character is found in poorly drained areas near the flats in Lower Animas, Lower Playas, and Lordsburg valleys. At most other places in these valleys the soil does not contain enough alkali to interfere seriously with the cultivation of crops. The soils of San Luis and Upper Animas valleys and of the greater part of Upper Playas and Hachita valleys are practically free from alkali. The distribution of alkali is more fully discussed under "Soil in relation to water supplies" in the descriptions of the valleys on pages 72-73, 82-83, 97-98, 106, 117-118, and 124-125. Areas in Lower Animas, Lower Playas, and Lordsburg valleys whose soils are strongly alkaline are indicated on the map (Pl. I).

#### PREVENTION OF ACCUMULATION OF ALKALI.

The first prerequisite for preventing the accumulation of alkali is good underdrainage, which depends on the texture of the soil and subsoil—whether it is sandy and readily permits water to move through it, or clayey and impervious. The caliche subsoils found in many parts of the Southwest also interfere seriously with the drainage. If drainage within the soil is good the salts added by irrigating water are kept moving downward and prevented from concentrating near the surface. The position of the water table is also important, for if the ground water is very shallow the salts washed down during irrigation will afterward rise with the capillary water and be redeposited near the surface. Excessive accumulation of



alkali is often due largely to faulty methods of irrigation. Fields that are to be irrigated by flooding should be carefully leveled, so that the water may spread evenly over the whole surface, for if not so leveled the water will seep laterally into the high spots that are not covered, and evaporation there will, in the course of time, cause rising and excessive accumulation of alkali. The essential thing, therefore, is to keep the salts moving downward. Given an adequate underdrainage, with all the irrigation water applied to a carefully leveled surface, the salts will be leached downward and can return to the surface only on evaporation of the soil moisture. In this connection the importance of restricting evaporation as much as possible may be mentioned. Some of the ways in which this can be done are described by Dorsey,<sup>1</sup> who says:

Any method of treatment that prevents evaporation necessarily retards the rise of the alkali. If evaporation were entirely eliminated there could be no surface accumulation of alkali. Unfortunately, however, we can not entirely prevent evaporation, although we can in a measure control it. Cultivation, mulching with straw or leaves, or shading the surface by crops tend to restrict surface evaporation. Frequent shallow cultivation, by keeping the upper few inches of soil in a loose condition, breaks the ascending column of capillary water and thereby reduces the quantity of water that can reach the surface. Scattering leaves or straw protects the surface from the direct rays of the sun and also reduces evaporation. \* \* \* Frequently, in the spring, after the winter rains have washed the alkali a short distance below the surface, it is possible to secure a stand of rapid-growing crops that will furnish a dense shade by the time hot weather comes on. Many cases are on record where land containing appreciable quantities of alkali have been utilized in this manner. The shade furnished by the crop checks excessive evaporation, while frequent surface irrigations still further operate to drive the alkali into the lower depths of soil.

On soils that normally contain little alkali the use of the average well water of southern Grant County is not likely to cause an excessive accumulation of alkali. In other words, troubles due to alkali are not likely to be caused by intelligent irrigation in areas where the conditions do not favor the accumulation of alkali through the natural watering by drainage waters.

Of soils that normally contain large quantities of alkali (occurring chiefly in the areas outlined on the map, Pl. I, and described on p. 84) some may be used without treatment for growing crops if precautions are taken to prevent a further increase of alkali, whereas others require the removal of some of the salts before crops can be started. The underlying cause of excessive alkali in these soils is a poor underdrainage. They are mostly of the heavy clay type, through which water does not penetrate easily, and consequently most of it evaporates at or near the surface and causes a dangerous accumulation of salts there. Though the alkali content of these soils may not actually have reached the danger limit, it is likely to do so in a short

<sup>1</sup> Dorsey, C. W., Reclamation of alkali soils: U. S. Dept. Agr. Bur. Soils Bull. 34, pp. 13-14, 1906

time, even with the use of the best irrigating waters, unless great precautions are taken. With care in the preparation of the land, the application of the irrigating water, and the selection of crops much of this land, even if it contains more alkali than is desirable, can probably be farmed with profit.

The lands that contain so much alkali that crops can not be started must undergo some such treatment as is described below.

#### TREATMENT OF ALKALI SOILS.

The first apparent effect of alkali is to retard the germination of the seed. Therefore before crops can be started on land containing large amounts of alkali it is often necessary to remove part of it preliminary to planting. Various methods have been proposed for freeing soils of alkali. Of these, flushing with flood water is worthy of trial on some of the lands of southern Grant County, in one of the ways described by Dorsey <sup>1</sup> in the following paragraphs:

*Flushing the surface.*—Frequently an attempt is made to free the soil from alkali by turning water across a field, holding it on the land for a short time, and then draining it off. The principle involved is to allow the water to dissolve the salts in the upper part of the soil and on the surface, and then by immediately draining it off to carry the dissolved salts away. \* \* \*

The conditions favorable for this treatment are rather heavy or somewhat impervious soils, with the alkali largely concentrated at the surface. \* \* \* The alkali, largely a surface deposit, will be dissolved and the greater part of the water will be drawn off with its dissolved salts. A few flushings may so reduce the quantity of alkali that crops can be started, and with the precautions of surface irrigation and restricting evaporation by shading the surface or by cultivation the land may be made productive. This method, although of somewhat limited application, may result in the permanent reclamation of alkali land.

*Flooding without artificial drainage.*—Certain definite conditions are necessary before this method can be recommended. The most essential points are that the soil be naturally well drained and the water table several feet below the surface. Under these circumstances the soil may be freed from even excessive quantities of alkali. After leveling the field sufficient water is added to cover the surface to a depth of several inches. By means of dikes or levees the water is held on the land and must of necessity soak through the soil, carrying with it the more readily dissolved salts. Repeated flooding finally leaches away the greater part of the alkali and enables the land to be cultivated. By care in handling such reclaimed land the chances for a second accumulation of salts are slight, provided that the ground water be kept sufficiently far below the surface. \* \* \* The success or failure of this method depends a great deal on choosing just the right time to start the crop. With the surface soil freed from alkali even to the depth of a few inches a piece of land may be entirely reclaimed. This enables the crop to start, and its growth effectually checks evaporation at the surface, while subsequent irrigation tends to reduce still further the alkali content of the soil. Sorghum has frequently been recommended as a suitable crop to plant on and where the quantity of alkali is still considerable. This crop, as has been pointed out, is able to withstand not a little alkali and at the same time admits of copious irrigation.

<sup>1</sup> Dorsey, C. W., Reclamation of alkali soils: U. S. Dept. Agr. Bur. Soils Bull. 34, pp. 18-19 1906.

The success of either of these methods depends on adequate drainage, the first method on subsurface drainage and the second on surface drainage. Flushing could probably be used successfully on some of the lands bordering the alkali flats, into which the wash water could be drained, provided the lands are high enough above the flats to give sufficient grade. Flood waters might be used for this purpose. Where the surface soil is somewhat sandy flooding might prove beneficial by washing the alkali down into the soil, so that crops could be started, after which the underdrainage might be improved sufficiently by deep cultivation to prevent further accumulation of alkali at the surface.

The application of gypsum or "land plaster" to alkali lands will neutralize black alkali, but no antidote has yet been found for white alkali. The neutralization of black alkali by gypsum can give lasting relief only where little or no white alkali is present. As most of the soils of southern Grant County that contain an excess of black alkali contain also considerable white alkali the benefit to be obtained by the use of gypsum would be small. No gypsum deposits are known in this area and the cost of shipping gypsum in from the outside at prevailing freight rates would be considerable. At the present value of land its general use would therefore probably not be warranted, but where orchard trees or other valuable plants are threatened with black alkali its use could be recommended.

## VEGETATION.

### GENERAL FEATURES.

The soil, water supply, and climate of the large open valleys and plains, where the relief is low and the drainage is imperfect, differ so greatly from those of the mountain areas, where the relief is high, the topography is rugged, and the drainage is free, as to give distinct individuality to the respective floras. The flora of the mountainous areas consists principally of forest trees and to a lesser degree of plants belonging to the cactus family; the flora of the valleys and plains consists chiefly of shrubs and grasses, trees being found only along the principal watercourses and singly or in small groups at springs and water holes.

### MOUNTAIN AREAS.

Light growths of forest are found in the Chiricahua National Forest, in the southern parts of the Peloncillo and Animas ranges, in parts of the Hatchet Range, and in the Gila National Forest, in the Little Burro Mountains. Pines predominate on the summits and higher slopes, and junipers, oaks, and cedars are commonly found on the lower slopes and on the foothills. Outside of these particular

tracts timber is very scarce. Except for a scattering growth of cedar, juniper, and small, stunted pines, the mountain ranges in the central and northern parts of the area are almost treeless. On the rocky slopes of these ranges there are, however, cacti of various kinds, principally the mescal, prickly pear, barrel cactus, and ocotillo. Beyond an occasional use of the mescal and prickly pear as a stock food, after removal of the spines, and of the ocotillo for making rabbit-proof fences around garden patches, these plants serve no economic use. The timber is in great demand on the farms in the valleys, chiefly for firewood and fence posts. Sheltered canyons and slopes of the mountains afford considerable grass, which is valuable for the late fall and winter grazing when the range grasses of the valleys, which mature earlier, have lost much of their nutritive value.

#### VALLEY AND PLAINS.

The diversified soil, water supply, and conditions of drainage in the valleys and on the plains are clearly reflected in the character and distribution of the native vegetation. Certain plants will select as a habitat areas having a particular set of conditions and will shun other areas where conditions are different. Thus, the vegetation found on the dense clayey soils of the central valley plains is entirely different in type from that found on the gravelly, well-drained soils of the upland slopes. The vegetation is thus segregated in more or less well-defined zones. In most places, however, soils of different classes grade into one another without well-marked boundaries. Consequently the floras mingle along the edges of the zones, which can be sharply delimited at but few places.

The segregation of certain plant types in particular localities serves to some extent to indicate the physical and chemical conditions of the soil and of the water supply and thus helps to determine the adaptability of the land for agriculture.

In the valleys of this region four zones of vegetation can usually be recognized. They are, named in order from lower to higher levels, (1) the barren zone, (2) the zone of alkali vegetation, (3) the mesquite zone, and (4) the zone of upland grass and brush.

*Barren zone.*—The barren zone, indicated on Plate II by parallel lining, comprises the alkali flats, or playas, which occupy the lowest parts of the valleys. As these playas receive the surplus run-off from the surrounding watersheds and have no outlets they are subject to periodical flooding and at certain times of the year they become shallow lakes. By the evaporation of the water the dissolved mineral salts and the fine clayey sediments held in suspension are deposited to form a dense clayey soil that is almost impervious to water and is heavily impregnated with various soluble salts, known collectively as "alkali." Areas subject to such action are shunned

by even the most alkali-resistant plants and are of course worthless for agriculture.

*Zone of alkali vegetation.*—The favorite habitat of the various alkali weeds and grasses is in narrow zones along the edges of the barren playas. Among the grasses salt grass (*Distichlis spicata*) and alkali sacaton (*Sporobolus airoides*) are the dominant species. The edges of the flooded areas usually mark the inner limits of this zone, though in some places clumps of alkali sacaton grow well out on the flats. The outer boundaries of this zone are usually not so well marked, the alkali vegetation giving way gradually to the vegetation of the next zone. The high alkali content of the soil of this zone makes farming on it precarious.

*Mesquite zone.*—Mesquite predominates in a zone intermediate between the zone of alkali vegetation and that of the upland grass and brush, and covers large areas of the central valley plains (Pl. IV, B, and Pl. VI, B). The principal areas of mesquite are outlined on the map (Pl. II), but the plant is by no means confined to these areas, for it is one of the most common shrubs in the region. It is found associated with the alkali vegetation on the clayey alkaline soils near the flats, with the sagebrush on the sand dunes, and with the hardy creosote brush on the gravelly slopes. It thrives best, however, on soil of intermediate grades, preferring the sandy loams along the edges of the central valley plain to the clay soils of the interior or the gravelly soils of the higher stream-built slopes. In the most favored localities it not uncommonly reaches heights of 12 or 15 feet, but it is generally not over 6 or 8 feet high.

The soils that are most favored by mesquite are usually the soils that are best adapted for irrigation, so that this plant is a valuable indicator of the physical condition of the soil. Mesquite land is hard to clear, and where the growth is heavy much labor is required to put it into condition for cultivation, but settlers will find themselves amply repaid in the long run for the extra labor needed to obtain a superior quality of soil by selecting land bearing a heavy growth of mesquite. It is used extensively for firewood.

*Zone of upland grass and brush.*—The most general botanical features of the zone of upland grass and brush are indicated by the notations on the map (Pl. II). This zone embraces the higher parts of the central valley plains and the stream-built slopes adjacent to the mountains and includes many kinds of soil and of drainage, the variety of these giving rise to an equally varied distribution of vegetation. Taken as a whole it is a complex of brush, grass, and nearly barren areas forming a disorderly patchwork.

The high, gravelly parts of the stream-built slopes are the favorite habitat of the familiar creosote bush. On account of the rough surface, the rocky soil, and the inaccessibility of ground water, farming

in these areas is usually impracticable. The grasses, of which there are numerous species, commonly known collectively as "grama grasses," are abundant over large areas of the more nearly level upland plains and of the lower and middle parts of the stream-built slopes. In many of the broad, shallow draws and in other areas that are occasionally covered by flood waters the grasses form a continuous turf, but usually they grow in scattered tufts or bunches. The gravelly and well-drained parts of the upland grass areas are usually dotted with yuccas. The upland areas contain much good land, which could be successfully farmed if water were available to augment the rainfall. Ground water is usually too deep in these areas to be used economically, but flood waters could in some localities be utilized. Eventually these lands may be reclaimed by improved methods of dry farming, but at present they do not offer a definite prospect of a livelihood to settlers.

## GROUND WATER.

### OCCURRENCE.

The conditions under which ground water occurs and the prospects for irrigation in the valleys of southern Grant County are described in detail on pages 69-125. The region contains no permanent streams and practically its only certain source of water is underground. The rock formations yield little or no water except at a few small mountain springs, which are valuable as watering places. Water occurs, however, in the gravelly beds of valley fill—generally in the main body of the fill but in Upper Animas Valley in gravel recently deposited in the trough excavated by Animas Creek out of the main body of fill.

### SOURCE.

The water in the valley fill comes from precipitation in the region, chiefly from rainfall on the mountains that border the valleys, and is discharged in freshets on the stream-built slopes, but also from the direct precipitation on the slopes and the valley plains. The upper parts of the stream-built slopes are generally gravelly and porous and allow the water that is shed on them to percolate downward readily. The denser fine-grained soils of the central valley plains, on the other hand, do not allow the water to penetrate easily and therefore very little of the water that is shed on these areas reaches the ground-water level. The proportion of the precipitation that is annually added to the ground-water supply therefore depends on the porosity of the material overlying the water-bearing beds.

The material composing the stream-built slopes in southern Grant County is only moderately porous, but it is believed that at least 5 per cent of the precipitation of these slopes percolates downward to

the ground-water level. A part of the rainfall on the mountains is lost by evaporation, a part is taken up by vegetation, a part sinks in the rock waste on the mountain areas and percolates through this waste to the valley fill, and a part sinks into the rock crevices; but from the steep, almost bare desert ranges of southern Grant County probably 50 per cent of the precipitation is shed on the stream-built slopes of the valleys. A much larger proportion of this water percolates to the ground-water level than of that which is precipitated directly on the stream-built slopes, for the entire volume of the mountain drainage is discharged upon the upper porous portions of these slopes, whereas a large part of the direct precipitation falls on the less porous lower portions. Probably as much as 15 per cent of the precipitation on the mountain areas percolates to ground-water level.

On the central valley plains most of the water that is precipitated is returned to the atmosphere, either by direct evaporation from the surface or through transpiration by plants. In areas having clay soils probably none of the water penetrates to the ground-water level, but in areas of sandy or gravelly soils some of the rainfall undoubtedly reaches the ground-water body.

#### HEAD AND ARTESIAN PROSPECTS.

At a few places the ground water is under pressure so great that it comes to the surface in springs (pp. 104-105, 113-114). In one locality it rises above the ground surface in wells (pp. 114-115), and in several wells it rises a few feet above the water table, or upper surface of the ground-water body, but it does not rise above the water table in most of the wells that have thus far been sunk. The absence of appreciable hydrostatic pressure is due principally to the discontinuity of the water-bearing beds and the absence of an effective artesian cover. It may be due also to a low outlet from the underground reservoirs into the Gila basin, a possibility indicated by a decided northward decline of the water table in most of the valleys (pp. 70-71, 89-91, 110-112).

To the writer's knowledge, the only serious attempt to obtain artesian water was made in Playas Valley and resulted in failure (p. 115). Many unverified stories are told of artesian flows accidentally struck by the early cattlemen in drilling wells to obtain water for stock, the flow being then deliberately stopped, windmills erected, and the water pumped in order to hide the fact from prospective settlers, who might dispute a monopoly of the range. At Ojo de las Cienegas, in Playas Valley (p. 114), small artesian flows were obtained in wells drilled to get water for stock. Instead of trying to stop the flow, however, the stockmen facilitated it, and the wells are flowing to-day. Although self-interest might have prompted an

occasional cattleman to keep the presence of artesian water secret, most of these stories are undoubtedly myths.

In the Lordsburg, Animas, San Luis, and Playas valleys conditions in general are believed to be unfavorable for artesian water, but the lower part of Hachita Valley is believed to afford a possibility of obtaining flows from deep wells sunk in the central trough of the valley.

#### WATER TABLE.

The water table, or upper surface of the zone of saturation, is usually an irregular surface, but the irregularities are less pronounced than those of the surface of the land. If sufficient data are obtained the water table can be represented on maps by contours that may show hills, valleys, and other features characteristic of surface topography.

The data obtained in southern Grant County were not sufficient to warrant contouring of the water table with respect to sea level, but measurements of depths to water in a large number of wells sufficed to show the position of the water table in relation to the land surface and to permit the outlining on the map (Pl. II, in pocket) of the areas with specified depths to water.

At a number of places where the elevation of the land surface was known the elevation of the water table above sea level was determined by measuring the depth to water, and these places were sufficiently numerous to give a good idea of the general shape of the water table. On the whole the water table conforms in general to the land surface. Thus in the troughlike valleys the water table also is in the form of a trough whose axis coincides closely with that of the valley and whose sides slope upward toward the mountain borders.

On the stream-built slopes, however, the grade of the water table is much less than that of the land surface, so that toward the mountains the land and water surfaces diverge from each other, and the depth to water becomes greater. In the principal valleys of southern Grant County there is a marked decline of the water table in a general northerly direction. This condition is discussed more fully in the descriptions of the valleys (pp. 69-125).

The form of the water table is continually readjusting itself to changing conditions of supply. If at any particular place the additions to the ground-water supply exceed the losses, the water table will rise; if the reverse is true it will fall. Additions or withdrawals of water at any place not only affect the water table there but, owing to its great mobility, may cause it to fluctuate appreciably at distant points. The chief controlling factor of the fluctuations of the water table in the valleys of southern Grant County



is the rainfall. In the valleys where the water occurs in the main body of the valley fill, the fluctuations of the water table are hardly noticeable; but in Upper Animas and San Luis valleys, where the water is contained in shallow deposits near the surface as perched water, the seasonal fluctuations may be great.

The depth to the water table varies greatly in different parts of the area. In a few places in Playas, Upper Animas, and San Luis valleys the water table coincides with the surface; in other places it lies several hundred feet below the surface.

#### SHALLOW-WATER AREAS.

In about 10 per cent of the area investigated, or approximately 370 square miles, water may be found at a depth of 100 feet or less. This area includes approximately 194 square miles in which the depth to water is 50 feet or less. As pumping for the irrigation of the ordinary field crops is usually considered feasible where the water level is 50 feet or less from the surface, water at that depth is generally referred to as shallow water.

The largest areas in which the ground water stands less than 50 feet from the surface are in Animas and Playas valleys. In Animas Valley there are two shallow-water tracts—one in the depressed central part of the lower valley and another smaller one in the Animas Creek trough of the upper valley. In Playas Valley a large tract in which the depth to water is less than 50 feet occupies the central parts of the upper and lower valleys and a small tract of shallow perched water is found in the Pot Hook Basin. Small shallow-water tracts are also found in the Hachita, Lordsburg, and San Luis valleys. (See Pl. II, in pocket.)

The following table gives estimated areas of tracts in which the depth to water in the different valleys is 100 feet or less:

*Areas in southern Grant County (not including San Simon Valley<sup>a</sup>) in which depth to water table is 100 feet or less.*

[Areas in square miles.]

Depth to water table (feet).	Lordsburg Valley.		Upper Animas Valley.		Lower Animas Valley.	
	Total area.	Arable area. <sup>b</sup>	Total area.	Arable area. <sup>b</sup>	Total area.	Arable area. <sup>b</sup>
Less than 15.....	0	0	20	20	8	1
15 to 25.....	0	0			35	14
25 to 50.....	4	0			36	26
50 to 100.....	42	33	( <sup>c</sup> )	( <sup>c</sup> )	53	45
50 or less.....	4	0	20	20	79	41
100 or less.....	46	33	20	20	132	86

<sup>a</sup> For information regarding San Simon Valley see U. S. Geol. Survey Water-Supply Paper 425-A.

<sup>b</sup> Areas in which the soil is suitable for general farming; excludes areas covered by lava beds, sand dunes, and alkali flats and other areas where the soil contains excessive alkali.

<sup>c</sup> Negligible area.

*Areas in southern Grant County (not including San Simon Valley) in which depth to water table is 100 feet or less—Continued.*

[Areas in square miles.]

Depth to water table (feet).	San Luis Valley.		Playas Valley. <sup>a</sup>		Hachita Valley.	
	Total area.	Arable area. <sup>b</sup>	Total area.	Arable area. <sup>b</sup>	Total area.	Arable area. <sup>b</sup>
Less than 15.....	c 7	c 7	20	10	1	1
15 to 25.....	(d)	(d)	60	50	2	2
25 to 50.....	(d)	(d)	70	70	6	6
50 to 100.....	c 7	c 7	80	60	3	3
100 or less.....	c 7	c 7	150	130	9	9

<sup>a</sup> Including the Pot Hook Basin.

<sup>b</sup> Areas in which the soil is suitable for general farming; excludes areas covered by lava beds, sand dunes, and alkali flats and other areas where the soil contains excessive alkali.

<sup>c</sup> Tested area. The total area may be considerably larger.

<sup>d</sup> Negligible area.

Not all the land in which water is found at shallow depths is suitable for farming, for such areas as are covered by lava, sand dunes, and alkali flats and areas bordering the flats where the soil contains excessive amounts of alkali must be classed as nonarable. Exclusive of these areas there are in southern Grant County in the valleys described about 130 square miles of arable land in which water may be found at a depth of 50 feet or less.

In tracts aggregating more than 150 square miles of arable land the depth to the water table ranges from 50 to 100 feet, and these tracts may be considered potentially irrigable. Whether they could profitably be reclaimed by pumped water at present is doubtful, but constant improvement in the efficiency of pumping machinery suggests that in time these areas also can be reclaimed.

#### QUANTITY OF WATER.

The quantity of water annually available for irrigation depends on the annual contributions to the ground-water supply and on the annual losses. With respect to surface drainage the greater part of the area is practically isolated. From the Animas, Lower Playas, and San Luis basins, comprising almost two-thirds of the total area, no surface water escapes, either in perennial streams or in floods. From the rest of the area no surface water escapes except a small amount in floods. The area is also almost completely isolated against influx of ground water from outside areas, but ground water probably escapes from Animas, Playas, and Lordsburg valleys into the Gila basin and from Hachita Valley into Mexico.

According to the records of the United States Weather Bureau, the average annual precipitation in the valleys of southern Grant County is about 10 inches (pp. 36-40). The precipitation in the mountain areas probably averages not less than 12 inches annually. On page 54 it is roughly estimated that 15 per cent of the precipitation on

the mountain areas and 5 per cent of that on the stream-built slopes reaches the ground-water reservoirs. According to these assumptions the annual accretions of ground water would aggregate from several thousand to several tens of thousands of acre-feet in each of the basins investigated.

Approximately an equal amount must at present be lost from the underground reservoirs by leakage, evaporation, or other natural processes. A considerable part of the water annually received could, however, be recovered by wells and used for irrigation.

In the Lordsburg, Lower Animas, Playas, and Hachita valleys, where the water is found in the main body of valley fill, the storage capacity of the underground reservoirs is large, but in Upper Animas and San Luis valleys the recoverable water is contained in gravels near the surface, the storage capacity is small, and if there were heavy pumping for irrigation one exceptionally dry year might cause a serious shortage of water.

### QUALITY OF WATER.

#### IMPORTANCE OF QUALITY.

The suitability of a water for a particular purpose depends on the kind and amounts of mineral or organic substances that it contains. A water that is absolutely worthless for one purpose may be satisfactory or even desirable for another. Thus a good irrigating water may be a poor drinking water, or vice versa, and a water which causes excessive foaming, scale, or corrosion in steam boilers may be entirely satisfactory for other industrial uses. In southern Grant County, where agricultural development depends largely on irrigation by water pumped from wells, the quality of the ground water is a matter of great importance.

Samples of water were collected from 60 wells and springs in the area and were analyzed by Dr. R. F. Hare, of the New Mexico experiment station. The results of the analyses and a statement by Dr. Hare describing the analytical methods used are given on pages 125-143.

#### SUBSTANCES DISSOLVED IN WATER.

Both surface and ground waters take into solution substances from the rocks and soil with which they come into contact, the most common being silica ( $\text{SiO}_2$ ), iron (Fe), aluminum (Al), calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K), and the carbonate ( $\text{CO}_3$ ), bicarbonate ( $\text{HCO}_3$ ), sulphate ( $\text{SO}_4$ ), chloride (Cl), and nitrate ( $\text{NO}_3$ ) radicles. The gases hydrogen sulphide ( $\text{H}_2\text{S}$ ) and free carbon dioxide ( $\text{CO}_2$ ) also occur in many ground waters. The substances most commonly deposited on evaporation of water

in this region are sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), sodium bicarbonate ( $\text{NaHCO}_3$ ), sodium sulphate ( $\text{Na}_2\text{SO}_4$ ), sodium chloride ( $\text{NaCl}$ ), calcium carbonate ( $\text{CaCO}_3$ ), calcium sulphate ( $\text{CaSO}_4$ ) and equivalent compounds of magnesium.

#### CLASSIFICATION OF WATERS WITH RESPECT TO TOTAL DISSOLVED SOLIDS AND CHEMICAL TYPE.

By means of analytical data the waters are classified as to their total mineral content and their chemical type and also as to their value for irrigation, domestic, and boiler use, the ratings being expressed both in figures and in words, according to the schemes developed by Stabler<sup>1</sup> and Dole.<sup>2</sup>

The waters are classified as to the mineral content as follows:

*Rating for total dissolved solids.*

Total dissolved solids (parts per million).		Class.
More than—	Not more than—	
----- 150 500 2,000	150 500 2,000 -----	Low. Moderate. High. Very high.

The chemical type of the water is expressed by naming the basic and acid radicles which are predominant with respect to their reacting values. The designation "calcium" (Ca) indicates that calcium and magnesium are predominant among the bases, the calcium being more abundant than the magnesium. Likewise the designation "sodium" (Na) indicates that sodium and potassium are predominant among the bases. "Carbonate" ( $\text{CO}_3$ ), "sulphate" ( $\text{SO}_4$ ), or "chloride" (Cl) shows which acid radicle is predominant, the term "carbonate" being understood to include both the carbonate and the bicarbonate. Combination of the two designations classifies the water by type—for example, "sodium-chloride" (Na-Cl), or "calcium-sulphate" (Ca- $\text{SO}_4$ ).

#### DISTRIBUTION OF WATERS ACCORDING TO TOTAL MINERAL CONTENT AND TYPE.

Among the 60 samples of water analyzed 6 different types are represented, and the total solids range from 135 to 6,913 parts per

<sup>1</sup> Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, 1911.

<sup>2</sup> Mendenhall, W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Cal.: U. S. Geol. Survey Water-Supply Paper 398, 1916. Deussen, Alexander, and Dole, R. B., Ground water in Lasalle and McMullen counties, Tex.: U. S. Geol. Survey Water-Supply Paper 375-G, 1916.

million. The geographic distribution of the waters with respect to total mineral content and type is shown in the following table:

*Geographic distribution of the waters according to mineral content and type.*

[Figures indicate number of samples.]

Valley.	Total dissolved solids.				Type.					
	Low.	Moderate.	High.	Very high.	Na-CO <sub>3</sub> .	Na-SO <sub>4</sub> .	Na-Cl.	Ca-CO <sub>3</sub> .	Ca-SO <sub>4</sub> .	Mg-CO <sub>3</sub> .
Upper Animas <sup>a</sup> .....	2	3	—	—	—	—	—	5	—	—
Lower Animas <sup>b</sup> .....	—	6	11	1	10	4	1	3	—	—
San Luis <sup>c</sup> .....	1	1	—	—	—	—	—	2	—	—
Lordsburg <sup>d</sup> .....	—	6	2	1	5	3	—	1	—	—
Upper Playas <sup>e</sup> .....	1	6	—	—	3	—	—	3	—	1
Lower Playas <sup>f</sup> .....	—	8	2	1	9	1	—	—	1	—
Hachita <sup>g</sup> .....	—	2	6	—	2	4	—	2	—	—
	4	32	21	3	29	12	1	16	1	1

<sup>a</sup> For analyses, see p. 143, Nos. 115, 124, 148, 172, and 175.

<sup>b</sup> For analyses, see p. 142, Nos. 40, 41, 42, 45, 57, 59, 60, 61, 62, 68, 76, 80, 83, 85, 87, 90, 102, and 106.

<sup>c</sup> For analyses, see p. 143, Nos. 181 and 189.

<sup>d</sup> For analyses, see p. 142, Nos. 4, 9, 13, 16, 20, 21, 25, 35, and 37.

<sup>e</sup> For analyses, see p. 143, Nos. 273, 294, 297, 303, 306, 312, and 313.

<sup>f</sup> For analyses, see p. 143, Nos. 201, 205, 218, 225, 227, 228, 237, 241, 246, 256, and 265.

<sup>g</sup> For analyses, see p. 143, Nos. 315, 319, 320, 321, 322, 323, 324, and 325.

The table shows that moderately mineralized waters are the most common, that about one out of every three is highly mineralized, and that waters whose mineralization is either low or very high are comparatively rare. The waters of the Lower Animas and the Hachita valleys are the most highly mineralized and those of the San Luis, Upper Animas, and Upper Playas valleys are least mineralized.

The table shows also that sodium-carbonate waters are the most abundant, calcium-carbonate waters are second, sodium-sulphate waters are third, and other types are rarely found. Sodium-carbonate waters are most prevalent in Lower Animas and Lower Playas valleys, which embrace the lower parts of closed drainage basins. Calcium-carbonate waters predominate in Upper Animas and Upper Playas valleys, which occupy the upper parts of drainage basins. The sodium-sulphate waters, all highly mineralized, were found only in Lower Animas, Lower Playas, Lordsburg, and Hachita valleys in association with other highly mineralized waters. In addition to those mentioned above, one of each of three other types of water is represented among the analyses. They are a sodium-chloride water from Lower Animas Valley, a calcium-sulphate water from the Pot Hook Basin in Lower Playas Valley, and a magnesium-carbonate water from Upper Playas Valley.

#### DISTRIBUTION OF CALCIUM AND MAGNESIUM.

The waters analyzed range in calcium content from 6.8 to 439 parts per million, twenty-three containing less than 25 parts per

million, twenty between 25 and 50, ten between 50 and 100, and seven 100 parts per million or more. The waters containing least calcium are found chiefly in San Luis Valley, Upper Animas Valley south of T. 28 S., R. 19 W., and the Lordsburg Draw. Although many of these waters are of the calcium-carbonate type they have a low total mineral content and contain less calcium than some of the more highly mineralized waters of other types. The waters with most calcium are found chiefly in the shallow-water area of Lower Animas Valley, north of Playas in Lower Playas Valley, and south of Hatchet Gap in Hachita Valley. Most of these waters are highly mineralized, and though they contain a large amount of calcium the calcium is not the predominating base.

The magnesium content of the waters analyzed ranges from 2.6 to 68 parts per million. In all except two of the waters (wells 21 and 41) it is less than the calcium content. In the water from well 41, in the northern part of Lower Animas Valley, the magnesium slightly exceeds the calcium, and in that from well 21, in the playa region of Lordsburg Valley, the magnesium equals the calcium. The water from New wells (No. 297) in the Upper Playas Valley is also rich in magnesium, and according to the methods of classification employed in this report it is a magnesium-carbonate water. The least magnesium is found in the waters from San Luis and Upper Animas valleys and in the waters of Lower Animas Valley south of the Wamel ranch. The waters of Hachita Valley, the upper part of Lordsburg Valley, and Lower Playas Valley north of Playas contain the most magnesium.

#### DISTRIBUTION OF SODIUM AND POTASSIUM.

In the analyses the alkali bases, sodium and potassium, were not separated, the total amount of the two bases being reported as sodium. Therefore wherever the term "sodium" is used in the discussion it is understood to include potassium.

In the waters analyzed the sodium ranges from 3.8 to 1,579 parts per million. Nine of the waters contain less than 25, eight from 25 to 50, eighteen from 50 to 100, twenty-three from 100 to 500, and two more than 500 parts per million of sodium. As a rule the waters from San Luis and Upper Animas valleys contain least and those from Lower Animas Valley the greatest quantity of sodium. Most of the waters of Lower Playas, Hachita, and Lordsburg valleys also contain large amounts. As the sodium salts are among the most soluble of the substances found in the ground waters they generally predominate in the highly mineralized waters. The distribution of the sodium is therefore very similar to that of the total dissolved solids.

