Issued May 15, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE STATE OF WASHINGTON, M. E. HAY, GOVERNOR; HENRY LANDES, STATE GEOLOGIST.

RECONNOISSANCE SURVEY OF SOUTHWESTERN WASHINGTON.

By A. W. MANGUM and Party.

MACY H. LAPHAM, Inspector in Charge, Western Division.

[Advance Sheets—Field Operations of the Bureau of Soils, 1911.]

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913

BUREAU OF SOILS.

MILTON WHITNEY, *Chief of Bureau.*
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SOIL SURVEY.

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Hugh H. Bennett, Inspector, Southern Division.
J. E. Lapham, Inspector, Northern Division.
Macy H. Lapham, Inspector, Western Division.
J. W. McKericher, Secretary.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
Washington, D. C., August 22, 1912.

SIR: I have the honor to transmit herewith the manuscript report and maps covering the soil survey of an area in southwestern Washington. The work in this area was performed during the field season of 1911, in cooperation with the State of Washington.

The work was supervised by Prof. Henry Landes, State Geologist, and Macy H. Lapham, of this Bureau, inspector in charge of the western division. Mr. A. W. Mangum had immediate charge of the work in the field and was assisted by H. L. Westover and Cornelius Van Duyne, of the Bureau of Soils, and H. K. Benson and T. C. Frye, of the Washington Geological Survey. Prof. E. J. Saunders, of the University of Washington, has contributed a valuable study of the climatic conditions of the area.

I have the honor to recommend the publication of this report as advance sheets of field operations of the Bureau of Soils for 1911, as authorized by law.

Very respectfully,

MILTON WHITNEY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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RECONNOISSANCE SURVEY OF SOUTHWESTERN WASHINGTON.

By A. W. MANGUM and PARTY.

INTRODUCTION.

The area surveyed includes all of Pacific and Wahkiakum Counties, the western part of Lewis County, all of Clarke and Cowlitz Counties, with the exception of a few mountainous townships, and that part of Skamania County that lies south of the National Forest Reserve.

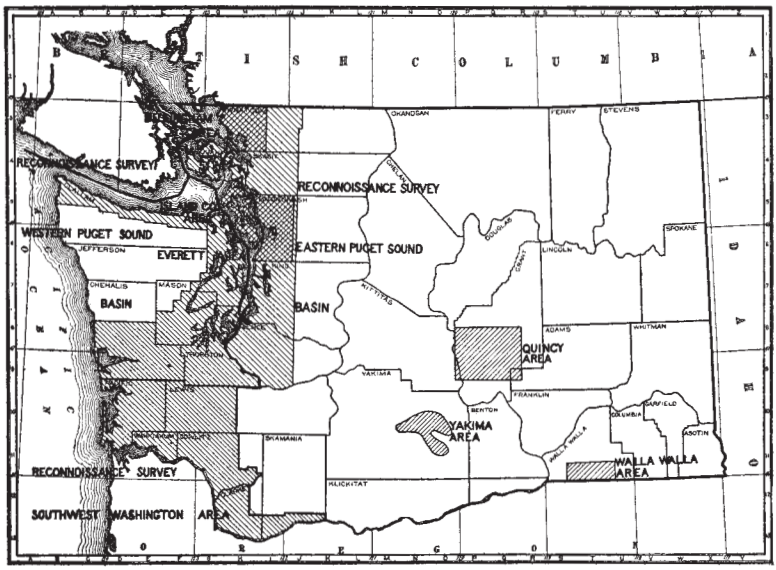

FIG. 1.—Sketch map showing areas surveyed in Washington.

The areas within these counties not covered by the survey consist principally of rough mountainous lands, lands still covered by a dense forest growth, or lands lying within the National Forests. The total area surveyed is 4,136 square miles, or 2,647,040 acres.

BASE MAP.

The base map used in the survey is on the scale of one-half inch to the mile and has been compiled mainly from township plots of

the United States Land Office and from surveys made by the various counties. In many localities, however, the maps were found to be very inaccurate, especially in regard to the road systems. Wherever practicable such errors were corrected by the parties in the field, though in a reconnoisance of this character it was impossible to make a complete revision of the base. A small area in the southern part of Clarke County is embraced by the Portland quadrangle of the United States Geological Survey and this was used as a base map in surveying the soils of this section.

SOIL AND LAND CLASSIFICATION MAPS.

Two maps accompany this report—a general soil map and a land classification map. The soil map gives the location and extent of the various types of soil which occur within the area. In the level to gently rolling sections of the area, where the land is well adapted to agriculture, and in areas that have already been developed agriculturally the soils have been mapped in considerable detail, but in the rough, mountainous sections of little agricultural value and in the regions covered by dense original forest growth it was impracticable to go into the detail necessary to separate isolated areas of soils differing slightly from the main types with which they were associated. Such areas are usually of small extent and have been classed as phases of the principal types, but where they are of sufficient extent or importance they have been indicated on the map by means of a symbol and described separately in this report.

The land classification map shows the extent to which the area has been developed agriculturally and gives, in a general way, the relative agricultural value or possibilities of the soils of the area. This map shows by colors the location and extent of (1) areas under cultivation, (2) areas which have been logged-off or burned over but are undeveloped agriculturally, (3) woodland or areas covered by a nonuniform or inferior growth of timber, classed by cruisers as unsuitable for lumber, (4) areas covered by the original forest growth of merchantable timber, (5) areas of beach and dune-sand, (6) tidal marshes, (7) sparsely timbered gravelly prairies, (8) swampy areas, and (9) unclassified areas included within the limits of cities, towns, and military reservations. The first class represents improved land which has been cleared of the stumps and underbrush and utilized for farming.

The second class represents land from which the merchantable timber has been removed either by lumbering or by forest fires, but which has never been cleared for agriculture. It also includes areas where the merchantable timber has been destroyed by forest fires, but which at present support a scattered growth of young timber. The third class represents land supporting an inferior or nonuniform

growth of timber, sparsely timbered areas, and areas of small timber, classed as unfit for the lumber mills. It also includes areas which have been burned over but are covered by a stand of dead timber, a considerable part of which is still of merchantable quality. Much of the small timber in this class is valuable for poles, piling, and ties. The fourth class represents the dense original forest growth, consisting principally of fir, hemlock, and cedar. This timber has not been damaged by fires and in some localities the stand has been estimated by cruisers to be as much as 50,000,000 to 60,000,000 feet to the section. The fifth class represents areas of drifting sands. These areas are at present of small agricultural value. The sixth class represents the low, marshy and semimarshy areas having only a slight elevation from sea level, which occur along the lower course of the Columbia River and its principal tributaries and along the lower courses of the small streams that empty into shallow bays. The seventh class includes sparsely timbered prairies, which are excessively drained and at present of low agricultural value. The eighth class represents fresh water marshy areas, usually occurring adjacent to inland lakes and not subject to fluctuation of water level due to tides or periodical floods of streams as are the marshy areas included under class six. The areas included under class nine are inclosed within the limits of cities or boundaries of military or other Government reservations and are not generally utilized for agricultural purposes, although locally small tracts may be devoted to the production of garden vegetables or farm crops.

The lands of the area have been separated further into five different classes, which show in a general way the relative agricultural value and the type of agriculture to which the lands are best adapted. These classes are indicated on the land classification map by symbols. The fact that several types of soil fall into the same class does not indicate that they are equally productive but that they are adapted to the same general type of agriculture. This separation of the land with this respect into classes is based on the texture of the soils and subsoils, the topography, natural drainage, tendency to erosion, and the possibilities of successfully developing the land agriculturally.

Class I represents lands which are adapted to general farming and justify immediate agricultural development; class II lands where the soil and moisture conditions are suitable for agriculture, but the hilly topography makes it better adapted to dairying and fruit growing than to general farming; class III land adapted to intensive farming, fruit growing, and pasturage; class IV, mixed lands or areas where small tracts of agricultural lands are scattered throughout extensive areas of nonagricultural land; class V, areas of forests, unclassified.

The lands included in the first class consist of the alluvial soils occupying the broad valleys of the principal rivers, the better drained

portions of the delta flats at their outlets, and the land occupying the level to gently rolling terraces and upland plateaus. The alluvial soils are for the most part very productive, but considerable areas are subject to overflow at times of high water, causing some of the lands occupying the lower depressions to remain in a wet or flooded condition until late in the spring months. As a whole, however, these soils are among the most productive in the area and when well drained they always produce very profitable yields of all crops grown. The alluvial lands are not difficult to clear, but considerable areas require draining or diking in order to put them in a condition suitable for the successful growing of crops. The lands occupying the terraces and gently rolling plateaus are also very productive. When thoroughly cultivated some of these soils produce yields equal to those obtained on the alluvial soils, but as a whole the yields are lighter and the crops grown are more subject to damage by drought. These uplands were originally covered by a heavy timber growth and it is more difficult to clear them and put them in condition for farming purposes than in case of the greater proportion of the valley lands.

The soils of the second class are usually productive, but the hilly topography often interferes with the agricultural development of the land. The difficulty of thoroughly cultivating the soils occupying the steeper slopes makes these lands better adapted to dairy farming than to other types of agriculture, as the areas can be used for pastures and only the more level areas broken for the production of the general farm crops. In some localities the soils occupying the hillsides have been utilized very successfully for the growing of fruits. The third class embraces the lighter textured sandy or gravelly soils. Owing to the open porous character of both the soil and subsoil it is difficult to conserve sufficient moisture for the successful growing of crops. The cost of clearing the land is so great and the moisture conditions are so unfavorable that only the intensive cultivation of small tracts has proved profitable. The fourth class includes the soils of the rough hilly and mountainous sections of the area. Most of the lands in this class contain a large percentage of stones in both soil and subsoil. The topography is steep and broken and areas of rock outcrop occur frequently. A large proportion of this land is of little or no agricultural value, but small level to gently rolling benches or upland plateaus seldom more than 160 acres in extent occur at frequent intervals throughout the areas of rougher land, and these are comparatively free from stones and are well adapted to agricultural purposes. The surrounding areas, however, are so rough and broken that the better tracts are frequently almost inaccessible. The fifth class embraces extensive areas still covered by a dense forest of fir, hemlock, and cedar. These forest lands are at present valued mainly for the heavy growth of timber they support. The areas of tidal marshes

and sand dunes and the areas which have already been developed agriculturally are also included in this class. These areas have been indicated on the map but are unclassified, as this classification deals only with the undeveloped agricultural lands of the area.

DESCRIPTION OF THE AREA.

The area surveyed, with the exception of the eastern part of Skamania County, lies west of the Cascade Mountains. The counties of Skamania, Clarke, Cowlitz, Wahkiakum, and Pacific border the Columbia River, which here forms the boundary line between the States of Washington and Oregon. This river also forms the southern and the greater part of the western boundary of the survey. Pacific, the extreme western county included in the area, is bounded on the west by the Pacific Ocean. The part of Lewis County included in the survey lies between Pacific County on the west and the Cascade Mountains on the east.

TOPOGRAPHY AND DRAINAGE OF SKAMANIA AND CLARKE COUNTIES.

The area surveyed in Skamania County consists of a narrow strip lying between the Columbia River on the south and the National Forest on the north. It varies in width from about 14 miles in the western part to less than 4 miles in the eastern part. In one locality—T. 3 N., R. 9 E.—a narrow area of the National Forest extends down to the Columbia River. Between Cape Horn and Underwood the Columbia River passes through the Cascade Mountain range in a deep gorge, the sides of which are often almost perpendicular walls of basalt.

The topography of the greater proportion of the area surveyed in Skamania County is rough and broken. Narrow, comparatively level benches or terraces sometimes occur along the Columbia, but for the most part the slopes of the mountainous to hilly uplands extend down to the present channel of the river. Back from the river the land rises in a series of steep, rocky bluffs, with level to gently rolling benches or plateaus at the summit of each slope. The country has the general appearance of being very rough and broken, but the series of benches gives it as a whole a terracelike topography, and extensive areas of level to gently rolling land occur at frequent intervals.

Farther back from the river, along the boundary of the National Forest, the topography becomes more rugged and mountainous, some of the higher peaks reaching an elevation of 5,000 to 6,000 feet above sea. Here the benches and plateaus are of small extent and occur principally along the lower slopes, bordering the courses of the larger streams.

The regional drainage of this part of the area is furnished by the Washougal and North Fork of the Washougal, which traverse the western townships; the Wind and Little White Salmon Rivers, which rise in the mountains to the north and empty into the Columbia between Stevenson and Underwood, and the White Salmon River, which forms the eastern boundary of the area and empties into the Columbia just east of Underwood. Many other smaller streams, such as Rock Creek, rise in the rough mountainous or hilly country and traverse the area in a general southerly direction, emptying into the Columbia River.

The topographic features of Clarke County consist of (1) level to gently undulating alluvial lands bordering the Columbia River, (2) gently rolling terrace lands, and (3) hilly to mountainous districts.

The alluvial valley of the Columbia is quite narrow in the eastern part of the county, and as the distance from the mountains increases it becomes broader, until along the southwestern and western boundaries of the county it has an average width of from 1 to 2 miles. The valley floor has the general appearance of being level, but low mounds and ridges, with shallow basins intervening, give it as a whole a gently undulating topography. Many shallow sloughs and basins which have only a slight elevation above the level of the river and contain water throughout the entire year occur at frequent intervals over this section of the area.

The terrace lands, which form a large proportion of the southern and western parts of the county, have the appearance of having been at one time comparatively level, but they have been eroded to such an extent by the numerous small streams which traverse this section that they have for the most part a gently rolling to rolling topography. Many extensive areas occur, however, which have a level to very gently undulating surface. The largest of these occur in the southern part of the county and are locally known as "Mill Plain" and "Fourth Plain." The hilly to mountainous region occurs in the northeastern part of the county. In this locality many of the hills reach an elevation of 4,000 to 5,000 feet above sea level, and the topography is often rough and broken.

Clarke County is drained principally by the Columbia River, which forms its southern and western boundaries, and by the Lewis River, forming its northern boundary. Salmon Creek and the South Fork of Lewis River also drain a considerable area in the northern and central parts of the county.

TOPOGRAPHY AND DRAINAGE OF LEWIS AND COWLITZ COUNTIES.

The topography of the western part of Lewis County is very rolling and hilly, becoming rough, broken, and mountainous in the

extreme southwestern corner. There is, however, a narrow belt of level valley land, having an average width of about 1 mile, bordering a branch of the Chehalis River, which traverses this section of the area. Both the northeastern and southeastern corner of the area surveyed in this county have a broken and hilly topography. A broad level to gently rolling plateau, embracing several townships, occurs east of the Northern Pacific Railway and between the Cowlitz and Newaukum Rivers. The level valley lands bordering the principal rivers have an average width of from 1 to 4 miles.

The Chehalis River and its main tributaries, consisting of the West and South Forks of the Chehalis, the Newaukum and Skookum Chuck Rivers, drain the greater proportion of the townships surveyed, with the exception of those in the southeastern corner, which are drained by the Cowlitz River and its small tributaries.

The characteristic topographic features of Cowlitz County are the level to gently rolling alluvial stream bottoms and terraces, the hilly areas, and the mountainous region. The alluvial bottoms and terraces embrace only a small proportion of the county. The principal areas of this class range in width from 1 to 3 miles and occur along the Cowlitz and Columbia Rivers. Other smaller bodies, however, occur along the larger stream courses in other parts of the county. These lands constitute the most valuable agricultural lands in the county. All of the central portion, including approximately two-thirds of the area surveyed in the county, falls into the hilly group. While some of these hills reach a comparatively high elevation and have rather steep slopes, only a small part of the land is too rough and broken for cultivation, and quite extensive areas of level to gently rolling land are often encountered on the summits of the hills and ridges.

The mountainous areas are confined chiefly to the extreme eastern and western parts of the county. The principal area embraces nearly all of the region lying east of R. 2 E. Another large area, covering approximately one and one-half townships, occurs in the extreme northwestern part of the county. While many small bodies of agricultural land occur in these areas, the greater part of the mountainous land is too rough and rocky for farming.

With the exception of the western tier of townships, which are drained principally by a number of small creeks emptying into the Columbia River, all of the county is drained by the Cowlitz, Kalama, and Lewis Rivers and their tributaries. The Cowlitz and its tributaries drain a larger proportion of the county than all of the other streams combined. The Kalama and Lewis Rivers, which drain the southern and southeastern parts of the county, rise in the mountainous districts and empty into the Columbia.

TOPOGRAPHY AND DRAINAGE OF PACIFIC AND WAHKIAKUM COUNTIES.

The topographic features of Pacific County consist of (1) mountainous districts, (2) hilly uplands, (3) alluvial bottoms, tide flats, and terraces, and (4) sandy areas bordering the Pacific Ocean. The mountainous district occupies a considerable area of the central and also a large proportion of the eastern and southeastern parts of the county. Numerous ravines and V-shaped valleys, narrow, rocky ridges, and areas of rock outcrop give these districts a rough and broken topography. The higher peaks attain an elevation of 5,000 to 6,000 feet above sea level. Nearly all of the principal streams of the county rise in this district. Small areas of less broken and even of comparatively level lands occur within the limits of the mountainous districts, but they are too inacessible to be used for agriculture.

The hilly uplands occupy the greater part of the remainder of the county. They consist of the lower hills and ridges between the mountainous districts and the alluvial valley lands. These uplands are traversed by numerous V-shaped valleys and ravines, but on the whole are comparatively free from areas of rock outcrop and have a less broken topography than the mountainous districts.

Narrow, comparatively level bottoms occur along most of the principal streams. These bottoms gradually become wider as the lower courses of the streams are approached, and near the outlet of the tidewater streams low, level, marshy areas exist, known locally as "tide flats." The small areas of terrace, or second bottom lands, which occur in some of the valleys are comparatively level.

The sandy areas occupy a strip one-half mile to 1 mile along the beach in the northwestern corner of the county and a long narrow peninsula which extends northward from a point near North Head, separating Willapa Bay from the ocean. These areas consist of a number of low, rounded ridges of sand, between which are long, narrow lakes and marshes, or bodies of Muck. A strip of drifting sand and sand dunes often occurs along the beach.

Willapa Bay receives the drainage water of the greater part of Pacific County. The drainage of a small part of the southeastern part reaches the Columbia River through Grays River and some of its tributaries, and a still smaller area in the east central part drains to the eastward into the Chehalis River through Elk Creek and other small tributaries. The Columbia River also receives a small part of the drainage water from the extreme southern part of the county through the Wallacut and Chinook Rivers. The streams which form the drainage system east of Willapa Bay are in order from north to south: Smith Creek and Willapa, Bone, Palux, Nemah, South Nemah, Nasel, and Bear Rivers. These streams rise in various parts of the rolling to hilly uplands. Cedar River, which drains the

extreme northwestern corner of the county, and North River empty into Willapa Bay from the north. The North River, with its chief tributary, Fall River, also drains the northeastern corner of the county, but for the most part the course of the river is just north of the county boundary line. Willapa River is the largest stream in the county. Its chief tributaries are the South Fork of the Willapa and Fairchilds, Wilson, Mill, Forks Prairie, Half Moon, and Trap Creeks. The Nasel is next in size, and its main tributaries are the South Fork of the Nasel and Salmon and Alder Creeks.

