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BUREAU OF SOILS.
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SOIL SURVEY OF THE HANFORD AREA, CALIFORNIA.

BY

MACY H. LAPHAM AND W. H. HEILEMAN.

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CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

MAPS.

SOIL SURVEY OF THE HANFORD AREA, CALIFORNIA.

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LOCATION AND BOUNDARIES OF THE AREA.

The area surveyed embraces the upper portion of the triangle formed by Kings County and the adjoining portion of Fresno County, and covers an area of 216 square miles. It consists of townships 17 to 19 S., R. 21 E., and 17 to 19 S., R. 22 E. This area is bounded upon the north by the fourth standard parallel south of the Mount Diablo par-

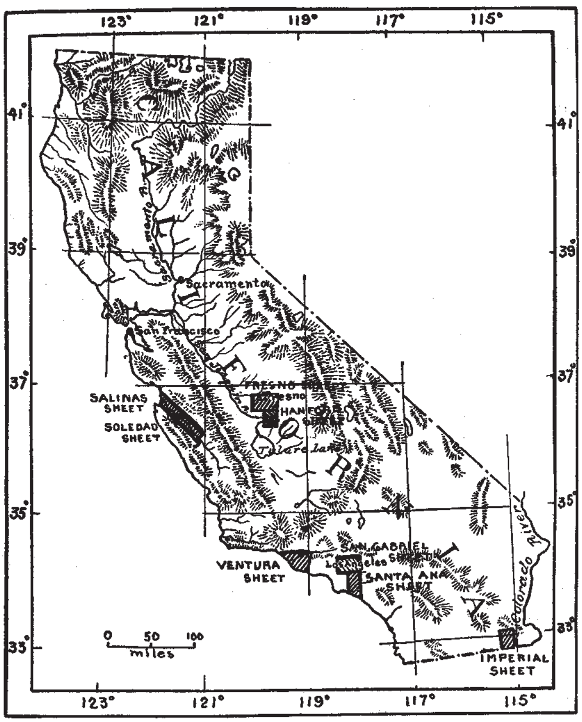

FIG. 20.—Sketch map showing areas surveyed in California.

allel, from which it extends southward for a distance of 18 miles. From Hanford, the county seat of Kings County, the area extends east and west for a distance of 6 miles. That portion of the area surveyed south of Kings River includes the major part of that portion of the Kings River Delta known as the "Mussel Slough country," the soils of which are noted for the production of fruit, consisting of raisin and wine grapes, peaches, apricots, prunes, and pears. Grain and alfalfa are also raised in some portions of the area. Several hundred acres of the important fruit belt to the southwest and in the vicinity of Lemoore were not included in the area surveyed. (See fig. 20.)

On the southeastern part of the maps accompanying this report and east of Cross Creek is included a small portion of the extensive tracts of land devoted to grazing and to dry farming for wheat. North of this quite an extensive body of alkali land is shown. This land extends nearly to the river and was once considered very valuable, but now much of it is abandoned, being ruined by alkali.

North of the main channel of Kings River the area includes a large portion of the Laguna de Tache grant, a tract of about 65,000 acres, formerly devoted almost entirely to grazing, but now opened up to settlement.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The history of the settlement of this portion of the San Joaquin Valley dates back to the old Spanish land grants, when grazing was practically the only form of agricultural industry pursued.

It was not until about 1860 that the practice of agriculture proper first found footing. The rapid settlement of the country had created the need of greater food supply, and attention was turned to the production of cereals. With the arid climate of the San Joaquin Valley, however, this industry became profitable only by the introduction of irrigation.

Although the practice of irrigation was known to the founders of the Spanish missions long ago, it was not until 1870 that it was first tried in this portion of the valley. At this time, the necessity of irrigation being recognized, the first of the canals, still in active service, was constructed by the cooperation of a score or more persons, to whom water was to be supplied. This canal is known as the Lower Kings River Canal and lies just west of the area surveyed, and hence is not shown upon the soil map. The construction of the People's Ditch, Last Chance Canal, Lakeside, Settlers', Riverside, and Mussel Slough canals followed rapidly. It is a singular fact that only the last named of these, constructed in 1875 at a cost of $50,000, and the only one now out of use, was constructed for purposes of speculation, all others being built and operated by the cooperation and agreements of residents who were to be benefited by the water. The three main canals in this area on the north side of Kings River were constructed about this time or a little later.

With the introduction of irrigation the raising of wheat and alfalfa became more profitable, as good crops no longer depended upon an uncertain and inadequate rainfall.

About 1885 fruit growing was commenced, and owing to favorable conditions of soil and climate rapidly displaced the less intensive system of farming, until it has become, to the north and west of Hanford, especially, the principal source of agricultural revenue.

Diversified farming and stock raising have also developed into an important feature of the agriculture of other portions of the area.

An abundant water supply, coupled with an inexpensive system of irrigation, has, however, not proved an unmixed blessing. The excessive and too often injudicious use of water has, as in every arid region, brought its attendant and inevitable evils, and in spite of promises of unfailing crop production in the first few years of irrigation, the "rise of the alkali," as it is known in the West, has begun to take place. Much land has already been seriously damaged, while more is threatened. This matter will be treated more fully later on.

Kings County, created by act of legislature in 1893, now has a population of about 10,000 and an assessed valuation of $7,000,000. With the development of the fruit industry in recent years, Hanford, the county seat, has become a thoroughly modern little city of 3,000 inhabitants. Its shipping facilities are good, and it is the natural center of the rich agricultural country about it.

North of the Kings River, in Fresno County, the country has until very recently been given up largely to grazing. Several large cattle ranches are still in operation in this vicinity. Alfalfa, small grains, and corn have been raised with considerable success upon the lands lying along the river. The portion of the area known as the Laguna de Tache Rancho is now being improved by an extension of the irrigation and drainage systems and opened up to settlement. North of this cultivated land and lying along the northern boundary of the area mapped is a large tract of alkali land, once very promising, but now, like much of the country still farther north, abandoned or given up only to grazing.

CLIMATE.

The climate of the upper or southern San Joaquin Valley is, like that of much of the southern interior of the State, subtropical and arid. It is characterized during the dry season by high temperatures, cloudless skies, cool nights, light and steady winds, low relative humidity, and lack of rainfall. In the wet season frequent fogs, rains, and frosts occur.

The records of the various stations of the Weather Bureau show very uniform temperatures throughout the San Joaquin Valley.

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The following table gives results of observations of temperature and precipitation in the Hanford area for a series of years, as given in reports of the Weather Bureau:

Normal monthly and annual temperature and precipitation for Hanford area.

Month.	Temperature.			Precipitation.		
	Fresno.	Huron.	Tulare.	Fresno.	Huron.	Tulare.
	°F.	°F.	°F.	*Inches.*	*Inches.*	*Inches.*
January	44.7	48.0	47.8	1.54	0.96	1.71
February	50.4	51.6	54.2	1.11	.74	.89
March	54.2	56.4	55.3	1.64	.94	1.30
April	61.6	60.3	63.4	.64	....	.41
May	68.4	69.5	68.8	.58	.27	.28
June	76.3	77.2	76.9	.15	.06	.19
July	82.4	86.0	83.1	.01	.07	.02
August	81.0	83.4	81.7	.04	.05	.01
September	73.5	73.2	71.8	.31	.01	.84
October	64.0	65.8	64.2	.62	.15	.31
November	55.4	56.8	54.2	.98	.39	.51
December	46.3	49.2	47.4	1.79	.97	.98
Normal annual	62.6	64.6	64.1	9.41	[a]4.61	7.45

[a] April omitted.

The records collected at Fresno show the average dates of killing frost as follows: Last in spring, March 1; first in autumn, November 14. These Fresno records are perhaps the most complete data available for the area covered by this survey, though from incomplete records it is thought that the area around Hanford is subjected to a longer and more severe frost period.

Nearly all the rainfall takes place during the rainy season, which lasts from November until the 1st of April. December, January, and March are considered the rainy months. Cloud-bursts are unknown and thunderstorms are infrequent, the rain generally falling in occasional gentle showers.

The annual rainfall increases steadily from the upper to the northern portion of the valley, ranging from less than 4 inches at Bakersfield to over 15 inches at Stockton. The minimum along the western side of the valley is believed to be even less than this, but no records are available. A statement of the distribution of the annual rainfall at Fresno, Huron, and Tulare, obtained from reports of the United States Weather Bureau, is included in the foregoing table.

The relative humidity is a determining factor in the oppressiveness of summer heat, or in the rate of evaporation from bodies of water or from soils. During the dry season, when the relative humidity is very low (averaging 30 to 40 per cent), the soils must be protected from excessive evaporation in order to conserve the moisture. This protection is an office of cultivation.

Records kept at Kingsbury from 1881 to 1886 show the amount of water evaporated from a water surface to be 46 and 59 inches from two tanks—one situated at the surface of the river and the other in the air—respectively.

The sensible temperature is also greatly affected by prevailing winds, which hasten evaporation and produce a cooling effect upon the body.

The prevailing winds of the San Joaquin Valley are light and steady, blowing from a northeasterly direction. Winds of high velocity are very rare. The only available wind records are those from the Fresno station. At this place the average hourly velocity for the year is 5.5 miles, varying from 3.4 miles in December to 7.5 miles in June.

At the Fresno station of the Weather Bureau there are on the average two hundred and thirty clear days, seventy-six partly cloudy days, fifty-nine cloudy days, and forty-four rainy days. The months of June, July, August, and September are practically cloudless.

Fogs occur in the winter months only. In an average year there are thirty-eight foggy days, the majority of them coming in December (thirteen days) and January (twelve days).

Although the days during the summer are exceedingly warm, the sensible temperature is much moderated, by the low relative humidity and the prevailing breezes. Sunstroke is unknown, and, on the whole, the climate is healthy and favorable to agricultural production. Pulmonary disorders and fevers are rare. The average death rate for Kings County for eight years was only 7.2 per 1,000 population.

PHYSIOGRAPHY.

The San Joaquin Valley constitutes the southern and larger portion of the great valley of California. Extending from the Tejon Mountains to the southern extremity of Stockton, Sacramento Valley, it covers, according to Grunsky (Water Supply and Irrigation Papers, No. 17, United States Geological Survey), an area of 11,500 square miles, having an average width of 40 miles, and being about 250 miles in length. Of this great area the east side of the valley, for reasons which will be considered later, is by far the larger and more important part. The elevation of the trough of the valley floor increases uniformly from a few feet at its lower or northern extremity to about 290 feet in the vicinity of Buena Vista Lake.