## DISTRIBUTION OF CARBONATE AND BICARBONATE.

Carbonates and bicarbonates have been considered together because of the readiness with which they are interconverted. In the presence of carbon dioxide the carbonate radicle is often changed into the bicarbonate, and the reverse process may take place when the carbon dioxide is removed.

The carbonate radicle was found present in seven waters, all of which were from the northern part of the Animas drainage basin with the exception of No. 241, which is from the Lower Playas Valley. It ranges in these seven from 5.7 to 56 parts per million.

The bicarbonate radicle was reported in all the waters in amounts ranging from 21 to 1,125 parts per million. It is found in least amount in the waters of San Luis and Upper Animas valleys and in greatest amount in those of Lower Animas Valley. In general its distribution is similar to that of total dissolved solids and sodium, although it varies through a smaller range than either of these.

## DISTRIBUTION OF SULPHATE.

The amounts of sulphate radicle in the waters analyzed range from 4.1 to 4,072 parts per million. As a group the waters from San Luis and Upper Animas valleys contain least sulphate, the average for the seven samples collected in these valleys being 18 parts, and none having more than 25 parts per million. In Upper Playas Valley the sulphate content of the waters is generally low. In Lower Playas Valley all the waters except those from wells 201 and 205 contain less than 80 parts per million of the sulphate radicle. The water from well 205, in the Pot Hook Basin, is unique, as it is the only water analyzed in which calcium and sulphate are found together as the predominant radicles. In Lordsburg Valley, in the region between Brockman and the alkali flats, the waters are generally high in sulphate, whereas in the Lordsburg Draw they contain only moderate amounts. In Lower Animas Valley the sulphate is very irregularly distributed and ranges between wide limits. In general the sulphate content is high. In the northern part of the valley the average for a group of three waters (wells 40, 41, and 42) is 438 parts per million; in the central and southern parts the average for 15 waters is 232 parts per million.

## DISTRIBUTION OF CHLORIDE.

Most of the waters analyzed have a rather low chloride content. Out of 60 waters, 49 contain less than 50 parts per million and 39 less than 30 parts. Six of the waters contain between 100 and 200 parts and three over 200 parts. The lowest amount of chloride reported is 5.8 parts and the highest 358 parts per million. With the ex-

ception of magnesium and the carbonate radicle, the range of the chloride is less than that of any of the other constituents determined. In 34 of the waters, or over one-half of those analyzed, the chloride ranges from 12 to 29 parts per million, both inclusive, a rather remarkable uniformity considering the variability in the amounts of the other constituents present.

The waters of San Luis and Upper Animas valleys contain the least chloride, the average for seven waters being 12 parts per million. Those of Upper Playas Valley and the adjoining area of Lower Playas Valley, as far north as the Whitmire ranch, rank next higher, with an average of 17 parts per million for 12 samples. In the region near Playas the average is somewhat higher, although none of the waters except one (well 201) contains more than 40 parts per million. The water from the Pot Hook Basin (well 205) contains 63 parts per million, which is considerably more than the water in the vicinity of Playas. In Hachita Valley the chloride content of the waters does not vary much from place to place, all the waters except one (well 324) containing less than 50 parts per million. In the Lordsburg Valley the waters vary considerably in content of chloride from place to place. Well 4, at the Black Mountain ranch, at the upper end of the valley, and well 37, at Double wells, at the opposite end of the valley, yield waters containing the least chloride (22 and 20 parts per million, respectively). The waters from wells 13 and 20, in the central part of the valley, in the vicinity of Roberts, contain the most chloride (126 and 313 parts per million, respectively). None of the other waters of the valley contain more than 50 parts.

In Lower Animas Valley the least chloride reported is 5.8 parts per million in the water from well 60, in the central part of the valley. The most reported was 358 parts, in the water from Hackberry well (No. 42), in the northern part of the valley. In a general way there is an increase in the chloride content of the waters from south to north. In the southern part of the valley, between Animas and Holmig wells, the average is about 16 parts per million, not much more than in Upper Animas and San Luis valleys, to the south; in the central part of the valley, between Holmig wells and the vicinity of the Southern Pacific Railroad, the average for 12 waters is 57 parts per million; in the northern part of the valley the average for a group of three waters (wells 40, 41, and 42) is 218 parts per million.

#### RELATION OF QUALITY TO DERIVATIVE ROCKS.

The ground waters of southern Grant County obtain some of the mineral matter that they contain directly from the rocks with which they come in contact before leaving the mountains, but most of the substance that they carry in solution is obtained from the sediments



through which they percolate after reaching the valleys. As the rocks of the mountains are the original source of the valley sediments, a certain relation exists between their character and the composition of the waters. Igneous rocks contain considerable calcium, magnesium, sodium, and potassium, but relatively small amounts of chloride or of sulphur, from which sulphate may be derived. Many of these waters yield sodium carbonate or "black alkali," calcium carbonate, and magnesium carbonate on evaporation. The sodium and potassium compounds are more soluble than the compounds of calcium and magnesium. The potassium appears to be held to a great extent by the clay or other residual matter, but the sodium goes into solution in the ground waters in relatively large amounts. The black alkali character of so many of the waters of southern Grant County is probably due to the great abundance of igneous rocks. Black alkali was determined in the salts formed on evaporation of 35 of the waters analyzed, or approximately 58 per cent. Waters which yield a residue high in sodium, carbonate, and bicarbonate are most abundant in Upper and Lower Playas valleys. Six out of seven waters in the former valley, and all in the latter valley, yield on evaporation black alkali in the form of sodium carbonate. In the Lordsburg, Lower Animas, and Hachita valleys the proportions are 7 out of 9, 17 out of 18, and 6 out of 8, respectively. None of the waters analyzed from the San Luis and Upper Animas valleys yield black alkali in the form of sodium carbonate.

#### QUALITY FOR IRRIGATION.

The injurious effects of alkali on vegetation and the ways in which it accumulates in the soil under natural conditions have been discussed under "Soil" on pages 44-50. Accumulation of alkali may take place through the use of irrigating waters by essentially the same processes as under natural conditions. The danger of accumulation of alkali through the use of irrigating water in a region depends largely on local conditions of drainage, climate, soil texture, distance to water level, and irrigation methods employed. A certain water may have been used for many years without injury to crops in one region, whereas in another region, where different conditions prevail, water of similar character, or water containing much less alkali, may render the soil unproductive in a short time. On account of the varying conditions, therefore, no hard and fast rule can be formulated for the amount of alkali permissible in an irrigating water.

Formulas developed by Stabler<sup>1</sup> for the classification of irrigating waters are based upon the relative toxicity toward plants of the different forms of alkali commonly present in water. The alkali

<sup>1</sup> Stabler, Herman, *Some stream waters of the western United States*; U. S. Geol. Survey Water-Supply Paper 274, pp. 177-179, 1911.

coefficient ( $k$ ) is defined as the depth in inches of water which, upon evaporation, would yield sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops. The larger this coefficient the better the water for irrigation. The alkali coefficient is not an absolute index of the value of the water for irrigation under all conditions but affords a useful basis for comparing the irrigating value of different waters. Whether the application of a water to a particular piece of land would actually result in injury depends, however, on the methods of irrigating, the crops grown, the character of the soil, and the conditions of drainage, and it must be understood that the alkali coefficient in no way takes account of such conditions.

The alkali coefficient ( $k$ ) used in the table of analyses (pp. 142-143) has been calculated by the following formulas:

- (a) If  $\text{Na}-0.65 \text{ Cl}$  is zero or negative,  $k = \frac{2040}{\text{Cl}}$ .
- (b) If  $\text{Na}-0.65 \text{ Cl}$  is positive but not greater than  $0.48 \text{ SO}_4$ ,  $k = \frac{6620}{\text{Na}+2.6 \text{ Cl}}$ .
- (c) If  $\text{Na}-0.65 \text{ Cl}-0.48 \text{ SO}_4$  is positive,  $k = \frac{662}{\text{Na}-0.32 \text{ Cl}-0.43 \text{ SO}_4}$ .

The symbols Na, Cl, and  $\text{SO}_4$  in the above formulas represent, respectively, sodium, chloride, and the sulphate radicle in the water, expressed in parts per million. The sodium and potassium are reported together as sodium. Waters to which formulas (a) and (b) are applicable can not be improved by chemical treatment but are likely to produce only "white alkali" in the soil. Waters to which formula (c) is applicable are likely to produce the more injurious "black alkali" in the soil but can be improved by the use of gypsum, or "land plaster."

The following classification, based on ordinary irrigation practice in the United States, expresses the comparative value of waters with different alkali coefficients:

*Classification of irrigation waters.*

Alkali coefficient, $k$ . <sup>a</sup>	Class.	Remarks.
More than 18.....	Good.....	Have been used successfully for many years without special care to prevent alkali accumulation.
18 to 6.....	Fair.....	Special care to prevent gradual alkali accumulation has generally been found necessary except on loose soils with free drainage.
5.9 to 1.2.....	Poor.....	Care in selection of soils has been found to be imperative and artificial drainage has frequently been found necessary.
Less than 1.2.....	Bad.....	Practically valueless for irrigation.

<sup>a</sup>  $k$  = depth in inches of water which upon evaporation would yield sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.

According to the above classification 32 of the waters analyzed are good for irrigation, 23 are fair, and 5 are poor. (See table on pp. 142-143.) In Upper Animas and San Luis valleys all the waters analyzed are good; in Upper Playas and Hachita valleys all are either

good or fair, with the good waters predominating; and in Lower Animas, Lordsburg, and Lower Playas valleys all three classes are represented. Two out of 18 waters from the Lower Animas Valley are classed as poor for irrigation. In Lordsburg Valley only 1 out of 9 and in Lower Playas Valley only 1 out of 11 waters analyzed are of poor quality for irrigation. It is encouraging to note that wherever a poor water is found it is the exceptional water in that particular area and that almost invariably satisfactory irrigating waters may be found in other wells close by.

#### QUALITY FOR DOMESTIC USE.

To be entirely satisfactory for domestic use water should be pleasant to the taste and have no perceptible odor, should be free from suspended matter, color, and disease-producing bacteria, and should contain a minimum of substances which cause hardness or excessive consumption of soap. Dole<sup>1</sup> makes the following summary statements in regard to the mineral content of water for domestic use:

Waters that do not exceed 200 parts per million in total hardness and do not contain enough mineral matter to have a disagreeable taste are acceptable for drinking and cooking, though some of them might not answer all requirements of a good municipal supply. Hardness greater than 1,500 parts renders water undesirable for cooking, and water much softer than that consumes excessive quantities of soap in washing. Approximately 250 parts per million of chloride makes a water taste slightly salty. Somewhat less of the carbonate and somewhat more of the sulphate are detectable by taste, yet though the lower a water is in mineral content the more acceptable it is as a source of domestic supply, the amount of dissolved substances that can be tolerated is much greater than is ordinarily believed. Alkaline carbonates apparently are most injurious, alkaline sulphates are least injurious, and alkaline chlorides occupy an intermediate position. Drinking water containing more than 300 parts per million of carbonate, 1,500 parts of chloride, or 2,000 parts of sulphate is unhealthy to most people. \* \* \* The most obvious effect of drinking water too high in mineral content is usually diarrhea.

Every housewife knows the meaning of hardness of water in the popular sense. Hard water causes scale in tea kettles, boilers, and hot-water pipes. It is due chiefly to calcium and magnesium, which cause excessive consumption of soap by the formation with the soap of insoluble compounds that have no cleansing value. Technically, hardness is usually expressed by a figure which represents the calcium (Ca) and magnesium (Mg) in the equivalent of calcium carbonate ( $\text{CaCO}_3$ ). It may be computed by the following formula:

$$\text{Total hardness as } \text{CaCO}_3 = 2.5 \text{ Ca} + 4.1 \text{ Mg}$$

Of the 60 waters analyzed 34 are classed as good for domestic use, 17 as fair, 5 as bad, and 4 as unfit. (See pp. 142-143.) In Upper Animas, San Luis, and Upper Playas valleys all the waters are good. In the other valleys most of the waters are good, although poor waters

<sup>1</sup> Deussen, Alexander, and Dole, R. B., *Ground water in Lasalle and McMullen counties, Tex.*: U. S. Geol. Survey Water-Supply Paper 375, p. 159, 1916.

are occasionally found. Lower Animas Valley contains the largest proportion of waters that are not satisfactory for domestic use. Out of 18 waters analyzed 2 are classed as bad and 2 as unfit, chiefly on account of their unsuitability for drinking. They contain large amounts of sodium and of the carbonate, sulphate, or chloride radicles, which give them a bad taste and may make them unhealthful to some people. One of the waters from Lordsburg Valley and one from Hachita Valley are classed as bad. In the Lower Playas Valley one is classed as bad and one as unfit. These waters are not good for drinking on account of excessive amounts of sodium salts present and not good for cooking and washing on account of their hardness. Poor domestic waters appear to be general in the region of deep water north of the alkali flats in Lower Animas Valley. On the whole, the waters throughout southern Grant County are, however, satisfactory for domestic use.

#### QUALITY FOR BOILER USE.

Certain mineral substances in natural waters cause excessive foaming, scale, or corrosion in boilers and therefore are objectionable when the water is used for making steam.

When water is heated and concentrated in boilers much of the dissolved matter is precipitated on the inside of the boiler as sludge or scale that increases the consumption of fuel, decreases the capacity of the boiler by clogging the tubes and steam pipes, and injures the boiler by allowing the plates and tubes to become overheated until they crack or burst. The sludge that collects on the bottom of the boiler can usually be removed by "blowing off," but the hard scale that clings to the inside surfaces must be removed by more expensive methods. Scale and sludge consist of the suspended matter and compounds of silica, iron, aluminum, calcium, and magnesium, the last two usually predominating, the calcium in the form of the sulphate and carbonate and the magnesium as the oxide or carbonate.

Foaming is caused by the formation of steam bubbles which do not break readily and interfere with the collection of the steam in the steam spaces and cause water to be carried out through the steam supply pipe to the engine cylinders. Many substances probably cause foaming, but as compounds of sodium and potassium remain dissolved in the boiler water after most other substances are precipitated the foaming tendency is usually measured by the amount of sodium and potassium in the water.

Substances that attack iron cause corrosion or "pitting" in boilers. Many ground waters contain hydrogen sulphide, free oxygen, carbon dioxide, or acids formed from organic matter, or freed in the boiler by the formation of hydrates of aluminum, iron, and magnesium. The acids formed during the precipitation of any of these substances may cause corrosion in boilers.

The following formulas adopted by Dole<sup>1</sup> from those developed by Stabler<sup>2</sup> have been used for computing the probable scale-forming ingredients (*s*), the probable foaming ingredients (*f*) (both in parts per million), and the tendency to cause corrosion (*c*). If silica ( $\text{SiO}_2$ ) is not reported the value 30 may be arbitrarily used for it in the first formula.

$$s = \text{SiO}_2 + 2.95 \text{ Ca} + 1.66 \text{ Mg}$$

$$f = 2.7 (\text{Na} + \text{K})$$

If  $0.0828 \text{ Mg} - 0.0336 \text{ CO}_3 - 0.0165 \text{ HCO}_3$  is positive, the water is corrosive (*C*). If  $0.0828 \text{ Mg} + 0.0503 \text{ Ca} - 0.0336 \text{ CO}_3 - 0.0165 \text{ HCO}_3$  is negative, no corrosion will occur because of the mineral constituents of the water (*N*). If  $0.0828 \text{ Mg} - 0.0336 \text{ CO}_3 - 0.0165 \text{ HCO}_3$  is negative but  $0.0828 \text{ Mg} + 0.0503 \text{ Ca} - 0.0336 \text{ CO}_3 - 0.0165 \text{ HCO}_3$  is positive, corrosion may or may not occur (?).

In these formulas  $\text{SiO}_2$ , *Ca*, *Mg*, *Na*, *K*,  $\text{CO}_3$ , and  $\text{HCO}_3$  represent, respectively, the amounts in parts per million of silica, calcium, magnesium, sodium, potassium, carbonate, and bicarbonate as determined by analysis.

The value of waters for boiler use in respect to their scale-forming, corroding, and foaming constituents may be expressed as follows:

*Ratings of waters for boiler use according to proportions of incrusting and corroding constituents and according to foaming constituents.*

Incrusting and corroding constituents.			Foaming constituents.		
Parts per million.		Classification. <sup>a</sup>	Parts per million.		Classification. <sup>b</sup>
More than—	Not more than—		More than—	Not more than—	
-----	90	Good.	-----	150	Good.
90	200	Fair.	150	250	Fair.
200	430	Poor.	250	400	Bad.
430	-----	Bad.	400	-----	Very bad.

<sup>a</sup> Adapted from Am. Ry. Eng. and Maintenance of Way Assoc. Proc., vol. 5, p. 595, 1904.

<sup>b</sup> *Ibid.*, vol. 9, p. 134, 1908.

Of the waters analyzed 5 have been classed as good for boiler use, 21 as fair, 20 as poor, 2 as bad, and 12 as very bad. Over four-fifths of the waters classed as poor or bad are objectionable chiefly on account of their strong tendency to foam. They include most of the highly mineralized alkaline waters of the Lower Animas, Lower Playas, Hachita, and Lordsburg valleys. Almost all of the waters analyzed will form some scale in boilers, for which treatment, either preliminary or in the boiler, is desirable, although not imperative, in

<sup>1</sup> Deussen, Alexander, and Dole, R. B., Ground water in Lasalle and McMullen counties, Tex.: U. S. Geol. Survey Water-Supply Paper 375-G, pp. 163-164, 1916.

<sup>2</sup> Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, pp. 171-177, 1911.

most cases. None of the waters except one from well 40 in the Lower Animas Valley are definitely corrosive, but there is a possibility of corrosion by the calcium carbonate waters and a few of other types.

#### DISTRIBUTION ACCORDING TO QUALITY.

The geographic distribution of the waters, graded as to their relative value for different purposes, according to the ratings given on preceding pages is shown in the following table:

*Geographic distribution of the waters according to quality for irrigation, domestic, and boiler use.*

[Figures indicate number of samples.]

Valley.	Irrigation.			Domestic use.				Boiler use.				
	Good.	Fair.	Poor.	Good.	Fair.	Bad.	Unfit.	Good.	Fair.	Poor.	Fad.	Very bad.
Lordsburg.....	1	7	1	6	1	1	1	-----	3	4	-----	2
Upper Animas.....	5	-----	-----	5	-----	-----	-----	2	3	-----	-----	-----
Lower Animas.....	10	4	4	4	10	2	2	-----	3	6	1	8
San Luis.....	2	-----	-----	2	-----	-----	-----	2	-----	-----	-----	-----
Upper Playas.....	5	2	-----	7	-----	-----	-----	1	5	1	-----	-----
Lower Playas.....	4	6	1	9	-----	1	1	-----	6	3	1	1
Hachita.....	5	3	-----	1	6	1	-----	-----	1	6	-----	1
	32	22	6	34	17	5	4	5	21	20	2	12

The ratings of the individual waters with respect to their suitability for these purposes are included in the table of analyses given on pages 142-143. A discussion of the waters is also given in the tions of the different valleys.

#### DESCRIPTIONS BY AREAS.

##### LORDSBURG VALLEY.

##### PHYSIOGRAPHY AND DRAINAGE.

Lordsburg Valley extends from the Pyramid Range to the divide near the Luna County line, and from the Little Burro Mountains to the Quartzite Hills and Black Mountain. (See map, Pl. I, in pocket.) It is drained northwestward into Lower Animas Valley. To the east Lordsburg Valley opens, without any visible barrier, into the great upland plains of Luna County known as the Antelope Plains; and to the south it opens into Playas and Hachita valleys, from which, however, it is separated by low alluvial divides. Where the Southern Pacific Railroad crosses the Antelope Plains divide the elevation is 4,587 feet; in the depression 4 miles southeast of Lordsburg it is about 4,200 feet. The general slope of the valley is northwestward, and the major drainage line parallels the Arizona & New Mexico Railway from Black Mountain to the vicinity of Lordsburg. Except on the upper parts of the alluvial slopes of the Pyramid Range and

Little Burro Mountains the drainage is sluggish, the flood waters in general spreading in thin sheets over the nearly level plain or passing down the shallow draws into the depression a few miles southeast of Lordsburg. This depression is occupied by three small playas, which in the rainy season hold a part of the flood waters but in the dry season are barren alkali flats. They cover an aggregate area of about a square mile. The overflow from these playas drains through the Lordsburg Draw, around the north end of the Pyramid Range, into the large playa in Lower Animas Valley.

## WATER TABLE.

In an area comprising about 46 square miles, including and contiguous to the Lordsburg Draw and the alkali flats southeast of Lordsburg, the depth to water is less than 100 feet. (See Pl. II, in pocket.) Throughout the rest of the area the depth to water in wells ranges from 100 to at least 300 feet. At Brockman, on the Arizona & New Mexico Railway, it is 130 feet; at the Black Mountain ranch, 227 feet; at Wilna, on the Southern Pacific Railroad, 188 feet; and at Separ, 300 feet.

The following tables show the altitude and depth of the water table at several points in the area, and the gradients of water table and land surface between these points:

*Depth to water table and elevation of land surface and water table at points in Lordsburg Valley.*

Locality.	Depth to water table.	Elevation of land surface above sea level.	Elevation of water table above sea level.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Separ.....	300	4,505	4,205
Brockman.....	130	4,322	4,192
Roberts.....	80	4,253	4,173
Southern Pacific pumping plant, 2 miles east of Lordsburg.....	a 60	b 4,220	4,160

*a* Information from pump man. Water stood 82 feet from surface in this well when first drilled.

*b* Close approximation.

*Gradients of the surface and of the water table between points in Lordsburg Valley.*

	Horizontal distance.	Land surface.		Water table.	
		Difference in elevation.	Gradient.	Difference in elevation.	Gradient.
	<i>Miles.</i>	<i>Feet.</i>	<i>Feet per mile.</i>	<i>Feet.</i>	<i>Feet per mile.</i>
Separ to Southern Pacific pumping plant, 2 miles east of Lordsburg.....	17	285	17	45	2.6
Separ to Brockman.....	6½	183	28	13	2.0
Brockman to Roberts.....	10	69	6.9	19	1.9
Roberts to Southern Pacific pumping plant.....	8	33	4.3	13	1.6
Separ to Roberts.....	11	252	23	22	2.0

In general the slope of the water table is toward the northwest, in the direction of the slope of the land surface. The slope is, however, only about 2 feet to the mile, or considerably less than that of the land surface, and consequently the depth to water increases up the slopes. The uniformity of the ground-water gradient makes it possible to predict with a fair degree of accuracy the depth to water at points intervening between those at which the elevations of the land and water surfaces are known. The slope of the water table northward indicates that there is a movement of ground water in that direction, possibly to an outlet into the Gila basin.

#### WATER-BEARING BEDS.

Underlying the valley is the usual succession of material of all degrees of fineness, ranging from fine clays to coarse gravels. The character and arrangement of the materials are shown by the plotted well logs in Plate V. Some of the beds consist of well-assorted materials whose particles are nearly all of uniform size; others are mixtures of particles of various sizes. Logs of all the wells except the Southern Pacific Co.'s abandoned well at Lordsburg and the railroad well at Separ show gravel as a common constituent of nearly all beds. The abandoned well at Lordsburg passes through several hundred feet of rock and the material penetrated by the Separ well contained a preponderance of clay below about 300 feet. Most of the materials are unconsolidated, although "cemented" gravel or sand is often reported.

Beds of unconsolidated sands and gravels that yield water freely occur at a number of horizons. The deep railroad well at Spear penetrates nine such beds, from 2 to 10 feet thick, five of which are below the 300-foot water level and are saturated, the other four being above this level and therefore dry. The "west" well at the Southern Pacific pumping plant east of Lordsburg passes through four beds from 10 to 13 feet thick, three of which are below the 82-foot water level and are saturated. In well "No. 3" at the same place a 60-foot stratum of saturated sand and gravel is reported to lie between the 110-foot and 170-foot levels and a 10-foot stratum of saturated sand and gravel to lie between the 285-foot and 295-foot levels. The Coom well (No. 25, Pl. V), in the Lordsburg Draw east of town, penetrates three porous strata, from 3 to 8 feet thick, below the water level.

#### QUALITY OF WATER.

Analyses of waters in the Lordsburg Valley from wells 4, 9, 13, 16, 20, 21, 25, 35, and 37 (Pl. II and Table 2) showed total solids ranging from 236 to 2,059 parts per million. Three of the waters (wells 9, 13, and 20) are highly mineralized sodium-sulphate waters,



five (wells 16, 21, 25, 35, and 37) are moderately mineralized sodium-carbonate waters, and one (well 4) is of the calcium-carbonate type.

No very definite conclusions as to the geographic distribution of the different types of water are warranted. In a general way, however, the analyses show that along the major drainage axis of the region, near which most of the wells are situated, sodium-carbonate waters predominate in the Lordsburg Draw, sodium-sulphate waters in the region between the alkali flats at the head of the Lordsburg Draw and Brockman, and calcium-carbonate waters probably in the region between Brockman and Black Mountain.

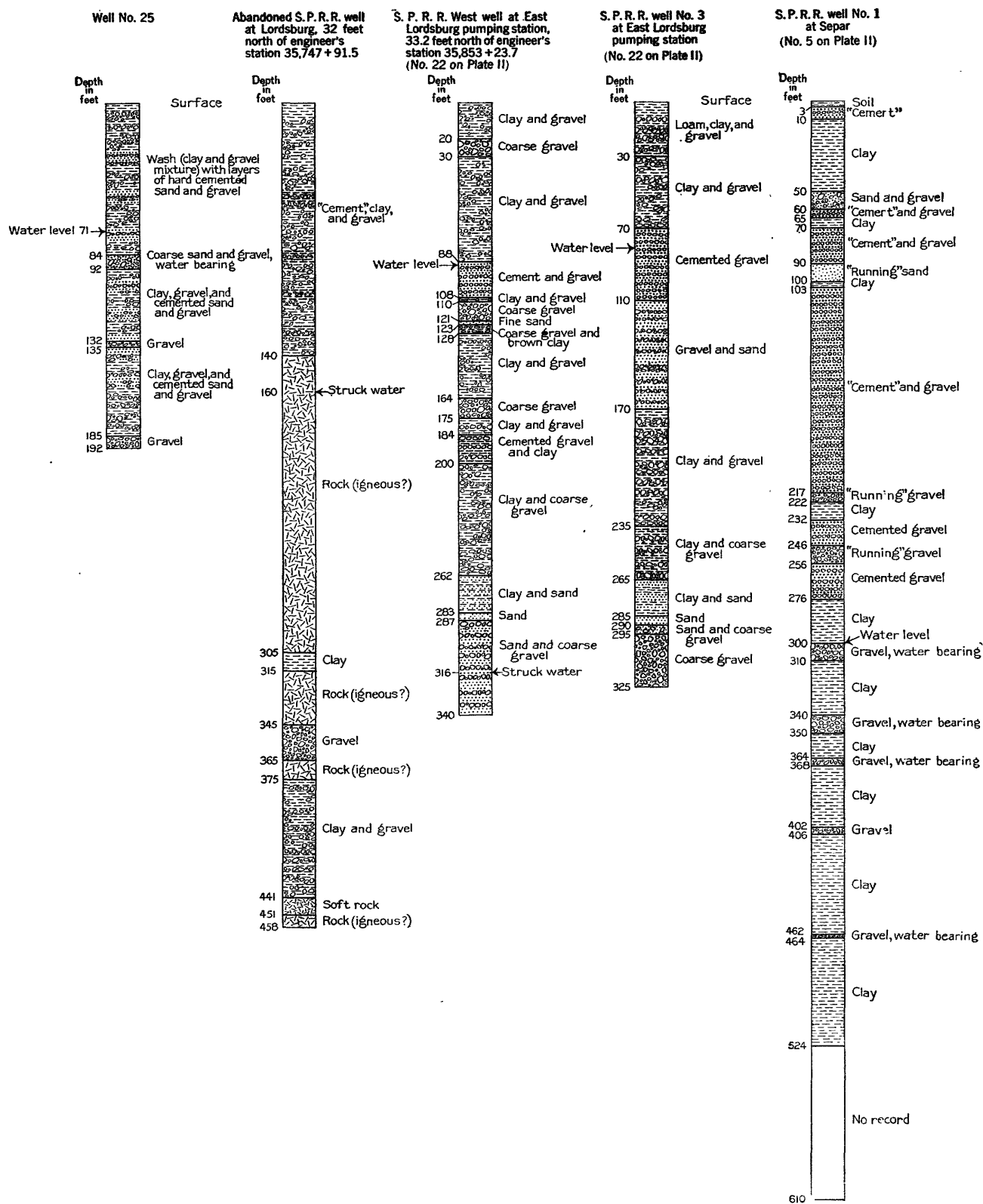
For irrigation one of the waters has been classed as good, seven as fair, and one as poor. The best irrigating water is yielded by well 4 in the upper part of the valley, and the poorest by well 20, 2 miles north of Roberts. Wells 9, 13, 16, 21, 25, 35, and 37 yield fair irrigating waters. All these waters can probably be safely used for irrigation on the land in the immediate vicinity of the wells from which they are taken. On some of the poorly drained land in the vicinity of the alkali flats, where natural conditions have caused the accumulation of considerable alkali in the soil, waters of this character might cause serious trouble. In the Lordsburg Draw, below, where the drainage is better, these waters if used intelligently would probably not cause injury to crops.

For domestic use all the sodium-carbonate waters and the calcium-carbonate waters have been classed as good. The sodium-sulphate waters are less acceptable on account of their hardness and taste. Water from well 9 is classed as fair, that from well 13 as bad, and that from well 20 as unfit.

For use in boilers the water from wells 4, 35, and 37 is classed as fair. The first, a calcium-carbonate water, has no tendency to foam but contains a moderate amount of scale-forming constituents and may cause corrosion in boilers. The last two are sodium-carbonate waters low in scale-forming substance and are noncorrosive, but they may cause some foaming. The waters from wells 16, 21, and 25, classed as poor for boiler use, are sodium-carbonate waters low in scale-forming substances and noncorrosive but have a tendency to foam. The sodium-sulphate waters from wells 9, 13, and 20 are high in both scale-forming and foaming constituents and therefore are unsatisfactory for boiler use. That from well 13 may also cause corrosion. The first two waters can be used after proper chemical treatment, but the water from well 20 contains so much mineral matter that effective treatment is not possible.

#### SOIL IN RELATION TO WATER SUPPLIES.

In the playa region southeast of Lordsburg and in the Lordsburg Draw which drains westward into the south alkali flat of Lower Animas



SECTIONS OF WELLS IN LORDSBURG VALLEY.

Valley the soils are of the fine-textured type derived from sand, clay, and silt. The small barren flats south of the Southern Pacific Railroad, which are frequently flooded and on the surface of which water stands until it evaporates, have the characteristic heavy clay soils produced under these conditions. Similar soils occur in places along the center of the Lordsburg Draw. On the plains north and east of the Lordsburg Draw the soils are in general sandy. Along the foot of the Burro Mountains is a broad belt of coarse gravelly soil, and a belt of similar soil extends along the base of the Pyramid Range.

Samples of soil were taken at a number of places in the area where the ground water is shallowest. (See map, Pl. I.) Soils containing injurious amounts of alkali are practically confined to the principal drainage line below the vicinity of Roberts station in the area outlined on the map (Pl. I). Samples 4, 6, and 14 were taken nearest the axis of the principal drainage. They contain respectively 0.87, 0.63, and 1.26 per cent of total alkali and 0.09, 0.19, and 0.04 per cent of black alkali. Of these, sample 6, taken in the barren flat nearest the Southern Pacific Railroad, is probably the worst on account of the large proportion of black alkali, although it contains less total alkali than either of the others. Sample 14, which contains the largest amount of total alkali, represents a less objectionable soil because the black alkali content is low and almost half of the total alkali consists of sodium sulphate, one of the least harmful of the white alkalies.

Back from the center of the draw the content of alkali steadily decreases. Sample 2, taken  $1\frac{1}{2}$  miles northeast of Lordsburg, on the north slope of the draw, about half a mile from its axis, contains only 0.29 per cent of total alkali, only one-fifth of which is black alkali. Sample 5, taken from a similar position relative to the drainage axis farther south, contains a little more total alkali (0.40 per cent) but a negligible quantity of black alkali. The alkali content of soils of this character should not interfere with the successful growing of all ordinary crops.

#### PUMPING PLANTS AND YIELDS OF WELLS.

The yield of wells in this region has usually been found sufficient for the particular needs for which the supplies were intended. Most of the wells are at ranches and cattle-watering places where the amounts required are so small that they can be furnished by wind-mills, but a number of wells have been sunk for railroad and town supplies.

In 1913 all water needed for municipal and railroad uses at Lordsburg was furnished by the Southern Pacific pumping plant, which is

2 miles east of the town. According to the pump man in charge an average of about 250,000 gallons a day was pumped. The water is lifted by steam pumps from a group of four wells about 300 feet deep. When running at full capacity the plant has an output of 18,000 gallons an hour, and this rate of pumping can be maintained continuously for at least 24 hours without exhausting the wells. Some data in regard to the capacity of the wells is given on the well-log sheet kindly furnished to the Geological Survey by Mr. K. D. Matthews, the resident engineer at Tucson, Ariz. A test on the well designated as the "West well" at East Lordsburg, made in October, 1897, showed a capacity of 2,000 gallons an hour from the 116-foot water stratum. When pumping from the 316-foot level near the bottom of the well 6,000 gallons an hour was obtained. During a test made in March, 1903, the well designated "well No. 3," at the same place, yielded 5,280 gallons an hour for 36 consecutive hours. Another well owned by the railroad company, situated in the town of Lordsburg and drilled most of the way through "rock" (see Pl. V), failed in four different tests to yield sufficient water and was therefore abandoned. At Separ the railroad company has two wells more than 600 feet deep. (For log of well see "No 1," Pl. V.) These wells, spaced 25 feet apart, are said to yield regularly about 4,000 gallons an hour for a period of 8 to 14 hours a day.