The area surveyed in Wahkiakum County may be separated broadly into four topographic divisions: (1) Mountainous regions; (2) hilly uplands; (3) the high plateau in the southeastern part of the county; and (4) the alluvial bottoms, "tide flats," and terraces.

The mountainous district occupies the northeastern part of the county. Its topography is rough and broken, with many narrow V-shaped valleys and steep, rocky ridges. The streams in this region are swift and have many rapids and falls. Their channels are either cut down into the bedrock or filled with gravel, cobbles, and bowlders.

The hilly uplands, which embrace the greater part of the county, consist of rolling to broken hills and ridges, increasing in elevation and ruggedness toward the northeast. These uplands differ from the mountainous district mainly in having a lower elevation and in being almost free from areas of rock outcrop, and the area of agricultural land is greater in this region than in the mountains. The southeastern part of the county is a high, gently rolling to rolling plateau, which is cut by several V-shaped valleys. Near the eastern border this plateau breaks away toward the Columbia River in a precipitous and sometimes almost perpendicular bluff of basalt. To the north the plateau becomes more and more rolling until it merges into mountainous districts. Except where the areas of tide flats occur, the uplands extend down to the present channel of the Columbia River and have a steep and often precipitous slope toward the stream.

Narrow alluvial bottoms occur along the lower courses of all of the larger streams of the county. In the case of the streams emptying into Grays Bay, such as the Deep and Grays Rivers and Crooked Creek, the bottom-land areas become wider near the mouths of the streams, and together with the deltas form quite extensive areas of tide flats. The most extensive area of tide flats occurs as a delta formation between the Skomaukee Creek and Alochaman River. Puget Island, in the Columbia River, is similar to these delta flats. The topography of both the bottom lands and tide flats is almost level, but the "flats" are traversed by many sloughs and old-stream channels.

Three streams and their tributaries compose the main drainage system of Wahkiakum County—Grays River, in the western and northern parts; the Skomaukee Creek, in the central; and the Alochaman River, in the eastern part. Deep River, Crooked Creek, and a few other small streams also assist the drainage of this section. All these streams flow into the Columbia River, as do several small streams draining the southeastern corner of the county. The extreme northwestern part of the county is drained by the Nasel River and Salmon Creek, which empty into Willapa Bay.

SETTLEMENT.

Clarke and Lewis are the more thickly-settled counties in the area surveyed. In these counties the alluvial valleys and the more level terrace lands have the most dense populations. A large proportion of the rolling to hilly uplands are very sparsely settled, while the rough and mountainous districts are practically uninhabited. The present settlement of Skamania County is confined almost wholly to the level to gently-rolling bench lands which border the valley of the Columbia River. Farther back from the river, where the county becomes more broken and mountainous, no settlement has taken place, except on the terraces bordering some of the larger rivers and in a few small isolated basins or valleys. In Cowlitz County the main settlements lie along the valleys of the Columbia, Cowlitz, and Lewis Rivers. Small areas, however, have also been developed in the uplands in all parts of the county with the exception of the rough, mountanious districts.

A very large proportion of both Wahkiakum and Pacific Counties is still covered by a dense forest growth or is in the undeveloped state of logged-off land. In Wahkiakum County the settlement has taken place mainly along the alluvial valleys of the Columbia and other principal rivers, while in Pacific County it is confined almost wholly to the river valleys, the delta flats, and the region around Willapa Bay.

CHIEF TOWNS.

The principal towns and cities located within the area surveyed consist of Centralia and Chehalis, in Lewis County, which have a population of about 8,000 and 5,000, respectively; Kelso, Castlerock, Kalama, and Woodland, in Cowlitz County, which are cities of from 400 to 2,000 inhabitants; Vancouver, in Clarke County, having a population of about 10,000; Stevenson, a town of about 387 inhabitants, located in Skamania County; Cathlamet and Skamokawa, located in Wahkiakum County, which are towns of from 200 to 400 inhabitants; and South Bend and Raymond, cities of from 2,500 to 3,000 inhabitants, located in Pacific County.

TRANSPORTATION.

All of the counties in the area surveyed have the advantage of transportation facilities by both water and rail. In Lewis County, however, water transportation is restricted, as boats can only run on the Cowlitz River during the winter and spring months, when the water in the streams is high.

The main lines of the Northern Pacific, Union Pacific, and Great Northern Railroads between Seattle, Wash., and Portland, Oreg., traverse Lewis, Cowlitz, and Clarke Counties, using a common track. A branch of the Northern Pacific Railway running from Centralia to South Bend, crosses Pacific County and the western part of Lewis County. A branch of the Tacoma & Eastern, which will traverse a part of the eastern portion of Lewis County, is now in course of construction. Another branch of the Northern Pacific passes through the northern part of Lewis County, connecting Centralia with the Grays Harbor branch of this road at Gate, Thurston County. The southern parts of Clarke and Skamania Counties are traversed by the Spokane, Portland & Seattle Railway, which follows the north bank of the Columbia River and connects with the Northern Pacific, Union Pacific, and Great Northern railroads at Vancouver, Wash. A branch of the Northern Pacific extends across Clarke County in a general northeast to southwest direction, connecting Vancouver with Yacolt. Several of the smaller towns and settlements in Clarke County are connected with Vancouver by an electric road.

The Ilwaco branch of the Union Pacific traverses the southwestern part of Pacific County, running from Megler, on the Columbia River, to Nahcotta, located on the narrow peninsular separating Willapa Bay from the ocean.

The river steamboats furnish all of the towns along the Columbia River with excellent transportation facilities for both passengers and freight. Willapa Bay, on the coast of Pacific County, is an excellent harbor, having about 28 feet of water at its entrance, and ocean steamers from various ports of the United States and foreign countries touch at the ports of South Bend and Raymond. A great many of the farmers along the Columbia River and Willapa Bay own small gasoline boats for use in transporting their products to the local markets. Vancouver and several other towns on the Columbia have a regular ferry service to the towns on the Oregon side of the river.

MARKETS.

The products of the numerous large lumber mills are shipped to almost every part of the United States and to foreign countries. The greater proportion of the agricultural products are sold on the local markets, but considerable shipments are also made to Portland,

Seattle, and to other of the larger cities along the coast. Almost all of the fruit grown in the area, with the exception of the prunes, is sold in the local markets. The prunes are dried and packed in the area and are there shipped in carload lots to various parts of the United States or are exported to foreign countries. The greater part of the output of the dairy farms is sold to the local creameries. However, considerable quantities of milk and butter produced in Clarke County are marketed in Portland. There are several large cities, such as Portland, Seattle, and Tacoma, within easy reach of all parts of the area surveyed, and these furnish a good market for all the more perishable farm produce not sold in the small local markets.

CLIMATE.[1]

GENERAL CLIMATIC CONDITIONS.

The climate of the area is determined by its position on the western slope of the Pacific coast mountains directly in the path of the prevailing westerly winds and the accompanying storm vortices which move over it from the Pacific Ocean. The greater part of the area is thus subject to the moderate winter and summer climate which is characteristic of large bodies of water. It is also protected by the Cascade Mountains and the other ridges north and east of it from the climatic extremes that are characteristic of the continental interior, which would otherwise be brought to it by occasional north and east winds.

The constant but irregular changes in the weather are caused by the movement of low-pressure areas or storm vortices across the area in an easterly direction. Toward these centers the air moves from all sides and ascends spirally. If they pass north of the section the winds blow from the south, are warm, and usually cause heavy precipitation, because the air becomes cooler. But if they pass south of the section the winds blow from the north, are cooler, and because the air is becoming warmer, cause less precipitation. These low-pressure areas or cyclones are accompanied by high-pressure areas or anticyclones, in which the air is slowly descending and moving spirally outward. They cause clear, cold weather in the winter, and warm, clear days, with cool nights, in the summer. Thus the weather conditions during any particular month or season will vary with the intensity, number, and position of these low-pressure and high-pressure areas which pass over this section of the State in their journey eastward.

The topography of the area plays such an important part in determining its climatic conditions that it may be well to notice the relations of the larger topographic features before describing the

[1] Prepared by E. J. Saunders, of the University of Washington.

climate in detail. A low mountain ridge, extending southward from the Chehalis River gap to the Columbia River, separates Willapa Bay on the coast from the southern part of Puget Sound Basin. The Cascade Mountains rise gradually east of this basin to elevations of 5,000 to 10,000 feet, the somewhat regular slopes being surmounted, west of the summit, by Mount Rainier, 14,500 feet high, and Mount St. Helens, about 10,000 feet high.

These features divide the section into climatic belts. The warm, moisture-laden winds, moving eastward under the influence of the prevailing westerlies and the storm vortices, are forced to ascend the western slopes of the coastal ridge, and, cooling, cause heavy precipitation—from 60 to 90 inches a year. This has been called the wet belt. As the air moves on eastward over the low-lying basin country the precipitation is much less because of the lower elevation and the fact that the air has given up a large portion of its moisture in passing over and around the coastal ridges.

This belt has been called the moist belt, having a precipitation of 40 to 60 inches a year, with a dry summer season. Then as the air is forced to ascend the western slope of the Cascade Mountains precipitation again increases until the summit is reached, where the rainfall is over 80 inches. There is thus produced a second wet belt. On the leeward side of the Cascades the precipitation gradually decreases until there is less than 20 inches a year, and this part of the area is known as the arid belt.

PRECIPITATION.

The average annual precipitation of the area (see fig. 2) shows a variation from over 80 inches on the west slope of the coastal ridge (Aberdeen 86.41 inches, South Bend 89.19 inches) to less than 20 inches on the leeward slope of the Cascades (Goldendale 15.53 inches, Fort Simcoe 12.81 inches). The lack of stations in the mountains and the short period of years during which observations have been kept at some of the stations make it difficult to arrive at a satisfactory average in all parts of the section, but the general distribution of precipitation is shown from obtainable data.

The heavy precipitation on the west slope of the Coast Mountains is caused by the forced ascent of moisture-laden air as it moves eastward and northward into the storm vortexes as they pass across the northern part of the State. This causes an increasing precipitation until the summit of the ridge is reached. Thus at North Head the precipitation is 64.05 inches, while at South Bend, farther inland, it is 89.19 inches, and if there were stations at higher elevations on this slope we should probably find over 100 inches precipitation, as in the Olympic Mountains, farther north.

East of this ridge, in the Puget Sound Basin and in the basin drained by the Cowlitz River, the total precipitation is much less. At Olympia it is 55.23, at Centralia 45.77, and at La Center 54.33 inches. In general this decrease in precipitation is explained by the increased distance from the ocean, the lower altitude, and the fact that the air in passing over and round the coastal ridge has been deprived of part of its moisture. The fact that Olympia and La Center show higher average precipitation than Centralia and Vancouver may be explained by their position directly east of Grays Harbor gap and Columbia River gap, respectively, which would allow the air to move inland still heavily moisture laden.

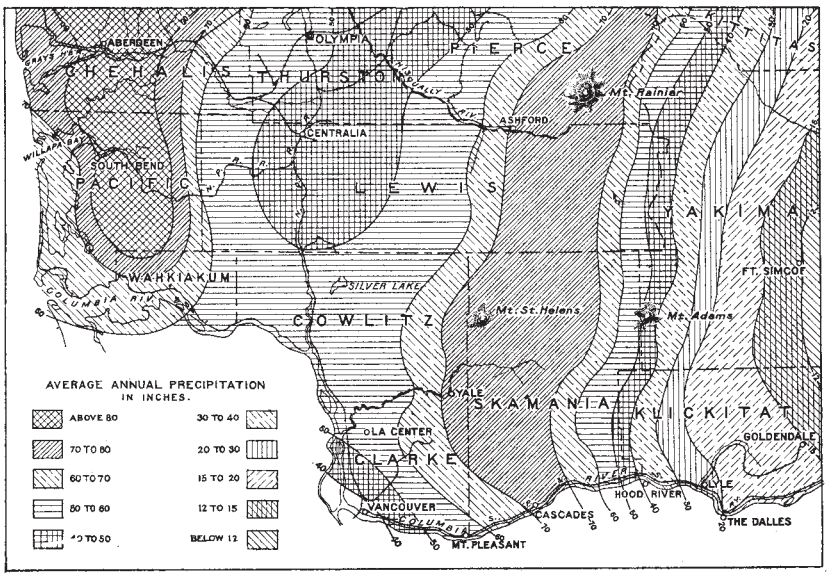

FIG. 2.—Sketch map showing average annual precipitation.

As the air is again forced to ascend the western slope of the Cascades the total precipitation becomes greater, and at Ashford there is 70.74 inches a year and at The Dalles 77.60 inches a year. After crossing the summit and descending on the leeward side the total precipitation quickly decreases because the moisture has been taken from the air in its passage over the mountains, and in descending the air is mechanically warmed and its capacity for moisture thereby increased. The total precipitation is 25.89 inches at Lyle, 25.91 inches at Cle Elum, 15.53 inches at Goldendale, and 12.81 inches at Fort Simcoe.

For the coast stations the greatest precipitation recorded for any year is 105.24 inches at South Bend and the least is 45.02 inches at North Head. In the Sound Basin the greatest amount recorded is 70.77 inches at Olympia and the least is 30.50 at Vancouver. On the

east slope of the Cascades, of the stations included Cle Elum has the highest for any year (34.51 inches) and Fort Simcoe the lowest (6.22 inches).

The snowfall of the area varies from 5 or 10 inches at the coast stations to 75 or 90 inches at the Cascade stations, decreasing very little on the east slope. The average is 83.5 inches at Cle Elum and about 49 inches at Lyle. The absence of stations in the mountains makes it impossible to give a correct estimate of the average amount of snow at the summit, but it is safe to say over 100 inches, and some years it is as high as 180 or 200 inches at the stations lower down on the slopes. At the lower elevations, and especially along the coast, the slight fall remaining on the surface only a few days at

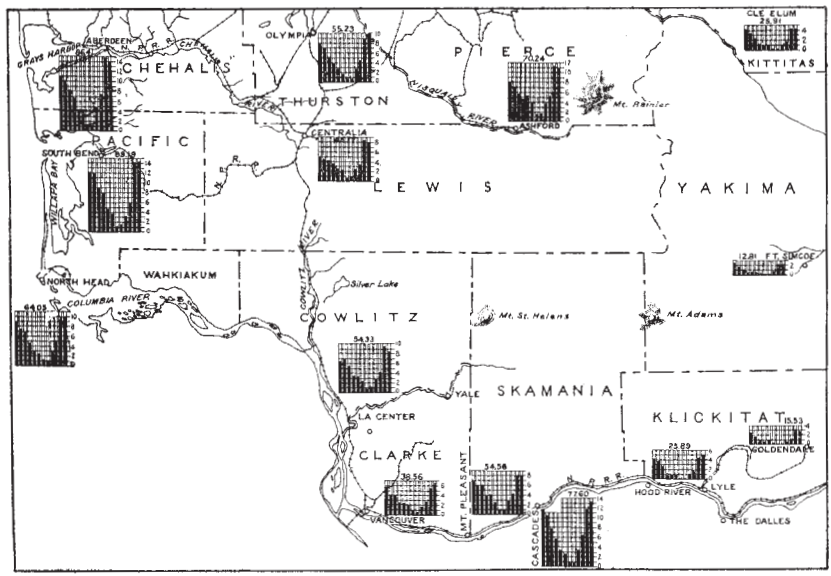

FIG. 3.—Diagram showing average monthly precipitation.

most has scarcely any effect on the general climatic conditions, but in the mountains it collects in large amounts and, remaining from year to year, greatly modifies the temperature conditions and the water supply of the streams, many of which have their source in the snow fields, and thus have a fairly constant supply even during the dry summer season. These streams, other conditions being favorable, should furnish excellent water power and water supply for irrigation and other uses.

The average monthly distribution of rainfall at the different stations is shown in figure 3. For all the stations, even those on the east slope of the Cascades, it will be noticed that there is a strong winter maximum of precipitation, more than half of the total pre-

cipitation occurring in the four months November, December, January, and February. For the coastal belt about 75 per cent of the total occurs in these four months, and in most cases November has the maximum monthly precipitation. For the stations on the eastern slope of the Cascades there is a less marked difference between the precipitation of the summer and winter months because of the continental influence in this locality, as seen in the heavy summer showers.

The reasons for the concentration of the precipitation in the winter months are: (1) The cyclonic or storm areas passing over the section from the west are more numerous and better developed in the winter than in the summer, thus causing more frequent and heavier precipitation in the winter months; (2) during the winter the ocean is warmer than the land, and the air laden with moisture moving from the warmer ocean is cooled quickly as it moves inland over the cooler land mass, thus causing rapid condensation and heavy precipitation. Condensation is increased as the air is forced to ascend rapidly in passing over the mountains. During the summer, however, the ocean is cooler than the land, and the air moving from the cooler ocean to the warmer land is not cooled sufficiently to cause the heavy precipitation that occurs in the winter. This effect is emphasized by the fact that the winter winds along the coast are prevailingly from the southwest and become cooler as they blow northward, thus causing more rapid condensation; while in the summer they are prevailingly from the northwest, becoming warmer as they blow southward and inland, and therefore do not cause heavy precipitation.

The November maximum of precipitation is no doubt due to the fact that during this month there are fewer prolonged cold spells which interfere with the landward movement of moisture-laden air than during December and January and therefore a greater number of days with heavy precipitation.

An important element in the climate of a section is the number of rainy, cloudy, and clear days. But the observations for cloudiness, being noninstrumental in most cases, are not as reliable as other climatic data. The following table gives for all the stations along the coast and for a few of the interior stations the annual means for the period covered by Weather Bureau observations:

Means of snowfall, rainy, cloudy, and partly cloudy days, southwestern Washington.

	Snow-fall.	Rainy days.	Cloudy days.	Partly cloudy days.	Clear days.
Coast stations.	*Inches.*				
Aberdeen	15.7	175	142	101	122
North Head	3.3	201	197	90	78
South Bend	4.9	160	104	89	172
Average	7.9	179	148	93	124
Basin stations.					
Olympia	10.0	163	152	124	82
Centralia	11.3	162	130	123	112
La Center	11.4	157	110	140	115
Vancouver	8.9	153	142	109	114
Average	10.4	158	134	124	106
East slope Cascades.					
Lye	49	127	145	108	112
Cle Elum	83.5	116	77	96	192
Average	66.2	121	111	152	152

The average year along the coast would have 179 days on which more than 0.01 inch of rain might be expected, 148 cloudy days, 93 partly cloudy days, and 124 clear days. The year in the interior basin would have 158 days with rain, 134 cloudy days, 124 partly cloudy days, and 106 clear days. The year on the eastern slope of the Cascades would have 121 rainy days, 111 cloudy days, 152 partly cloudy days, and 152 clear days.

The relative humidity of the air west of the Cascades is always higher than on the east slope and causes low and high temperatures to be felt more than they are east of the Cascades.

TEMPERATURE.

The mean annual temperatures show a variation of about 7°, from 45.3° at Cle Elum on the east side of the Cascades to 52.2° at Vancouver on the west side. But this slight variation in mean annual temperature gives very little idea of the actual differences in temperature between the different parts of this section, as it has a marine climate, with rather even temperatures the year round on the west side and a continental climate with high summer and low winter extremes on the east side of the Cascade Mountains.

