Series 1935, No. 21

Issued July 1941

Soil Survey

The Sacramento-San Joaquin Delta Area California

By
STANLEY W. COSBY
University of California

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY
In cooperation with the
University of California Agricultural Experiment Station

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SOIL SURVEY OF THE SACRAMENTO-SAN JOAQUIN DELTA AREA, CALIFORNIA

By STANLEY W. COSBY, University of California [1]

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United States Department of Agriculture in cooperation with the University of California Agricultural Experiment Station

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AREA SURVEYED

The Sacramento-San Joaquin delta area is in the west-central part of the Great Valley of California, its westernmost point being 40 miles east of San Francisco. The area extends up the Sacramento River to a point within 20 miles of Sacramento and southward up the San Joaquin River to a point within 10 miles of Tracy (fig. 1). The somewhat irregular boundaries are drawn so as to include all important areas of the highly organic soils that distinguish this relatively flat, sea-level district and to exclude as much as possible the mineral soils that lie on the margins of the encircling valley plains.

[1] Elvin Moorehead, of the Federal Land Bank of Berkeley, Calif., assisted in the field work.
[2] The Soil Survey Division was transferred to the Bureau of Plant Industry July 1, 1939.

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The Sacramento-San Joaquin delta area constitutes a distinct geographic unit, as to physiography, soils, and agriculture, and covers a total area of 481 square miles, or 307,840 acres. A part of San Joaquin County forms more than one-half of the total area, and parts of Sacramento, Contra Costa, and Solano Counties make up the rest.

Two early reconnaissance soil surveys (*7*, *9*)[3] jointly cover the whole of the Sacramento-San Joaquin delta area; in these, the organic deposits are grouped collectively under the designation of muck and peat. In three recent detailed soil surveys (*2*, *3*, *5*), which cover certain marginal parts, some of this material was classified as the Egbert and the Ryde organic soils. The present survey extends this classification to the remaining area of the delta and establishes a more detailed differentiation of these and associated soils.

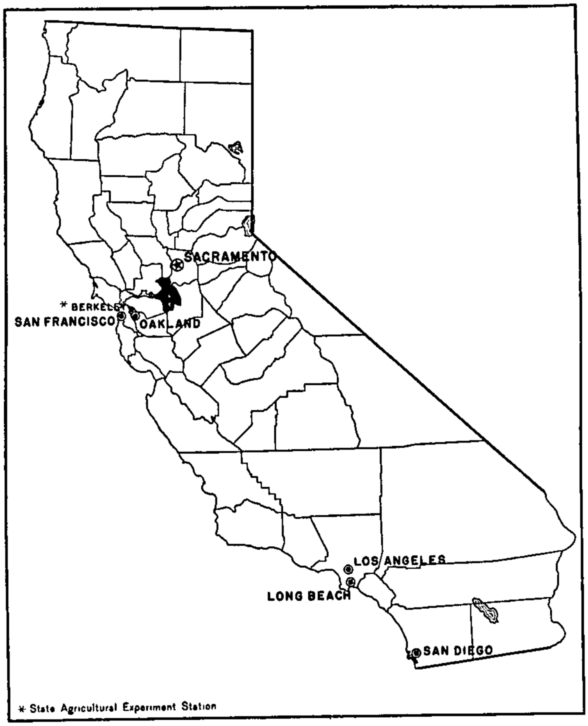

FIGURE 1.—Sketch map showing location of the Sacramento-San Joaquin delta area, Calif.

The physiographic aspects of the Sacramento-San Joaquin delta area are as distinctive as its soils. It has many of the characteristics of a delta at the confluence of the Sacramento and San Joaquin Rivers, and this fact accounts for the general usage of that designation. Somewhat more correctly, however, the area represents a marsh-filled structural basin, in which the drainage from 58,000 square miles is temporarily restrained before passing on a westward course through the relatively narrow Carquinez Strait, its single outlet to the sea.

Throughout its entire extent, the land surface of the delta lies approximately at mean sea level. At only a few points do the elevations rise to heights of 15 feet above; whereas in many places it is as much as 5 feet and in a few places more than 10 feet below sea level. There are two unimportant exceptions to this generalization. Along one side of the western apex of the delta area the Montezuma Hills bordering the Sacramento River southward from Rio Vista, reach

[3] Italic numbers in parentheses refer to Literature Cited, p. 47.

elevations of 200 feet or more, and on the other side the extensive body of uneven aeolian materials along the south bank of the San Joaquin River east of Antioch reach elevations of more than 100 feet. Both features are described in detail in two earlier reports (*2*, *3*).

The larger streams, together with hundreds of minor waterways, interlace the delta and divide it into scores of interfluvial units, or islands. The banks along these channels have been built up to heights of some 10 feet above the level of the adjacent ground, which is lower than the stream. At one time, streams overflowed these ridges during flood periods. From this alluvial rim the surface of each island drops, saucerlike, with a decreasing gradient toward the interior. The central parts nearly everywhere lie below mean sea level.

A century ago the delta area was a vast tule marsh. The purer and denser stands of great bulrush, or tule (*Scirpus lacustris*), occupied the central part of each island, where shallow water covered the surface practically all of the year. On the stream-built ridges, tules were replaced in part by a cover of reeds, sedges, and some woody hydrophytes, and in the small ponds and lakes constituting the deeper headwaters of some of the minor sloughs, waterlilies and associated water plants were common.

During the last 80 years, reclamation activities have removed this virgin vegetation. Today the entire delta area is utilized for the production of crops, except a very few scattered areas—generally small islands in the major waterways—which remain in their virgin condition and support a cover of tules.

Levees,[4] of mineral alluvium wherever available, have been built up along all the important stream ridges, confining stream channels sufficiently large to carry the normal floodwaters. Intersecting canals, protected similarly by levees, have been cut across many of the larger islands. These provide additional protection from overflow and also facilitate drainage of the enclosed cropland. The land surface still is several feet below the natural level of the water and necessitates a more or less constant operation of pumps to lift the water from the interior drainage systems over the levees into the stream channels.

The delta area is now divided into more than a hundred definitely named islands and tracts, each a complete reclamation unit or district with levees, drainage systems, and irrigation facilities. Some idea of the completeness of reclamation can be obtained from the fact that the total value of crops grown in the delta during the 10-year period 1924–33 amounted to $250,000,000, an average annual return for the entire decade of only slightly less than $100 per acre of cultivated land.

The hundreds of miles of navigable waterways[5] are at the same time an economic advantage and a disadvantage.

Shallow-draft boats cheaply transport the greater part of the crops to market over these waterways. Large passenger-cargo steamers maintain regular services from San Francisco to both Stockton and Sacramento. In 1933 completion of a deep-water channel enabled transoceanic ships to reach Stockton, which is rapidly becoming an important inland seaport.

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[4] The estimated total length of present levee systems is about 1,500 miles.
[5] The total length of navigable channels is estimated as between 600 and 800 miles.

In contrast, however, travel by land is materially handicapped by the multiplicity of waterways.[6] A score of county-operated ferries and a small number of private ones transfer vehicles and passengers from one island to another, although gradually bridges are being built as finances permit. In general, roads and buildings are of poor construction and are maintained with difficulty, owing to wet and unstable ground conditions. Wherever possible they are located along the levees or on other higher and less poorly drained sites.

The principal roads commonly follow the crests of levees or traverse the particular island along the mineral ridge of some former channel. Only a few important arterial routes are paved, and these are the only ones suited to heavy traffic in all seasons. One of the more important is the Borden Highway, which extends westward from Stockton across the southern half of the delta. Another, the River Route, follows the bank of the Sacramento River. Along this latter highway are Rio Vista, Isleton, Ryde, Walnut Grove, and other small towns of the delta. Along it also, especially in the vicinity of Walnut Grove, are many large and beautiful homes, which contrast significantly with the dwellings in other parts of the area. No large urban settlements are within the delta area, although several are just outside its boundaries. Of these, Stockton, with a population of 47,963 in 1930, is the nearest and most important.

The San Francisco-Barstow line of the Atchison, Topeka & Santa Fe Railway, which more or less parallels the Borden Highway, is the only railroad that actually traverses the delta area. A line of the Southern Pacific Company swings through Tracy, skirting the southern part of the area; and its branches, as well as those of the Western Pacific Railroad and the Sacramento Northern Railway (electric), extend into some of the more northerly parts.

Industrial development within the delta area is represented chiefly by the several large canneries along the Sacramento River. These are primarily concerned with processing the large asparagus crops; some 90 percent of the world's production of canned asparagus is reported to originate in these plants. There is a small mint-oil distillery on Victoria Island, and a large sugar mill is in process of erection on a site near Clarksburg, just north of the delta area. When completed, the latter will be the third such factory serving the sugar-beet growers of this vicinity. The other two are at Manteca and Tracy, outside the area. They receive their shipments of beets by barge or by rail.

CLIMATE

The Sacramento-San Joaquin delta area, with its hot rainless summers and cool moist winters, has a Mediterranean type of climate. Cool ocean breezes blowing inland through the Carquinez Strait reduce summer temperatures somewhat below those of other parts of the Great Interior Valley. Because of this influence, much of the delta may even be restricted to the cool Mediterranean subtype (Csb) of Koppen's classification (*8*). Fogs originating outside the Golden Gate during summer, and locally during winter, tend further to ameliorate the

[6] A few of the islands, especially Rindge Tract and Mandeville, Medford, and Woodward Islands, and somewhat smaller islands in the heart of the delta, still are accessible only by water.

extremes of temperature. The mean temperature is about 60° F. for the year, between 45° and 50° for the 3 winter months, and between 70° and 75° for the 3 summer months. The average length of the frost-free season, that is, between the last killing frost and the first killing frost, is almost 10 months.

The mean annual rainfall varies slightly in different parts of the area. It reaches a maximum of about 18 inches in the central and eastern parts, and a minimum of 10 to 12 inches in the southern part. The zone of lower precipitation represents the influence of the Mount Diablo block to the southwest, as the rain-bearing winds commonly blow from that direction. More than 50 percent of the annual precipitation falls during the winter, and less than 5 percent during the summer, which at times is entirely rainless. Despite the absence of summer rains, the atmospheric humidity is moderately high, owing to the extensive areas of free water surface and to the fogs.

The United States Weather Bureau does not maintain stations within the delta area, although records covering 50 years or more are available from stations just outside its boundaries. Table 1, compiled from records of the station at Antioch, for the period 1879–1938, presents data typical of the western part of the area. Table 2, compiled from the records of the station at Stockton, covering the period 1867–1938, reflects climatic conditions in the east-central section. Table 3, reporting the monthly, seasonal, and annual precipitation for the stations at Rio Vista, Galt, and Tracy, are more or less characteristic of the northwestern, northeastern, and southeastern parts of the area, respectively.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Antioch, Contra Costa County, Calif.*

[Elevation, 46 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1898)	Total amount for the wettest year (1889)
	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
December	48.2	79	14	2.14	0.72	6.54
January	47.1	88	23	2.73	.79	.95
February	51.3	83	24	2.24	1.32	.52
Winter	48.9	88	14	7.11	2.83	8.01
March	55.7	92	30	1.74	.45	4.81
April	61.1	96	28	.58	.15	.46
May	66.0	104	36	.39	.40	1.07
Spring	60.9	104	28	2.71	1.00	6.34
June	73.2	111	43	.10	.10	(1)
July	76.6	112	45	.01	.00	.00
August	75.2	109	43	.02	.00	.00
Summer	75.0	112	43	.13	.10	(1)
September	71.9	109	38	.34	.15	.00
October	64.4	104	32	.53	.84	4.51
November	54.7	90	25	1.20	.00	2.09
Fall	63.7	109	25	2.07	.99	6.60
Year	62.1	112	14	12.02	4.92	20.95

1 Trace.

TABLE 2.—*Normal monthly, seasonal, and annual temperature and precipitation at Stockton, San Joaquin County, Calif.*

[Elevation, 20 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1929)	Total amount for the wettest year (1906)
	°F.	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*
December	44.7	71	20	2.31	1.78	8.05
January	44.4	68	21	2.94	1.12	4.69
February	50.2	79	24	2.29	.78	2.85
Winter	46.4	79	20	7.54	3.68	15.59
March	54.3	87	31	2.18	.79	5.88
April	59.5	91	31	.91	.47	1.74
May	64.8	102	39	.62	.00	1.70
Spring	59.5	102	31	3.71	1.26	9.32
June	71.2	108	40	.12	.92	.41
July	75.4	110	42	.01	.00	.00
August	73.6	105	40	.01	.00	[1]
Summer	73.4	110	40	.14	.92	.41
September	68.8	104	45	.31	.00	.10
October	62.9	92	36	.62	.06	[1]
November	53.1	84	25	1.46	.00	1.01
Fall	61.6	104	25	2.39	.06	1.11
Year	60.2	110	20	13.78	5.92	26.43

[1] Trace.

TABLE 3.—*Monthly, seasonal, and annual precipitation at Rio Vista, Solano County; Galt, Sacramento County; and Tracy, San Joaquin County, Calif.*

Month, season, and year	Rio Vista [1] (Elevation, 35 feet)			Galt [2] (Elevation, 49 feet)			Tracy [3] (Elevation, 64 feet)		
	Mean	Total amount for the— Wetest year (1906)	Total amount for the— Driest year (1917)	Mean	Total amount for the— Wettest year (1906)	Total amount for the— Driest year (1885)	Mean	Total amount for the— Wettest year (1889)	Total amount for the— Driest year (1898)
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
December	2.91	6.51	0.92	3.11	9.10	2.33	1.88	6.85	1.26
January	3.84	5.16	1.23	4.13	7.27	1.30	1.96	.60	.70
February	3.22	3.08	3.91	2.74	3.21	.12	1.39	.55	.61
Winter	9.97	14.75	6.06	9.98	19.58	3.75	5.23	8.00	2.57
March	2.46	6.78	.76	3.17	7.81	.00	1.71	3.20	.35
April	1.07	1.80	.36	1.43	1.62	.82	.85	.30	.00
May	.59	2.36	.04	1.02	2.16	.00	.58	.75	.60
Spring	4.12	10 94	1.16	5.62	11.59	.82	3.14	4.25	.95
June	.17	.53	.00	.17	.77	.00	.15	.00	.00
July	[4]	.00	.03	[4]	.00	.00	.01	.00	.00
August	.02	[4]	[4]	.01	.00	.00	.01	.00	.00
Summer	.19	.53	.03	.18	.77	.00	.17	.00	.00
September	.35	.21	.23	.28	.36	.00	.19	.00	.00
October	.86	[4]	.00	.88	[4]	.00	.47	3.02	.15
November	1.65	1.26	.25	1.73	1.10	5.56	1.06	2.59	.20
Fall	2.86	1.47	.48	2.89	1.46	5.56	1.72	5.61	.35
Year	17.14	27.69	7.73	18.67	33.40	10.13	10.26	17.86	3.87

[1] Record for the period 1893–1938.
[2] Record for the period 1878–1915.
[3] Record for the period 1879–1915.
[4] Trace.

Although minor variations in climate between one part of the delta area and another have left no recognizable imprints either on soils or on agriculture, the broader conditions of climate are clearly reflected in both. The high water table and the long warm dry summer have promoted the development of soils having comparatively high concentrations of mineral salts at or near the surface. The downward movement and ultimate removal of lime and other salts, such as occurs in localities of heavy summer rainfall, does not occur here, and the soils in general belong to the eutrophic class of organic soils (*6*) or the pedocalic group of mineral soils. This and other aspects of the soil-climate relationship will be discussed in detail later in the section on Morphology and Genesis of Soils.

Agriculture is closely related to the broader climatic conditions, especially the rainless summers. Irrigation is practiced generally. The production of asparagus, corn, potatoes, and many other vegetables commonly involves the operation of elaborate irrigation systems that maintain the water supply at carefully determined levels. Thus, the satisfactory production of crops requires irrigation, owing to the dry summer, as well as adequate drainage, owing to the low position of the delta area. The comparative infrequency of severe frosts allows the profitable production of certain out-of-season crops, such as winter-grown potatoes. The moderating atmospheric humidity explains, at least in part, the large acreage planted to corn, which is not grown extensively in any other section of California. Although favoring corn, the summer temperatures are not sufficiently high or constant for the profitable production of rice. The nightly drop in temperature, associated with the ocean breezes, has been chiefly responsible for the failure to obtain a crop of this small grain, which is successfully grown in more northerly parts of the Sacramento Valley.