At Brockman, about midway between Lordsburg and Hachita, the Arizona & New Mexico Railway Co. has a 6-inch well 152 feet deep and a pumping plant consisting of a gasoline engine and a plunger pump. This well supplies about 28,000 gallons in the 10 hours that it is pumped each day.

In the Lordsburg Draw, NE.  $\frac{1}{4}$  sec. 34, T. 22 S., R. 18 W. (No. 25, Pl. II), Mr. Frank R. Coom has installed a pumping plant for irrigation. It consists of a 20-inch well 192 feet deep (for log of well see Pl. V), equipped with an American Well Works 2-stage vertical turbine pump driven by a direct-connected 20-horsepower electric motor. The pump is set 85 feet below the surface, 14 feet below the normal water level, and is said by the owner to deliver from 150 to 200 gallons a minute. When pumping at a normal speed the vacuum gage attached to the pump ordinarily registers a vacuum of 21 inches, which is equivalent to a suction head of about 24 feet. This indicates that the pump is working under a total theoretical head of 85 feet (distance pump is set below surface) plus 24 feet, or 109 feet, and that the drawdown is 38 feet. Apparently the over-all efficiency of the plant is only about 25 per cent. At 4,200 feet, which is the approximate elevation of the well, the practical suction lift<sup>1</sup> in good practice should not exceed 18 feet, or 16 inches of vacuum. The efficiency

<sup>1</sup> Practical suction lift is equal to the vertical distance the water is to be lifted by suction plus the head due to friction.

of the plant could therefore probably be increased by lowering the pump in the well.

One mile north of Lordsburg in the draw (No. 30, Pl. I), the Lordsburg Water, Ice & Electric Co. has installed a pumping plant from which it is intended to supply the town. This plant consists of a 5-stage American Well Works turbine pump direct-connected to a 35-horsepower electric motor. The capacity of the plant when working under the several hundred feet of head necessary to force the water to the town reservoir is about 300 gallons a minute. The well is about 190 feet deep and the water stands 65 feet from the surface. It is cased with 20-inch casing to the 115-foot level and with 12-inch casing below. There are two well-defined strata of water-bearing gravel, one 90 feet below the surface and one 180 feet below.

### UPPER ANIMAS VALLEY.

#### PHYSIOGRAPHY AND DRAINAGE.

Upper Animas Valley is a long, comparatively narrow valley trending nearly due north and south between continuous parallel ranges of mountains—the Peloncillo Range on the west and the Animas Range on the east. It extends from a low alluvial divide, 9 miles north of the Mexican border, to the vicinity of Animas station, on the El Paso & Southwestern Railroad. Its length measured between these limits is about 33 miles and its average width, between the bases of the bounding ranges, about  $8\frac{1}{2}$  miles. It drains northward into Lower Animas Valley.

Upper Animas Valley differs from all the other valleys in the area except Lower Hachita Valley in that both the central and lateral drainage lines follow definite channels cut into the valley fill.

The principal drainage is northward along the axis of the valley through Animas Creek. On the east side the lateral tributary drainage is generally from the southeast, and that on the west side from the southwest, or along the slope which is the resultant of two component slopes, one in the direction of the principal drainage—north—and the other in the direction of the alluvial slopes—east and west toward the center of the valley and at right angles to the principal drainage.

Animas Creek rises in several branches on the east flank of the Peloncillo Range, flows eastward across the valley for 4 miles, and then makes a bend at right angles to the north. It follows a definite channel, meandering from side to side across the floor of the flat, for 20 miles below its source and disappears 2 miles north of the XT ranch. The flow in Animas Creek depends entirely on the seasonal distribution of the rainfall. During the rainy season a small permanent stream is maintained for most of the distance along the first 15 miles of its course in the valley, the water disappearing occasionally below the

gravels for short distances and reappearing as a surface flow farther downstream. Like other streams of the arid region, it is subject to very rapid fluctuations, often reaching torrential proportions and overflowing its banks during violent rainstorms and subsiding quickly when the storm is over. In parts of its course, as in the hills before it emerges into the valley (see map, Pl. I), the surface flow is permanent nearly the whole year. Between the Gray ranch and "The Box" flow is maintained by two groups of springs or "cienegas"—one at the Gray ranch and the other near the mouth of Clanton Creek.

The principal tributaries of Animas Creek are Rough, Bull, Adobe, and Indian creeks on the east side, and Clanton, Whitmire, and Prairie creeks, Horse Camp Draw, and a number of equally large watercourses on the west side. Some of these tributaries are fed by springs near their sources and maintain small permanent flows over their bedrock channels in the mountains and for short distances out in the valley, but the middle and lower courses of all are dry except during short periods of heavy rainfall or the rapid thawing of snow, which sometimes accumulates on the higher crests of the ranges. Evidently there is some underflow through the gravels of these watercourses for considerable distances out from the mountains, because the dry channels are often fringed with cottonwoods and other trees that do not thrive unless well supplied with water.

The most distinctive feature of Upper Animas Valley is the trough which has been cut along the longitudinal axis of the valley by Animas Creek. Where Animas Creek emerges from the mountains the trough is about a quarter of a mile wide; it gradually widens down the valley toward the north to about  $1\frac{1}{4}$  miles at its mouth,  $4\frac{1}{2}$  miles south of Animas station. The bottom of the trough is flat and is bordered by bluffs on both sides. These bluffs are 70 to 80 feet high along the upper end of the valley but diminish downstream until they disappear at the lower end of the trough where it merges into the broad plain of Lower Animas Valley. At "The Box," 3 miles north of the Gray ranch, the trough has been channeled out of hard coarse-grained porphyritic rock, and forms a gorge a quarter of a mile long and 75 to 100 feet wide, with vertical rock walls 20 to 25 feet high. Five miles farther north the front of a rock spur extending out from the Peloncillo Range forms the west bluff for a distance of about a mile. Except at these two places the trough has been channeled entirely out of valley sediments, and the bluffs represent the truncated ends of stream-built slopes leading from the mountains (Pl. I, B, p. 114).

Through gashes in the bluffs on both sides numerous dry streamways enter the Animas Creek trough. In the larger streamways head-end erosion has proceeded several miles up from the trough. The result of these processes is an extensive dissection of the whole valley surface by a network of deeply sunk stream channels (Pl. VI, A).



A. EROSION OF STREAM-BUILT SLOPES IN UPPER ANIMAS VALLEY; ANIMAS PEAK IN BACKGROUND.



B. LOWER ANIMAS VALLEY, SHOWING NORTH ALKALI FLAT.

The present topography can be attributed to four processes—the accumulation of débris to form the valley surface; the cutting of the central Animas Creek trough, which, as shown by material in wells, extended at least 30 feet below the present floor of the trough; the filling of the central Animas Creek trough to the present level; and the erosion of the stream-built slopes that border the Animas Creek trough. (See fig. 6.)

The destruction of stream-built slopes by the same agencies that built them is not uncommon. This effect is illustrated on a grand scale by the Gila conglomerate, along Gila River, correlated by Gilbert<sup>1</sup> with the detrital deposits that form the valleys and plains of the adjacent region. After stating that “the watercourses which cross these deposits are sinking themselves into them instead of adding to their depth,” he says, “in the accumulation and subsequent excavation of the beds there is recorded a reversal of conditions.” To account for the period of accumulation preceding the present period of extensive dissection of the deposits along the Gila, Gilbert reasons that some condition must have existed which determined the discharge of the streams at a higher elevation than at present. A succession of depositional and erosional processes in part similar to that in the Gila Valley is recorded on a smaller scale in the topography of Upper Animas Valley.

Lower Animas Valley was formerly occupied by a lake whose shore features can be traced nearly to the mouth of the Animas Creek trough and suggest that the processes listed above have been intimately connected with the oscillations of the water level of the lake, erosion taking place when the lake stood low and aggradation when it stood high.

A theory which appears better to fit the facts, however, is that the erosion of the trough occurred during the lake epoch, when the run-off was heavy, and that aggradation characterized the more arid prelacustrine and postlacustrine epochs.

The building up of the detrital slopes and the cutting of the Animas Creek trough could possibly have taken place simultaneously and have had nothing to do with the fluctuation of the ancient lake. Upper Animas Valley is comparatively narrow, and the bordering mountains are steep and massive. The distance between the head and foot of the stream-built slopes being short, there is little opportunity for the run-off, spread out over these slopes, to concentrate so as to do much erosive work before reaching the middle of the valley. But the waters coming from both sides concentrate at the axis of the valley and, flowing in volume along the axis toward the Lower Animas depression, are more likely to have sufficient erosive power to cut a trough. If the material found in

<sup>1</sup> Gilbert, G. K., U. S. Geol. and Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 540-541, 1875.



the wells of the Animas Creek trough has been correctly interpreted as having been deposited later than the bulk of the valley sediments the surface of Lower Animas Valley must, however, at one time have been lower than at present by an amount equal to at least the thickness of these deposits, a condition that implies some reversal of physiographic processes. Material is now being laid down on top of the old lake sediments in Lower Animas Valley by the run-off in the same manner as in other parts of the area, the coarser sediments being deposited nearest the base of the ranges and the clays and finer sediments being carried out farthest from the mountains into the center of the valley. In Upper Animas Valley material from the mountains and much that is being eroded from the lower and middle parts of the stream-built slopes is being deposited on the floor of the Animas Creek trough.

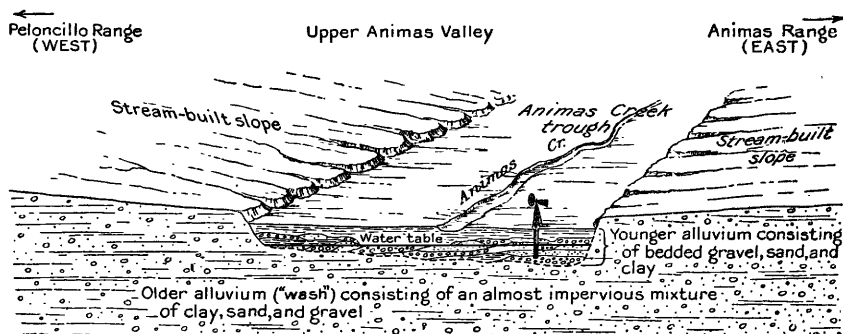


FIGURE 6.—Section across Animas Creek trough showing typical ground-water conditions.

#### OCCURRENCE OF GROUND WATER.

Shallow water occurs in the recent alluvial fill of the Animas Creek trough. In the lower part of this flat-bottomed trough, where most of the wells are located, the recent alluvium consists in general of 8 to 10 feet of clayey or sandy soil underlain by beds of clean gravel and sand, aggregating 10 to 12 feet in thickness and resting on a basement of reddish, gravelly, nearly impervious clay, commonly called "wash" (fig. 6). This "wash" is the older fill in which the Animas Creek trough was channeled. The gravel in the recent fill is the water-bearing bed. It shows great variability in thickness and composition and is not continuous for any great distances. It has the characteristics of deposits laid down by a stream. The gravel is in many places cross-bedded. It contains a good deal of sand but is usually free from clay, so that on the whole it is a good water container. The thickest recent fill and the most productive gravels usually occur on the side adjacent to the highest and steepest bluffs. At the lower end of the flat the best wells are

located along the east side, as is shown by the well sections in figure 7. In well 112, for instance, located at the western edge of the flat, the recent fill is 19 feet thick. Although there is 11 feet of gravel it is practically all above the water level, and hence the well yields

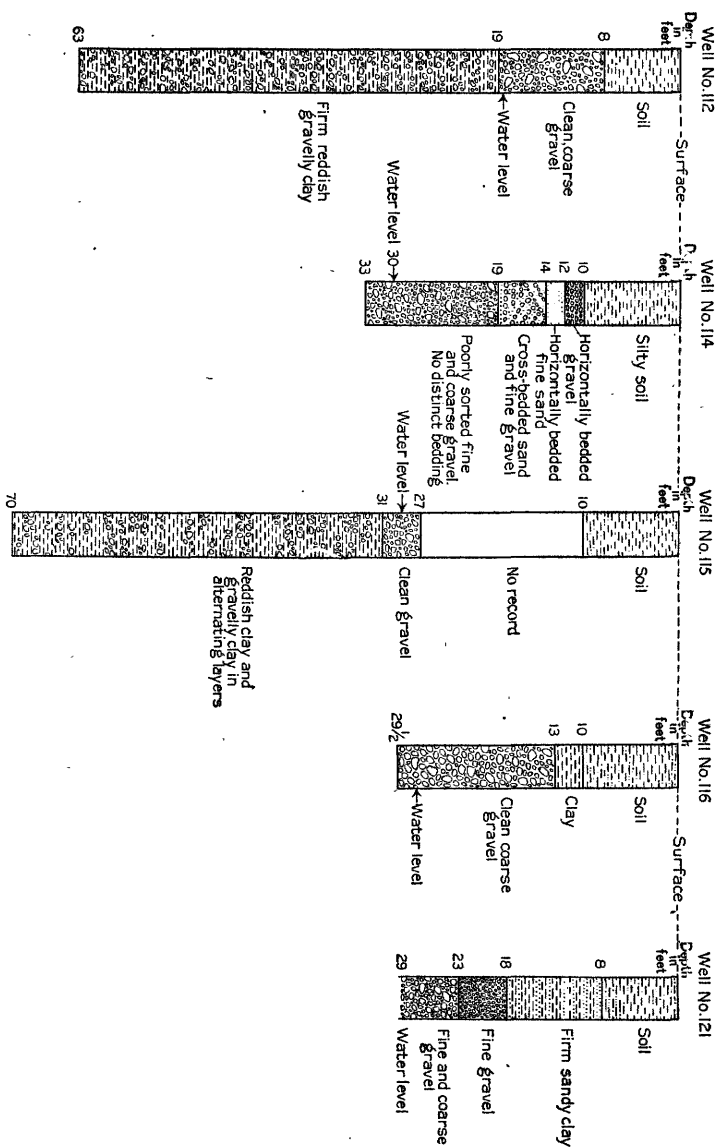


FIGURE 7.—Sections of wells in Upper Animas Valley.

very little water. In well 115,  $1\frac{1}{4}$  miles east of well 112, on the opposite side of the flat-bottomed trough, the recent fill is 31 feet thick, the lower 2 feet of which is gravel saturated with water. This well furnishes enough water for a windmill but has never been

tested with a power pump. In several other wells along the east side of the valley in this vicinity (Nos. 114 and 116, fig. 7) ample supplies of water were obtained in gravel.

Farther up the valley, south of the Dunnagan ranch, the gravel is not so well sorted and is even more irregularly distributed, and the prospects of obtaining large water supplies are therefore poorer. Gravels saturated by the underflow occur along the borders of Animas Creek, and most of the wells in the upper part of the Animas Creek trough are located close to its channel. Wells at some distance from the creek often fail to furnish a sufficient supply.

On account of the irregular distribution of the water-bearing gravel the yield that may be obtained from wells at any particular place in the Animas Creek trough can be determined only by actual trial. One well may pass into a buried gravel channel and yield an abundance of water, whereas another one a short distance away, may miss the gravel beds entirely and yield little or no water. Often several wells must be sunk in a particular area before a successful one is obtained. However, as all the wells are shallow and are sunk by the settlers themselves, this condition works no great hardship.

Additions to the ground-water supply are made by the run-off from the adjacent watershed poured into the Animas Creek trough through the numerous gullies opening into it from the sides, and to some extent by the rain which falls directly into the trough, and by percolation from buried gravel channels in the older fill.

The amount of good water-bearing material is comparatively small, and consequently the storage capacity of the formation is also small and fluctuations in the water table are frequent, the rise and fall being governed chiefly by the seasonal rainfall. As the demands made on the ground-water supply are as yet small the effects due to pumping are hardly appreciable, but the continued development of this supply for irrigation is liable to cause a considerable lowering of the water table.

#### IRRIGATION DEVELOPMENTS.

Up to the present not much has been accomplished toward developing ground water for irrigation in the Upper Animas Valley. In November, 1913, when this region was examined, a pumping plant consisting of a No. 5 horizontal centrifugal pump driven by a gasoline engine was being installed on the farm of Ben Pague in the SW.  $\frac{1}{4}$  sec. 10, T. 28 S., R. 19 W. (well 114, Pl. II, in pocket), and a pumping plant with a 12-horsepower gasoline engine and a No. 5 centrifugal pump was installed on the farm of B. H. Pague,  $2\frac{1}{2}$  miles farther south, in the SE.  $\frac{1}{4}$  sec. 27, T. 28 S., R. 19 W. (well 124, Pl. II). These were the only serious endeavors being made at that time for the utilization of ground waters for irrigation on a comprehensive

scale. Many small orchards and garden patches were being irrigated by windmills in connection with small earth storage reservoirs. Flood waters were also being used to some extent to irrigate small fields.

In the higher parts of the valley outside of the Animas Creek trough irrigation by pumped water is not practicable, as shallow water in sufficient quantities is generally not available. Along some of the watercourses on the stream-built slopes small amounts of water for stock can be obtained through shallow wells tapping the underflow. As far as is known no deep wells have been sunk on these upland areas, but the non water-bearing nature of the upper portion of the main mass of the valley fill is revealed in a well sunk at the XT ranch, in the SE.  $\frac{1}{4}$  sec. 30, T. 29 S., R. 19 W., 200 feet east of the present ranch well (No. 160, Pl. II). This well is reported to have been drilled to a depth of 305 feet through reddish sandy clay yielding little or no water. Wells higher up the slopes would pass through more gravelly material, but the depth to water would be greater.

#### ARTESIAN PROSPECTS.

Conditions in Upper Animas Valley are not believed to be favorable for artesian water. The main body of the valley fill has not been prospected to any great depth, the deepest well, so far as known, being the 305-foot well at the XT ranch. To this depth at least the valley fill is undoubtedly of fluvial origin. The material found in the XT well is rather vaguely described as "reddish sandy clay soil," but for the whole depth it is said to have been similar to the older stream-deposited material underlying the recent sediments in the Animas Creek trough. Below the depth of this well the character of the valley fill is not known, but there is no reason to believe that it differs very radically. If it is of fluvial origin it can have no great regularity either in composition or arrangement.

In the artesian area of San Simon Valley, which lies west of Animas Valley, a persistent bed of impervious blue clay blankets the water-bearing beds and prevents the water from escaping upward except through wells. Though the upper beds of the main body of valley fill along the middle of Upper Animas Valley have been proved to be nearly impervious they are not believed to be continuous far enough up the slopes of the valley to form an effective artesian cover. It is, of course, possible that the valley is underlain by a persistent clay bed similar to that in San Simon Valley

#### QUALITY OF WATER.

Analyses were made of the water from wells 115, 124, 148, 172, and 175 in the shallow-water belt. (See map, Pl. II, and Table 2, p. 143.) In mineral content they range from a minimum of 136

parts per million of total dissolved solids, in the region near the head of the valley, to a maximum of 290 parts per million at the lower end of the valley. The waters from different parts of the valley all show a close resemblance to each other in chemical composition, all being of the calcium-carbonate type. In this respect they differ from the waters of most of the valleys of southern Grant County. The low mineralization and uniformity in chemical composition of the waters is due to the character of the rocks in the adjacent mountains, chiefly of igneous origin, to the elevated position of the water-bearing beds resulting in isolation from the beds of adjoining areas, and to the conditions under which the beds were laid down. The deposits in the Upper Animas trough were laid down by streams under drainage conditions that did not favor the accumulation of alkali, and hence these deposits do not supply much soluble matter to the water that enters them. As a whole the waters of Upper Animas Valley are the best waters in southern Grant County. They are excellent for irrigation and domestic use and not objectionable for boiler use. The waters from wells 172 and 175 in the upper part of the valley are classed as good for boiler use; those from wells 115, 124, and 148, located lower down in the valley, have some tendency to foam and to form considerable scale and have therefore been classed as fair.

#### SOIL IN RELATION TO WATER SUPPLIES.

The soils of the stream-built slopes, or "mesas," above the Animas Creek trough are derived from debris brought down from the mountains. On account of the narrowness of the valley the grades of the stream-built slopes are comparatively steep and the soils are coarse, their principal constituents being gravel and sand. Along the bottoms of the draws and at other places where storm waters collect and soak into the ground a good growth of native grasses and shrubs attest the fertility of the soil.

The soils in the Animas Creek trough are largely a secondary product of the mesa soils. They consist mostly of sand, silt, and clay washed down from the mesas and redeposited. At the mouths of some of the larger arroyos the coarser materials have been washed down into the trough and the soils are gravelly.

The porosity of the soil and the surface drainage have prevented the accumulation of alkali in the soil. Soil samples were taken in three localities. Samples 33 and 34 (see map, Pl. I) were taken in the thickly settled region in the lower part of the valley. They contained only negligible amounts of alkali, sample 33 showing 0.10 per cent of total alkali and 0.05 per cent of black alkali, and sample 34 showing 0.15 per cent of total alkali and 0.05 per cent of black alkali. Sample 49 (see map, Pl. I), taken nearer the head of

the valley, contained 0.15 per cent of total alkali and 0.05 per cent of black alkali. On soils of this character all the ordinary crops can be successfully grown.

### LOWER ANIMAS VALLEY.

#### PHYSIOGRAPHY AND DRAINAGE.

*General features.*—Lower Animas Valley lies between the Pyramid and Peloncillo ranges and extends from the vicinity of the El Paso & Southwestern Railroad to the northern end of the area described in this report. The Pyramid Range, which borders the valley on the east, trends nearly north and south. The Peloncillo Range, which borders the valley on the west, trends west of north and crosses the State line 7 miles south of the northern boundary of the area described in this report. The divergence of the mountain borders causes a widening of Lower Animas Valley toward the north. Its average width is about 12 miles. The axial part of the valley consists of a low, nearly level plain, about 5 miles wide. Bordering this lowland on both sides are wide stream-built slopes, which extend down from the mountains with gentle gradients, but which at their lower ends pitch abruptly downward to the central plain.

The bank that borders the central plain is hardly distinguishable in some places and is very conspicuous in others, but it can be traced around nearly the whole circumference of the central plain and gives this plain a distinctive and sharp boundary. Certain marked resemblances between this feature and old beaches leads to the belief that it originated at the time the lake existed in the valley and that it marks the old shore line. Such a bank could have been formed by delta deposits of sheet floods.

The central plain or axis of the valley is noticeably nearer the western than the eastern side. The position of the axis relative to the bounding ranges has been determined by the difference in the size of the stream-built slopes on the two sides of the valley. The Peloncillo Range on the west side, especially along the 20-mile stretch between the El Paso & Southwestern Railroad and Steins Pass, is narrow and low, and the relatively small amounts of waste originating on its flanks gives rise to correspondingly short debris slopes. The Pyramid Range on the east is wider and larger and furnishes more sediments. Hence the debris slopes that border this range have extended farther into the valley and crowded the axis toward the opposite side.

The Animas drainage basin, of which Lower Animas Valley is a part, is in the form of an inverted L with Upper Animas Valley forming the leg, Lordsburg Valley the toe, and Lower Animas Valley the heel of the letter. The drainage from Upper Animas Valley to the south and from Lordsburg Valley to the east is discharged into

Lower Animas Valley and finds its way to the lowest depression in the basin northeast of Steins Pass, where a large playa, has been developed. Much of the storm water discharged into Lower Animas Valley from the canyons in the mountains along its border is absorbed by the coarse sediments that form the upper parts of the stream-built slopes. That which is not absorbed follows down the slopes in broad shallow draws and is shed upon the central plain. A few of the streamways are rather deep, but there is no such general dissection of the stream-built slopes as in Upper Animas Valley.

On the central plain most of the drainage is northward in the general direction of the slope. Owing to the very gentle slope the movement is sluggish, and practically no erosion has taken place. Most of the run-off from the east side of the valley and some from the west side eventually finds its way through a shallow depression extending from the vicinity of the Holmig wells, past the Seven-Twelve ranch, northward along the eastern edge of the central plain and under the railroad trestle near the Southern Pacific Railroad sidetrack at Conrad, into the alkali flat north of the track.

*Alkali flats.*—On the central plain in the northern part of the valley are two alkali flats. (See Pl. I, in pocket.)

The north flat forms the floor of a roughly circular depression. It is approximately  $5\frac{1}{4}$  square miles in area and is from 3 to 8 feet below the general surface of the plain. The flat is perfectly level and has a smooth, hard surface stained with alkali and absolutely devoid of vegetation (Pl. VI, B). On the west side the flat is bordered by a short, abrupt gravelly slope leading up to the plain, but on the remaining sides it is separated from the plain by a continuous, low, symmetrical embankment or ridge of gravel and sand. This feature has been described as one of the beach ridges of ancient Lake Animas (p. 86).

The south flat occupies the lowest portion of the valley and has an area of approximately  $16\frac{1}{4}$  square miles. On the west it is bounded by a short, abrupt sandy slope leading up to the plain 3 or 4 feet above it and on the north by a small sand ridge. On the east it has no definite boundary but gradually merges into the Lordsburg Draw, which here opens into it. On the south it is at present bounded by the embankment of the Southern Pacific Railroad.

The flat is level, has a smooth, hard surface, and no vegetation except a few scattered clumps of alkali sacaton.

The alkali flats no doubt represent the remnants of ancient Lake Animas. That the lake survived in the depression of the north flat long after it had begun to recede and left the older strand features high and dry is proved by the existence of a distinct terrace, several feet up on the inward slope of the beach ridge at the northern end of the depression.

*Sand dunes.*—Sand dunes cover an area of about 30 square miles in the region north of the alkali flats, chiefly in Tps. 21 and 22 S., Rs. 19 and 20 W. The sands have been piled up in low hills and ridges by the wind. Generally the dunes are not over 15 or 20 feet high, but in some places near the southern border of the area, where the sand sheet is thickest, they reach a height of 50 or 60 feet. The building of the dunes is probably closely connected with the history of the ancient lake whose shore line is traceable along the southern boundary of the sand area (p. 87). At the present time movement of the sand by the winds is retarded to a large extent by the vegetation. Mesquite and sagebrush, evidently preferring the loose sandy soil of the sand area to the denser soil of the surrounding plain, is scattered over the entire area (Pl. III, B, p. 26). The geology of the sand deposits is described on page 35.

*Lava beds (malpais).*—Lava, commonly known in this region as "malpais" (Spanish, badland), covers a portion of the plain west of Animas (Pl. I, in pocket). It is spread out in a thin sheet over an irregular area approximately 22 square miles in extent. The lava sheet is about 12 miles in length and extends from a point at the base of the Peloncillo Mountains  $4\frac{1}{2}$  miles south of Pratt northward to a point in the center of the valley east of Cowboy Pass. Its greatest width, approximately along the line of the El Paso & Southwestern Railroad, is about  $3\frac{1}{2}$  miles.

The average elevation of the lava sheet above the plain is 15 or 20 feet, although it varies considerably from place to place, ranging from a few feet where the adjacent plain has been built up by sedimentation to 45 feet where the plain has been worn down by erosion. Along the eastern and southern margins small detached areas of lava rise above the plain not far from the main lava sheet. Obviously the detached masses are connected with the main mass underground and have become separated by a building up of the plain (Pl. VII, A).

The relation of the lava sheet to the major features of the existing topography and to minor differences between the topography that existed when the lava was poured out and that now existing is clearly shown in the shape and position of the lava sheet. (See Pl. I, in pocket.) The general slope of the lava sheet is northward along the axis of the valley. It is highest at the southern end, where it extends up the stream-built slope to the base of the Peloncillo Mountains. The vent from which most of the lava flowed was probably located here. From the base of the mountains the course of the lava flow was northeastward down the stream-built slope almost to the center of the valley and then northward along its axis, corresponding in a measure to the course that a stream of water would follow at the present day. Near its source the lava stream was deep, and the minor irregularities of the surface over which it flowed were



not expressed in the contour of its surface after it solidified; but at the northern extremity of the flow the lava flood was comparatively shallow, and here the irregularities of the surface over which it flowed are indicated in the outline of the lava area. The tongues of lava that extend from the main mass out on the plain probably indicate depressions in the old landscape; reentrants of the plain into the lava area were high places in the original surface.

The surface of the lava area is extremely rough. It is covered with loose angular fragments of lava and interrupted with fissures, caverns, and jagged projections of all descriptions. Travel over it on foot or horseback is difficult, and travel by wheeled conveyances is impossible except along established roads.

*Shore features of ancient Lake Animas.*—In the inclosed desert valleys the stream-built slopes if not modified by some other agency extend down from the borders of the mountains and merge into the flat central part of the valley without any perceptible break in gradient. In Lower Animas Valley, however, the edges of the central plain are

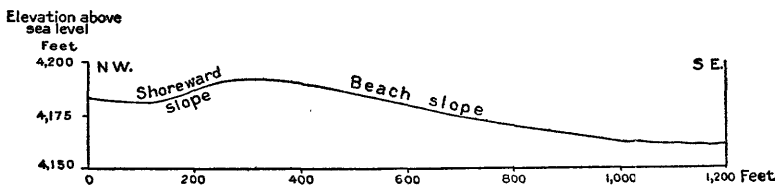
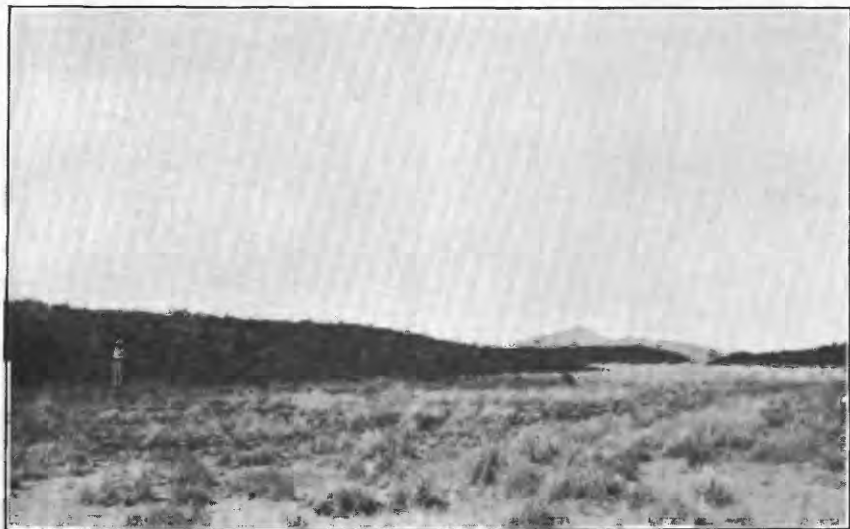


FIGURE 8.—Profile of beach ridge of ancient Lake Animas.

in most places sharply marked either by a break in slope or by low, symmetrical ridges or embankments of sand and gravel. At the lower end of the valley, where these features are best developed, they exhibit well the characteristics of beach slopes and beach ridges.

On the west side an old beach, strewn with waterworn, flattened pebbles resembling the typical shore shingle found along modern beaches, extends in a continuous line a distance of 9 miles from a point near the northeast corner of sec. 31, T. 22 S., R. 20 W., not far from the south end of the north alkali flat, to the north line of sec. 18, T. 24 S., R. 20 W.,  $1\frac{1}{4}$  miles south of the Southern Pacific Railroad. The most conspicuous feature of this old beach line is the gravel ridge that extends for  $4\frac{1}{2}$  miles from a point one-fourth mile north of the southeast corner of sec. 31, T. 22 S., R. 20 W., to the middle of the north line of sec. 25, T. 23 S., R. 21 W. The ridge is 500 to 600 feet wide at the base, about 30 feet high on the lake side, and 10 feet high on the opposite side. Longitudinally the crest line, except for local irregularities, is practically level. The wide, gently rounded crest and the long, gravelly sweeping slope on the east side which formed the beach of the ancient Lake Animas is shown in figure 8.



A. QUATERNARY LAVA (MALPAIS) RESTING ON VALLEY FILL, SHOWING DETACHED MASSES SEPARATED FROM MAIN MASS BY BUILDING UP OF ALLUVIAL PLAIN.



B. BEACH RIDGE ON WEST SIDE OF LOWER ANIMAS VALLEY, SHOWING DRAINAGE GAP; PELONCILLO MOUNTAINS IN BACKGROUND.

The low area immediately back of the ridge was probably originally covered by the old lake, but as the ridge was built up it was cut off from the main body of water and transformed into a lagoon. The drainage from this area and from parts of the stream-built slope and of the mountain range back of it now finds outlet through two gaps in the ridge near the middle of the west line of sec. 13, T. 23 S., R. 21 W. (See Pl. I, in pocket, and Pl. VII, B.)

On the east side of the valley the old beach is distinct for a distance of  $11\frac{1}{2}$  miles, from a point on the south side of the Lordsburg Draw about  $1\frac{1}{2}$  miles north of Pyra (middle of east line of sec. 28, T. 22 S., R. 19 W.) southward along the edge of the central plain to about the north line of sec. 18, T. 24 S., R. 19 W., 3 miles north of the Seven-Twelve ranch. In sec. 6, T. 24 S., R. 19 W., and in secs. 19 and 30, T. 23 S., R. 19 W., it is marked by small beach ridges, but along the rest of its course it consists of a single gravelly beach slope extending 10 to 25 feet above the valley floor.

A small but distinct beach ridge extends along the north side of the Lordsburg Draw for about  $1\frac{1}{2}$  miles. It is in secs. 20 and 21, T. 22 S., R. 19 W., between the eastern edge of the sand area and a small group of rocky hills  $2\frac{1}{2}$  miles north of Pyra. The northern shore of the old lake probably coincided closely with the edge of the present sand-hill area, where traces of an old beach are displayed at a number of points. A beach ridge was developed at some distance from the shore along the north, east, and south borders of the present alkali flat south of the Hackberry well. This ridge is about 4 miles long, 15 feet high on the lake side, and 5 feet high on the shoreward side, and has an average width of about 200 feet across the base. A lagoon probably occupied the area between it and the outer shore along the edge of the sand area.