The floor of the valley is formed by smooth, even plains, which extend upon each side of the valley to the foothills, having an average slope of from 5 to 10 feet to the mile only. The plains are unmarked by any striking feature of landscape, being very flat, and are treeless except for a growth of willows and cottonwoods along stream channels and of valley oak on the delta land. They end in the arid foothills and mountains of the Coast Range upon the west, while to the east rise the lofty snow and forest crowned ridges of the Sierra Nevada Mountains, some of them more than 14,000 feet above the valley floor. The valley is divided into three unequal portions by the flat, low delta deposits from the Kern and Kings rivers.

Into this arid region is poured the waters from 20,000 square miles of mountain watershed, less than one-fourth of which is on the west side. Of the perennial rivers rising in the high Sierras, Kern, Kings, San Joaquin, Merced, Tuolomne, and Stanislaus are the most important. No perennial streams flow from the west side. The Kings River, having a watershed of 1,700 square miles, most of which is in the high mountains of the Sierras, breaks into the San Joaquin Valley a little northeast of the city of Fresno and about 20 miles distant. From this point, for the most part flanked by gradually disappearing bluffs, it flows in a southwesterly direction until Kingsburg is reached, in the northeastern corner of Tulare County. Here the bluffs give way entirely, and the river enters upon the valley plain, dividing into a number of meandering streams. It is here that the Kings River Delta begins. From this point the main channel finds its way as a broad, shallow stream, frequently obstructed by sand bars, to the valley trough, a distance of about 30 miles. The banks of the river are low, ill defined, and wooded with a heavy growth of valley oak, with some cottonwood, willow, and sycamore. After reaching the valley trough it turns aside and flows in a southerly direction into the Tulare Lake Basin. South of the main channel the country is cut by numerous sloughs, the remnants of abandoned river channels, extending in a southwesterly direction toward the lake. Some are continuous for many miles; others make their appearance as disconnected sinks only. They contain considerable seepage water in the wet season, and are usually bordered by willows and frequently by a vigorous growth of tule. The name applied to the region, the Mussel Slough Country, is taken from the slough by that name. Burris Slough is a former connection between Kings River and the channel now occupied by Cross Creek. Some of these old waterways have been silted up by river action, while others have been artificially closed to form reservoirs. The country slopes toward the lake basin at the rate of about 4 feet per mile.

The delta streams of Kings River usually occupy low ridges, a trifle higher than the surrounding country.

North of the main channel the water finds its way through Cole River, Murphy Creek, and Jolda Canal to Steamboat Slough, and thence into the San Joaquin River, the country having a slope in this direction of about 4 feet to the mile. While formerly Kings River emptied into Lake Tulare, considerable water is now diverted for irrigation purposes, while of that remaining, except in the high-water season, nearly or quite all reaches the San Joaquin River.

Cross Creek, on the east of the area under discussion, receives its waters from a branch of the Kaweah River, and, flowing in a southwesterly direction, empties into Tulare Lake.

The San Joaquin Valley was at one time undoubtedly occupied by a large body of water, probably connected with the Pacific Ocean. Into this was carried the débris of the surrounding mountains, until the basin was filled to a great depth. As the streams laden with the waste of the Sierras entered this lake or arm of the sea, their velocity was suddenly checked, causing a deposition of the material in suspension—the finer material the farther from the inlet of the stream. This action built up a series of deposits with gradual slope extending from the stream inlets out into the valley. As these became very extensive they gradually came together, and by coalescence formed a valley plain with gentle slope extending from the base of the mountains to the valley trough. This has also taken place upon the west side of the valley, but owing to less river action, to a much smaller extent. Hence the accumulations on the east have forced the valley trough, marked by the San Joaquin River, nearer the west side. Somewhat similar action has produced the present Kings River delta in later times.

Lake Tulare is a shallow depression in the center of Kings County. Bordering it are the rich delta and swamp lands of the Kings, Kaweah, and Tule rivers and the dry plains and hills of the Tejon and Coast ranges, now the seat of important oil and mineral industries.

Only a few years ago Lake Tulare was the largest fresh-water lake west of the Rocky Mountains; now much of its bed is producing heavy crops of grain and alfalfa, and the greater part of the lake bottom is filed upon and claimed as redeemable land.

Grunsky gives the following facts in regard to the fluctuations of Lake Tulare: In 1853 the lake was full, but it subsided until 1861, when the surface was 204 feet above sea level. The winter of 1861–62 was remarkable for its heavy rains, and the lake rapidly rose to an elevation of 220 feet, overflowing through Fresno Slough and San Joaquin River, and covering an area of about 800 square miles. From this time the water receded until 1863, then rose again rapidly until nearly the height of 1861 was reached. Since 1861–63 it has rapidly receded.

In the season of 1900 the lake was entirely dry. The winter of 1900–1901, in striking contrast to those immediately preceding, was marked by an unusual amount of rain and snow in the mountains, and the following season was characterized by another stage of high water, and a large amount of water again found its way into the lake, causing considerable damage and apprehension on the part of recent settlers in the basin. The lake is estimated to have covered an area 18 by 35 miles in extent at that time.

Although the water was at one time considered fit for purposes of irrigation, its rapid concentration by evaporation has rendered it unfit for any purpose whatever. In the winter of 1888–89 the fish in the lake began to die, and an analysis revealed the presence of 303 grains of solid matter per gallon of water. The results of analyses of this water by Hilgard are given in detail below:

Analyses of water from Lake Tulare.

Constituent.	Date of taking sample.		
	January, 1880.	June, 1888.	February, 1889.
	Grs. per gal.	*Grs. per gal.*	*Grs. per gal.*
Total solids	81.80	204.7	303.07
Soluble after evaporation	71.16	186.9	279.97
Sodium chloride (common salt)	22.17	....	95.79
Sodium sulphate (Glauber's salt)	17.23	....	73.76
Sodium carbonate (sal soda)	27.92	74.3	94.74
Potassium sulphate	3.24	....	15.68
Insoluble after evaporation	8.36	3.7	6.97
Calcium sulphate (gypsum)	....	....	1.47
Calcium carbonate	2.97	....	1.07
Magnesium carbonate	4.95	....	2.55
Silica	.44	....	1.87
Organic matter and water	2.88	14.1	16.12

Previously an extensive west-side irrigation system had been proposed, the water to be taken from the lake. Fortunately, however, this project had been abandoned before much of the work had been carried out.

GEOLOGY.

The primary formation of the Sierra Nevada Mountains consists of granite, which is often associated with secondary materials consisting of volcanic ash, pumice, basalt, sandstone, etc.

The soils of the Hanford area are composed of these materials disintegrated and laid down in deep beds. The entire absence of outcrop, bowlders, and gravel would indicate that this took place in rather deep water. In the Fresno area two geological formations have been described by Messrs. Means and Holmes; the red formations consisting of red sandstone, sands, and sandy loams, and the white formation consisting of pumice, volcanic ash, white sands, sandy loams, loams, and clays.

The red formation is derived largely from mixed granitic and basaltic material disintegrated but not greatly decomposed, and is free from the alkali salts, while in the white formation varying quantities of volcanic ash seem to be present and alkali salts are always found.

The soils of the Hanford area fall naturally into two classes, viz, plains soils and delta soils.

To the soils of the plains belong those found along the northern and northeastern borders of the area. They are derived from the white formation.

The delta soils, as the name implies, are found on the delta portion of the area. They consist of materials brought down by the streams and mixed with the original bench or plains soils. They are partly derived from both the white and red formations, and contain as a rule a considerable amount of mica and other material evidencing their granitic origin.

Associated with the delta soils there is one type, the San Joaquin black adobe, that is essentially a Sierra foothill soil modified by stream or lacustrine action.

The position and extent of these soil types are shown upon the soil map accompanying this report.

SOILS.

The soils of the plains consist of sands and sandy loams, usually occurring in very deep, well-stratified deposits. They cover extensive areas of the valley floor, are without marked physiographic features, and becoming commingled with the true delta soils gradually pass into the soils of the delta region.

The soils of the Kings River delta occur as irregular swales, streaks or sinks of sands and sandy loams, with indefinite boundaries often grading imperceptibly from one type into another. They contain more or less mica and feldspathic sand and were laid down by meandering streams.

The following table gives the acreage of the various types of soil found in the area:

Areas of different soils.

Soil.	Acres.	Per cent.
Plains soils:		
Fresno sand	20,790	15.0
Fresno sandy loam	10,860	7.9
Delta soils:		
Hanford fine sand	51,250	37.1
Hanford fine sandy loam	30,010	21.7
Fancher sandy loam	19,860	14.4
San Joaquin black adobe	5,470	3.9
Total	138,240	....

FRESNO SAND.

The Fresno sand is a loose, incoherent white sand, rather coarse in texture. The typical Fresno sand never clods, but falls into a loose mulch at the surface when cultivated. It is usually 6 feet or more in depth and very uniform.

In the Mussel Slough region a local modification of this type occurs in narrow strips, extending in a northeast and southwest direction. In this case the soil consists of a coarse, loose white sand, devoid of organic matter and plant food, which manifests itself in narrow barren strips cutting through the otherwise rich and verdant orchards and vineyards. A striking example of this occurs one-half mile north of Banner, on the Santa Fe Railroad.

