U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA AGRICULTURAL EXPERIMENT STATION, THOMAS F. HUNT, DIRECTOR; CHARLES F. SHAW, IN CHARGE SOIL SURVEY.

SOIL SURVEY OF THE WILLITS AREA, CALIFORNIA.

BY

WALTER C. DEAN, OF THE UNIVERSITY OF CALIFORNIA.

MACY H. LAPHAM, INSPECTOR, WESTERN DIVISION.

[Advance Sheets—Field Operations of the Bureau of Soils, 1918.]

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
Washington, D. C., April 3, 1920.

SIR: I have the honor to transmit herewith the manuscript report and map covering the survey of the Willits area, California, and to recommend that they be published as advance sheets of Field Operations of the Bureau of Soils, 1918, as authorized by law.

The selection of this area was made after conference with the State officials cooperating with the Bureau in the work of surveying and classifying the soils of California.

Respectfully,

MILTON WHITNEY,
Chief of Bureau.

Hon. E. T. MEREDITH,
Secretary of Agriculture.

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MAP.

Soil map, Willits area sheet, California.

SOIL SURVEY OF WILLITS AREA, CALIFORNIA.

By WALTER C. DEAN, of the University of California.—Area Inspected by MACY H. LAPHAM.

DESCRIPTION OF THE AREA.

The Willits area is situated in the central part of Mendocino County, Cal., about 120 miles northwest of San Francisco. The area is bounded on all sides by hills and mountains which form a part of the Coast Ranges. Approximately 30 square miles, or 19,200 acres, are included in the area, which has a maximum width east and west of about 4¾ miles and length north and south of about 8 miles.

No complete base map suitable for the purpose of plotting soils was available at the time the work was started in the area, but use was made of a map under construction in connection with a drainage survey then in progress.[1] This map covered only the lower, flatter parts of the included Little Lake Valley and was supplemented by planetable traverse work by members of the soil-survey party.

FIG. 1.—Sketch map showing location of the Willitts area, California.

The Coast Range belt of northern California lies between the coast on the west and the Sacramento Valley on the east, occupying a belt 50 to 70 miles wide. It consists essentially of a series of mountain ridges with intervening valleys varying considerably in width, height, and topographic details. The Little Lake Valley consists of one of the intermountain valleys locally widened into a basin. This, together with a portion of the hills and smaller stream valleys draining into it, is included within the boundaries of the Willits area. (Pls. I and II.) The elevated parts of this area have a topography varying from gently sloping and well-rounded to steep and abrupt. The greatest extent of comparatively smooth country in the hilly sections is in the southern part of the survey, but other smaller areas of this character occur in many places on the slopes above the valley floor. The valley lands are typically smooth surfaced and gently sloping. The northern end of the Little Lake Valley is an almost

[1] Conducted by the Division of Soil Technology of the University of California.

flat depression, the outlet of which is too small to care for the normal drainage, a lake of considerable size being formed each winter.

The elevation of the railroad station at Willits, which is on the west side and toward the southern and higher part of the main valley, is 1,365 feet. Outlet, lying about 4 miles from Willits in the northern part of the area, is 1,339 feet above sea level. Ridgewood siding, situated in the hills a few miles south of the area, has an elevation of 1,913 feet. The highest mountain in the vicinity, Mount Sanhedrin, 25 or 30 miles northeast of Willits, has an elevation of 6,200 feet.

Regional drainage is adequate over the area as a whole, but is lacking in the low-lying northern end of the Little Lake Valley. Conditions there are described in the chapter on drainage, which follows the description of the soils in this report.

Mendocino County was formed in 1859, with Ukiah, 25 miles south of Willits, as the county seat. About three-fourths of the early settlers came from the Southern and Central States, and the rest from other parts of the United States and from foreign countries. According to the 1910 census, the population of Mendocino County was 23,929, all of which was rural. In the relatively small part of the county covered by the Willits area the population is predominantly American. A few Italians were brought in at one time to work in the lumber mills, but most of them live in the town of Willits.

Over 75 per cent of the population of the area is in the central and southern half of the Little Lake Valley, which includes the town of Willits. According to the 1910 census the population of Willits was 1,153. The only other populated center is at Northwestern, approximately 2 miles northwest of Willits, on the Sherwood branch of the Northwestern Pacific Railroad. This is a town of approximately 200 people, built up around the lumber mill located at that point. Outlet, which has only a post office and three or four houses, is a flag station on the main line of the railroad in the northern part of the area. Lahm is a siding on the railroad near the southern boundary of the area, where wood for fuel is loaded on the cars.

The main line of the Northwestern Pacific Railroad, operating between San Francisco and Eureka, traverses the area from north to south. At Willits connection is made with a branch line which runs through Northwestern to Sherwood, outside the survey, and also with a line operated by the California Western Railroad & Navigation Co., which terminates on the coast at Fort Bragg, 40 miles distant.

A State highway approximately parallels the main line of the railroad, but at the time of the soil survey had not been paved, although grading was completed. In addition, a system of fair to good county

roads affords access to most of the lands now cropped, but there exist areas of land suited to agriculture which are somewhat inaccessible at the present time. The telephone and the daily mail reach nearly all parts of the area.

Farming is the principal industry in the region covered by the survey. Truck and fruit crops are grown to such a small extent that the produce is all utilized in the area. A part of the poultry products and grain and grain hay is disposed of in supplying the local demand, but a part is shipped out, usually to the cities about San Francisco Bay.

CLIMATE.

The climate of the Willits area corresponds in its general features with that of the valleys along the Russian River to the south. However, the rainy season is longer and has lower temperatures, while during the shorter dry season the temperatures also average slightly lower ordinarily. During the seven years for which records are available the only month during which precipitation has not occurred is August. In June, July, and September very little rain normally falls, although exceptions to this rule have been noted. In general, the precipitation comes in gentle to moderately heavy rains of an intermittent character, but heavy downpours continuing with little intermission for periods of several days occur at times and result in swollen streams and more or less flooding of the lower lying lands.

No detailed temperature records are available for the area. However, it appears that the Little Lake Valley is climatically intermediate between Ukiah, 25 miles to the south, and Branscomb, about 30 miles to the northwest and nearer the ocean, at both which places the Weather Bureau maintains a station. Summer temperatures throughout the area covered by the survey normally range between 40° and 104° F., and occasionally mount to 110° F. During winter the temperature range is approximately from 13° to 60° F.

A rainfall record for Willits, kept by the Northwestern Pacific Railroad, covers the period between July 1, 1911, and June 30, 1918. This record, together with a table showing the mean monthly and annual precipitation at Branscomb and Ukiah for certain periods of years, follows.

Mean monthly and annual precipitation at Willits, Branscomb, and Ukiah.

Month.	Willits. Elevation, 1,365 feet; length of record, 7 years, 1911 to 1918.			Branscomb. (Elevation, 2,000 feet; record for 18 years.)	Ukiah. (Elevation, 620 feet; record for 25 years.)
	Mean.	Total amount for driest season (1917–18).	Total amount for wettest season (1913–14).		
July	0.08	0.00	0.16	0.12	0.02
August	.00	.00	.00	.04	.01
September	.66	.39	.00	1.15	.57
October	1.15	.00	.00	5.81	1.78
November	5.47	4.82	8.48	14.05	4.15
December	8.50	4.06	14.92	12.98	6.65
January	11.58	2.76	23.07	19.16	8.35
February	8.39	9.45	8.85	17.55	6.17
March	4.32	5.52	2.58	12.74	5.55
April	2.83	1.98	3.82	4.13	2.45
May	1.75	.00	1.31	2.82	1.26
June	.28	.00	.82	1.39	.30
Year	45.01	28.98	64.01	91.94	37.34

According to the Weather Bureau records, the average date of the last killing frost in spring at Branscomb is April 9, and the date of the latest ever recorded is May 27. Corresponding dates for Ukiah are April 14 and May 16. According to information obtained from farmers, the last killing frost in spring ordinarily occurs in the Willits area between May 15 and June 1, but has come even a little later. However, it is considered a reasonably safe practice to plant crops susceptible to frosts by June 1. The frost records for Branscomb show the average date of first killing frost in fall and earliest in fall to be November 9 and October 4, respectively, and for Ukiah, November 1 and October 2, respectively. As is the case in the spring, conditions seem to be also more unfavorable in the fall in the Willits area than for the stations cited outside the survey. Farmers agree that danger exists after September 1, although usually frost severe enough to kill vegetation does not occur until about the middle of September. Of course, there are favored and sheltered locations in the area where the growing season is several weeks to a month longer than in the more exposed places, but the approximate dates given seem to apply to at least the main floor of the Little Lake Valley.