The mean annual range of temperature, or the difference between the average temperatures of the warmest and coldest month is quite different in different belts of the area. The coastal stations show a very low annual range of only 20.5° at South Bend, with a Janu-

ary average of 42.1° and a July average of 62.6°; and still lower, 16.2° at North Head, with a January average of 41.8° and a July average of 57.9°. The basin stations show a slightly higher range, 29.3° at Vancouver, with a January temperature of 37.7° and a July temperature of 67°. Centralia has a range of 25.8°, with a January average of 38.5° and a July average of 64.3°.

The stations on the eastern slope of the Cascades show a still higher range. Cle Elum, with a January average of 28.4° and a July average of 63.8°, has a mean range of 35.4°; and Lyle, with a January temperature of 33.8° and a July temperature of 69.8°, has a mean annual range of 36°.

The absolute annual range in temperature shows similar marked differences on the west and east side of the mountain ridges. The highest temperature recorded at South Bend is 103° and the lowest 12°, giving an absolute range of temperature of 91°. At North Head the range is 98°, or from 104° to 6°. In the interior basin the absolute range goes as high as 106° at La Center, from 100° to —6°, and 104° at Vancouver, with a maximum of 105° and a minimum of 1°. On the eastern slope of the Cascades the absolute range is much greater. At Lyle it is 127°, with a maximum of 105° and a minimum of —22°, and at Cle Elum 128°, with the highest 104° and the lowest —24°.

Athough these extremely high and low temperatures are occasionally recorded, such extremes rarely occur, especially along the coast. East of the mountains the higher summer temperatures are more common and one or more cold waves may be expected each winter.

The average daily range of temperature is remarkably low for the coastal stations but somewhat higher for stations farther inland, especially those on the east slope of the Cascades. In both cases the greatest daily ranges occur during the summer months when, with bright, warm days, the evenings are generally quite cool and pleasant.

While this remarkable uniformity of temperature may be accounted for by the fact that the winds come from the Pacific Ocean, which is warmer in winter and cooler in summer than the adjacent land areas, and thus causes higher winter temperatures and lower summer tempeatures than would otherwise occur, we must take into account also the effect of the low pressure or storm areas. The usual winter track of these storm-producing areas is so far to the northward that southerly and southwesterly winds prevail, and these being warmer cause higher temperatures. Then, too, the condensation of the moisture carried by these moisture-laden winds causes an appreciable rise in temperature and thus increases the warming effect of the southerly oceanic winds. As a result of these conditions the rainy days which accompany the passage of a cyclonic area to the north of the section,

and of which there are a considerable number during the winter months, are particularly mild and enjoyable. When the storm center is so far south that northerly winds prevail, the weather is generally fair, and if a high pressure or anticyclonic area extends over British Columbia we have cold northerly or northeasterly winds and a cold spell usually results, with snow flurries or clear, frosty weather. These cold spells are infrequent, while the warm spells are of frequent occurrence during the winter, and thus the mild winters are interrupted by only one or two colder spells, which are generally of short duration.

During the summer very few well-developed storm areas move over the section and the winds coming from the Pacific, and gener-

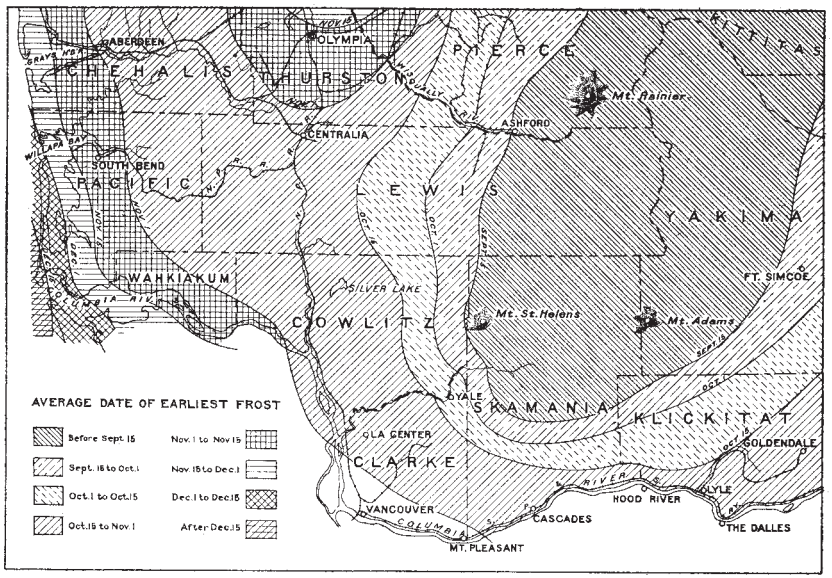

FIG. 4.—Sketch map showing average dates of earliest frosts in fall.

ally from a northerly direction, moving toward the continental low-pressure area to the southeast, cause low temperatures with considerable cloudy weather but little precipitation. At this time dry weather prevails and the nights and forenoons are cool, while the afternoons are pleasantly warm. When a high-pressure area extends over British Columbia and eastern Washington the days are clear and warm with pleasant, cool nights.

KILLING FROSTS.

From the dates on which the earliest killing frosts in the fall and the latest killing frosts in the spring have occurred at the different stations, the average date in each case has been worked out and the results platted in figs. 4 and 5. Although there is great irregularity

in the dates in the different years, these maps indicate approximately for the different belts the dates between which the earliest and latest frosts may be expected. As they usually occur under the influence of an extensive high-pressure area, the date in any particular year is apt to be the same for a number of stations. The marine influence and the influence of altitude are well shown on the map, also the influence of river valleys, which either allow the cold air to drain away toward lower levels or, if wide and flat, allow the colder air to collect in them from the surrounding slopes and thus are subjected to earlier and later frosts than the adjacent uplands.

The earliest killing frosts in the fall occur in the Cascade Mountain belt on the east slope, the average date for Cle Elum being Sep-

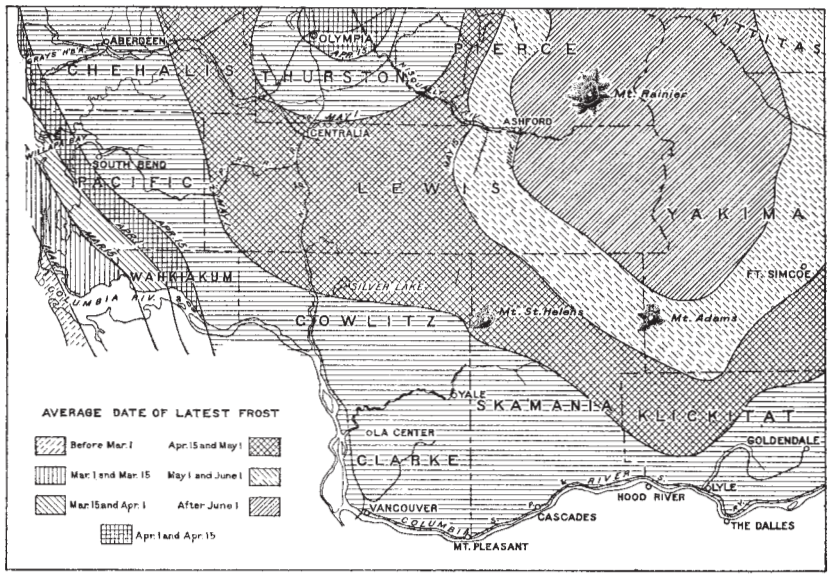

FIG. 5.—Sketch map showing average dates of latest frosts in spring.

tember 7 and for Lyle October 18, and frosts have occurred at Cle Elum as early as August 12 and at Lyle as early as September 21. On the west side the average date for first frost is October 14 at Centralia, October 22 at Aberdeen, November 5 at Olympia, and November 12 at Vancouver; and frosts are recorded as early as September 8 to September 20 at these stations. At North Head the average date is December 22 and the earliest frost recorded is November 26. From these figures it will be seen that frost may be expected on the west side any time after September 15, but commonly does not occur until October 15.

The latest killing frosts in the spring are also recorded at the stations on the eastern slope of the Cascades. At Cle Elum the average

date is June 9 and at Lyle April 23, and frosts have occurred as late as July 26 and June 18 at these two stations.

On the west side the average dates are as follows: Centralia, May 6; Aberdeen, April 27; Olympia, April 16; and Vancouver, April 18. Frosts have occurred as late as June 3 at Centralia and about May 18 at the other stations. At North Head frost is not apt to occur after February 9, but has occurred as late as March 23.

WINDS.

The winds of the section are prevailingly from the west, but they are modified in the summer and winter by the different relations of the high and low pressure areas over the Pacific Ocean and the interior of the continent in the two seasons. During the summer the prevailing high pressure over the Northern Pacific Ocean causes northwesterly winds along the coast, while in the winter the passage of the cyclonic areas in rapid succession to the north and high pressure over a more southerly portion of the Pacific Ocean causes southwesterly winds. Variable winds are caused by the passage of cyclonic and anticyclonic areas, the direction depending on the position of the station in regard to the centers of low or high pressure. Thus, an anticyclonic area to the east will cause an easterly or northeasterly wind, while a cyclonic area to the north and east will cause southerly and southwesterly winds.

The winds seldom attain a velocity of more than 45 miles an hour, the average high winds in the winter blowing from 25 to 45 miles and in the summer at a somewhat lower velocity. The total number of windy days on the west side is small, and there are fewer windy days in the summer months than during the winter months.

During the summer the west and northwest winds from the ocean are cool and usually cause cool, cloudy weather or light rainfall. The northeast and east winds, coming from the interior, are warm and dry, causing warm days and cool nights with the highest diurnal variation of temperature during the year.

During the winter the southwest and west winds are warm and moist, causing heavy rainfall and warm weather, with very little diurnal variation of temperature. The northeast and east winds, from the east side of the Cascade Mountains, are cold and bring with them the low temperatures of the interior, causing the cold spells of the winter season.

SUMMARY.

The climate along the coast and western slope of the Cascades is decidedly marine in character. The low annual and daily ranges, the slow and rather slight changes in temperature, and the decided winter maximum in precipitation, with a very light rainfall in the

summer, are the striking features of the climate. Few realize that in this section the summer conditions, at least for four months, amount practically to aridity and make irrigation necessary for full growth of fruits and vegetables. The idea that it rains all the time, even during the winter months, is decidedly erroneous. There are many clear, pleasant days during the months of maximum rainfall, and the rainy days, except occasionally when accompanied by high winds, are warm and pleasant and are looked forward to with pleasure after a few days of cold, frosty weather, which are the result of the passage of a high-pressure area. The conditions from May to October are ideal for outdoor life and not warm enough to be unpleasant for those who have to stay in the city. During these months there are on the average from 5 to 12 rainy days per month, very few days on which the thermometer registers temperatures above 85°, and no oppressively hot nights.

On the eastern slope of the Cascades, however, extremes of temperature are more common, but the air is dry, and thus the high and low temperatures are not as noticeable as they would be on the coast. Warm winds in the winter and cool winds in the summer help to moderate the temperatures and, when not too strong, furnish a pleasant relief from the extremes in summer and winter.

As has already been stated in other reports, many have ascribed this equable climate of the western coast to the Japan current and any changes that may occur between one year and another to changes in the Japan current. It is true that the Japan current raises the temperature of the North Pacific a few degrees above what it would be if no current existed, but even this effect would not be felt on our coast if it were not for the prevailing westerly winds. As has been already shown, the prevailing westerly winds, the cyclonic storms, and the condensation of the moisture contained in the air are the chief factors in causing equable conditions along the coast. No permanent changes of climate are shown by the records, and any slight differences that may be observed between the weather of two winter seasons or two summer seasons, or even between two months, can be easily accounted for by irregular variations in the path of the cyclonic storms as they pass eastward over the coast. If the storm areas are south, the winds will be from the north and cooler, clearer weather will result; but if north, the winds will be from the south and warmer weather, with more abundant rainfall, will follow.

AGRICULTURE.

The first settlement of the area began about 1825 at Vancouver, which was a trading post of the Hudson Bay Company. As the population of this settlement increased small tracts of the surrounding lands were put under cultivation. Areas of the gravelly terrace

lands adjacent to Vancouver have been cultivated for over 50 years. Small grains and potatoes were the principal crops grown by the early settlers.

The lumber industry has been the principal factor in the development of the area. The entire region surveyed, with the exception of the alluvial lands along the Columbia River, the "tide flats," and a few small gravelly prairies, was originally covered by a dense forest; and a large part of the rolling upland districts, especially in Pacific and Wahkiakum Counties, still supply a heavy growth of fir, hemlock, and cedar. The lands bordering the larger streams were the first to be cleared of the timber, and consequently the greater part of the agricultural development has taken place in the alluvial valleys and along the adjoining level to gently rolling terrace lands. A larger area of land has been brought under cultivation in Clarke and Lewis than in any other counties included in the survey, as a large proportion of the extensive terrace and alluvial stream bottom lands which occur in these counties were cleared of timber at an early date, and the level topography and productive soils make them well adapted to farming.

Agriculture has progressed more slowly in the rolling uplands. The cost of clearing the land of the stumps and underbrush is so great that only small areas are under cultivation. The logs and underbrush are usually removed by burning, and the land is then sowed to grasses and used for pasture. Dairy farming is the principal industry in the upland districts. Small dairy and fruit farms are located throughout the uplands of Clarke, Cowlitz, and Lewis Counties, but in Pacific, Wahkiakum, and the greater part of Skamania the uplands have been developed to a much less extent.

The average cost of clearing the logged-off uplands of the stumps, logs, and underbrush and getting them in condition for the cultivation of crops ranges from $50 to $150 an acre. General farming is practiced mainly on the alluvial stream bottom and terrace soils and on the soils occupying the upland farms, where large areas could be cleared at a comparatively small cost. Hay and small grains, chiefly oats, are the principal crops grown, although a small acreage is also planted to potatoes, orchard fruits, small fruits, and vegetables. A more intensive agriculture is practiced on the small acreages cultivated in the uplands than in the areas of more level topography. In the former districts small tracts are cultivated to fruits, small fruits, potatoes, and vegetables, while the larger partially cleared areas are utilized as pasture for dairy stock. Throughout all of the upland districts dairy products are the principal source of income. Over a large part of Clarke County and the eastern part of Skamania County fruit growing is the most important branch of agriculture,

and large areas of the level to gently rolling terrace and bench lands are in orchards.

Prunes are grown to a limited extent in various parts of the area, but in Clarke County extensive areas are planted in prune orchards, and the growing and curing of this crop is one of the most important industries in this section of the survey. In Clarke County more than 6,000 acres are planted in prunes, and where the land is well cultivated and the orchards are well taken care of a very fine quality of fruit is produced. Many carloads of the dried fruit are shipped out of the area annually, and this crop has become one of the principal sources of income to the farmers of the southern part of the area. During an average season these orchards produce from 4 to 8 tons of the green fruit per acre. When the fruit is of good quality and has not been damaged by the cool rains of the early fall months about 3½ tons of the green fruit produces 1 ton of the dried product. If, however, the fruit is of an inferior quality it sometimes requires 4 tons or more of the green fruit to make a ton of the dried product. Other fruits, such as apples, pears, cherries, plums, and quinces are also grown to a limited extent in almost all sections of the area. In most localities these fruits are not grown on a commercial scale, and the small orchards seldom produce more fruit than is necessary for home use or to supply the demands of the small local markets. The majority of the orchards receive little or no attention, but when properly cared for the trees grow very rapidly, mature early, and produce a very fair quality of fruit.

Cherries do exceedingly well in many parts of the area, annually producing very large yields of a fine quality of fruit. The Royal Ann and Lambert are the principal varieties grown. Pears do well on many types of soil, the Bartlett, Anjou, and Comice being the most common varieties.

Fruit growing on a commercial scale is beginning to receive more attention in all the counties included in the survey, and the shipments to markets outside of the area are annually increasing.

The growing of apples is rapidly becoming of considerable importance in the eastern part of Skamania County (see Pl. I, fig. 1). The region lies on the eastern side of the Cascade Mountains and receives less rainfall and a larger number of sunshiny days than the remainder of the area. The climatic conditions of the section seem very favorable for the production of a fine quality of apple, and when well cared for the orchards do exceedingly well without irrigation. There are several old orchards in this locality which annually produce large yields, although little or no attention was given to the trees after they were planted. During recent years, however, the adaptability of this part of the area to fruit growing has begun to be recognized and a considerable acreage has been planted to

apples and peaches. None of the recently planted apple orchards are yet old enough to produce a full crop of fruit, but the peach trees are producing good yields.

Apple trees are usually planted about 30 feet apart, and the peach trees are then set out between the rows. When the apple trees are matured the peach trees are removed. Some of the orchard land is cultivated also to potatoes or strawberries or to a cover crop, such as vetch or Canada field peas. As a rule the trees are sprayed twice a year—once when they begin to bud and again when they are in bloom. The Spitzenberg, Delicious, Yellow Newton, and Arkansas Black are the principal varieties of apples, while the Late Crawford and Early Crawford are the most common varieties of peaches. The peach trees usually begin bearing in about 3 years, but it usually requires 5 to 6 years for the apple trees to come into bearing.

Small fruits, consisting mainly of red raspberries, blackberries, loganberries, and strawberries, are grown to some extent in all the agricultural districts of the area and produce excellent yields. The evergreen blackberry grows wild in many places; but as yet no attempt has been made to cultivate it, although this fruit has proven very profitable in the counties farther north. The growing of winter strawberries has proved very profitable in some sections of Pacific County. These berries ripen in September, October, and November, and some are put on the market as late as the early part of December. The Magoon berry is the variety grown. During the earlier part of the season the blooms are pinched off, preventing the vines from bearing until late in the fall. The area cultivated to these berries is small, but the crop commands very high prices. These strawberries are usually grown on areas where deposits of Peat and Muck have been covered by a shallow layer of sand. Such areas are usually found along the boundary between light sandy types of soil and the basins occupied by deposits of peat and muck.

In the western part of Pacific County there are approximately 100 acres of Muck in cranberries. (See Pl. I, fig. 2.) These Muck lands are first drained by means of open ditches. The surface, 3 to 5 inches, which has a fibrous, peaty texture, is then removed, and the underlying muck is covered to a depth of 4 to 5 inches by a layer of sand. The sandy covering is laid down over the surface by means of a pump. These deposits of organic matter are in a poorly drained condition and are underlain by sand. A hole is dug to the underlying sand and water, and the sand is pumped out and distributed evenly over the surface. The removing of the fibrous surface material is known as "scalping," while the process of covering the surface with sand is called "sanding." The cost of preparing these Muck areas for cranberry culture, including clearing, drainage, scalping, and sanding, varies from $250 to $500 an acre; but after the

land is planted in cranberries there is little or no expense in connection with the production of the crop outside of the cost of picking, packing, and shipping the crop to market. The sanding of the land is necessary in order to keep out the weeds, prevent the spoiling of the berries, and to keep the berries off of the damp, mucky soil. The average yield ranges from 75 to 130 barrels per acre, but it usually requires about 4 or 5 years for the plants to come into full bearing. The acreage of muck soil utilized for the growing of cranberries is increasing, but the amount of land suitable for this crop is relatively small. The cost of the undeveloped cranberry lands ranges from $100 to $300 an acre.