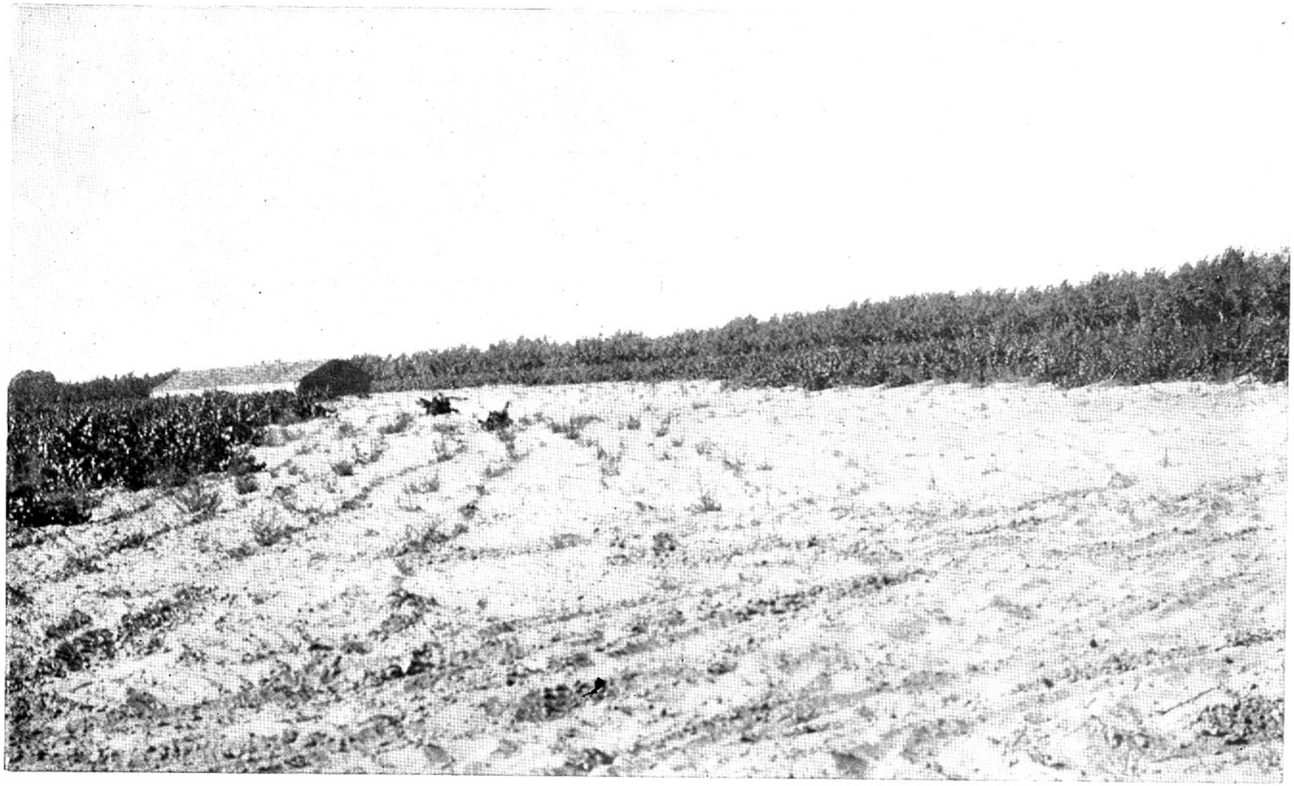
To the north of Kings River this soil is mostly unirrigated and is either utilized as pasture or allowed to lie idle. Limited areas yield fair average crops of wheat and alfalfa in favorable seasons, but this soil can not be successfully dry-farmed, as it dries out rapidly. South of the river when well irrigated it produces good crops of grain, alfalfa, and fruit. It is best adapted to apricots, peaches, and other fruits requiring good drainage. Water sinks readily into the soil and when present in excess it finds a ready outlet by seepage through the coarse pores to the lower levels.

The typical Fresno sand covers rather large areas on the plains along the northern boundary of the Hanford area, the bodies extending in a southerly direction. In a more or less modified form it is present in occasional patches and long narrow strips through the delta lands. On the plains it overlies the Fresno sandy loam. The areas of this soil are generally slightly higher than the surrounding country, frequently marking former or present stream channels. It is derived from the white Fresno formation, more or less modified by stream and wind action. Much of that lying along streams has been worked over and piled up as sand bars, spits, or ridges. In the delta country stream modification has produced a phase of this soil found in limited areas, which is darker in color, contains considerable mica and loam, is compact, and clods in cultivation.

These phases are all modified by wind action, and stream channels are often filled up and adjoining soils buried by this sand. The state of decomposition of this soil is not as far advanced as that of the soils of finer texture, many of the original rock minerals being still present as coarse or medium-sized grains easily recognized by the unaided eye or with a magnifying glass of low power. Disintegration and decomposition are still taking place rapidly. This soil appears to contain sufficient plant food for most crops, although it is rather easily leached.

Upon the plains the Fresno sand is practically free from alkali. The alkali salts may, and do, exist in the lower depths of the soil, or in the underlying Fresno sandy loam, but unless the ground water should be raised, thus causing concentration of the alkali in the surface, there is no serious danger from alkali upon this type.

In the delta region it is likewise generally free from alkali, although in low places an accumulation of the alkali salts has occurred from the



NARROW STRIP OF FRESNO SAND RUNNING THROUGH VINEYARD.

This sand is so open and porous that it is not supplied with sufficient water by subirrigation and so is unproductive. If it were surface irrigated it would produce crops.

proximity of the water table to the soil surface. A little drainage and careful management will, however, remove this trouble.

The Fresno sand is the prototype on the Pacific coast of the Norfolk sand or typical early truck soil of the Atlantic coast States.

The following table gives the mechanical analyses of typical samples of Fresno sand:

Mechanical analyses of Fresno sand.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5582	Sec. 4, T. 17 S., R. 21 E.	Sand, 0 to 12 inches.	0.38	1.18	1.86	28.48	16.86	24.40	14.12	10.32	1.84
5584	Sec. 29, T. 18 S., R. 21 E.	Sand, 0 to 12 inches.	......	1.60	5.86	28.20	15.46	18.58	12.92	13.52	3.18
5583	Subsoil of 5582....	Sand, 12 to 72 inches.	.07	.42	4.20	26.32	19.16	25.96	14.32	7.72	1.57
5585	Subsoil of 5584....	Sand, 12 to 72 inches.	.02	1.30	6.85	39.46	14.00	11.66	10.32	11.70	4.16

FRESNO SANDY LOAM.

This soil is a fine sandy loam, white in color, the surface of which in the dry season is fine and ashy, whence its local name of white-ash land is derived. The state of decomposition is fairly well advanced, but disintegration is still going on rapidly.

The soil covers extensive tracts along the north and northeastern boundaries of the Hanford area. It occurs in irregular bodies cut by streaks and areas of Fresno sand, and is in its natural condition treeless and without marked physiographic features. It is sometimes overlain by Fresno sand, and it has a slight slope in the direction of the natural drainage. It is derived from the white sand and loam formations of the Fresno area, described by Means in the Report for 1900, mingled with varying amounts of volcanic ash. It was laid down in deep water and along streams and has since been modified by river action. In some places the sand, and in others the volcanic ash, predominates.

At an average depth of 2 feet the subsoil becomes heavier, and a little below this a lime-magnesium hardpan occurs, which softens upon application of water and changes to a bluish clay. In its dry condition it is very hard, sometimes, along soil boundaries, appearing at the surface, and at other places often not encountered until a depth of from 4 to 6 feet has been reached.

The results of mechanical analyses of typical soils and subsoils are given below:

Mechanical analyses of Fresno sandy loam.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5586	Sec. 17, T. 17 S., R. 21 E.	Sandy loam, 0 to 12 inches.	0.90	1.52	0.00	2.32	4.90	22.48	19.00	37.46	10.84
5588	Sec. 24, T. 18 S., R. 22 E.	Sandy loam, 0 to 12 inches.	2.13	2.24	0.00	2.42	4.38	17.66	18.66	39.64	11.03
5587	Subsoil of 5586....	Sandy loam, 12 to 72 inches.	.23	1.16	0.00	3.28	3.06	19.20	16.32	48.50	7.49
5689	Subsoil of 5588....	Sandy loam, 12 to 72 inches.	.29	1.26	1.76	3.14	3.82	16.96	31.50	31.76	9.61

The alkali areas of this soil are of no agricultural value under present conditions. At one time this type was considered a fine soil for fruit and general farming and was valued as high as $50 per acre, but it is now mostly abandoned to alkali flats or used only as pasture and valued at only $5 per acre. The Hanford area contains about 8,000 acres of such land, entailing a loss in valuation of $360,000. Water sinks into this soil readily unless the soil is puddled, when it becomes impervious and bakes upon drying. The natural drainage is poor. With thorough artificial drainage and plenty of irrigating water, this alkali land can be reclaimed. Water or moist soil is always found beneath the hardpan.

The alkali of this land was originally concentrated in the hardpan. Irrigation, effecting a rise of the water table, has in most cases been the cause of the rise of the alkali salts and their appearance at the surface. In the alkali of this soil sodium chloride (common salt) and sodium carbonate (black alkali) predominate. The following results of alkali determination made in the field to the depth of 6 feet show the present distribution of the alkali:

Distribution of alkali in the soil at different depths.

Locality.	Percentage of total salts present in—					
	First foot.	Second foot.	Third foot.	Fourth foot.	Fifth foot.	Sixth foot.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Sec. 6, T. 17 S., R. 22 E.	0.94	0.58	0.34	([a][b])	([b])	([b])
Sec. 9, T. 17 S., R. 21 E.	1.62	[a].41	[a].36	([b])	([b])	([b])
Sec. 23, T. 18 S., R. 22 E.	[a].90	.92	1.30	.64	.42	.44

[a] Hardpan. [b] Less than 0.2 per cent.

The cross-lined portion of this soil area shown upon the alkali map indicates the alkali as concentrated in the first 2 feet. The hardpan contains less alkali than the soil above it, while below the hardpan the soil is practically free from alkali.

FANCHER SANDY LOAM.

The Fancher sandy loam covers a considerable area near the center of, and small areas throughout, the Hanford district. It generally occurs in irregular bodies or strips at the same general level as the surrounding country, though it is sometimes found in shallow depressions.

It is formed of the Hanford phase of the Fresno sand intermixed with a considerable proportion of alluvial material of organic and granitic origin.

The state of decomposition is well advanced, the soil containing an abundance of mineral plant foods and usually of nitrogenous and other organic matter. This soil varies much in texture and grades imperceptibly into the adjacent soils. The mechanical composition of soil and subsoil is shown below.

Mechanical analyses of Fancher sandy loam.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5579	Sec. 15, T. 18 S., R. 21 E.	Sandy loam, 0 to 12 inches.	0.17	2.52	1.86	13.40	9.02	22.48	23.56	17.48	7.19
5577	Sec. 25, T. 18 S., R. 21 E.	Sandy loam, 0 to 12 inches.	.56	3.68	1.74	10.26	7.30	21.96	21.72	21.92	10.76
5578	Subsoil of 5577....	Sandy loam, 12 to 72 inches.	.03	2.68	1.96	8.88	7.32	22.66	25.60	23.92	7.07
5580	Subsoil of 5579....	Sandy loam, 12 to 60 inches.	.05	2.34	1.36	13.20	10.72	21.88	22.78	21.44	7.27
5581	....do............	Sandy loam, 60 to 72 inches.	.23	1.50	.82	15.06	21.90	28.66	13.68	13.36	4.01

The soil is of a grayish color, 6 feet or more in depth, and a striking feature is the presence of large mica flakes. It contains enough clay to bind the soil grains, and if cultivated in a wet condition often bakes and forms clods. It is, however, a valuable fruit soil, and is devoted largely to the growing of grapes, apricots, pears, and prunes.