AGRICULTURAL HISTORY AND STATISTICS

Before 1850, the year Congress passed the Swamp and Overflow Act, no attempt was made to grow crops in the delta area. It was a vast tule marsh dissected with waterways and rich in wildlife. The Federal Government owned it, and only transient fishermen, trappers, and hunters visited it. Under the terms of the act, however, title gradually passed through the State into the hands of private individuals and organizations who undertook to reclaim these lands, which were too wet to produce crops in their natural condition. As the production of crops depends on successful removal of the naturally excessive quantities of water, the history of the agricultural development of this area parallels the history of its reclamation.

EARLY RECLAMATION EFFORTS

Immediately following passage of the act several programs of reclamation were instituted, notably Reclamation District No. 17, which occupied a narrow strip along the east bank of the San Joaquin River south of Stockton. As in other contemporary efforts, the problem was relatively simple. This district includes the slightly higher lying peripheral mineral soils, with a water table normally about 3 feet below the surface, and its reclamation involved no more than the construction of simple levees—a comparatively low one to bar the inflow of surface water from nearby higher lands, and a slightly higher one along the river to prevent inundation during periods of heavy run-off. These levees were built of mineral alluvium by means of plows and scrapers. No ditches were constructed, and no provision was made for drainage. The land produced heavy yields of barley and wheat during the winter and spring and in addition provided pasturage in other seasons.

Reclamation soon extended deeper into the delta, encompassing some of the outlying bodies of peat land, and here a slightly more complex problem arose. The higher water table necessitated some provision for drainage, and the increased difference between land and stream levels necessitated higher levees. Tidal gates were built into the levees, to which, in some instances, a simple system of drainage ditches conducted the excess water.

Many interesting and ingenious methods of construction were tried in the endeavor to erect levees of peat. In at least one instance, large blocks of this matted fibrous material were dug out and carefully fitted into two parallel walls, the space between being filled with loose material. Elsewhere, redwood posts were driven along the outer slope to support a mat of willow brush protecting the less resistant organic material of the levee. All such methods proved ineffective, however. The only levees that resisted the floodwaters were those built of mineral material and situated along the natural stream ridges.

Despite numerous costly and disheartening failures in the construction of levees during these early years, the notably high yields obtained on the organic soils stimulated further advance into the delta.[7] During the period from the early sixties until well into the eighties, many reclamation units were organized with varying degrees of success. Many failed to pass beyond the initial promotion stage, others carried on for a few seasons of crop production before succumbing to the force of the waters, and only a very few managed to survive to the present day.

During the last quarter of the nineteenth century, the greater part of the farming was performed by orientals, who outnumbered the white farmers. The Chinese first began farming on Sherman Island in 1870, after having built levees around a large part of that island by hand and wheelbarrow. They were flooded out in 1878 and reestablished themselves on Staten Island in 1881. In September 1881 an English concern attempted the reclamation of a very large acreage on both Roberts and Union Islands, but damaging floods caused heavy losses. Most of the financial backers of reclamation during this period expected to receive large returns through leasing to companies formed by orientals. Largely to obtain the high rentals offered by these groups, reclamation was initiated during this period on tracts and islands including: (1880–84) Newhope District, Bishop Tract, and Twitchell, Andrus, and Brannan Islands; (1886–88) Terminous and Brack Tracts; and (1893–97) Grand and Coney Islands and Clifton Court, Drexler, and Smith Tracts.

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[7] A news item appearing in the Stockton Daily Independent on June 18, 1857, reported that 10 acres of peat land on Rough and Ready Island produced, during a 5-month period, 2,000 heads of cabbage, 3,000 muskmelons, 30 bushels of tomatoes, 1,000 pounds of onions, 20,000 pounds of potatoes, 200 bushels of corn, and 2,000 pounds of squash, in addition to quantities of beans, peppers, beets, and radishes.

RECENT RECLAMATION METHODS

Toward the close of the last century, the development of the clamshell dredger revolutionized the construction of levees in the delta area. Previously, levees had been comparatively small and built largely of surface materials. Many of them literally were hand-made. Landowners who could afford to build their levees highest were least injured by floods, although in every year the seasonal high water breached many levees, inundated large tracts of land, and put them, temporarily at least, out of production. The floating barge and long boom[8] of the clamshell dredger allowed deep cuts along the outer side of the levee, making the underlying mineral material available for the building of higher and stronger levees (pl. 1, *A*). The new method of construction not only advanced reclamation into the very heart of the delta area but also led to a reorganization and refinancing of most of the older units. By the close of the second decade of the present century, practically the whole of the delta had been reclaimed.

IRRIGATION AND DRAINAGE

The advance into the heart of the delta area created far more complex problems than those experienced in earlier years. Not only was it necessary to construct higher and sturdier levees, in order to avoid inundation, but elaborate drainage systems also became essential to maintain the water at an optimum level for plant growth. Originally, pumps apparently were installed along the levees to remove the floodwaters impounded after a break in the levee, so that the land could be returned to production as soon as possible after the break was repaired. Later, their use was extended to lifting excess water over into the stream. The drainage system gradually evolved from simple ditches into the intricate system now used throughout the delta.

Along with the development of facilities for drainage came a belated recognition of the need for irrigation. As the two procedures are so closely related, the present methods for both irrigation and drainage can best be presented together. Water for irrigation is withdrawn from stream channels in three ways: (1) Through a culvert or floodgate, which penetrates the levee; (2) through a pipe siphon, which arches upward to a point just below the crest of the levee; and (3) by pumping, which may involve a specific plant or may consist of operating the drainage pump in reverse direction. The second method is used most.

Irrigation water is generally carried in ditches about 10 feet wide. These ditches parallel the levee about 100 feet inside the inner toe and discharge into lateral ditches 4 feet wide, dissecting the island into checks ranging in size from 20 to 50 acres. The water flows from these laterals into smaller temporary spud ditches, about 10 inches wide and about 20 inches deep, which parallel the crop rows at intervals of 50 to 100 feet.

Water is raised to the desired height by means of dams in the lateral ditches and by means of baffles in the spud ditches, causing the groundwater level to rise in each check. The ground water is maintained at different levels for different crops and for different stages in growth of

[8] At present these large dredgers are equipped with 150-foot booms and with buckets handling 3 cubic yards of material.

the same crop. For instance, in the production of celery the water table is held practically at the surface.

Excess water from the spud ditches generally discharges into ditches that carry the water supply to the next check. Ultimately the excess water empties into drainage canals. Most of the larger canals are about 10 feet deep and 25 feet wide. These canals conduct the excess water to the pumping plant, which lifts it over the levees and discharges it back into the stream channel outside the levee. During the early days of development most of the pumps were operated by steam; today practically all are operated by electricity. The present trend is toward the installation of automatic controls because of their greater accuracy and economy of operation.

DEVELOPMENT OF INTENSIVE AGRICULTURE

Hand in hand with increased security from overflow and greater control over the ground water, an intensive agriculture developed in the delta area. It had been a common practice after the initial reclamation to devote the first season to burning the dry tules and otherwise preparing the land for crop production. Small grains—principally wheat and barley—were grown, and yields of 25 to 35 sacks [9] per acre were common. Potatoes, yielding from 150 to 250 sacks per acre, and onions were grown in alternate years by many farmers. Many islands were utilized to pasture dairy animals and other livestock, which were removed to higher lands soon after the water in the streams began to rise. If a few seasons elapsed without serious breaks in the levee, it was not uncommon for potatoes, onions, corn, and other intensive field crops to replace the grain entirely.

Following the reclamation of the more centrally located tracts, where the soils were formed from organic materials, accidental fires caused almost as severe damage as did breaks in the levee. Many of them started by sparks from harvesting machinery, and they generally burned until quenched by autumn rains. As soon as the destructiveness of these fires was fully realized, the farmers tried to check them quickly. The commonest method was to breach the levee and allow water to flow in from adjacent stream channels. This method with minor changes continues in use today.

Asparagus, now a principal crop, was not planted extensively before the nineties. Perfection of the canning process gave the impetus to the rapid rise of asparagus production. A cannery was erected on Bouldin Island in 1892, and the profitable demand for its product was reflected in the extensive acreage planted to this crop in the immediate vicinity of the factory. Later a second plant was erected on the same island, and planting totaled nearly 10,000 acres. In 1904 a disastrous flood covered Bouldin Island to a depth ranging from 10 to 20 feet for nearly a year, despite tremendous expenditures of effort and money to free the land of water. In the meantime the crop harvested from the small plantings of asparagus in other parts of the delta brought such relatively high prices that asparagus soon became established on most of the islands. This crop now occupies over 77,000 acres.

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[9] The capacity of grain sacks in the different markets in California ranges from 100 to 125 pounds, but the general average is about 2 bushels.

Sugar beets were first produced in the delta only within the last two decades, although for more than 40 years they have been grown on surrounding mineral soils. They were first planted in the northern part of the delta, where the soils commonly have a somewhat lower content of organic matter than those in the southern part. High yields in some places have encouraged heavy plantings during recent years throughout the entire delta. Many of these plantings, however, have given disappointingly low returns on the more highly organic soils.

PRESENT CROP ACREAGES

No separate data regarding crop acreages and yields in the delta area are available for the earlier years. Accurate data covering the 10 years 1924–38, excluding the years 1933–37, collected by the California Department of Public Works, Division of Water Resources, form the basis for table 4.

TABLE 4.—*Acreages of irrigated crops and nonirrigated crops and total acreages reported in the Sacramento-San Joaquin delta area, Calif., for stated years* [1]

Crops	1924	1925	1926	1927	1928	1929	1930	1931	1932	1938
Irrigated crops:	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Alfalfa	31,034	26,011	25,998	26,238	26,673	27,048	26,930	26,882	25,378	31,342
Asparagus	54,129	51,974	55,601	47,897	53,971	62,044	70,269	70,580	71,709	77,311
Beans	36,459	37,590	51,802	47,678	38,429	32,315	[2] 29,166	[2] 26,992	[2] 16,147	[2] 10,997
Sugar beets	21,375	16,685	7,936	14,527	14,722	[2] 21,553	24,058	[2] 30,915	28,621	[2] 36,311
Celery	4,065	5,330	7,392	7,888	7,813	8,721	5,969	6,303	[2] 7,418	[2] 6,914
Corn	27,392	24,029	23,955	26,944	40,268	40,855	54,533	[2] 55,798	52,807	40,457
Fruit (mostly pears)	16,180	12,772	17,771	17,261	15,763	14,935	14,504	10,775	9,480	6,196
Grain and hay	31,853	11,166	33,196	34,723	43,632	39,112	35,452	65,086	79,996	89,823
Onions	3,886	5,989	5,810	4,340	3,668	4,159	4,341	[2] 3,769	[2] 3,299	[2] 1,304
Pasture	1,035	5,273	4,161	2,736	6,284	2,746	7,686	12,748	12,052	12,386
Potatoes	27,872	22,071	21,503	28,422	24,914	18,046	[2] 18,839	18,042	14,558	10,650
Seed crops	930	3,459	2,883	3,526	6,453	9,515	5,352	8,967	5,844	3,235
Other crops	4,021	4,737	6,471	3,590	5,909	7,678	15,334	[2] 6,498	[2] 10,716	11,999
Total irrigated crops [2]	260,231	227,086	264,479	265,770	288,499	[3] 292,845	312,433	343,355	338,025	338,925
Nonirrigated crops:										
Grain, hay, and pasture	78,416	-------	-------	-------	49,300	78,444	93,506	30,239	29,145	30,819
Total	423,000	405,716	420,000	421,000	421,000	435,000	437,566	434,909	434,909	434,909

[1] From Reports of Sacramento-San Joaquin Water Supervision, California Department of Public Works, Division of Water Resources. (*11, pp. 341–357; 12, p. 88; 13, p. 109; 14, p. 128; 15, p. 101; 1, p. 110.*) No census of crop acreages was made during the period 1933–37, inclusive.
[2] Includes some second crop or interplanting.
[3] Irrigated fields, totaling 4,118 acres, were flooded and produced no crop.

The total gross value of the crops grown in 1931 was almost $23,000,000 of which sum asparagus contributed over $7,000,000, sugar beets over $3,000,000, potatoes almost $3,000,000, celery almost $2,000,000, and corn and fruit over $1,000,000.[10] Asparagus, potatoes, celery, corn, and onions are grown almost exclusively on the more highly organic soils. Intensive cultural practices, much hand labor and, in general, heavy applications of fertilizer, are involved in the production of these crops. It is a common practice among the better established growers to fertilize their land for potato crops with variants of a 0–10–12 [11] fertilizer at the rate of about 1 ton per acre, or of a 0–20–24 mixture at about half that rate.

[10] Data taken from table 94, Sacramento-San Joaquin Water Supervisor's Report for the year 1931 (*14, p. 212*).
[11] Percentages, respectively, of nitrogen, phosphoric acid, and potash.

Fruit (chiefly Bartlett pears), beans, alfalfa, and seed crops are grown, for the most part, only on the somewhat better drained, less highly organic soils and mineral soils, such as those along the major stream channels or bordering the delta proper. The methods used are similar to those used on mineral soils in other parts of the State. Here, the particular advantage lies in the ample and inexpensive supply of water for irrigation. Fertilization is not generally practiced for these crops.

Wheat and barley, for both grain and hay, as well as sugar beets and truck crops, are grown to about an equal extent on organic and mineral soils. Spud-ditch subirrigation is practiced on the organic soils, whereas surface irrigation through lateral ditches is used for sugar beets and truck crops on mineral soils. On the latter soils the grain and hay crops are seldom if ever irrigated. Sugar beets and truck crops receive occasional applications of fertilizer; generally they follow some other crop that has been fertilized.

LABOR

Despite the passage of the Alien Land Law in 1913, farming practices in the delta area continue to show a marked Asiatic quality. Large labor gangs, chiefly Filipinos, are employed on the centrally located tracts and islands, where they provide the hand labor for many such crops as asparagus and sugar beets. Japanese and Chinese foremen frequently head labor gangs, and American-born members of both these races lease and operate important acreages. Although a large part of the landowners continue the old methods of leasing and large-scale operation, there is some trend toward a closer settlement by native-born Caucasians. In general, however, lack of potable water for household use and the dominant physical landscape discourage ownership of small tracts and erection of attractive homes.

AGRICULTURAL PESTS AND PROBLEMS

The qualities of soil and moisture that promote the high crop yields likewise induce luxuriant, persistent, and costly weed growth. The price of control is a long-continued and well-directed cultural operation involving both hand and mechanized labor. The eelworm (a nematode particularly damaging to potatoes) has heavily infested a few sections. To eliminate these pests a common practice is to burn the topmost few inches of the soil. Although this destroys quantities of weeds and undesirable seeds, the practice is of doubtful efficacy against the nematode.

"ALKALI"

Farmers in many parts of the delta must contend with injurious concentrations of soluble salts ("alkali"). An extensive and adequate study should be conducted to determine the character and distribution of the salt accumulations and to develop effective methods of control. The advance of saline water into the delta channels from the Bay region has recently become a subject of intensive investigation. With the approach of each dry summer when stream run-off is scant, the waters of the channels temporarily become increasingly saline. In a few recent years, especially 1924, 1926, and 1931, the limit of salinity permissible for plant growth in irrigation waters has extended well inland. At such times growers suspend the late summer irrigations from affected channels.

The general practice of subirrigation promotes the concentration of salts in the surface soil, where it constitutes a menace to crop production. The organic soils are extremely permeable and have a high water-holding capacity. Salt-laden moisture rises particularly rapidly in them during the drier seasons of the year because of the high water table. When adequate underdrainage is maintained, the winter rains tend to wash much of the surface accumulation of salts downward into the soil mass. These movements are surprisingly rapid and extensive.

If the movement of soil moisture could be maintained predominantly in a downward direction, little or no accumulations of salts would result. Already some growers are experimenting with methods of surface irrigation, for example, the use of overhead sprinkler units on small areas. Caution must be used in reversing the direction of the movement of soil water, however, in order to avoid excessive leaching of the soil with the consequent loss of the more soluble plant-nutrient elements.

BURNING AS A CULTURAL PRACTICE

Burning is all too common in the delta area. Controlled firing of the surface soil has been practiced for many years in the preparation of potato fields. It eliminates many of the weeds, checks some pests, makes available a larger quantity of potash, and produces a smooth fine-grained tilth in the fields.