A lake conforming to the shore features described above would extend from the Hackberry well south for nearly 15 miles to the vicinity of the Boss ranch and the Seven-Twelve ranch, covering all of the central plain between these points so as to include a large part of the south half of T. 22 S., all of T. 23 S., and most of T. 24 S., in R. 20 W. The lowest part of the valley now occupied by the larger alkali flat would be submerged to a depth of 35 or 40 feet. An arm of the lake would extend up the Lordsburg Draw to the playas at its upper end.

Features similar to those described from the lower part of the valley are also found farther south in the region north of the El Paso & Southwestern Railroad. A line of low bluffs facing the valley and resembling the front of a wave-cut beach terrace extends along the western edge of the central plain from Cowboy Pass south for  $7\frac{1}{2}$  miles to within  $1\frac{1}{2}$  miles of Pratt. A similar bluff borders the eastern edge of the central plain for  $1\frac{1}{2}$  miles just east of the Wamel

ranch. Several long, low embankments, or ridges, composed of coarse sand and waterworn gravel and bearing some resemblance to the beach ridges farther north, extend out on the plain from the eastern edge of the malpais area that occupies the center of the valley. One of these ridges extends from the northern tip of the malpais area in a southeasterly direction across the plain for more than 4 miles to the road a quarter of a mile north of the Wamel ranch. A small ridge extends westward from the point of a lava tongue near the SW.  $\frac{1}{4}$  sec. 1, T. 27 S., R. 19 W. About half a mile farther south the wagon road approaching Animas from the northwest follows along the top of a similar ridge extending from the edge of the malpais for  $1\frac{1}{2}$  miles out on the plain. This ridge, which is the most conspicuous of the three, rises about 5 feet above the plain and has an average width of about 50 to 60 feet. A growth of yucca and other desert shrubs along the crest brings it out in sharp contrast to the bare plain surrounding it. Aside from the shore features displayed along its edges, the level central plain, in the character and disposition of its sediments, its general form, and its relation to the bordering stream-built slopes has many of the characteristics of an old lake bed.

There is no difficulty in outlining approximately the boundaries of a lake which would conform to the northern group of shore features in the lower part of the valley. The features making up the southern group, on the other hand, can not be fitted to any body of water which could exist under present topographic conditions. A lake conforming to the gravel ridge  $1\frac{1}{2}$  miles northwest of Animas would be approximately 4,390 feet<sup>1</sup> above sea level and would therefore stand about 190 feet above the divide<sup>2</sup> that separates the Animas drainage basin from that of Gila River and would submerge the old beaches in the lower part of the valley to a depth of 200 feet. To bring the shore features in the lower and upper parts of the valley into position so that they could have been formed contemporaneously along the same body of water would therefore necessitate a relative vertical displacement of 200 feet. These two groups of features may have been formed at different stages of the lake and may have originally been at different levels, but the upper beaches could not have originally stood higher than the divide unless the Gila Valley had contained a great body of water at this time, of which there is no evidence. More precise leveling will be necessary before a satisfactory explanation of the high-level strands in the Animas Valley will be possible.

<sup>1</sup> Estimated from known elevation at Animas station, given as 4,394 feet in Dictionary of Altitudes of the United States: U. S. Geol. Survey Bull. 274, p. 640, 1906.

<sup>2</sup> Elevation of Summit station on Arizona & New Mexico Railway, given as 4,207 feet (idem, p. 651).

## GROUND WATER.

## DEPTH TO WATER.

The depth to water in the central plain of Lower Animas Valley ranges from about 10 feet in the center of the plain, east of Steins Pass, to about 180 feet in the upper part of the valley, south of Animas station. From about 70 well measurements made during the summer and fall of 1913 it is estimated that approximately 132 square miles is underlain by water-bearing beds at a depth of 100 feet or less below the surface. This estimate includes 8 square miles in which depth to water is 15 feet or less, 35 square miles in which depth ranges from 15 to 25 feet, 36 square miles from 25 to 50 feet, and 53 square miles from 50 to 100 feet. As shown on the map (Pl. II, in pocket), ground water occurs at a depth of 15 feet or less below the surface in a roughly oval-shaped area, about 5 miles long from north to south, and about  $1\frac{3}{4}$  miles wide, lying just south of the big alkali flat and near the east side of the central plain. This area includes about one-half of the eastern half of T. 24 S., R. 20 W., and a small part of T. 23 S., R. 20 W.

Outward from this area of shallowest water the depth increases in all directions. The zone of 15 to 25 foot depth to water includes almost all of the southern half of the south alkali flat in T. 23 S., R. 20 W., nearly half of the next township south, and the northeast corner of T. 25 S., R. 20 W. The 25 to 50 foot zone includes the middle and western parts of the alkali flat in T. 23 S., R. 20 W., a narrow strip along the west and east sides of T. 24 S., R. 20 W., and along the west side of Tps. 24 and 25 S., R. 19 W., and a large area in the central portion of T. 25 S., R. 20 W. The 50 to 100 foot zone extends in a very narrow strip along the east and west edges of the central plain, including a part of the bordering stream-built slopes, in Tps. 23 and 24 S., R. 21 W., and Tps. 24 and 25 S., R. 20 W., on the west side and in Tps. 23, 24, and 25 S., R. 19 W., on the east side. It also includes most of T. 26 S., R. 20 W., and the tongue of land extending south into the malpais area in T. 27 S., R. 20 W. In the north it includes the northern portion of the big alkali flat and the lower part of the Lordsburg Draw.

## FORM OF THE WATER TABLE.

The boundaries on the map show the relation of the water table to the land surface and are not water-table contours. As elevations of the surface at the tops of wells that were measured were not available it was not possible to construct a contour map of the water table, but the data at hand afford a basis for certain generalizations in regard to the behavior of the water table. Thus, it is known that the general slope of the water table is toward the north. At Animas

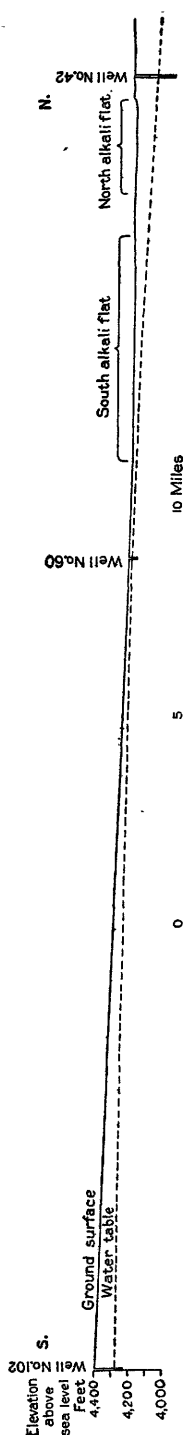


FIGURE 9.—Section showing relation of water table to surface of ground in Lower Animas Valley.

station, on the El Paso & Southwestern Railroad, the surface is about 4,395 feet above sea level, and the depth to the water table 120 feet, making the water table about 4,275 feet above sea level. At the Leahy well (Nc. 60 on the map, Pl. II, in pocket),  $19\frac{1}{2}$  miles north of Animas, the surface is about 4,150 feet above sea level, the depth to the water table is 10 feet, and the water table about 4,140 feet above sea level. At Animas, therefore, the surface is 245 feet and the water table 135 feet higher than at the Leahy well, showing a surface slope of  $12\frac{1}{2}$  feet per mile and a water-table slope in the same direction of approximately 7 feet per mile. Thus, whereas the water table and the land surface slope in the same direction, the land surface has the steeper gradient, so that the two converge toward the north and the depth to water decreases in that direction.

Northward from the Leahy well, on the other hand, the water table and the land surface diverge and the depth to water increases. Between the Leahy well and the south end of the big alkali flat there is only a slight decrease in elevation, and across the alkali flat the elevation remains practically the same, but the water table continues to slope northward at about the same rate as farther south, or at least it is so indicated by wells along the west edge of the central plain. For example, at well 47 (Pl. II, in pocket) the depth to water is 33 feet, but at well 44, 3 miles farther north and at about the same elevation, the depth to water is 49 feet, an increase of 16 feet, or approximately 5 feet per mile. This decline of the water table toward the north end of the valley seems to indicate that there is leakage of ground water out of this drainage basin into the Gila basin. Figure 9 shows the conditions as outlined above in diagrammatic form.

On the stream-built slopes adjacent to the central plain the water table is generally inclined toward the central plain, but as this inclination is less than that of the surface the depth to water increases toward the mountains.

There is an abrupt change in the ground-water level 4 or 5 miles south of the El Paso & Southwestern Railroad. At the XT stock wells (No. 104), 2 miles south of Animas, in the southern part of T. 27 S., R. 19 W., the depth to water is reported to be about 180 feet, and farther south, in the two northern tiers of sections in T. 28 S., R. 19 W., the depth is about the same, but in the next tier south—secs. 15 and 16 in the same township—the depth to water is not over 30 feet. The explanation of this break in the water table appears to be that compared to the body of ground water of Lower Animas Valley that in Upper Animas Valley is a perched water body, as represented in figure 10.

The ground water in Upper Animas Valley occurs in gravels that lie at a shallow depth below the surface and form part of the recent fill laid down on the almost impervious clay and gravel mixture of the older fill. The gravels of these recent alluvial deposits appear not

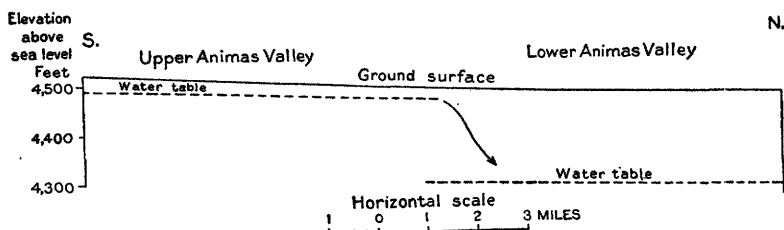


FIGURE 10.—Section showing relative positions of water tables in Upper Animas and Lower Animas valleys.

to extend out below the expanded central plain of Lower Animas Valley. Hence, wells in this plain of the lower valley do not encounter the shallow-water bed but must be sunk to a lower stratum of gravel. This lower stratum may continue southward beneath Upper Animas Valley and could possibly be reached in the upper valley if deeper wells were drilled. The older fill is probably porous enough in the vicinity of the drop in the water table to allow the water from the upper gravel to sink to the lower stratum, for the underflow does not accumulate sufficiently to reach the surface.

#### WATER-BEARING BEDS.

The central plain of Lower Animas Valley is underlain by unconsolidated deposits consisting of beds of clay, sand, and gravel, and various mixtures of clay, sand, and gravel. In vertical section the different classes of material are arranged in definite layers more or less distinct from each other. Laterally the individual beds change rapidly by gradation from one class of material into another, making the identification of any particular bed in two different wells impossible if the wells are widely separated and uncertain even if they

are only a short distance apart. Figure 11 shows an attempt to correlate the beds exposed in two wells on the Keithley place in the SE.  $\frac{1}{4}$  sec. 13, T. 25 S., R. 20 W. The wells are 530 feet apart and are 1 mile west of the east edge of the valley (wells 85 and 86, Pl. II, in pocket). The beds exposed in the walls of the wells were carefully measured and similar beds in the two wells were correlated. The resulting section shows how the individual beds thin out or thicken within short distances, producing an interlocking series of wedge-shaped or lens-shaped bodies. This section is thought to represent fairly the general attitude of the upper 60 or 70 feet of beds in all of the central plain. A few wells in the upper part of the valley go to depths of about 200 feet, but in the lower part of the valley all the wells are less than 100 feet deep and there is therefore no information as to the character of the lower beds.

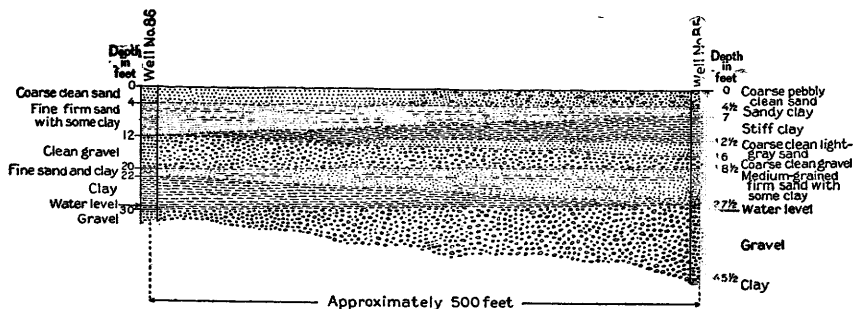


FIGURE 11.—Section showing characteristic lenticular shape of beds of valley fill on east side of Lower Animas Valley. Based on correlation of beds exposed in wells indicated.

Figure 12 shows the plotted logs of wells representative of conditions in their respective localities. The finer sediments predominate near the center of the valley, but there is a decided increase in the proportion of coarse sediments toward the edges of the valley. In a 50-foot section of the Leahy well (No. 60, Pl. II, in pocket), for instance, there is only about 20 per cent of gravel; whereas in a 34-foot section of the Haydon well (No. 68) nearly 50 per cent of the material consists of gravel, and in the two Keithley wells (Nos. 85 and 86) there are respectively 60 per cent of gravel in a 40-foot section and 40 per cent of coarse sand and gravel in a 34-foot section. (See fig. 11.) On the stream-built slopes above the central plain the proportion of coarse material is still larger. In the De Moss well (No. 49), for example, a 70-foot section shows over 90 per cent of coarse material of which 15 per cent is clean coarse sand and gravel and the rest coarse angular gravel mixed with clay and commonly referred to as "wash."

The sediments beneath the central plain of Lower Animas Valley to the depths ordinarily penetrated by wells were probably laid down in the lake that existed here in ancient times and were more thoroughly



assorted and more regularly stratified than the stream deposits. The thickness of the lake sediments has not been determined. The log of the Winkler well (see p. 110), in Lower Playas Valley, where a lake existed which was probably contemporaneous with the one here, shows unconsolidated, bedded clays, sands, and gravels to a depth of 350 feet, below which to a depth of 836 feet the materials were so thoroughly cemented as to render them almost impervious. The top of this cemented material may or may not mark the bottom of the lake sediments. At any rate it marks the depth beyond which it would seem futile to hope for favorable conditions for ground water.

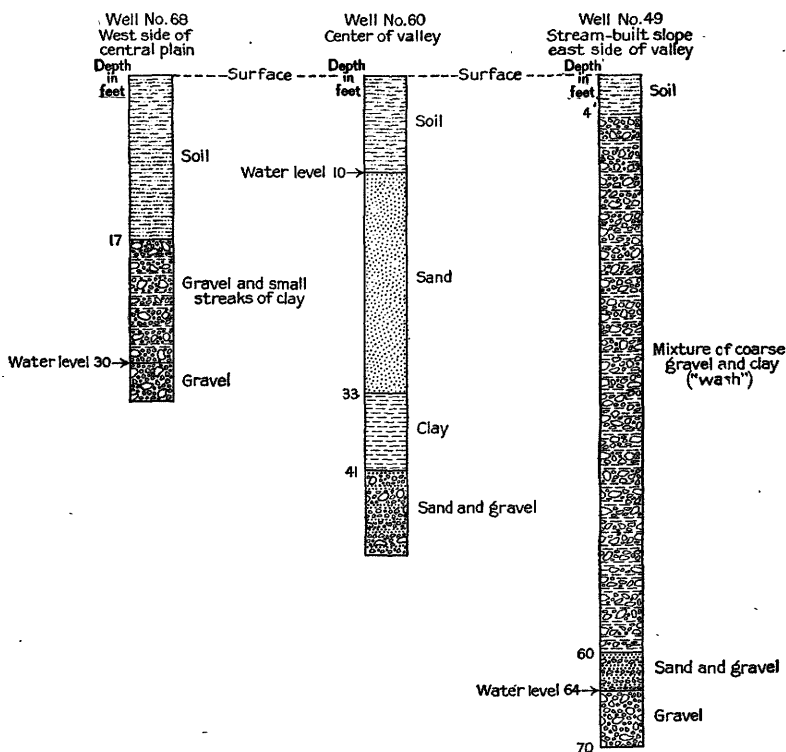


FIGURE 12.—Sections of wells in Lower Animas Valley.

Wells in Lower Animas Valley draw their supply from the sands and gravels that occur in the saturated zone below the water level. In the central part of the valley, where most of the wells are situated, two water-bearing strata are usually recognized, the first generally between 30 and 40 feet below the surface and the second between 60 and 70 feet. As the water level varies from place to place there are of course many exceptions to this rule, but it is usually necessary to tap at least two water-bearing beds in order to obtain a supply adequate for irrigation. It is not improbable that still other water-bearing beds could be found by drilling deeper into the valley fill,

## QUALITY OF WATER.

## AMOUNTS OF TOTAL DISSOLVED SOLIDS.

Samples of water were collected from 18 wells in Lower Animas Valley. (See Pl. II, in pocket, and Table 2, wells 40, 41, 42, 45, 57, 59, 60, 61, 62, 68, 76, 80, 83, 85, 87, 90, 102, and 106.) Ten of these waters are of the sodium-carbonate type, of which seven may be classed as highly mineralized with total solids ranging from 516 to 1,340 parts per million and three as moderately mineralized with 282 to 432 parts per million of total solids. Four are highly mineralized sodium-sulphate waters, containing 768 to 3,165 parts per million of total solids. Three of the waters are of the calcium-carbonate type and carry 421 to 491 parts per million of total solids, and one is a sodium-chloride water, containing 1,340 parts per million of total solids.

The waters from wells north of the Southern Pacific Railroad are with one exception (well 83) much more highly mineralized than those from wells south of the railroad—that is, in the valley as a whole there is a steady increase in the mineral content of the waters from south to north. This may be due to the fact that a decided northward slope of the water table has resulted in a general movement of ground water in that direction and its consequent increased mineral content by contact with buried strata of alkali. (See pp. 89–91). Water absorbed by the ground near the head of the valley would gradually increase in mineral content in its passage northward by coming into contact with the soluble salts in the soil. The movement of the water underground is necessarily very slow and the opportunities for leaching are correspondingly great; and water that enters the ground comparatively pure may in the long distance that it has to travel attain a concentration equal to that of the highly mineralized waters at the north end of the valley. The soils in the low central part of the valley are heavily charged with mineral salts on account of peculiar conditions of drainage. As the shore features show, the valley has long been a closed basin, and old soils containing much soluble matter are probably buried in the zone of circulating ground waters. Though waters moving northward and gathering mineral matter along the axis of the valley are at places diluted by purer waters that enter it from the sides, this action is doubtless counterbalanced by the addition of more concentrated solutions from other points. The relation of the water table to the mineral content of the ground water is shown diagrammatically in figure 13, in which the shaded area represents the mineral content of water from representative wells situated along the axis of the valley and the upper boundary of the shaded area represents on an exaggerated scale the profile of the water table.

Certain exceptions in the general northward increase of mineral content of the waters can be explained by the irregular distribution of salts in the deep soils below the ground-water level. This irregularity is illustrated in wells 61 and 62, on the Sellards place in the NE.  $\frac{1}{4}$  sec. 14, T. 24 S., R. 20 W. The waters from these two wells, which are within a short distance of each other, differ not only in character but also in their content of total solids, the irrigating well (No. 62) yielding a calcium-carbonate water containing 421 parts per million of mineral matter, and the domestic well (No. 61), a few hundred feet away, yielding a sodium-sulphate water containing 1,060 parts per million of dissolved matter. This difference in composition is probably due to the fact that the water is drawn from different strata in

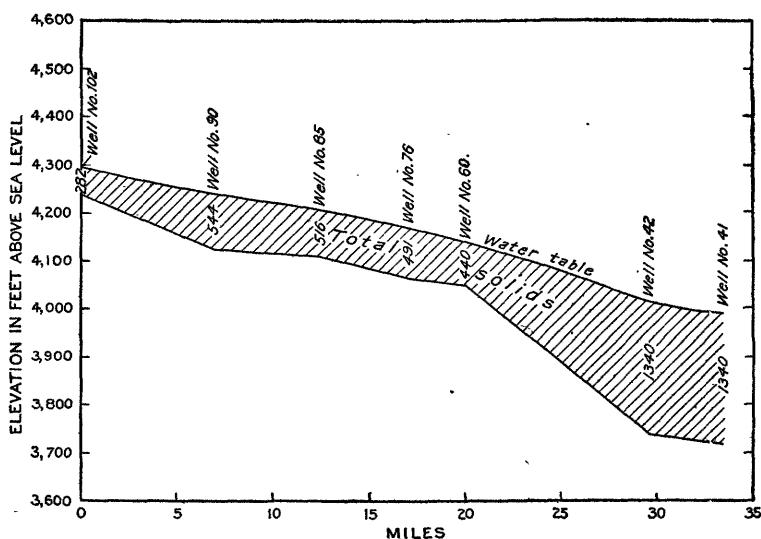


FIGURE 13.—Diagram showing relation of water table to total solids dissolved in ground waters of Lower Animas Valley. Numbers in shaded area indicate total solids in parts per million.

the two wells, the domestic well, 19 feet deep, drawing its water from the first stratum, and the irrigating well, 39 feet deep, tapping the second stratum with the first cased off. A similar difference exists between the waters from the irrigating well of J. P. Kerr (No. 83) and the well of M. B. Keithley (No. 85), both of which are in sec. 13, T. 25 S., R. 20 W. The water from the Keithley well contains 516 parts per million of dissolved solids, whereas that from the Kerr well contains 3,165 parts per million, or more than six times as much. The Kerr well is 45 feet deep and the other is said to be about the same depth.

It has been the experience of well drillers in the region that "good" or "bad" waters do not occur at any particular horizon and that the quality of water from any particular water bed does not depend

on its depth or relative position. As one driller expressed it: "The alkali seems to occur in pockets and there is no regularity. Sometimes the first stratum is more alkaline and sometimes the second." The water-bearing formations of the valley have been prospected to only comparatively shallow depths and deeper beds may yield water of more uniform and possibly better quality.

#### QUALITY FOR IRRIGATION.

According to the rating given on page 65, ten of the waters analyzed have been classed as good, four as fair, and four as poor for irrigation. The best water examined is that from Sellard's irrigating well (No. 62), and the poorest is a sodium-carbonate water from an old, unused well (No. 45) west of the south alkali flat in the SE.  $\frac{1}{4}$  sec. 30, T. 23 S., R. 20 W. Though this water contains only about three times as much mineral matter as that from well 62, it is rated as more than sixty times as harmful on account of the large proportion of sodium and carbonate in it. Two of the waters classed as poor (Nos. 45 and 83) are in the area in which the water table is within economical pumping distance from the surface. The use of these waters for irrigation under ordinary irrigation practice would probably result in time in the deposition of so much alkali in the soil that even the most resistant crops could not grow. Waters of this type have been used with some success in certain regions on very loose porous soils with good drainage, but they would be almost sure to ruin the land in a short time under the conditions existing in Lower Animas Valley. Three of the waters (Nos. 59, 61, and 68) which are considered fair for irrigation could probably be used successfully in the valley if special care were taken to prevent accumulation of alkali in the soil. The waters classed as good will ordinarily not require special precautions to prevent accumulations of alkali. Conditions of drainage and soil in some portions of the valley, however, are such that much alkali has accumulated in the soil through natural causes. (See map, Pl. I, in pocket.) In these areas the continued use of even the best waters may make the land unproductive unless proper precautions are taken. Some of the ways in which accumulations of alkali can be prevented and alkali land can be reclaimed are described on pages 47-50.

#### QUALITY FOR DOMESTIC USE.

Four of the waters have been classed as good, ten as fair, two as bad, and two as unfit for domestic use. Those classed as good are calcium-carbonate or sodium-carbonate waters with a mineralization not exceeding 440 parts per million of total soluble salts. They have no perceptible taste, are fairly soft, and are acceptable for all domestic uses. Most of the waters designated as fair are the more highly mineralized

sodium-carbonate and sodium-sulphate waters, yielded by well along the west side of the central valley plain in Tps. 24 and 25 S., R. 20 W. They are not especially hard, but they have a slight taste, hardly perceptible to persons accustomed to their use but quite evident to others, which makes them less acceptable for drinking. The highly mineralized waters, from wells 40 and 41, in the northern portion of the valley, and well 45, west of the south alkali flat, are not good for domestic use, on account of their disagreeable taste, which makes them obnoxious to most people though they are not necessarily unhealthful. Well 83 yields the most highly mineralized water. The high sulphate content gives it a disagreeable taste and may make it unhealthful to some persons.

#### QUALITY FOR BOILER USE.

None of the waters analyzed has all the qualifications of a good boiler water, most of them possessing objectionable foaming tendencies caused by the presence of considerable sodium. About half the waters are high in scale-forming constituents, though only one is definitely corrosive. Among the waters examined that from the west one of Wamel's "railroad wells" (No. 102) at Animas station comes nearest being a good boiler water in all respects. The waters from wells 57 and 106 are next best and may be considered fair boiler waters in that they are noncorrosive and contain only moderate amounts of foaming and scale-forming constituents. These waters can be used without much trouble if the boilers are cleaned regularly. All the other waters except the most highly mineralized (from wells 41, 42, 45, and 83) could probably be successfully used after preliminary chemical treatment.

#### SOIL IN RELATION TO WATER SUPPLIES.

Most of the soils of Lower Animas Valley are of alluvial origin, and from the viewpoint of the farmer the alluvial soils alone are important. They show variations in color, texture, and chemical composition from place to place. In general the soils of the stream-built slopes along the edges of the valley are gravelly—coarse gravelly along their upper portions and finer down the slopes toward the center of the valley. The soils of the central plain, derived largely from the finer sediments, consist of sand, silt, and clay in various proportions.

Table 2 (pp. 144-149) includes 21 analyses of soils from Lower Animas Valley. The content of soluble matter, or alkali, of these soils is shown graphically on the map (Pl. II, in pocket). The greatest amount of alkali is contained in the soil of the barren flats that occupy the center of the valley, but large amounts also occur in areas bordering the barren flats. The area in which the samples

showed over 0.60 per cent of white alkali or over 0.20 per cent of black alkali is outlined on the map (Pl. II). Numerous investigations in the western United States have shown that on soils in which the alkali content exceeds these limits ordinary crops are likely to suffer. Outside the area outlined, which includes half of T. 22 S., R. 20 W., almost all of T. 23 S., and three-fourths of T. 24 S., the soil in general does not contain enough alkali to prevent the successful growing of all the ordinary crops. The gravelly and sandy soils of the stream-built slopes at the sides of the valley are comparatively free from alkali. The soils of the plains at the northern end of the valley also contain very little alkali. Sample No. 1 (see Table 2 and map, Pl. II), taken at the northern edge of the sand-dune area, shows a little more than 0.04 per cent of total alkali, a negligible amount in so far as successful production of crops is concerned. Southward from the south line of T. 24 S., Rs. 19 and 20 W., the alkali content of the soil steadily diminishes. In T. 25 S., Rs. 19 and 20 W., the danger from alkali is confined to certain small areas, chiefly along the shallow draws where the grade is low and the drainage waters move sluggishly. In T. 26 S., R. 20 W., and in the region west of the Wamel ranch and south to Animas station soil samples show only a negligible amount of alkali.

The area in which the soil contains injurious amounts of alkali includes all that in which the depth to water is less than 15 feet and most of that in which the depth to water is from 15 to 25 feet. This distribution might lead to the conclusion that a definite relation exists between the depth to water and the alkali content of the soil. In many shallow-water regions such a relation exists, because the water rises to the surface by capillarity and on evaporation deposits alkali in the soil. In Lower Animas Valley, however, the alkali area includes not only the area of shallow water but also an area where the ground water is deep. Beneath the north flat, for instance, the depth to water exceeds 100 feet, but the soil contains as much or more alkali than that in the region south of the Southern Pacific Railroad, where the water is nearest the surface. The position of the area of greatest concentration of alkali is determined by the topography rather than by the position of the water table.

#### PUMPING PLANTS AND IRRIGATION.

When the region was examined, in 1913, irrigation had not progressed beyond the experimental stage, but several pumping plants had been installed with a view toward irrigation on a moderately large scale. A plant belonging to J. W. Johnson (well 57), on the SE.  $\frac{1}{4}$  sec. 1, T. 24 S., R. 20 W., consists of a 20-horsepower Foos engine and a two-stage American turbine pump. It is reported that this plant furnishes from 400 to 500 gallons of water per minute and

can be run steadily at this rate for 10 to 12 hours without exhausting the supply. The well is 57 feet deep and the depth to water is 27 feet. A plant in the SW.  $\frac{1}{4}$  sec. 11, T. 24 S., R. 20 W. (well 60), belonging to J. A. Leahy, consists of a turbine pump and a 15-horsepower Venn Severin oil engine. The depth to water here is only 10 feet, the shallowest in the valley. The capacity of the plant is not known.

A plant in the NE.  $\frac{1}{4}$  sec. 14, T. 24 S., R. 20 W. (well 62), belonging to D. F. Sellards, consists of a 9-horsepower Stover engine and a No. 4 centrifugal pump and delivers 300 gallons per minute according to a test by the owner. This test has been maintained for 11 consecutive hours without appreciable diminution in the supply. The depth to water here is 12 feet.

A 12-horsepower pumping plant in the NE.  $\frac{1}{4}$  sec. 13, T. 25 S., R. 20 W. (well 83), belonging to J. P. Kerr, furnished enough water to irrigate a small acreage of field crops in 1913. The normal water level here is 24 feet below the surface. Several smaller plants, not extensively used for irrigation, are scattered throughout the shallow-water area.

In the upper part of the valley, where the water is deeper, there are several small pumping plants used principally for watering stock. W. J. Wamel has two small plants used for stock watering—one at the Holmig place in sec. 14, T. 26 S., R. 20 W. (well 90), and one at the Wamel ranch in the NE.  $\frac{1}{4}$  sec. 36 in the same township (well 96). The equipment at the Holmig place consists of a  $2\frac{1}{2}$ -horsepower Fairbanks-Morse gasoline engine, connected to a 5 by 7 inch well cylinder. The well is 79 feet deep and the normal water level is 74 feet below the surface. At the rate of about 30 gallons per minute the well can be pumped dry in one and one-half to two hours. At the Wamel ranch a 4-horsepower engine is used to pump from a well 150 feet deep in which the normal water level is 93 feet below the surface. This well may be pumped all day at the rate of 30 to 40 gallons a minute without a noticeable lowering of the water level.

One mile east of Animas station, in the NE.  $\frac{1}{4}$  sec. 19, T. 27 S., R. 19 W., there is a small pumping plant (well 101), owned by John Burns, which is equipped with a 6-horsepower gasoline engine connected to a plunger pump. The depth of the well is 157 feet, and the water normally stands 127 feet below the surface. The owner reports an output of 22,000 gallons per day, which is equivalent to about 30 gallons per minute.

Throughout the valley many small orchards and garden patches are irrigated by means of windmills in connection with storage reservoirs.

In 1913 the aggregate acreage irrigated by pumped water in Lower Animas Valley did not exceed 300 acres, or less than 2 per cent of

the area in which the water table is less than 50 feet below the surface. The amount of ground water discharged through evaporation and transpiration in the shallow-water area is not great, and there are indications that there is leakage of ground water out of the basin. The supply of ground water annually available, however, is without doubt adequate for much more irrigation than has hitherto been practiced in the valley, and further developments can safely be made.

### SAN LUIS VALLEY.

#### LOCATION AND DRAINAGE.

San Luis Valley lies south of Upper Animas Valley and extends into Mexico. It occupies a closed drainage basin that is separated from the Animas basin by a low divide 9 miles north of the international boundary, and from Yaqui River basin by a low divide about 4 miles south of the boundary. It is bordered on the east by the San Luis Range and the southern part of the Animas Range, and on the west by the Guadalupe Range and the southern part of the Peloncillo Range. The watercourses have not in general extended their channels much beyond the edges of the mountains and they rarely carry water. Cloverdale Creek, however, drains a considerably larger area than any of the others and maintains a small permanent flow during most of the year along its upper course. It rises near the Arizona State line and flows southeastward through a narrow valley between low, wooded foothills, to Cloverdale post office, where it emerges upon the plain and continues in the same direction along a definite channel until it is diverted southward into Mexico by the old beach ridge in the center of the valley (p. 101). It finally discharges through a breach in the ridge into the depression occupying the lowest part of the closed drainage basin.

#### ANCIENT LAKE CLOVERDALE.

Near the east side of the plain forming San Luis Valley there is a flat-floored depression about 25 or 30 feet below the general level of the plain. In form it is a nearly perfect ellipse, 7 miles long and 5 miles wide, its major axis extending north and south. At the south it projects into Mexico about 1 mile. Along two-thirds of its circumference, for 16 miles, from the foot of the San Luis Range in Mexico along the west and north sides and the east side to the San Luis Pass, this depression is inclosed by a remarkable ancient shore feature consisting of an embankment 15 to 70 feet high, locally known as the "dam" or "levee." From San Luis Pass southward and southwestward, along the foot of the San Luis Range to the southern extremity of the "dam," the depression is bordered by low bluffs consisting of the truncated edges of short, steep stream-built



débris slopes that fringe the range. It is not strange that the striking feature known as the "dam" should have attracted more than passing notice from travelers in this region and at least three investigators have mentioned it. Gaillard<sup>1</sup> and Mearns<sup>2</sup> were inclined to the theory that it is of human origin, but Huntington,<sup>3</sup> who visited the region later, recognized it as an ancient beach ridge and pointed out the improbability of its having been constructed by man on account of its great size. He says:

To build such a structure would, by actual computation, require the work of 1,000 men for 50 to 100 years. The physiographer, however, needs no such computation to prove that the "dam" is not of human origin. It presents the characteristic features of a lacustrine strand, much exaggerated, however, but still unmistakable. At some past time, presumably during the glacial period, a lake must have stood here, and must have been swept by winds of unusual severity, forming beaches of exceptional dimensions.