Fogs are prevalent during winter, but are mainly local. They are considered of some benefit to crops, not only because of their moistening effect and because they reduce loss by evaporation to a minimum, but also because they tend to lessen the severity of frosts. In summer some fog from the coast occasionally reaches the area.

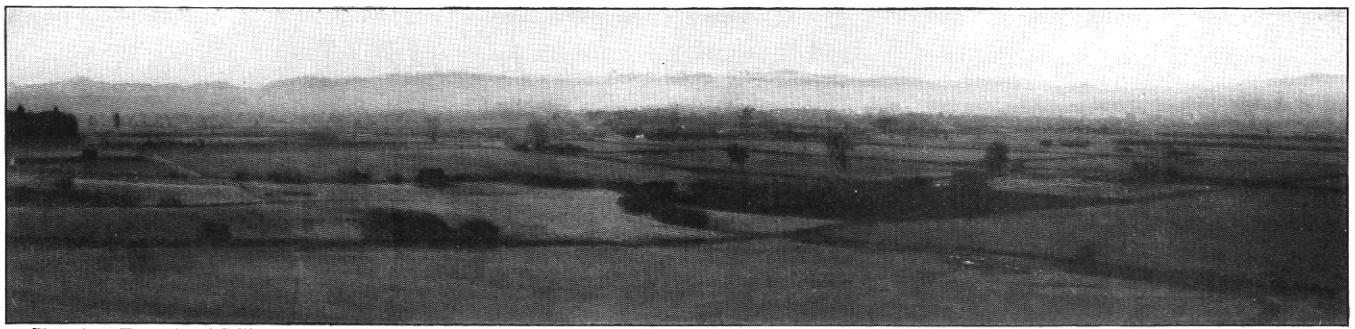

Photo from University of California.

PANORAMIC VIEW LOOKING SOUTH TO WEST ACROSS LITTLE LAKE VALLEY FROM LITTLE LAKE SCHOOL, SHOWING TYPICAL CONDITIONS ON THE BETTER DRAINED PORTIONS OF THE VALLEY.

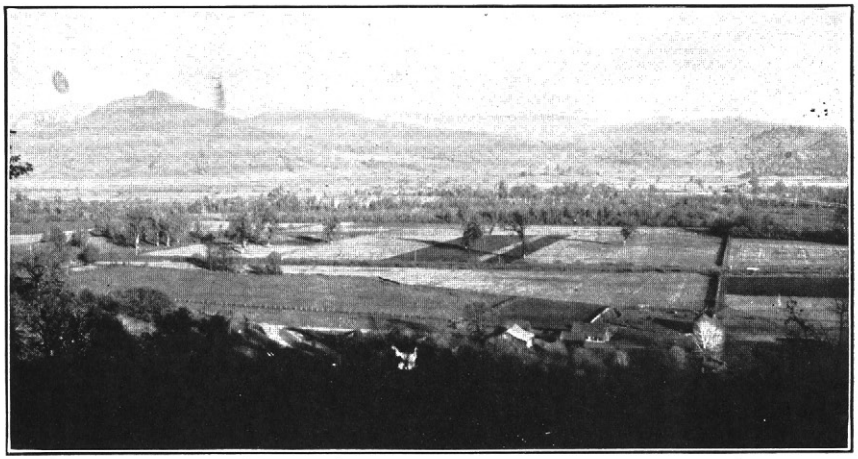

Photo from University of California.

FIG. 1.—VIEW LOOKING EAST ACROSS LITTLE LAKE VALLEY JUST NORTH OF WILLITS.

Yolo fine sandy loam and Yolo loam on the valley floor. Olympic loam and Rough mountainous land on the hills.

Photo from University of California.

FIG. 2.—VIEW LOOKING NORTHWEST ACROSS THE LOWER FLAT BASIN OF LITTLE LAKE VALLEY.

Occupied by the Wapato silt loam and the Wapato silty clay and the heavy phase of the latter, with Altamont fine sandy loam and Rough mountainous land on the hills.

Wind movements are moderate. Gentle winds blowing from the ocean and coming from the northwest occur intermittently in summer. Occasional drying north winds occur in the spring, but never cause injury to crops.

The factor of climate, and specifically of frost, is the feature largely controlling agriculture and its development in the Willits area. Owing to the short growing season, the choice of crops is necessarily limited to either quick-maturing or hardy plants, and any attempt to grow less hardy crops is likely to end in failure.

AGRICULTURE.

The first settlement and the beginning of agricultural development in the Willits area dates back to 1855, when three men brought in a drove of cattle from Marion County. For 40 to 45 years thereafter little farming was done. Cattle and sheep raising occupied most of the attention of the settlers, and the only crops grown were for home consumption and stock feed. The best lands were held for about $35 an acre, and until the building of the railroad, which was definitely projected in 1900, the valley was so isolated by distance and bad roads that little progress was possible. In the early nineties a company spent a considerable amount of money in developing an orchard enterprise, planting prunes, apples, and pears. The project was a failure, the trees suffering from unfavorable climatic conditions and from lack of care.

It is impossible to give statistics in regard to crops or live stock, as the area covered by the survey constitutes only a small part of Mendocino County, and the available census figures apply to the county as a whole. The information given in this chapter on agriculture is mainly the result of observations in the field and of facts gathered in interviewing the farmers.

As the area became more thickly settled, the acreage planted to grain and grain hay increased, until at the present time these crops are by far the most important grown. About half the planting is wheat, mainly the Bluestem variety, while the remaining 50 per cent is about equally divided between barley and oats. In normal years about 75 per cent of the grain crops is thrashed and the rest cut for hay. The climatic conditions, especially the rainfall, are the principal factors determining the proportion of these crops harvested for grain and hay from year to year.

Potatoes, carrots, turnips, and other hardy vegetables are grown to a small extent. The quality of such crops is good. The Burbank and Peerless seem to be the preferred varieties of potatoes. Corn, beans, and tomatoes, although sometimes maturing satisfactorily in favored localities, are uncertain crops for the area as a whole, because of the severe frosts which often come late in the spring.

The total acreage of deciduous fruits is small and the output insignificant. The orchards are mainly apple, of which a number of varieties are grown. Nearly all the plantings are on soils of the Yolo series, chiefly the loam and fine sandy loam. Pears appear to do well when given the proper care. The few trees found are mainly the Bartlett and certain winter varieties. Climate is the limiting factor in fruit culture.

Dairying has not progressed to any extent as an industry in the area. One of the main reasons is that alfalfa has never been grown successfully on a large scale in the valley. Winterkilling, which has commonly taken place, is thought to have been caused by the high water table which exists over such a large part of the better alluvial soils during the time of the spring floods.

Beef cattle are pastured in the hills and uncultivated lands of the valley. The favorite breeds are the Hereford and Durham. Hog raising is of some importance. Sheep husbandry has to a great extent been abandoned. At an earlier time it was quite important, but a period of low prices and the ravages of coyotes brought about a very material reduction of the flocks. Many parts of the hills and mountains included within the survey are moderately to rather heavily forested and are valued more for their lumber and fire wood than for the scant pasturage which necessarily exists with such conditions of growth. Brushy areas are very common, especially in the elevated parts of the survey, and these also support a poor growth of grasses.

Poultry husbandry is not very important, only a few of the farmers having large flocks of chickens. The eggs produced are either consumed locally or shipped to San Francisco. Turkeys are raised in greater numbers than chickens, and when prices are good form a profitable source of income on many of the farms. Most of the turkeys go to the San Francisco Bay region.

Most of the farmers have equipment which is modern and adequate for their operations. Tractors are not in general use, although there are a few in the valley. Most of the plowing, harrowing, and harvesting work is done with horses. Practically no fertilizers are used and about the only rotation practiced is the interchanging of the grain crops, wheat, barley, and oats.