Nevertheless this practice has lowered the surface level, increasing the cost and difficulties of drainage throughout a large part of the delta area, and may ultimately threaten the economic feasibility of farming the land. The ratio between the volume of unburned organic soil and that of resultant ash is approximately 6 to 1; a 6-inch burning, therefore, lowers the surface level by about 5 inches.[12] Surveys along a 10-mile line across three reclamation units[13] that are farmed in accordance with general practice show a total average subsidence during a 12-year period of some 27 inches or approximately 2 inches per year (*10*). Controlled burnings have been responsible for most of this subsidence.

Like erosion in the upland mineral soils, such fires destroy a large part of the land capital of the farmer. The uneven configuration of completely burned areas aggravates the problem of irrigation, drainage, and cultivation. Not the least important injurious effect of burning is that it destroys only the organic and volatile matter and

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[12] Samples collected in the delta and burned in the laboratory of the Division of Soil Technology show even larger losses in volume.
[13] Bacon and Mildred Islands and Lower Jones Tract.

leaves the mineral material behind. Thus, the concentration of soluble salts tends to increase in the surface soil where this condition causes the greatest damage to crops.

SOIL-SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field.

The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers, or horizons, called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail; and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil [14] and its content of lime and salts are determined by simple tests.[15] Drainage, both internal and external, and other features, such as relief, or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics soils are grouped into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. In places two or more of these principal units may be in such intimate or mixed pattern that they cannot be clearly shown separately on a map but must be mapped as (4) a complex. Areas of land, such as coastal beach or bare rocky mountainsides, that have no true soil are called (5) miscellaneous land types.

The most important group is the series, which includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics and the same natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first found. Thus, Egbert, Staten, and Ryde are names of important soil series in this area.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. The class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Ryde clay loam and

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[14] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality, higher values indicate alkalinity, and lower values indicate acidity.

[15] The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction.

Ryde silty clay loam are soil types within the Ryde series. Except for the texture of the surface soil, these soil types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, which differs from the type in some minor soil characteristic that may have practical significance. Differences in relief, stoniness, and the depth to a discordant underlying material frequently are shown as phases. For example, Ryde clay loam, shallow phase, is differentiated and mapped in this area. Within the normal range of relief for a soil type there may be areas that are adapted to the use of machinery and the growth of cultivated crops and others that are not. Even though no important differences are evident in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, important differences may exist in respect to the growth of cultivated crops. In such an instance the more sloping parts may be segregated on the map as a sloping or a hilly phase. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, complexes, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS AND CROPS

A variety of soils, both organic and mineral, occur within the Sacramento-San Joaquin delta area. All the organic soils belong to the class designated by Stokes as Eutrophic soils (*6*) that is, organic soils on which conditions of plant nutrition are good, as contrasted with some organic soils in other parts of the world on which conditions of plant nutrition are fair or poor. The organic soils, which are confined to the delta basin, occupy a larger aggregate acreage and are the more typical of this low-lying area. The mineral soils, however, display a wider variety of characteristics, as they occupy the margin of the area, where they represent the small parts of larger bodies beyond the boundaries of this survey. As the mineral soils are fully described in other recently published reports (*2*, *3*, *5*), they will be treated briefly here; major attention will be given to the organic soils.

Forty-one differentiations of the soils in the Sacramento-San Joaquin delta area are shown in color on the accompanying soil map. These soils are placed in two groups: (1) Soils of the delta basin, developed mainly on organic materials, and (2) soils of the delta margin, developed on mineral materials. One miscellaneous land type, made land, is also mapped. A detailed description and discussion of the agricultural importance of these soils follow, the accompanying soil map shows their distribution, and table 5 gives their acreage and proportionate extent.

TABLE 5.—*Acreage and proportionate extent of the soils mapped in the Sacramento-San Joaquin delta area, Calif.*

Soil type	Acres	Percent	Soil type	Acres	Percent
Correra peat	5,312	1.7	Columbia silty clay loam	15,232	5.0
Venice peaty muck	17,216	5.6	Columbia silty clay	7,680	2.5
Staten peaty muck	61,952	20.1	Made land	3,584	1.2
Egbert muck	61,248	19.9	Oakley sand	1,600	.5
Egbert muck, shallow phase	16,832	5.5	Montezuma adobe clay	192	.1
Egbert muck, burned phase	11,136	3.6	Capay silty clay loam	512	.2
Roberts muck	1,536	.5	Lindsey clay loam	768	.2
Burns clay loam	9,280	3.0	Antioch fine sandy loam	256	.1
Piper fine sandy loam	3,264	1.1	Stockton adobe clay	1,408	.5
Piper-Egbert complex	1,280	.4	Stockton clay loam	384	.1
Ryde clay loam	20,544	6.7	Merced sandy loam	4,800	1.6
Ryde clay loam, shallow phase	6,528	2.1	Zamora loam	64	(1)
Ryde silty clay	2,112	.7	Alviso clay	448	.1
Ryde silty clay loam	11,520	3.8	Marcuse clay	2,752	.9
Ryde silty clay loam, shallow phase	7,040	2.3	Rincon clay loam	448	.1
Sacramento loam	320	.1	Brentwood clay loam	384	.1
Sacramento mucky loam	3,392	1.1	Brentwood clay	192	.1
Sacramento clay loam	13,248	4.3	Solano silty clay	1,344	.4
Sacramento silty clay loam	2,176	.7	Herdlyn loam	128	(1)
Sacramento adobe clay	5,440	1.8	Clear Lake adobe clay	2,240	.7
Columbia sandy loam	1,600	.5			
Columbia loam	448	0.1	Total	307,840	......

[1] Less than 0.1 percent.

SOILS OF THE DELTA BASIN

The soils of the delta basin are, for the most part, organic soils and associated soils in which advanced alteration and an admixture of mineral materials have played an important role.

The more highly organic soils of the delta basin are the Correra, Venice, Staten, and Egbert soils. Of these, Correra peat is inextensive and insignificant agriculturally, but it represents the extreme condition in raw, unaltered parent organic materials within this area. The Venice, Staten, and Egbert soils represent different conditions or stages in alteration of the parent peat materials. These soils occupy the low parts of the basin, which lie near sea level, have no natural drainage, and have a high water table.

The Burns and Piper soils have reached a more advanced stage in decomposition and oxidation than the soils mentioned, and perhaps are influenced by a different type of parent organic materials and an environment in which the accumulation of organic and sedimentary materials may have alternated. These soils have a lower organic-matter content and occupy slightly more elevated and better drained positions than the peats and mucks.

The soils of the Ryde series have developed under conditions favoring the alternate accumulation of organic materials and mineral sediments. In general, they are made up of an overwash of alluvial materials recently deposited over older organic and mineral materials.

The soils of the Sacramento and the Columbia series are the only distinctively mineral soils of the delta basin. The Sacramento soils comprise dark fine-textured alluvial sediments deposited from turbid floodwaters in backwater-overflow areas; the Columbia soils comprise lighter colored materials recently accumulated on stream-built levees or ridges that are slightly higher and better drained than the surrounding land.

PEATS, MUCKS, AND ASSOCIATED ORGANIC SOILS

Correra peat.—Correra peat, as it occurs in this area, consists of practically unaltered virgin deposits of peat (*4*)[16] characteristically having two layers—a comparatively thin layer of material derived from tule, or bulrush (dominantly *Scirpus lacustris* L.), overlying a deeper accumulation of fibrous remains of reed (chiefly *Phragmites communis* Trin.). In a few localities small quantities of other plant remains are present, but they do not materially alter the general character even of the deeper deposits, although they are distinct enough for identification.

The occurrence and uniformity of this tule-on-reed peat indicate that for a long time—probably during the entire period of accumulation—the relation between ground-water level and land surface was more or less constant. The slow and continuous subsidence of the mineral base[17] apparently equaled the slow accumulation of plant remains. The comparative purity of the reed-formed material which in some places exceeds a depth of 30 feet, tends to support such a theory. The surficial layer of tule-formed material, which in few places exceeds 3 feet in thickness, indicates that this plant has been dominant only during comparatively recent times.

By far the larger part of Correra peat remains unreclaimed and continues to support a cover of native plants. In some localities a dense and almost pure stand of tules occurs, although, in general, some reeds, willows, and herbaceous plants are also included. The diminishing numbers of wildlife are gradually concentrating on the virgin areas of this soil, and they continue to attract trappers and hunters.

Only slightly more than 200 acres of Correra peat lie within the levees of existing reclamation units, and less than one-half of this acreage is devoted to crop production. The small bodies on the Egbert Tract and on Bacon, Bouldin, and Mandeville Islands show a slight alteration of the surface material, but in general they possess the following characteristic profile: To a depth ranging from 10 to 20 inches the material consists of brown fibrous-matted tule peat containing an abundance of light-brown small fibrous roots and dark-brown or almost black shiny tule rhizomes. This material contains varying small quantities of dark brownish-gray finely divided altered plant material; it has a pH value of about 5.0 and an organic-matter content of about 80 percent. Below this layer and extending downward to a depth ranging from 30 to 45 inches is brown or light-brown raw fibrous-matted tule-reed peat similar to the surface material but containing many identifiable stems and roots of reeds, which become even more numerous in the lower part. This material grades into the underlying brown softer and more altered reed peat. Thin layers of darker brown highly altered material occur at various depths but aggregate less than 10 percent of the soil mass. This material is associated with either tule fragments or herbaceous vege-

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[16] In earlier surveys, such as the reconnaissance soil surveys of the Sacramento Valley and the Lower San Joaquin Valley (7, 9), no attempt was made to separate the other organic soils from Correra peat, and all were grouped under the designation "muck and peat."

[17] This same phenomenon is in some places related to oceanic level and is expressed as the rising water surface.

tation or both. Such incidental layers probably represent accumulations during a period when the reed cover was thinner and less pure, as following a fire or an abruptly changed water level.

Venice peaty muck.—Venice peaty muck is formed from tule-reed peat. This soil occurs in flat basinlike areas that under natural conditions are saturated with ground water and covered with a dense growth of tules.

Venice peaty muck has a partly decomposed and altered organic surface soil, grading into an essentially unaltered organic subsoil, which abruptly overlies the light-gray mineral base common throughout the delta area. The surface soil is about 16 inches thick and consists of dark-gray loose soft-fluffy partly altered and decomposed peaty muck. This material contains brown or light-brown fragmental fibrous remains of tules and reeds, the former dominating. The reaction is definitely acid—showing a pH value of about 5.0—and the organic-matter content is about 50 percent or less. The surface soil gives way to an underlying layer of brown matted fibrous peat consisting principally of horizontal-lying and flattened fragments of reed stems and tule rhizomes, bound together by the vertical-piercing smaller roots of reeds and tules. This material is slightly more acid than the surface soil and contains about 60 percent of organic matter. Beginning at a depth ranging from 4 to 8 feet, the lower part of the subsoil becomes very strongly acid—having a pH value of 4.0 to 4.5—and characteristically contains small quantities of dark-brown or almost black fine-grained organic material. In a few localities, thin lenses and layers of material derived from a variety of plants, other than tules and reeds, are present.

In general, the subsoil is comparatively uniform in character throughout, and in its essentials it is identical with the material composing the lower parts of Correra peat. The mineral substratum below the organic deposits consists of light-gray or light bluish-gray alluvial and lacustrine material varying in texture from sandy loam to fine sandy clay. This is massive and comparatively impervious—although far from being cemented or consolidated—and has a high content of finely divided mica, practically no organic matter, and a neutral reaction.[18]

Venice peaty muck occurs in the central part of the delta area, principally on Venice, Mandeville, McDonald, and Bouldin Islands. Here it is associated with the Staten and Egbert organic soils, from which it is separated on the basis of its lower stage of alteration. As drawn, the boundaries are, however, more or less arbitrary, and a few small areas of either of the two associated soils are included. Included also are small areas that were mapped as Egbert clay loam in Contra Costa County (*3*) but are now believed to conform more closely to Venice peaty muck.

Practically all of Venice peaty muck has been reclaimed and is now under cultivation. Owing to its loose and permeable character, water moves readily through it in all directions, and its water-holding capacity is high—between three and seven times its own weight. This has proved to be one of the more satisfactory soils of the delta area for the production of celery. In contrast with the less fibrous and peaty

[18] Among 100 samples tested, the lowest pH value was 6.4 and the highest was 8.4. Less than 10 samples contained sufficient lime carbonate to effervesce when treated with dilute hydrochloric acid.

organic soils, Venice peaty muck allows many cultural operations at times when the soil is saturated, an important factor in growing such crops as celery.

Staten peaty muck.—Staten peaty muck, like Venice peaty muck, is developed from tule-reed peat. It has reached a more advanced stage of decomposition and alteration than has Venice peaty muck, and commonly is less acid and contains more soluble salts. The same general conditions of relief, drainage, and vegetation characterize the two soils, although Staten peaty muck commonly occupies very slightly higher positions than does Venice peaty muck.

Staten peaty muck has a moderately altered surface soil grading into a slightly altered subsoil. The 15-inch surface soil consists of dark-gray loose soft-fluffy partly decomposed organic material, which here and there contains very small quantities of brown fibrous plant remains. It has a slightly less acid reaction than the surface layer of the Venice soil—a pH value of about 5.5 to 6.0—and a 40- to 50-percent content of organic matter. This layer gives way more or less abruptly to an upper subsoil layer of dark-brown matted fibrous peaty material containing considerable very dark brown or black fine-granular organic matter. The material in this layer is only slightly more acid than that in the surface soil, although it contains about 70 percent of organic matter. Below a depth ranging from 20 to 50 inches the matted fibrous character gradually becomes less pronounced, the small vertically oriented root fragments become fewer, and a layered appearance develops. The acidity and the organic content remain about the same. The mineral substratum, which is from 6 to 20 feet below the surface, is essentially identical with that underlying Venice peaty muck.

Staten peaty muck is the most extensive organic soil mapped in the delta area. It occurs throughout the central part, extending from a small body in Clifton Court Tract in the south-central part to larger bodies on Grand Island in the north-central part and the Rindge Tract in the east-central part. It is associated with the Venice and Egbert organic soils, from which it is differentiated on the basis of profile development. A few bodies of these two soils are included in mapping.

All this soil has been reclaimed and brought under cultivation. Combined with a high water-holding capacity, its somewhat firmer consistence causes it to be more retentive of moisture than Venice peaty muck. It likewise can be more easily brought into a condition of satisfactory tilth. The soil is well suited for the production of potatoes, asparagus, celery, corn, and other field crops. Barley and wheat are grown on a considerable acreage of this soil; the rank growth of weeds, however, especially wild mustard, together with the general tendency for the grain to lodge, necessitates special handling at harvest time. The small grains produce equally good yields, at a slightly lower cost, on some of the other more mineralized soils.

This soil as mapped includes small areas of peat as recognized in the earlier and less detailed surveys of Contra Costa County (*3*) and the Lodi area (*5*).

Egbert muck.—Egbert muck, together with its two subordinate phases, exhibits a further alteration of organic material with a higher admixture of alluvial mineral soil than in the Correra, Venice, and Staten soils. It is commonly less acid and contains more soluble salts, and it is somewhat denser in the upper part of the subsoil. Like the Staten and Venice organic soils, the Egbert soils occur in comparatively flat areas where, under natural conditions, they are saturated with water and support a dense growth of tules, reeds, and similar hydrophytes. Broadly speaking, but with several exceptions, Egbert muck tends to occupy somewhat higher upstream situations than do either of the less altered soils.

Egbert muck has a moderately altered to well-decomposed 14-inch surface soil that grades almost imperceptibly into an upper subsoil layer of slightly more dense but otherwise similar material, which, in turn, grades into a lower subsoil layer of loose permeable material. The surface soil consists of dark-gray soft granular to fluffy muck containing few or no fragmental remains of plants. The reaction is moderately acid, as the pH value ranges from 5.5 to 6.0, and the content of organic matter is about 40 percent or less. No distinct demarcation exists between the surface soil and the subsoil, which consists of dark-gray moderately soft fine-grained peaty muck. Horizontal-lying fragments of reeds and tules are numerous in the subsoil. The upper subsoil layer has a slightly more acid reaction, with a pH value of 5.5 or less, and a slightly higher organic-matter content than the surface soil. The material has rather firm moderately dense consistence and more or less platy structure. Such features are barely discernible in the normally wet soil but are more distinct in dry exposures. The lower subsoil layer has a much less acid reaction, with a pH value of about 6.0, and a higher content of organic matter. Small lenses and strata of less altered brown fibrous peaty material occur in the lower part of the subsoil in some places, as do similarly thin and erratic strata of light grayish-brown soft silty clay. In some of the latter places, charred and carbonized plant fragments are present immediately beneath the mineral stratum, suggestive of an earlier inundation of sediment-laden waters preceded by a period of fires. The subsoil rests abruptly on the light-gray mineral substratum at a depth ranging from 4 to 20 feet or more.