Oats are grown extensively on some of the alluvial bottom and terrace soils and to a less extent on a few of the upland types (see Pl. II, fig. 1). The oats produced are of the best quality, and large yields are always secured. The yield obtained on the alluvial soils ranges from 50 to 100 bushels per acre, while the upland types produce from 40 to 80 bushels per acre. A small quantity of wheat is grown in some sections. The yield of grain is very high, some of the land producing 30 to 40 bushels per acre; but the berry is of very poor quality, and little, if any, is used for milling purposes. Hay is grown extensively in almost every part of the area. Clover and timothy do exceedingly well on many types of soil, often producing 3 to 5 tons per acre. Kale does well and is grown to a considerable extent on many of the dairy farms. It produces a large tonnage per acre and is used as a winter forage crop for dairy stock. Vetch is grown as a cover crop in many of the small orchards and is also used for feeding purposes. Alfalfa is grown without irrigation on a small acreage in several parts of the survey. This crop does fairly well, and where a good stand has been secured three cuttings a year are obtained.

Irish potatoes are one of the staple crops of the area. This crop is grown successfully on almost every type of agricultural land and seldom, if ever, fails to produce profitable yields. The yields vary from 150 to 500 bushels per acre, depending on the character of the soil and the efficiency of cultivation. Hops were formerly a very important crop in almost every county included in the survey; but the uncertainty of securing good prices for the crop has resulted in a great decrease in the acreage cultivated to it, and in many localities hop growing has been entirely discontinued. A large acreage is still grown in Lewis County. The yields range from 1,200 to 2,000 pounds per acre, and during recent years the high prices obtained have made this a very profitable crop.

Flax and hemp are grown to some extent on some of the alluvial soils in Lewis County, but the acreage planted to these crops is so small that they are at present of relatively little importance.

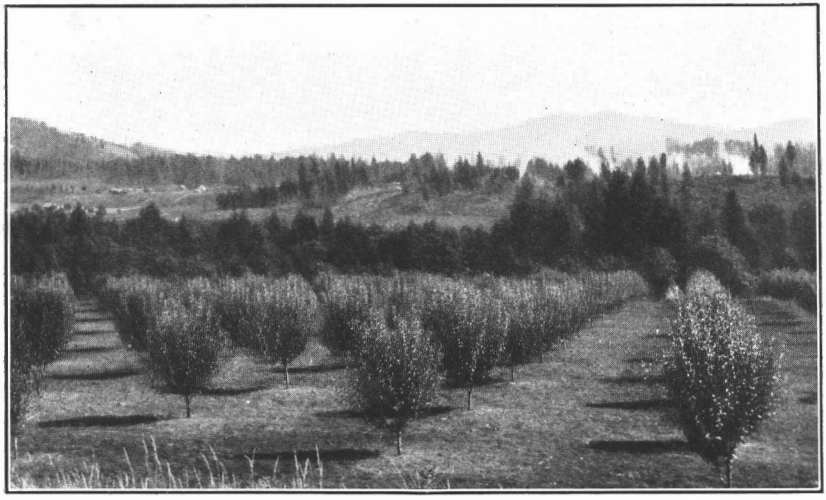

FIG. 1.—APPLE ORCHARD NEAR UNDERWOOD, SKAMANIA COUNTY.

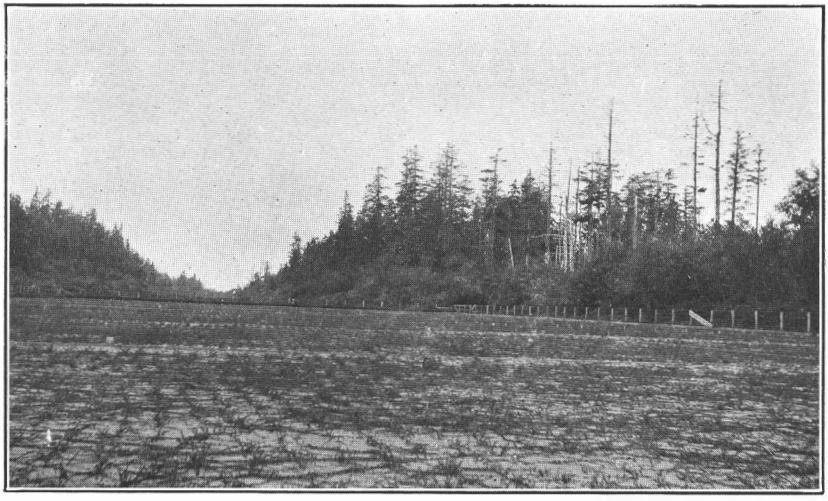

FIG. 2.—NEWLY PLANTED CRANBERRY BOG, PACIFIC COUNTY.

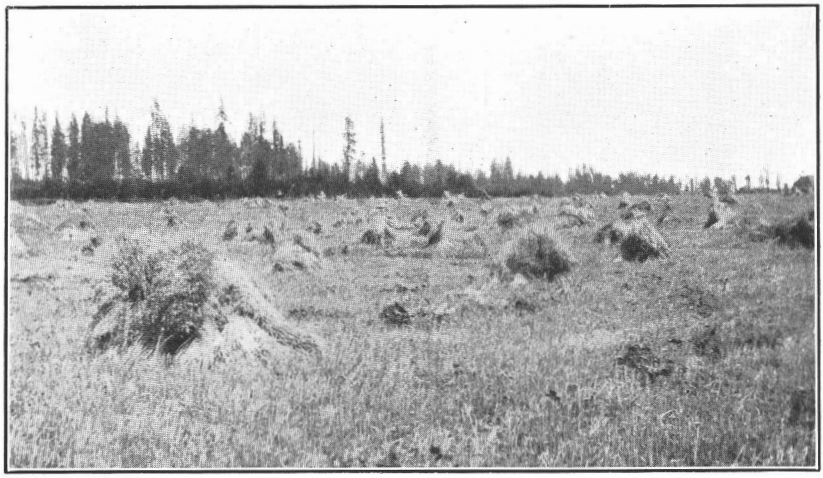

FIG. 1.—OATFIELD ON FELIDA SILT LOAM, NEAR VANCOUVER.

FIG. 2.—DUNESAND ENCROACHING ON FOREST GROWTH.

Garden vegetables, such as peas, beats, carrots, turnips, pumpkins, squash, lettuce, celery, cabbage, cauliflower, and rhubarb, are grown in almost every part of the area. A small quantity of truck is shipped to Portland but these crops are grown mainly for home use and to supply the small local markets.

Dairy farming is one of the most important industries in the area, and in many localities dairy products are the chief source of income to the farmers.

The climate and soils seem well adapted to the growing of forage crops. Kale, vetch, clover, and timothy give abundant yields, and there is usually pasturage throughout the winter. The mild winter climate makes it unnecessary to provide warm shelter for the stock. During recent years the greater proportion of the farmers throughout the area have replaced their old dairy stock with highly improved breeds of cattle.

A large plant for manufacturing condensed milk is located in Lewis County, and small creameries are found in almost every farming community of the area. These plants furnish a ready market for all the milk and cream produced, and in many sections the supply is not sufficient to meet the demands of the local markets.

The milk is collected and brought to the creameries or condensing plant by agents of these establishments, who make daily trips over certain routes. In some localities cream separators are used on the farms, and the cream is taken to the creameries by the farmers.

In some sections of the area the raising of improved breeds of stock is becoming an important industry. The climatic conditions, the abundance of pure water furnished by the many small streams and rivers, and the fact that good pasturage is available throughout the greater part of the year renders a large part of the area surveyed well adapted to the raising of horses, dairy and beef cattle, and hogs.

Poultry farming is carreid on very profitably on many small areas of rough or partially cleared land near the larger local markets. Poultry products bring good prices and this industry is rapidly growing in importance.

The area as a whole has been developed agriculturally to such a slight extent that little is known concerning the especial adaptation of the crops grown to certain types of soil. There are several types of soil within the area that have never been cultivated and there are many others of which only small areas have been farmed. Muck and Peat are used in the growing of cranberries and winter strawberries. The heavy silty loam soils of the alluvial valleys are better adapted to the small grain and hay crops than those occupying the rolling uplands. The soils found in the small upland basins are also well adapted to the production of oats and hay, and when well drained

they often produce yields equal to those obtained on the alluvial valley soils. The Puget silt loam and Puget fine sandy loam seem well adapted to the growing of truck crops, but as yet they are not used extensively for trucking. The well-drained silt loams and silty clay loams occupying the terraces and gently rolling uplands are the best soils in the area for the production of fruits. This is especially true of the eastern part of Skamania County, where both the soil and climatic conditions are favorable to fruit growing.

No regular system of crop rotation is practiced in the area. In some localities potatoes or small grains are sometimes followed by some hay or forage crops, but most frequently the land is planted to the same crop for many consecutive years.

The agricultural methods in general use throughout the area are, as a rule, poor. Deeper plowing would be beneficial on almost every type of soil. On the uplands and terraces the plowing should be done in the fall, as this will put the soil in better condition to take up the moisture during the winter months and cause it to break up into a loamy, friable condition when replowed in the spring. During the growing season the surface should be given frequent shallow cultivation in order to prevent the loss of soil moisture by evaporation.

Over the greater part of this area no atempts are made to keep the soils in a productive state. This can be done by a more general use of barnyard manure, a systematic rotation of crops, and the growing and turning under of vetch, Canada field peas, or some other leguminous crop. Lime would also be beneficial on almost all of the soils, especially those occupying the rolling uplands.

The usual method of clearing the land of logs and underbrush by burning it over is often very injurious to the soils, but the great expense involved in clearing the logged-off lands by any other means seems to make this method necessary. The burning destroys a large amount of the humus in the soil and leaves the land in an impoverished condition. This may be remedied to some extent by the application of barnyard manure and by growing and turning under the green manuring crops mentioned.

The majority of the orchards in the area are given very little attention. When well cared for and thoroughly cultivated the trees always produce good yields, but in many localities the trees are not sprayed or pruned and receive little or no cultivation.

The farm labor employed in the area is very efficient and commands good wages, but owing to the constant demand for laborers by the lumber mills and logging camps it is usually very scarce, especially during the season for harvesting the grain crops.

The majority of the farms in the area are operated by the owners, although small tracts are often rented for cash or farmed on shares.

The larger farms are located in the alluvial valleys or on the comparatively level river terraces. The area under cultivation on these farms seldom exceeds 320 acres, while the average would be only about 40 to 80 acres. In the upland districts the difficulty of clearing the land causes the average farm to be much smaller than those located in the alluvial valleys. In many parts of the rolling uplands small tracts of 5, 10, or 20 acres are cultivated, while the larger areas seldom exceed 40 or 50 acres.

The value of the farm lands of the area varies considerably according to their location in relation to the local markets and railroads, with their topography, with the general character of the soils, and with the extent to which they have been developed. The highly productive lands, located near the larger local markets, is held at $300 to $500 an acre. The logged-off and partly cleared lands, which could be profitably utilized for agriculture, range in value from $10 to $40 an acre, while some of the Rough stony land, not well adapted to farming, is valued at $2.50 to $10 an acre. The lands which are still covered by forests are at present valued according to the character of the timber they support.

Better farm practices, such as deeper plowing, more frequent shallow cultivation of the surface soil, the general use of barnyard manure on all of the soils, the use of lime on the heavier upland types, systematic rotation of crops, which includes the growing and turning under of vetch, Canada field peas, or some other legume, are recommended to increase the productiveness of the soils of the area.

SOILS.

The soils of the area have been separated broadly into 6 groups, the separation being based upon their geological origin, process of formation, and general topographic features. These groups are as follows:

(1) Residual soils, or those formed directly from weathering of underlying rocks in place and including (*a*) soils of the rolling to hilly upland districts, (*b*) soils of the rough, mountainous districts.

(2) Soils derived from alluvial material deposited over former flood plains of the larger streams or as outwash plains. They occupy terraces now elevated well above existing flood plains. This group is subdivided into (*a*) soils derived from glacial material; (*b*) soils derived mainly from nonglacial material.

(3) Soils derived from recent alluvial flood plain and delta deposits, which include (*a*) soils of the recent or present flood plains, and (*b*) alluvial and sedimentary estuarine deposits of tidal flats and river deltas.

(4) Soils derived from deposits in shallow lake basins or poorly drained depressions, mainly of lake-laid sediments.

(5) Soils derived from marine beach and from eolian or wind-laid deposits.

(6) Soils derived maily from accumulations of organic matter.

Under the above broad grouping of the soil material the soils have been further classified into soil series and soil types. There are 23 distinct series, comprising a total of 54 types, and 4 classes of miscellaneous material not recognized as falling under the series classification. The separation into soil types is based upon differences in color, texture, and structure of the soil and subsoil material, origin, processess of formation, and relation to agriculture. The soil series include soils similar in all the characteristics mentioned, with the one exception of texture.

Areas occur throughout many of the principal soil types which vary slightly from the typical soil in texture, topography, and color, or in uniformity of depth of the surface soil. These areas, however, are of small extent and are due to the modification of the typical soil by erosion, the presence of a larger quantity of organic matter in the surface soil, or to other local influences. In a reconnoissance survey of this character no attempt was made to go into the detail necessary to separate the areas covered by such phases from the main types with which they are associated. The more important phases of the types, such as the presence of gravel or rock fragments in the soil or subsoil, or areas where the soil has only a shallow depth above the underlying bedrock, have been indicated on the soil map by means of symbols, while the location, extent, and general character of the less important phases are referred to in the description of the several types where such conditions occur. The general characteristics of the soils of the various groups and series are briefly as follows:

RESIDUAL SOILS.

(*a*) Soils of the Rolling and Hilly Upland Districts.

The soils occupying the rolling to hilly upland districts of the area are derived directly from the weathering of the underlying rocks. These consist mainly of a massive volcanic formation, for the most part basalt, but in places andesitic or related rocks. The soils are uniformly of fine texture, principally clay loams and silty clay loams. Many of them are closely related, two or more types often being derived from the same geological formation, though differing in texture, color, topography, or natural drainage, or in their content of fragmental rock or organic matter. The parent rocks contain a considerable quantity of iron, and the derived soils are generally light brown to reddish brown in color. The weathering of this basalt and other closely related rocks gives rise to the soils of the Olympic series, the Aiken series, and the Underwood series.

A large part of the rolling uplands in Pacific and Wahkiakum Counties, and also considerable areas in Lewis and Cowlitz Counties, are underlain by Tertiary shales and shaly sandstones. Along some of the ridges extensive areas of a hard, fine-grained sandstone occur, but the material derived from this rock has entered into the formation of the soil only to a slight extent and is usually overlain by the arenaceous shales and argillaceous sandstones, which weather rapidly to a considerable depth, giving rise to the reddish-brown silty clay loam of the Melbourne series. The small streams cut through the soft sandstone and shales very rapidly, forming deep, V-shaped valleys between the narrow ridges. The soil along the steeper slopes is usually very shallow, and in some localities it has been entirely removed by erosion, leaving areas of the underlying rock exposed on the surface.

Within this group are also included most of the areas mapped as Rough stony land. The material so classed consists of areas usually of rough topography. The soil is shallow and rocky, being either broken by rock outcrop or of stony character. It is without agricultural importance.

(*b*) Soils of the Rough Mountainous Districts.

In the rough mountainous districts no attempt has been made to map the soils in the detail observed in those parts of the area better adapted to agriculture.

The texture of the fine earth composing the soil of the rough mountainous districts varies from light loams to silty clay or clay loam. Most of the types carry a large quantity of small, angular gravel, bowlders, and large rock fragments, both on the surface and in the subsoils. Small areas occur at intervals throughout this region which would be classed as Rough stony land in areas where more detailed mapping were possible. On the other hand, small benches or plateaus frequently occur where the soil is practically free from stones and could be profitably used for farming, and would be recognized as individual soil types in a more detailed survey. Those areas are, however, usually of small extent, and, in addition, the rough character of the surrounding country makes them almost inaccessible.

The soils of the rough mountainous areas are derived through weathering from the underlying basalt and other closely related volcanic rocks. The soil occupying the steeper slopes is very shallow and stony, and large areas of the bedrock are often exposed at the surface. Near the summits of the higher mountains occur many steep bluffs, almost perpendicular walls of basaltic rock. The soils along the lower, more gentle slopes and on the small, comparatively level benches or plateaus are usually deep, as they are formed to

a large extent from material which has worked its way down to these more level areas from the precipitous slopes of the higher mountains. The soils of the mountainous districts are included with those of the Olympic series, previously noted as occuring in the rolling to hilly districts.

SOILS OF THE ALLUVIAL TERRACES AND OUTWASH PLAINS.

(*a*) Soils Derived from Glacial Material.

The soils occupying the terraces formed from glacial material occur along the courses of rivers which rise in the glaciated mountainous districts.

The material from which the most of such soils are derived was deposited during the time when these stream valleys served as an outlet for the waters from melting glaciers. The principal terraces of this character lie along the Lewis and Cowlitz Rivers. The outwash material here consists almost wholly of more or less stratified deposits of sand, rounded gravel, cobbles, and small bowlders. The soils derived from this material are of light-brown to reddish-brown color and have a light sandy or gravelly texture, which causes the natural drainage to be excessive. These soils belong to the Everett series, previously recognized in the surveys of that part of the State lying west of the Cascade Mountains and north of the area included within this survey. As previously recognized, however, the Everett series includes material of both the unmodified drift or till and the modified drift or outwash deposits, and the series does not characteristically occur as stream-valley terraces.[1]

Along the Toutle River, and to a less extent along the Lewis and Kalama Rivers, occurs a series of moderately recent terraces, the most of which are not greatly elevated above the present stream flood plains. The lower of these have been formed by stream deposits of rather recent date, the material being derived from erosion of earlier deposits of glacial material lying nearer the headwaters of the streams. As mapped, however, the material includes some earlier glacial outwash deposits and some small areas of undifferentiated glacial till. Typically the material is composed of fine sand, sand, and gravels, derived chiefly from pumice and a very porous andesitic rock, occurring in the vicinity of Mount St. Helens, deposited along these valleys by glacial waters. The thickness of these terrace deposits is unknown, but wells along the Toutle Valley show that it often exceeds 40 feet. The gravels found in the formation consist principally of fragments of pumice and porous andesite, but a few

[1] See Reconnoissance Soil Survey of the Eastern Part of the Puget Sound Basin, Washington., Field Operations of the Bureau of Soils, 1909; and Reconnoissance Soil Survey of the Western Part of the Puget Sound Basin, Field Operations of the Bureau of Soils, 1910.

rounded fragments of basalt are also present. The three types of soil derived from these deposits are recognized as members of the Toutle series.

Along the valley of the upper part of the Cowlitz River and extending northwestward to the valley of the Chehalis River occurs a series of terraces which represent old glacial outwash plains. These terraces are underlain by imperfectly stratified deposits of gravel, consisting mainly of small, rounded fragments of basalt. Data obtained from wells indicate that the gravel formation extends to a depth of more than 150 feet. Overlying the gravel is a surface covering of silty clay soil, which has an average depth of 3 to 6 feet. The greater part of the surface material is derived from the weathering of the underlying gravel formation, but a part has probably been washed down and deposited by water as a shallow surface covering over the coarser gravel bed. The topography of these terraces varies from level to gently rolling. On the more rolling areas the soil is well drained and has uniformly a reddish-brown color. These areas are occupied by the soils of the Salkum series represented by a single type, the Salkum silty clay. On some of the more level areas, however, where the drainage is not so thorough, the soil contains a considerable quantity of organic matter and has a dark-gray to dark-brown color. These areas are occupied by the soils of the Winlock series, likewise represented by a single member—the Winlock silty clay. Soft, partially decomposed basaltic gravel is frequently encountered in the deeper subsoils of both the Salkum and Winlock soils.