In normal times the labor supply is ample and is mainly native American. As a matter of fact, the labor question apparently can not become very acute under existing farming conditions, as the various farmers do most of their own work. Farms range in size from 5 or 10 acres to several hundred acres, but prevailingly consist of about 80 acres. Most of the farmers own and operate their own places, and the number of renters is comparatively small.

Land values outside of the town of Willits or immediately adjacent thereto range from $5 to $200 an acre. The hilly and mountainous

areas, which are underlain by bedrock, in many places at shallow depth, are seldom held for more than $10 an acre, except where forested, when they may be worth three or four times as much. The best lands in the valley sell for $150 to $200 an acre, while the low hills of deep soils and the poorly drained bottom lands are commonly valued around $50 an acre.

SOILS.

The soils of the Willits area are identified with three main provinces or groups of soil-forming materials, which differ not only in origin, mode of formation, and other features, but are further differentiated by more or less striking contrasts in topography and in the character of the underlying material. The soils of the first group are designated as residual and are derived from the disintegration and weathering in place of consolidated rocks. The soils of the second group, designated as old valley-filling soils, are derived through the weathering and modification in place of old, unconsolidated, water-laid deposits. In the third group are placed recent alluvial soils, those formed from materials recently deposited by streams and to some extent by surface wash and which have not undergone material changes in profile or in mineralogical character or suffered other internal modification since their deposition. Soils in the last group are still in process of accumulation. In addition to these main groups a type of miscellaneous material, Rough mountainous land, has been mapped.

A rather striking characteristic of the soils of the area covered by the survey, and a characteristic which appears to even greater extent farther north in this State and along the coast in Oregon and Washington, is the presence of a varying degree of mottling in the color of practically all the subsoils. The cause of this can be traced to the relatively high rainfall, coupled with inadequate surface or subsurface drainage over parts of the area.

The residual soils, which are not extensive in the Willits area, occur only in the hills and mountains of the western, northern, and northeastern parts. The old valley-filling soils are more extensive than the residual soils. Types in this group predominate in the southern part of the area, and occur to a less extent on the western and eastern sides. They occupy rounded low to moderately elevated hills and remnants of terraces or old alluvial fans, and lie in a position intermediate in elevation between the soils of the first and third groups. The recent alluvial soils greatly exceed in area the soils of the first two groups. Alluvial soils cover all the central valley part of the area and also extend back along streamways into the hills.

Each of the three groups mentioned includes different kinds of soils which are recognized as belonging to different series, and each series is represented by one or more soil types. The soils of a given

series possess a number of characteristics in common, such as origin, mode of formation, topography, color, and subsoil and substratum features, which distinguish them from the soils of other series in the same or different groups. Difference in texture, which is determined by the proportion of coarse and fine material present, is the basis for type distinction within the series.

The soil type is the unit of classification in mapping. Slight variations in texture, topography, drainage, or other features within a type may justify the mapping of soil phases. Such distinctions are made in the present survey in case of several of the types. The nature of the country combined with the relatively small scale of the published map does not permit showing all the types and phases separately or exactly. The soils are intricately mixed in certain places and gradations in materials between the various soils are in other places gradual. This results in the necessity for some grouping of the materials, but the areas undifferentiated are usually of minor importance.

In the Willits area the residual soils are represented by two series, including two types and one phase; the old valley-filling soils by two series, including two types and one phase; and the recent alluvial soils by two series, including four types and two phases.

The residual soils occur on the foothills and mountain slopes. The rocks giving rise to this group of soils apparently belong largely to the Franciscan series and consist predominantly of sandstones, shales, and their metamorphosed equivalents, such as quartzite. Included with these sedimentary rocks and also occurring separately in more or less well defined areas are basic igneous intrusions and such rocks more or less metamorphosed. In general the rocks are intricately associated and as a result the residual soils derived from them are subject to frequent changes in character and origin, which renders mapping somewhat difficult. The sedimentary rocks are confined mainly to the western part of the survey. The basic igneous formations are not only found in this section, but also in the hills of the northern and eastern parts of the area.

The residual soils are relatively unimportant in the Willits area, but the soil series represented have been mapped extensively in other parts of the State. As a group they occupy a hilly to mountainous topography, which varies from relatively smooth and gently sloping to dissected and steep. Areas of nonagricultural land too small to map are included. Rock outcrop occurs here and there. The drainage is in many places excessive.

The residual soils derived from basic igneous rocks have been classed with the Olympic series and those from sedimentary rocks in the Altamont series.

The soils of the Olympic series are typically brown to dark brown in color, with a reddish or rusty-brown shade in many places. The

subsoil is light brown or grayish brown, ordinarily somewhat compact, and not uncommonly contains varying proportions of angular rock fragments. The subsoil is sometimes lacking, bedrock directly underlying the surface material. Rock outcrops occur in places, bedrock usually occurring at relatively shallow depths, rarely deeper than 4 feet. The topography is rolling to steep and hilly and drainage is good to excessive. The Olympic soils are derived mainly from basic igneous intrusives and their metamorphosed equivalents. As mapped in the Willits area, some material is included which, being derived from quartzite and sedimentary rocks, really represents Altamont material, and also several bodies of soil of a reddish to distinctly red color belonging in the Aiken series as recognized in other areas in the State. This is treated as a phase of the Olympic in this area. One type, the loam, with a red phase is mapped.

The types included in the Altamont series have brown to dark-brown soils and yellowish-brown or lighter brown subsoils. They contain moderate supplies of organic matter and occasionally small amounts of angular rock fragments. The subsoil is somewhat compact and bedrock is usually encountered at depths of less than 5 feet, with outcrops in some places. The soils occupy rolling, hilly, and mountainous areas and are well drained. The Altamont series is derived mainly from sandstones, shales, and metamorphosed sedimentary rocks. In this area some small, unimportant areas of soils derived from basic igneous intrusives are included, owing to the intimate association of the different rock formations. One type of this series is mapped in this survey, the fine sandy loam.

The soils derived from old valley-filling material have been formed from unconsolidated sedimentary deposits of an earlier period subsequently eroded, leached, and weathered, usually with the development of heavier and practically always more compact subsoils. The color of the subsoil ordinarily differs somewhat from that of the surface soil. Soils belonging to this province are of moderate extent in the Willits area, but are widely distributed, occurring in all but the central and northern parts. They are more important in agriculture than the residual soils, but very much less so than the soils of recent alluvial origin. The old valley-filling soils usually occupy a position intermediate in topography and elevation between the groups just referred to and differ from the latter in that they are undergoing removal by erosion or are slowly being covered by deposits of recent alluvial material. The topography varies from gently sloping to steep. Their characteristic occurrence is on low rounded hills and remnants of old terraces and alluvial fans. Surface drainage is ample, but subsoil drainage is in many places restricted. In the Willits area members of two series, the Willits and the Kimball, are mapped.

The surface soils of the types included in the Willits series are medium brown to rather dark brown and the subsoils yellowish brown or dull yellow to grayish brown and in most cases mottled. The supply of organic matter is moderate. The subsoil is usually heavier textured than the surface soil and is always compact. The substratum is similar to the subsoil. The series occupies old river terraces, dissected alluvial fans, and rolling hilly areas. Drainage is usually fairly good, but in places the heavy compact subsoil restricts the internal movement of water. The materials forming the soils of this series come originally from sedimentary rocks. One type, the fine sandy loam with a heavy phase, occurs in the Willits area.

The types included in the Kimball series have reddish-brown to red soils and mottled, compact, red to yellowish-brown subsoils, in many places streaked with reddish iron stains. The soils contain a moderate supply of organic matter. The substratum is usually similar to the subsoil, but a gray color is not uncommon. The soils occupy low, rounded hills and the drainage is good. Only one type, the gravelly clay loam, is mapped in the area. The most obvious feature that distinguishes the Kimball from the Willits series is the difference in color of the surface soil.

The recent alluvial soils are the most extensive and important in the area, covering all of the lower lying bottom lands in the Little Lake Valley, as well as in the smaller tributary valleys. They are the most recently formed deposits, have been laid down as stream flood plains and alluvial-fan material, and are still in process of accumulation. Both soil and subsoil are readily permeable to roots and water, in contrast with the soils of the old valley-filling group, whose heavy, compact subsoils retard root growth and moisture movement, and with the residual soils, in which bedrock occurs at shallow depths. No consistent relations exist between surface soil and subsoil as regards either color or texture. The materials giving these soils are derived from the various rocks of the region, but probably the greater part is from sedimentary formations. The soils are characterized by smooth, gently sloping to nearly flat surfaces. Drainage is good, except in the northern end of the main valley, where an intermittent lake forms each winter. The soils fall in two series, the Yolo and the Wapato.