Egbert muck is exceeded only by Staten peaty muck in total extent. Both large and small bodies occur throughout the delta area. They are associated with other organic soils and with the two variations mapped as phases. From the former they are differentiated on the bases of degree of alteration and content of mineral matter, and from the latter on the bases of depth to the underlying mineral material and degree of burning. The two phases are discussed under separate headings in subsequent paragraphs.

Practically all of this soil is under cultivation, and it has proved to be one of the most satisfactory soils in this area for a wide variety of crops. Water readily penetrates the soil, unless it has been allowed to dry out completely, and the soil can retain large quantities of water—several times its own weight. This relatively firm fine-grained soil works into an extremely satisfactory seedbed with less difficulty than do either more fibrous or more mineral soils. Potatoes, asparagus, corn, sunflowers (pl. 1, *B*), sugar beets, and the small grains produce highly satisfactory yields. Even celery yields as well on Egbert muck as it does on Venice peaty muck, although somewhat more difficulty is involved in cultural operations.

As recognized in this survey, this soil includes the areas recognized in the included part of the Contra Costa County (*3*) and the Suisun area (*2*) soil surveys as Egbert clay loam and Egbert loam, which border the valley-plain soils and contain less organic matter than typical Egbert muck.

Egbert muck, shallow phase.—The shallow phase of Egbert muck differs from the typical soil principally in its slight depth to the mineral substratum. In some localities, particularly where a marshland type of vegetation advanced comparatively recently on the bordering mineral plain, this soil also contains slightly more brown fibrous plant remains, especially in the upper part of the subsoil, than the typical soil. In this respect these minor occurrences approach the characteristics of Staten peaty muck. Commonly this shallow soil lies very slightly higher than typical Egbert muck, although under natural conditions it is similarly saturated with ground water and supports a dense cover of tules, reeds, and associated plants.

Typically, this shallow soil has a 14-inch surface soil consisting of dark-gray soft faintly granular muck that has a moderately acid reaction and an organic-matter content of about 40 percent. This grades into an upper subsoil layer of similar dark-gray material having a slightly more acid reaction and a higher content of organic matter, chiefly tule rhizomes and reed stems arranged horizontally. In the deeper areas—where the mineral substratum lies about 2 feet or more below the surface—a lower subsoil layer of varying character occurs in most places. This layer ranges from one identical with the lower subsoil layer of typical Egbert muck to one of stratified almost wholly mineral sediments. These latter strata commonly consist of brownish-gray soft silty clay having a pH value ranging from 5.5 to 6.0 and an organic-matter content of about 15 percent. Thin planes of light-brown or straw-colored soft plant fragments separate the strata in most places.

Although not so extensive as typical Egbert muck, this shallow soil nevertheless occupies a large total area. The largest single body borders the eastern boundary of the delta area from the vicinity of Stockton northward. This extensive strip merges with the deeper typical soils on the west and to less degree grades into the dark, poorly drained mineral soils of the lower valley plain on the east. This same relationship characterizes other similarly situated bodies of the shallow phase of Egbert muck along the western boundary of the area. The agricultural activities on this soil likewise represent a transition from those of the delta proper to those of the grain-farming and livestock-producing districts of the lower valley plain.

Most of this land is reclaimed and under cultivation. Asparagus, potatoes, sugar beets, corn, and other intensively grown field crops produce satisfactory yields on the areas of somewhat deeper soil, although parts of the areas of shallow soil still support a cover of native vegetation and are used chiefly for grazing. The principal difficulty in utilizing the shallow soil for crop production is the provision of adequate and dependable drainage. The massive and somewhat impermeable mineral substratum restricts the movement of water, which not only complicates the problem of drainage but also that of irrigation. Also associated with a slight depth to the mineral substratum is the comparatively heavy concentration of soluble salts in the surface soil, a condition reaching its greater severity in the areas of shallowest soil, where it is augmented by the addition of salt-carrying drainage waters from the adjacent mineral soils.

Egbert muck, burned phase.—Although practically all of the organic soils of the delta area show some evidence of having been burned, certain localities have suffered severely from this cause. Areas where burning has materially modified the original profile are separated as Egbert muck, burned phase. Unless smoothed by cultural operations, this land has a somewhat uneven surface even where it was originally comparatively flat.

As mapped, certain minor variations occur in the profile of this burned muck, particularly in the subsoil characteristics. The surface material, to a depth ranging from 10 to 30 inches, consists of gray or rather brownish gray granular to faintly cloddy soft mucky material, which contains numerous root fragments of contemporary vegetation but practically no remnants of the original plant remains. It also contains many buff or light reddish-gray lumps and particles of ash, which crush readily between the fingers, indicating the readiness with which the evidences of severe burning disappear under cultivation. In most places the surface soil has a pH value of about 7.0 and contains about 40 percent or less of finely divided organic matter. It likewise shows a comparatively high concentration of soluble salts, although the latter feature is a more or less ephemeral condition associated with contemporary circumstances of drainage. The surface material grades into a subsoil of dark-gray softly firm peaty muck containing varying quantities of fragmental plant remains, chiefly reed roots and stems and light-brown ash particles. In places, a thin layer of almost pure ash separates the surface material from the subsoil, which rests on the mineral substratum at a depth ranging from 30 to 60 inches. The latter is commonly light brownish gray and in a few places contains some mottling of rust brown in its upper 6 inches.

This burned soil is extensive in the southeastern part of the delta area. The small body in the Lower Jones Tract was burned recently and not so deeply as elsewhere; it has a subsoil similar to that of the adjoining bodies of Egbert muck. The larger part of the burned muck is associated, however, with the extensive areas of Burns clay loam on Roberts and Union Islands. It is separated from the latter soil type because of its content of recognizable ash particles and its greater depth to the mineral substratum.

The land is productive under proper management. Asparagus produces heavy yields of high quality. Sugar beets, small grains, alfalfa, and grain sorghum grow successfully, as do potatoes, onions, corn, and other crops, although these latter crops are somewhat better suited to the deeper, more highly organic Egbert and related soils. Problems of drainage and alkali are somewhat more aggravated on this burned muck, and irrigation of the crops involves certain difficulties. Only a small part—in general the deeper soil—can be irrigated by spud ditches. Most of the water for irrigation is applied through surface canals and furrows as on most mineral soils.

Roberts muck.—Roberts muck is somewhat similar to Egbert muck. It apparently represents a further stage in alteration and decomposition of organic matter and commonly has somewhat lower acidity and greater content of lime and soluble salts. In the delta area it occurs in nearly flat basinlike areas and appears to have developed through the alteration of a deposit of tule-reed peat several times the thickness of the present layer of organic material.

Undisturbed areas have a ½-inch surface layer of gray fine mealy or powdery soft mucky material. The surface soil proper extends to a depth of 6 to 8 inches and consists of dark brownish-gray firm muck that breaks down readily, when dry, into small angular lumps. This has a pH value of about 5.0 and an organic-matter content of about 30 percent. It grades into an upper subsoil layer of dark-gray or black moderately firm highly organic muck having a pH value of about 4.5 and an organic content of 30 percent. This material has a faintly developed platy structure and contains numerous horizontal-lying fragments of black carbonized plant remains and a less quantity of brown partly decomposed pieces of roots and stems. At a depth ranging from 20 to 30 inches this material, in turn, gives way somewhat abruptly to gray firm massive clay in which the pH value is about 5.0 and the organic-matter content is 10 percent. With increasing depth, the numerous vertical root holes, which are stained with rust brown and are so characteristic of the horizon, become less pronounced and the reaction slightly less acid. The characteristic underlying mineral substratum becomes more and more evident and is well evidenced at a depth ranging from 5 to 8 feet.

Roberts muck comprises four small bodies along each side of Burns Cut-off and on Rough and Ready and Roberts Islands. Despite its limited extent, it has a distinctive and significant profile. Typically, it is markedly dissimilar to the Egbert, Ryde, and Burns soils, with which it is associated, although along its boundaries it merges with the adjacent soils. The organic material in the upper layers is loose and permeable and has a comparatively high water-holding capacity. The somewhat tighter and dense materials in the lower layers tend to limit the agricultural value of this soil, especially where they occur at a slight depth.

At one time all Roberts muck was under cultivation, but at present the northern part of the body on Rough and Ready Island is being developed for industrial sites in connection with Stockton. The southern part, together with the bodies on Roberts Island, is utilized for the production of a rather wide range of field crops, including wheat, barley, corn, grain sorghum, alfalfa, asparagus, and potatoes. Good yields are obtained from the first-named crops, but the asparagus beds are old and are gradually being removed. Potatoes make only fair yields, far less than are common on more highly organic soils, such as Egbert muck. Water is supplied both through surface ditches and through spud ditches. In general, the former method of irrigation has proved somewhat more satisfactory for grain and hay crops, and the latter for corn, asparagus, and potatoes.

Burns clay loam.—Burns clay loam appears to represent an advanced stage in formation of a eutrophic organic soil from a shallow tule-reed peat. Alteration of the original mantle of plant remains has reached a stage in which a layer ranging from only 1 to 2 feet of organic material remains. Below this depth, the processes of soil development have invaded and altered the underlying mineral base to produce a distinctive and conspicuous feature—a multiplicity of small almost straight vertical root holes, which are coated with a metallic-like deposit and encircled by a highly stained cylindrical zone.

Burns clay loam occupies low ridges and minor elevations where the underlying mineral material comes to the surface in places. At some time in the past these were undoubtedly covered to varying depths by the original mantle of peat, the virgin terrain having a smooth configuration and a much higher ground-water level than at present. Today the Burns soil is comparatively well drained, particularly in contrast with adjacent lower lying bodies of more highly organic soils, and a cover of annual weeds and grasses has displaced the tule-reed vegetation.

Burns clay loam has a surface soil, 18 inches or less thick, consisting of dark-gray friable granular loose clay loam having a pH value of 5.5 to 6.0 and containing about 30 percent of markedly decomposed organic matter. This grades into an upper subsoil layer of gray firm but permeable silty clay loam, which is variously mottled in its lower part with bright-yellow and rust-brown stains and accumulations. This material has a slightly lower acidity than the surface soil and contains only about 10 percent of highly altered organic matter. It gives way more or less abruptly, at a depth of about 28 inches or less, to brownish-gray or somewhat light brownish-gray firm massive material. In it the trend toward decreased acidity and organic matter with increasing depth is continued. The upper part has a pH value of slightly less than 7.0 and an organic-matter content of about 5 percent, and the lower part has a pH value of about 7.0 and an organic-matter content of about 3 percent. Vertical root holes, so conspicuous in the upper part, become smaller, less numerous, and less prominently coated and stained in the lower part. The characteristic light-gray massive mineral substratum lies from 30 to 50 inches below the surface and extends to undetermined depths. This consists of dense clay materials interstratified with fine sand.

Burns clay loam occurs only in the southeastern part of the delta area on Roberts, Union, and Victoria Islands and on the Upper and Lower Jones Tracts. Most of the southernmost bodies are larger than the more northern ones. Typically, bodies of this soil are associated with extensive bodies of the burned phase of Egbert muck, from which they are differentiated by their distinctive profiles, especially in the lower subsoil layer, by their slightly higher position, and by their better drainage. Most of the more northern bodies are little more than narrow meandering ridges that rise slightly above the general level of the surrounding areas of Egbert muck, shallow phase. On a few ridge crests the surface layer of organic material is entirely absent and the soil profile approximates that of the Columbia soils. If these areas were large enough to be shown on the map, they would be differentiated as Columbia silty clay loam.

The upper layers of Burns clay loam have a comparatively high water-holding capacity and are readily penetrated both by plant roots and by moisture. Irrigation is principally by means of surface ditches. As the application of water by this method is more difficult in the narrow and small bodies, most of them are utilized for the production of the winter-grown crops of barley and wheat, for pasturage, or for building sites. Most of the larger and more nearly flat bodies in the southern part of the area are irrigated by both the furrow and check methods. When this is done, the Burns soil produces fairly high yields of corn, grain sorghum, alfalfa, and barley. Dry beans and asparagus return fair to good yields.

Piper fine sandy loam.—Piper fine sandy loam has many characteristics in common with Burns clay loam, particularly in the relatively thin surficial layer of organic material and the distinctive vertical root holes in the lower part of the subsoil. It differs materially from the Burns soil, however, in that its entire upper part contains a large quantity of calcium carbonate and soluble salts. The Piper soil occupies low mounds and ridges that have a roughly aeolian configuration and appear to represent a comparatively recent emergence of dunes and similar wind-modified bodies of sands somewhat related to the nearby bodies of Oakley sand. At some time in the past these emergent minor elevations probably were covered to varying depths by a mantle of peat, which gave the original terrain a more or less smooth almost flat configuration. The level of the ground water undoubtedly was much higher than at present. Now, however, Piper fine sandy loam is well drained to almost droughty, especially on the higher ridges. A thin cover of saltgrass and herbaceous annuals has replaced the former tule-reed vegetation.

The surface soil of Piper fine sandy loam is about 8 inches or less thick and consists of gray friable loose fine sandy loam with a pH value of 8.0 or more and an organic-matter content of less than 15 percent. The material in this layer effervesces in dilute hydrochloric acid and has a low content of the more soluble salts, although this latter condition varies markedly from place to place and from time to time. It grades into an upper subsoil layer of light brownish-gray firm or very faintly cemented sandy loam that breaks under gentle pressure into small irregular lumps. The material in this layer effervesces vigorously in dilute acid and contains a multiplicity of small vertical root holes, which are stained in the same manner as those in the Burns soil but in addition have thin inner walls of calcium carbonate. The material in this layer has about the same organic-matter content and reaction as the surface soil but contains a comparatively large quantity of soluble salts. The lower part of the subsoil, reached at a depth of about 20 inches, has about the same alkalinity as the upper part, but it contains only about 5 percent of organic matter and has a more yellowish to more reddish coloration and a much heavier calcareous coating on the inner walls of the distinctive root holes. At a depth ranging from 24 to 42 inches this grades in turn into light grayish-brown soft massive sandy loam with fewer root holes and a less pronounced coloring. No visible lime, a negligible content of organic matter, and a pH value of 7.0 or less mark the material in this layer, which gradually merges, at a depth ranging from 30 to 60 inches, into light-gray rather loose noncalcareous sandy loam with a similar reaction and similar content of organic matter. The material throughout the entire profile is gradational from one horizon to the next. Fine particles of mica and quartz are present throughout the solum.

This soil occurs in numerous small bodies on and in the vicinity of the Bethel Tract in the west-central part of the area, largely in association with the Egbert and Staten soils, from which it is differentiated by its distinctive profile, somewhat higher position, and better drainage. In a few bodies on the upper part of the ridges or mounds, this soil grades into a light-brown nonsaline soil, which is mapped as Oakley sand where the bodies are large enough to justify separation.

Piper fine sandy loam is pervious and loose and, except in the thin surficial layer, has a relatively low water-holding capacity. Its high content of soluble salts ("alkali") narrowly limits its agricultural value. Pasture is its chief use, although a small part has at times been planted to barley, low yields of which are obtained. The uneven configuration and the smallness of the individual bodies make irrigation infeasible; but it is doubtful whether the concentration of salts could be reduced for profitable production of crops, even if an ample and satisfactory supply of water could be secured.

Piper-Egbert complex.—Treated collectively under this designation are numerous undifferentiated bodies of the Piper and Egbert soils. These bodies not only are too small to show individually on the scale of mapping used but are separated by comparatively wide transitional zones.

Where typically developed, the Piper soil of this complex has essentially the same profile characteristics as those of Piper fine sandy loam. It generally occupies slightly smaller and lower elevations than typical Piper fine sandy loam, has less well developed drainage, and has a somewhat thicker surface layer. In the aggregate, the relatively typical Piper soil constitutes only about one-fourth of the total area of this complex. In the Egbert soil of this complex the depth to the underlying mineral substratum is less than in typical Egbert muck, generally ranging from 3 to 8 feet or more. Marked variations in depth occur within short distances, owing to the very irregular configuration of the underlying mineral deposit. Relatively typical Egbert soils constitute another one-fourth of the total area mapped under this collective designation.