A small area of glacial outwash gravel, which occurs just north of Centralia, is also included in the glacial terrace group. This area represents the southern end of the extensive outwash plain which occurs to the north in Thurston County and consists of a mass of rounded gravel and cobble covered by a shallow layer of sand. The soil derived from this material is recognized as a member of the Spanaway series.

(*b*) Soils Derived Mainly from Nonglacial Material.

In the valleys of most of the principal rivers in the area, and especially along the Columbia River, terraces occur which represent the earlier flood plains of the streams. Some of these terraces are very old and have an elevation of 300 to 400 feet above the present level of the streams. In some localities the small streams have cut deep valleys through the older terraces, causing the surface to have a gently rolling to rolling topography.

The material forming the older benches differs from that found on the lower and more recent terraces in both texture and structure. Both the soil and subsoil to a depth of 6 feet or more consist prin-

cipally of silt and clay, with no indication of stratification except in a few areas where beds of gravel outcrop along the steeper slopes bordering the small streams. The material originally deposited in these older terraces has weathered to a considerable depth, and in many cases the silt and clay derived from the weathering of the underlying rock or washed down from the adjacent hills has also entered into the formation of the soil. The presence of much rounded, water-worn quartzite gravel scattered over the surface is the principal evidence that these terraces were formed originally by the action of water. The dark reddish-brown soils of these older terraces and benches, underlain by yellowish-brown or reddish-brown compact subsoils, have been placed in the Hesson series.

The greater proportion of the level to gently rolling terrace lands occupying a somewhat lower elevation along the courses of the larger streams are underlain by stratified deposits of sand and gravel, with occasional pockets or layers of cobbles or small, rounded bowlders. The coarse statified sands and gravels are covered to an average depth of 3 to 10 feet by finer deposits of sand, fine sand, silt, and clay. In some localities a considerable quantity of fine water-worn gravel occurs mixed with the finer surface material. These terrace formations give rise to the soils of the Lauren, Camas, Kelso, Wind River, Nasel, and Doty series. The terraces occupied by the Doty, Nasel, and Camas series, however, have a lower topographic position and are of more recent origin than those occupied by the Lauren, Wind River, and Kelso soils.

Several extensive areas of high terrace deposits occur in the southern part of Clarke County. Here the terrace material consists of a compact, imperfectly stratified mass of gravel and small cobbles, which is overlain to a depth of 6 to 24 inches by a layer of sandy and fine gravelly material. These areas have a very level topography and the surface material contains a considerable quantity of organic matter, which gives it a dark-brown to black color. These coarse gravelly deposits give rise to the soils of the Sifton series.

In the western part of Clarke County occurs an extensive terrace formed of compact deposits of fine sand, very fine sand, silt, and clay, laid down in strata varying from a few inches to several feet in thickness. No coarse sand or gravels are encountered here to a depth of 30 to 40 feet below the surface. Smaller areas of similar formation are also found in the southern and southeastern parts of the county. The surface soils contain a relatively large proportion of organic matter and are dark-gray to dark-brown in color. This material gives rise to the soils of the Felida series, but when it borders the terraces of coarser material which forms the soils of the Lauren series it has also entered into the formation of the Lauren fine sandy loam.

SOILS OF THE RECENT RIVER FLOOD PLAINS AND DELTAS.

(*a*) Soils of the Recent or Present Alluvial Flood Plains.

The alluvial soils occupying the flood plains of the principal rivers are derived from material which has been brought down by the waters of the streams and deposited over these low valley lands at times of high water.

Along the streams which rise in glaciated districts, such as the Cowlitz, Lewis, and Kalama Rivers, the soils are composed mainly of reworked glacial material. These valleys were first covered by deep deposits of fine sand, but, with the exception of narrow areas bordering the present stream channels, this sand has been covered to a depth of from 1 to 5 feet by more recent sediments of silt and clay, the deposition of which is still taking place. These deposits give rise to the soil of the Puget series.

Along the Columbia and a branch of the Lewis River the alluvial deposits have many of the characteristics of those from which the Puget soils are derived. Immediately along the streams narrow areas of fine sandy loam occur, but over the greater part of the valleys the sandy deposits are overlain by a shallow layer of silt and clay. The material deposited in these valleys differs, however, in origin from that which forms the Puget soil, as it is derived principally from nonglacial material. The silty soils differ from those of the Puget series in being generally of dark brown color, while the sandy members of the series are of a light brown to yellowish-brown color. A considerable quantity of mica is present in both the soils and subsoils. The soils which owe their origin to these alluvial deposits are recognized as members of the Columbia and Sacramento series.

The alluvial soils along the valleys of the streams traversing the district occupied by the residual soils of the Olympic and Melbourne series are naturally composed of material which has been eroded from these types. They have been placed in the Chehalis series.

(*b*) Soils of the Estuarine and Delta Tidal Flats.

The soils occupying the tidal flats and delta lands found at the mouths and along the lower courses of some of the larger streams emptying into the Columbia River and Willapa Bay are very similar in texture and origin to those occupying the stream valleys. The fine sand, silt, and clay brought down by the streams has been deposited in the shallow waters at the outlet of the rivers, eventually building up extensive semimarshy flats, lying slightly above sea level. These deposits are in mode of formation to be considered as water-laid or sedimentary, rather than of alluvial origin, but merge insen-

sibly into the alluvial types and are derived from the same material. In so far as they are of agricultural importance they have been included with the previously described alluvial soils, mainly of the Chehalis series.

SOILS OF THE LAKE BASINS.

Small, shallow basins and poorly drained depressions, which receive the drainage waters from the surrounding areas, occur at intervals over the level to gently rolling terraces or bench lands and in some parts of the gently rolling upland districts. Some of these basins are entirely surrounded by areas of gently rolling topography and have no natural drainage outlets, while others represent broad, shallow valleys which are now occupied by a small stream seldom large enough to furnish adequate drainage for the adjacent lands. These basins have been gradually filled up by material washed into them from the lands occupying a higher position, but many of them still remain in a wet and flooded condition during the greater part of the winter and spring months. The soil occupying such areas contain a relatively large quantity of organic matter, owing to the decay of a rank growth of vegetation under swampy or poorly drained conditions. In some localities these basins are referred to as "beaver-dam land" or "swale land." The soils vary to some extent in texture, but always contain a high percentage of silt and clay. The subsoils consist mainly of a compact, impervious clay or silty clay, but pockets of sand or gravel sometimes occur at depths ranging from 18 inches to 3 feet below the surface. Deposits of diatomaceous earth are often found in the subsoils. The soils of these basins have been placed in the Tower series.

SOILS OF THE MARINE BENCH AND EOLIAN DEPOSITS.

Narrow areas of sand or of a mixture of sand and gravel occur along the coast in Pacific County. This material is purely a beach deposit and is of such limited extent that it was impracticable to attempt to separate it from the Dunesand, limited areas of which lie back of the beaches. These areas have been mapped as Coastal beach and Dunesand. They are of small extent and of little agricultural value. Occupying the greater part of the spit separating the waters of Willapa Bay from the sea in Pacific County and occurring also in the extreme northwestern part of the county are relatively extensive areas of soil material which has been transported by winds. These areas either extend to the beach or lie just inland from the areas of Coastal beach and Dunesand. This material was originally laid down along the beaches by waves and shore currents, but has later

been blown inland, forming deep deposits of fine sand, mapped under the Westport series.

SOILS DERIVED MAINLY FROM ACCUMULATIONS OF ORGANIC MATTER.

Some of the basins and low depressions in the area are occupied by deep accumulations of organic matter which owe their origin to slow decomposition of the remains of rank vegetation under swampy or poorly drained conditions. The organic matter is in various stages of decomposition. In some areas it is thoroughly broken down, all semblance of its original structure having been lost. Here it has been mixed with silt and clay and forms typical Muck. Other deposits are of a more fibrous texture and have more the characteristics of Peat. These two stages in the decomposition of the organic matter are frequently found in areas of small extent and are so closely associated that they could not be separated on a map of the scale adopted in this survey. The more extensive areas occur in Pacific County, where they are being utilized profitably for agriculture. This material has been designated and mapped as Muck and Peat.

The various types of soil encountered in the area vary considerably in agricultural value. The greater proportion of the soils occupying the alluvial valleys, the terrace lands, and the shallow basins are well adapted to agriculture and are very productive. Those occupying the rolling uplands are on the whole also well adapted to farming, but many of the types are excessively drained, while the value of others is decreased by the character of the topography. A large proportion of the types in the mountainous districts are either too stony or too rough to be well adapted to agriculture. Small areas occur at intervals which could be very profitably cultivated, but many of the rougher and more broken areas are valuable chiefly for forestry.

The following table gives the areas of the different soils:

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Olympic stony loam	663,040	25.0	Aiken stony clay	26,624	1.0
Melbourne silty clay loam	614,400	23.2	Olympic stony clay loam	9,984	
Olympic silty clay loam	414,976	15.8	Light-colored landslide phase	7,680	1.0
Shallow phase	3,072		Dark-colored landslide phase	8,704	
Salkum silty clay	141,568	5.3	Winlock silty clay	25,088	.9
Chehalis silty clay loam	83,712	3.1	Lauren gravelly coarse sandy loam	23,040	.8
Felida silt loam	61,696	2.3	Lauren sandy loam	22,016	.8
Olympic loam	47,104	1.8	Doty silty clay loam	20,992	.8
Sacramento silty clay loam	46,336	1.7	Lauren fine sandy loam	20,736	.8
Olympic silt loam	39,424	1.5	Westport fine sand	20,224	.8
Hesson clay loam	37,888	1.4			
Chehalis clay loam	34,560	1.3			
Chehalis silty clay	28,416	1.1			

Areas of different soils—Continued.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Puget fine sandy loam	20,224	0.8	Spanaway gravelly sandy loam	5,376	0.2
Underwood loam	19,968	.7	Everett gravelly loamy sand	4,864	.2
Rough stony land	17,152	.6	Olympic clay, dark-colored landslide phase	4,352	.1
Nasel silty clay	15,872	.6	Chehalis clay	3,840	.1
Tower clay loam	14,848	.6	Toutle coarse sandy loam	2,304	.1
Kelso silty clay loam	14,080	.5	Lauren silt loam	2,048	.1
Puget silt loam	11,264	.4	Camas gravelly sandy loam	2,048	.1
Dark phase	2,304		Everett loamy sand	1,792	.1
Aiken silty clay loam	12,032	0.4	Chehalis loam	1,792	.1
Sifton gravelly sandy loam	11,520	.4	Tower fine sandy loam	1,536	.1
Columbia fine sand	11,008	.4	Wind River gravelly loam	1,536	.1
Camas silt loam	8,704	.4	Toutle very fine sand	1,280	.1
Porous subsoil phase	1,792		Wind River loam	1,280	.1
Toutle gravelly coarse sand	10,240	.4	Wind River sandy loam	1,024	.1
Wind River gravelly sandy loam	9,984	.4	Wind River fine sandy loam	1,024	.1
Muck and Peat	7,936	.3	Tower clay	768	.1
Coastal beach and Dune sand	7,168	.3	Camas stony gravelly loam	512	.1
Nasel gravelly clay loam	6,656	.2			
Everett stony sandy loam	5,632	.2	Total	2,647,040	

RESIDUAL SOILS.

Olympic Series.

The soils of the Olympic series have light-brown to reddish-brown surface soils resting on brown subsoils of lighter color than the surface soils. The types are frequently of silty texture. They are derived from basaltic rocks, which underlie the surface at a depth ranging from 3 to 25 feet and which occur in weathered fragments upon the surface and in the soil and subsoil. The series is thus residual.

In small areas andesitic material has influenced the soils, and locally colluvial material from the same rocks has been included.

The soils of the Olympic series occupy rough, hilly or mountainous regions. Drainage is thorough to excessive. The areas are heavily forested with fir, hemlock, cedar, and spruce. Owing to the rough topography and relatively inaccessible location, little agricultural development has occurred, nor can much be expected. Usually the soils are much better adapted to forestry than to cultivation. Areas of small extent are comparatively level, and these in some instances might be utilized for dairying or for crop production.

OLYMPIC STONY LOAM.

Typical areas of the Olympic stony loam consist of rather dark-brown, sometimes reddish-brown, heavy loam to silty clay loam,

extending to a depth of 12 to 18 inches. The subsoil is a slightly reddish-brown or light-brown silty clay loam to a depth of 1 to 3 feet or more. As mapped, however, the type includes some undifferentiated areas of red or deep reddish-brown soils of the Aiken series and extensive areas of light yellowish-brown soil, recognized as constituting a light-colored phase of the typical soil.

In the typical areas both soil and subsoil contain many small angular fragments of basalt. The number of these increases rapidly near the bedrock, which is found anywhere from 1 to 6 feet below the surface. The depth of the type is subject to considerable variation on account of the rough topography. Areas of other soils of the Olympic series varying from a stony loam, a stony clay loam, or silty clay loam to silty clay, occur within the limits of the type, but the topography and inaccessibility of the mountainous districts rendered the separation of these areas impracticable, and all have been grouped under the general name of Olympic stony loam. Outcrops, mainly of basaltic rocks, are common throughout the type. Near these outcrops and on the steep slopes there are usually many large angular fragments of basalt, both on the surface and in the soil. In several localities, especially near areas of Melbourne silty clay loam, there are outcrops of Tertiary sandstones and shales, which have had more or less influence in the formation of the type.

The largest area of the typical soil occupies the mountainous district comprising the central and the southeastern parts of Pacific County, the southwestern part of Lewis County, the northwestern part of Cowlitz County, and the northeastern part of Wahkiakum County. An extensive area is found also in the northeastern part of Lewis County. Other smaller areas occur in southeastern Lewis County and southern Wahkiakum County.

The topography of the Olympic stony loam is rough and broken, and on account of its elevation and the large area of rock outcrop the greater part of the type may be classed as mountainous. The higher areas of the type reach an elevation of 5,000 to 6,000 feet. The drainage is often excessive. Many of the larger streams of the area head in this type. The type has its origin in the more or less complete weathering of the underlying basaltic rocks in place, but small areas are formed of a mixture of the weathered material of igneous rocks and Tertiary sandstones and shales.

Olympic stony loam, light-colored phase.—The light-colored phase of the type to a depth ranging from 12 to 20 inches consists of a yellowish-brown to light reddish-brown loam, silty loam, or silty clay loam carrying small angular basaltic fragments and small, spherical, iron-cemented pellets. Where the land has not been cultivated or burned over there is usually a shallow surface covering of decayed vegetation, giving the soil in such places a darker color

and more silty texture. The subsoil is a yellowish-brown or sometimes a slightly reddish light-brown silty material, which is heavier in texture and more compact in structure than the soil. This material may extend to a depth of 15 feet or more, but as a rule the bedrock is encountered at 1 to 3 feet below the surface. Large quantities of large and small fragments of basalt and allied volcanic rock are usually found scattered over the surface and mixed with the soil. In some places they are so numerous as to practically prohibit cultivation, but small areas comparatively free from stone occur at frequent intervals. On some of the ridges and along the steeper slopes more or less extensive areas of rock outcrop are encountered. This phase, like the typical Olympic stony loam, is subject to considerable local variations in color, texture, and structure of the soil and subsoil material. Some of these variations would in a detailed survey probably be sufficient to warrant differentiation as distinct soil types.

The light-colored phase of the Olympic stony loam occupies extensive areas in the mountainous regions in Cowlitz, Clarke, and Skamania Counties. As a whole it has a rough and broken topography. The streams flowing through these regions have cut deep canyons, the slopes being very steep or precipitous and the ridges generaly narrow. In some sections, however, small, flat depressions or level to rolling areas are encountered.

The steep topography insures good surface drainage. The texture of the soil and subsoil is such that the material may be made to retain much moisture by proper treatment where the fine material extends to a depth of 2 to 3 feet or more, but crops grown in places where the soil is very stony or shallow are almost certain to be seriously damaged by drought. Along the steep slopes the material of this phase of the Olympic stony loam has been modified by extensive slides and by the addition of talus material, while in the more level areas large accumulations of organic matter have changed the original characteristics of the soil to some extent.

Very extensive areas of the type support a heavy growth of virgin forest, consisting mainly of fir, with some cedar, spruce, and hemlock. A large part of the type, however, has either been logged off or burned over. Up to the present very little attempt has been made to use the soil for farming. A large part of the type is so rough and stony that it will probably never be of much value, but the local areas could undoubtedly be profitably used for dairying and for fruit growing where the elevation is not too great. Portions of the type could also be used for grazing land, but as a whole it is best adapted to forestry. Most of the large streams of the eastern and central parts of the area have their sources in the type. The presence of the forests retards the flow of water into the valleys and tends to prevent floods

along the middle and lower courses of these streams, or at least to make them less severe. The removal of these forests would probably cause many of the streams of the area which are now perennial to dry up during a part of the year.

The type is valued chiefly for its timber. Logged-off tracts are held at $2.50 to $10 an acre, but no sales are reported.

OLYMPIC LOAM.

The surface soil of the Olympic loam, to an average depth of 12 inches, is a light-brown to slightly reddish-brown loam of rather silty texture, which contains a variable quantity of rounded or subangular fragments of basaltic rock. The color of the soil material is, upon the whole, somewhat lighter than is typical for the soils of the Olympic series. A large quantity of small, rounded pellets of soil material, cemented by iron, occur in the soil and on the surface. The larger of these are seldom more than one-fourth inch in diameter and many of them are so soft as to be easily crushed in the fingers. The rounded appearance of the small bowlders found scattered over the surface and mixed with the soil is probably due to spherical weathering of the basaltic rock. The subsoil consists of a light yellowish-brown to slightly reddish-brown silt loam, which becomes heavier with depth, grading at an average depth of 24 to 30 inches into a silty clay loam or silty clay. Rounded bowlders and cobbles occur throughout the subsoil.

The type occupies high rolling hills, often capped by more or less extensive level to gently rolling plateaus. The hillsides are often steep and rocky and the small streams traverse deep V-shaped valleys. Along the base of some of the higher hills the land slopes more gently in a series of low, rounded mounds, originating in slides, to broad, shallow valleys, almost wholly surrounded by the rolling uplands.

Drainage is well established, but is seldom excessive, and the type is retentive of moisture, the heavy subsoil retarding the downward movement of water. The type occurs mainly in Clarke County, where it covers extensive areas. It is of residual origin and derived predominantly from basaltic rocks, but along the lower slopes and ridges it includes a large amount of landslide material, which has weathered along the slopes of adjacent high elevations and has slid down to lower levels.