The types included in the Yolo series have rather light brown to dark brown or dark grayish brown soils and light-brown or light yellowish brown to dark-brown or dark grayish brown heavy subsoils. The content of organic matter is moderate to high. The series occupies gently sloping alluvial-fan and stream-valley areas, with a smooth surface well suited to tillage. Only the types located in or near the intermittent lake bottom are poorly drained. Two types, the fine sandy loam and the loam, the latter with a gravelly phase, occur in this survey.

The types included in the Wapato series are characterized by rather dark brown or dark grayish brown soils and brown or dark-brown to drab subsoils mottled with yellow, gray, and brown. The surface soils normally contain a moderate to large proportion of organic matter. The subsoils are moderately heavy to heavy in texture and in many places tough or compact. In some cases the subsoil is stratified, the various layers differing widely. Both the surface soil and subsoil are generally deficient in lime. The series occupies stream bottoms, broad flats, and shallow depressions. The materials giving this series come originally from sedimentary and basic igneous rocks. Both surface drainage and subdrainage are restricted, and the lower lying areas are subject to overflow.

The Wapato series is distinguished from the Yolo series by slightly darker colored surface soils, compact, mottled subsoils, and more poorly developed drainage. The silt loam and the silty clay, the latter with a heavy phase, occur in this survey.

In addition to the series described, the map shows lands classified as Rough mountainous land. This includes rather extensive areas of mountainous and hilly country where the surface, except in occasional small areas, is too steep and rough to permit cultivation.

The following table gives the name and actual and relative extent of the several types of soil in the area. The distribution of these types is shown on the accompanying map.

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Rough mountainous land	6,912	36.0	Wapato silt loam	960	5.0
Yolo loam	3,648	23.3	Altamont fine sandy loam	832	4.3
Gravelly phase	832		Wapato silty clay	512	3.4
Willits fine sandy loam	2,752	15.3	Heavy phase	128	
Heavy phase	192		Kimball gravelly clay loam	128	.7
Olympic loam	1,088	6.3	Total	19,200	
Red phase	128				
Yolo fine sandy loam	1,088	5.7			

OLYMPIC LOAM.

The surface soil of the Olympic loam consists of 6 to 15 inches of rather light grayish brown to dark-brown loam, carrying in many places small amounts of angular rock fragments. The soil material is shallow over most of the type, and in many places partially disintegrated or solid bedrock directly underlies the soil. When present, the subsoil rarely extends below 3 feet. It is in most places of the same or of a slightly heavier texture than the surface soil, but is usually more compact. In areas of deeper material the texture is clay loam and mottles of light brown or grayish brown occur. Angular rock fragments are more abundant in the subsoil than in the

surface soil, but roots penetrate to the underlying rock without much difficulty. Rock outcrops are numerous. The Olympic loam contains a fair supply of organic matter, and the soil absorbs moisture readily and retains it fairly well.

The type includes some areas in which the soil material is slightly lighter in texture than typical, in some cases approximating a fine sandy loam. This variation occurs in the areas lying west of the State highway and on both sides of the Sherwood Road and extending from the outskirts of Willits, 1½ miles north and northwest of that town. Small bodies of this variation occur in one or two other places in the area, but, as is the case with the larger bodies mentioned, the variation from the typical is too slight to be of any practical importance.

Two small areas of soil derived from old valley-filling material with hardpan present at some depth also are mapped with the type. If more important they would have been mapped as Madera, a series found extensively in some other parts of the State. These areas lie about two-thirds of a mile southeast of the Little Lake School and approximately one-half mile west of the point where Berry Creek leaves its canyon and flows out into the valley. These bodies are characterized by a brown loam surface soil underlain by a thin 2 to 4 inch layer of impenetrable hardpan, which normally occurs at a depth of about 12 inches. The material below the hardpan is very similar to the subsoil of the Willits series, ranging from a gravelly sandy loam to a clay loam in texture. These soil areas have a low agricultural value.

The Olympic loam is the most extensive residual soil in the area. It occurs in bodies scattered through the hill region in the western, northern, and northeastern parts of the survey. The topography varies from gently sloping to steep and rough. Landslides occur in some places, although not extensively. The type has been differentiated from the adjacent Rough mountainous land because of a topography less steep and more favorably adapted to agriculture, but some small areas unsuited to farming because of surface features are included. The soil is residual in origin, and derived from basic igneous rocks. Small areas of soil from sedimentary rocks are included, owing to difficulty of separation. Drainage is usually adequate, although some areas of moderate extent suffer from accumulation of seepage waters.

Though moderately friable, the soil must be tilled only when moisture conditions are favorable or a poor seed bed results. Less than 5 per cent of the type has ever been farmed, grain and grain hay being the only crops grown. Pasture thus forms practically the only use made of the land. The growth of wild grasses is in the main rather poor, even in the open areas where larger vegetation is

lacking. Much of the surface has a covering of brush and open forest.

Because of the shallow soil and unfavorable topography, the Olympic loam in this survey must be classed as a poor farming soil. Land prices rarely exceed $5 to $10 an acre, unless the forest growth has commercial value.

Olympic loam, red phase.—The soil mapped in this area as the red phase of the Olympic loam in reality belongs in the Aiken series, mapped in other areas in the State. The surface soil varies from 12 to 18 inches in depth and consists of a brownish-red or dark-red to red clay loam containing considerable organic matter and a moderate to rather high percentage of small, angular rock fragments. The subsoil is usually a yellowish-red to dark-red clay loam or clay, rather compact, and also carrying varying amounts of angular rock fragments. It is permeable to water and readily penetrated by the roots of deep-rooted plants. At depths between 24 and 48 inches, the subsoil rests on bedrock and in a few cases outcrops of the parent rock occur.

The Olympic loam, red phase, is of small extent in the area, being confined to three small bodies situated in the northeastern part. It has a smooth, gently sloping to moderately steep surface, and lies at the base of the hills bordering the floor of the valley. On the upper margins it merges with Rough mountainous land. As in case of typical Olympic loam, the phase comes mainly from basic igneous rocks. Drainage is good.

Most of the Olympic loam, red phase, is farmed and yields moderately good crops of grain and grain hay. Some of the land is used for pasture. It supports a scattered open growth of brush and larger trees. It is held at a higher price than the typical Olympic loam. The application of barnyard manure would be beneficial, as the supply of organic matter is not as high as is desirable.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the typical Olympic loam:

Mechanical analyses of Olympic loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
575103	Soil	4.5	7.5	3.7	13.7	12.9	38.1	19.8
575104	Subsoil	3.7	11.2	5.3	18.0	14.0	24.8	23.2

ALTAMONT FINE SANDY LOAM.

The surface soil of the Altamont fine sandy loam consists of a rather light brown to dark-brown friable fine sandy loam 8 to 15

inches deep. It is usually free from gravel, but in places on the steeper slopes and crests of hills contains a small amount of sandstone and shale fragments. The content of organic matter is moderate.

The subsoil is typically yellowish brown or light brown in color, but a distinct reddish-brown to red variation occurs in places throughout the body of the type situated along the Sherwood Road, beginning at a point about a mile northwest of Willits and extending northwestward to the boundary of the area. The texture of the subsoil varies from a fine sandy loam or loam to a clay loam. Small quantities of angular rock fragments are not infrequently scattered through this material. The subsoil is compact, more or less mottled and stained with iron. Water and roots penetrate the material with some difficulty. Bedrock, mainly of sedimentary formation, normally is encountered at depths between 18 inches to 5 feet. Here and there the surface soil rests directly upon the parent rock without occurrence of a distinctive subsoil layer, but outcrops of the rock are rare.

The Altamont fine sandy loam is the most important residual type in the area for farming. It is moderately extensive. Six areas are mapped, all of which are situated in the hill region in the western part of the survey between Broadis Creek west of Willits and the northern boundary. The surface varies from gently sloping and fairly smooth to quite steep and more or less dissected. Streams crossing the type flow in deep gullies. Drainage is ample. The soil is residual from sedimentary and metamorphosed sedimentary rocks. A few small spots from basic igneous rocks are included, owing to the mixed occurrence of the various formations and consequent difficulty of separation.