The remaining area mapped consists of various transitions between the Egbert and Piper soils. Except for variations introduced by the uneven mineral base, these transitions grade from typical Egbert muck through a more and more shallow development of the upper organic mantle. As this becomes less than 24 inches thick, an ill-defined mottling and small root holes appear in the upper few inches of the mineral substratum. With continued thinning of the organic mantle, the stained, coated vertical root holes become more numerous, and the surface layer gains in mineral material. The entire sequence between the Egbert and Piper soils suggests the series of stages in soil development and the progressive alterations of the organic soil material, as these are believed to intervene between the typical soils of these two series.

Bodies of the Piper-Egbert complex are associated with typical bodies of Piper fine sandy loam on the Bethel Tract and on Jersey Island. Irregularity of drainage, depth to mineral substratum, and content of soluble salts impose definite limitations on the utilization of these complex soils for agricultural purposes. Although some bodies of the more typical Egbert soil possess certain qualities that make them ideal for crop production, their limited extent and their proximity to other unsuitable soils make extensive farming operations impracticable. Only about 10 percent of the total acreage is planted to crops, chiefly barley for hay or grain; the rest either is utilized for the grazing it affords or remains idle.

RYDE SERIES

The Ryde soils—represented in the delta area by three types and two phases—differ materially from all the aforementioned soils. In character of parent materials and profile development they are related to the Egbert soils and to the organic soils having an admixture of mineral soil material. They are formed bv slowly accumulated remains of reeds, sedges, and, to less extent, herbaceous and woody hydrophytes. Comparatively large quantities of fine-textured mineral sediments are present, either thoroughly mixed with the organic remains or in thin lenses and layers separating more highly organic strata. In a few instances the underlying strata are identical with the material of the Egbert soils, the contact between the two indicating a more or less sudden change in the vegetative cover as a result of some comparatively sudden alteration of the environmental conditions.

The soils of the Ryde series are extensive in the delta basin, where, characteristically, they border the small sloughs and waterways or occur at intermediate elevations. Many of the larger and more important bodies occupy positions between bodies of the Egbert and Columbia soils. In places the soils of this series merge into the adjoining soils without definite lines of demarcation; elsewhere the Ryde soils overlie the Egbert along the lower edge of the bodies and are in turn overlain by the Columbia soils along the upper edge, the thinning of the overlying material again making any boundary between the soils of these three series more or less arbitrary.

The typical member of the Ryde series has a surface soil, ranging from 12 to 18 inches in thickness, consisting of gray or light grayish-brown granular to lumpy fine-textured material that has an acid reaction and contains about 30 percent of well-altered organic matter. This grades into an upper subsoil layer of gray soft massive mucky clay loam or clay with similar reaction and content of organic matter. Plant remains, both woody and fibrous, are numerous and range from rich rust brown to charred and carbonized black. At a depth ranging from 20 to 40 inches, the upper part grades into the lower part of the subsoil, which comprises more or less poorly defined layers differing in color and in content of organic matter. The individual layers range from dark-gray slightly matted fibrous peaty material to brownish-gray or light brownish-gray soft massive silty clay or clay. With increased depth the clay strata tend to dominate; at a depth ranging from 8 to 30 feet they merge into the light-gray mineral substratum common to the area as a whole.

The Ryde soils are relatively loose and permeable, have a high water-holding capacity, and are well suited to the growing of a wide range of field crops. Barley, sugar beets, and asparagus produce highly satisfactory yields.

As mapped in the delta area, the series includes certain bodies of soils that have little or no agricultural value and on which even the more hardy crops seldom produce more than light yields.[19] These bodies occur in the southeastern part of the area, especially on Bacon

[19] The reason for this was sought during the survey, but no recognizable feature of these bodies could be consistently correlated with plant failure. The cause of this lower fertility should be studied further, and, if it is found, it would constitute a basis for differentiation from the typically productive soils of the Ryde series.

Island and the McDonald Tract, where they wind as a narrow and low slough ridge across the central part of the cultivated area. Owing to their slightly higher elevation, they are, for the most part, well drained. A few of them support small orchards of struggling and nonthrifty pears and cherries. The reaction in these peculiarly unproductive inclusions is somewhat more acid than in the typical Ryde soil; in some instances they have a pH value as low as 4.5.

Ryde clay loam.—Ryde clay loam has a profile typical of the Ryde series but includes areas of darker color, which are similar to and represent a transition to the related Egbert soils. The 15-inch surface soil is gray granular to faintly cloddy clay loam having a pH value of 5.5 to 6.0 and containing about 30 percent of well-altered and finely divided organic matter with an admixture of alluvial mineral soil. This material grades into a subsoil that is similar but has a somewhat firmer and more massive quality and a lower organic-matter content. Although the numerous fragments of roots and stems of reeds and small sedges, which compose the organic matter in the subsoil, retain recognizable morphological features, they have undergone considerable alteration and have stained and mottled the adjacent mineral material to a marked degree. The upper part of the subsoil has a pH value of about 5.0 to 5.5 and an organic-matter content generally less than 20 percent. The lower part of the subsoil, extending from a depth of about 36 inches to about 100 inches, includes in places variously thick layers of dark-gray or dark brownish-gray softly fibrous peaty material. These peaty layers become thinner and less numerous with increased depth, giving way to thickening strata of the light brownish-gray finely divided organic and mineral clays. Below a depth of about 9 feet these mineral strata become the dominant feature and are separated from one another by almost paper-thin sheets of tan or light straw-colored fragments of reeds and sedges. The mineral material has an organic-matter content of about 15 percent and a pH value slightly below 6.0. The thin laminae of plant remains are almost wholly organic and highly acid (with a pH value as low as 4.0). In a few instances the gray underlying mineral base is as much as 30 feet below the surface; it approaches neutral in reaction and has only a negligible content of organic matter.

Ryde clay loam is the most extensive Ryde soil mapped. Fairly large bodies are in the northern part of the area, particularly on Ryer, Grand, Andrus, and Tyler Islands, where this soil is typically associated with the Egbert and Columbia soils. All these soils have a moderately high water-holding capacity, are loose and permeable, and, with a few exceptions, have a smooth almost flat surface. Although the Ryde soils, like the Egbert and related soils, have a relatively high water table under natural circumstances, artificial drainage has been established throughout the greater part of their area, and they are now almost entirely under cultivation. Good yields of many different crops are produced on Ryde clay loam, among which the more important are asparagus (pl. 2, *A*), sugar beets, seed crops, corn, grain sorghum (pl. 2, *B*), and small grains. As mapped in the southern part of the area, Ryde clay loam includes an inextensive nonproductive variation. This inclusion occupies the small, meandering ridges and has a limited supply of moisture, a high content of salts, and a decidedly more acid reaction than the typical soil. Crops planted on adjacent soils ordinarily cease abruptly at its boundary.

As mapped in this survey, the clay loam includes a part of Ryde silty clay loam of the Lodi area (*5*), in which only the silty clay loam type was recognized. Areas of Egbert clay loam, light-colored phase, as recognized in the Suisun area (*2*), are now recognized as conforming to the Ryde soils and are included with Ryde clay loam of the Sacramento-San Joaquin delta area.

Ryde clay loam, shallow phase.—This soil differs from typical Ryde clay loam in the presence of a highly organic subsoil that is markedly similar to the horizontal-lying materials of the Egbert and the Staten soils. The surface soil consists of gray faintly lumpy clay loam with a pH value of about 5.5 and an organic-matter content of about 30 percent. In places this material grades, at a depth ranging from 12 to 18 inches, into an upper subsoil layer of gray slightly firmer peaty clay loam having a comparatively high content of distinguishable plant fragments. Elsewhere the surface soil immediately overlies the characteristic organic subsoil at a depth ranging from 15 to 50 inches. This subsoil layer comprises lenses and layers consisting principally of dark-gray soft permeable well-altered organic material containing appreciable quantities of brown or light-brown fibers of reeds and associated plants. In a very few places this organic subsoil contains moderately thick layers of dark-brown highly fibrous and matted peat, which, in turn, contains only very small quantities of dark-gray highly altered material. The organic-matter content of the subsoil approximates 60 percent in such places, although in general it is only about 40 percent. The pH value ranges from 5.5 to 6.0.

Ryde clay loam, shallow phase, occurs mostly in the southeastern and west-central parts of the delta area. It generally borders typical Ryde clay loam on the lower side and represents an overlay of the Ryde material over materials of the Egbert or Staten soils. Owing to the organic subsoil, this shallow soil generally is more permeable than typical Ryde clay loam, has a higher water-holding capacity, and is somewhat better suited to a wide range of the more intensively grown field crops, including potatoes, onions, and sunflowers, as well as sugar beets, asparagus, corn, and small grains.

Ryde silty clay.—Ryde silty clay consists of a comparatively recent overwash of mineral alluvium resting on a thin layer of notably altered organic matter. The proportions of mineral and organic matter vary from place to place, but the mineral component predominates in most places. On the whole, however, the dominant and most conspicuous feature is the buried organic layer.

Typically, this soil includes a layer of surface material about 12 inches thick, consisting of grayish-brown or light reddish-brown lumpy or cloddy silty clay that is slightly stained and mottled with yellow and rust brown. In the areas where this layer is thicker (it has a maximum thickness of some 30 inches), it becomes lighter in color and more highly mottled with light-gray, yellow, and rust-brown stains. It rests abruptly on dark-gray or black firm but permeable faintly granular well-decomposed mucky material containing a few fibrous remains of plant fragments. In few places more than

12 inches and most commonly about 8 inches thick, this buried layer grades into brownish-gray mottled stained firm clay with a high organic-matter content. This, in turn, grades, at a depth ranging from 24 to 48 inches, into gray less mottled dense clay and ultimately into the characteristic underlying light-gray mineral substratum.

Most areas of this soil lie on each side of the Calaveras River, in the Smith and Sargent-Barnhart Tracts. None of the soil in the Smith Tract is utilized for crop production, as this tract is the site of a recent suburban expansion of the city of Stockton, the western part being occupied by a golf course and the eastern part by residential subdivisions. In the Sargent-Barnhart Tract, however, it is devoted wholly to agricultural pursuits. It is planted chiefly to corn, beans, alfalfa, and asparagus. Smaller, more poorly drained areas northeast of Holt are used mainly for pasture.

The mineral surface soil is moderately impervious, owing to its fine texture, firmness, and density. In contrast, the organic layer is extremely permeable, and lateral movement of water, particularly from the deeper ditches along the river bank, is free. A large part of the soil is irrigated by taking advantage of this circumstance; a small acreage at the western edge of the body is irrigated by spud ditches, and some of the soil at the eastern edge receives surface irrigation as on the adjacent mineral soils of the lower valley plain.

Ryde silty clay loam.—The profile of Ryde silty clay loam is typical of the soils of the Ryde series, but like Ryde clay loam it includes areas of darker colored more highly organic material, which is transitional toward the Egbert soils. The only important difference between the silty clay loam and the clay loam members is one of more silty texture. The 15-inch surface soil is gray or somewhat light gray granular to lumpy silty clay loam having a pH value of about 5.5 and an organic-matter content of about 30 percent. The organic matter is finely divided and noticeably altered. The surface soil grades into a somewhat firmer more massive subsoil containing numerous moderately altered, yet identifiable, plant fragments; otherwise these two layers are similar. The upper part of the subsoil is slightly mottled and stained with light gray, yellow, and rust brown and with almost black alteration products. The lower part, which extends from a depth of about 30 inches to a depth of slightly more than 50 inches, comprises strata of dark-gray softly fibrous peaty materials and strata of light brownish-gray finely divided organic and mineral clays. With increasing depth the former strata decrease in importance and magnitude, and below a depth of about 100 inches the clayey strata predominate. In these deeper parts the thinning laminae of organic material consist of light-colored softly fragmental pieces of reeds and sedges. The several component strata in the subsoil have approximately the same pH value and the same content of organic matter as the corresponding strata in the clay loam member of the Ryde series.

Small and large bodies of Ryde silty clay loam are scattered throughout the delta area. Most of the larger bodies are in the northern part, between bodies of either Columbia or Sacramento soils on the one hand and the Ryde or Egbert soils on the other. These bodies are comparatively smooth, almost flat, and only slightly higher than the interior parts of the island or tract. They are capable of being irrigated by the usual systems of spud ditches and are devoted largely to the production of the same crops as are grown on the Egbert soils. Beans, sugar beets, and seed crops are well adapted to Ryde silty clay loam, although large acreages are utilized for asparagus, potatoes, onions, and even for small and less satisfactory plantings of celery.

The smaller bodies predominate in the southern part, where they commonly occupy narrow winding ridges of former open sloughs. In the latter situations a nonagricultural variant of the soil occurs. Owing to their slightly higher elevation, all these narrow bodies are well drained, compared with adjacent areas of Egbert soils. They are irrigated with difficulty and are generally devoted to the production of such nonirrigated crops as the small grains, including milo.

Ryde silty clay loam, shallow phase.—The shallow phase of Ryde silty clay loam differs from typical Ryde silty clay loam in having a more highly organic lower subsoil layer, comparable to the material of the Egbert or Staten soils. This soil has a typical surface soil, consisting of a gray or gray-brown faintly lumpy to cloddy silty clay loam having a pH value of about 5.5 and an organic-matter content slightly less than 30 percent. An upper subsoil layer is present in places at a depth of about 15 inches. This consists of gray silty clay loam or silty clay, that has a moderately high content of recognizable plant remains and slight mottles of rust brown and yellowish brown and is slightly more firm and dense than the surface soil. At a depth ranging from 15 to 50 inches and averaging about 24 inches the upper subsoil layer or the surface soil rests on the characteristic definitely organic subsoil. This layer is made up of varying layers and lenses of dark-gray well-altered organic material containing appreciable quantities of light-brown plant fragments and dark-brown fibrous and matted peat. The altered organic material is the more common, and normally it has an organic content of about 50 percent, with the pH value ranging from 5.5 to 6.0. The light-gray mineral substratum lies at a varying depth.

Ryde silty clay loam, shallow phase, is mapped largely in the more northern part of the delta area. It is closely associated with typical Ryde silty clay loam and generally represents the contact or transitional zone between that soil and the adjacent Egbert or Staten soils. Owing to its more highly organic character and its consequently higher water-holding capacity and permeability, this soil is somewhat better suited to many of the more intensively grown field crops than is typical Ryde silty clay loam. Except for a slight tendency to puddle and become cloddy, which necessitates greater attention to bring it into satisfactory tilth, the shallower soil is as well suited as Egbert muck for the production of such crops as potatoes, corn, and onions and is wholly satisfactory for the production of less-demanding crops, such as asparagus, sugar beets, and small grains.

SACRAMENTO SERIES

Members of the Sacramento series are essentially mineral in character, although they have a moderately high content of thoroughly altered and incorporated organic matter. They are developed on alluvial sediments occurring in basinlike depressions abutting the alluvial ridges of the major streams. They exhibit an immature but moderately developed profile, which is largely obscured by the frequent surficial additions of new alluvium that continued until stopped by fairly recent reclamation of the land.

Although the Sacramento soils occur in comparatively large bodies along the northern and eastern boundaries of the area, they are not peculiar to the delta area as are the soils previously described. They occupy far more extensive bodies along the Sacramento River north of this area. Typically, they have a 12- to 18-inch surface soil consisting of gray or rather dark gray lumpy or cloddy fine-textured mineral material that contains about 10 percent of well-decomposed organic matter. This layer normally has a pH value of about 7.0 (neutral). In places, more or less altered fragments of contemporary vegetation are present and slight rust-brown mottles stain the root holes. This material grades into an upper subsoil layer of slightly lighter colored, less organic, somewhat more clayey, and more dense material. It has a neutral to very slightly alkaline reaction. The lower part of the subsoil, between depths of 30 and 50 inches, is dull-gray or rather bluish gray silty clay or clay, which is more or less dense and massive. In places, lime occurs in disseminated form, and a few soft calcareous concretionary accumulations are present.

In most places in the delta area, the Sacramento soils contain slightly more organic matter, show a more acid reaction throughout, and include fewer accumulations of lime in the lower part of the subsoil than the Sacramento soils mapped elsewhere in California. The somewhat higher organic-matter content makes for a better condition of tilth and a higher water-holding capacity than are typical. From the point of view of agricultural utilization, these soils approach the quality of the Ryde soils. Highly satisfactory yields of sugar beets, small grains, and other field crops are produced.