The Fancher sandy loam holds water well, but is easily drained. In much of this soil area the water table is kept very close to the surface during the irrigating season, and certain small areas and depressions have become water-soaked, resulting in the drowning out of crops and the accumulation of an excess of alkali salts. This condition may be easily remedied, however, by drainage.

Generally speaking this soil is free from alkali. Overirrigation, especially by subirrigation, is, however, always dangerous, as the soluble salts present, which may be harmless when distributed through the soil, if concentrated at the surface, may be injurious or even prohibitive of plant growth. Seepage waters from the overloaded subsoil have, in numerous instances, caused such an accumulation of the alkali salts at the surface of this type of soil. A drainage ditch or underdrains at intervals of 200 to 400 feet would in a short time remove this trouble. It is only in these small areas, where the alkali salts have been brought in and concentrated in the surface, that this soil contains enough alkali to reach the limit of danger.

HANFORD FINE SAND.

The Hanford fine sand occurs in irregular and often continuous bodies throughout the Hanford area, being cut by strips and areas of the Fresno sand and Fancher sandy loam. It also often occurs along former or present stream channels in a slightly elevated position, where the land has not been subject to lacustrine deposits or to recent overflow.

The soil, which carries much mica and finely abraded sand, is largely of granitic origin. It is essentially a delta soil, owing its deposition to river action, and at the present time much of this material may be seen suspended in the river and canal waters at flood time. It is well decomposed and contains a good supply of available plant food.

In texture this soil is a light, yellowish fine sand, easily cultivated and containing enough loam and organic matter to produce good crops. It is usually 6 feet or more in depth and readily erodes when exposed to the action of running water. The abundance of micaceous material gives it a peculiar soft and silky or greasy feel when rubbed between the fingers.

ALFALFA FIELD ON THE HANFORD FINE SAND.

This crop is not surface irrigated but subirrigated. Also shows characteristic growth of valley oaks found on these soils.

The mechanical composition of typical soils and subsoils is indicated below:

Mechanical analyses of Hanford fine sand.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5590	Sec. 10, T. 18 S., R. 21 E.	Fine sand, 0 to 12 inches.	0.05	2.44	0.00	2.14	3.48	34.26	36.10	16.74	3.89
5592	Sec. 10, T. 17 S., R. 22 E.	Fine sand, 0 to 12 inches.	.09	3.16	0.00	0.00	1.26	16.20	41.28	31.88	5.15
5591	Subsoil of 5590....	Fine sand, 12 to 72 inches.	.03	3.12	0.00	.78	.92	16.06	25.60	45.28	6.99
5593	Subsoil of 1592....	Fine sand, 12 to 72 inches.	.09	2.74	0.00	0.00	1.86	22.28	37.40	28.72	8.33

Alfalfa, grain, and fruit of all kinds are raised upon this soil, with good yields when free from alkali. It is a splendid truck soil when well drained and is one of the finest orchard and vineyard soils in the area, producing especially large crops of grapes, apricots, and pears. In nonirrigated sections it has been dry-farmed to wheat with fair results in favorable seasons.

This soil is occasionally underlain by loam or soft, sandy clay, but not by true hardpan. Its natural drainage in the northern and western portions of the area is good, except in depressions. It would, however, respond very quickly to artificial drainage, and in general would be benefited by it.

In that portion of the delta region west of Mussel Slough this soil is free from alkali, with the exception of a few local depressions having a slight accumulation of salts upon the surface. East of the Mussel Slough, however, much of this soil shows a very serious accumulation of alkali to a depth of 6 feet. The natural drainage is here not so good as in the western portion of the area, and the land is much influenced by the alkali soils upon the northeast, from which it receives the drainage water. While in the western half of the area sodium sulphate appears to be the predominating alkali salt, sodium chloride appears to be the more common salt here. The soil also contains a large amount of sodium carbonate (black alkali) in this section, which manifests itself in the blackened crust and dark pools of the area. Many of the local alkali spots in this section appear to be spreading, and many areas of formerly valuable alfalfa and grain land have been greatly damaged. To recover its normal condition much of this land in the east Hanford area will require thorough drainage, or perhaps the application of gypsum in local black-alkali spots, where an excess of total salts does not occur.

This soil in its virgin state usually contains but a small amount of alkali, which is, moreover, well distributed through the soil and will cause no trouble, unless concentrated at the surface by excessive irrigation.

HANFORD FINE SANDY LOAM.

The Hanford fine sandy loam is found in extensive deposits in the northern and southwestern portions of the area and in occasional smaller patches throughout the area. The smaller areas generally mark local depressions or sinks and are usually found in the vicinity of sloughs or drainage basins. Willow and tule growth, with certain native lowland grasses, frequently cover these smaller areas. The larger areas constitute the flood plain of Kings River or its minor streams. The banks of the river where these deposits occur are very low, the river being confined within them at times of high water by levees.

Much of this land produces valuable pasture for stock. It is noted also for its fine growth of valley oak. It is usually slightly below the level of the surrounding country.

This soil is a mixture of the Hanford fine sand and a considerable amount of rich alluvial material and organic matter. It is deposited in rather quiet water from the overflow waters of the river, is well decomposed, and is generally about 6 feet or slightly less in depth, grading into a loam. Considerable clay and fine silt is present in this soil, and, although easily cultivated when irrigated and well drained, if not handled with discretion it frequently puddles and bakes, becoming very hard. A certain phase of the type found in a few sinks and tule beds contains much silt and clay, making a very sticky, heavy soil.

The mechanical composition of soils and subsoils is shown in the following table:

Mechanical analyses of Hanford fine sandy loam.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5596	Sec. 11, T. 18 S., R. 22 E.	Sandy loam, 0 to 12 inches.	0.10	2.54	0.00	4.98	6.46	21.58	19.00	30.06	14.56
5594	Sec. 33, T. 17 S., R. 21 E.	Sandy loam, 0 to 12 inches.	.87	5.78	Tr.	4.00	3.18	9.36	22.96	37.80	14.95
5595	Subsoil of 5594....	Sandy loam, 12 to 72 inches.	.10	3.28	0.00	3.50	2.96	9.76	27.58	42.62	9.38
5597	Subsoil of 5596....	Sandy loam, 12 to 72 inches.	.13	1.36	1.20	3.88	3.34	12.92	22.86	39.94	14.25

This land produces good crops of wheat, rye, barley, corn, alfalfa, and, in some sections, fruit if well drained and properly cultivated. It is well suited to the raising of indian corn and sorghum, and will produce any crop suited to a bottom land. Owing to its water-soaked condition in some places during flood season, drainage should be resorted to in order to get the best results from this soil. It is very resistant to the erosive action of running water.

With the exception of a few local swales and sinks, this soil is free from alkali. Alkali accumulations sometimes occur in depressions from seepage and the proximity of the water table to the surface, such areas frequently showing an excess of carbonates or black alkali. Applications of gypsum and thorough drainage are the only remedies.

SAN JOAQUIN BLACK ADOBE.

This soil is found in the southeastern portion of the Hanford area, lying along Cross Creek, and is distinguished from the contiguous soil areas by no physiographic feature.

The geological formation of the Sierra foothills consists of granite with a certain amount of intrusive volcanic material. It disintegrates rapidly under action of weathering into a sandy loam containing coarse sand and undecomposed particles of rock. Further disintegration of the sandy loam produces a red adobe which covers extensive tracts along the foothills, and which, like the sandy loam, contains considerable quantities of coarse sand and fine gravel. This red adobe soil when carried down by streams, deposited in the valleys below, and modified by the action of water and swamp growth, takes on a darker color and produces the San Joaquin black adobe.

This soil is much more thoroughly decomposed than the Sierra adobe from which it is derived, and contains a relatively high percentage of very thoroughly incorporated organic matter. It is usually 6 feet or more in depth and is underlain by river sand. To the east the San Joaquin black adobe shades off very gradually into the soils of the plains. The mechanical analyses of the soil and subsoil follow:

Mechanical analyses of San Joaquin black adobe.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5598	Sec. 25, T. 18 S., R. 22 E.	Black adobe, 0 to 12 inches.	0.16	3.84	0.00	3.42	1.98	5.86	10.40	50.34	23.12
5599	Subsoil of 5598....	Black adobe, 12 to 72 inches.	.71	3.90	2.06	2.52	1.40	7.58	7.48	59.84	23.29

As in all adobe, this soil possesses peculiar and much heavier properties than are indicated by the mechanical analyses. Although a silt loam in texture, it is very dense and sticky, and if worked when wet readily puddles, clods, and bakes. Upon drying, the surface of the puddled soil cracks in lines at right angles to each other, dividing the mass into small cubical blocks from a small fraction of an inch to an inch in diameter.

This adobe in places assumes the properties of the "dry-bog soils," which are for the most part soils of this type. In this form the surface, by repeated cracking, is reduced to a loose, dry mulch, which condition exists to the depth of several inches.

The adobe lands in the Hanford area are irrigated and used as pasture, or dry-farmed to wheat, barley, rye, and alfalfa. These crops, if well started, produce a fair yield in favorable seasons. Still, on the whole, the type is poorly adapted to dry-farming for wheat and other crops that root shallow and produce but little shade, as the cracking of the surface allows the roots to become dried, and injury to the plant results.

This is the soil which in the foothills, in other areas, has proved so well adapted to the raising of citrus fruits.

Water percolates but slowly through this soil. Drainage, however, has not as yet been found necessary, except in portions adjacent to sloughs and streams. The proximity of the water table to the surface has nowhere east of Cross Creek given cause for alarm; only areas adjacent to the Fresno sandy loam have become badly affected by alkali. Although the alkali soils occur more or less throughout the adobe area, they have fortunately not become concentrated by subsurface irrigation. If irrigated heavily this process would doubtless need to be supplemented by thorough drainage.

HARDPAN.

One very interesting feature often met with in the soils of the arid regions is hardpan. This subject has been discussed by Means and Holmes in their report upon the Fresno area. The red hardpan of the Fresno area does not appear in the Hanford area, and it is with the white alkali hardpan, which occurs only in the Fresno sandy loam, or "white ash" soil, that we are concerned.

Hardpan may or may not be charged with the alkali salts. The white hardpan under discussion is, in its natural state, the seat of the greater part of the alkali of this soil type, and hence is known as an alkali hardpan. Over much of the area of the Fresno sandy loam north of Kings River the alkali salts, dissolved out of the hardpan by the rising subsoil water, have been brought to the surface.