After carefully examining its structure and comparing it with similar features observed elsewhere in the area the writer of this paper indorses Huntington's explanation.

The beach ridge is remarkable for its continuity and regularity of outline as well as for its size. From the breach through which Cloverdale Creek and the drainage from the south enters the depression, one-half mile south of the Mexican boundary, it continues without a break for 7 miles northward to a narrow gap through which a small watercourse from the west passes. The crest of the ridge is remarkably level. At the time of the survey of the Mexican boundary a stadia survey of part of the ridge was made by Capt. Gaillard. At the Mexican line near boundary monument 67 the elevation of the crest was determined to be 5,161.10 feet and at a point  $3\frac{1}{2}$  miles north of the boundary 5,161.40 feet, a difference of less than one-half foot. Figure 14 shows profiles across the ridge at various points.

Profile A-A' is a profile of the ridge at boundary monument 67. The ridge here has a rounded crown with smooth gentle slopes extending to the floor of the depression on the east and to the plain on the west. The elevation of the crest above the foot of the slope is here 25 feet on the east side and 15 feet on the west. The width across the base is about 500 feet.

Profile B-B' is a profile across the ridge  $3\frac{1}{2}$  miles north of the boundary. Here the crest is 10 feet above the plain on the west and 30 feet above the floor of the depression on the east. On the east side there

<sup>1</sup> Gaillard, D. D., A gigantic earthwork in New Mexico: *Am. Anthropologist*, vol. 9, No. 9, pp. 311-313, Sept., 1896.

<sup>2</sup> Mearns, E. A., Mammals of the Mexican boundary of the United States: *U. S. Nat. Mus. Bull.* 56, pt. 1, p. 24, 1907.

<sup>3</sup> Huntington, Ellsworth, The climatic factor as illustrated in arid America: *Carnegie Inst. Washington Pub.* 192, p. 70, 1914.

is a series of three benches which are probably old shore lines marking successive lake levels.

Profile C-C' is a profile across the ridge near the north end of the old lake where the ridge begins to widen toward the east. Here the crest of the ridge is 25 feet above the lake floor and 20 feet above the plain to the north. A single broad terrace, corresponding probably to the upper terrace of profile B-B' is shown on the south side. Eastward toward the Animas Range the ridge widens out considerably and becomes more irregular in outline.

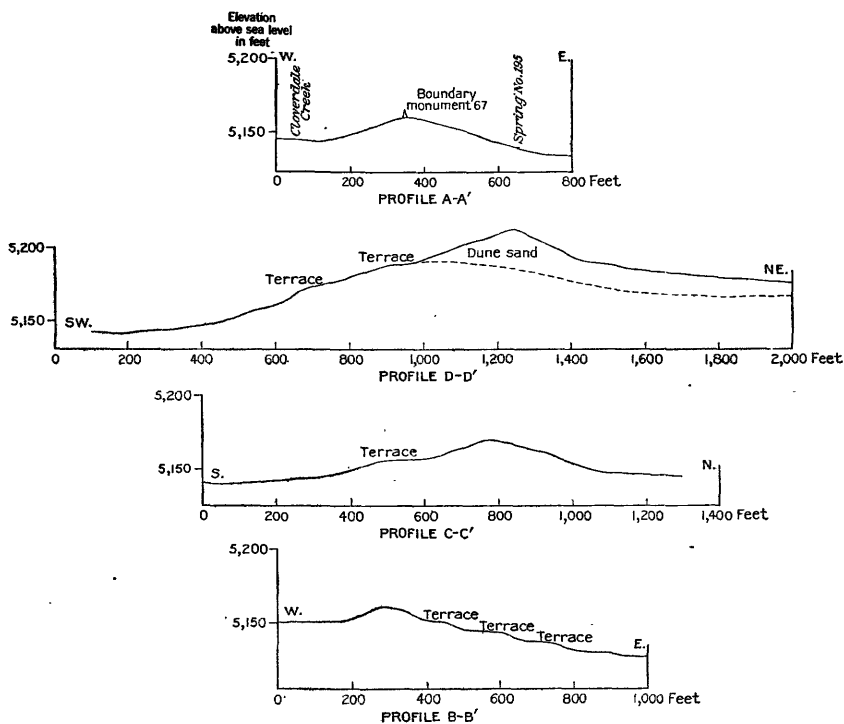


FIGURE 14.—Profiles of beach ridge of ancient Lake Cloverdale in San Luis Valley.

Profile D-D' is a northeast-southwest profile across the highest part of the ridge near the center of sec. 24, T. 33 S., R. 20 W. The crest is here about 70 feet above the floor of the depression and 35 feet above the surface on the opposite side, and the ridge has a width at the base of about 1,200 feet. Sand blown on the ridge by the winds has increased its height by about 20 feet over its original elevation. Sand has also been piled in dunes back of the ridge for some distance. At several places gaps have been cut through the ridge by temporary streams from the mountains. A number of springs along the foot of the debris slope back of the ridge have given rise to grassy meadows in the hollows between the sand dunes and have also encouraged the

growth of a small forest of oaks and junipers in an area about 2 miles long and half a mile wide back of and parallel to the ridge.

About half a mile north of the San Luis Pass road the ridge narrows and comes to an end. South of the road the old shore line is continued parallel to the San Luis Range as a bluff or short, abrupt slope leading from the floor of the depression up to the débris slopes that extend back to the edge of the mountains.

The material out of which the beach ridge has been built appears from surface indications to be mostly coarse sand with some gravel. The top and sides of the ridge are everywhere strewn with pebbles, very much waterworn and usually flattened. The following log of a well dug near the crest of the ridge on the farm of Louis Carrier (No. 184, Pl. II, in pocket) throws some light on the character and distribution of the materials. The materials have been deposited in fairly regular layers. The sands where they occur as a distinct bed are very clean and well graded, indicating that they were sorted and laid down by the action of water.

*Log of well of Louis Carrier (No. 184), in the NW.  $\frac{1}{4}$  sec. 33, T. 33 S., R. 20 W.*

	Thickness.	Depth.
	<i>Feet.</i>	<i>Feet.</i>
Soil.....	3	3
Clean coarse pebbly arkose and quartz sand; pebbles and sand grains angular; very little waterworn.....	8	11
Material similar to above but containing much yellow clay.....	39	50
Clean coarse pebbly arkose and quartz sand.....	6	56
Coarse pebbly sand and yellow clay.....	4	60

Winds blowing across the surface of bodies of water drive part of the water before them toward the shore. If they strike the shore obliquely they induce currents which flow parallel to it and perform all the functions of a running stream in sorting and distributing the shore sediments and building them into beaches, bars, spits, and various other features. Waves beating on the shore also do much work in rehandling the sediments and eroding the shore line into terraces and sea cliffs on the steeper shore slopes. Thus, the bluff along the foot of the steep débris slopes of the San Luis Range on the eastern and southern sides of the Upper Animas Lake were probably formed chiefly by the waves beating back the débris brought down by streams. On the north and west sides, where the waters of the lake extended out on the plain, the slopes were too flat for the formation of cliffs and terraces by the waves, and the currents flowing parallel to the shore formed beach ridges. As these ridges could not be built up above the level of the water in the lake, it follows that at the time they were formed the edge of the lake was some distance back of the ridge which was separated from the outer shore by a narrow lagoon. All evidences of the outer shore line have, however, long

since been obliterated. For a long time while the waters were receding the beach ridge actually marked the shore line as shown by the beach terraces cut along its inner slope.

#### GROUND WATER.

##### OCCURRENCE AND QUANTITY.

As far as present developments show the occurrence of ground water in the San Luis Valley is very local. Small supplies have been obtained from shallow wells and springs in the valley of Cloverdale Creek and on the plain west of the beach ridge from Cloverdale south to the Mexican border, from shallow wells on the floor of the old lake a short distance east of the beach ridge, and from springs along the Mexican border near the south end of the lake bed.

That most of the valley fill consists of material which is essentially non-waterbearing seems to be indicated by a deep well drilled by the Victoria Land & Cattle Co. (Diamond "A") several years ago near the center of the valley, close to the present Fitzpatrick well (No. 181, Pl. II). In the Fitzpatrick well all the water occurs in a gravel bed about 4 feet below the surface. The deep well, drilled, it is said, to a depth of 500 feet, yielded no appreciable amount of water after passing through the shallow gravel bed, and it was finally abandoned in favor of the shallow dug pit which now serves as a well.

Along the channel of Cloverdale Creek and in areas adjacent to the more or less indefinite drainage lines farther south on the west side and in places on the floor of the old lake a top layer of sand and gravel has been deposited. Much of the run-off is absorbed and stored in this porous sand and gravel and it is from these materials that most of the available water supplies are obtained. In areas where this top layer of water-bearing material does not occur wells are usually failures. The fact that these beds are irregularly distributed and are in many places hidden by a thin layer of soil usually makes it impossible to tell in advance whether wells at any particular place, even in close proximity to good wells, will yield a sufficient supply of water and has been illustrated from time to time at various places. On the farm of H. N. Awtrey, less than a mile southeast of a spring (No. 193), two holes, one 16 feet deep and another 80 feet deep (No. 192), were dug and no water was obtained. On the Bramlett place, less than a mile east of the Garcia spring (No. 195), a hole (No. 196) 45 feet deep was dug without getting water. The water-bearing beds are generally underlain at no great depth by an impervious stratum which prevents the water from seeping downward, so that the water table is usually very close to the surface. Along Cloverdale Creek and the area to the south the water in most of the wells stands within 15 feet of the surface. At the Wolf well (No. 185), on the bed

of the old lake, and at the Fitzpatrick well (No. 181), one-half mile farther north, the water is still nearer the surface.

Near the south end of the old lake bed much coarse débris has been washed down from the San Luis Range and deposited in large alluvial fans that extend out over the old lake floor for a mile or more. At a number of places springs emerge at the base of these fans. At the Lang ranch there are two large springs (Nos. 189 and 190), and at the Gavalando ranch, half a mile west of the Lang ranch, there is another spring (No. 197). These springs are probably derived from water that seeps through the porous material of the alluvial slope and is prevented from sinking by underlying impervious lake beds.

The Garcia spring (No. 195), situated near boundary monument No. 67, at the foot of the east slope of the old beach ridge, is believed to be of still more local origin. As has already been pointed out, the drainage from Cloverdale Creek and from a number of other water-courses from the west follows along the outer side of the beach ridge. Some of this water, seeping through the porous materials of the ridge, emerges as a spring at the lower level of the foot of the inside slope (A-A', fig. 14). At a number of places in the region south of Cloverdale and west of the beach ridge the water table comes to the surface and forms springs. In the valley of Cloverdale Creek 1 mile northwest of Cloverdale post office a large spring emerges on the slope on the north side of the creek. It is not surprising that wells and springs have been known to go nearly dry in years of little rainfall when the shallowness of the water-bearing beds and their small storage capacity is considered. As the water supply of any particular year is largely dependent on the rainfall for that year, a single dry year is likely to cause an alarming depletion in the supply, and a number of dry years in succession are almost certain to cause a serious shortage of water. In 1904 nearly all the wells and springs in the valley went dry or diminished greatly in yield, and thousands of cattle died for lack of sufficient water. The records at Lordsburg show that the precipitation in 1904 was 8.70 inches and but little below the average of about 10 inches for the northern region, but that this year was preceded by a 6-year drought, during which the average annual precipitation was only 5.95 inches.

#### QUALITY OF WATER.

Waters were analyzed from the Fitzpatrick well (No. 181) and from a spring at Lang's ranch (No. 189). (See map, Pl. II and Table 2.) They are moderately mineralized calcium-carbonate waters closely resembling those from the Upper Animas Valley. For irrigation, domestic, and boiler use they are entirely satisfactory.

## SOIL IN RELATION TO WATER SUPPLIES.

Several types of soil are represented in San Luis Valley. Gravelly soils occur along the base of the mountains and in parts of the old lake bed which occupies the center of the valley, and sandy soils derived from the sand hills along the northeastern beach ridge cover a small area back of the ridge. Soils consisting largely of silts and sands but usually containing some gravel predominate along Cloverdale Creek. The region outside of the areas mentioned contains soil of all these types and also some soil in which clay is an important constituent.

No surface indications of alkali were noted anywhere in the area. Sample 53, taken in a dry-farmed field half a mile west of the old beach ridge (see map, Pl. I, in pocket), showed on analysis only 0.11 per cent of total alkali and 0.01 per cent of black alkali. In the lowest part of the bed of the old lake north of the Lang ranch, where flood waters occasionally collect, the soils may possibly contain a greater amount of alkali.

## PLAYAS VALLEY.

## LOCATION.

Playas Valley lies between the central and easternmost mountain chains. A low alluvial divide extending from Mount Gillespie, in the Animas Range, to Hatchet Gap, separates the valley into two parts, commonly known as the upper and lower valleys.

## DRAINAGE OF UPPER PLAYAS VALLEY.

Upper Playas Valley is a broad plain that slopes in general northward and is drained through Hatchet Gap into Hachita Valley. From the south end of the valley northward to the Ojo de las Cienegas the east and west sides are drained by distinct systems which are separated by a ridge or swell so inconspicuous as hardly to be detected without the use of leveling instruments. The ridge can, however, be seen extending northeastward from a point on the road  $2\frac{1}{2}$  miles north of the High Lonesome wells. In the vicinity of Ojo de las Cienegas the draws from the two sides unite and form a broad, shallow draw that leads north-northeastward toward the gap.

Deer, Brusby, and Walnut creeks discharge the run-off from most of the west side of the Animas Range. In the mountains, where the channels of these creeks are on rock, small flows are maintained during the rainy summer months and during the colder months late in the fall and in winter, but where they cross the porous sediments of the valley their waters rapidly sink and they flow only during times

of heavy precipitation. Deer Creek, the largest of these streams, rises in the heart of the Animas Range in several branches that lead southeasterly to a point within 3 miles of the Mexican border, where they unite to form the main channel, which continues eastward for 2 or 3 miles along the northern end of the Whitewater Hills, makes a right-angled bend toward the north upon emerging into the plain, continues northward to its confluence with Brushy Creek, and thence leads northeastward to its junction with Walnut Creek,  $2\frac{1}{2}$  miles south of Walnut wells. From this point the trunk channel carrying the combined waters of these three streamways continues northeastward past Walnut wells for several miles but finally becomes indefinite and merges into the plain, where the waters spread in broad shallow draws.

The east-side drainage, although distinct from that on the west side, is less well defined. Most of the run-off from the west side of the Hatchet Range finds its way northward along a shallow draw that extends from a point north of Antelope wells, through the central part of the plain, toward Ojo de las Cienegas. As a rule the storm waters after leaving the mountain arroyos spread over the plain and do not follow any definite channel.

#### DRAINAGE OF LOWER PLAYAS VALLEY.

Lower Playas Valley lies in a small closed basin whose waters drain into an alkali flat known as Playas Lake. It is bounded on the east by the Hachita Range and the Coyote and Quartzite hills; on the west by the Pyramid and Animas ranges, and by an alluvial divide across the gap separating these two ranges. On the north it is separated from the Animas drainage basin by a low alluvial divide, and on the south it is separated from Upper Playas Valley by another low alluvial divide. The total area of the drainage basin is about 370 square miles.

#### PLAYAS LAKE.

*Present "lake."*—Playas Lake is a long, narrow alkali flat that occupies a depression in the axial portion of Lower Playas Valley (Pl. III, A, p. 26). It extends from a point 1 mile north of Lake post office for 14 miles north to a point within  $2\frac{1}{2}$  miles of Playas station. Its greatest width is about  $1\frac{1}{2}$  miles near its north end. Near the south end it narrows in places to less than a quarter of a mile. Its area is about 8 square miles. The surface of the flat when dry is smooth and hard, checkered with innumerable small sun cracks and mottled with brown and white alkali stains. In the rainy season the flat is usually covered with water which is rarely over a few inches deep.

From the floor of the barren flat rather abrupt slopes lead up to the edge of the detrital plains, which extend in more gradual slopes to the bases of the mountains that border the valley on either side. (See fig. 16, p. 114.)

*Ancient lake.*—Certain evidence tends to show that the depression now occupied by the barren alkali flat of the dry season and the evanescent lake of the rainy season contained at a former time a much more permanent and larger body of water. At different points around the perimeter of the depression the plain ends in a short, abrupt slope or bluff that faces the flat and is strewn with flattened, waterworn pebbles which resemble the typical shore shingle of modern beaches. On the west side a low bluff, resembling a beach terrace, extends from Playas station southward nearly to the Whitmire ranch. At various other points this same feature is seen, but at no place is it so distinct and continuous for such a long distance.

The former existence here of a permanent lake is suggested by several other features, such, for example, as the belt of sand dunes that stretches along the eastern edge of the alkali flat for 6 miles near its northern end. On the eastern edge, near the southwest corner of the NW.  $\frac{1}{4}$  sec. 9, T. 28 S., R. 17 W., near the top of a rather abrupt slope up from the flat is a deposit of soft, reddish, stratified sandstone that contains many small tubular cavities which are lined with a calcareous substance and which may have been produced by organisms that lived in the shallow water on the shores of the ancient lake.

The old shore line can be traced with reasonable accuracy along the east and west sides. At many places the shore features have been obliterated by erosion, but by connecting the points where they can be identified the course of the ancient strand can be fairly well outlined. At the north and south ends of the old lake shore features are generally lacking, and the position of the shore line is largely a matter of conjecture. From Playas station the depression continues northward as a shallow, gradually narrowing draw nearly to the divide northwest of the Quartzite Hills. No shore features occur here, but judging from the general elevation of the ground the lake probably filled this draw. At the south end, in the vicinity of Hatchet Gap, the depression broadens out and merges imperceptibly into the plain of Upper Playas Valley. As no shore features have been preserved the position of the ancient lake shore is here very uncertain, but it was apparently near the drainage divide that separates Upper Playas Valley from Lower Playas Valley.

From the elevation of the old shore line above the floor of the present flat, it appears that the depth of water in the deepest part of ancient Lake Playas was 35 to 40 feet.



## GROUND WATER.

## WATER-BEARING BEDS.

The occurrence of the ground water in Playas Valley is in many respects similar to that in Lower Animas Valley. Sediments which consist of unconsolidated clays, sands, and gravels and are saturated to the level of the water table fill the intermontane rock trough to an unknown depth. There is no record of borings in the valley having gone down to bedrock, but from the records of at least one well it is known to be very deep in the center of the valley. This well (No. 264), drilled on the Winkler place in the SE.  $\frac{1}{4}$  sec. 7, T. 30 S., R. 16 W., in search for artesian water, was put down to a depth of 836 feet through the valley fill. Another well (No. 301), 13 miles south on the old Cheney place, in the SE.  $\frac{1}{4}$  sec. 18, T. 32 S., R. 16 W., is said to have been drilled down 350 feet without striking bedrock. Still farther south two wells (No. 312) at High Lonesome are, respectively, 265 and 250 feet deep. The Antelope wells (No. 313), about 1 mile north of the Mexican border and less than 2 miles from the edge of the hills, are said to be over 200 feet deep. All these wells apparently end in valley fill.

If the rock trough occupied by Playas Valley was excavated by erosion the fill may be deepest in the middle. If, on the other hand, the trough has resulted from faulting along the west front of the Hatchet Range, as is suggested by the structure of the tilted lava blocks and by the high limestone cliffs, the lowest part of the trough is probably on the east side near the fault line.

The different classes of material making up the valley fill are as a rule sorted and laid down in layers which are locally distinct but not continuous. The plotted logs of wells in different sections of the valley are shown on Plate VIII. The wells whose logs are given are fairly typical of the sections in which they are situated.

Wells in the Lake and Hatchet Gap regions generally pass through three strata of sand or gravel. The first stratum, consisting usually of coarse, clean sand, is reached within 10 to 15 feet of the surface; the second, consisting usually of gravel and coarse sand, is within 40 to 50 feet of the surface; and the third, consisting of gravel, within 60 to 70 feet of the surface (Pl. VIII). The first stratum is, in most of the wells, above water level and consequently dry, but the second and third strata are generally saturated and yield water freely, the third usually yielding the most. That more water-bearing beds may be found below the depth to which wells are usually drilled in this region is shown by the record of the deep well drilled on the Winkler place, in which no less than nine water-bearing beds were penetrated between the depths of 300 and 350 feet. The following log of this well was furnished by Mr. A. S. Lewis from memory:

*Log of Winkler well (No. 264), in the SE.  $\frac{1}{4}$  sec. 7, T. 30 S., R. 16 W.*

	Thickness.	Depth.
	<i>Feet.</i>	<i>Feet.</i>
Clay.....	50	50
Nine or 10 strata of water-bearing gravel and coarse sand from 2 to 10 feet thick, interbedded with impervious clay.....	300	350
Mostly coarse cemented "rhyolite" sand or fine gravel.....	486	836

The material separating the strata of porous sand and gravel is impervious clay or a mixture of sand and clay which in many wells is firm enough to stand without casing. A calcareous substance known as caliche was reported in the upper portions of many of the wells.

In the vicinity of Walnut wells the succession of beds is in general similar to that farther north.

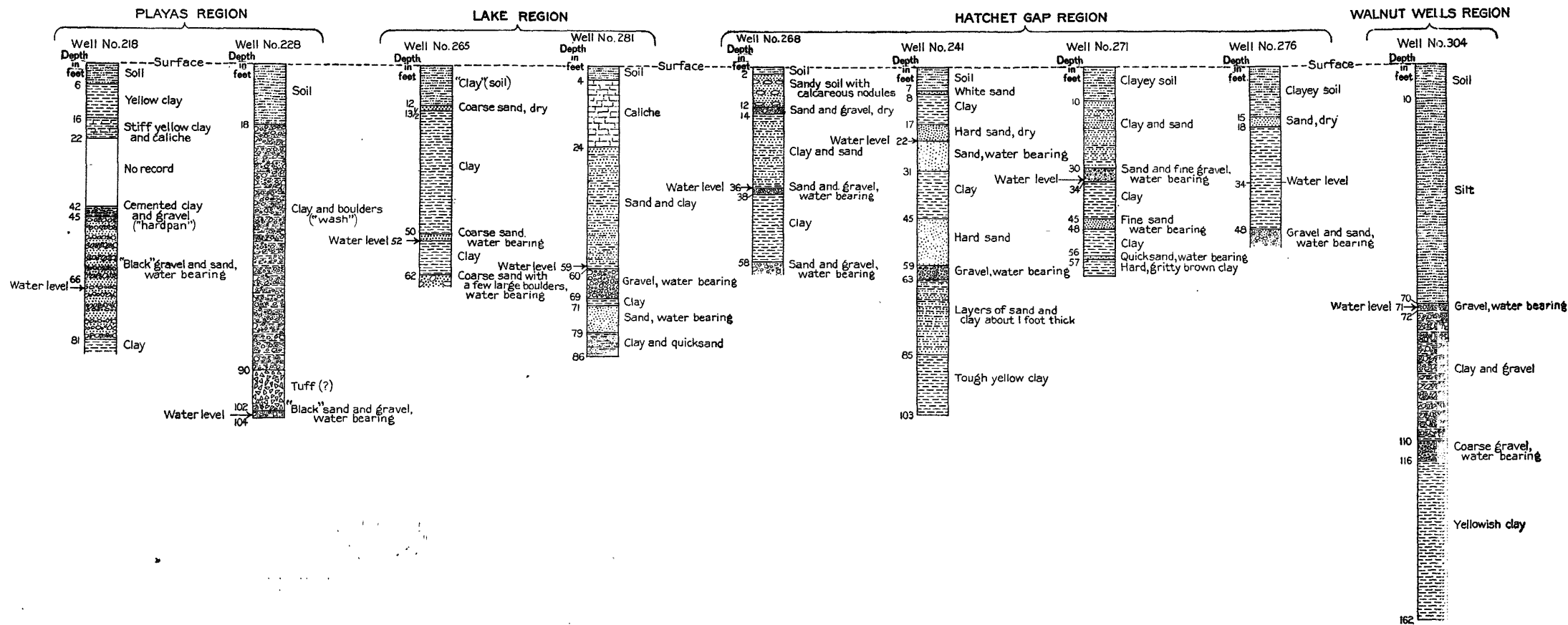
The Britton well (No. 307) in a depth of 74 feet passed through four thin strata of fine gravel. The well of R. K. Keith (No. 300) penetrates the first gravel stratum at a depth of 25 or 30 feet, and from that depth down to the water level at 59 feet passes through alternate layers of clean gravel and reddish clay. In the Massey well (No. 304) there are two water-bearing beds of coarse gravel the first between the depths of 70 and 72 feet and the second between 110 and 116 feet. (See Pl. VIII.)

In the vicinity of Playas none of the wells of which records were obtained penetrated below a first horizon of water-bearing beds. The character and arrangement of the water-bearing beds varies a good deal from place to place. In some wells the water is contained in a single thick bed of sand and gravel. In F. S. Cooper's well (No. 218), at the post office, this bed is reported to be 36 feet thick (see Pl. VIII), and a similar thick bed of sand and gravel is reported in the well of Turnley Walker, half a mile north. In other wells in this vicinity the water-bearing beds at the same horizon are thin beds of sand between layers of clay or hardpan. Below the hardpan the water is in many places under some pressure, so that when a hard layer is penetrated the water rises 5 or 6 feet in the well.

The record of well 228, plotted on Plate VIII, shows conditions on the stream-built slope west of Playas. In this well a single thin bed of water-bearing sand and gravel was found at the bottom between depths of 102 and 104 feet. The overlying material consisted largely of "wash," a mixture of poorly assorted gravel in a matrix of sandy clay.

#### FORM OF THE WATER TABLE.

The principal additions to the ground-water supply are made near the base of the ranges that bound the valleys where the mountain streams emerge upon the loose, porous detrital deposits of the plains;



SECTIONS OF WELLS IN PLAYAS VALLEY.

therefore the water table is highest here and slopes toward the lower parts of the valley. A section across the valley would show the water table as a concave line, not concentric with but in general respects similar to the surface of the land. From the center of the valley toward the base of the mountains both the surface of the land and the water table rise, but as the ground surface has the greater gradient they gradually diverge as they approach the mountains so that the depth to water increases.

The rise of the water table in the direction of the mountains is well shown by comparing the water levels in two wells near the north end of the alkali flat. In well 227, on the west margin of the flat, the depth to water is 42 feet; in well 225, 2 miles to the east, on the slope leading up from the opposite side of the flat, the depth to water is 52 feet. The ground surface at well 225 is at least 30 feet higher than well 227. Therefore the water table rises 20 feet, or 10 feet to the mile.

As in Animas Valley (pp. 89-91), the water table has a gentle slope northward in the direction of its longitudinal axis. In the upper valley between Walnut wells and Hatchet Gap the grade is very slight, but in the lower valley it is quite decided.

At Walnut wells the depth to water is 50 feet and at Hatchet Gap it is about 35 feet, a difference of 15 feet. The ground surface at Walnut wells is estimated to be about 25 feet higher than at Hatchet Gap; therefore the water table is 10 feet higher, and a grade of 0.7 foot per mile in 14 miles is indicated.

In the lower valley the alkali flat serves as a convenient datum plane for calculating the grade of the water table, for when the flat is flooded the water is spread over the entire surface to a nearly uniform depth, showing that the floor is almost level. At the southern end of the flat the water table can be reached by boring to a depth of about 4 feet. Near the northern margin of the flat the depth to water in well 227, which is 15 feet above it, is 42 feet. From the floor of the alkali flat, therefore, the depth to the water table must be about 27 feet, or 23 feet more than at the other end of the flat, 14 miles south. This relation gives an average grade of 1.6 feet per mile.

The decline of the water table northward in the lower valley as well as in the upper valley is significant. It indicates, first, that the ground water of the upper valley moves northward into the lower valley and that little if any of the water escapes through Hatchet Gap into Hachita Valley, and, second, that the combined ground waters of Upper Playas and Lower Playas valleys find an outlet somewhere north of Playas.

That little ground water from Upper Playas Valley escapes through Hatchet Gap is also indicated by the fact that in the vicinity of the gap the water table of Playas Valley is much higher than in Hachita Valley, the water bodies of the two valleys probably being separated

by a rock barrier that spans the gap underground. (See p. 122.) Along the east and west sides the water body of Lower Playas Valley is inclosed by the rock masses of the mountains, so that if the combined ground waters of the upper and lower valleys escape from the basin it must be northward beneath the open plain into Lordsburg Valley, where the water table is lower than in Playas Valley. As the water table of Lordsburg and Animas valleys also declines in a general northerly direction, it may be that the ground waters of Playas Valley eventually reach the Gila basin together with those of Lordsburg and Animas valleys. (See pp. 71, 90.)

#### PRINCIPAL SHALLOW-WATER AREA.

Playas Valley comprises approximately 150 square miles in which the water-bearing beds are less than 100 feet below the surface, including 70 square miles in which depth to water ranges from 50 to 100 feet, 60 square miles in which it is 25 to 50 feet, and 20 square miles in which it is 25 feet or less. (See Pl. II, in pocket.) At the south end of the alkali flat water was found at a depth of  $3\frac{1}{2}$  feet. The zone in which the depth to water is less than 25 feet extends in a narrow strip from the Whitmire ranch south to the divide between the upper and lower valleys and includes the south half of the alkali flat. The second zone, in which the depth to water is between 25 and 50 feet, encircles the first zone, includes the north half of the alkali flat, and extends from Playas station south to Walnut wells. The third zone, in which the depth to water is between 50 and 100 feet, extends around the second zone,  $4\frac{1}{2}$  miles north of Playas and southward to a point  $2\frac{1}{2}$  miles south of Walnut wells.

The data represented on the ground-water map (Pl. II) were obtained by measuring the water level in about 100 wells. Most of the wells are grouped in three general areas, namely, in the vicinity of Playas station, where the average depth to water is between 50 and 60 feet, the vicinity of Hatchet Gap, where the average depth to water is between 25 and 40 feet, and the vicinity of Walnut wells, where the average depth to water is between 55 and 70 feet.

#### SHALLOW-WATER AREA AT POT HOOK.

East of Playas the front of the northward-trending Hachita Range swings sharply to the northeast and brings the range to a point one-half mile south of the El Paso & Southwestern Railroad. The Coyote Hills to the north likewise come to a point one-half mile north of the railroad by a sudden swing toward the southeast. A wedge-shaped sector of Playas Valley extends into the recess thus formed to the alluvial divide separating the Playas and Hachita drainage basins. Pot Hook, a settlement of five or six families, is

near the center of this sector along a shallow draw that drains from the Hachita Valley divide westward toward Playas.

Along this draw, within an area of about 1 square mile, are 8 or 10 wells, most of them not more than 50 or 60 feet deep. The depth to water in the wells that were measured ranges from 17 to 38 feet. The elevation of the water table is about 4,510 feet above sea level, or 280 feet higher than at Playas.

The conditions believed to produce the high-water table at Pot Hook are represented in figure 15.

The ground-water body appears to be perched on a rock shelf above the main body of ground water of Playas Valley, the water being contained in the porous rock waste that covers the shelf and being prevented to some extent from seeping away into the deep valley fill to the west by some sort of a rock barrier near the outer edge of the shelf. Basalt and other fine-grained volcanic rocks

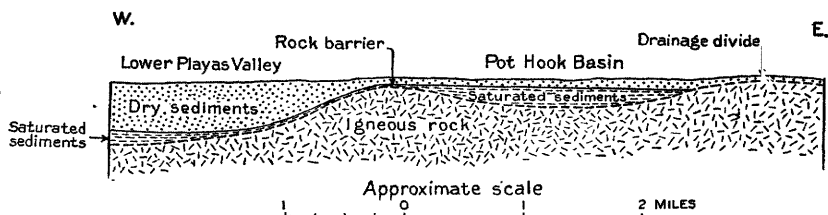


FIGURE 15.—Hypothetical section showing conditions producing shallow water at Pot Hook.

which may be parts of such a barrier outcrop on the plain at a number of places near the western margin of the shallow-water area.

The wells furnish sufficient water for watering stock and for domestic uses, but the quantity available for irrigation is probably very small, as all the water in this area comes from the rain that falls on the surface and the storm waters shed from a small drainage area.

#### SPRINGS.

Springs emerge at intervals along nearly the whole western margin of Playas Lake. Some of the inhabitants of the region attribute the origin of these springs to a very deep-seated mysterious agency. At some of the springs much bluish mud is exuded, which piles up around the mouths of the springs and becoming dry forms "mud hummocks." During the summer of 1913 some one claimed to have discovered that these mud deposits indicated the presence of oil, so that considerable local excitement resulted and the whole alkali flat and much of the contiguous territory was staked out as oil land.

All the springs are near the base of the rather steep slope on the west side of the Playas Lake depression. In one place, at least, where a well and a spring were found close together, it was definitely

determined that the normal water table and the first water-bearing stratum in the well were at a considerable elevation above the outlet to the spring, as is shown in figure 16. From this it would seem that the springs are caused by the Playas Lake depression, which extends below the normal ground-water level.

At one place, near the south end of the alkali flat, the relative positions of the well and spring are reversed, well 239, in which the depth to water is 10 feet, being below spring 254. This condition may, however, be explained by assuming that the spring is the result of leakage from the first water stratum, which has been completely worn away at the well, and that the water stratum tapped by the well is really a second and lower water-bearing bed.