Sacramento loam.—Sacramento loam has a more alkaline reaction throughout than is characteristic of the other Sacramento soils as developed in this area, and in this respect it more closely approximates the typical Sacramento soils developed outside the area. The surface soil is about 12 inches thick and consists of dark-gray rather loose granular loam having a comparatively high content of very fine sand. Some roots and fragments of contemporary vegetation are present, mottles are very faint, and the reaction is neutral. In a few places, the content of calcium carbonate is sufficient to produce effervescence in dilute hydrochloric acid. The surface soil grades almost imperceptibly into an upper subsoil layer of dull-gray very slightly compact loam or clay loam having a somewhat more pronounced mottling of rust-brown and yellowish-brown stains. At a depth ranging from 24 to 50 inches this material, in turn, grades into a lower subsoil layer that is lighter gray or more brownish gray, is less dense and compact, and, here and there, contains visible lime accumulations. This material has a definitely alkaline reaction, a pH value of 8.0 or more, and it grades more or less abruptly into the light-gray massive mineral substratum, which generally is calcareous.

Sacramento loam is mapped only in the northeastern part of the delta area. It merges along its lower boundary with the finer textured soils of the same series. Although the greater part of the soil is utilized for the production of field crops, especially alfalfa and sugar beets, comparatively large acreages are planted to beans, seed crops, and orchard fruits. Tree fruits—chiefly Bartlett pears—are planted on the less alkaline areas, and even on such areas they are seldom so satisfactory as those on the nearby bodies of Columbia soils.

Two small bodies are in the Newhope District, north of Beaver Slough. These are characterized by a decidedly sandy and permeable subsoil containing variable quantities of fine mica particles. These two bodies occupy minor ridges above the general elevation of adjoining soils and appear to represent a former location of the Mokelumne River channel. The difficulty of irrigating them adequately, together with their low water-holding capacity, restricts their utilization to the production of winter-grown grains. Even for this purpose they are somewhat less well suited than are the heavier members of the Sacramento series.

Sacramento mucky loam.—Sacramento mucky loam has a surface soil of dark-gray or dark brownish-gray smooth fine-textured mucky loam that has a high organic-matter content and includes fragments of partly decayed vegetable matter. It overlies a somewhat more compact, heavier textured, and less organic dull brownish-gray or bluish-gray subsoil. Calcium carbonate occurs in nodular accumulations and in disseminated form in the lower part of the subsoil, which also includes in many places conspicuous crystals and segregations of gypsum. Rust-brown and gray mottlings are present in this layer.

The surface soil is granular, friable, and easily tilled. The subsoil material is somewhat grayer than in the other soils of the Sacramento series and contains a comparatively large quantity of lime. It is readily permeable and has a high water-holding capacity. The water table stands within a few feet of the surface, and under natural conditions, drainage is impaired. When drained and protected from overflow, the soil is productive and is utilized mainly for the production of asparagus and other special crops. Alfalfa is grown to some extent, but the soil is not well suited for this crop, as the inadequate internal drainage is unfavorable for the deeper rooted plants.

Sacramento clay loam.—Sacramento clay loam is the most extensive and most widely distributed soil of the Sacramento series in the delta area. It is somewhat more acid and has a slightly higher content of organic matter, compared with typical Sacramento soils. The surface soil, which extends to a depth of 12 to 18 inches, consists of dark-gray loose faintly lumpy clay loam having a pH value of about 5.5 to 6.0 and containing about 10 percent of thoroughly altered organic matter. This grades into very slightly compact somewhat massive heavy clay loam, marked with rust-brown and yellowish-brown stains along the root channels and crevices. At a depth ranging from 30 to 50 inches this material grades, in turn, into a lower subsoil layer having a slightly lighter gray color, a looser and more permeable structure, and about a clay loam texture. The material in the lower subsoil layer, like that above, is noncalcareous and is marked by blotches and spots of rust brown and light gray, indicative of decidedly imperfect drainage conditions. In a few places the lower part of the subsoil includes one or more relatively thin layers of dark-gray softly fibrous organic loam, approaching in character the subsoil material in the Egbert and Ryde soils. With increasing depth the material in the lower horizon gradually becomes lighter gray and merges with the underlying mineral substratum at a depth ranging from 5 to 10 feet.

Sacramento clay loam occurs in large and small bodies, widely distributed throughout the delta area. More than half the total area is in the northern part, between the vicinity of Clarksburg, and southward to Cache Slough. These bodies occupy flat parts of the interfluvial islands and are associated with areas of Columbia silty clay loam and Sacramento loam along their upper margins, and along their lower limits they grade into areas either of the more highly organic Egbert soils or of the finer textured members of the Sacramento series. The smooth configuration, fairly satisfactory tilth, and normally high water table make this soil well suited to a wide range of field crops, including asparagus, sugar beets, alfalfa, and small grains. A narrow interrupted strip of this soil extends along the northeastern boundary of the area, particularly from Steamboat Slough to a point north of Beaver Slough in the Newhope District. Along the eastern and higher margin the soil grades into the poorly drained mineral soils of the Stockton and Merced series. Along the western boundary it grades into the more highly organic Egbert and Ryde soils. The gradation between these two extremes is reflected in the fact that the more eastern part of the body is devoted to the production of grain and pasture, and the more western part is planted to crops more characteristic of the organic soils, such as sugar beets, asparagus, and small grains.

In the southern extremity of the delta area, from Rough and Ready Island to Roberts and Union Islands, several large bodies of Sacramento clay loam aggregate nearly 4,000 acres. These are associated with equally extensive bodies of Egbert muck, burned phase, and Burns clay loam, into which they merge along their boundaries. In this section barley is probably the chief crop, although comparatively large acreages of alfalfa, milo, and corn are producing satisfactory yields. Dairying, as a result, has become an important enterprise on these bodies.

Sacramento silty clay loam.—Sacramento silty clay loam occupies flat shallow basinlike areas only slightly above and in places slightly below sea level.

The surface soil is dull dark brownish-gray silty clay loam, somewhat plastic when wet, although it breaks up under cultivation into a friable and granular structure more characteristic of soils of lighter texture. It is underlain at a depth ranging from 6 to 18 inches by lighter brownish gray somewhat more compact silty clay loam, clay loam, or clay. Both surface soil and subsoil are mottled with rust-brown and yellow iron stains, especially along root channels and in other openings. The lower part of the subsoil contains irregular seams and mottlings of accumulated lime, and at an average depth of about 48 inches it rests on a lighter brownish gray or dark bluish-gray substratum of calcareous clay loam or clay.

A comparatively high organic-matter content contributes to the friable structure. Under natural conditions drainage is inadequate, but where drained and protected from overflow the soil is well suited to the production of field and intensively grown special crops of the delta area. Sugar beets, onions, beans, and asparagus yield well, and barley and other small grains grow successfully.

Sacramento adobe clay.—Sacramento adobe clay, like Sacramento clay loam, is slightly more acid and has a somewhat higher content of organic matter than the typical Sacramento soils mapped elsewhere. The 12-inch surface soil is dark-gray or dark slightly brownish gray loosely granular to cloddy clay. The pH value is about 6.5. This material contains much silt and about 10 percent of organic matter thoroughly admixed and incorporated with the mineral matter. When wet it is plastic, and when dry it develops a characteristic adobe or adobelike structure, as it shrinks, checks, and forms large irregular blocks that are further reduced by secondary checks to small irregular fragments and granular segregations. Stains on the root walls and crevices are more pronounced and definite than in the coarser textured members of this series. The surface soil grades into an upper subsoil layer of slightly heavier textured, lighter gray, and somewhat more compact and dense material. This extends to a depth ranging from 30 to 60 inches and grades into somewhat bluish gray massive silty clay, which, in a few places, contains disseminated lime and small soft concretions.

A large part of Sacramento adobe clay occurs in association with soils of several other series of mineral soils along the western boundary of the delta area. Southward from the Hotchkiss Tract a narrow and intermittent band of Sacramento adobe clay lies between large areas of Egbert muck and the more mineral soils of the lower valley plain, of which Marcuse clay is the most extensive. Most of the soil in this vicinity is utilized for pasturing livestock. Barley and milo are important crops on the few cultivated areas, except that a few of the small areas along the eastern boundaries where Sacramento adobe clay merges into the Egbert soil and where the organic-matter content is slightly higher than elsewhere are planted to asparagus. The yields are somewhat lower than on the more organic soils to the east, and the plantings of asparagus can hardly be called successful.

COLUMBIA SERIES

The Columbia series—represented in the delta area by four soil types—consists of noncalcareous mineral soils of recent alluvial accumulation. Typically, these soils occupy slightly elevated alluvial ridges along the more important waterways, receiving at every overflow of the stream fresh increments of material derived from a wide variety of sources. A conspicuous feature of this material is the small but characteristic quantity of finely divided mica, indicative of a granitic source, which suggests a relationship between this material and the light-gray underlying mineral substratum of the delta proper. The deeper and more typical areas of the Columbia soils border the riverbank; with increasing distance from the stream the sloping surface tends to flatten, drainage becomes poorer, and the soil profile approaches in character that of the lower lying bodies of the Ryde and other more organic soils.

The surface soil of a typical Columbia soil consists of a light grayish-brown, in places distinctly buff, fine-textured mineral deposit and is highly mottled with streaks and blotches of rust brown, yellow, and light gray. The lighter textured soils are loose and permeable; the heavier textured soils are more compact. The reaction is neutral to slightly acid, and the content of organic matter is low—about 3 percent. Without definite demarcation, this material, at a depth of about 20 inches, grades into the subsoil, which is more or less stratified as to texture, slightly lighter in color, and somewhat more highly mottled but otherwise is essentially similar. With increasing depth, mottles become few and a light-gray color becomes dominant until the light-gray mineral substratum is reached at a depth ranging from 70 to 120 inches below the surface.

In addition to naturally formed alluvial ridges, the Columbia soils, as mapped in this and other soil surveys, occupy some areas that have resulted largely through man's disturbance of a natural equilibrium along the streams. When high water ruptured the man-made levees, the floodwaters carried in and deposited stream alluvium over extensive areas of the lower lying interfluvial lands. Comprising materials from both the natural alluvial-built ridge itself and the outer stream bottom, the resultant deposit generally represents a comparatively thin layer of Columbia material spread over the buried soil. These inclusions have all the essential features of normal Columbia soils, except for shallowness and a slightly less pronounced mottling. At present no good basis exists for separating them from the typical Columbia soils, particularly where they merge into one another and have an involved and uncertain history.

Under natural circumstances the Columbia soils support an open growth of willows and cottonwood together with a ground cover of shrubs, grasses, and herbaceous annuals. Despite the evidence of poor drainage in the mottled character of these soils, their slightly higher position and generally sloping surface promote a better water relation than characterizes the soils in interior sections of the interfluvial units. Alfalfa, seed crops, pear orchards, and a wide variety of other intensive crops grow on the Columbia soils of the delta area. Farmers in this area especially prize these soils for producing pears.

Columbia sandy loam.—The surface soil of Columbia sandy loam consists of light-brown loose very faintly aggregated sandy loam that varies markedly from place to place in its content of coarse sand particles. Except for a few roots and fragments of contemporary vegetation, the content of organic matter is negligible. The reaction in most places is neutral. At a depth ranging from 15 to 30 inches the surface soil grades imperceptibly into a subsoil of similar material faintly mottled with rich brown, yellow, and light gray. In most places the subsoil rests abruptly on dark-gray highly organic material that represents the surface soil of a buried Ryde or Egbert soil.

Columbia sandy loam covers a small total area, and by far the larger part of it originates through alluvial deposits following the breaching of the nearby levee. Specific dates of origin can be definitely assigned to many areas. For example, the body centrally situated in the western part of Brannan Island was built up after the breaching of the Sacramento River levee during the high water of March 1907. Similarly, the body on Sherman Island had its origin in the levee failure of 1889, and that on Bouldin Island in the disaster of March 1904.

The low water-holding capacity of Columbia sandy loam and its generally slightly higher position above extensive adjoining soils limit its agricultural value. A large part of the land is under cultivation, however, and the areas of shallower soil, where the buried organic material provides the major zone of root activity, are planted principally to barley, alfalfa, and asparagus. A brushy growth of willows and weeds covers some of the land, which is essentially wasteland, although it provides some poor pasturage.

Columbia loam.—The 10- to 14-inch surface soil of Columbia loam is friable granular loam mottled with brown and yellow iron stains. This is underlain by a subsoil composed of stratified medium to fine sandy materials that are permeable and moderately to highly mottled with iron stains. Roots and moisture penetrate the soil. Drainage is favorable where the soil adjoins stream channels, but in lower lying, flatter areas where the surface material has been superimposed over darker colored organic soils a high water table limits development of the deeper rooting plants.

This soil is very inextensive but is mainly under cultivation and is utilized for alfalfa, asparagus, milo, beans, vegetables, and grain crops. Alfalfa is reported to yield about 5 tons an acre, and yields of other crops are good.

Columbia silty clay loam.—Columbia silty clay loam is the most extensive and most widely distributed member of the Columbia series. It has a profile typical of the Columbia soils. The surface soil is light-brown or buff friable to faintly cloddy silty clay loam. The material in this layer is neutral in reaction, contains less than 5 percent of organic matter, and is slightly mottled in its lower part with rust-brown and yellow stains. It grades imperceptibly at a depth ranging from 12 to 20 inches into an upper subsoil layer of light-brown firm to massive more highly mottled material having about the same characteristics as the surface material. This layer grades, in turn, into a lower subsoil layer, or substratum, that is more gray and very little mottled. Below this is the light-gray massive mineral material.

Most of the larger bodies of this soil are in the central and more northern parts of the area, particularly along the main channels and distributaries of the Sacramento and Mokelumne Rivers, and several small bodies are contiguous to the San Joaquin River and its distributaries. With the exception of those areas adjoining the Sacramento River in the extreme northern end of the area, the various bodies of Columbia silty clay loam grade into slightly lower lying bodies of the Egbert and Ryde soils. In places, particularly along the lower margins of the bodies, the soil is comparatively thin and rests at a depth of 3 feet or less on the buried material of either the Egbert or the Ryde soils.

This soil is permeable, has a moderately high water-holding capacity, and may be readily put in a good condition of tilth. A small part of it is planted to barley and other small grains, yields of which are highly satisfactory. The greater part of the land—practically all of the northern areas—is set out to orchards of pears, plums, peaches, cherries, and other fruits or is utilized for the production of beans, truck crops, and vegetable seed. The soil seems to be excellently suited for the latter uses, owing to the ease with which an almost perfect seedbed can be prepared.

As recognized in this survey, Columbia silty clay loam includes a small part of the soil mapped as Columbia very fine sandy loam of the Lodi area (*5*). Only the very fine sandy loam was recognized in that survey, and the soil grades into silty clay loam in the vicinity of the boundaries of the two areas.

Columbia silty clay.—The 15-inch surface soil of Columbia silty clay consists of light-brown or reddish-buff softly firm to cloddy silty clay. In a few places the undisturbed immediate surface material has a definitely gray cast, although the prevailing color is light brown. This material has a low content of organic matter and is neutral in reaction. Many very fine root holes and crevices thread the material. These are stained and coated with rust brown and yellow, especially in the lower part. The surface soil grades into a lower layer of light-brown or light grayish-brown rather dense massive silty clay or clay, which is even more highly mottled than the surface material. In turn, this grades almost imperceptibly through a lower subsoil layer of intermediate material into the light-gray mineral substratum.

Columbia silty clay is mapped mainly in the west-central and north-central parts of the area. More than one-half of the total acreage occurs on Sherman Island. Here, the soil is comparatively shallow and rests, at a depth ranging from 15 inches to about 40 inches, on the slightly fibrous and highly organic surface material of the Egbert soils. It represents a comparatively recent overwash, and much of it is probably related to the inundations during the earlier days of reclamation. Practically all of the bodies on Sherman Island are under cultivation and are almost exclusively planted to asparagus, a crop especially well suited to this shallow soil. About 1,000 acres of Columbia silty clay occur on Brannan Island, and here the soil ranges from about 40 inches to more than 10 feet in depth. Many different crops are grown on these bodies—tree fruits on the slightly higher situations along the river, alfalfa and barley on intermediate slopes, and asparagus and sugar beets on the lower lying and more shallow soil. Small areas are on Roberts and Medford Islands and elsewhere; these are variously used and commonly represent narrow tongues bordering the more important channels.