The topography reduces to some extent the agricultural value of the land, and much of its area is better adapted to dairying and to fruit growing than to the production of general farm crops. The more level and gently rolling areas are, however, well adapted to farming and produce good yields of all crops grown. The average yield of oats is about 30 bushels per acre, but much larger yields are not uncommon. Wheat is grown to a small extent and produces

heavy yields. Irish potatoes yield from 150 to 200 bushels per acre. There are many small orchards on this type and the trees do exceedingly well, but the crop is often curtailed by late frosts. Clover and timothy yield from 2 to 3½ tons of hay per acre, and kale and other forage crops produce large yields. Dairy farming is the principal industry.

The type in its native condition is covered with the forest growth usually found on the Olympic soils, but large areas have been logged off or burned over.

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

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.*
5509109	Soil	2.2	6.4	5.2	15.0	13.5	43.5	14.4
5509110	Subsoil	1.7	5.4	4.2	10.1	9.6	54.5	14.7

OLYMPIC SILT LOAM.

The soil of the Olympic silt loam consists of a light reddish-brown clay loam, with an average depth of 18 inches. Some small, nearly level areas on the top of the broad divide are marked by a surface accumulation of organic matter and consist of 3 or 4 inches of a black clay loam or silt loam, underlain by the typical soil. The texture of the type is very uniform throughout its extent.

The subsoil is a light-brown to yellowish-brown heavy clay loam to clay. The type is one of the deepest residual soils of the area and is free from rock fragments and rock outcrops, except along the lower slopes of deep draws and small valleys. Cuts along logging roads and streams show that the depth to the underlying rock is from 25 to 50 feet.

The only body of the type mapped in this area occurs in the southwestern part of Cowlitz County and the southeastern part of Wahkiakum County. It occupies a high tableland between 1,200 and 1,500 feet in elevation, which as a whole has a gentle slope toward the east and southeast. The narrow V-shaped valleys of the upper courses of the few streams encountered gradually deepen and become rocky canyons in their middle and lower sections. The divides between the streams are broad and gently rolling to rolling. The type is the most level residual soil of the area. The tableland breaks away abruptly toward the west and merges gradually into the higher-lying Olympic stony loam on the north and the Olympic silty clay loam on the east. On the south it descends to the Columbia

River by a precipitous rocky slope or by a perpendicular bluff of basalt.

The drainage of the type, although a little retarded on the broad divides, is adequate.

The Olympic silt loam is formed by the weathering of basalt or other basic igneous rocks. On account of the gentle topography and the resistance to erosion, the rate of degradation has been slow and a thick mantle of weathered material has accumulated above the parent rock. Some of the streams have cut down into the Tertiary sandstones and shales along their lower courses, but these rocks have not contributed to the formation of the type.

A part of the Olympic silt loam still supports a heavy growth of fir, hemlock, and cedar. Several small areas devoted to general farm crops and dairying are found in Cowlitz County. A few small farm orchards are apparently doing well and producing a good grade of fruit. The type furnishes good pasturage and dairying is the chief source of the income of the farmers. Under favorable conditions 1 acre of this type should produce from 2 to 3 tons of hay, from 35 to 80 bushels of oats, or from 200 to 300 bushels of potatoes. Fruit growing, especially pears, should prove profitable.

The type is a desirable one for general farming purposes, but at present much of it is inaccessible. Large areas have been logged off, but no effort has been made to put them on the market. The present value of the land ranges from $20 to $40 an acre.

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

Mechanical analyses of Olympic 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.*
550909, 550911....	Soil.....	0.1	1.0	0.9	2.7	3.6	73.5	18.3
550910, 550912....	Subsoil.....	.0	.4	.8	2.7	6.1	68.9	21.1

OLYMPIC STONY CLAY LOAM.

The Olympic stony clay loam includes locally undifferentiated areas of soils of the Aiken series of limited extent. It also includes in the southeastern part of the area surveyed two quite extensive phases. These have been designated as the light-colored landslide phase and the dark-colored landslide phase, respectively. These two phases would in a more detailed survey probably be recognized as distinct soil types. They are indicated upon the soil map by symbols and will be separately described.

As typically developed the Olympic stony clay loam consists of 12 to 18 inches of clay loam, often of silty texture and of yellowish-

brown to reddish-brown color, resting on a light-brown to yellowish-brown heavy clay loam. The subsoil is usually underlain by basalt or some closely related volcanic rock at comparatively shallow depths. The thickness of the material overlying the bedrock varies all the way from 2 or 3 inches to several feet and on many of the steeper slopes small areas of rock outcrop are frequently found. Both soil and subsoil usually have some small, spherically weathered rock fragments and soft iron pellets and a large proportion of angular rock fragments of various sizes. The type consists almost entirely of residual material derived from the weathering of basalt or other basic igneous rocks. In many places on the steeper slopes a large part of the fine material has been eroded away, leaving barren areas of basalt or masses of fragmental rock.

The typical areas are confined to the southwestern part of Cowlitz County and the southeastern part of Wahkiakum County. They occur as narrow strips along many of the creeks in this part of the survey, occupying the slopes along these streams, and the topography is usually steep and in a few cases almost precipitous.

Owing to the shallowness of the soil in many areas and the steep topography the natural drainage is excessive, but those areas that show a considerable proportion of fine material retain moisture fairly well.

Though the original timber growth, consisting chiefly of fir, has been removed from a large part of the type practically none of it is under cultivation. It is almost certain that the very steep and rocky areas will never have any value as agricultural land, but some of the better areas could probably be used for growing tree fruits.

Olympic stony clay loam, light-colored landslide phase.—The light-colored landslide phase of the Olympic stony clay loam consists of from 12 to 18 inches of a light-brown to a light reddish-brown clay loam of rather silty texture, usually containing large quantities of spherical basaltic or andesitic rock fragments and iron-cemented pellets. These rock fragments and pellets are often so thoroughly weathered or of such soft character as to be readily crushed in the fingers. The soil is frequently covered with a thin layer of decayed vegetation, thus giving it superficially a dark color and a conspicuously loamy texture.

The subsoil is reddish-brown to yellowish-brown, somewhat silty loam or silty clay loam, also carrying basalt fragments, but considerably less abundant than in the soil. On the slopes the soil is frequently covered by a surface accumulation of a foot or more of fragmental rock, while other small areas are comparatively free from stones. Bedrock is encountered at all depths from 1 to 6 feet, and small rock outcrops are common on the higher ridges and along the steep slopes.

A large part of the type is so stony as practically to prohibit the use of farm machinery, but some of the less stony areas may be easily cultivated.

The greater part of the material that goes to make up this soil has been derived from the weathering of basalt or closely related volcanic rocks. The most of this material, however, owes its present topographic position to landslides, which occur extensively in the region. This has produced a characteristically hummocky topography, with numerous small flats, moundlike areas, and steep slopes. Many of the individual slides cover an area of from one to several acres. In most cases there has been but little overturning or disturbance of the soil material, the movement having probably taken place slowly, and the soils are in character essentially residual.

Five areas of the light-colored landslide phase of the Olympic stony clay loam, all in Skamania County, have been mapped in this survey. The largest of these, about 9 square miles in extent, lies just north of Butler. Other areas occur at intervals along that part of the Columbia River lying between Cape Horn and Carson. The topography of the main body of this soil, near Butler, varies from nearly level to rough and broken, the greater part being hilly to broken. The other areas occupy very steep, sometimes almost precipitous, slopes along the Columbia River. The soil is fairly retentive of moisture when given the proper cultivation, but the drainage on the shallower and more stony portions of the type is naturally excessive. The native vegetation usually consists of a scattering and inferior stand of fir, with a few cedar and hemlock trees. The better areas of the type, however, still support considerable merchantable timber. The cultivated areas are too small to give a definite idea of the productiveness of the type. The rough stony areas or areas where the soil is very shallow are not suited to any form of agriculture and could best be utilized for forestry. Where the soil can be cultivated tree fruits could probably be grown with a fair degree of success, while grass and grain could be produced on the heavier phases. On account of the rough topography and stony nature of the soil, it is not adapted to general farming, and only those crops can be profitably grown that require intensive methods of farming and that produce large returns from small acreages.

Values placed on this phase of the type range from $5 to $40 an acre.

Olympic stony clay loam, dark-colored landslide phase.—The dark-colored landslide phase of the Olympic stony clay loam consists of 8 to 15 inches of a dark brown or dark reddish-brown clay loam, usually containing considerable organic matter and becoming nearly or quite black when wet.

The subsoil is a brown heavy loam, which usually changes to a lighter color at a depth of about 30 inches. Both soil and subsoil

contain a relatively high proportion of angular to roundish basaltic fragments of varying sizes, and also many small, soft, iron-cemented pellets. As a rule, large quantities of the rock fragments and pellets occur strewn over the surface and distributed through the soil to a depth of several feet. At times 50 to 75 per cent of the soil is made up of stones of all sizes up to 2 feet or more in diameter, and occasionally large masses of basalt are encountered. Some small, undifferentiated areas of a stony clay, as well as areas having a much lighter texture than the typical soil, have been included with the type.

The proportion of stones in many cases is so large as practically to prohibit cultivation, though small areas comparatively free from stone are occasionally found.

The soil owes its origin chiefly to the decomposition of basalt and related volcanic rocks. As in the light-colored landslide phase of this type, very little of this material occupies its original position, as it has been moved slowly down the slopes by slides. That the material has also in some places been subjected to the action of running water is indicated by the frequent occurrence of rounded cobbles and bowlders along the slopes.

The dark-colored landslide phase of the Olympic stony clay loam occupies foothills lying between the Columbia River and the more mountainous country to the northward. The topography as a whole is rather rough and some of the slopes are very steep. A large number of rocky knolls and ridges from 10 to 50 feet high, with intervening deep basins having no outlet, give the surface a very broken appearance approaching a glacial topography. Sometimes these basins are quite large and fill with water, thus forming many shallow lakes. Because of the broken topography and the presence of large quantities of rock and gravel in the soil and subsoil, the type dries out much more readily than the dark-colored landslide phase of the Olympic. Where the coarser material is not so abundant the soil is fairly retentive of moisture. Only two bodies of this phase occur in the area, both being found in Skamania County. One area of some 10 to 12 square miles lies west of Stevenson and another of 4 to 5 square miles is located $1\frac{1}{2}$ miles east of Carson.

The original forest growth, consisting chiefly of fir, with a sprinkling of cedar and hemlock, still remains over the greater part of the type, though the stand is generally light and the quality inferior. Only a very few areas are under cultivation and these are small. A large part of the type is so stony that it is doubtful if it will ever have much value as an agricultural soil. The less stony areas, however, could be utilized profitably in growing tree fruits. Other small areas free from stones may be used for production of the general farm crops.

Lands of this type of soil are valued at $15 to $40 an acre, depending on the quantity of stone present and the nearness to market.

The following table gives the results of mechanical analyses of the soil and subsoil of the two phases of this soil:

Mechanical analyses of Olympic stony clay loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Dark-colored landslide phase:		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
550947	Soil	1.6	5.1	3.5	12.6	10.9	41.3	24.5
550948	Subsoil	.6	4.1	5.1	18.6	9.5	43.8	18.0
Light-colored landslide phase:								
550943	Soil	1.5	4.7	4.4	11.1	12.9	42.6	23.1
550944	Subsoil	.8	4.0	3.5	12.1	11.1	46.9	21.6

OLYMPIC SILTY CLAY LOAM.

This type embraces, in addition to the areas recognized as typically developed, several phases. The minor phases are referred to only in the description of the soil type, but the two more important phases are indicated upon the map by symbols.

The typical soil consists of a brown to yellowish-brown or slightly reddish-brown silty clay loam, 6 to 24 inches deep, underlain by a compact clay loam or clay of silty texture, which varies in color from yellowish-brown, distinctly mottled, to a reddish-brown, only faintly mottled with gray. Areas in which the immediate surface material is of dark color often occur in the forested districts. The color here is due to a high content of organic matter. The type also includes some undifferentiated areas of red soils of the Aiken series. The subsoil material usually rests upon bedrock at depths of 1 to 15 feet or more and small areas of rock outcrop occur at frequent intervals in the rougher portions of the type. A few angular to subangular fragments of basalt or andesite are found on the surface and in the soil of most of the type, and where there is only a shallow covering of fine earth over the underlying rock or on eroded slopes or ridges these fragments are often so numerous as to interfere seriously with cultivation. Occasionally small quantities of rounded cobbles occur, but in most cases they have probably resulted from the concentric weathering of the parent rock. The soil usually contains a few thoroughly weathered small rock fragments and shotlike iron-cemented pellets, which, however, are rather uncommon in the subsoil. The dry cultivated surface usually has a grayish appearance, particularly in depressions where the drainage is deficient.

An important phase of this type occurs in the northern part of Cowlitz County, where in many places both soil and subsoil are a

grayish-brown clay or clay loam, which in some instances is hardly at all mottled with yellow, while in other cases these mottlings may become very numerous.

Another phase occurs along the western slope of Mount Pleasant, as well as on many other slopes throughout the type. Here the soil is a brown clay loam, underlain by a mottled gray and brown clay loam or clay, which is usually neither so heavy nor compact as in the typical subsoil. The dry cultivated surface of such bodies usually has a gray or grayish-brown color.

Between Carrollton and Kelso and about 2½ miles west of Kelso, in Cowlitz County, narrow strips of this soil containing considerable quantities of waterworn gravel are found. The presence of this gravel indicates that the soil has been reworked to some extent by streams, but as the areas are small they have been included with the type and indicated on the map by symbol as a gravelly phase. Other bodies of this soil type are underlain by bedrock at shallow depths and contain many rock fragments and small areas of outcropping rock. Many small areas of this character were encountered in various parts of the type, and wherever they are of sufficient extent have also been indicated on the map by the use of a symbol as a shallow phase.

The presence of rounded, waterworn quartzite pebbles along the south slope of the area lying north of La Center in Clarke County indicates that in this location some early alluvial terrace material has entered into the formation of the soil. While many of these phases would be recognized as types in a detailed survey, on account of the inaccessibility of much of the type and the similarity of the several phases in topography, agricultural value, and origin, the slight differences in color, texture, and quantity of fragmental rock present hardly seemed to justify any further attempt at separation in the present survey.

The Olympic silty clay loam occupies the most of the interior and northeastern portion of that part of Cowlitz County included within the survey and extends to the Columbia and Lewis Rivers on the south. It also covers the southeast corner of that part of Lewis County included within the survey. West of the Cowlitz River it continues from Cowlitz County through the western part of Lewis County as a strip one-half mile to 3 miles wide and extends from the county line near Little Falls northward to Doty. A smaller area occurs in the northwestern part of Clarke County. The topography varies from rolling to hilly or even mountainous in areas where the type reaches an elevation of 3,000 to 5,000 feet or more. The slopes along the streams are sometimes very steep, though in most cases they are not so steep as to preclude their use for some branch of agriculture. On the other hand, quite extensive areas of

level to gently rolling lands occur on many of the ridges or upland plateaus. The soil type is friable under cultivation and the texture and structure of the soil and subsoil enable it to retain moisture through long dry periods. Drainage is seldom excessive, though it is usually adequate. Some small depressions and very flat areas, however, would undoubtedly be benefited by laying tile drains.

The Olympic silty clay loam is a residual soil, having resulted from the weathering of the underlying basaltic or andesitic rocks. In Lewis County small areas of soft sandstone and shales are included within the areas covered by the type, and in these localities they have undoubtedly exerted considerable influence on the character of the soil. In some cases the original characteristics of the soil have been modified by erosion and by large accumulations of organic matter. Extensive areas of this type are still covered with the original timber growth, consisting chiefly of fir, cedar, and hemlock, and a tangled undergrowth of vine, maple, huckleberry, and salal. While extensive areas still remain in timber, there are also large tracts which have either been cut over or burned.

Many small farms are located on the type, but the greater proportion of the logged-off land is still in an undeveloped state. The type is well adapted to dairy farming. The level areas can be used for the production of hay and grain, and the steep slopes for pasturage. It would seem that alfalfa should do well, provided the proper care is taken in preparing the land. With thorough cultivation, tree fruits, particularly apples and prunes, should do well. In fact, almost any crop grown in the region could be produced at a profit on the more level areas, if given the proper treatment.

The crops grown at present are chiefly clover, oats, and potatoes, with small quantities of fruit. From $1\frac{1}{2}$ to $2\frac{1}{2}$ tons of clover is not an uncommon yield, and in many seasons a second crop is secured. Oats produce from 60 to 100 bushels and potatoes from 150 to 200 bushels per acre. A mixture of oats and peas, sometimes sown for hay, gives large yields. Fair crops of fruit are usually obtained, but the product is used largely for home consumption, and as the trees are seldom given the attention that they should receive the yields and quality are apt to be rather inferior. Strawberries are also successfully grown on this soil, and very profitable yields are secured with good cultural methods. Generally speaking, however, the yields obtained from all these crops could be increased by more thorough cultivation and by the application of stable manure or the plowing under of some leguminous crop. In many cases applications of lime should also prove beneficial.

Highly improved lands of this type of soil are held at $100 or more an acre, but undeveloped tracts may be had for $10 to $20, the price depending chiefly on location.

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

Mechanical analyses of Olympic silty 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.*
550963	Soil	0.5	3.0	1.4	5.6	10.0	53.6	25.7
550964	Subsoil	.3	2.0	1.5	4.2	6.5	44.6	40.7

OLYMPIC CLAY, DARK-COLORED LANDSLIDE PHASE.

The dark-colored landslide phase of the Olympic clay is similar in origin, mode of formation, and topography to the landslide phases of the Olympic stony clay loam and bear the same relation to the typical soils of the Olympic series. The typical Olympic clay does not, however, occur within the limits of this survey except as local bodies of small extent, which were not mapped separately, but were included with the associated soils.

The soil of the dark-colored landslide phase of the Olympic clay to an average depth of 12 to 15 inches consists of a brown to nearly black clay, which is very sticky and waxy when wet. The dry cultivated surface usually has a dark reddish-brown cast. The subsoil, which is a heavy, waxy clay, and usually of brown color, frequently checks and cracks when it is dry. It is sometimes mottled with gray, yellow, red, and brown. Both soil and subsoil contain a small quantity of spherical rock fragments and rounded, apparently water-worn bowlders, as well as angular fragments of basalt. This coarser material is distributed through the soil and scattered over the surface in considerable quantities. Near Collins the surface soil is usually darker in color and of heavier texture than the typical soil, while the subsoil is frequently a light yellowish gray. Other local undifferentiated areas of somewhat lighter texture than the average soil also occur. Like the landslide phases of the Olympic stony clay loam, the soil owes its origin primarily to the decomposition of basalt and related volcanic rocks, but the greater part of this material has been moved and modified by slides. The presence of cobbles and gravels, apparently water worn, along the slopes would seem to indicate that in some cases the soil has been more or less affected by stream erosion.

The dark-colored landslide phase of the Olympic clay is confined to Skamania County. The largest area lies just north of Stevenson and embraces approximately 3 square miles. Smaller areas occur southwest of Carson and in the vicinity of Collins. While some parts of the areas are fairly level, the greater proportion is more or less rolling or hilly, with slopes, which in a few cases are very steep. Owing to

the heavy texture and compact structure of both the soil and subsoil, crops seldom suffer from drought when given the proper cultivation. In the fall and winter months, when rains are frequent, the soil becomes so sticky that it can be cultivated only with difficulty, but during the growing season, when heavy rains are uncommon, it is easily handled.