Beneath the hardpan layer is a pervious stratum which is saturated in the wet season with water, and which, protected from evaporation by the overlying impervious layer, always remains in a moist condition. Hardpan is detrimental to agriculture, not only in that it frequently carries an excess of the alkali salts, but also because it interferes with root penetration and with drainage. The last-mentioned attribute is the one most threatening in this particular region, but as the white hardpan of the Fresno plains usually becomes softened up and pervious to water upon irrigation, it is believed that as drains are installed it will gradually break up and disappear.

METHODS OF CULTIVATION AND IRRIGATION.

In the practice of diversified farming, with grain and alfalfa as the chief products, the methods of cultivation in vogue in the Hanford area differ but little from those in general use. It might be said, however, that cultivation is often too shallow to obtain maximum crops, or to improve the condition of the land. The saving of time and labor is apt to be made at the expense of thorough cultivation in all regions where an extensive system of agriculture is practiced. In arid regions where crops root much more deeply than in humid regions, a deeper system of cultivation can be practiced without injury to root growth. Another advantage of deep and thorough cultivation in irrigated sections consists in the checking of evaporation, thus effecting a saving in the water supply and reducing the accumulation of the alkali salts to a minimum.

In the case of the fruit lands the practice of cultivation is much more thorough. Deeper plowing is, as a rule, resorted to, and the ground is harrowed frequently. This effectually removes weeds and produces a fine tilth. In a portion of the fruit belt, in which the soils have a tendency to clod, rolling is sometimes resorted to. This should in every case be followed immediately by the harrow in order to check excessive evaporation and the rise of the alkali, induced by firming the surface.

Deep and thorough cultivation not only removes noxious weeds, but cuts off the capillary pores of the soil through which the underground water finds its way to the surface to be evaporated. It also distributes through the soil the alkali salts which may have accumulated upon the immediate surface, thus reducing their noxious effect upon plants by incorporating them with a greater volume of soil. The application of these principles has, to a great extent, been the secret of the success of the Kings County fruit growers.

The water supply of the Hanford area is drawn from Kings River, Cross Creek, and a limited number of artesian wells. Of the three, Kings River is by far the most important. Fed by the melting snows of the Sierras, it is maintained at its high-water stage from the beginning of April to the end of July, while its low-water condition is reached in September and continues through January. At the Government gaging station at Red Mountain, 15 miles east of Sanger, it has an average annual flow of from 2,500 to 3,000 second-feet.

The water of Kings River is noted for its purity, being practically free from soluble mineral salts and considered one of the best waters known for irrigating purposes. Field determinations have shown in every case the presence of less than 8 parts of soluble salts in 100,000 parts of water. Great injury is often done to land in arid regions by irrigating with water containing a dangerous proportion of the alkali salts, but that any appreciable amount of alkali salts will be added to the soils by the use of Kings River water need never be feared.

From Kings River this area receives its water through the canals previously mentioned, the flow of many of which is perennial.

The eastern portion of the area is watered by Cross Creek, a branch of the Kaweah River, which rises in the mountains some distance east of Visalia. Kaweah River is subject to greater irregularities of flow than is Kings River, and much of its water that should naturally enter the Cross Creek channel is previously diverted for purposes of irrigation. Hence the Settlers and Lakeside canals, which receive their waters from Cross Creek, are subject to flow only during high water. Irrigators are, however, able to carry crops through upon the supply obtained, except in unusually dry seasons. The character of this water, while not equal to that of Kings River, is very good.

The use of artesian waters for purposes of irrigation, while of considerable importance in some of the surrounding country, is practiced but very little in the Hanford area.

Of the several canal systems now in service, all are owned and controlled by the people served. As the need of water supply grew in newly settled portions of the country, the several canals were constructed in succession by cooperation of the farmers interested. This accounts for the number of canals. One or two canals could have been made to do the same work with less waste and expense.

Water is furnished stockholders in the more successful canal corporations at a cost of about 25 cents per acre per year. Shareholders receiving more water than they need for their own use sell to less fortunate farmers, usually for 50 cents per acre per season. In the distribution each shareholder is allowed an amount of water proportional to his share, and the cost of construction and maintenance of the canal system is borne in the same manner. The distribution of water is usually placed in the hands of a superintendent. Accurate means of measuring the water allowed to each person is usually wanting, the judgment of the superintendent being relied upon in this matter.

The irrigation of the Hanford area is somewhat unique. The soils of this region are exceedingly porous. Before irrigation was practiced in this region ground water was found at a depth of from 10 to 20 feet. Now, however, it is nowhere deeper than 10 feet in the irrigated section, and during the irrigating season will average not deeper than 4 feet from the surface. This has led to a modification of the usual method of applying the water.

All the soils of this region are now irrigated by what is known as subsurface irrigation, or irrigation by percolation. It consists simply in raising the water table until the water moistens the surface or thoroughly saturates the soil from below. Water is very seldom applied to the surface of the ground. Flooding is practiced only in order to drown out gophers or squirrels, or occasionally in an attempt to remove alkali. The main canals and distributing ditches are constructed with a very light grade, the fall often being reduced by check weirs. This is in order that the ditches may be kept nearly full. In early spring these canals and distributaries are opened and allowed to fill. The water sinks rapidly into the open, porous, spongy soils and the water table is rapidly raised. Irrigation is considered complete when water begins to appear upon the surface in local depressions. This takes place through April and May. The distributing ditches are usually temporary, although sometimes permanent. Canals and ditches as a rule follow sand ridges from which the water rapidly percolates to the lower levels and into the subsoil. In orchards and vineyards the distributing ditches are not confined to ridges, but follow the borders of the inclosure or pass between the rows. They are usually from 200 to 400 feet apart. Some lands lying near main canals have no distributing ditches at all.

Of the advantages of this system that which first appeals is the first cost of construction and maintenance. This system calls for few distributing canals and involves no troublesome preparation of the land, construction of gates, checks, leveling of surface, etc. The cost of construction of the small distributing ditches used in this area is estimated by Grunsky to be from $2 to $4 per acre.

The labor and cost of operation is also reduced to a minimum. Irrigation by this method requires but little attention, the canals and ditches are simply kept full of water and the process of irrigation goes on and involves no expense for hiring of attendants. Again, the presence of troublesome checks and furrows in the land, which interfere with cultivation and cropping, is avoided.

This system, however, while cheap and efficient, in a way, is not without its disadvantages. Of these, waste of water is an important item. From these canals and ditches a large amount of the water entering the soil goes to fill the pores of the soil below the zone of root penetration, and hence its benefits are lost to plant growth. Again, a large amount of it finds its way by seepage into old sloughs and sinks where it also is useless.

The wholesale flooding of low-lying lands and the temporary and often permanent water-logging of the soils is also an evil that should not be overlooked. Soils saturated with water in this manner for long periods of time may not only have all the valuable mineral plant food leached from them, but changes in their physical properties take place, rendering them inert and unworkable. This water-logged condition also, in the presence of organic matter and sodium salts, may cause the formation of the dreaded sodium carbonate or black alkali, which is more destructive of plant growth than is the white alkali from which it is formed.

What is probably the worst feature of this system of irrigation, however, is the tendency toward the accumulation of the alkali salts in injurious amounts upon the surface. Many thousands of acres of valuable land in the West have been ruined in this manner. Even a very small amount of alkali present in the soil may, when dissolved by the free water of the soil, carried to depressions by seepage, and concentrated by evaporation, produce very serious results. The effect of the water-soaked condition of the Hanford area in flood time is to furnish water for an excessive amount of evaporation from the soil surface. This water has removed a certain amount of alkali from the soil through which it has passed, often long distances, and in the process of evaporation all this alkali in solution is raised to the soil surface and there deposited. Small areas damaged by seepage waters always have a tendency to increase in size. Much of the serious alkali conditions of portions of the Hanford area are directly due to the method of irrigation practiced. With the open, porous soils of this area and the drainage basins which nature has provided, much of this trouble would undoubtedly have been avoided had these natural drainage channels been kept open and surface instead of subsurface irrigation been practiced.

With a system of drainage provided, and the irrigating water applied to the surface, all these lands can undoubtedly in time be reclaimed. In the meantime, this dangerous method of irrigation should not be long continued in portions of the area still unaffected by alkali, unless it is modified or supplemented by drainage.

ALKALI IN THE SOILS.

The alkali in the soils of the Hanford area contains a mixture of several chemical compounds, as is indicated in the analysis given below:

Average composition of the alkali in the soils of the Hanford area.

Ions.	Per cent.	Conventional combinations.	Per cent.
Calcium (Ca)	0.45	Calcium sulphate ($CaSO_4$)	1.53
Magnesium (Mg)	0.36	Magnesium sulphate ($MgSO_4$)	1.78
Sodium (Na)	33.68	Sodium sulphate (Na_2SO_4)	52.52
Potassium (K)	0.79	Potassium chloride (KCl)	1.51
Sulphuric acid (SO_4)	37.98	Sodium chloride (NaCl)	9.35
Hydrochloric acid (Cl)	6.38	Sodium carbonate (Na_2CO_3)	23.87
Carbonic acid (CO_3)	13.50	Sodium bicarbonate ($NaHCO_3$)	9.44
Hydrogen carbonic acid (HCO_3)	6.86		
	100.00		100.00

The analysis shows the alkali to be composed largely of sulphates, with about 24 per cent of carbonates and 10 per cent of chlorides. Of these salts the carbonates are the most harmful to the growth of plants. Soils containing carbonates are generally known as "black alkali" soils. According to the classification of alkali soils as proposed by Cameron in Bulletin No. 17, Division of Soils, an alkali soil of this type would correspond to the Salt Lake type. He considered the Salt Lake type to be a mixture of two types, one resulting from the reaction between calcium carbonate and sodium chloride and the other resulting from the reaction between calcium sulphate and sodium chloride. Other investigations made by this Bureau have shown that the alkali salts which come from the Coast Range Mountains of California are largely composed of the salts which would result from the reaction between calcium sulphate and sodium chloride and that the salts which come from the rocks of the Sierra Nevada Mountains are those which would result from the reaction between calcium carbonate and sodium chloride. The Hanford area is situated between these two ranges of mountains and receives the drainage from both. Therefore the salts which are brought down by the streams would be found mixed over the area. More extended examination of the alkali of the soils shows plainly that along the western border of the area the predominant salts are sulphates and along the eastern and northern parts the salts are largely chlorides and carbonates. In no part of the area were large areas of either the Fresno or Salt Lake types found. All of the alkali soils contained sodium carbonate, and therefore the entire area of alkali soils are "black alkali soils."