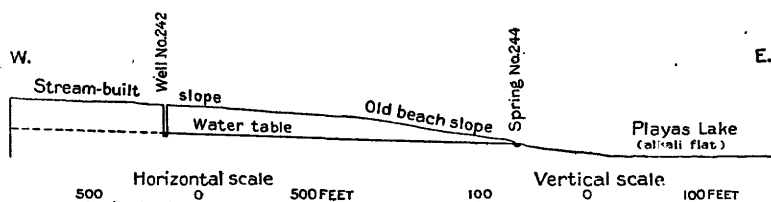


FIGURE 16.—Section showing position of water table and typical conditions causing springs at outcrop of water-bearing beds on west side of Playas Lake depression

#### ARTESIAN WATER.

*Wells at Ojo de las Cienegas.*—The only flowing wells in the valley are the two at Ojo de las Cienegas (No. 294). The first well was bored in 1899 and is 4 inches in diameter and 98 feet deep. The second well, bored in 1904, is 6 inches in diameter and 102 feet deep. In December, 1913, the first well was discharging 1.6 gallons per minute through an outlet 7 feet above the ground and the other was flowing at the rate of 4.6 gallons per minute from an outlet 4 feet above the ground. The flow is continuous and is collected in a large earth reservoir (Pl. IX, A). The supply is sufficient for several hundred head of stock, for domestic use at the ranch, and for a small garden.

It is reported that in boring the wells layers of cemented calcareous material were encountered at several horizons and that one of these layers lies immediately above the water-bearing bed of quicksand. This condition partly explains the presence of artesian water, for if an impervious stratum of this character occurs under the water-bearing bed and if these impervious strata with the interposed water-bearing bed continue up the slope to an elevation above the mouth of the well the water that seeps into the water-bearing bed at this higher level and down between the confining layers would, if tapped at a lower level by borings, rise above the surface. A spring (No. 292) three-eighths of a mile north of the wells may be explained in a similar way, for many springs are essentially natural artesian wells and are governed by the same general laws.



4. ARTESIAN WELLS DISCHARGING INTO EARTH STORAGE RESERVOIR; OJO DE LAS CIENEGAS.



B. BLUFFS BORDERING ANIMAS CREEK TROUGH.



*Prospects.*—The conditions upon which artesian flows at Ojo de las Cienegas depend are evidently local. In other parts of the valley attempts to get artesian water have not been successful. The Winkler well, in the valley 6 miles below Ojo de las Cienegas, is reported to have been drilled to a depth of 836 feet. An earlier attempt was made on the old Cheney place, 7 miles above Ojo de las Cienegas, where a well (No. 301) was put down to a depth of 350 feet. In the Winkler well the water is said to have risen at first within 15 feet of the surface but now stands at the common water level of the region. In this well the last 486 feet of drilling was in part consolidated sediments. (See log on p. 110.) If the log of the well as reported is reliable it would seem to indicate that the deeper valley sediments have become cemented to such an extent as to destroy their water-bearing qualities. The tests have, however, been too few to be regarded as conclusive.

#### QUALITY OF WATER.

*Upper Playas Valley.*—Waters were analyzed from wells 273, 294, 297, 303, 306, 312, and 313. (See map, Pl. II, in pocket, and Table 2.) They include three sodium-carbonate waters (wells 273, 294, and 313), three calcium-carbonate waters (wells 303, 306, and 312), and one magnesium-carbonate water (well 297). Calcium-carbonate waters predominate south of the vicinity of Ojo de las Cienegas and sodium-carbonate waters north of Ojo de las Cienegas. In total mineral content the waters range from 144 to 437 parts per million. In general the mineralization of the waters increases toward the north, the water with the least soluble matter occurring in the High Lonesome wells (No. 312) and the most highly mineralized water in the South Hatchet wells (No. 273).

Conditions of soil and ground water are favorable for irrigation farming in most of the central valley plain north of Walnut and Gilbert wells, the districts most favored by settlers being at the north end of this area in the vicinity of Hatchet Gap and at the south end near Walnut wells. All the waters from the Walnut wells district have been classed as good for irrigation. From the Hatchet Gap district the only water that was analyzed is that from the South Hatchet wells (No. 273). As an irrigating water it compares favorably with those classed as fair in Lower Playas Valley. Natural conditions in this part of the valley do not favor an excessive accumulation of alkali in the soil and most of the waters can probably be used successfully.

For domestic use all the waters have been classed as good. For boiler use the artesian water from Ojo de las Cienegas (well 294) is probably the best and that from well 273 at the South Hatchet wells the worst. The others are fair boiler waters.

*Lower Playas Valley.*—Waters were analyzed from wells and springs Nos. 201, 205, 218, 225, 227, 228, 237, 241, 246, 256, and 265 in Lower Playas Valley. (See map, Pl. II, in pocket, and Table 2.) They include one sodium-sulphate water containing 6,913 parts per million of total solids (well 201, 4 miles northeast of Playas) and one calcium-sulphate water containing 55 parts per million of total solids (well 205, at Pot Hook). The others are sodium-carbonate waters whose mineral content ranges from a minimum of 253 parts per million of total solids at the south end of the valley to a maximum of 501 parts per million in the northern part. It has been shown that in Lower Animas Valley the mineral content of the waters increases northward in the direction of the slopes of the water table (pp. 94-97). In Lower Playas Valley the water table also slopes northward and there is a similar increase in the mineralization of the waters in that direction. The recent geologic history of the two valleys is very similar. In both valleys alkali flats exist as remnants of former lakes in which the drainage waters collected. Upon evaporation of the water some of the salts carried in solution were precipitated and became mixed with the fine sediments that settled in the still waters of the lakes. It is probable that some of the more highly mineralized waters found in the northern part of Lower Playas Valley originated at the other end of the valley and attained their present concentration in their passage northward by coming in contact with buried sediments impregnated with alkali.

The calcium-sulphate water from well 205, at Pot Hook, is the only water of this type represented among the waters from southern Grant County that were analyzed. The fact that it differs from the other waters of Lower Playas Valley is not surprising when it is remembered that the water body of the Pot Hook Basin is distinct from the main ground-water body and perched several hundred feet above it (p. 113).

For irrigation the waters from wells 205 and 225, and springs 237 and 256 have been classed as good, those from wells 218, 227, 228, 241, 246, and 265 as fair, and that from well 201 as poor. The best waters are from spring 256, near the south end of the alkali flat, and from spring 237, at the Whitmire ranch. Both springs are on uneven alkali land that is poorly adapted for irrigation. The waters from wells 241 and 265, classed as fair, were being used successfully for irrigation when the region was visited in 1913. Waters of this kind should give equally good results in other parts of this district.

In the shallow-water area in the vicinity of Playas all the waters except that from well 201, and possibly that from well 227, are satisfactory irrigating waters. The water from well 227 contains more sodium and carbonate than any of the other waters of this class and

might cause trouble if used on poorly drained soil. The water at Pot Hook is satisfactory for irrigation.

For domestic use all the waters are good except those from wells 201 and 205, which have been classed as unfit and bad, respectively. The calcium-sulphate water from well 205 is acceptable for drinking but is not very satisfactory for cooking or washing on account of its hardness. The water from well 201 is unfit for all domestic uses. It is not only very hard but is unpleasant to taste and would probably prove unhealthful. For boiler use the water from well 205 is classed as bad, that from well 201 as very bad, and that from wells 218, 227, and 228 as poor. The last three can not well be used in the raw state but may be made usable by chemical treatment. The other waters from the valley are classed as fair. They may be used in the raw state but will be improved by preliminary chemical treatment.

#### SOIL IN RELATION TO WATER SUPPLIES.

*Upper Playas Valley.*—From the vicinity of the Gilbert wells and Walnut Wells northward to the divide between the Upper Playas and Lower Playas basins the soils are composed principally of fine sand, silt, and clay; southward from these wells to the Mexican boundary the soils are predominantly sandy. The soils on the upper parts of the stream-built slopes, close to the mountains, are of the usual gravelly type.

Soil samples 44, 47, 48, 50, 51, and 52 were collected in Upper Playas Valley. The results of analyses are given in the table on pages 144-149, and the localities at which the samples were taken are shown on the map (Pl. I, in pocket). The soils represented by these samples contain only from 0.11 to 0.28 per cent of total alkali and from 0.02 to 0.15 per cent of black alkali. None of the samples show harmful amounts of either white or black alkali except No. 47, taken  $1\frac{1}{2}$  miles north of Ojo de las Cienegas, which is near the toleration limit of most crops.

*Lower Playas Valley.*—In Lower Playas Valley conditions of drainage and soil are similar to those in Lower Animas Valley. Clay soils occur along the longitudinal axis of the valley in a belt from 1 to  $1\frac{1}{2}$  miles wide and extending from the south margin to a point within 4 miles of the north margin of the drainage basin. A part of this area is occupied by the barren flat known as Playas Lake, in which flood waters charged with mineral matter and fine sediments in suspension collect from all parts of the watershed. Upon evaporation of the water the fine clay of sediments and the dissolved mineral matter are left on the ground and form a compact, almost impervious clay soil strongly impregnated with alkali.

Bordering the narrow central belt of clay soils on both sides and forming the surface of the lower portions of the stream-built slopes are broader belts of sandy soil that grade into the gravelly soil of the intermediate and upper portions of the slopes.

Soil analyses and study of the surface indications of alkali and the vegetation were used in outlining on the map (Pl. I, in pocket) the approximate area in which the soils contain an excessive amount of alkali. It is a comparatively small area, including the barren alkali flat and a narrow zone surrounding it. Of the soil samples collected from this area, No. 32, taken 3 miles north of the Whitmire ranch in the barren flat, shows the largest amount of alkali. It contains 1.28 per cent of total alkali, of which about one-fourth is black alkali. Samples 31 and 39, taken on the slopes bordering the barren flat, contain, respectively, 0.49 and 0.62 per cent of total alkali and 0.20 and 0.13 per cent of black alkali.

The horizontal distribution of alkali in the soil is very uneven—that is, the alkali is largely confined to certain spots usually to be detected by the familiar surface indications. Thus even in small fields the alkali content may vary greatly from place to place.

This irregularity of distribution is well illustrated by two samples (Nos. 37 and 38) taken on the Lane farm, about 1 mile southeast of the south end of the barren flat. These two samples, although taken within less than one-fourth mile of each other, show wide differences in content of alkali. Sample 37, taken in an alkali spot in an irrigated orchard, contains 0.50 per cent of total alkali and 0.23 per cent of black alkali, whereas sample 38, taken in an alfalfa field, contains only 0.14 per cent of total alkali and 0.07 per cent of black alkali, a quantity almost negligible as far as the successful growing of ordinary crops is concerned. It is probable that the area indicated on the map contains small tracts of fairly good soil, and that, on the other hand, there are localities outside of the area indicated in which the soil contains undesirable amounts of alkali.

Outside of the area outlined on the map the soils do not, however, in general, contain enough alkali to interfere seriously with the successful growing of crops. The clay soils in the vicinity of Playas station, represented by samples 25 and 28, are rather high in black alkali—0.14 and 0.13 per cent, respectively—although the amount of total soluble salts (0.31 and 0.26 per cent) is relatively low. Sample 43, representing a clay soil from the southern part of the valley, contained only 0.15 per cent of total alkali and 0.09 per cent of black alkali.

The sandy soils bordering the central clay belt contain only relatively small amounts of alkali. In these soils, represented by samples 29, 35, 40, and 42, the total alkali ranged from 0.17 to 0.25 per cent and the black alkali from 0.02 to 0.10 per cent.

## IRRIGATION.

Out of more than 100 wells in Playas Valley in 1913 only two were equipped with pumping machinery adequate for irrigation on a considerable scale. Most of the settlers have come into the region recently, and have thus far irrigated only small patches by the aid of windmills or small, inexpensive gasoline engines attached to ordinary plunger pumps.

The pumping plant of A. F. Lane (well 241), 5 miles northwest of Hatchet Gap, in the SW.  $\frac{1}{4}$  sec. 32, T. 29 S., R. 16 W., consists of a small gasoline engine connected to a plunger pump that lifts about 80 gallons of water per minute. In 1913 there were about 60 acres of land under cultivation, mostly in alfalfa and maize. The plant is of course inadequate for the irrigation of this amount of land, but a fair crop was raised.

A 4-horsepower pumping plant belonging to A. S. Lewis (well 265), in the SW.  $\frac{1}{4}$  sec. 7, T. 30 S., R. 16 W., delivers about 60 gallons per minute. Mr. Lewis supplements the pumped water by making use of flood waters which come down the slopes from the west and which are controlled and diverted into the irrigating ditches by a series of low embankments and shallow ditches usually made with a plow.

## HACHITA VALLEY.

## PHYSIOGRAPHY AND DRAINAGE.

Hachita Valley is characterized by a well-marked central draw that extends from a point a short distance south of Black Mountain southward to the vicinity of Hatchet Gap, and thence southeastward to the Mexican border. North of Hatchet Gap the draw would hardly be identified as a distinct topographic feature if its conspicuousness were not greatly magnified by the uniformly thick and luxuriant growth of forage grasses on its clayey bottom in contrast to the more scattered and sparse growth on the more gravelly and less well-watered slopes of the bordering plain. The position of its boundaries as indicated on the map (Pls. I and II, in pocket) is based almost entirely on these differences in soil and vegetation.

South of Hatchet Gap the boundaries of the draw are sharply defined by parallel lines of bluffs, which represent the truncated edges of the detrital slopes that extend down from the base of the ranges bounding the valley. The bluffs are first seen along the north side of the draw a mile west of the Hatchet ranch. At the Hatchet ranch they appear on both sides of the draw, and they continue with few interruptions and gradually increasing height along both sides to the Mexican border. The average height of the top of the bluffs above the floor of the draw is about 18 feet, the maximum height at several places being 25 or 30 feet.

The excavation of the draw in the lower part of Hachita Valley below the level of the plain has started a general dissection of the alluvial slopes leading down from the Hatchet Mountains and the Apache Hills. The lowering of the outlet for the flood waters coming down the slopes is causing these waters to cut deeply into the slopes which they formerly built up and tending to confine them to definite channels which open into the main central draw through gashes in the bluffs. Many of the larger gullies have cut back considerable distances from the central draw and developed into tributary draws similar to the main draw.

A feature resembling an old shore line exists a quarter of a mile west of the Cabin wells, near the Mexican boundary. (See map, Pl. I.) The presence of this feature and the appearance of the broad level plain to the east in Mexico leads to the belief that there existed here one of the lakes so common at a certain period in recent geologic time throughout this area and in adjoining areas in Arizona.

The physiographic conditions in the lower part of Hachita Valley are exactly parallel to those in Upper Animas Valley. In each the draw is a central trough cut into the valley fill and bounded by bluffs which are the truncated edges of the alluvial slopes; in each the draw presumably opens at the lower end upon an ancient lake bed; and in each the stream-built slopes have been extensively dissected by the lowering of the base-level.

#### GROUND WATER.

##### OCCURRENCE AND QUANTITY.

In Hachita Valley the ground water occurs in the main body of valley fill. The well data available are too meager to give a very definite idea of the character and arrangement of the sediments, but as the valley is a typical waste-filled trough the conditions are probably similar to those in the other valleys where the bulk of the material is stream laid. A generalized section would probably show a succession of thin lenticular beds of clay, sand, and gravel interbedded with thicker beds of "wash" consisting of an unsorted mixture of these three classes of material. The sediments underlying the central draw near the Mexican boundary are probably better sorted and more regularly arranged than those underlying the greater part of the valley because here they have probably been laid down in the still waters of a former lake.

The yield of the water-bearing beds has never been thoroughly tested. With the exception of the railroad well at Hachita, which supplies the railroad and the town, none of the wells in the valley are required to furnish water except for watering stock and for domestic uses. The only part of the valley where water is reached within

economical pumping distance for irrigation is the small area near the Mexican border. The quantity of water available here is believed to be ample for all needs, even if irrigation were extended over the whole area. In the rest of the valley, where irrigation is not feasible, the quantity of water available is believed to be sufficient for all needs likely to arise in connection with the further extension of the industries for which the region is best suited, namely, dry farming and stock raising.

#### DEPTH TO WATER.

The shallowest water is found at the lower end of the arial draw near the Mexican boundary, where, in the Cabin wells, the water table stood 13 feet below the surface in September, 1913. Up the draw the depth to water steadily increases. At Double wells, 2 miles above the Cabin wells, the depth to water is 47 feet; at the Hatchet ranch, 10 miles above, it is 111 feet; at the North Hatchet wells, 15 miles above, it is 165 feet; at the Eightmile wells, 18 miles above, it is 203 feet, and at Twomile wells, 25 miles above, it is 253 feet. The average increase for 25 miles is about 10 feet per mile. From the axial draw toward the mountains the depth to water probably increases more rapidly.

The area near the Mexican border within which the depth to water is less than 100 feet contains about 9 square miles and is in the shape of a triangle whose base extends for 5 miles between boundary monuments 44 and 45 and whose apex is in the middle of the draw, 3 miles west of the international boundary.

The area includes a tract of 2 square miles in which the depth to water ranges from 25 to 50 feet and a tract of 1 square mile in which the water is less than 25 feet from the surface. (See Pl. II, in pocket.)

#### POSITION OF THE WATER TABLE.

By comparing the elevation of the surface of the ground and the depth to water at the extremities of the valley it is shown that the water table slopes southward along the axis of the valley in the same direction as the land surface but at a lower rate. At the Twomile wells, near the north end of the valley, the elevation of the ground is about 4,440 feet above sea level, and the depth to water 253 feet (well 316, Table 1), so that the elevation of the water table is about 4,187 feet. At the Cabin wells, at the south end of the valley, the elevation of the ground is about 4,135 feet, the depth to water 13 feet (well 315, Table 1), and the elevation of the water table about 4,122 feet. In a distance of 25 miles, therefore, the land surface descends 305 feet, or approximately 12 feet per mile, and the water table descends 65 feet, or about  $2\frac{1}{2}$  feet per mile.

The southward slope of the water table indicates that there is a general movement of the ground water in that direction to an outlet somewhere in Mexico.

Figure 17 shows the relation of the water table in Hachita Valley to that of Playas Valley in the vicinity of Hatchet Gap. No wells were found in the Hachita Valley near the gap, so that the exact depth to water could not be determined. Some inhabitants in the region state that water can not be obtained here, but whether their opinion is founded on fact or merely on conjecture is not known. The depth to water in the nearest wells in the central draw of the valley gives some clue as to the probable depth to water at the gap. For instance, at North Hatchet wells the depth to water is 165 feet and at the Hatchet ranch it is 111 feet, a decrease southward of 11 feet per mile. If the average decrease is the same between North Hatchet wells and Hatchet Gap the depth to water there should be about 130 feet.

In Playas Valley the depth to water in the vicinity of the gap is about 27 feet, or approximately 100 feet less than in Hachita Valley.

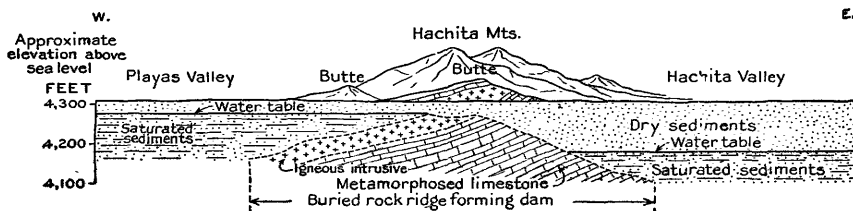


FIGURE 17.—Hypothetical section showing subterranean rock barrier across Hatchet Gap separating ground-water bodies of Hachita and Playas valleys.

This difference is probably caused by the rock masses of the Hatchet and Hachita ranges being continuous at a short distance below the surface and forming an effective barrier against the escape of ground water from the Playas Valley into the Hachita Valley but making no interference with the free passage of surface drainage through the gap. As the principal movement of ground water in the Playas Valley is believed to be northward, it is probable that little water ordinarily spills over the underground dam (p. 111). If, however, the ground water in Playas Valley rises above the top of the barrier, some underflow takes place and the subterranean rock dam acts as a regulator to limit the height of the water table in Playas Valley. If the ground water is at present spilling over, this level may indicate the approximate level of the top of the underground dam.

#### ARTESIAN CONDITIONS.

According to local report, there is a flowing well in the valley on Mexican territory about 3 miles east of boundary monument 45, but none of the wells on United States territory flow.

In one of the Cabin wells, one-fourth mile west of the Mexican line, the water is under some pressure, but not enough to bring it to



the surface. This well consists of a dug pit 20 feet deep and a drill hole extending about 125 feet below the bottom of the pit. When the well was being finished the water is reported to have flowed over the top of the casing at the bottom of the pit and to have risen to about the present water level in the well, which is 13 feet below the ground surface. In the other wells in the valley, except the railroad well at Hachita, the water is under little or no head.

Most of the wells in the valley have been drilled only a short distance below the normal water level and are not deep enough to be regarded as tests for artesian water. The deepest well is the one belonging to the El Paso & Southwestern Railroad at Hachita, which is down 685 feet. The following incomplete log of this well was taken from the "well profile" sheet, furnished by the railroad through Mr. R. S. Trumbull:

*Log of well (No. 315) of El Paso & Southwestern Railroad at Hachita.*

	Thickness.	Depth.
	<i>Feet.</i>	<i>Feet.</i>
Gravel.....		105
Coarse gravel.....		135
Conglomerate, no water.....		285
Very coarse gravelly wash.....		305
Very hard shale.....		375
Red gravel; water rose 100 feet; firm flow.....		415
Running sand.....		455
Solid blue flint.....	15	465
Hard white shale.....		505
Quicksand.....	7	525
Hard gray shale.....		555
Very hard conglomerate.....		565
Coarse gravel.....		585
Coarse gravel.....		635
Sand; no water.....		655
Solid boulder.....	10	685

The log is incomplete in that the thicknesses of the different materials are not given and the descriptions of the materials are rather vague, but it is sufficient to show that conditions in the northern part of the valley are probably not favorable for artesian water. Although the water was under considerable pressure in a gravel bed, encountered at a depth of 415 feet below the surface, it did not rise above the normal level of the water table in the region. Furthermore, the "solid boulder, 10 feet thick," reported in the bottom of the well, may be the bedrock, and if so, deeper drilling in search of other beds containing water under greater pressure would be futile.

In the southern part of the valley conditions are believed to be more favorable for artesian water. Here the valley is more trough-like, the stream-built slopes being large and inclining steeply from the borders of the mountains, and in addition, the central draw is sunk below the general level of the surface. In the area of shallow water near the Mexican border the water is under some pressure even at comparatively shallow depths, and if deeper beds were penetrated it

is possible that water would rise to the surface. Even in this locality, however, deep drilling for artesian water should not be undertaken without due consideration of the expense and uncertainty of the venture.

#### QUALITY OF WATER.

Waters analyzed from wells 315, 319, 320, 321, 322, 323, 324, and 325 (see map, Pl. II, and Table 2) include four sodium-sulphate waters, two sodium-carbonate waters, and two calcium-carbonate waters. The different kinds of water are irregularly distributed, none of the types represented persisting over any considerable area. In the region between Hachita and the Badger well the amount of dissolved matter in the waters is fairly constant, ranging from 509 to 577 parts per million. In the region between the Badger well and the Mexican boundary the degree of mineralization of the waters varies between wide limits, ranging from 337 to 1,659 parts per million of total solids.

For irrigation all the waters from the region north of the Hatchet ranch are classed as good. On account of the depth at which they occur, however, it is doubtful whether they could be profitably pumped. In the region south of the Hatchet ranch the waters are as a rule of poorer quality. That from well 325 (Cabin wells) compares favorably with the best of the waters from the northern region, but the others are only fairly satisfactory for irrigation. Of the two waters analyzed from the shallow-water area adjacent to the Mexican boundary, where irrigation by pumping is feasible, that from Cabin wells would be a safe water to use on any of the land there, but that from Double wells (No. 324) might cause trouble if used on some of the heavier soils that already contain considerable alkali.

For domestic use all of the waters are classed as good or fair except that from Double wells, which is classed as bad. This water from Double wells is objectionable for cooking and washing on account of its hardness and also is high in sodium and sulphate, which gives it a bad taste.

None of the waters are entirely acceptable for boiler use in their raw state. That from well 322, classed as fair, may be used as it comes from the well. Softening with lime is advisable. The other waters, classed as poor and bad, demand chemical treatment before they can be safely used.

#### SOIL IN RELATION TO WATER SUPPLIES.

The soil of the draw extending along the axis of the valley from the region north of Hachita to the Mexican boundary consists principally of silt and clay washed down from the bordering stream-built slopes. Sandy soils occur on the plains extending north, east, and

south from Hachita and in narrow belts bordering the axial draw as far south as Hatchet Gap, and belts of gravelly soils border the edges of the mountains. From Hatchet Gap southward almost to the Mexican boundary the gravelly soils of the stream-built slopes on both sides of the valley extend to the edge of the draw, and the intermediate belts of sandy soil are missing. A narrow belt of fine-textured clay and silt soils extends along the international boundary from Cabin wells southward to the vicinity of boundary monument 46.

Soil samples 27, 41, 45, and 46, the analyses of which are given in the table on pages 146-149, were collected from Hatchet Valley. (See map, Pl. I.) The first three were taken at widely separated points along the axial draw. Sample 46 was taken 4 miles south of the center of the draw, near boundary monument 46. Sample 45, taken in the draw near the Mexican boundary, was the only one which showed a harmful amount of alkali. It contained 0.94 per cent of total alkali and 0.11 per cent of black alkali, enough to seriously injure most cultivated crops. Fortunately this sample represents only a small area of clay loam in the center of the draw.

#### IRRIGATION.

Irrigation by ground waters is not feasible except in the shallow-water area at the lower end of the valley. Parts of the central draw outside of the shallow-water area are, however, excellently adapted to the utilization of flood waters. At certain seasons large quantities of water are shed into the draw from the bordering stream-built slopes and by proper manipulation this water can to some extent be controlled and applied to the land. On the farm of O. O. Fichen, in sec. 23, T. 30 S., R. 14 W., flood water is used very successfully. In 1913 this farm produced perhaps better crops than any other farm in southern Grant County. Equally good opportunities exist at many other places in the draw below Hatchet Gap. Between Hatchet Gap and Hachita the same methods of irrigation can be applied to a certain degree, although perhaps not so readily, for here the draw is too little depressed below the general level of the plain and the lateral drainage is not sufficiently localized in definite channels to allow the flood waters to be concentrated and collected before applying them to the land.

#### METHODS OF WATER ANALYSIS.

By R. F. HARE.

The analyses of water were made in the following manner: The total solids were determined by evaporating measured amounts of water and drying the residue for one hour at 100° C. The residue was dissolved, calcium precipitated as oxalate, and the precipitate

dissolved in acid and titrated with a standard solution of potassium permanganate. Magnesium was precipitated with sodium phosphate in the filtrate from the calcium oxalate, separated by filtration, ignited, and weighed as magnesium pyrophosphate. The content of sodium and potassium was not determined directly but was computed from the following formula, which is based on the difference between the sum of the reacting values of the acids and the sum of the reacting values of the bases. This difference divided by the reacting value of sodium gives the calculated value for sodium and potassium in parts per million:

$$\frac{(0.0333 \text{ CO}_3 + 0.0164 \text{ HCO}_3 + 0.0208 \text{ SO}_4 + 0.0282 \text{ Cl}) - (0.0499 \text{ Ca} + 0.0821 \text{ Mg})}{0.0434} = \text{Na} + \text{K}$$

The carbonate and bicarbonate radicles were determined by titration with N/20 potassium bisulphate. The sulphates were precipitated with barium chloride and weighed as barium sulphate. Chlorine was determined volumetrically with N/30 silver nitrate. The black alkali, consisting of sodium carbonate and sodium bicarbonate, was determined in a separate portion of the water by evaporating a measured portion to dryness, igniting gently, dissolving in boiling water, and titrating with N/20 acid potassium sulphate, phenolphthalein being used to indicate the carbonate and methyl orange to indicate the bicarbonate of sodium.

In examining the samples of soil 50 grams of the air-dried soil was added to 500 cubic centimeters of distilled water, the mixture was thoroughly agitated, allowed to stand over night, and filtered. Portions of this filtrate were analyzed in the same manner as the water samples, except that the method used in determining black alkali in most of the samples makes no distinction between sodium carbonate and sodium bicarbonate. In this method an excess of standard sodium carbonate is evaporated with the soil solution and the filtrate from the redissolved residue is titrated with N/50 sulphuric acid, with erythrosine as indicator. In a few of the samples (Nos. 40, 44, 47, 48, 50, 51, 52, and 53) the carbonate and bicarbonate of sodium were determined as in the water samples. In each entry, however, the result is the sum of the content of sodium carbonate determined by analysis and the sodium bicarbonate calculated to its equivalent of sodium carbonate.

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# TABLES.

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TABLE 1.—Records of wells and springs in southern Grant County, N. Mex.

[Samples marked \* analyzed by R. F. Hare; see Table 2, pp. 142-143.]

No.	Location.			Owner or name.	Type.	Depth.	Water level.		Method of lift.	Use of water.	Miscellaneous data.
	T.	R.	Quar- ter.				Depth be- low surface.	Date.			
1.....	24	13	19 NW.	Watkins.....	Bored.....	Feet. 249	Feet. 188	Sept. 12 1913.	None.....	Not in use.....	Water stratum at 209 feet. Clay and gravel. Hardpan at 170 feet. Reddish clay mixed with sand and gravel at bottom.
2.....	24	14	24 NE.	C. W. Pushel.....	Dug.....	a 205	No water.	do.....	do.....	do.....	
3.....	25	14	b 20	Chiricahua ranch.....	Bored.....	267	b 160	Sept. 18	Windmill.....	Stock.....	
*4 (2 wells).....	26	15	15 SW.	Black Mountain ranch of Victoria Land & Cattle Co. Southern Pacific Co.	do.....	610	227	do.....	Windmills.....	Stock and do- mestic.	
5 (2 wells).....	24	15	19 SW.	J. D. Weems.....	do.....	400	300	Sept. 14	Steam pumps.....	Locomotive, etc.	For log see p. 1. V; ca- pacity pp. 72-74. Struck water at 301 feet. Owner says it rose 50 feet when first drilled.
6.....	24	15	19 SW.		do.....	147+	b 300	Sept. 13	Windmill.....	Domestic.....	
7 (2 wells).....	25	15	31 SW.	Hudson wells of Vic- toria Land & Cat- tle Co.	Bored.....	147+	147+	Sept. 18	do.....	Stock.....	
8 (2 wells).....	25	16	26 NW.		do.....	153	163	do.....	Windmills.....	do.....	
*9.....	25	16	21 SE.		Dug 31 feet and bored.	91+	91+	do.....	Windmill.....	do.....	
10.....	25	16	16 SE.	Arizona & New Mex- ico Ry.	Bored, 6 inches.....	153	120	do.....	Gasoline and plunger pump.	Locomotive, etc.	For capacity see p. 74.
11.....	24	17	35 SE.		do.....	76	76	Sept. 17	Windmill.....	Stock.....	
12 (3 wells).....	24	17	35 NE.		do.....	70	70	do.....	Windmills.....	do.....	
*13 (3 wells).....	24	17	26 NW.	John Muir.....	1 dug and bored; 2 bored.	100, 100, 66	63	do.....	Gasoline and plunger pump, and windmills.	Stock and do- mestic.	
14.....	24	17	9 SE.		Dug.....	81	81	Sept. 16	Windmill.....	Stock.....	
15.....	24	17	8 SE.		do.....	b 85	b 85	do.....	do.....	Stock and do- mestic.	
*16.....	24	17	8 NE.		do.....	85	85	do.....	do.....	do.....	
17.....	24	17	5 NW.		Dug.....	b 119	b 119	do.....	do.....	Not used.	
18.....	24	17	4 SE.		Bored, 6 inches.....	55	55	do.....	None.....	Stock.....	
19.....	24	17	5 SE.		do.....	70	70	do.....	Windmill.....	do.....	

a Well unfinished.

b Approximate.

c 25 feet apart.

TABLE 1.—Records of wells and springs in southern Grant County, N. Mex.—Continued.

[Samples marked \* analyzed by R. F. Hare; see Table 2, pp. 142-143.]

No.	Location.			Owner or name.	Type.	Depth.	Water level.		Method of lift.	Use of water.	Miscellaneous data.
	T.	R.	Sec.	Quar- ter.			Depth be- low surface.	Date.			
*20 (3 wells).....	23	17	32	N.E.	2 bored; 1 dug <sup>b</sup> .....	<i>Feet.</i> .....	<i>Feet.</i> 41	1913. Sept. 16	Windmills.....	Stock.....	Alkali shows on pipes; water tastes salty.
*21.....	23	28	1	S.W.	Bored.....	.....	60	Sept. 15	Windmill.....	.....do.....	Capacity under test, 6,000 gallons per hour at 316 feet and 2,000 gallons per hour at 116 feet. Cost of well, \$1,231. Quality of water, good.
22 (west well) <sup>d</sup> .....	23	18	2	N.E.	Bored, 6 inches.....	340	.....	.....	Steam pump.....	Industrial and domestic.	Cost of well, \$1,231. Capacity under 34-hour test, 6,230 gallons per hour.
(east well) <sup>d</sup> .....	23	18	2	N.E.	Bored, 8 inches.....	320	88	.....	do.....	do.....	For log see Pl. V; de- scription of plant p. 74.
(well No. 3) <sup>d</sup> .....	23	18	2	N.E.	Bored, 11½ inches.....	325	82	.....	do.....	do.....	
23.....	22	18	34	N.E.	Dug.....	.....	68	Oct. 13	Windmill.....	Irrigation and domestic.	
24.....	22	18	34	N.W.	do.....	.....	67	do.....	20-horse power electric-motor		
*25.....	22	18	34	S.E.	Bored, 20 inches.....	192	71	do.....	turbine pump. 14-horse power gasoline en- gine and 2- inch well cyl- inder.	Domestic.....	
26 (3 wells).....	22	18	33	N.E.	Bored.....	150, 137	99	do.....	Windmill.....	do.....	
27.....	22	18	33	N.E.	do.....	.....	87	do.....	8-horse power gasoline en- gine and plunger pump.	do.....	
28.....	22	18	28	S.E.	do.....	.....	68	do.....	Windmill.....	do.....	
29.....	22	18	28	S.E.	Bored; 20 and 12 inches.	.....	65	do.....	Electric motor and turbine pump.	Not in use. (?)	See p. 75.
30.....	22	18	28	S.W.	Bored.....	.....	.....	do.....	Windmill.....	Not in use.	Material taken from well is angular gravel and sand in clay matrix.
31.....	22	18	28	S.W.	Bored.....	.....	77	Oct. 15	Windmill.....	Not in use.	