MISCELLANEOUS LAND TYPE

Made land.—As mapped in the delta area, made land comprises the several comparatively large areas of soil resulting from the operations of hydraulic dredgers along the channels of the two major rivers. It consists of unassorted deposits, several feet thick, and of river sand, together with an admixture of silt and clay. These have been pumped into certain situations enclosed by levees adjacent to the rivers and normally rise to the height of the encircling levee. In one place, at the southern tip of Brannan Island, a second levee has been built and filled with additional dredger spoil. In addition to the areas along the Sacramento River, from Steamboat Slough downstream, several have been built recently of this material along the course of the new deep-water channel to Stockton. Generally, a dense growth of willows rapidly covers the areas. In some places, however, wind blowing becomes a problem before this cover establishes itself. This condition seems to prevail along the Sacramento River, and it has been necessary to protect the several bodies along that stream with plantings of bunchgrass, set out by hand.

Made land is largely nonagricultural and probably will be utilized principally for grazing purposes. A number of small experimental plantings of truck crops and potatoes have been made on this raw material, with moderate success. New methods and practices will have to be developed, particularly for the control of soil moisture, before the land can be used profitably for cultivated crops.

SOILS OF THE DELTA MARGIN

The irregular boundaries of the delta area include all of the more highly organic soils that are peculiar to this deltaic basin and exclude all but a minimum of the mineral soils that are more characteristic of the adjacent valley plain. The soils of the first group are described in the preceding pages; it now remains to mention the surrounding areas of mineral soils only briefly, as they have already been covered in considerable detail in recent soil surveys (*2*, *3*, *5*), to which the reader is referred for more detailed descriptions.

Oakley sand.—Oakley sand (*3*) is a noncalcareous soil formed of material transported and modified by wind action, and it has the characteristic configuration of aeolian deposits. There is no evidence of the development of a profile. The soil consists throughout of light-brown loose to slightly firm somewhat loamy sand. Small bodies border the southern margin of the western apex of the delta area, where they have largely been brought under cultivation. Plantings of almonds and grapes predominate.

Montezuma adobe clay.—Montezuma adobe clay (*3*) is a mineral pedocalic soil having a moderately mature profile and developed on old transported materials. The surface soil of dark-gray or black adobe clay overlies a lighter colored calcareous subsoil. The soil is developed on the firm sediments that gave rise to the Montezuma Hills of the northwest side of the Sacramento River below the town of Rio Vista. This is a soil of small extent and is devoted entirely to the production of small grains, particularly wheat and barley.

Capay silty clay loam.—Capay silty clay loam (*2*) is a mineral pedocalic soil having a moderately well developed profile. It has a dull grayish-brown surface soil and a lighter colored heavier textured slightly calcareous subsoil. It is developed on valley alluvial deposits having their source mainly in sedimentary rocks. A very small body of this soil occupies the low nearly flat basin in the upper part of the Hastings Tract. This area is poorly drained, and most of it is planted to barley.

Lindsey clay loam.—Lindsey clay loam (*2*) is a calcareous mineral soil having a rather strongly developed profile and occurring in low alluvial basinlike areas with restricted drainage. Its dull-gray surface soil rests on a lighter colored heavier textured calcareous subsoil that contains some lime concretions in the lower part. Several very small bodies occur in the delta area, along the western boundary northward from Rio Vista. These have moderate to high contents of salts and are used for the limited grazing they afford.

Antioch fine sandy loam.—Antioch fine sandy loam (*2*) is a pedocalic mineral soil having a pronounced solonetzlike profile and developed on slightly elevated alluvial plain and terrace materials. A light-brown sandy loam surface soil rests abruptly on a dense columnar clay horizon that is slightly calcareous in its lower part. Three or four very small bodies of this soil are in the vicinity and north of Rio Vista. They are valuable chiefly for the grazing they afford, although in some seasons they are planted to barley or wheat.

Stockton adobe clay.—Stockton adobe clay (*2*, *5*) is a pedocalic mineral soil developed on the lower almost flat part of the valley plain. Drainage is poor, and the dark-gray or black adobe clay material rests, at a depth of about 3 feet, on a comparatively impervious substratum. The lower part of the subsoil, at the point of contact with the substratum, generally is marked by intermittent plates of lime hardpan. A few small bodies border the northwestern boundary of the delta area, and larger ones border the eastern boundary, north of Stockton. Some of the less poorly drained areas are planted to barley with fair success; the greater part of the land is utilized, however, for the grazing it affords.

Stockton clay loam.—Stockton clay loam (*5*) occurs in the eastern part of the delta area, where it joins the Stockton soils of the Lodi area. Compared with Stockton adobe clay, it occupies slightly more elevated ridges or areas, has a little better developed drainage, and generally lacks lenses or plates of lime cementations in the subsoil. The surface soil is dark-gray or black cloddy clay loam, underlain at a depth ranging from 6 to 12 inches by dark cloddy clay loam or clay. This grades into dull-gray material containing soft concretions and accumulations of lime. The soil is shallow, is imperfectly drained, and is best utilized for small grains and pasture.

Merced sandy loam.—Merced sandy loam (*5*) is a mineral pedocalic soil having a fairly strong development of a profile. It occurs on the nearly flat lower parts of the valley plain in association with Stockton adobe clay. The dark-gray sandy loam surface soil has an alkaline reaction and rests at a depth of 24 inches or less on a subsoil layer or substratum of massive moderately firm slightly finer textured material containing concentrations of lime carbonate. Several small bodies are along the eastern boundary, from the Shima Tract northward. Drainage is poor, and salts have accumulated in injurious quantities. The land is used chiefly for grazing.

A few very small areas of a lighter colored soil are included in mapping. These were recognized in the adjoining Lodi area (*5*) as Merced sandy loam, light-colored phase. Another inclusion joins with Hanford sandy loam, calcareous-subsoil phase of the Lodi area, into which it grades.

Zamora loam.—Zamora loam (*3*) is a mineral noncalcareous soil. It has a youthful to immature profile and is developed on old alluvial materials of the lower parts of slightly sloping alluvial plains and fans. The dull-brown surface soil rests on a darker colored, more compact, and heavier textured upper subsoil layer. This grades into a light-brown firm relatively pervious lower subsoil layer. The material is noncalcareous throughout. One very small body is situated northwest of Werner, and two are in the extreme western part of the area. The latter two are planted in part to barley and in part are used by a commercial gun club. The first-mentioned body is planted to an orchard, which is a part of a much larger planting of trees on a slightly higher soil.

Alviso clay.—A few small bodies of the highly saline recent littoral deposit designated as Alviso clay (*3*) occur along the south shore line of the San Joaquin River east of Antioch. These are little more than salt or brackish marshes supporting a cover of pickleweed (*Salicornia* sp.) and saltgrass, and they are entirely nonagricultural.

Marcuse clay.—Marcuse clay (*3*) is a calcareous mineral soil having a weakly to moderately well developed profile. It occurs in the lower and more nearly flat part of the valley plain. Within the delta area it occupies long irregular narrow strips bordering the western boundary from the Byron Tract northward to the Hotchkiss Tract. It has a dull-gray heavy clay surface soil resting on a comparatively permeable although slightly heavier textured subsoil. The subsoil is highly calcareous, as is the surface soil in a few instances, and the whole soil is subject to injurious concentrations of saline salts. For this reason, and also on account of its imperfect drainage, Marcuse clay has low agricultural value and is used chiefly for the grazing of livestock.

Rincon clay loam.—Rincon clay loam (*3*) is a mineral pedocalic soil having a moderately developed profile and occurring on the lower parts of alluvial fans and piedmont plains. The surface soil is brown or rather dark brown slightly cloddy clay loam, which rests on a slightly more dense and heavier textured subsoil. Lime occurs in the lower part of the subsoil in disseminated and soft concretionary form. Two small bodies border the western boundary of the delta area west of Werner. They are planted largely to barley or are devoted to grazing.

Brentwood clay loam.—Brentwood clay loam (*3*) is a mineral soil of pedocalic tendency, having a somewhat weakly to moderately well developed profile. The surface soil is brown or rich brown and rests on a slightly heavier textured richer colored upper subsoil layer. This grades into the lower part of the subsoil, which is lighter colored, more permeable, and, in many places, calcareous, and contains thin seams of calcium carbonate in some places. Only one small body is in the delta area, along the western boundary south of Werner. This soil is associated with Brentwood clay and with the more extensive Marcuse clay. One part of the area joins with an area of Brentwood sandy clay loam in Contra Costa County (*3*), and here the surface soil is somewhat more sandy than elsewhere. Grazing is the only use for this soil.

Brentwood clay.—Brentwood clay (*3*) has a dark-brown silty clay surface soil and a somewhat heavier textured, more dense, and more compact upper subsoil layer, which grades into a lower subsoil layer that is similar, except that it contains rather heavy accumulations of lime. Two small bodies of this soil occur in association with Marcuse clay along the western boundary of the delta area, southwest of Werner. This soil occupies the lower and almost flat part of the nearby valley plain. It is more poorly drained than is typical for the Brentwood soil occurring elsewhere and is used principally for the grazing of livestock. A small acreage is planted to barley in some seasons.

Solano silty clay.—Solano silty clay (*3*) is a mineral pedocalic soil having a strongly developed solonetzlike profile. A gray partly deflocculated surface soil rests abruptly on a subsoil of dark brownish-gray dense columnar clay. This grades into a lower horizon of more permeable, yet massive, material containing both disseminated lime and soft calcareous concretions. One body of Solano silty clay, about 500 acres in extent, borders the boundary in the southwestern corner of the delta area. Its imperfect drainage and content of salts restrict its use to grazing.

Herdlyn loam.—Herdlyn loam (*3*) is a pedocalic mineral soil having an imperfectly developed solonetzlike profile. It consists of light reddish-brown partly deflocculated loam resting abruptly on dull reddish-brown dense clay of columnar structure. This grades into light reddish-brown less compact slightly calcareous material containing some soft calcareous concretions. One very small body of the soil occurs in the southwest corner of the delta area where it merges with the body of Solano silty clay. Like that soil, Herdlyn loam is restricted by impeded drainage and salt content to whatever grazing it affords.

Clear Lake adobe clay.—Clear Lake adobe clay (*3*) is a mineral soil of relatively high organic-matter content, developed on old alluvial materials in low, flat, or shallow basinlike areas where drainage is poorly developed. The surface soil is dull dark brownish-gray or black heavy clay that is plastic when wet and shrinks and cracks when dry, forming a characteristic adobe structure. It is underlain by compact dark-colored material, which becomes lighter brown, dull yellowish brown, or dull gray, mottled with rusty brown in the lower part. This contains lime segregations in the form of thin seams and mottlings. The surface soil is difficult to till except under favorable moisture conditions, when it can be worked into a friable condition with heavy farming machinery. The soil is used in part for pasture and in part is cultivated, mainly to wheat and barley.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of environment acting upon the soil materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by (1) the physical and mineralogical composition of the parent soil material; (2) the climate under which the soil material has accumulated and existed since accumulation; (3) the relief, or lay of the land, which influences the local or internal climate of the soil and its drainage, moisture content, aeration, and susceptibility to erosion; (4) the biologic forces acting upon the soil material; that is, the plants and animals living upon and in it; and (5) the length of time the climatic and biologic forces have acted on the soil material.

The Sacramento-San Joaquin delta area constitutes one of the more distinct elements in the complex physiographic and soil pattern of California. Its peculiar pedologic, physiographic, agronomic, and other features make it definitely unique.

Although the soils differ markedly from other soils in California, most of the soils—especially those having a high content of organic matter—display many common characteristics and bear close relationships to one another. Even the mineral soils, which border the delta proper, have many features in common. All are developed on transported materials of mixed mineralogical composition, and generally have moderately well developed profiles of more or less definite pedocalic tendency. They range from brown to dark gray, with the gray tones predominating. With but few not very significant exceptions, they occupy almost flat basinlike situations on the lower slopes of the encircling valley plain, where they are subject to poor drainage and to injurious concentrations of salts. Collectively, these bodies constitute the broad transitional zone between the better drained mineral soils of the upper valley plain and the wet organic soils of the deltaic basin.

The organic soils bear an even closer relation to one another than do the mineral soils. Four of them at least—possibly six—are derived from the water-saturated mantle of tule-reed peat. This great accumulation of plant remains aggregates about 250,000 acres and extends in a systematically interrupted mantle from its apex at the junction of the Sacramento and San Joaquin Rivers, northward, eastward, and southward. It rests upon a base of light-gray mineral sediments—partly lacustrine and partly alluvial—at a depth ranging from less than 2 feet along the eastern margin to slightly more than 40 feet at its western tip, and averaging about 18 feet.

More than 100 deep samplings have been made in this organic mantle. There is no evidence of buried stream channels, only of infrequent thin strata of mineral material that has been washed in locally on some former land surface. It appears highly probable that all the major streams and most of the minor ones have occupied essentially their present positions during the entire period of organic accumulation. As the mineral base subsided and the organic deposits accumulated, the streams simultaneously built up their bordering alluvial ridges.

These deposits of accumulated plant remains exhibit remarkable uniformity throughout their occurrence; even the differences between the deeper and the shallower accumulations are more dimensional than qualitative. In general, they consist of a comparatively thin surficial layer of tule peat resting on a massive fibrous mat of reed peat, which reaches downward to the mineral base. These deposits have been classified by Dachnowski-Stokes (*6*) as the "San Joaquin fibrous tule-reed peats." The Correra, Venice, and Staten organic soils unquestionably have been formed from this type of material, and it seems probable that the soils of the Egbert, Roberts, Burns, and Piper series have had a similar origin, with an admixture of more or less mineral material. Apparently they have been modified in several ways: (1) By the breaking down of the relatively fine, fibrous, and matted plant remains, which have been changed to more or less carbonized, humified, loose, nonfibrous, crumbly organic material; (2) by subsidence into a denser and more compact condition, especially in the lower part of the subsoil; and (3) by accumulation of salts and lime. The latter is more or less transitory and not uniform. The high moisture-holding capacity of the organic material, its loose and permeable character, and the frequent heavy applications of fertilizer cause marked variations both in hydrogen-ion content and in salinity within short distances and within brief periods of time. Drainage, irrigation, cultivation, and burning have all had modifying influence on these soils, and in many places subsidence has been considerable since the land was reclaimed. Some of the differences in these soils are doubtless due to the character of the vegetation giving rise to the different layers rather than to processes of soil development.

Of the organic soils derived from the tule-reed peat, Correra peat apparently is the least altered. Venice peaty muck consists of a finer textured, apparently partly altered surface soil resting on an essentially unaltered subsoil. Staten peaty muck appears to represent a slightly more advanced stage in decomposition. It has an altered surface soil and a partly altered subsoil. The Egbert soils have a higher proportion of mineral matter than do the Correra, Venice, and Staten soils. They consist of a markedly altered surface soil grading into a slightly more dense and equally altered subsoil, which includes strata of alluvial sediments in places. Roberts muck represents a still more advanced stage in alteration. It has a highly altered and mineralized surface soil, a fairly well developed platy and dense subsoil, and an underlying mineral substratum, into which the soil-forming processes are beginning to penetrate. Burns clay loam is characterized by a thoroughly altered surface soil in which the organic matter has been almost destroyed. This material grades into a distinctly modified subsoil. The Piper soil is similar in profile to the Burns but differs in having a comparatively high content of lime and soluble mineral salts.

Tables 6 and 7 present the results of laboratory determinations of the reaction, the organic-matter content, and the relative quantities of the several soluble salts, as these occur in the several typical major horizons of organic soils.