The alkali map accompanying this report shows the areas affected, classified according to the mean amount of salts contained in the first 6 feet of soil, the arbitrary subdivisions being lands containing less than 0.20 per cent, those containing from 0.20 to 0.40, from 0.40 to 0.60, from 0.60 to 1 per cent, and from 1 to 3 per cent of alkali.

On land containing less than 0.20 per cent of alkali all crops suited to the soil type do well. Where the land contains from 0.20 to 0.40 per cent of salts most crops can be grown, although when the major limit (0.40 per cent) is reached certain crops, notably alfalfa, most tree fruits, grapes, and grain crops, begin to suffer. However, pears and figs (if the land be sufficiently drained) and beets, onions, sorghum, and some grasses, including alfilaria and sporobolus, will grow quite well on such land.

On land containing from 0.40 to 0.60 per cent of alkali few crops will survive, only the salt grasses, alkali heath, and various alkali weeds being able to subsist.

In this area no cultivated plants were found on land with 0.60 per cent of alkali in it, excepting two cases where pear trees were doing well on land the surface foot of which contained as much as 1 per cent of alkali. There was, however, little alkali below the first foot.

Land containing from 0.60 to 1 per cent is practically worthless, unless some of the alkali is removed. Pear trees may grow if well started and if all the alkali is in the first 2 feet, but in general, aside from pasturing, lands in this class have little agricultural value. Such land grows salt grass, however.

Land containing from 1 to 3 per cent of alkali is so salty that many of the alkali grasses will not grow on it. A few of the weeds do fairly well, and occasionally a little salt grass is found, though under these conditions the salt grass takes more the form of a bunch grass, growing in small tufts. As stated, the map is based on the alkali content of the soil averaged for a depth of 6 feet. The content of the surface foot may be more or less than the average shown, though for practical purposes the 6-foot average is the best indication of the capabilities of the soil. This is because many plants grown on the area go to that depth for food and also because the soils are of such nature as to permit capillary movements through that depth.

On the northern boundary of the alkali map certain areas are indicated with black cross lines. These areas average to the depth of 6 feet from 0.20 to 0.40 per cent of alkali; but they have a concentration in the first few feet of soil, due to the presence of hardpan.

The acreage of land carrying the various percentages of alkali is as follows:

Areas of alkali lands, classified according to degree of salt content.

Grade of alkali soil.	Acres.	Per cent.
0 to 0.2 per cent alkali	82,100	58.4
0.2 to 0.4 per cent alkali	40,340	29.2
0.4 to 0.6 per cent alkali	7,720	5.6
0.6 to 1 per cent alkali	1,770	1.3
1 to 3 per cent alkali	6,310	4.5
Total	138,240	....

It is likely that at present no special system of drainage need be applied to the immediate Mussel Slough region, for there the amount of alkali in the subsoil is small and the surface water not dangerously near the surface. One precaution should be immediately taken, however, namely, the old drainage channels in the area should be cleaned out and opened. At present these channels are dammed in many places to help raise the water table during the drier part of the season. The practice, if persisted in, will certainly cause much valuable land to become damaged by alkali. To keep all the avenues of natural drainage closed continually can not help but cause an accumulation of salts in the seepage areas.

By cleaning out the old water courses and putting in gates where dams now exist the question could be met to the satisfaction of those concerned. At flood season these channels could be opened and the seepage be allowed to drain from the land. Small lateral drains could be laid where alkali flats now exist, thus correcting present evils and benefiting surrounding lands. During the part of the season when more water is needed the gates could be closed and the water table raised somewhat if thought necessary. Experience teaches that a water table at 6 or 8 feet is more favorable to orchard crops than one only 4 or 5 feet below the surface, as is now the case in this area.

The reclamation of the alkali land lying east of Hanford is an important problem and one which should receive attention. By an examination of the underground water map (Pl. LXXI), a general notion of the drainage necessary for this section can be obtained. The drainage of the upper portion of the area could doubtless be carried to Cross Creek, while that of the lower parts of the tract could be connected with the different sloughs. Large drainage canals would be necessary in the northern half of the area, owing to the level character of the country. The natural receiving basin for the drainage of this area is Tulare Lake. Most of the land in this lake basin has been filed on during the last few dry years, when the lake has been low. Should the basin be used as a receiver for the drainage an additional expense will be incurred in acquiring title to the lands which would be flooded. The evaporation in this climate is so rapid, however, that a relatively small area would be needed for the reception of the drainage waters, and there will always be the central portion of the lake bed, which will not be filed upon. Very likely this central portion will serve as a drainage reservoir of sufficient size.

The soil of the alkali district immediately in question is quite sandy in texture, and therefore easy to drain, and although it is underlain in places by more or less loam or clay, if once reclaimed to the depth of such deposits, future complete reclamation would be assured. There is little hardpan in the area within 6 feet of the surface.

The dairy interest is quite well developed in this district, and during the first stages of reclamation the growing of alkali-resistant crops, such as sorghum and root crops, using them both for soiling crops and ensilage, would at once bring an income from land which at present is of little value. Much of the alkali land would soon grow good crops of alfalfa. The soil finally might be used for any of the crops suited to the climate.

Both the total-alkali map and the map showing black-alkali conditions (Pl. LXXII, p. 476) have been prepared from observations and tests made in the field. In the Hanford area results show that the soils most affected with white alkali are the soils which also carry the most black alkali. From a study of the black-alkali map we find that the Fresno sandy loam type of soil contains generally a high percentage of black alkali. The Hanford fine sand, containing the large alkali tract previously mentioned, comes next to the white-ash soil in its content of black alkali. These two conditions harmonize when we take into consideration the relations which exist between these two types of soil.

No serious trouble from black alkali may be looked for in the soils of the Mussel Slough region, from present indications, though that section contains black alkali in some places. As to the soils lying above Kings River and south of Coles Slough, serious trouble need not be anticipated from black alkali when these lands shall be brought under irrigation, for the reason that very little alkali is present in the subsoil. The same may be said of the land south of Murphy Creek, much of which area, lying within the Hanford sheet, is at present under cultivation.

The land, however, above Coles Slough and Murphy Creek, while not at present threatened, will nevertheless become more or less impregnated with both white and black alkali as irrigation becomes more general, through seepage water from above, unless precautions are taken to insure proper drainage.

In unirrigated arid land it is difficult to detect the presence of black alkali without applying chemical tests. In land that has water, a little practice will enable the farmer to recognize the alkali if it exists in appreciable or harmful amount. One of the surest indications of the existence of black alkali in a soil is the tendency of such soil to puddle readily, to "set," and to be very difficult to put into proper tilth. Another common indication is the presence of a brown crust on the soil. The brown surface has been produced by the alkali bringing the organic matter (humus) of the soil to the surface in solution. Upon drying, the humus and alkali remain and are evidenced by the brown or black color of the surface soil. The presence of black alkali is also shown by the brown or black color of seepage waters, where they collect in pools or puddles on the surface.

Crops can grow in soils containing a little black alkali, though few cultivated crops can withstand an amount greater than 0.10 per cent.

Two methods for the elimination of black alkali are available: First, drainage; second, the application of gypsum or land plaster to the soil.

Black alkali can be drained from the land, though not as readily as can white alkali, since the presence of sodium carbonate tends to puddle the soil and the carbonate salts seem to cling to the soil grains with greater tenacity.

The second method, that of applying gypsum, is a corrective in that it changes the alkali from the corrosive black type into white alkali, which is much less harmful. The change is brought about by a chemical reaction, and hence the amount of land plaster required to be added per acre can be determined very closely when the amount of black alkali in the soil is known.

Amount of gypsum required to neutralize sodium carbonate in a soil.

Per cent of sodium carbonate in soil.	Tons of gypsum necessary to neutralize an acre to a depth of 1 foot.[a]	Per cent of sodium carbonate in soil.	Tons of gypsum necessary to neutralize an acre to a depth of 1 foot.[a]
0.01	0.3	0.20	5.7
.05	1.4	.30	8.5
.10	2.8		

[a] The weight of 1 acre-foot of soil is taken as 3,500,000 pounds

The price of gypsum in the San Joaquin Valley is $4 to $6 per ton. At such a price it will be seen that the cost of neutralizing 0.10 per cent of sodium carbonate in the surface foot of soil will be from

$11 to $17. This is not very encouraging when it is considered that after all no alkali will be actually removed from the soil. As will be seen further on, at a slightly greater cost underdrainage can be installed and all of the alkali, both black and white, removed.

It must be borne in mind that land already carrying an amount of white alkali sufficient to damage crops can not be benefited by the addition of gypsum to overcome the black alkali which it may also contain. Gypsum may make such soils more easily tilled, but it can offer little relief from alkali. An example of this character may be found on the north boundary of the Hanford sheet. The white-ash soil in this locality contains already too much white alkali for crops, and also an excess of black alkali. The only recourse here is thorough drainage.

UNDERGROUND AND SEEPAGE WATERS.