32	23	18	29 NW.	Mart Hardin		c 100	79	do.	Gasoline engine and 34-inch wall cylinder.	Domestic.	
33 (2 wells)	23	18	29 NE	B. B. Olney	Bored		81	do.	Windmill.	do.	Cost of drilling, \$1.50 per foot; casing, \$0.47 per foot.
34	23	18	29 NE		do.	167	106	do.	do.	do.	
*35	23	19	13 SE.			f 113	98	Oct. 16	do.	Stock and domestic.	
36	23	19	12 SE.	Brown		240	240	Oct. 15	do.	do.	
*37 (2 wells)	23	19	5 NW.	Double wells.	Dug and bored.	94+	94+	Oct. 16	Windmill.	Stock.	
38	23	19	20 NW.		Bored.		115	Oct. 20	Windmill.	Not used.	
39	21	21	1 SE.	Leary "B."		300+	c 300	Oct. 17	Gasoline engine and windmill.	Stock and domestic.	
*40 (3 wells)	21	21	34 SE.		Bored.		c 250	Oct. 19	Windmill.	Stock.	
*41	21	21	25 SW.	Leary "B."	do.	c 420	c 200	do.	Windmill.	Stock and domestic.	
*42	22	20	18 SE.	Hackberry well of Highland Cattle Co. (Box "M").	do.	c 250	c 150	Oct. 22	Gasoline engine and windmill.	Suction pipe down 180 feet.	
43 (3 wells)	22	20	23 NE.	Highland Cattle Co. (Box "M").	Dug and bored.		c 200	Oct. 20	do.	do.	
44	23	20	18 SW.		Bored.	(A)	49	Oct. 27	None.	Not in use.	Clay, sand, and fine gravel on dump.
*45	23	20	30 SW.		Dug.		38	do.	Windmill.	Not used.	
46	23	31	31 NW.				37	Oct. 23	None.	do.	
47	24	21	1 NE.				33	do.	Gasoline engine and windmill.	Stock.	
48	23	19	31 NW.	De Moss.	Dug.		37	Oct. 25	Windmill.	Not used.	
49	23	19	31 NW.	do.	do.		65	do.	Bucket.	Domestic.	For log see fig. 11.
50	24	19	6 SW.		do.		39	do.	Gasoline engine and pinger pump.	do.	
51	24	19	7 NW.		do.		35	do.	None.	Not in use.	
52	24	19	7 SW.		Bored.		30	Oct. 30	Windmill.	Stock.	
53	24	19	18 SW.		Dug.		334	Oct. 31	None.	Not used.	
54	24	19	19 NE.	Henry Owens.	do.	51	No water.	do.	do.	No water.	Well-bedded coarse sand, angular gravel, and clay.
55	24	20	1 NW.		Bored.	(A)	28	Oct. 25	do.	Not in use.	
56	24	20	1 SE.	J. W. Johnson			234	do.	Windmill.	Domestic.	Water in gravel and quicksand. For further description see pp. 98-99.
*57	24	20	1 SE.		Dug and bored.	57	27	do.	Gasoline engine and turbine pump.	Irrigation.	Water-bearing gravel strata at 14 and 18 feet depth.
58	24	20	3 SW.	G. E. Cadman.	Bored(?)	c 20	131	do.	Hand pump.	Domestic.	
*59	24	20	7 NW.	J. P. Massfield.	Dug.		29	Oct. 24	Windmill.	Stock.	

g West well.  
 h Not finished.

d Data furnished by Southern Pacific Co.  
 e Plant newly installed. Intended for municipal use.  
 f Measured depth. Originally 130 feet deep.

a In use.  
 b Not in use.  
 c Approximate.

TABLE 1.—Records of wells and springs in southern Grant County, N. Mex.—Continued.

[Samples marked \* analyzed by R. F. Hare; see Table 2, pp. 142-143.]

No.	Location.			Owner or name.	Type.	Depth.	Water level.		Method of lift.	Use of water.	Miscellaneous data.
	T.	R.	Sec. Quarter.				Depth below surface.	Date.			
*60.....	24	20	11	SW.	J. A. Leahy.....	Bored.....	<i>Feet.</i> 50	1913. Oct. 25	Oil engine and turbine pump.	Irrigation.....	Dump shows clay and clean sand. For further description see p. 99.
*61.....	24	20	14	NE.	D. F. Sellards.....	Bored.....	19	Oct. 31	Hand pump.....	Domestic.....	For description see p. 99.
*62.....	24	20	14	NE.	do.....	Bored.....	39	do.....	Gasoline engine and centrifugal pump.	Irrigation.....	
63.....	24	20	14	SE.	S. J. Wright.....	Bored.....		do.....	10-horsepower gasoline engine and centrifugal pump.	do.....	
64.....	24	20	14	SE.	J. J. Campbell.....	Dug.....	(a)	do.....	None.....	Not in use.....	Water in fine gravel and quicksand.
65 (2 wells).....	24	20	15	SE.	Sam Killebrew.....	Bored.....	11	do.....	Windmill.....	Domestic.....	Small amount of water at 16 feet. Water-bearing gravel and quicksand at 35 feet.
66.....	24	20	15	NW.	Mrs. M. J. Swan.....	Bored.....	21	do.....	do.....	do.....	For log see fig. 11.
67.....	24	20	16	SE.	W. W. Guess.....	Bored.....	45	Nov. 1	do.....	do.....	
*68.....	24	20	18	NE.	J. C. Haydon.....	Dug.....	34	Oct. 24	Bucket.....	Domestic.....	
69 (3 wells).....	24	20	20	SW.	D. B. Smith.....	Bored.....	35 36 37	Nov. 1	Windmill.....	Stock and domestic.....	
70.....	24	20	21	NE.	W. W. Carlson.....	Bored.....	18	Oct. 27	do.....	Domestic.....	
71.....	24	20	22	NW.	G. A. Porter.....	Bored.....	20	Oct. 31	do.....	Domestic.....	
72.....	24	20	23	SE.	A. E. Kerr.....	Bored.....	18	do.....	Windmill.....	do.....	
73.....	24	20	23	NW.	do.....	Bored.....	16	do.....	do.....	do.....	
74 (2 wells).....	24	20	23	NE.	S. J. Wright.....	Dug.....	11	do.....	Windmill.....	Stock.....	
75.....	24	20	25	SE.	Robert Guess.....	Bored.....	13	Nov. 2	Bucket pump.....	Domestic and irrigation.....	
76.....	24	20	25	SE.	do.....	Bored.....	21	do.....	do.....	do.....	
77.....	24	20	32	NE.	Best ranch of Mansfield Land & Cattle Co.	Bored.....		Nov. 1	Windmill.....	Stock.....	
78 (2 wells).....	24	20	36	SE.	Seven-Twelve ranch of Mansfield Land & Cattle Co.	Bored.....	40	Nov. 2	Horsepower and windmill.	Stock and domestic.....	Drawdown 9 feet, with windmill pumping.

79	26	1 SW.	J. P. Mansfield.	Dug.		19	Nov. 3	Domestic.	
80	26	4 NW.	do.	Dug.	45	No water.	Nov. 2	Stock.	
81	26	6 NE.	do.	Dug.			Nov. 2	No water.	
82	26	6 SE.	Bickford ranch of J. P. Mansfield.	Dug and bored.			do.	Stock.	
83	26	13 NE.	J. P. Kerr.	do.	33 1/2	24	Nov. 3	Domestic.	See p. 99.
83 1/2	26	13 NE.	do.	do.	45		do.	Irrigation.	
84	26	13 NE.	M. B. Kethley.	Dug and bored.		27	do.	Domestic.	For log see fig. 10.
85	26	13 SE.	do.	do.		29	do.	Intended for irrigation.	Do.
86	25	13 SE.	do.	do.		29	do.	Stock and do-mestic.	
87 (2 wells).	25	16 SW.	T. J. McCanna.	do (?)	45, 50	40	Nov. 4	Stock and do-mestic.	
88	25	33 SW.	Mansfield, Land & Cattle Co.	do.		40	do.	Not in use.	
89 (2 wells).	25	34 NE.	W. J. Wamel.	Dug.	53	No water.	Nov. 5	No water.	Pumped dry in 14 hours at 30 gallons per minute.
90 (2 wells).	25	14 NE.	Holmg wells of W. J. Wamel.	do.	79	74	do.	Stock.	Regularly stratified clean gravels show in well walls.
91	25	13 NW.		Dug.	46	No water.	do.	No water.	
92	25	20 SW.		do.	41		Nov. 6	Not in use.	
93	25	29 SW.	Washburn.	Dug and bored.		61	do.	Stock and do-mestic.	
94	25	32 NW.	S. Henderson.		60	53 1/2	Nov. 12	Domestic.	
95	25	32 SE.	J. C. Henderson.		63	62	do.	do.	
96 (3 wells).	25	36 NE.	W. J. Wamel.	1 dug; 2 bored.	103, 150, 131	93	Nov. 7	Stock and do-mestic.	For further description see p. 99.
97	27	17 SW.	Antelope (El Paso & Southwestern R. R.).	Bored.				Locomotive, etc.	
98	27	17 NE.	Hosman Arnold.	Bored.	128	113	Nov. 10	Domestic.	Well sunk through alternate layers of sand and clay.
99	27	17 SW.			157	126	do.	Gasoline engine and 31-inch well cylinder.	Material mostly pebbly clay.
100	27	18 NE.		Bored.		117	do.	Not in use.	For further description see p. 99.
101	27	19 NE.	John Burns.		157	127	Nov. 14	Domestic and irrigation.	
*102 (3 wells).	27	20 NE.	"Railroad wells" of W. J. Wamel.	1 dug; 2 bored.	122, 149, 156	113	Nov. 10	Stock and do-mestic.	
103	27	31 NE.	T. T. ranch.			139	Nov. 11	Not in use.	
104 (2 wells).	27	32 NE.	Isaac H. Arnold.	Bored.		No water.	do.	Not in use.	
105	27	33 NE.			153		do.	Not in use.	

a One well with windmill and 1 with horsepower bucket pump. b 12-horsepower Stover gasoline engine.

c House well.

d Irrigating well located 100 feet east of house well.

e One well with windmill and 1 with horsepower bucket pump. f 12-horsepower Fairbanks-Morse gasoline engine to 5-inch well cylinder.

g Old well.

TABLE 1.—Records of wells and springs in southern Grant County, N. Mex.—Continued.

[Samples marked \* analyzed by R. F. Hare; see Table 2, pp. 142-143.]

No.	Location.			Owner or name.	Type.	Depth. Fect.	Water level.		Method of lift.	Use of water.	Miscellaneous data.
	T.	R.	Quar- ter.				Depth be- low surface.	Date.			
*106 (2 wells)...	27	20	9 NW.	Lee Pague		76½	Fect. 75	1913 Nov. 12	Windmills	Stock and do- mestic.	Well sunk through grav- elly clay most of dis- tance.
107	27	20	16 SE.	Bob Pague	Dug	104	98	do.	Windmill	Not in use.	Well walls show il- sorted angular gravel all the way down.
108	27	20	21 SW.		do.	195	No water.	Nov. 11	None		For log see p. 36.
109	27	20	26 SW.	Bob Pague		137	No water.	Nov. 15	None	Stock.	Water level fluctuates with seasons. For log of new well see Pl. VII.
110	28	19	4 SW.				do.	do.	do.	Not in use.	For log see Pl. VII.
111	28	19	8 NW.	Frank Bunts	Dug	238, 463	do.	Nov. 14	Windmill	Domestic	
112 (2 wells)...	28	19	9 SW.				do.	do.	do.	do.	
113	28	19	9 SE.	J. B. Seale	do.	(c)	26	do.	do.	do.	
114	28	19	10 SW.	Ben Pague	do.	32	30	Aug. 16	Gasoline engine and centrifugal pump.	Irrigation	
*115	28	19	15 NW.	J. S. Carruth		40	29	Nov. 14	Windmill	Domestic	
116	28	19	15 NW.	do.			28	do.	do.	Stock	For log see Pl. VII. Drawdown of 8 feet with 8-foot mill pump- ing
117	28	19	15 SW.				25½	Nov. 15	do.	Stock	Wells connected by drifts. Very small yield. Insufficient sup- ply.
*118 (3 wells)...	28	19	21 NW.	Mrs. Ballard	Dug	19	17	Nov. 14	Windmill	Stock and do- mestic.	
119	28	19	21 SW.		do.		18	Nov. 15	do.	Not used.	
120	28	19	22 NW.	Chas. S. Lightner	do.	(c)	27	do.	do.	do.	For log see Pl. VII.
121	28	19	15 NE.				29	do.	do.	do.	
122	28	19	22 NW.				26	do.	do.	do.	
123	28	19	22 SW.				31	do.	do.	do.	
*124	28	19	27 SE.	B. H. Pague	do.	35	31	do.	Windmill Gasoline engine and centrifugal pump.	Domestic and irrigation.	See p. 80.
125	28	19	27 SE.	do.	do.		30	Nov. 17	Windmill	Stock	

126 (2 wells).	28	19	27	NW.	do.	do.	25	20	Nov. 15	do.	Horsepower and pump.	Domestic.	Wells 25 feet apart and connected by drift. Small yield.
127.	28	19	27	NW.	B. F. King.	do.		20	do.	do.	Not used.	Not used.	
128.	28	19	27	NW.	do.	do.		26	do.	do.	Windmill.	Domestic and irrigation.	Soll 11 feet thick, gravels 11 feet thick.
129.	28	19	27	SW.	M. A. Wood.	Dug.	25	22	Aug. 16	do.	Windmills.	Domestic and irrigation.	
130.	28	19	27	SE.	do.	do.	25 1/2	25	Nov. 17	Nov. 17	Windmill.	Not used.	A number of shallow wells dug here. No water obtained.
131.	28	19	28	NE.	do.	do.		No water.	Nov. 15	Nov. 15	None.	do.	
132.	28	19	34	NE.	do.	do.	27 1/2	27	Nov. 17	Nov. 17	do.	do.	
133.	28	19	34	NE.	do.	do.		27	Nov. 17	Nov. 17	Windmill.	do.	
134 (3 wells).	28	19	34	SE.	Connors.	do.		23	Nov. 18	Nov. 18	do.	do.	
135.	28	19	35	NW.	W. W. Eades.	do.		23	Nov. 17	Nov. 17	do.	do.	
136 (3 wells).	28	19	35	SW.	R. S. Austin.	do.		25	Nov. 18	Nov. 18	Windmills.	Domestic and irrigation.	4 acres of orchard irrigated by 3 windmills.
137 (3 wells).	28	19	35	NW.	do.	do.		e23, 25	Nov. 13	Nov. 13	Windmills.	Stock.	
138.	29	19	3	SW.	Mrs. C. A. Bullion.	do.		20	Nov. 17	Nov. 17	Windmill.	Domestic.	
139.	29	19	4	NE.	Schoolhouse.	do.		/ 40	Nov. 18	Nov. 18	do.	do.	
140.	29	19	4	NE.	do.	do.		16 1/2	Nov. 17	Nov. 17	Windmill.	Domestic.	
141.	29	19	4	SE.	Isaacs.	Dug.		16 1/2	Nov. 18	Nov. 18	Bucket.	Domestic.	
142.	29	19	9	SE.	do.	do.		19 1/2	Nov. 17	Nov. 17	Windmill.	Domestic.	
143.	29	19	9	NW.	do.	do.		18 1/2	Nov. 18	Nov. 18	Windmill.	Domestic.	
144.	29	19	9	NW.	do.	do.		17	Nov. 17	Nov. 17	do.	do.	
145.	29	19	9	NE.	do.	do.		18 1/2	Nov. 17	Nov. 17	do.	do.	
146 (2 wells).	29	19	9	NE.	do.	do.		18 1/2	Nov. 18	Nov. 18	Windmill.	Domestic.	
147.	29	19	10	NW.	Tax Gallowan.	do.		22 1/2	Nov. 18	Nov. 18	do.	do.	
*148.	29	19	17	NE.	do.	do.		22 1/2	do.	do.	do.	do.	
149.	29	19	17	NE.	do.	do.		19	do.	do.	do.	do.	
150.	29	19	17	NE.	do.	do.		17	do.	do.	do.	do.	
151.	29	19	17	SE.	do.	do.		16 1/2	do.	do.	do.	do.	
152.	29	19	20	NE.	B. Burkett.	do.		17	do.	do.	Windmill.	do.	
153.	29	19	20	NW.	do.	do.		14 1/2	do.	do.	do.	do.	
154.	29	19	20	SW.	do.	do.		13	do.	do.	Windmill.	do.	
155.	29	19	20	SE.	do.	do.		12	do.	do.	do.	do.	
156.	29	19	20	SE.	do.	do.		12	do.	do.	do.	do.	
157.	29	19	20	SE.	do.	do.		18	do.	do.	do.	do.	
158.	29	19	29	NW.	do.	do.		20	Nov. 19	Nov. 19	Windmill.	Stock and domestic.	Unsuccessful deep well bored 200 feet east. See p. 81.
159.	29	19	30	NE.	XT ranch headquarters.	do.		20	Nov. 19	Nov. 19	Windmill.	Stock.	
160.	29	19	30	SE.	do.	do.		12	do.	do.	Windmill.	Stock.	
161.	29	19	30	SE.	A. B. Ward.	Dug.		20	do.	do.	do.	Domestic.	
162.	29	19	31	SW.	Mrs. Dunnigan(?).	do.		25	do.	do.	do.	Not used.	
163.	29	19	31	SW.	Mrs. Chas. Spear(?).	do.		25	do.	do.	do.	Not used.	
164.	29	19	31	SW.	XT ranch.	do.		12	do.	do.	Windmill.	Stock.	

<sup>c</sup> Well at barn.  
<sup>d</sup> Approximate.

<sup>c</sup> Sunk short distance below water level.

<sup>d</sup> Several wells.

<sup>a</sup> Well at house.  
<sup>b</sup> New well unfinished.

TABLE 1.—Records of wells and springs in southern Grant County, N. Mex.—Continued.

[Samples marked \* analyzed by R. F. Hare; see Table 2, pp. 142-143.]

No.	Location.			Owner or name.	Type.	Depth. Feet.	Water level.		Method of lift.	Use of water.	Miscellaneous data.
	T.	R.	Sec. Quarter.				Depth below surface.	Date.			
165.....	30	19	7	SW.	Steve Dunnagan.....		Feet. 28	1913. Nov. 20	Windmill.....	Stock and domestic.....	
166.....	30	20	1	SE.				Nov. 19	do.....	Domestic.....	
167.....	30	20	20	NE.	Bored.....		29	Nov. 20	do.....	do.....	
168.....	30	20	25	NW.	Victoria Land & Cattle Co.....	55	No water.		None.....	Not used.....	
169.....	30	20	25	NW.	Victoria Land & Cattle Co.....				Windmill.....	Stock.....	
170.....	30	20	35	SE.			22				
171.....	30	20	11	NW.	Wm. Birchfield.....				Windmill.....	Stock.....	
*172 (3 wells).....	31	20	10	SE.	Victoria Land & Cattle Co.....				Windmills.....	do.....	
173.....	31	20	15	SE.	E. W. Taylor.....	27		Aug. 17			Coarse, poorly assorted sands and gravels.
*174.....	31	20	15	SW.	Morehouse.....		26½	Nov. 20			
175.....	31	20	22	NW.	E. G. Howe.....		17	Nov. 24	Windmill.....	Domestic and stock.....	
176.....	32	20	4	NE.	Wm. Burcham.....	24		do.....	None.....	Not in use.....	Poorly bedded gravel with some clay. Group of springs here form a small marsh ("denega").
177.....	32	20	16	NW.	Gray ranch of Victoria Land & Cattle Co.....		0	do.....	do.....	Stock and domestic.....	
178.....	32	20	17	NE.	Victoria Land & Cattle Co.....		15	do.....		Stock.....	
179.....	32	20	22	SW.	do.....		23	do.....	do.....	Not in use.....	
180.....	33	19	17	SW.	Juniper Spring.....		0		do.....	Stock.....	For account of deep well bored here see p. 104.
*181.....	33	20	27	SW.	Fitzpatrick well of Victoria Land & Cattle Co.....		4	Nov. 29	Windmill.....	do.....	
182.....	35	20	30	NW.			13	Nov. 28	None.....	Not used.....	Poorly assorted gravel and clay.
183.....	35	20	32	NW.			10	do.....			
184.....	35	20	33	NW.	Louis Carrier.....			do.....		Domestic.....	For log see p. 103.
185.....	33	20	34	NW.	I. I. Wolf.....		4	Nov. 29	Windmill.....	Stock and domestic.....	Shallow pit dug in gravel.
186.....	33	21	23	SE.	Victoria Land & Cattle Co.....		0	Nov. 27	None.....	Stock.....	

137	33	21	24	SW.	Mrs. Lloyd	Dug.	13	do.	do.	Not used.
138	33	21	24	SE.	Safford.	do.	13	do.	Windmill.	Stock and do-
*139	34	19	19	N.E.	Victoria Land & Cat-		6	Dec. 2		Stock.
140	34	19	19	N.E.	the Co.		6	do.		Stock and do-
					Lang ranch of Vic-					mestic.
141	34	20	4	N.W.	the Co.					
142 (2 wells).	34	20	5	SW.	H. N. Awrey.	Dug.	No water.	Nov. 23	None.	Not used.
143	34	20	5	SW.			0	Nov. 23		
144	34	20	6	N.E.			0	Nov. 27		Not in use (?)
145	34	20	7	SE.	Garcia.		0	Dec. 2		Domestic.
146	34	20	23	SW.	Bramlett.	Dug.	No water.	do.	None.	Domestic.
147	34	20	23	SW.	Gavallando.		6	do.		do.
148	34	21	1	N.E.	J. H. Turpin.	Dug.	13	Nov. 27	Bucket.	Water rises within 8 feet of surface in rainy season.
149	34	21	1	SE.	J. M. Clark.	do.	64	do.		Material taken from well is mostly pebbly clay with some fine gravel.
200	34	21	12	N.E.	Victoria Land & (at-	2 bored; 1 dug.	11	do.		
*201 (3 wells).	34	21	28	SE.	the Co.	Bored.	58	Oct. 8	Windmills.	Domestic.
202	26	17	28	N.W.			83	do.	Windmill.	Stock.
203	26	17	33	SE.	B. F. Briggs.		75	do.	None.	Not in use.
204	27	16	20	N.E.			20	Oct. 5	Windmill.	Domestic and
*205 (2 wells).	27	16	8	N.W.	G. Livingstone.	Dug and bored.	24	Oct. 4	Windmills.	stock.
206 (3 wells).	27	16	8	N.W.			28	Oct. 5	do.	Stock.
207 (2 wells).	27	16	8	N.E.	Victoria Land & Cat-		d 38, e 28	do.	do.	do.
208	27	16	21	SW.	the Co.	Dug /	17	do.		
209	27	17	5	SW.	P. M. Egan.	Bored.		Oct. 7	Windmill.	do.
210 (3 wells).	27	17	5	SE.	Victoria Land & Cat-		90	do.		Domestic.
					the Co.					
211	27	17	5	SW.	Walton Walker.	Dug and bored.	63	do.	Windmills.	Stock.
212	27	17	6	SE.			85	Oct. 6		
213	27	17	7	SE.	Turnley Walker.		78	Oct. 7	Windmill.	Domestic.
214	27	17	7	SW.	R. W. Baker.		104	Oct. 6		
215	27	17	8	N.W.	R. E. Orr.		64	Oct. 7		
216	27	17	8	SE.	El Paso & South-	Bored.	68	do.	None.	Not in use.
					western R. R.					
217	27	17	8	SW.	Elkins Orr.	do.	54	do.		Domestic.
										Sunk through clay and water - 3 feet. Capacity of pump about 30 gallons per minute. For log see Pl. IX.
*218	27	17	8	SW.	F. S. Cooper.		66	Oct. 4	Gasoline engine and plunger pump.	do.

a Spring.

b Sunk short distances below water level.

c Not in use.

d Used with windmill.

e Old disused well 250 feet northwest of used well.

f Old mine shaft (?).

TABLE 1.—Records of wells and springs in southern Grant County, N. Mex.—Continued.

[Samples marked \* analyzed by R. F. Hare; see Table 2, pp. 142-143.]

No.	Location.			Owner or name.	Type.	Depth.	Water level.		Method of lift.	Use of water.	Miscellaneous data.
	T.	R.	Quarter.				Depth below surface.	Date.			
219	27	17	NE.	I. B. Wade.		<i>Feet.</i>		1913.			
220	27	17	NW.	Sharp.		70	66	Oct. 7	None.	Not in use.	
221	27	17	SW.			80	44	Oct. 6	Windmill.	Domestic.	
222	27	17	SE.		Bored.	63	61	do.			
223	27	17	NE.	J. A. Queen.		83	43	Oct. 2	do.	do.	
224	27	17	SE.				46	Oct. 6	do.	do.	
225	27	17	NW.	R. E. Groom.		70	52	Oct. 5	do.	Stock and domestic.	Struck water in sand and fine gravel at 60 feet.
226	27	17	SW.								
227	27	17	NE.	W. H. Adams.	Bored.	70	56	do.	None.	Not in use.	Layers of clay and gravel. For log see Pl. IX.
228	27	17	NE.	B. H. Baker.		53	42	Oct. 2	Windmill.	Domestic.	
229	28	13	NE.	Livermore Spring.	do.	(b)	104	Oct. 6	Bucket.	do.	
230	28	16	SW.	Cottonwood Spring.						Stock.	
231	28	16	SE.	Bennett.							
232	28	16	SE.								
233	28	17	NE.	Victoria Land & Cattle Co.			0	Oct. 1	None.	Stock.	
234	28	17	NE.	do.			0	do.	do.	do.	
235	28	17	SE.	do.			0	do.	do.	do.	
236	28	17	SE.	Whitnire ranch of Victoria Land & Cattle Co.			0	do.	do.	do.	
237	28	17	SW.				0	do.	do.	Domestic.	
238	28	17	SW.				0	do.	do.	Domestic.	
239	28	17	SW.				0	do.	do.	Domestic.	
240	28	17	SW.				0	do.	do.	Domestic.	
241	28	17	SW.				0	do.	do.	Domestic.	
242	28	17	SE.		Dug.		41	Sept. 30	do.	Not used.	
243	28	16	NW.		Dug.		10	do.	do.	do.	
244	28	16	NE.	A. F. Lane.	Dug.		30	do.	do.	do.	
245	28	16	SW.	do.		103	22	do.	do.	Irrigation.	
246	28	16	SW.		Dug.		22	do.	do.	and pump.	
247	28	16	SW.		Dug.		26	Dec. 17	do.	Stock.	
248	28	16	SW.		Dug.		26	Oct. 1	do.	do.	
249	28	16	SW.		Dug.		26	Dec. 17	do.	Domestic.	
250	28	16	SW.		Dug.		26	Dec. 16	do.	Domestic.	

See p. 119 and Pl. IX.



351	29	17	26	SE	F. C. Bohne					Dec. 16	Windmill		Domestic.
352	29	17	26	NE	Gibson					Dec. 17	None		Not used.
353	29	17	27	NE						do.	None		Stock
354	29	17	30	NW			45+			Sept. 30			Not used.
355	29	17	36	SE		Dug				do.			Stock
356	29	17	36	SE						do.			Domestic.
357	30	16	4	SW	Geo. W. Lambert		64			Sept. 29			Domestic.
358	30	16	3	SW			45			do.			Domestic.
359	30	16	5	SE	Tom Burts	Dug 20 feet; bored; 6-inch casing.	104			Aug. 19			Domestic.
360	30	16	5	SW	Tom Barkeley					Sept. 29	Unsuipped.	do.	Clay and sand.
361	30	16	6	NE			164			Dec. 12	None	Not in use.	
362	30	16	7	NW	Wilcox	Dug	24+			do.	Windmill		For description see p. 109. See p. 119 and Pl. IX.
363	30	16	7	NE						do.			Domestic.
364	30	16	7	SE	Geo. Winkler	Bored.	836			Dec. 16	Gasoline engine and pump.	Irrigation and domestic.	
365	30	16	7	SW	A. S. Lewis					Sept. 29		Not used.	For log see Pl. IX.
366	30	16	10	NE	Hatchett Cattle Co. (?)					Dec. 12	Windmill	Stock	
367	30	16	11	NW	L. E. Predmore		40			Sept. 29		Domestic.	
368	30	16	11	NW	do.		68			do.		Stock	
369	30	16	11	SW	O. F. Peterson		37			Sept. 29	Windmill	Domestic	For log see Pl. IX.
370	30	16	11	NW	Wm. E. Henry		60			Sept. 23		Stock and do- mestic.	
371	30	16	11	SE	J. R. Worthington		25			Aug. 18	do.	Stock	
372	30	16	12	NW	do.	Dug				Sept. 23	Windmills	Stock	
373 (2 wells)	30	16	12	SW	South Hatchett wells of Hatchett Cattle Co.		70			Dec. 13	None	Not used.	For log see Pl. IX.
374	30	16	14	NW	Phil. Davis	Dug	354			do.	Windmill	Domestic	
375	30	16	14	SW	D. D. Upshaw		48			do.	do.	do.	
376	30	16	15	SE	Thos. Upshaw		34			Dec. 12	Windmill	Domestic	Drawdown 8 feet when pumping 30 gallons per minute. For log see Pl. IX.
377	30	16	16	NE	Geo. Godfrey	Dug				do.			
378	30	16	17	NE						do.			
379	30	16	17	SW						Dec. 11	Gasoline engine and pump.	Domestic	
380	30	16	17	NW	Thos. Winkler		88			Dec. 12	Windmill		
381	30	16	18	NW						do.			
382	30	16	22	NW	Upshaw	Dug	46			Dec. 12	Windmill		
383	30	16	22	NE			41			do.	do.		
384	30	16	22	SE						do.	do.		
385	30	16	23	SW						do.	do.		
386	30	16	27	SW						Dec. 12	Windmill		
387	30	16	34	SE			78			do.			
388	30	16	34	SE			74+			do.			
389	30	16	34	SE						do.			
390	30	16	34	SE						do.			
391	30	16	34	SE						do.			
392	30	16	34	SE						do.			
393	30	16	34	SE						do.			
394	30	16	34	SE						do.			
395	30	16	34	SE						do.			
396	30	16	34	SE						do.			
397	30	16	34	SE						do.			
398	30	16	34	SE						do.			
399	30	16	34	SE						do.			
400	30	16	34	SE						do.			
401	30	16	34	SE						do.			
402	30	16	34	SE						do.			
403	30	16	34	SE						do.			
404	30	16	34	SE						do.			
405	30	16	34	SE						do.			
406	30	16	34	SE						do.			
407	30	16	34	SE						do.			
408	30	16	34	SE						do.			
409	30	16	34	SE						do.			
410	30	16	34	SE						do.			
411	30	16	34	SE						do.			
412	30	16	34	SE						do.			
413	30	16	34	SE						do.			
414	30	16	34	SE						do.			
415	30	16	34	SE						do.			
416	30	16	34	SE						do.			
417	30	16	34	SE						do.			
418	30	16	34	SE						do.			
419	30	16	34	SE						do.			
420	30	16	34	SE						do.			
421	30	16	34	SE						do.			
422	30	16	34	SE						do.			
423	30	16	34	SE						do.			
424	30	16	34	SE						do.			
425	30	16	34	SE						do.			
426	30	16	34	SE						do.			
427	30	16	34	SE						do.			
428	30	16	34	SE						do.			
429	30	16	34	SE						do.			
430	30	16	34	SE						do.			
431	30	16	34	SE						do.			
432	30	16	34	SE						do.			
433	30	16	34	SE						do.			
434	30	16	34	SE						do.			
435	30	16	34	SE						do.			
436	30	16	34	SE						do.			
437	30	16	34	SE						do.			
438	30	16	34	SE						do.			
439	30	16	34	SE						do.			
440	30	16	34	SE						do.			
441	30	16	34	SE						do.			
442	30	16	34	SE						do.			
443	30	16	34	SE						do.			
444	30	16	34	SE						do.			
445	30	16	34	SE						do.			
446	30	16	34	SE						do.			
447	30	16	34	SE						do.			
448	30	16	34	SE						do.			
449	30	16	34	SE						do.			
450	30	16	34	SE						do.			
451	30	16	34	SE						do.			
452	30	16	34	SE						do.			
453	30	16	34	SE						do.			
454	30	16	34	SE						do.			
455	30	16	34	SE						do.			
456	30	16	34	SE						do.			
457	30	16	34	SE						do.			
458	30	16	34	SE						do.			
459	30	16	34	SE						do.			
460	30	16	34	SE						do.			
461	30	16	34	SE						do.			
462	30	16	34	SE						do.			
463	30	16	34	SE						do.			
464	30	16	34	SE						do.			
465	30	16	34	SE						do.			
466	30	16	34	SE						do.			
467	30	16	34	SE						do.			
468	30	16	34	SE						do.			
469	30	16	34	SE						do.			
470	30	16	34	SE						do.			
471	30	16	34	SE						do.			
472	30	16	34	SE						do.			
473	30	16	34	SE						do.			
474	30	16	34	SE						do.			
475	30	16	34	SE						do.			
476	30	16	34	SE						do.			
477	30	16	34	SE						do.			
478	30	16	34	SE						do.			
479	30	16	34	SE						do.			
480	30	16	34	SE						do.			
481	30	16	34	SE						do.			
482	30	16	34	SE						do.			
483	30	16	34	SE						do.			
484	30	16	34	SE						do.			
485	30	16	34	SE						do.			
486	30	16	34	SE						do.			
487	30	16	34	SE						do.			
488	30	16	34	SE						do.			
489	30	16	34	SE						do.			
490	30	16	34	SE						do.			
491	30	16	34	SE						do.			
492	30	16	34	SE						do.			
493	30	16	34	SE						do.			
494	30	16	34	SE						do.			
495	30	16	34	SE						do.			
496	30	16	34	SE						do.			
497	30	16	34	SE						do.			
498	30	16	34	SE						do.			
499	30	16	34	SE						do.		</	

TABLE 1.—Records of wells and springs in southern Grant County, N. Mex.—Continued.