TABLE 6.—*pH determinations, ignition loss, and content of soluble salts*[1] *of samples of several organic soils in the Sacramento-San Joaquin delta area, Calif.*

Soil type and sample No.	Depth	pH	Ignition loss	CO_3	HCO_3	Cl	SO_4	Na	Ca	Mg
	Inches		*Percent*	*Parts per million*	*Parts per million*	*Parts per million*	*Parts per million*	*Parts per million*	*Parts per million*	*Parts per million*
Venice peaty muck (sample No. 5)	0- 10	5.0	43	0	90	240	240	300	90	24
	10- 36	4.8	64	0	36	240	192	300	54	12
	36-108	4.8	59	0	36	72	150	(2)	162	9
	108-252	[3] 3.8	50	0	0	30	[3] 735	0	132	24
	252+	6.0	2	0	-------	48	108	(2)	60	36
Staten peaty muck (average of 17 samples)	0- 16	6.0	50	0	90	240	510	200	130	40
	16- 58	5.9	69	0	72	98	144	120	38	18
	58-123	5.9	68	0	60	140	375	240	100	26
	123-172	6.3	15	0	36	64	247	(2)	17	20
	172+	6.8	4	0	140	175	245	120	120	38
Egbert muck (average of 4 samples)	0- 20	5.5	35	0	80	180	1,175	215	210	180
	20- 87	5.3	30	0	54	92	840	(2)	138	64
	87-177	5.9	34	0	54	47	150	(2)	60	26
	177+	6.6	7	0	175	30	87	(2)	12	8
Roberts muck (sample No. 71)	0- 7	4.9	33	0	88	1,280	510	478	478	115
	7- 13	4.6	33	0	43	1,325	195	360	368	110
	13- 19	4.8	10	0	43	775	156	360	205	70
	19- 24	5.0	5	0	35	215	115	150	50	30
	24- 36	5.2	5	0	35	215	65	150	50	20
Burns clay loam (average of samples Nos. 85 and 86)	0- 18	5.4	28	(4)	(4)	660	595	430	165	80
	18- 24	5.7	12	(4)	(4)	300	230	300	70	25
	24- 36	6.8	5	(4)	(4)	135	135	215	30	10
	36- 54	7.0	4	(4)	(4)	75	100	(2)	25	15
Piper fine sandy loam (sample No. 91)	0- 20	8.2	14	(4)	(4)	220	1,520	430	170	110
	20- 28	8.2	5	(4)	(4)	330	1,840	865	245	115
	28- 40	6.8	1	(4)	(4)	445	3,345	865	720	140
	40- 54	6.8	1	(4)	(4)	445	1,370	505	255	85
Ryde clay loam (average of samples Nos. 63, 64, and 67)	0- 22	6.0	25	0	25	390	100	430	275	100
	22- 89	5.4	15	0	45	210	90	110	25	20
	89-209	5.8	34	0	35	50	150	(2)	25	15
	209-222	5.3	30	0	65	50	290	(2)	50	20
	222+	6.4	6	0	85	45	105	0	45	10

[1] Determined with water content five times that required for saturation.
[2] Trace.
[3] Erratic possibly very local.
[4] Not determined.

TABLE 7.—*Organic-matter content of samples of certain soils from the Sacramento-San Joaquin delta area, Calif.*[1]

Soil type and sample No.	Depth	Organic matter	Soil type and sample No.	Depth	Organic matter
	Inches	*Percent*		*Inches*	*Percent*
Roberts muck:			578709	0–16	60.0
578701	0–6	31.0	578710	16–40	77.2
578702	6–24	42.6	Staten peaty muck:		
578703	24–57	10.5	578711	0–12	61.8
Burns clay loam:			578712	12–40	70.6
578704	0–7	9.3	Venice peaty muck:		
578705	7–20	4.1	578713	0–12	83.0
578706	20–38	2.8	578714	12–40	55.8
Venice peaty muck:			Ryde silty clay loam:		
578707	0–16	58.5	578715	0–14	34.3
578708	16–48	64.2	578716	14–30	46.2
Egbert muck:			578717	30–42	36.4

[1] Determined by ignition after oven drying 4 days at 60° and 5 days at 70° C.

Three additional series of soils—the first partly, the others wholly mineral—complete the group of soils that have given a definite pedologic distinction to the delta area. Members of these series are comparatively extensive and occur in all parts of the delta, those of the first two either on or near the alluvial ridges along the interlacing waterways and those of the third near the lower flat overflow basins.

The first of these, soils of the Ryde series, are developed from a deposit of fine-textured mineral sediments and impure reed-sedge peat containing varying admixtures of herbaceous plant remains. The Ryde soils occur on the immediate banks of most of the small sloughs and in positions that are slightly more distant from the major streams. In such places they occupy more or less gently sloping plains intermediate in elevation between the higher mineral soils of the stream ridges and the lower interfluvial bodies of highly organic soils. On the bases of their profile characteristics, parent material, and the circumstances of site, it is apparent they have developed from a more or less distinctive type of both mineral and organic material, which may in part have been accumulated from a thin vegetative cover of reeds and sedges mixed with herbaceous marsh plants. Such a cover would allow the comparatively slow inflow of sediment-laden waters from adjacent streams and would promote the settling of these sediments.

The Columbia series, the second of this group, comprises recent alluvial soils of the mineral order. They occupy the stream-built ridges along all the major streams and represent the recent or contemporary deposits of stream-borne sediments washed from a wide variety of upper-valley soils and rocks. The low to moderate content of fine particles of mica suggests that part, at least, of this material has had its source in the granitic rocks of the Sierra Nevada. Most of the Columbia soil material has been deposited at times of heavier stream flow or floods, and it is more or less stratified, with the strata dipping away from the crest of the stream-built ridges. It is relatively permeable and is maintained in a moist condition the greater part of the year. These soils occupy the highest elevations of the delta. They are strikingly mottled with the rust-brown and gray stains indicative of prolonged periods of overflow or of poor drainage. The Columbia soils of the delta area support a native cover of grasses, woody shrubs, and trees and represent the first zone of mineral deposition, which lies just above the second zone occupied by the soils of the Ryde series.

The soils of the third member of this group, the Sacramento series, are developed on low-lying flat interfluvial positions intermediate between the alluvial Columbia soils of the stream-built ridges and the organic soils of the delta basin. They have developed on the finer sediments deposited from turbid waters of backwater overflow basins. Grasses and herbaceous plants cover the land, and patches of tules and reeds grow in the lower wet areas. Although basically mineral, these soils have a comparatively high organic-matter content, are dark, and, unlike the Ryde and the Columbia soils, characteristically have soft nodules, mottlings, or thin seams of segregated lime in the compact and heavy-textured iron-stained subsoils.

Relationships between the several more important soils of the delta area may be summarized as follows: The delta soils proper occupy a network of mineral ridges (Columbia soils) along the major streams built up at times of high water. Below this, as well as along the minor sloughs, is a slightly sloping zone occupied by the Ryde soils, formed from an admixture of fine-textured mineral sediments and organic accumulations. Below this intermediate zone and occupying the major part of the interfluvial units, are the Sacramento soils and the Venice, Staten, Egbert, Roberts, Burns, and Piper soils. The soils of the last group have developed mainly from the tule-reed peat and are differentiated according to differences in profile development, decomposition, oxidation, and mineralization. Encircling the whole, but not a definite part of the delta itself, is the marginal rim of mineral soils, which represents the intermediate, transitional zone along the lower limits of the surrounding extensive valley plains.

SUMMARY

The Sacramento-San Joaquin delta area is in the west-central part of the Great Valley of California. It covers an area of 481 square miles, or 307,840 acres, most of which is occupied by organic soils developed on tule-reed peat in various stages of decomposition and oxidation, together with an admixture of mineral alluvial sediments. Narrow meandering bands of alluvial soils, associated with stream-built ridges, traverse the areas of the organic soils, which lie but slightly above or even slightly below sea level, and which are surrounded by marginal mineral soils of the valley plain.

The native conditions promote an extensive marshland vegetation. Most of the organic soils have been reclaimed by protection from overflow by an extensive system of levees and by artificial drainage. An intricate system of natural drainage channels and artificial canals forms a large number of islands, or so-called tracts. These islands now constitute one of the more important and unique agricultural sections of the State.

The climate of the area is characterized by hot, rainless summers and cool, moist winters, with frequent fogs. The mean annual rainfall ranges in different parts from about 10 inches in the southern part to about 18 inches in the central and eastern parts.

Corn, potatoes, onions, sugar beets, asparagus, celery, and other special vegetable and field crops are grown on the organic soils under irrigation and a system of control of the shallow water table.

Marginal areas of mineral soil, many of which are poorly drained and salty, are utilized for pasture and grains. Beans, alfalfa, vegetables, flower seeds, and pears are important crops on the better drained alluvial soils occupying the stream-built ridges.

Orientals, mainly Filipinos, furnish most of the hand labor necessary in intensive cultivation of asparagus, celery, sugar beets, and other crops commonly grown. Drainage, planting, and tillage operations, however, are performed on an extensive scale and wherever possible by modern, highly mechanized farming equipment.

The highly organic soils include Correra peat, Venice peaty muck, Staten peaty muck, Egbert muck, with its shallow and burned phases, and Roberts muck. With the exception of Correra peat and Roberts muck, which are inextensive, these soils form the central and agriculturally important soils of the area.

Burns clay loam and the Piper and Ryde soils have been developed on intermingled and associated organic and mineral materials. Of these the Ryde soils are the most extensive and important.

The alluvial mineral soils belong to the Sacramento and the Columbia series. The Sacramento series includes dark soils developed on sediments deposited in flat backwater overflow basins and river bottoms. The Columbia series includes lighter colored, better drained alluvial soils of lower organic-matter content, compared with the Sacramento soils, associated with the more elevated stream-built ridges. In agricultural use the Sacramento soils approach the Ryde soils. The Columbia soils, being better drained, are utilized for small areas of alfalfa, flower and vegetable seeds, and pears.

The soils of the delta margin, mainly mineral in character, with variable admixtures of organic matter, are developed on the materials of the valley plain and for the most part represent a transition between the organic soils of the flat and depressed river delta basin and the better drained soils of the alluvial fans and valley floor. They belong to several soil series that are described briefly in this report but are discussed in detail in other soil surveys.

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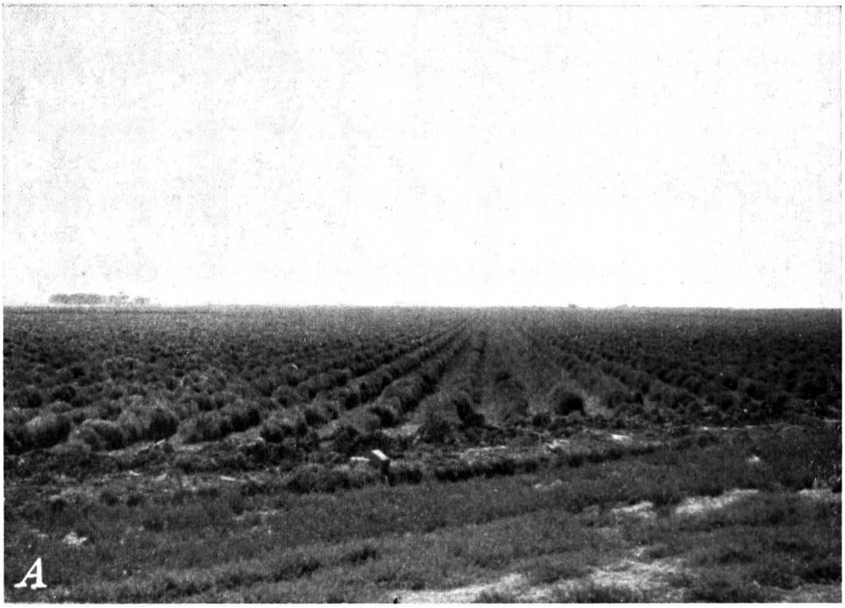
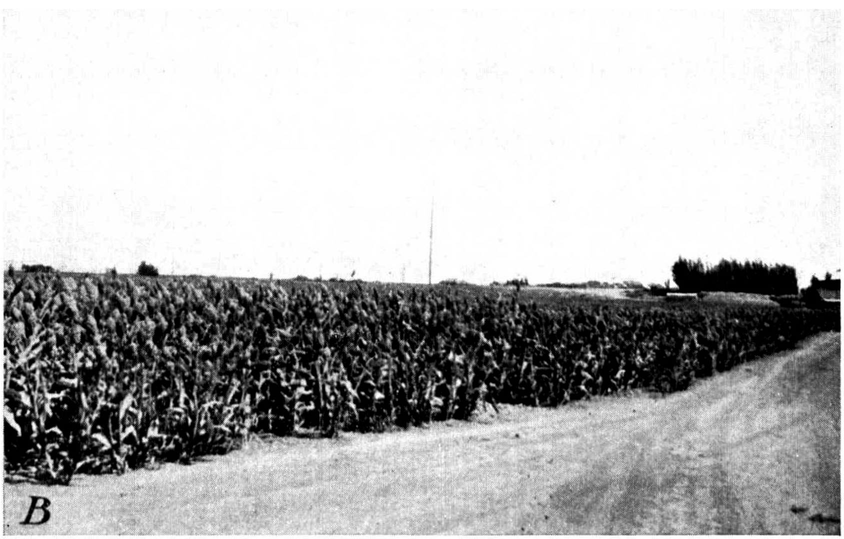
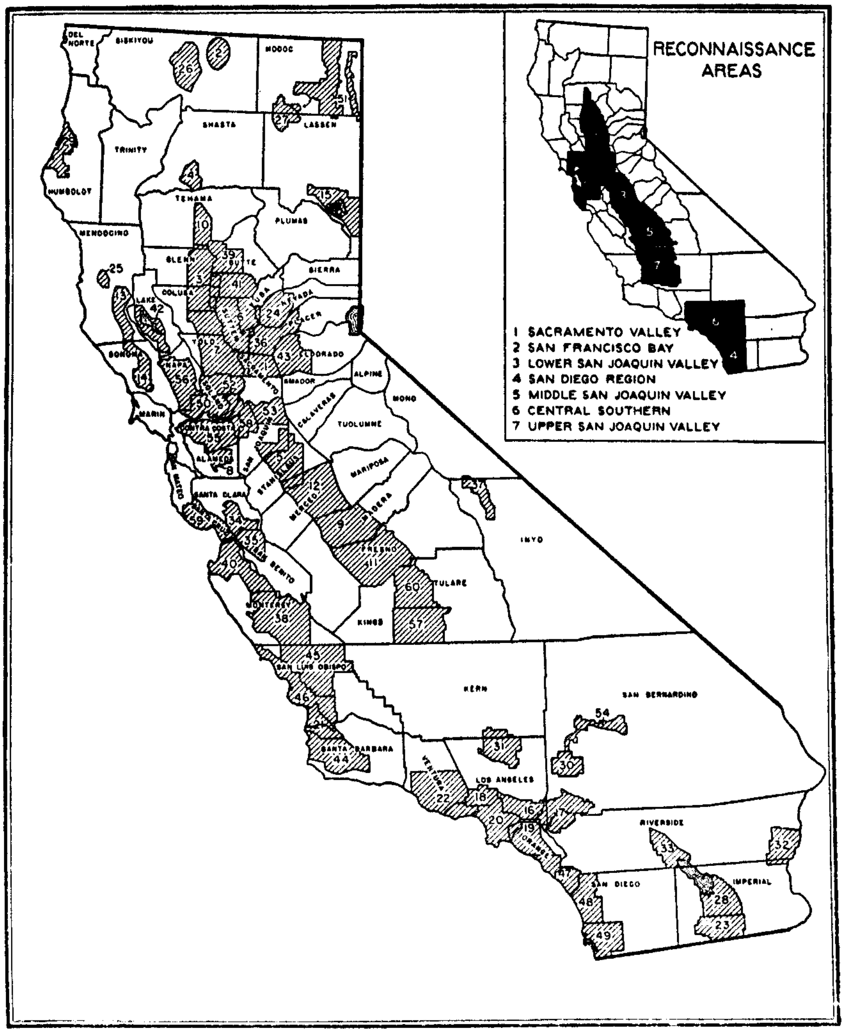
A, Large clamshell dredger used in extensive levee construction and drainage operations. *B*, Sunflowers on Egbert muck. In some years sunflowers are grown commercially on the organic soils of this area for human food, birdseed, poultry feed, and the extraction of oil.





A, Asparagus on Ryde clay loam, viewed from the river levee; *B*, grain sorghum on Ryde clay loam near Rio Vista.



Areas surveyed in California, shown by shading

1. Sacramento
2. Butte Valley
3. Colusa
4. Redding
5. Modesto-Turlock
6. Marysville
7. Woodland
8. Livermore
9. Madera
10. Red Bluff
11. Fresno
12. Merced
13. Ukiah
14. Healdsburg
15. Honey Lake
16. Pasadena
17. Riverside
18. San Fernando
19. Anaheim
20. Los Angeles
21. Santa Maria
22. Ventura
23. El Centro
24. Grass Valley
25. Willits
26. Shasta Valley
27. Big Valley
28. Brawley
29. Eureka
30. Victorville
31. Lancaster
32. Palo Verde
33. Coachella Valley
34. Gilroy
35. Hollister
36. Auburn
37. Bishop
38. King City
39. Chico
40. Salinas
41. Oroville
42. Clear Lake
43. Placerville
44. Santa Ynez
45. Paso Robles
46. San Luis Obispo
47. Capistrano
48. Oceanside
49. El Cajon
50. Suisun
51. Alturas
52. Dixon
53. Lodi
54. Barstow
55. Contra Costa
56. Napa
57. Pixley
58. Sacramento-San Joaquin Delta
59. Santa Cruz
60. Visalia

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