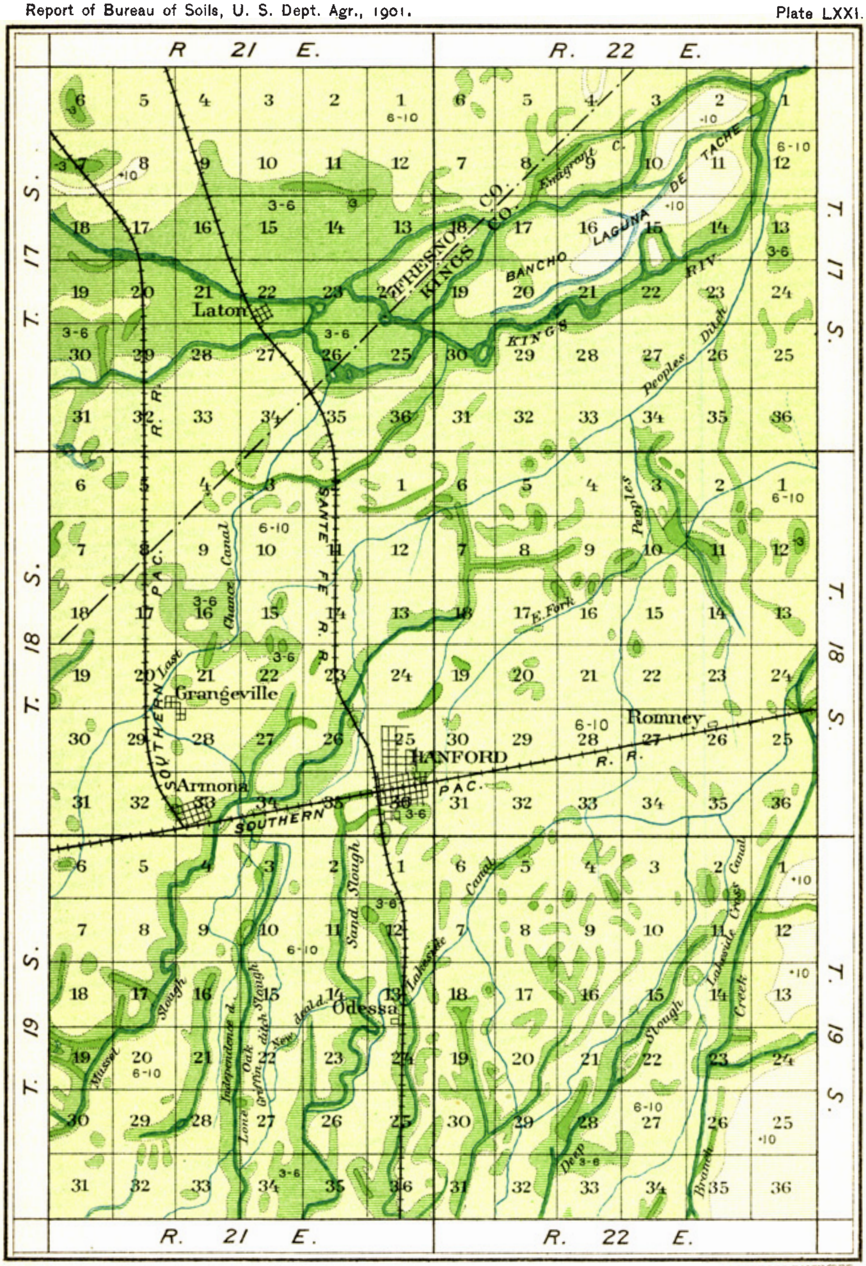
The underground water of the Hanford area previous to the construction of irrigation canals, from evidence taken over the area, was found at a depth of from 12 to 20 feet.

The rainfall of the area averages about 9 inches yearly. Aside from this meager supply, the ground water conditions were maintained at the depth mentioned through the influence of seepage water from Kings River and Cross Creek. The lands lying nearer Cross Creek, or the eastern half of the area, though of about the same elevation, received less seepage than the Mussel Slough soils; hence the lower water table was found originally in the east. The result of irrigation has been to raise the average water table to a uniform depth of from 6 to 10 feet over practically the whole area.

By reference to the water map we find that a few districts lying without the heavily irrigated territory have an average water table below 10 feet from the surface. Wells sunk in these districts to a depth of 12 or 14 feet give a water supply throughout the year. This water has its source largely in the nearest irrigating district and is brought in by seepage.

The district above Cole Slough and Murphy Creek owes its conditions largely to the Emigrant and Liberty canals. During the spring and early summer those canals are at their maximum capacity, and as a result the water table below them rises at that time to within about 4 feet of the surface.

Lying near and to the north of Cole Slough and Murphy Creek is a large overflowed area. This overflow is brought about largely by the construction of a levee immediately below Murphy Creek. This levee prevents the flooding of the agricultural land between this creek and Kings River during the spring freshets. Murphy Creek, however, during this period is taxed beyond its capacity and, as a result, overflows its north bank and floods an area of several square



UNDERGROUND WATER MAP, HANFORD SHEET

-3	3-6	6-10	+10
Water less than 3 feet deep	Water from 3 to 6 ft. deep	Water from 6 to 10 ft. deep	Water more than 10 ft. deep

miles to the depth of from 3 inches to 2 feet. This area is drained later, but water may be reached at from 3 to 6 feet below the surface throughout the year. Plans for draining this area more thoroughly are being considered.

The land lying between Cole Slough and Kings River has little water other than the seepage during early spring. Lands contiguous to the above channels near their lower union are covered in the early season with "backwater," though otherwise they are favorably located for cultivation. None of the above area is cultivated.

The land between Murphy Creek and Kings River carries a shallow water table throughout the year. It is protected by levees on both the river and creek sides, and is never flooded, though the water in Kings River is sometimes higher than part of the land thus protected.

The remainder of the Hanford area lies below Kings River and is protected much of the distance along that stream by a levee. This district contains about 145 square miles, all parts of which are under irrigation. The water table of this area has been raised from a general average of 16 feet to within (in certain parts of the season) 4 feet of the surface, while in certain seepage areas it reaches the surface.

In general the result of irrigation has been to raise the water table 12 feet in the area. When we take into consideration that the same rise of ground water has taken place over another 100 square miles of land contiguous to the Hanford area the item becomes astonishing.

During the drier part of the season the water in the canals is lowered quite perceptibly, and in some districts ceases to flow. The old river channels of the delta plain then also lose much of their water by seepage. The ground water of the whole area sinks correspondingly—rapidly in the more porous soils, but more slowly in the heavier soils or soils underlain by clay or sandy clay—until during the winter months we find the average depth to ground water to be about 7 feet. [a]

Taking these data as a basis, we find that an amount of water is added yearly to the delta soils by the different canals sufficient to raise the water table 3 feet. To this must be added the downward seepage, the lateral seepage from the area, the amount taken for crop production, and the amount evaporated from the surface.

As mentioned before, the method of irrigation in the district is peculiar, in that the water is seldom applied to the surface. The plan is to to fill the subsoil with water by putting into it all the supply obtainable during the flood season, thus bringing the water table sufficiently near the surface to supply the crops by capillarity. The district is certainly well adapted to this method of irrigation. The higher parts of the area are the slightly raised sand ridges. Canals are constructed upon these ridges, and the resulting seepage is very great.

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[a] The average depth to ground water in the early part of April, 1901, on the delta plain was about 6 feet. The canals were just beginning to fill.

Where the land is surface irrigated the general plan is to carry shallow ditches across the surface at variable distances apart, and again to rely upon seepage to distribute the required moisture.

Perhaps the greatest danger in this method of irrigation is the fact that it brings water continually from the lower soil depths, which is distributed by extensive lateral percolation. The water thus travels

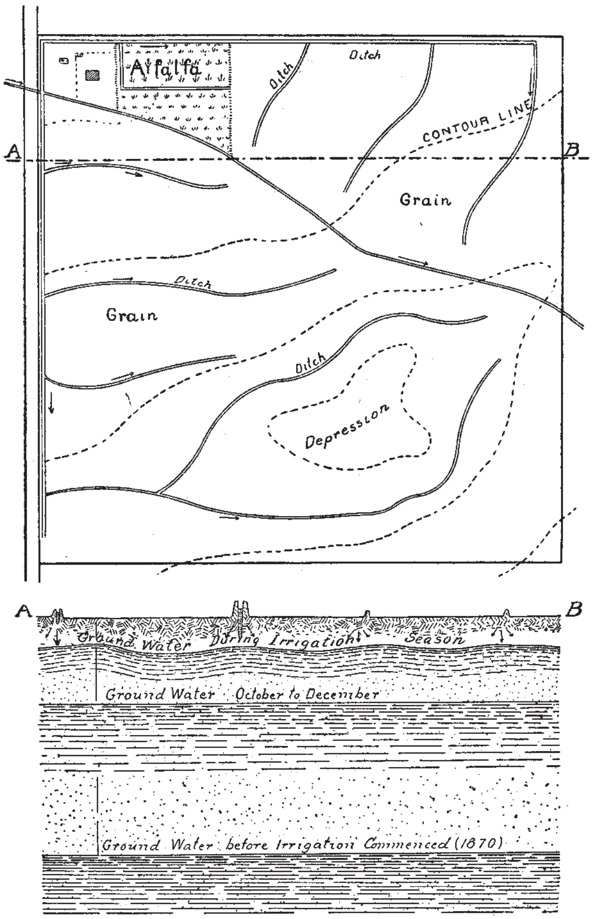
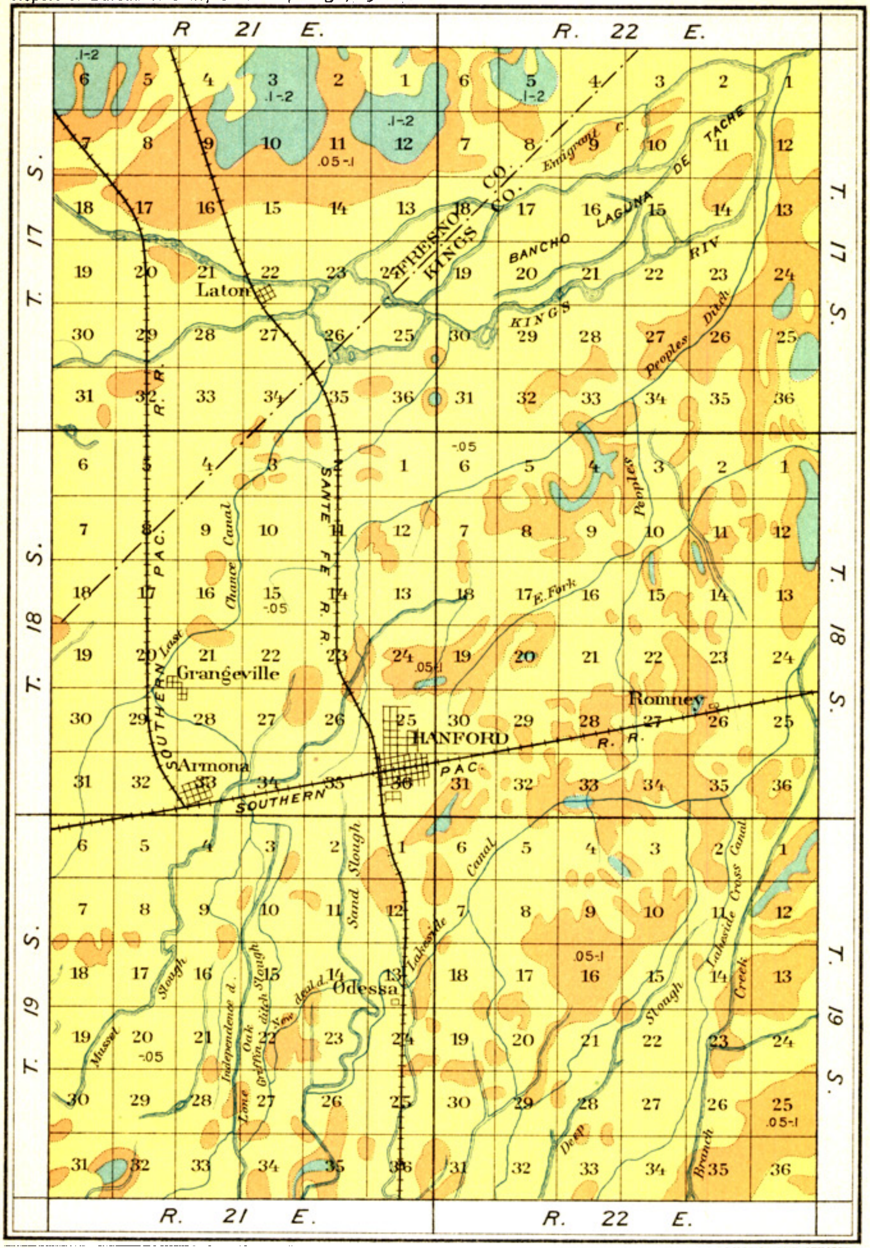


FIG. 21.—Map and section showing irrigation by filling subsoils with water, Mussel Slough country, California. (After Grunsky.)

long distances through soils having more or less alkali, which it dissolves and finally carries to the surface. The operation is a continuous one, and it is inevitable that under such conditions surface alkali will accumulate.