In the virgin state the Altamont fine sandy loam supports a rather heavy growth of forest trees and brush, including pine, fir, redwood, oak, madrona, and manzanita. Some of the type has been cut over and now supports a second growth. The small percentage cleared and farmed is cropped almost entirely to grain and grain hay. Where the soil material is deep and cultural methods are good, the yields are fairly satisfactory.

Land values are low, and, except in some of the better developed locations, generally range between $5 and $20 an acre.

Because of the somewhat open nature of the soil, it is important in cultivating this soil to give careful attention to the conservation of moisture. Deep plowing and thorough and frequent cultivation should be employed, and barnyard manure applied to the fields whenever practicable.

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

Mechanical analyses of Altamont fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
575101	Soil	2.9	4.3	4.4	19.8	22.7	32.6	13.2
575102	Subsoil	1.6	5.1	5.9	25.6	21.9	28.9	11.0

WILLITS FINE SANDY LOAM.

The surface soil of the Willits fine sandy loam is light-brown, yellowish-brown or brown friable fine sandy loam from 12 to 18 inches deep, containing in many places small quantities of rounded gravel. The soil is rather low in organic matter, except in small scattered, heavily forested areas, where a dark-brown color of the soil indicates a high percentage of leaf mold in the immediate surface. The line of demarcation between the surface soil and subsoil is in most places very distinct, and the color of the latter is prevailingly yellowish-brown mottled with yellow. Seams and strata stained reddish with iron are not uncommon, and in the lower subsoil a gray layer may occur or a number of such layers may alternate with layers of the yellowish material. The texture of the subsoil varies from a light fine sandy loam or gravelly sandy loam to a clay loam or clay. The heavier materials are typical and occur over the greater part of the areas. The subsoil is compact and contains here and there strata that are extremely compact. The mottling of the subsoil is pronounced in the typical material but scarcely noticeable in that of lighter texture. Water and roots with difficulty penetrate the compact clay and clay loam materials. The substratum resembles the subsoil quite closely in texture, structure, and color. If anything it is more compact and the gray color is more common and more pronounced.

Gravelly areas of this soil of considerable extent are indicated on the soil map by the appropriate symbol. One such area lies near the town of Willits. A large area is situated around and southeast of Sawyer School. Except for the higher gravel content of the surface soil and the occurrence of a reddish subsoil in a small area a little over one-half mile east of Sawyer School the gravelly areas closely resemble the typical soil.

Though confined to the southern half of the area, the Willits fine sandy loam is one of the most extensive types in the area. It forms nearly all the farming land in the southern, more elevated part of the valley, and smaller areas extend along the eastern margin and lie near the town of Willits.

The type has a gently sloping to rather steep and hilly topography, though the surface in detail is generally smooth. Surface drainage

is good, but subdrainage is restricted, except where the underlying material is predominantly sandy. The material giving rise to this type is much older than that giving soils of the Yolo series, and represents alluvium which has been subjected to much erosion and to leaching and weathering since its deposition. It is derived mainly from sedimentary rocks.

Much of the type has never been farmed, and has a moderate to heavy forest cover, part of which is second growth. Oak, madrona, pine, fir, and manzanita grow vigorously. The farmed areas are cropped almost exclusively to grain and grain hay. The yields are smaller than those on the soils of the Yolo series. Land values are quite variable, and depend largely on the surface conditions, elevation, and accessibility. They range from $30 to as much as $75 an acre.

Deep tillage, conservation of moisture, and increasing the supply of organic matter are the main factors to be considered in handling the Willits fine sandy loam.

Willits fine sandy loam, heavy phase.—The heavy phase of the Willits fine sandy loam has a surface soil consisting of 9 to 14 inches of brown to dark-brown loam containing a moderate amount of organic matter.

The subsoil is typically a stiff, compact, mottled clay, but a somewhat lighter textured clay loam may occur. In places the color of the lower subsoil is a uniform gray. Small quantities of gravel are scattered through the subsoil in a few places, but the admixture is not sufficient to affect the structure to any appreciable extent. Water moves slowly and roots have some difficulty in penetrating the subsoil material.

The substratum resembles the subsoil in texture and compactness, and is either yellowish or grayish in color. In the eastern part of the single body of the phase, approximately 1½ miles southeast of Whitcomb School, beds of grayish shale are uncovered 8 to 10 feet below the surface in some drainage cuts. In the extreme southeast corner of this body similar beds, but predominantly of reddish color, outcrop in a few places.

The Willits fine sandy loam, heavy phase, is of minor extent and importance. It is confined to a single area lying approximately 1 mile north of the southern boundary of the survey.

The phase has a gently sloping to rolling or hilly topography. The surface is fairly smooth, except for a number of deep drainage ways with steep dissected to almost perpendicular banks. Surface drainage is adequate, but subdrainage is restricted. The material forming this soil has been washed mainly from sedimentary rocks.

The soil tends to pack somewhat under beating rains, but under ordinary conditions is absorptive of moisture. It also retains moisture

well when properly cultivated. Tillage is not difficult when the soil contains the right amount of moisture and a favorable seedbed is formed under normal conditions. At least 50 per cent of this soil still supports its native covering of grass, brush, and more or less scattered forest. The remainder is cropped to grain hay and grain. The yields are slightly better than on the lighter textured typical soil, but the phase is less accessible and the prices of land of the two kinds is about the same.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the typical Willits fine sandy loam:

Mechanical analyses of Willits fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
575107	Soil	0.1	3.8	4.1	20.2	22.9	35.9	11.9
575108	Subsoil	1.0	2.1	2.3	15.8	18.8	31.8	28.0

KIMBALL GRAVELLY CLAY LOAM.

The surface soil of the Kimball gravelly clay loam consists of a reddish-brown to yellowish-red or dull-red gravelly loam, 12 to 18 inches deep. It contains a moderate supply of organic matter and absorbs and holds moisture well. The subsoil is compact but not as heavy in texture nor as red as in some occurrences elsewhere in the State. It is usually a gravelly loam or gravelly sandy loam, though in many places a compact fine sandy loam is encountered in the lower subsoil. Strata having any one of these three textures are apt to occur at any depth. The color is prevailingly yellowish brown, iron stains giving a reddish cast in certain strata. The lower subsoil may be grayish yellow. The substratum is quite similar to the subsoil in color, texture, and compactness. Water moves with moderate freedom in the subsoil and is held well, owing to the compact structure. Roots penetrate the material without much difficulty.

A variation in the surface material occurs in the larger body of the type lying 1 mile south of the Little Lake School, the texture in the southern half and the western margin of this particular area approximating a gravelly fine sandy loam. Tillage is consequently easier and the soil is a degree more friable than is typical. Some variation also exists in the gravel content, the smaller body situated about one-half mile south of the Little Lake School containing less gravel than is typical for the soil as a whole.

The type is of minor extent and importance, being confined to two areas lying south of the Little Lake School, which is situated in the

eastern part of the survey. It occupies hilly country, with gentle slopes predominating. Drainage is good. The material has been accumulated as alluvial deposits washed mainly from areas of sedimentary formations.

The soil is easily tilled, and when handled in proper moisture conditions works into a favorable seed bed. Over 50 per cent of it has never been farmed and is heavily forested with oak, madrona, pine, manzanita, and brush. Grain and grain hay comprise the only crops. The yields are fairly satisfactory, though not as good as on the adjacent younger Yolo soils.

Conservation of moisture by deep plowing and proper tillage is the most important means of increasing yields.

The following table gives the results of mechanical analyses of fine earth samples of the soil and subsoil of this type:

Mechanical analyses of Kimball gravelly clay loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
575111	Soil	2.6	5.2	3.2	15.3	16.2	31.3	26.0
575112	Subsoil	1.3	4.9	5.2	27.3	18.2	25.7	17.4

YOLO FINE SANDY LOAM.