A few small areas of this soil have been placed under cultivation, but the greater part of the type is still in an undeveloped state. The crops grown at the present time are principally hay and oats. Hay produces 1½ to 2 tons per acre. Potatoes also give only profitable returns. The acreage devoted to fruit production is steadily increasing, and so far as can be judged by the present condition of the orchards, very fair returns should result. Apples are always in demand at a fair price. The type is also well adapted to dairy farming, producing good grain, grass, and forage crops.

The greater part of the undeveloped tracts of this type can be purchased for about $40 an acre, though areas near town are held at a somewhat higher figure.

Aiken Series.

The types of the Aiken series have dark brick-red or purplish-red to dark reddish-brown soils and brighter red or reddish-brown subsoils. In areas where the content of organic matter is large the surface material may be a dark-brown, showing little, if any, of the reddish color. The series is residual from basalt, with admixture in some places of materials from andesitic or other eruptive rocks. Bowlders and smaller fragments of these rocks are found through the soil mass, and the bedrock itself lies generally at shallow depths below the surface. The areas lie on slopes or plateaulike uplands and have a topography ranging from gently sloping to steep, rough, and broken. The soils are efficiently to excessively drained, but are naturally retentive of moisture.

Aiken stony clay.

The soil of the Aiken stony clay consists of an inch or two to 12 inches of dark reddish-brown clay, containing a large quantity of fragmental basalt. The subsoil is a heavy reddish-brown or red clay, which becomes heavier with depth. This is underlain by bedrock at a depth which often varies considerably, even in areas of small extent. In some of the more level areas and on small benches the soil is deep and comparatively free from stones, but on the steeper slopes it is shallow and stony, with frequent outcropping ledges of the parent rocks. The largest area of this type occurs in the southeastern part of that portion of Clarke County included

within the survey. Several smaller areas occur in the east-central part of this county and in western Skamania County.

The Aiken stony clay is a residual soil, derived from basalt and other volcanic rocks. Some of the soil occupying the level benches or small plateaus has slid down or been washed down from adjacent steep slopes, but as the origin is the same there is little or no difference in the soil of these areas and that which is formed directly from the underlying rock. As a whole, the topography is steep and broken, and the larger part of the type is of little agricultural value. Small benches and plateaus occur at intervals throughout the region, and these could be farmed. The many small streams traversing this region furnish good surface drainage, but the heavy clay subsoil prevents the rapid movement of water downward, and moisture conditions are fairly good.

Very little of the Aiken stony clay is at present under cultivation. A few small comparatively level benches or plateaus are farmed and have proved very productive. Where the topography is not too rough and the soil is comparatively free from stones small areas have been planted in orchards with excellent results. Clover and timothy are also grown to some extent, and the yields of hay are large. Irish potatoes, of which a small acreage is planted, yield from 150 to 300 bushels per acre. On the whole, dairying and fruit growing are the most promising industries. The rough and broken sections are valued mainly for the growth of timber they support.

The results of mechanical analyses of samples of the soil and subsoil are given in the following table:

Mechanical analyses of Aiken stony 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.*
5509101	Soil	0.5	2.1	2.1	4.9	5.5	38.4	46.5
5509102	Subsoil	.2	1.5	1.1	3.9	6.0	49.1	38.1

AIKEN SILTY CLAY LOAM.

The surface soil of the Aiken silty clay loam consists of 10 or 12 inches of brown to dark reddish brown silty clay loam, carrying subangular or angular fragments of basalt. These fragments, however, are not numerous enough to give the soil the characteristics of a gravelly or stony soil or to interfere seriously with the cultivation of the land. The soil contains a large amount of organic matter and in many of the more level areas the quantity of humus in the surface 3 or 4 inches is sufficient to give the soil a dark-brown color. The subsoil consists of a reddish-brown or neutral brown silty clay loam,

which becomes heavier in texture and more compact in structure as the depth increases until at 30 to 36 inches it changes to a heavy silty clay.

The Aiken silty clay loam occurs in the southeastern part of Clarke County and in the southwestern part of Skamania County. The topography is rolling to gently rolling. The hills are rounded and the slopes are seldom steep enough to interfere with cultivation, except where the land slopes abruptly toward the narrow valleys of some of the larger stream courses. Many comparatively level or very gently rolling benches or plateaus occur at intervals throughout this type.

The rolling topography, together with the many small stream courses which traverse this section of the area, give the type as a whole good natural drainage.

The Aiken silty clay loam is a residual soil, derived through weathering from the underlying volcanic rocks, mostly basalt. Only a small area of this soil is under cultivation, the greater proportion being covered with the original forest growth of fir, hemlock, and cedar or lying in the undeveloped state known as logged-off land. Owing to the high altitude of a large proportion of the type the crops grown are subject to injury by early fall or late spring frosts. Oats, hay, fruits, small fruits, potatoes, and vegetables are the principal crops. During an average season they yield well. Oats ordinarily produce from 40 to 60 bushels per acre. The soil seems well adapted to both clover and timothy and large yields of hay are always secured. Small acreages have been set in orchards of apples, pears, cherries, and prunes. When properly cared for they produce large yields of fruit of good quality.

The results of mechanical analyses of typical soil and subsoil samples are given in the following table:

Mechanical analyses of Aiken silty 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.*
5509121	Soil	0.2	1.4	2.0	5.9	12.3	51.5	26.7
5509122	Subsoil	.4	1.3	1.4	4.7	9.0	62.5	20.7

UNDERWOOD SERIES.

The types of the Underwood series have yellowish-brown to grayish-brown soils and subsoils. Numerous small, soft pellets, consisting of weathered basaltic material or of aggregates formed by the cementing of soil by iron salts occur in the types. These are most numerous near the surface and range in size from coarse sand to

pellets above one-half inch in diameter. Fragments of basalt the size of small gravel to large bowlders, many of spherical form, the result of concentric weathering, are of frequent occurrence in both soil and subsoil.

The Underwood soils are mainly of residual origin, but they include some areas of colluvial formation, particularly along lower slopes. The types are derived principally from basalt, although andesite may have contributed to their formation to a small extent.

Along the steeper slopes the parent rock outcrops frequently.

Members of this series occupy rolling to steep and hilly foothill districts and the footslopes of mountains. The areas are well drained. A scrubby growth of fir and hemlock covers much of the land. Where favorably located it may be used for farming to some extent without irrigation. Some of the soils require irrigation for effective development, as they occur along the eastern slope of the Cascade Mountains, where conditions are considerably less humid than in the region occupied by the Olympic and the Aiken soils.

UNDERWOOD LOAM.

The Underwood loam is a yellowish-brown or light-brown loam of silty texture, with a depth of 18 inches, underlain by a light-brown to yellowish-brown loam or silt loam of somewhat lighter texture than the soil, extending to a depth of 3 feet or more. The change of color takes place gradually between the depths of 16 and 20 inches. Where the surface is level or nearly so both soil and subsoil are somewhat heavier in texture and slightly darker in color than in the rolling areas. Small patches were found where the subsoil was a stiff reddish clay. The type is underlain by bedrock at a depth of from 25 to 50 feet below the surface. A typical feature of the type is the presence of round, iron-cemented pellets and fragments of basaltic rock, about one-fourth inch in diameter. These are most numerous on the surface, especially on exposed surfaces, where some of the fine soil material has been washed away, but they occur throughout the soil and subsoil, the quantity gradually decreasing with depth. These fragments and pellets are soft and can be crushed between the fingers. The soil may be cultivated under a wide range of moisture conditions.

A shallow phase of the Underwood loam occupies the northern part of the area that lies east of Little White Salmon River. It differs from the true type chiefly in the depth to the underlying rock, which is encountered anywhere from 2 to 25 feet below the surface. The average depth is here from 6 to 8 feet. The soil of this phase is slightly lighter in color and often shallower in depth than the typical soil. Residual bowlders or bedrock are often encountered

in the subsoil at a depth of 2 feet or more. A few shattered outcrops of rock occur within the phase and small fragments of the rock are occasionally found in both soil and subsoil. This phase has a higher elevation than the typical Underwood loam. Another small area of this phase occurs west of Little White Salmon River.

A stony phase also occurs on Underwood Mountain and on the steep slope on the east side of Little White Salmon Valley. The fine material of the phase is the same as that of the typical soil, but there are many angular rock fragments of various sizes and numerous rock outcrops. The weathering of the underlying rock has not kept pace with the removal of the weathered material by erosion and creep, although small pockets of deeply weathered material occur.

Another phase occurs in the area northeast of Stevenson, where small bodies have a darker colored and heavier textured soil and a lighter colored subsoil than the true type.

The Underwood loam is confined to the eastern half of Skamania County. The largest area lies between the Little White Salmon and White Salmon Rivers, a smaller area occurs just east of the Little White Salmon River, a rather extensive area lies northeast of Stevenson, and a small area about 1½ miles northwest of Collins.

The surface of the greater part of the Underwood loam is rolling to hilly. Small areas have an undulating to gently rolling surface, and a few steep slopes occur along the streams and on the stony phase. The elevation of the type varies from 1,000 to 3,000 feet above the Columbia River. The rolling surface and open texture of the soil insure good drainage. Small, shallow areas and the steep slopes are apt to suffer from drought, especially in the eastern part of the country.

The Underwood loam is a residual soil, which was formed by the weathering of a basalt or closely related basic igneous rocks.

Comparatively extensive areas of the type are still covered with the original growth of fir. Old burned-over areas have a recent growth of alder and fir.

The areas of the Underwood loam in the eastern part of Skamania County lie east of the Cascade Range and receive less rainfall and more sunshine than the areas of the type lying near the central part of the county. These different climatic conditions render certain of the areas better suited to particular varieties of crops than others. Although climatic conditions, good air and soil drainage, and in some cases topography cause the whole type to be less adapted to fruit growing, the areas of the type in the central part of the county are not so good for fruit and better adapted to general farm crops than the areas in the eastern part of the county.

Until the last two or three years the development of the type has been very slow. Small, scattered areas had been previously cleared

and principally set to orchards. Some of these trees, though neglected and improperly cultivated, are still producing a good grade of fruit. A considerable acreage has been set to apples and peaches within the last two or three years, and these orchards are making a vigorous growth without irrigation. As a rule, the orchards are given clean cultivation, but potatoes, alfalfa, strawberries, and truck crops are sometimes grown between the rows. None of the young apple orchards are in bearing, but the peaches are doing well. The orchards are sprayed twice with lime-sulphur, the first time when they are in bud, the second just after the bloom has fallen. The leading varieties of apples are Spitzenberg, Yellow Newton, Jonathan, Delicious, and Arkansas Black. The favorite varieties of peaches are the Elberta and Late and Early Crawford. Prunes, pears, cherries, and apricots are grown to some extent and promise good yields of fine fruit. The varieties of pears grown are Anjou, Comice, Bartlett, and Winter Nellis, and of cherries, Royal Ann, Lambert, and Black Republican.

Good yields of potatoes are secured in favorable seasons. A few small patches have been sown to alfalfa. It is apt to suffer slightly from drought during the summer months. Medium yields are secured from two or three cuttings per season. A small acreage is devoted to strawberries. The yields are good and the berries have fine eating and shipping qualities. Clark's seedling is the chief variety grown. Truck and garden crops do well.

Although considerable difficulty in securing water by means of wells is encountered along the bluff road east of the Little White Salmon Valley, a plentiful supply is secured in solid rock on the higher portions of the type from wells from 30 to 50 feet deep. It is doubtful whether the supply is sufficient to warrant an attempt to irrigate by pumping. Irrigation is not practiced on this type, but there is no doubt that it would be beneficial. A plentiful supply of water for irrigation could be secured by diverting water from the Little White Salmon or the White Salmon River far up their courses. The expense of installing such a system is prohibitive at the present stage of development.

The type is deficient in organic matter and would be benefited by the plowing under of green crops.

The shallow phase of the type and at the same time the farthest from market is selling for $125 to $175 an acre, and the more desirable portions are bringing from $175 to $250 an acre. In either case the price is the same whether the tract is timbered or not. In the vicinity of Stevenson the type is valued at $40 to $50 an acre. No sales of orchard tracts are reported.

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

Mechanical analyses of Underwood 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.*
550913, 550931.....	Soil.....	2.7	8.4	9.9	13.6	10.6	44.2	10.6
550914, 550932.....	Subsoil.....	1.3	6.9	8.1	12.2	9.0	50.6	11.8

MELBOURNE SERIES.

The soils of the Melbourne series are brown to reddish-brown, the immediate surface often dark brown. They frequently carry a large number of soft shale fragments and iron concretions or pellets of silty texture. They are sticky when wet, but friable under favorable moisture conditions. The subsoils are yellowish brown or brown, rather heavy in texture, and compact in structure, and usually deep. The parent rocks seldom lie within 3 to 5 feet of the surface, and rock outcrops are infrequent. Where not too rough and hilly the soils of this series are well adapted to agriculture.

They are residual in origin, having resulted from the decomposition of arenaceous shales and argillaceous sandstones of Tertiary age. The rocks are fine textured and in the sandstones the quartz grains are mixed with a fine silty material, while interstratified with the sandy beds are layers of shaly sediments.

The soils of this series occupy extensive upland areas, having an undulating to hilly and broken topography. There are a few small level areas on high plateaus, but a large proportion of the area is so rough as to prohibit the use of improved farm machinery. Much of it is suitable for dairy farming. The rougher areas when cleared are subject to damage by erosion. The drainage is well established. The forest growth consists of fir, with small amounts of cedar, spruce, and hemlock.

MELBOURNE SILTY CLAY LOAM.

The soil of the Melbourne silty clay loam is a medium-brown to dark-brown silty clay loam, with an average depth of 16 inches, underlain by a yellowish-brown to mottled brown, yellow, and gray compact silty clay loam or clay loam to a depth of 3 feet or more. Both soil and subsoil usually contain soft, angular fragments of shale, the number of which increases with depth. Bedrock is encountered at an average depth of 5 to 6 feet. When dry the soil is friable and works up easily, but when wet it is sticky and the subsoil slightly plastic.

The color of the type and the depth to the underlying rock are subject to considerable variation. More or less extensive areas of nearly black soil are common throughout the type. Such areas occur around the heads of shallow draws and even on some of the steeper slopes. In other localities, especially east of Centralia and near Alder Creek, the soil has a reddish-brown color, and the subsoil is light-brown, with a slightly reddish tinge. The depth to the underlying rock depends upon the relative rate of the weathering of the rocks and the rate of the removal of the weathered material. This depth varies from 1 to 15 feet; the shallow depths are found on the steep slopes and in the rough and broken sections of the type. The areas where the rock is found within 12 or 18 inches of the surface comprise a very small percentage of the type. In such cases the soil rests almost directly upon the bedrock, but little true subsoil material occurring. Areas where the rock is encountered within 18 to 36 inches of the surface are more common.

Exposures along deep cuts show that the depth of the soil and the color of the subsoil are subject to change within short distances. Along these cuts the line of contact between soil and subsoil is undulating and its depth varies from 12 to 24 inches below the surface. The subsoil may be a yellowish-brown, a mottled brown, yellow, and gray, or even solid gray or drab.

When the type is underlain by a coarse-grained, friable sandstone, as in the divide south of North River and along Elk Creek in Pacific County and north of Doty in Lewis County, the texture of the soil and subsoil varies from a sandy clay to the typical silty clay loam, depending upon the degree of weathering to which the underlying sandstone has been subjected. As these sand grains break down readily when rubbed between the fingers, the phase has been included in the type.

Another phase occurs about 2 miles northwest of Chehalis and also about a mile northeast of Curtis, in Lewis County. These areas have a gray to light grayish-brown silty clay loam, 15 inches deep, underlain by a mottled yellow and gray loam or by a silty clay loam. There is considerable variation in color and texture within the phase. It owes its origin to the lighter-colored shales and sandstones that underlie it.

The type erodes readily and on some of the slopes of logged-off areas gullies have developed, extending into the mottled subsoil.

The Melbourne silty clay loam comprises a large part of the uplands of Pacific and Wahkiakum Counties and of the northern and western portions of that part of Lewis County included in the survey. Several small areas of the type also occur in the northern part of Cowlitz County.

The topography of the Melbourne silty clay loam varies from hilly to broken. Small rolling and even comparatively level areas occur throughout the type. It is less hilly and more rolling east of Centralia, in Lewis County, and along the east side of the southern part of Willapa Bay, in Pacific County. Numerous ravines and V-shaped valleys furnish good surface drainage. In some localities the drainage is often excessive. The type occupies a lower position than the adjoining Olympic stony loam.

The Melbourne silty clay loam is a residual soil formed by the weathering of the underlying arenaceous shales and argillaceous sandstones of Tertiary age.

Fir and a scattering of cedar, spruce, and hemlock comprise the original timber growth.

Scattered areas, as a rule small and adjacent to the stream bottoms, are the only cleared portions of the type. The largest lies northwest of Menlo, in Pacific County. The important crops are oats and hay, the former yielding from 30 to 60 bushels per acre, the latter from 1 to 2 tons per acre. The greater part of the oats is cut for hay. Fruit and potatoes are grown chiefly for local consumption. These cultivated areas are parts of larger farms on the bottoms and are used chiefly for growing feed for stock and as pasture. The type is adapted to dairy farming, as the rolling areas can be used for growing winter feed crops and the hilly areas furnish good pasturage. The broken areas of the type should be kept in forest, as the steep slopes would quickly erode when cleared. The logged-off and burned areas afford grazing during a large part of the year. Corn crops should be sown on rolling cultivated fields of the type in order to prevent erosion during the rainy season. The type is usually deficient in organic matter after the repeated burnings to which it is subjected in clearing. Green manure crops would increase its productiveness.

The rougher portions of this type are valued at $2.50 to $10 an acre and the more level to gently rolling portions are held at $15 to $40 an acre. Improved land of this type is valued at $100 to $150 an acre.

MISCELLANEOUS.

ROUGH STONY LAND.

The Rough stony land includes areas which are too rough and rocky to be of any agricultural value. Rock outcrop and angular fragments of basalt make up a large part of the surface, though some areas have considerable quantities of reddish-brown clay loam or clay intermingled with the stone.

Two classes of Rough stony land are found in the survey. The first represents areas of rock outcrop which occur on some of the high peaks and ridges and which have little or no soil. The second class

includes rocky bluffs bordering some of the larger rivers and usually represents areas where these streams have cut deep canyons through the underlying basaltic formation. Other small bodies included with this type represent places where the soil is shallow and the surface strewn with rock fragments. Such areas are not always extremely rough.

The most extensive areas of Rough stony land are found in the southeastern part of Cowlitz County. Several bodies occur along the Columbia River in Wahkiakum and Skamania Counties.

The native vegetation consists chiefly of fir, which in many cases is of very inferior quality.

The type as a whole has no agricultural value, but some small areas that have considerable soil and that are not excessively stony could probably be used for growing tree fruits.

SOILS OF THE GLACIAL PLAINS AND RIVER TERRACES.

Everett Series.