On the other hand, it is known that the movement of water within the soils of this area is rapid, and therefore, were the natural drainage channels opened, most of the land would soon be well drained, leaving



BLACK ALKALI MAP, HANFORD SHEET

-.05	.05-.1	.1-.2
Less than .05 per cent	From .05 to .1 per cent	From .1 to .2 per cent

the few alkali spots in the cultivated areas to be removed by surface flooding. In the larger alkali areas underdraining by ditches and tiles would hasten the reclamation. At present in the better drained areas alkali has accumulated only in basins so situated as to receive much seepage water.

If present conditions continue the limit to surface accumulations of alkali will be controlled only by the supply from below. Should all the alkali from the first 6 feet of soil be concentrated at the surface the damage resulting will be serious. The method of irrigating has done much to make the alkali tract east of Hanford what it is.

Underlying the delta plains is a well-defined artesian-water basin. Flowing wells are reached at from 800 to 1,200 feet depth, but no artesian water is used within the area for irrigation purposes.

Many moderately deep wells are to be found throughout the area, their depth varying from 80 to 300 feet. The water from all the deeper sources is of good quality.

AGRICULTURAL CONDITIONS.

The greater part of the Hanford area lies within what was eight years ago a part of Tulare County. At that time Kings County was formed, with Hanford as the county seat. The earlier agricultural development of the county, therefore, formed a part of the development of Tulare County. Since the separation of the counties the agricultural growth of the Hanford area has been rapid.

Previously to 1870 the area was given up largely to grazing. At that time the construction of the Lower Kings River Canal began. The earlier efforts in agriculture were concentrated on the cereal crops, principally wheat, though for the past twelve years diversified farming has been extensively adopted. At the present time about one-fourth of the area is devoted to range land and dry-farming, one-fourth to orchard and vineyard, and the remainder to various grain crops, alfalfa, and truck.

Nearly all of the range land is on the large Laguna de Tache Ranch. Much of this grazing land is entitled to water from the Liberty and Emigrant canals and can be opened to settlement.

A very small part of the area, lying principally east of Cross Creek, is dry-farmed. An estimate would place this district at about 4,000 acres, of which perhaps one-fourth is dry-farmed to wheat and barley, the remainder being pasture.

Of the 138,240 acres surveyed about 108,000 acres are under ditches and about 96,000 acres are actually irrigated and cultivated.

The general boundary of the cultivated area is Murphy Creek and Kings River on the north, Old Burris Slough and Cross Creek on the east, and the limits of the survey on the south and west. Within this district there are about 8,000 acres of waste land, in the sense that it at present carries an excess of alkali on the surface. This land is either allowed to remain idle or is used for pasturing small bunches of cattle, often dairy cows.

On the cultivated lands the principal orchard crops are peaches, prunes, apricots, and pears. Other orchard crops, notably apples, figs, Simoni prunes, and a few plums, are grown.

In viticulture the raisin grape is the article most produced. The Lucerne vineyard, lying within the area, consists of 960 acres, being the largest raisin vineyard in the world. There are many smaller vineyards. The land given to orchard and vineyard is about equally divided. Two, and sometimes three, crops of grapes are gathered each year. The first crop is nearly all used for raisin production, while the later yields are made into wine.

The Fancher sandy loam, a part of the Hanford sandy loam, and that part of the Hanford fine sandy loam free from excess of alkali are the types of soil most sought for the location of orchards and vineyards. Of these three the Fancher sandy loam is most used for fruit culture, although the Hanford fine sandy loam is so similar that to say both types are equally adapted for orchards and vineyards would be quite safe. Of the three types the Hanford fine sandy loam is best adapted to the cereals.

It is a noteworthy fact that pear trees are often planted on soil containing too much surface alkali for most any other crop. Their resistance to alkali seems to be a matter of common knowledge to the orchardists. Enthusiasts claim that a pear tree once well started will grow in any alkali soil.

A common practice in setting such orchards on alkali soil is to dig large holes and bring in alkali-free earth, in which to start the trees. The supposition is that the rapid growth of the young pear tree will enable it to resist the alkali by the time the salts impregnate the added soil. Often this precautionary method of planting is not taken, however.

Pear trees are often planted on the Hanford fine sand.

During 1900 there were shipped from Kings County 160 cars of green fruit, 1,950 cars of dried fruit, 240 cars of canned fruit, and 80 cars of wine. While these figures are for the county at large, they yet enable one to form an estimate of the fruit products of the area surveyed, because the greater part of the orchards and vineyards lie within its boundaries.

A large part of the Hanford area is devoted to the production of the cereal crops and alfalfa, of which barley leads in acreage, followed by wheat. The heavier lands of the Hanford fine sandy loam are well adapted to growing corn. Truck farming is carried on for the local markets only.

Alfalfa flourishes on nearly all the soils of the area, and produces seed well everywhere except where alkali is very strong, in which case the seed does not mature.

During 1900 there were shipped from the county 1,800 cars of hay. The hay is largely alfalfa and barley, with some wheat. The greater part of this is baled in the field. Most of it goes to San Francisco, Los Angeles, and Arizona.

In connection with the production of grain and hay, the dairy interests of the area also hold importance. A number of creameries and skimming stations are operated in the district. The Hanford cheese factory last year produced 292,000 pounds of cheese. The Hanford creamery has a butter capacity of 3,000 pounds daily, though less than that amount is generally produced.

The average price paid for milk by the creameries in 1900 was $1.20 per hundredweight.

The Hanford fine sand lying east of the Mussel Slough district is either used as pasture land or given up largely to the production of the cereals. This also is the locality where dairying is most extensive. Kings County holds seventh place among the counties of the State for production of butter and cheese.

The raising of live stock is an important and apparently flourishing part of the agriculture of the area, and it is not uncommon to see droves of range steers grazing upon second and third growth alfalfa. These steers are brought in from the surrounding ranges to fatten upon this luxuriant feed. Indications point toward this section as one likely to grow in importance in the production of thoroughbred live stock. Stock can be raised here as cheaply as anywhere in the country. In 1900 some 1,500 cars of cattle were shipped to market from Kings County.

Parts of the area are pretty well seeded with squirrel-tail grass, or "foxtail," as it is commonly called. This grass (*Hordeum jubatim*) grows very readily in nearly all parts of the country. It seeds in early spring, however, and disappears. When it takes possession of the land it is a great menace, sometimes making it necessary to burn over large areas of valuable alfalfa land. It is not alkali resistant, but generally seeks the best land. Two other weeds—the common cocklebur and the wild sunflower—are also found, and in some places are sufficiently numerous to be detrimental to crops. The river and slough areas are apparently most troubled with these two pests. Thorough cultivation should eliminate these weeds. Some parts of the area are quite well seeded to Johnson grass. It is unfortunate for the agriculture of the district that this pest has obtained a foothold, and while it is not yet formidable the question of its extirpation should receive at once the united attention of the farmers.

Nearly all the land on both sides of the main channel of Kings River is covered with a scattering growth of large white-oak trees. A rough estimate would place the area of the land so occupied at about 10,000 acres. This land is generally low and the soil type is the Hanford fine sandy loam. It is much used for pastures, though some parts of it are cultivated. Several species of willow and sycamore are also found in the timbered area. The wood is used entirely for fuel, bringing in the local market from $4 to $5 a cord. A part of the firewood is shipped to the larger towns, where it commands an even higher price.

The railroad facilities of the country are very good. The Southern Pacific and Santa Fe systems both have lines through the area. The near-by stations of Armona, Lillis, and Remnoy on the Southern Pacific and Guernsey, Banner, Hageman, and Laton on the Santa Fe furnish ample trackage for freight shipments. At Lucerne Vineyard a branch spur is built southward about a mile to facilitate shipments from the large warehouses of that company.

In the town of Hanford are a large cannery and winery, besides several packing houses for preparing dried fruit for shipment. Armona also has several packing establishments.

The fruit market is largely eastern, while the hay and live stock are used on the coast, the demand as yet being hardly met by local production. Wheat is milled and the flour consumed largely on the coast. The surplus of milled products is beginning to go to the new island possessions and to the Orient, and part of the unmilled wheat reaches the Liverpool market.

The price of unimproved land in the vicinity of Hanford ranges from $30 to $50 an acre, while improved land with water rights can be bought for from $50 to $200 an acre.

The cost of production within the area is not excessive. Cooly and Japanese laborers do much of the farm work where large areas are cultivated. The machinery used is generally of the latest pattern, and includes many implements specially adapted to the peculiar needs of the crops grown. But these labor-saving devices have not entirely displaced the hoe, which is still used in the vineyards during certain parts of the season.

Generally speaking, the roads of the area are serviceable, and the general adoption of broad tires for heavy wagons does much toward keeping them so. In some localities the excess of sand makes the roads quite heavy for traffic, though the common practice of putting a heavy coating of refuse hay or straw in such places does much to relieve the inconvenience. The sprinkling of roads with crude oil is being practiced in some sections of the State with success. Oil so used prevents the blowing of dust, and some such practice on the roads in the orchard districts of the Hanford area would be of great benefit to the fruit industry.

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