The surface soil of the Yolo fine sandy loam, to a depth of 15 to 24 inches, consists of a brown, open-structured, friable fine sandy loam. Minor variations in color, ranging from light brown to dark brown or dull grayish brown, occur in a few spots. Along drainage ways and places where streams have overflowed their banks small amounts of gravel are not uncommon and the texture is sometimes lighter and sandier than typical. The soil contains a fair amount of organic matter, is easily tilled, absorbs moisture readily, and retains it quite well. The subsoil of the type is usually a light-brown or yellowish-brown fine sandy loam, containing strata of loam and occasionally of silt loam texture. Areas lying in the lower parts of the valley and adjacent to soils of heavy texture sometimes have layers of dark-brown clay loam or clay in the deeper subsoil. Strips of the type bordering stream ways may contain sandy and gravelly strata. Roots penetrate the subsoil with ease and moisture is absorbed readily and is retained fairly well, except in small areas of especially loose and porous structure.

Four small gravelly areas included with the type are shown on the map by means of symbols. They lie in the vicinity of Outlet in the extreme northwestern corner of the area, along Davis Creek in the southeastern part of the survey, and southwest of Little Lake School.

The Yolo fine sandy loam is of moderate extent, but areas of the type are distributed in practically all parts of the area, in most places as rather narrow strips along streams. It forms parts of gently sloping alluvial fans, stream bottoms, and nearly level areas of alluvial valley plains. It has a smooth surface except where broken by drainage ways. In the higher parts of the small valleys where the streams emerge from the hills, the channels are in many cases between 10 and 20 feet deep. Drainage of the type is excellent, except in small low-lying areas in the northern part of the valley where water stands for several weeks during periods of high water in the intermittent lake.

The soil represents recent alluvial material laid down in its present position by spreading streams. Over much of the type small quantities of fresh material are added during each flood period. The soil materials forming this soil are derived as wash from the various rocks and old valley filling deposits of the region, but originate predominantly from sedimentary formations.

With the exception of some uncleaned brushy strips along a number of the streams the type is practically all under cultivation. The principal crops are grain and grain hay, but there are a few small family orchards and some plantings of potatoes and truck crops. Yields are very good when good methods of farming are practiced. Land values vary from $150 to $200 an acre, the higher price usually being for land in the more elevated southern part of the valley.

Incorporation of organic matter, deep tillage, conservation of moisture, and protection from overflow are factors to be considered in the best utilization of the Yolo fine sandy loam.

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

Mechanical analyses of Yolo fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
575113	Soil	0 6	2.9	3.4	21.2	24.7	32.6	14.9
575114	Subsoil	1.3	3.4	3.9	31.0	25.0	22.1	13.1

YOLO LOAM.

The surface 15 to 30 inches of the Yolo loam consists of a brown to dark-brown medium textured loam, which in places is relatively high in silt and usually possesses a friable open structure. Small quantities of gravel are scattered throughout the soil in many situations, but not in quantities large enough to have any appreciable effect on cultivation. In places spots of lighter or heavier texture than typical exist, but the type as a whole is quite uniform in texture,

The content of organic matter is comparatively large and as a result the power of the soil to retain moisture is above the average.

The subsoil in many places resembles the surface soil in texture but may be slightly heavier, approximately a silty clay loam. The color ranges from medium or light brown to yellowish brown. Along stream ways and old, partly or wholly filled drainage channels some small unimportant areas occur in which the subsoil is gravelly and is composed of stratified materials largely of a light, porous, and sandy nature. While under this condition moisture is not held very tenaciously, the subsoil of the type generally absorbs and holds water very well.

A variation having a dark grayish brown surface soil has been included with the type. The soil is somewhat too dark to be typical Yolo loam, but only a few scattered spots and areas occur, and of these only three areas are large enough or clearly enough defined to merit comment. One is located along the eastern bank of Davis Creek in sec. 17, T. 18 N., R. 13 W. Another lies about 1 mile east, in section 16. The third area is approximately 3 miles northwest of the other two, lying along the State highway in the western part of section 6 in the same range and township. Except for a slightly higher content of organic matter and little greater power to hold water, the variation is of minor importance.

The Yolo loam is the most extensive soil in the area. It is confined to the valley division of the survey and covers the greater part of the valley lands outside of the area covered by the intermittent lake.

The type has a smooth, uniform, gently sloping to nearly level surface, practically the only irregularities being the channels cut by streams. These channels vary in depth from a foot or two, where occurring well out in the valley, to 10 or 20 feet near where the streams emerge from the hills. Drainage is usually good, the important exception being in the northern part of the main Little Lake Valley where small areas are annually subject to overflow and over which water stands for varying lengths of time. The material forming the type has been derived from sedimentary rocks, to some extent from basic igneous rocks, and from old valley filling deposits, reworked and laid down in its present position by spreading streams.

The Yolo loam is the most important soil in the area and most of it is under cultivation. The principal crops are grain and grain hay, of which the yields are good. Small scattered acreages of potatoes and truck crops produce well. A few small orchards, mainly of apples, exist, but most of the trees have not received the best care. The soil is inherently an excellent type for farming, and unfavorable climatic features are the cause of the rather narrow range in crop adaptation. Land values vary from $150 to $200 an acre. Some of the poorly drained land is held at a lower figure.

Deeper tillage, more careful conservation of moisture, and, in the case of orchard culture especially, the introduction of more up-to-date methods, are steps that would increase the returns from this type.

Yolo loam, gravelly phase.—The Yolo loam, gravelly phase, consists of a brown to dark-brown loam, containing a varying quantity of rounded, waterworn gravel, and having a depth of 15 to 30 inches.

The subsoil in places resembles the surface soil closely, but for the most part is a shade lighter in color and in places is in texture a clay loam. The gravel content is normally less than in the surface soil. Roots penetrate the subsoil without difficulty. The soil does not contain enough gravel seriously to interfere with cultivation. The content of organic matter in the soil is moderate to good, and moisture is absorbed readily and held fairly well.

In the northern and northeastern parts of the Little Lake Valley and over a few scattered areas along the western border and north of Willits the gravelly phase has a darker color than typical. Here the soil is dark grayish brown and appears almost black when wet. If of greater extent these areas would have been recognized as a distinct series. The variation is, however, of little importance either in extent or in difference of value for agriculture.

The Yolo loam, gravelly phase, is of moderate extent. With the exception of a few scattered areas along the eastern margin of the area the phase is confined to the northern half of the survey, where areas occur at various points along the margin of the main valley. These occupy gently sloping alluvial fans issuing from the hills and, with the exception of eroded drainage channels, have a smooth surface. Drainage is good. Excepting small areas in pasture, the phase is all under cultivation, being cropped to grain and grain hay. The yields are fairly good. Land values, which vary with location, generally range between $100 and $150 an acre.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the typical Yolo loam:

Mechanical analyses of Yolo loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
575115	Soil	0.5	0.6	1.0	11.9	23.3	44.2	18.6
575116	Subsoil	.4	2.8	2.7	13.0	15.7	44.8	20.6

WAPATO SILT LOAM.

The surface soil of the Wapato silt loam consists of 12 to 18 inches of a dark-brown slightly mottled smooth-textured silt loam, containing a moderate supply of organic matter. The subsoil is somewhat

variable. To a depth of 5 feet it may consist of light yellowish brown silt loam in places somewhat mottled, but strata of fine sand or fine sandy loam are not uncommon in areas near existing abandoned drainage channels. The lower subsoil, from 5 to 6 feet, is everywhere heavier than the upper subsoil, being a clay loam, or silty clay loam, and in places material of this texture and of dark-brown color directly underlies the surface soil. The color of the lower subsoil is brown or light brown and in most areas, mottled. A part of the type occupies the lower part of Little Lake Valley and is subject to annual overflow. The soil is here characterized by a somewhat hard slick surface that offers more resistance to the penetration of water than the higher, better drained areas.

The Wapato silt loam is of moderate extent. It occurs in the northern and central parts of the Little Lake Valley. The surface is smooth and nearly flat, except where broken by shallow drainage ways. The soil is still in process of formation, each year receiving fresh deposits of alluvial material.

Drainage is fair over the higher lying more southerly areas, but elsewhere water stands on the surface for weeks at a time during the rainy period, and it is late in the season before the soil becomes sufficiently dry to be in a fit condition to plow. The soil consists of alluvial material deposited in its present position by streams issuing from areas occupied by sedimentary and basic igneous rock formations and old valley-filling deposits.