Samples marked \* analyzed by R. F. Hare; see Table 2, pp. 142-143.]

No.	Location.			Owner or name.	Type.	Depth.	Water level.		Method of lift.	Use of water.	Miscellaneous data.
	T.	R.	Sec.				Depth below surface.	Date.			
292 *	31	16	8	SW.	Victoria Land & Cattle Co.	Feet.	Feet.	1913.		Stock	
293	34	16	8	SW.	do.	18	No water.		None	Not used	
*294 (2 wells)	34	16	17	NW.	Ojo de las Ciencas.	98, 102	Flow.	Dec. 11	do.	Stock and domestic.	Description on p. 114.
295	21	16	24	SE.	Jas. H. Robertson.	160	84	Dec. 10	Gasoline engine and windmills.	Stock and domestic.	Well ends in rock
296 (2 wells)	33	17	34	SE.	Young	b 200	129	Dec. 11	do.	Stock	Regularly bedded gravel, sand, and reddish clay.
*297 (2 wells)	33	16	3	NE.	New wells.	41	No water.	Dec. 9	None	Not used.	
298	33	16	6	NE.	J. F. Sidham (?)			do.	Windmill	Stock and domestic.	
299	32	16	7	NW.	W. D. Krebaum.	82	50	Dec. 7	do.		Alternate layers reddish clay and gravel.
300	32	16	17	NE.	R. L. Keith.		59				
301	33	16	13	SE.	Deaton	350		Dec. 9	do.		
302	32	16	13	SW.	Jackson	(c)	56		do.		
*303 (3 wells)	32	16	22	NW.	Gilbert wells	b 105	63	do.	Windmills	Stock	Plenty of water for 16-foot mill; $\frac{3}{4}$ by 48-inch well cylinder. For log see Pl. IX.
304	32	16	20	NW.	M. L. Massey.	162	71	Dec. 7	Windmill	Stock and domestic.	
305	32	17	13	SE.	J. A. Townsend.	507	494	Dec. 9	do.	do.	
*306 (2 wells)	32	17	13	NE.	Walnut wells		56		Windmills	Stock	4 strata of fine gravel.
307	32	17	13	SW.	Britton	74	72	Dec. 9	do.	do.	
308	32	17	24	SE.	J. F. Sidham.	100	74	Dec. 7	Windmill	Stock and domestic.	
*309	33	16	13	NW.	Alamo Huesco.		0	do.		Not in use.	Reddish sandy clay and small amount of fine gravel.
310	3	13	3	SE.		163	173	Dec. 6	None		Struck water at 142 feet; rose to 125 feet.
311	33	17	3	NE.	Land (?)	142	125	Dec. 8		do.	A new well being drilled; dug 40 feet in reddish bouldery clay. Water in gravel.
*312 (2 wells)	33	17	33	SE.	High Lonesome wells of Victoria Land & Cattle Co.	250, 265	136	Dec. 6	Gasoline engine and windmills.	Stock and domestic.	

*313 (2 wells)...	34	16	13	SW.	Antelope wells of Victoria Land & Cattle Co.	do.	b 220	173 +	Dec. 3	Windmills	do.
*314 (2 wells)...	26	15	34	NW.	Pat Hook ranch of Victoria Land & Cattle Co.	do.			Sept. 19	do.	Stock.
*315.....	27	15	35	SW.	Twomile well.	Bored.	b 300	233	Aug. 21	do.	do.
*316.....	27	15	36	NE.	El Paso & Southwestern R. R.	do.	685			Steam pumps	Railroad and town.
*317 (2 wells)...	28	15	15	NE.	Fourmile wells.	do.			Sept. 28	Windmills	Stock.
*318.....	29	14	4	NW.	Doyle wells.	do.	d 238	203	do.	Windmills	do.
*319 (3 wells)...	29	15	20	SE.	Eightmile wells.	do.	s 196	165	do.	do.	do.
*320 (2 wells)...	29	15	20	SE.	North Hatchet wells of Hatchet Cattle Co.	do.					
*321.....	30	14	29	NW.	Badger well of Hatchet Cattle Co.	do.		b 100	Sept. 23	Windmill	Stock.
*322.....	30	14	33	NE.	O. O. Richey.	Dug.	(e)	107	do.	Bucket	Domestic
*323 (3 wells)...	30	15	14	NW.	Hatchet ranch of Hatchet Cattle Co.	Bored.	s 141	111	do.	Windmills	Stock and domestic.
*324 (2 wells)...	31	14	2	NE.	Double wells of Hatchet Cattle Co.	do.		47 1/2	Sept. 24	do.	Stock.
*325 (2 wells)...	31	14	12	SE.	Cabin wells of Hatchet Cattle Co.	Dug and bored.	b 145	13	do.	do.	Stock and domestic.
*326 a.....	34	15			Dog Spring.						Water under some pressure when struck.

a Spring.

b Approximate.

c Sunk short distance below water level.

d Middle well.

e 1 well.

TABLE 2.—Analyses of well and spring waters from southern Grant County, N. Mex.

[Parts per million unless otherwise stated. R. F. Hare, analyst.]

Determined quantities.										Computed quantities. <sup>b</sup>						Classification. <sup>c</sup>					
No.	Total dissolved solids at 100° C.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na + K). <sup>d</sup>	Carbonate radi- cle (CO <sub>3</sub> ).	Bicar- bonate radi- cle (HCO <sub>3</sub> ).	Sul- phate radi- cle (SO <sub>4</sub> ).	Chlo- ride radi- cle (Cl).	Black alkali.		Water of crys- tallization organic and vola- tile mat- ter. <sup>d</sup>	Scale- form- ing and con- stitu- ents.	Foam- ing hard- ness consti- tuents.	Total hard- ness CaCO <sub>3</sub> .	Alkali coeffi- cient.	Prob- abil- ity of corro- sion. <sup>e</sup>	Mineral content.	Chem- ical char- acter.	Quality.		
									Sodium car- bonate (Na <sub>2</sub> CO <sub>3</sub> ).	Sodium bicar- bonate (NaHCO <sub>3</sub> ).									For do- mestic use.	For use in boilers.	For irriga- tion.
4	280	30	11	31	0.0	146	35	22	39	44	79	140	85	120	75	(?)	Moderate.	Ca-CO <sub>3</sub>	Good.	Fair.	Good.
9	1,022	31	22	280	0.0	398	364	50	199	204	78	160	760	168	6.2	N	High.	Na-SO <sub>4</sub>	Fair.	Very bad.	Fair.
12	861	104	28	136	0.0	281	263	126	0	13	76	380	370	375	14	(?)	do.	do.	Bad.	Poor.	Do.
16	466	17	12	127	0.0	209	138	36	119	123	34	100	340	92	13	N	Moderate.	Na-CO <sub>3</sub>	Good.	do.	Do.
20	2,069	119	68	451	0.0	363	785	313	0	35	144	500	1,220	576	5.2	(?)	Very high.	Na-SO <sub>4</sub>	Unfit.	Very bad.	Poor.
21	477	11	11	135	56	180	81	29	232	206	65	80	370	73	7.3	N	Moderate.	Na-CO <sub>3</sub>	Good.	Poor.	Fair.
22	453	7.2	6.1	141	14	256	78	26	238	219	54	61	380	43	6.7	N	do.	do.	do.	do.	Do.
23	465	17	7.4	83	0.0	136	88	43	133	114	94	92	240	73	18	N	do.	do.	do.	Fair.	Do.
37	236	16	7.4	67	6.3	177	30	20	83	70	2.4	89	180	70	14	N	do.	do.	do.	do.	Do.
40	1,413	100	19	313	0.0	64	655	196	0	15	98	360	840	328	8.0	C	High.	Na-SO <sub>4</sub>	Bad.	Very bad.	Do.
41	1,340	7.2	7.4	418	38	569	275	101	570	460	213	63	1,100	48	2.5	N	do.	Na-CO <sub>3</sub>	do.	do.	Poor.
42	1,340	20	8.2	425	19	1,125	385	368	33	48	74	100	1,100	84	4.6	N	do.	Na-Cl	Fair.	do.	Fair.
43	1,268	26	3.0	442	19	1,125	16	49	845	180	180	110	200	77	1.6	N	do.	Na-Cl	Unfit.	do.	Poor.
45	432	34	11	62	5.7	202	68	26	159	103	80	150	220	130	20	N	Moderate.	do.	Good.	Fair.	Good.
57	745	41	14	171	0.0	344	192	35	180	195	121	170	460	160	8.6	N	High.	do.	do.	Fair.	Bad.
60	440	64	8.2	54	0.0	306	50	5.8	116	134	107	260	140	194	22	N	Moderate.	Ca-CO <sub>3</sub>	Good.	Poor.	Good.
61	1,060	91	6.1	273	0.0	316	382	133	61	74	19	310	740	253	10	N	High.	Na-SO <sub>4</sub>	Fair.	Very bad.	Fair.
72	73	70	17	18	0.0	212	63	17	55	57	108	260	50	245	110	(?)	Moderate.	Ca-CO <sub>3</sub>	do.	do.	Good.
73	38	23	15	187	0.0	328	287	17	232	210	108	170	500	162	8.3	(?)	High.	Na-CO <sub>3</sub>	do.	Very bad.	Fair.
76	491	74	9.1	67	0.0	267	186	29	22	31	64	260	180	222	46	(?)	Moderate.	Ca-CO <sub>3</sub>	do.	Poor.	Good.
80	545	66	12	93	0.0	291	151	17	66	83	62	240	250	214	29	N	High.	Na-CO <sub>3</sub>	do.	do.	Do.
83	3,165	110	44	822	0.0	336	1,499	283	17	39	236	430	2,200	455	4.2	(?)	Very high.	Na-SO <sub>4</sub>	Unfit.	Very bad.	Poor.

85	516	41	11	106	0	224	149	26	66	74	66	170	230	148	19	N	High	Na-CO <sub>3</sub>	Fair	Poor	Good.
87	708	53	11	134	0	253	216	46	50	77	171	240	300	210	25	N	do	Na-SO <sub>4</sub>	do	Bad	Do.
90	544	52	14	96	0	257	162	23	17	57	80	210	260	187	35	N	do	Na-SO <sub>4</sub>	do	Poor	Do.
102	282	29	4.7	24	0	122	25	12	22	24	122	120	92	92	24	N	Moderate	do	Fair	Do.	
106	370	47	3.7	64	0	171	84	12	23	18	83	140	170	105	28	N	do	do	do	Do.	
115	290	47	8.6	10	0	115	19	12	0	4.4	221	180	27	140	68	N	do	Ca-CO <sub>3</sub>	do	Do.	
124	245	42	4.6	30	0	138	22	23	0	0	62	160	24	124	68	N	do	do	do	Do.	
148	150	20	4.3	14	0	79	16	12	0	6.6	55	96	38	68	160	N	do	do	do	Do.	
172	386	16	2.6	10	0	49	16	12	0	4.4	57	82	27	51	100	N	Low	do	Good	Do.	
175	128	12	4.6	6.3	0	41	20	12	0	4.4	71	73	17	49	310	N	do	do	do	Do.	
181	128	12	2.0	12	0	47	22	12	0	4.4	73	74	35	51	150	N	Moderate	do	do	Do.	
189	135	6.8	2.0	3.8	0	21	12	12	0	4.4	92	55	10	29	250	N	do	do	do	Do.	
201	6,913	439	66	1,579	0	368	4,072	167	39	24	51	1,400	4,300	1,400	2.3	N	Very high	Na-SO <sub>4</sub>	Unsat.	Very	Poor.
205	985	22	57	98	0	323	392	63	Tr.	22	52	510	260	560	25	N	High	Ca-SO <sub>4</sub>	Bad	Bad	Good.
218	421	22	9.1	106	0	272	72	17	152	183	61	510	260	92	20	N	Moderate	Na-CO <sub>3</sub>	Good	Poor	Good.
223	450	18	21	74	0	275	70	35	137	114	56	180	200	186	20	N	do	do	do	Fair.	
227	501	18	6.9	142	0	316	79	29	235	241	71	94	889	73	6.7	N	High	do	do	Poor	Fair.
228	476	20	8.6	130	0	281	77	40	138	180	62	100	350	85	7.9	N	Moderate	do	do	do	Do.
237	370	30	13	61	0	221	59	12	127	131	88	140	160	128	21	N	do	do	do	Fair.	Good.
241	357	18	9.1	86	16	153	72	29	122	136	49	100	230	81	14	N	do	do	do	do	Fair.
245	308	20	7.1	59	0	155	32	12	100	39	83	100	160	79	16	N	do	do	do	do	Do.
246	266	19	13	45	0	152	54	12	83	105	74	110	120	101	37	N	do	do	do	do	Good.
255	253	21	6.1	55	0	177	33	12	77	39	38	160	150	77	18	N	do	do	do	do	Fair.
273	437	20	7.4	101	0	269	84	29	152	180	93	100	270	80	12	N	do	do	do	Poor	Do.
294	243	13	7.1	44	0	153	29	12	55	44	74	80	120	62	24	N	do	do	do	Good	Do.
297	295	24	16	37	0	156	41	16	44	35	62	130	100	142	46	N	do	Mg-CO <sub>3</sub>	do	Fair	Do.
305	340	41	16	40	0	215	35	26	44	22	78	180	110	168	40	N	do	Ca-CO <sub>3</sub>	do	do	Do.
306	200	31	8.6	28	0	160	20	16	33	22	18	140	76	113	46	N	do	do	do	do	Do.
312	144	26	5.1	5.3	0	101	4.1	7.2	0	6.6	47	120	14	85	280	N	Low	do	do	do	Do.
313	254	17	2.6	62	0	139	48	17	42	48	39	80	179	63	18	N	Moderate	Na-CO <sub>3</sub>	do	do	Fair.
315	538	29	5.2	28	0	143	206	29	21	42	62	129	350	95	22	N	High	Na-SO <sub>4</sub>	Fair	Poor	Good.
319	546	43	28	98	0	253	131	46	21	65	85	208	268	222	31	N	do	Na-CO <sub>3</sub>	do	do	Do.
320	544	73	27	46	0	223	141	46	0	4.3	101	290	120	253	40	N	do	Ca-CO <sub>3</sub>	do	do	Do.
321	809	41	21	113	0	240	147	32	64	70	49	138	209	189	15	N	do	Na-SO <sub>4</sub>	do	do	Fair.
322	337	57	14	78	0	263	26	17	86	90	21	380	219	122	14	N	Moderate	Na-CO <sub>3</sub>	Good	Fair	Good.
323	577	139	63	312	0	189	239	26	8.3	13	42	250	270	223	32	N	High	Na-SO <sub>4</sub>	Fair	Very	Good.
324	1,669	139	63	312	0	424	686	156	8.3	22	94	940	840	606	9.2	N	do	do	do	do	Fair.
325	417	57	21	56	0	256	104	23	33	31	30	230	150	229	57	N	Moderate	Ca-CO <sub>3</sub>	Fair	Poor	Good.

<sup>a</sup> By difference.

<sup>b</sup> C=corrosive; N=noncorrosive; (?)=corrosion uncertain or doubtful.

<sup>c</sup> Numbers correspond to those of records on page 129-141.

<sup>d</sup> Computed as explained in text.

<sup>e</sup> Classified as explained in text.

TABLE 3.—Analyses of soils from southern Grant County, N. Mex.

No.	Location.			Position in quarter.	Designation.	Physiographic situation.	Depth to ground water.	Vegetation.	Physical character of soil.
	T. S.	R. W.	Sec.						
1	24	19	SW.	Southeast corner of SW $\frac{1}{4}$ .		Low sandy ridge extending from sand-dune area.	Feet. 300	Scattered mesquite.....	Loose reddish sand.
2	27	18	SE.	Near center of south line.		Food slope bordering draw	85	None.....	Loose, sandy, somewhat pebbly.
3	22	20	NE.	Northwest corner of SW $\frac{1}{4}$ .		Level plain above alkali flat depression.	175	do.....	Sandy.
4	25	17	SW.	Center of south line of SE $\frac{1}{4}$ .		Outwash slope bordering playa region.	80	Scattered mesquite and other brush.	Clayey, gravelly sand.
5	23	17	SW.	Center.		"Mud" plain adjacent to playas.	75	Few small mesquite and scant grass.	Clay soil, inclined to sun bake and crack.
6	25	18	SE.	Southwest corner.		Bed of playa.	60	None.....	Clay.
7	23	20	NW.	Northwest corner.		Plain between alkali flats.	120	Scattered tufts of alkali sycamore.	Heavy clay; surface sun-baked and cracked.
8	25	20	SE.	Center of NE $\frac{1}{4}$ .		Alkali flat.	100	Alkali sycamore.	Fine clayey sand, inclined to sun bake and crack.
9	23	20	SW.	Northwest corner of SW $\frac{1}{4}$ .		North side of draw draining into alkali flat.	25	Scattered tufts of alkali sycamore.	Heavy clay soil; hard sun-baked surface.
10	25	20	NW.	Southwest corner of NW $\frac{1}{4}$ .		Slope bordering alkali flat.	25	Range grasses and alkali vegetation.	Fine grained, sandy; scoured surface.
11	25	20	NW.	Center of NE $\frac{1}{4}$ .		Alkali flat.	20	None.....	Heavy clay soil; hard sun-baked surface.
12	25	20	NW.	do.....			33	Grass.....	Sandy clay.
13	25	20	SW.	Southwest corner.		Sandy slope bordering alkali flat.	55	Scattered mesquite, sage, and creosote thorn.	Sandy, pebbly.
14	25	17	SW.	Near center of north line near well.		West slope of broad shallow draw.	23	Grass and mesquite.....	Sandy loam.
15	25	19	SW.	Southwest corner.	Seven-Twelve ranch.	End of outwash slope from mesa.	27	Scattered mesquite.....	Do.
16	25	20	SE.	Southwest corner.	J. W. Johnson.	East side of central valley.	10	Grass and scattered mesquite brush.	Heavy clayey loam; surface sun-baked and cracked.
17	24	20	SW.	Near center of west line.	I. A. Leach.	North side of central valley plain.	30	Scattered tall mesquite.....	Sandy loam.
18	25	20	NE.	Southwest corner.	J. C. Haydon.	West side of central valley plain.			

a Estimated.

Water-soluble constituents of soil (expressed in percentages of total soil).														
No.	Depth of soil analyzed.	Total soluble solids (total alkali).		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na + K).	Carbonate radicle (CO <sub>3</sub> ).	Bicarbonate radicle (HCO <sub>3</sub> ).	Sulphate radicle (SO <sub>4</sub> ).	Chloride radicle (Cl).	Water and undetermined constituents.	Black alkali (sodium carbonate, Na <sub>2</sub> CO <sub>3</sub> ).		Alkali content.
		Average for partial soil sections.	Average for total soil sections.									Average for partial soil sections.	Average for total soil sections.	
1	0-1	0.042	0.042	0.005	0.005	0.004	0.0	0.022	0.012	0.006	0.0	0.017	0.038	Negligible.
2	1-4	0.042	0.042	0.006	0.006	0.006	0.0	0.022	0.008	0.009	0.0	0.042	0.038	Weak.
3	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.110	0.035	0.007	0.009	0.059	0.089	Weak.
4	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
5	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
6	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
7	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
8	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
9	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
10	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
11	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
12	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
13	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
14	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
15	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
16	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
17	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.
18	0-1	0.042	0.042	0.006	0.006	0.007	0.0	0.114	0.049	0.017	0.071	0.049	0.089	Weak.

<sup>a</sup> Calculated.

TABLE 3.—Analyses of soils from southern Grant County, N. Mex.—Continued.

No.	Location.			Position in quarter.	Designation.	Physiographic situation.	Depth to ground water.	Vegetation.	Physical character of soil.
	T. S.	R. W.	Sec.						
19	24	20	25	SE.		Central valley plain drainage axis.	<i>Fed.</i> a 20	Scattered mesquite and alkali vegetation.	Clay; sun baked and cracked.
20	24	20	33	NE.		Central valley plain	a 25	Tall mesquite and much saccaton.	Sandy loam, light gray at surface; reddish subsoil.
21	25	20	6	NE.	J. P. Mansfield.	Slope of central valley plain.	46	Tall mesquite and some creosote brush.	Sandy, with small amount of gravel.
22	25	20	14	NW.		Central valley plain	a 30	Saccaton and scattered mesquite and sagebrush.	Sand.
23	25	20	17	SE.		Near edge of central valley plain.	a 65	Heavy mesquite and grass.	Sandy loam.
24	25	20	25	SE.	W. J. Wamel.	Outwash slope bordering central valley plain.	a 60	Heavy mesquite.	Reddish sand.
25	26	17	33	NE.	B. F. Briggs.	Western edge of draw.	75	Scant grass.	Clay soil somewhat gravelly.
26	26	20	32	SE.	J. C. Henderson.	Tongue of plain extending into malpais area.	62	Grass.	Silt.
27	27	15	35	SW.		Center of draw.	223	do.	Loam.
28	27	17	8	SW.	F. B. Cooper.	Gently sloping plain.	66	Scattered low brush; some mesquite.	Clayey, with considerable caliche.
29	27	17	10	SW.	J. E. Ezell.	do.	a 100	Scant grass; no brush.	Clayey, with some gravel.
30	27	20	12	NW.		Central plain near malpais area.	a 105	Grass.	Gravelly sand with some clay.
31	28	17	16	NE.		East edge of sand-dune area.	a 50	Widely scattered brush, mostly mesquite; some saccaton grass.	Sandy, with some gravel.
32	28	17	17	NE.		West side of alkali flat.	a 30	None.	Clay, hard sun-baked surface.
33	28	19	15	SW.		Center of flat.	a 25	Thick grass.	Silt.
34	28	19	34	SE.		Center of draw.	a 25	Grass.	Loam.
35	29	16	18	NE.		Stream-built slope.	a 100	Scattered brush, mostly creosote and alkali mesquite.	Gravelly sand.
36	29	16	30	SW.		West side of alkali flat.	3½	Mexican salt grass and alkali saccaton.	Sandy clay.

a Estimated.



No.	Depth of soil analyzed.	Water-soluble constituents of soil (expressed in percentages of total soil).										Alkali content.		
		Total soluble solids (total alkali).		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium <sup>a</sup> (Na+K).	Carbonate radicle (CO <sub>3</sub> ).	Bicarbonate radicle (HCO <sub>3</sub> ).	Sulphate radicle (SO <sub>4</sub> ).	Chloride radicle (Cl).	Water and undetermined constituents.		Black alkali (sodium carbonate, Na <sub>2</sub> CO <sub>3</sub> ).	
		Average for partial soil sections.	Average for total soil sections.										Average for partial soil sections.	Average for total soil sections.
19	Feet.	0.912	1.074	0.024	0.003	0.243	0.060	0.098	0.049	0.262	0.223	0.034	0.047	Excessive.
20	1-4	1.128		0.024	Trace.	0.285	0	0.120	0.197	0.266	0.237	0.051	0.146	Strong.
21	0-1	0.440	0.645	0.009	0.003	0.130	0.021	0.100	0.116	0.055	0.056	0.195		
22	0-1	0.714		0.009	0.003	0.248	0.063	0.092	0.260	0.086	0	0.034	0.027	Negligible.
23	0-1	1.196	1.179	0.024	0.007	0.041	0.001	0.153	0.023	0.020	0.009	0.024		
24	0-1	0.199		0.034	0.006	0.025	0.001	0.146	0.022	0.014	0	0.085	0.028	Weak.
25	0-1	1.173		0.011	0.001	0.088	0.009	0.119	0.020	0.031	0.045	0.102		
26	0-1	0.244	0.286	0.008	0.002	0.087	0.015	0.122	0.048	0.029	0.051	0.069	0.072	Strong.
27	0-1	1.208	0.992	0.014	0.002	0.070	0.012	0.140	0.038	0.014	0.049	0.110	0.055	Weak.
28	0-1	1.234		0.019	0.003	0.372	0.006	0.122	0.632	0.041	0.071	0.084	0.137	Medium.
29	0-1	0.127	1.01	0.016	0.005	0.032	0	0.099	0.016	0.014	0	0.084	0.050	Negligible.
30	0-1	0.238	0.308	0.007	0.003	0.047	0.006	0.114	0.008	0.014	0.007	0.127	0.050	Weak.
31	0-1	1.108	1.139	0.010	0.005	0.060	0.010	0.149	0.043	0.043	0.060	0.050	0.137	Medium.
32	0-1	0.308		0.004	0.003	0.015	0	0.102	0.007	0.008	0.060	0.050	0.050	Negligible.
33	0-1	0.150	0.221	0.024	0.006	0.009	0.006	0.123	0.020	0.011	0.006	0.050	0.017	Weak.
34	0-1	0.216	0.281	0.015	0.003	0.015	0.006	0.120	0.018	0.006	0.070	0.084	0.137	Medium.
35	0-1	0.168	0.250	0.014	0.006	0.042	0	0.122	0.034	0.012	0.018	0.094	0.025	Weak.
36	0-1	0.350		0.007	0.003	0.075	0.010	0.149	0.047	0.029	0.094	0.170	0.049	Negligible.
37	0-1	0.202	0.217	0.011	0.003	0.075	0	0.122	0.030	0.023	0.029	0.101	0.049	Strong.
38	0-1	0.223		0.011	0.004	0.065	0	0.073	0.063	0.035	0.029	0.046	0.203	Excessive.
39	0-1	0.081	0.100	0.015	0.003	0.013	0	0.073	0.008	0.007	0	0.050	0.323	Strong.
40	0-1	0.108		0.024	0.002	0.016	0.028	0.177	0.008	0.009	0.040	0.178	0.060	Negligible.
41	0-1	0.487		0.009	0.005	0.127	0.028	0.177	0.009	0.009	0.122	0.203	0.203	Strong.
42	0-1	1.126	1.437	0.011	0.005	0.375	0.098	0.100	0.009	0.040	0.122	0.203	0.203	Excessive.
43	0-1	1.331	1.279	0.012	0.005	0.411	0.115	0.202	0.212	0.212	0.096	0.373	0.323	Excessive.
44	0-1	0.068		0.010	0.005	0.010	0	0.081	0.011	0.005	0.027	0.050	0.060	Negligible.
45	0-1	1.022	1.01	0.012	0.005	0.014	0	0.081	0.011	0.005	0.016	0.050	0.060	Negligible.
46	0-1	1.156		0.028	0.008	0.090	0	0.124	0.035	0.005	0	0.046	0.049	Do.
47	0-1	1.173	1.151	0.011	0.002	0.035	0	0.100	0.020	0.006	0.023	0.046	0.100	Weak.
48	0-1	1.178	1.194	0.019	0.003	0.096	0	0.122	0.028	0.006	0.048	0.042	0.098	Do.
49	0-1	0.200		0.011	0.004	0.094	0	0.122	0.028	0.006	0.048	0.042	0.098	Do.
50	0-1	1.152	1.161	0.011	0.003	0.094	0	0.122	0.028	0.006	0.048	0.042	0.098	Do.
51	0-1	0.164		0.012	0.002	0.041	0	0.134	0.011	0.006	0.027	0.098	0.098	Do.

<sup>a</sup> Calculated.

TABLE 3.—Analyses of soils from southern Grant County, N. Mex.—Continued.

No.	Location.				Position in quarter.	Designation.	Physiographic situation.	Depth to ground water.	Vegetation.	Physical character of soil.
	T. S.	R. W.	Sec.	Quarter.						
37	29	16	31	SE.	Near center of east boundary of NE. $\frac{1}{4}$ .	A. F. Lane.	Central plain.	Feet. 22	Irrigated orchard on cleared mesquite land.	Clay loam.
38	29	16	32	SW.	Northwest corner.	do.	do.	22	Irrigated alfalfa on cleared mesquite land.	Loam.
39	29	17	10	NE.	Center of NE. $\frac{1}{4}$ .	do.	Slope above alkali flat.	(c)	Alkali saccaton and Mexican salt grass.	Sandy.
40	29	17	26	NW.	Near center of north line.	do.	Slope toward Playas Lake	b 50	Mesquite and grass.	Coarse sand.
41	30	14	33	NW.	Northeast corner.	O. O. Richen.	Center of draw.	107	Grass.	Loam.
42	30	16	7	NW.	Northwest corner.	do.	Central plain.	b 35	Thick mesquite.	Sandy loam.
43	30	16	10	NW.	do.	do.	do.	b 30	Mesquite and small amount of grass	Heavy clay loam.
44	30	16	22	SE.	Near center of south line.	do.	Shallow draw along east side of central plain	b 40	Mesquite and grass.	Clay loam
45	31	14	12	NE.	Southeast corner at Mexican boundary.	do.	In draw short distance south of center.	b 10	Mesquite and grass, also crucifixion thorn.	Do.
46	31	14	36	SE.	At boundary monument.	do.	Level plain.	b 100	Tall mesquite and little grass.	Do.
47	31	16	9	NW.	Center of SW. $\frac{1}{4}$ .	do.	Level central plain.	b 40	Mesquite and grass.	Do.
48	31	16	27	NW.	Northeast corner.	do.	do.	b 60	Thick mesquite and grass.	Do.
49	31	20	22	NW.	Center of NW. $\frac{1}{4}$ .	E. G. Howe.	Alluvial fan of Prairie Creek.	17	Nourigated Indian corn.	Sandy loam.
50	32	16	8	NE.	NW. $\frac{1}{4}$ near wells.	do.	Level central plain.	54	Mesquite and grass.	Clay loam.
51	32	16	15	SW.	Southeast corner of SW. $\frac{1}{4}$ .	New wells of Gilbert Wells.	do.	63	Grass and scattered brush.	Do.
52	32	16	18	SW.	Center of east line of NE. $\frac{1}{4}$ .	Jackson.	do.	56	Grass.	Reddish sand.
53	33	20	33	NW.	Southwest corner of NW. $\frac{1}{4}$ .	Louis Carrier.	Plain west of beach ridge.	b 10	Plowed field, formerly grass land.	Gravelly loam.

b Estimated.

c Springs 200 feet south.

No.	Depth of soil analyzed.	Water-soluble constituents of soil (expressed in percentages of total soil).											Alkali content.	
		Total soluble solids (total alkali).		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO <sub>3</sub> ).	Bicarbonate radicle (HCO <sub>3</sub> ).	Sulphate radicle (SO <sub>4</sub> ).	Chloride radicle (Cl).	Water and undetermined constituents.	Black alkali (sodium carbonate, Na <sub>2</sub> CO <sub>3</sub> ).		
		Average for partial soil sections.	Average for total soil sections.									Average for partial soil sections.		Average for total soil sections.
37	0-1	0.425	0.504	0.005	0.003	0.130	0.064	0.153	0.042	0.020	0.063	0.233	0.233	Strong.
38	1-4	.531	.161	.008	.003	.080	.075	.168	.063	.023	.095	.233	.067	Weak.
39	0-1	.140	.141	.016	.002	.031	.0	.122	.025	.006	.002	.064	.134	Strong.
40	0-1	1.792	.624	.008	.007	.563	.252	.070	.452	.081	.021	.068	.032	Negligible.
41	0-1	.235	.166	.009	.005	.064	.0	.088	.016	.007	.041	.052	.023	Do.
42	0-1	.132	.145	.006	.010	.020	.0	.052	.022	.014	.024	.042	.075	Weak.
43	0-1	.178	.248	.020	.003	.043	.0	.125	.049	.005	.034	.017	.094	Do.
44	0-1	.097	.150	.024	.006	.024	.0	.125	.023	.007	.043	.085	.025	Weak.
45	0-1	.268	.161	.011	.003	.056	.0	.149	.020	.012	.063	.085	.064	Do.
46	0-1	.169	.389	.008	.002	.020	.0	.040	.029	.009	.003	.034	.025	Negligible.
47	0-1	.162	.161	.029	.006	.025	.0	.146	.018	.007	.005	.025	.107	Strong.
48	0-1	.142	.084	.006	.006	.021	.006	.215	.020	.009	.045	.025	.0	Weak.
49	0-1	1.183	.029	.010	.010	.352	.006	.112	.079	.049	.079	.076	.0	Medium.
50	0-1	.228	.343	.029	.003	.014	.008	.122	.084	.012	.046	.0	.155	Negligible.
51	0-1	.400	.225	.023	.022	.042	.006	.177	.010	.005	.043	.125	.024	Weak.
52	0-1	.224	.183	.006	.005	.062	.006	.177	.080	.007	.075	.029	.062	Do.
53	0-1	.226	.183	.013	.006	.070	.012	.131	.119	.016	.049	.046	.027	Negligible.
54	0-1	.198	.155	.024	.010	.025	.0	.088	.029	.006	.009	.054	.017	Do.
55	0-1	.178	.116	.021	.006	.027	.0	.092	.023	.007	.055	.079	.087	Negligible.
56	0-1	.168	.283	.011	.004	.065	.0	.137	.063	.019	.058	.060	.027	Do.
57	0-1	.274	.139	.013	.005	.066	.0	.119	.063	.012	.050	.020	.017	Negligible.
58	0-1	.286	.131	.018	.009	.011	.0	.082	.022	.012	.046	.030	.017	Do.
59	0-1	.162	.111	.016	.015	.011	.0	.101	.030	.009	.046	.030	.014	Do.
60	0-1	.122	.113	.005	.005	.063	.0	.093	.019	.036	.036	.034	.014	Do.
61	0-1	.134	.114	.007	.006	.049	.0	.089	.010	.005	.033	.015	.015	Do.
62	0-1	.098	.088	.012	.005	.005	.0	.087	.013	.007	.033	.013	.014	Do.

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