The lower lying parts of the Wapato silt loam, which have never been farmed, support a native growth of wild grasses, willow, cottonwood, scattered oak, and brush. Most of the tree and brush growth is confined to strips along the stream ways and to areas where streams spread out and disappear through a system of branching distributaries. The higher and better drained areas of the type in places have a similar growth but a considerable acreage has been plowed, some clearing along the streams has been done, and crops of hay, grain, and to a lesser extent, potatoes have been profitably grown. Wild hay is cut and stock is pastured where the type remains in its virgin state. Land values are variable and depend on the location of the area and the condition of drainage. The better areas under cultivation are held at $100 to $150 an acre.

As is the case with all the soils in the northern half of the Little Lake Valley proper, drainage is the first step in any attempt to improve the land for agriculture. Deep plowing and thorough cultivation are also important and necessary if maximum yields are to be obtained.

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

Mechanical analyses of Wapato silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
575119	Soil	0.6	0.4	0.3	2.6	9.9	66.9	19 1
575120	Subsoil	.4	1.4	1.3	6.1	11.4	53.2	26.2

WAPATO SILTY CLAY.

The surface soil of the Wapato silty clay, to a depth of 12 to 30 inches, consists of a dark-brown to dark grayish brown slightly mottled silty clay. The shallower covering of surface material occurs where the type rather imperceptibly merges into the Wapato silty clay, heavy phase. Adjacent to the Wapato silt loam and other lighter types, as much as 30 inches of top soil, uniform alike in texture and color, is not uncommon. The subsoil is usually of silty clay texture, but is sometimes apparently less silty than the surface material. The color is dark grayish brown and somewhat mottled, and included layers of clay are in many places very dark brownish gray, similar to the subsoil of the adjacent heavy phase of the type. In the lower lying parts mottling is pronounced and a somewhat compact condition exists, but not to the extent of preventing root penetration.

The type, which is of moderate extent in the area, is confined to a single body situated in the lower lying northern end of the main Little Lake Valley. It is characterized by a smooth, uniform, nearly flat surface, and occurs where the lower, flatter, marginal parts of alluvial fans have coalesced to form the bottom of the intermittent lake. The only interruptions in the smooth surface are a few small drainage ways, which seldom attain a width of over 10 feet or a depth of more than 2 or 3 feet. The type has poor drainage being subject to overflow and standing water for several months during the rainy season.

The material forming the soil consists of recent alluvial sediments laid down in their present position by branching distributaries of intermittent streams. Deposition is still taking place during periods of high water.

The type has never been farmed and supports a native growth of wild grasses and a few scattered oaks. Tules flourish over a small part of the lower lying area. The cutting of wild hay and the use of land for pasture form the basis of value of the land and prices are consequently low.

Owing to its untilled condition and the fact that it becomes the bottom of a shallow lake in winter, the soil is packed hard and more or less puddled. If farmed, plowing would undoubtedly prove rather difficult for the first year or two or until such a time as a more

granular, friable condition could be developed. The supply of organic matter is moderate to good, and the soil is retentive of moisture. No permanent or important improvement of this land can take place until it has been thoroughly drained. After this, deep tillage and thorough cultivation, with the purpose of aerating and loosening the soil, should be practiced, care being taken to plow the land only when in the right moisture condition.

Wapato silty clay, heavy phase.—The Wapato silty clay, heavy phase, consists of 15 to 24 inches of dark-brown to a very dark brownish gray clay, somewhat mottled, relatively high in silt. The top inch or two of the soil is often slightly lighter textured and lighter colored than the material immediately below, approximating a dark-brown silty clay loam.

The subsoil is a stiff heavy clay or silty clay, compact and extremely sticky when wet. The prevailing color is very dark gray, almost black, but in the lower lying areas the deeper subsoil, between 5 and 6 feet, is in most places bluish gray. Mottling occurs but not to the same extent as in soils derived from old valley-filling deposits. Water moves very slowly through this heavy-textured material and is held tenaciously. Plant roots find penetration somewhat difficult.

The Wapato silty clay, heavy phase, is confined to a single soil area lying in the lowest part of Little Lake Valley and extending as a narrow strip from the outlet of this depression at its northwestern end, a mile and a quarter to the south. The phase has a smooth nearly level surface, broken only by one or two shallow drainage ways. The land is partly or wholly under water from shortly after the first heavy rains in the fall till late the following spring. Drainage is wholly inadequate. The origin is similar to that of the typical Wapato silty clay.

The land of this phase has never been farmed. It supports a growth of tules and wild grasses. A few oaks occur around the higher better drained margins of the area. At present the only use made of this land is for pasture and it is held at a low price. It could be improved in the same way as the typical soil.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the typical Wapato silty clay:

Mechanical analyses of Wapato silty clay.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
575121	Soil	0.0	0.8	0.7	4.0	2.0	51.6	40.9
575122	Subsoil	.0	.0	.6	1.2	1.4	54.0	42.8

ROUGH MOUNTAINOUS LAND.

Rough mountainous land consists of hilly, mountainous, badly dissected areas too uneven and irregular or rocky to be used for farming.

Most of the soil material is residual in origin, but in the southern part of the area some of it consists of old valley-filling deposits. The controlling factor in its classification is the nonagricultural character of the land. In the soil features other than topography it is like the residual types or old valley-filling types, depending on whether it has the origin of one or the other of these groups.

Rough mountainous land occurs as a belt around the entire survey and covers an extensive area. A considerable proportion of the land supports a moderate to heavy growth of forest, including pine, fir, redwood, oak, and madrona. Here lumbering and the cutting of wood for fuel has been carried on. Other areas are more open and brushy and are utilized as pasture. In some locations, usually more or less inacessible, patches of land an acre or two in extent, are moderately smooth and suitable for farming. Where the soil is sufficiently deep, fair returns from crops are possible in these exceptional areas.

DRAINAGE.[1]

Agricultural development in that portion of Little Lake Valley lying north of the main road running east from Willits is controlled largely by the overflow conditions which exist there during the winter and spring months. Outlet Creek, which passes through a narrow gorge in the extreme northwestern part of the area, furnishes the only means by which the valley is drained, and the insufficiency of this outlet is the cause of this unfavorable condition. Even in years of minimum rainfall a lake forms in the lower part of the valley.

The total watershed drained by this creek above the railroad bridge, one-half mile east of Outlet, is approximately 72 square miles, all but about 11 square miles of which may be considered as hilly to mountainous.

Entering the valley are six more important creeks, namely, Willits or Mill Creek from the west, Broadis, Baechtel, and Hale Creeks from the southwest, Davis Creek from the southeast, and Berry Creek from the east. There are in addition two creeks from the west, one from the south, two from the east and one from the north, which have some influence on the local drainage condition.

Owing to the heavy rains which frequently occur in this region and the limited area and mountainous character of the watershed, all of

[1] This chapter written by Prof. W. W. Weir, drainage engineer, assistant professor of soil technology, University of California.

these creeks are at flood stage at the same time. The rainfall tables given in the chapter on climate show that the annual rainfall may exceed 60 inches; the floods, however, are more nearly in proportion to the severity of individual storms than to the annual precipitation. Accurate daily rainfall records are available for this area only for the period since September, 1911. During this short period, however, it is probable that very near the extremes of both maximum and minimum annual precipitation have occurred. For the seasons ending June 30, 1914, and June 30, 1918, there occurred 64.01 inches and 28.98 inches of rain, respectively. During January, 1914, rain occurred every day from the 12th to the 27th, except on the 16th, with a maximum daily precipitation of 3.01 inches and 3.41 inches on the 21st and 22d, respectively. In February of the same year there were five consecutive days on which it rained in excess of 1 inch, or a total of 8.05 inches for the period. The maximum daily precipitation occurring during the period of these records was 6.50 inches on December 31, 1913.

Although all of these storms caused excessive run-off and high water in the lake, the greatest flood since the valley has become more thickly settled occurred early in February, 1915, and was caused by a storm beginning January 25 and ending February 4, during which time 15.70 inches fell, as follows:

Rainfall during storm—Jan. 25 to Feb. 4, 1915.

Date.	Inches.	Date.	Inches.
Jan. 25	0.36	Feb. 1	2.30
Jan. 26	.08	Feb. 2	4.65
Jan. 27	1.05	Feb. 3	2.26
Jan. 28	.99	Feb. 4	1.02
Jan. 29	.92		
Jan. 30	1.03	Total	15.70
Jan. 31	1.04		

An interesting and significant feature of the drainage of this valley is that although all of the larger creeks have deep, wide channels that occupy a considerable portion of their respective valleys at the point where they enter the main valley, none of them are directly connected with Outlet Creek. The sudden decrease in the velocity of flow in these creeks which occurs upon their entering the main valley has caused them to deposit most of the suspended material which they carry, so that the channels become entirely filled by the time they have reached the flat portion known locally as the lake bed. This condition, combined with the incapacity of Outlet Creek to remove the water as fast as it enters, causes the formation of the lake, which, during the high water of February, 1915, covered approxi-

mately 1,875 acres and was 12 feet deep over an area of about 300 acres. The high-water mark, or shore line, shown on the soil map represents the 1,330-foot contour, at which stage the lake has a storage capacity of approximately 12,250 acre-feet. At the time just referred to, water stood 17 feet deep, or at an elevation of 1,329.4 feet in Outlet Creek at the railroad bridge and at an elevation of 1,324.6 feet, 1,322.1 feet, and 1,315.9 feet, or 16, 15, and 12 feet deep at points three-fourths, 1, and 2 miles below the railroad bridge. It has been estimated that the maximum amount of water entering the valley during a 24-hour period represents a run-off of approximately 3 inches over the water shed or 5,700 cubic feet per second, while during the same period the maximum discharge of Outlet Creek at the railroad bridge was approximately 3,800 cubic feet per second.

A drainage survey conducted by the College of Agriculture, University of California, at the time of the soil survey indicated that it would not be feasible or practicable to construct drainage works of sufficient magnitude to entirely relieve the situation just described. This survey shows that adequate drainage would require that the flood stage of Outlet Creek be lowered to an elevation of 1,318 at the railroad bridge or about 11 feet below the present flood stage, but that owing to the narrowness of the Outlet Creek canyon, the slight fall obtainable and rocky character of the creek bed the necessary improvement could be made only at a great expense and probable encroachment upon the right of way of the Northwestern Pacific Railroad. The survey further shows that an extensive and elaborate system of flood channels or by-passes would be necessary to conduct the flood waters from the points where the creeks begin to overflow to the channel of Outlet Creek at the railroad bridge and that such a system of by-passes would be so expnesive and occupy such a large portion of the area to be reclaimed as to be impracticable.

SUMMARY.

The area surveyed comprises the Little Lake Valley and a part of the surrounding hilly and mountainous country. It is situated in the central part of Mendocino County, Cal., 120 miles northwest of San Francisco. The survey includes 30 square miles, or 19,200 acres, and has a maximum length of about 8 miles and extreme width of 4¾ miles.

The main valley part of the area is an oval basin with the lowest depression at the northern end. The hills and mountains rise rather abruptly around the sides and are gently sloping to steep.

All the streams entering the valley are intermittent. The principal ones are Willits or Mill, Broadis, Baechtel, Hale, Davis, and Berry Creeks. The slopes all flatten out and the stream channels

disappear in the lower end of the valley, Outlet Creek, in the northwestern corner of the survey, ultimately receiving all the drainage and carrying it out of the area. Regional drainage is ample in all except the lower northern end of the Little Lake Valley, where a lake forms each winter.

No figures are available concerning the population of the Willits area, although it is rather sparse. According to the census of 1910, the town of Willits had a population of 1,153. It is the only town of any size in the survey.

The main line of the Northwestern Pacific Railroad and two branches connecting at Willits supply ample transportation facilities. Roads, schools, and other public conveniences are good. The agricultural products grown within the area are either consumed locally or shipped to the markets about San Francisco Bay.

The climate is marked by a wet winter season and a dry summer season, the latter being short and less well defined than is the case in the great interior valley of California or in the smaller valleys along the Russian River to the south. The mean average rainfall for the period 1911 to 1918 is 45.01 inches. Frosts are severe and occur late in the spring and early in the fall. They are the limiting factor controlling the range of crops which can possibly be grown in the area. Fogs are prevalent in winter. Wind velocities are not high.

Agriculture is the main industry, but the only crops grown extensively are grain and grain hay. Truck and fruit crops and poultry are produced on a small scale. Land values are variable and range from $5 to $10 for rather steep and shallow hill soils to $150 or $200 for the best well-drained bottom land.

The arable soils of the Willits area are classified broadly into three main groups: (*a*) Residual soils, or those occupying the hills and mountains and derived by weathering in place from underlying consolidated rock; (*b*) old valley-filling soils, or those derived from unconsolidated, old, weathered, water-laid deposits; and (*c*) recent alluvial soils. This last group is by far the most important. In addition to the soils of the three provinces named above, a class of miscellaneous material designated as Rough mountainous land, which is largely nonagricultural, is mapped.

Agricultural development in the northern lower lying end of the Little Lake Valley is largely controlled by the flood and overflow conditions which exist during the winter and spring months. A drainage survey conducted by the College of Agriculture, University of California, at the time of this survey indicates that it would not be feasible or practicable to construct drainage works of sufficient magnitude entirely to relieve this undesirable condition.

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[PUBLIC RESOLUTION—NO. 9.]

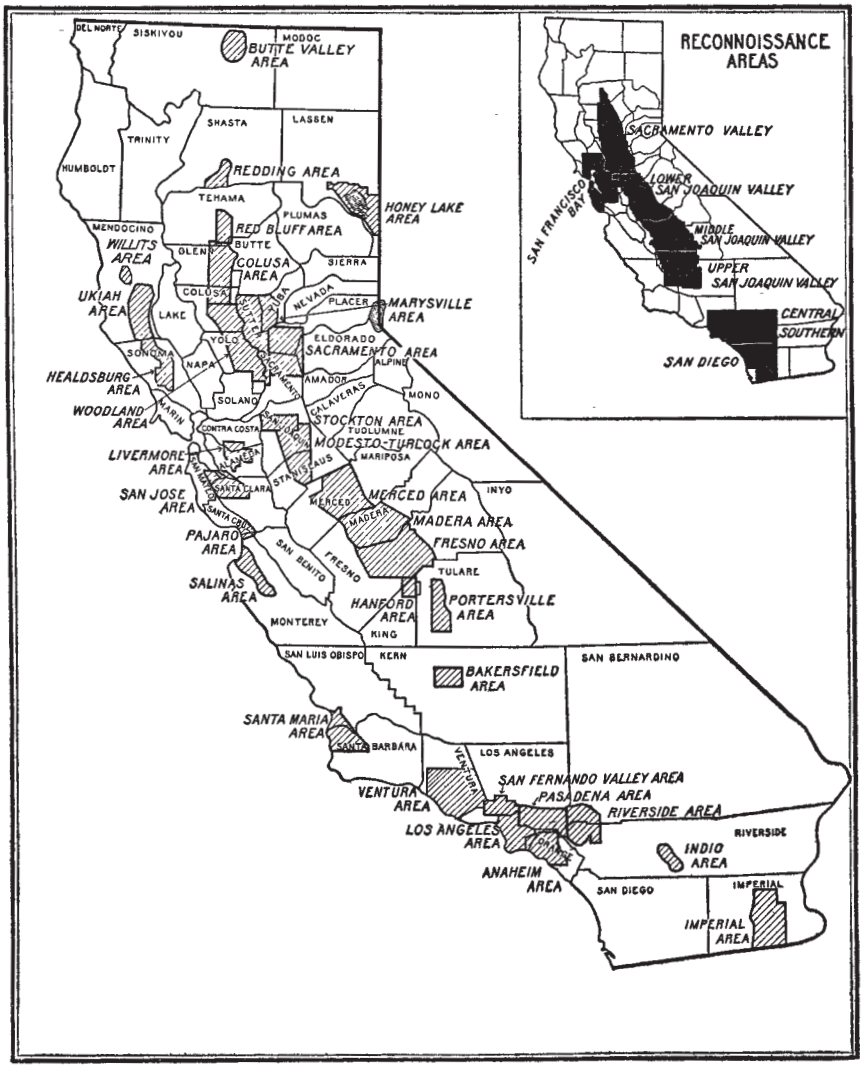
JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided,* That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]



Areas surveyed in California.

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