The Everett soils are derived from both glaciated upland and terrace material, both ice-laid and water-laid, either till or modified drift. These deposits consist mainly of sand and gravel, but compact silt and clay strata sometimes occur in the deeper parts. The material comes from basaltic and crystalline rocks. The soils are light brown to light reddish brown and the subsoils light brown to gray. They are usually gravelly and porous. In some of the types small iron-cemented pellets are conspicuous.

This series occupies country of varied topography and includes sloping to undulating plateaus and hilly to mountainous areas. The surface is marked with morainic ridges, kames, kettle holes, and lake basins. Bowlders lie on the surface or embedded in the soil mass. Rock outcrops are also found in some places.

The types are excessively drained and erosion is severe in many sections.

At present much of the area of this series is covered with heavy forests of fir, cedar, spruce, and hemlock, and a considerable proportion of the land is better adapted to forestry than to farming.

EVERETT GRAVELLY LOAMY SAND.

The soil of the Everett gravelly loamy sand to a depth of 8 to 10 inches consists of a light-brown, medium to coarse loamy sand containing a high percentage of small gracial gravel and sandy iron pellets. The first 3 or 4 inches, owing to the accumulation of organic matter in this part of the soil, has a rather loamy texture and a dark-brown to black color. Small quantities of glacial bowlders are frequently found in the surface soil. The subsoil consists of a

light-brown to grayish-brown, medium to coarse sand, lighter in color and texture than the surface soil and containing a considerably greater proportion of gravel and cobblestones. This material is usually underlain at a depth of 3 feet, or sometimes less, by a mass of waterworn cobbles and bowlders of all sizes up to a foot or more in diameter. As a rule, however, the gravel and stones are not present in the surface soil in sufficient quantities to interfere seriously with cultivation.

Four bodies of Everett gravelly loamy sand have been mapped in the area. Three of these occur as flat-topped terraces along the Cowlitz River in the southern part of Lewis County, and one along the Lewis River in the extreme southeastern part of Cowlitz County. The largest body is located 1 mile south of Salkum and embraces approximately 4 square miles. The other areas range in extent from one-half to 1 square mile. The soil is derived mainly from the coarser deposits of sand and gravel laid down by the waters of the melting glaciers and subsequently more or less reworked or modified by the streams.

The topography is generally level or gently rolling, with a few steep slopes on terrace fronts. Drainage is excessive, the coarse gravelly subsoil allowing the water to seep rapidly downward; and during the growing season, when the rainfall is light, the soil remains in a very dry condition, and the crops are almost certain to be injured.

At present practically none of the type is under cultivation. During the early spring months, when there is usually considerable rainfall, it furnishes fair pasturage. Under intensive methods of cultivation small fruits and certain truck crops could probably be grown with a fair degree of success. Parts of the type are so situated as to make irrigation practicable, and where water is available a wide variety of crops can be successfully grown.

Land of this type is held at $5 to $40 an acre, or more where it supports merchantable timber.

EVERETT LOAMY SAND.

The soil of the Everett loamy sand consists of 10 to 15 inches of a reddish-brown or brown loamy sand or sand of medium to coarse texture. A considerable quantity of small iron-cemented pellets and glacial gravel occurs on the surface and mixed with the soil. Where the type has not been cultivated or burned over the surface 3 or 4 inches contains a relatively large quantity of decaying organic matter which gives the soil a more loamy texture and a darker color than elsewhere. The subsoil is a light-brown to gray, medium textured sand or loamy sand, containing variable quantities of rounded glacial gravels and iron pellets. At varying depths below 3 feet this subsoil rests upon a mass of waterworn gravel, cobblestones, and

larger bowlders, while on the steep terrace slopes larger accumulations of this material are found.

All of the Everett loamy sand occurs in the extreme southeastern part of Cowlitz County, where three areas have been mapped along the Lewis River. The largest of these occurs as a strip 3 miles long by one-third mile broad, approximately 1 square mile in extent. The other two bodies embrace about one-fourth square mile each. In this area the Everett loamy sand usually occurs as a series of terraces having an average elevation of 20 to 40 feet above the stream. The tops of these terraces are level to gently rolling, while the slopes are very steep. Owing to this position and the porous subsoil, the drainage is excessive, but when cultivated intensively the better areas produce fair yields. The soil is derived from the weathering of sandy glacial deposits which were more or less modified at the period of deposition by the action of glacial waters.

The native vegetation consists chiefly of fir and hemlock, with an undergrowth of salal and brakes. The greater part of the type has been logged off or burned over, but very little of it is under cultivation. When cultivated every possible means to conserve the moisture should be used, and even with such precautions crops are frequently damaged by drought. If intelligently cultivated, land of this type should produce profitable yields of strawberries and other small fruits. Under present conditions it is best adapted to crops that require intensive cultivation and can be profitably grown on a small acreage. With irrigation the soil would be well adapted to nearly all the crops grown in the region.

The value placed on the Everett loamy sand is practically the same as for other members of this series.

EVERETT STONY SANDY LOAM.

The soil of the Everett stony sandy loam to an average depth of 12 inches consists of a light-brown to reddish-brown sandy loam or loamy sand of medium to coarse texture, containing a very high percentage of gravel. Large numbers of rounded glacial bowlders of all sizes up to a foot or more in diameter are found strewn over the surface and distributed through the soil. Where the type has not been cultivated or burned over the surface three or four inches, owing to the large content of organic matter, is more loamy and much darker colored. From 40 to 70 per cent of the subsoil consists of rounded glacial gravel and bowlders. The interstitial material is a light-brown to gray coarse sand or loamy sand. Just east of Yale, in Cowlitz County, a small body included with this type is of heavier texture and more pronounced reddish-brown color than the typical soil. In Lewis County, where this type joins heavier textured types, the soil has been modified by the addition of fine silt and clay particles.

In many cases the large quantity of stones in the soil practically prohibits cultivation, but in other cases these stones can be removed with no great difficulty, and when this has been done the soil is easily handled.

The Everett stony sandy loam is derived mainly from glacial outwash material from which the greater proportion of the fine material has been removed by the swiftly flowing waters from the melting ice.

Only six bodies of this type have been mapped in the area, and none of these is very extensive. The largest one embraces less than 2 square inches. Two bodies occur along the Cowlitz River in Lewis County, one about 3 miles below and the other about the same distance above Toledo. The four remaining bodies are found in the southeastern part of Cowlitz County, where they occur as narrow strips along the Lewis River and some of its minor tributaries.

The Everett stony sandy loam in the main has a level to gently rolling topography. In Cowlitz County it occurs along the Lewis River as a series of flat-topped terraces with very steep slopes, lying from 20 to 60 feet above the river. The areas in Lewis County have a lower elevation and are not marked by the steep terrace slopes.

Owing to the extremely porous nature of the soil, drainage is excessive, and as a result crops grown on it are almost sure to suffer from drought. The characteristic forest vegetation consists chiefly of fir, with a dense undergrowth of salal and brakes. The stand of timber is generally light, the trees small, and the lumber of medium quality only. Much of the type has been burned or cut, but only a few very small areas are under cultivation. It is quite possible that some of the less stony areas could be utilized to a small extent for pastures and for fruit growing, and with an adequate supply of water for irrigation a large variety of crops could be successfully grown. The stonier and rougher areas probably always will be most profitably used for lumber production.

Land of the type ranges in value from $5 to $40 an acre, depending chiefly on nearness to market.

Toutle Series.

The soils of the Toutle series are grayish-brown, light brown, or light gray in color, and the subsoils are light gray to light brown. The material giving these types has been deposited along the courses of existing streams which formerly carried the waters of the melting glaciers. It consists, therefore, of stratified deposits, usually of porous character, and composed principally of pumice and vesicular basaltic and andesitic fragments. The soils occupy level to undulating terraces lying above overflow. They are forested principally with fir, hemlock, and cedar. Drainage is everywhere well established and in the types of coarser texture is excessive.

TOUTLE GRAVELLY COARSE SAND.

The Toutle gravelly coarse sand consists of 10 to 12 inches of a light gray or light grayish-brown coarse sand, carrying considerable quantities of rounded pumice and porous andesitic gravel. The soil is usually covered with 2 or 3 inches of decayed vegetable matter, giving the immediate surface a dark brown or black color and a loamy texture. Varying quantities of water-worn cobblestones and bowlders are found scattered over the surface and disseminated through the soil, frequently becoming so abundant on the terrace slopes as to offer serious hindrance to cultivation. The subsoil is an ashy gray to light grayish-brown sand, of similar texture to that of the soil and containing a much larger proportion of gravel, cobblestones, and bowlders than the soil, the proportion of such material increasing with depth. The rock fragments are usually small, though some of them are a foot or more in diameter, and in both soil and subsoil consist chiefly of pumice and very porous andesitic rocks with a small percentage of compact basaltic or other related volcanic rocks. Small quantities of a white, silty rock flour are frequently found in the soil and subsoil. Some small, shallow depressions included with the type are somewhat finer textured and have much more humus, making the soil in such places more productive than the average for this land.

The type is of alluvial origin, the material constituting it having been derived chiefly from pumaceous and andesitic rocks with a smaller quantity from basalt. As typically developed it represents reworked glacial outwash material deposited along streams having their source in the glaciated region around Mount St. Helens. It is usually distinctly stratified, but some small, undifferentiated areas of ice-land material or glacial till are included. In a survey of sufficient detail these would be recognized under a distinct soil series. The largest area, embracing 4 or 5 square miles, is found in the vicinity of Toutle in northern Cowlitz County. A narrow strip of this soil borders the Toutle River along the greater part of its course through the area. Other small and unimportant bodies lie along the Kalama and Lewis Rivers.

Areas of the Toutle gravelly coarse sand form terraces usually above overflow. The surface is usually level, though sometimes marked by low ridges or mounds and shallow depressions, giving it the appearance of being gently undulating. There are a few steep slopes where the terraces descend to lower lands, but these cover only small areas. The terrace tops are nearly always flat. Owing to the loose, incoherent structure of the soil and subsoil the natural drainage is excessive and crops are almost certain to be injured by drought. In the depressions, however, where the soil is not so porous and where

there is an abundance of humus the moisture conditions are much better.

The greater part of the Toutle gravelly coarse sand still supports an excellent stand of fir, cedar, and hemlock. Practically no attempt has been made to develop this land, though a few small areas occupying depressions have been placed under cultivation. In such places from 1½ to 2½ tons of hay and 40 to 60 bushels of oats per acre are secured, but these yields are very much larger than could be secured from the greater part of the type. Under present conditions the type as a rule does not carry sufficient moisture to insure profitable yields of the crops that mature during the late summer or early fall. In most cases plenty of water can be obtained for irrigation, under which the soil should be well adapted to a variety of crops, such as oats, hay, potatoes, small fruits, and some truck crops. The type is generally deficient in humus and this must be supplied before the best results can be secured.

The value of nearly all the type is based primarily on the stand and quality of the forest that it supports. The small cleared tracts can not be purchased at less than $1 an acre.

The results of mechanical analyses of samples of the soil and subsoil are given in the following table:

Mechanical analyses of Toutle gravelly coarse sand.

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.*
550975	Soil	11.2	22.8	13.3	22.1	11.4	14.6	4.7
550976	Subsoil	12.1	22.4	12.7	22.3	12.5	14.4	3.5

TOUTLE VERY FINE SAND.

The Toutle very fine sand consists of 8 to 12 inches of gray to grayish-brown very fine sand, resting on a subsoil of light-gray very fine sand or loamy very fine sand, extending to a depth of several feet, where it rests on a coarse deposit of gravel. The surface of the type frequently has a thin covering of decaying organic matter, which imparts a darker color and loamy texture to the soil. Both soil and subsoil frequently show brown, iron-stained fragments and soft iron-cemented pellets and some gravel, consisting chiefly of pumaceous rocks. Small quantities of a whitish rock flour are sometimes noticeable throughout the 3-foot section. The texture and structure of this soil make it one easily cultivated.

The fine sand of which this soil is composed has resulted from the grinding of pumice, porous andesites, and some more compact volcanic rocks by ice and water. The fine material thus formed has been carried down by streams and deposited in alluvial terraces.

Where cuts occur in this type it is generally seen to be distinctly stratified, though part of the small body lying in the vicinity of the town of Castlerock gives very little evidence of such stratification and is probably of ice-laid material.

Three bodies of Toutle very fine sand have been mapped in Cowlitz County. They occur as terraces near the mouth of the Toutle River and have an elevation of 20 to 30 feet above the stream bed. The largest body does not contain much more than one-half square mile, and the total area of the type is not much more than 1 square mile.

The soil as a whole has a fairly level topography, though low mounds and shallow depressions occur at frequent intervals, causing the surface to be gently undulating. The loose, incoherent nature of the material making up the soil and subsoil results in excessive drainage over the greater part of the type.

All the original forest growth, consisting of fir, cedar, and hemlock, has been cut, though up to the present time practically no attempt has been made to cultivate this soil. It lies in the undeveloped state known as "logged-off" land. Owing to its porosity and the low humus content, the yields that could be secured at present would be very low. With proper management the type could be built up to a state where truck and other crops that mature early in the season could be profitably grown, but even with all precautions late maturing crops would be almost certain to suffer from drought. The best results can never be expected until irrigation is supplied. Under irrigation almost any crops grown in the region could here be produced successfully.

Owing to position near the railroad land of this type of soil is held at a somewhat higher figure than the greater part of the other soils of this series.

TOUTLE COARSE SANDY LOAM.

The soil of the Toutle coarse sandy loam consists of 10 to 12 inches of light brown to grayish brown coarse sandy loam of light texture, underlain by a light-brown coarse sandy loam somewhat coarser and lighter in texture than the soil. The subsoil usually rests upon a stony and gravelly substratum at considerable depths. Small quantities of fine gravel occur in both soil and subsoil, and also numerous small, spherical pellets, consisting of the soil material cemented by iron compounds. These are easily crushed in the fingers. They are composed mainly of the finer mineral particles, as shown by mechanical analysis. The soil has in the field the physical character of a coarse sand, but under cultivation would probably in time develop a heavier texture, owing to breaking down of these mineral aggregates. The type has, therefore, been given a textural classification in accordance with the results of mechanical analysis.

The immediate soil surface is usually covered by 1 to 3 inches of decaying vegetable matter, giving rise to a superficial dark color and slightly loamy texture.

The type owes its origin to the deposition of glacial outwash or of eroded glacial drift material. Five inextensive bodies of this soil have been mapped in the area, all in Cowlitz County. One body is located just northwest of Castlerock, two in the southeastern part of the county along the Lewis River, and two along the Toutle River. The combined area of these bodies is approximately 3 square miles.

The Toutle coarse sandy loam occupies terraces having an elevation of 10 to 50 feet or more above the stream beds. The topography is generally level, with a few low ridges and shallow depressions. Owing to this position and to the porous structure of the soil and subsoil, the natural drainage is so thorough that crops nearly always suffer from drought. In order to insure any degree of success every possible precaution must be taken to conserve the soil moisture. Some areas still support a fair stand of fir, cedar, and hemlock, though much of the type has either been logged off or burned over. The few small cleared areas are devoted chiefly to the production of hay and grain, of which the yields are very light. During the seasons of abundant rainfall the type furnishes fair pasturage.

With irrigation this soil should be well adapted to a variety of crops, but under present conditions it is doubtful if the yields to be reasonably expected on the greater part of the type would justify the outlay of capital necessary to prepare it for crop production.

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

Mechanical analyses of Toutle coarse 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.*
50987	Soil	14.4	22.7	11.3	16.8	8.6	18.0	7.9
550988	Subsoil	14.6	26.0	12.4	17.9	7.3	14.8	7.0

SALKUM SERIES.

The Salkum series includes types with brown to reddish-brown soils and reddish-brown to light-brown subsoils. At depths of 3 to 6 feet beds of stratified glacial outwash gravel are found. The gravel has usually undergone advanced weathering, often being reduced to a mass of clay or rendered sufficiently soft even at a depth of 10 or more feet to be easily cut by the spade in wells or excavations. These soils occupy extensive ancient terraces and outwash plains. The surface varies from flat to undulating or gently rolling, the original ter-

race topography having been modified by erosion. The gravel is mainly composed of basalt but includes some andesitic material. The Salkum soils are well drained. They support a forest of fir and hemlock with some cedar.

SALKUM SILTY CLAY.

The Salkum silty clay consists of 10 to 14 inches of light-brown to reddish-brown silty clay, underlain by a compact, heavy, reddish-brown silty clay. In poorly-drained areas the soil is considerably darker in color and the subsoil is yellow or mottled yellow and gray. At an average depth of 4 to 10 feet the subsoil material rests upon a bed of basaltic or andesitic gravelly cobbles and bowlders, many of which have weathered into a compact clay. This substratum frequently extends to a depth of 100 feet or more.

Along the stream banks and on the slopes which separate the terraces bordering the Cowlitz River much of the finer soil material has been washed away, leaving a gravelly phase of the type. In a detailed survey such areas would be mapped as a distinct soil type, but on account of their small extent they are included in the present survey with the Salkum silty clay and their location indicated on the soil map by gravel symbols. On account of its rough topography and stony surface, the phase has a low agricultural value, though some of it is cleared and cultivated with the adjacent soils. The type is confined entirely to Lewis County, where it embraces a large part of the uplands and extends from the eastern boundary of the survey to the town of Adna on the west and from the Cowlitz River on the south northward to the city of Chehalis.

The Salkum silty clay occurs as broad, level to rolling upland plateaus or terraces. The slopes are seldom steep, except along the streams and terrace breaks. The topographic position insures good natural drainage over most of the type. Some small depressions would be benefited by artificial drainage. On the other hand, the crops are seldom seriously affected by drought, as the texture and compact structure of the soil and subsoil enables it to retain moisture through long dry periods.

The type occupies glacial outwash plains and owes its origin largely to the weathering of the underlying gravel, consisting chiefly of rounded basalt fragments. Some of the fine surface material, however, probably consists of silts and clays that have been washed down and deposited over the coarser gravelly stratum.

The original forest growth consisted chiefly of fir, with a scattering stand of spruce, cedar, and hemlock. Near the line of the Northern Pacific Railway a large proportion of the merchantable timber has been removed and the areas either left undeveloped or placed under

cultivation. Farther back the type is still covered by a valuable forest growth.

The Salkum silty clay is one of the best upland types in the region surveyed. It is well suited to nearly all crops grown in the area, but is especially adapted to the growing of small grains and grasses, crops that depend on the use of improved farm machinery for their successful cultivation. The leading crops are oats, barley, rye, wheat, and clover, timothy, and other grasses. Oats yield from 40 to 80 bushels, with an average of 60 bushels per acre. Wheat yields from 25 to 45 bushels, with an average of 35 bushels per acre. Clover and timothy return a yield of 1 to 2 tons of hay, with an average of $1\frac{1}{2}$ tons, per acre, and other crops in like proportion. Fruit also does well, the elevation of the type giving greater immunity from frosts than is enjoyed by the valley soils. Because of this fact, as well as the level topography and the consequent ease with which the soil can be cultivated, the Salkum silty clay is held in high esteem. Improved farms of this type are valued at $75 to $150 an acre, while undeveloped "logged-off" tracts are held at $10 to $40 an acre, depending on location.

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

Mechanical analyses of Salkum 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.*
25264	Soil	0.5	1.2	1.1	3.3	3.1	59.4	31.5
25265	Subsoil	.2	1.1	1.2	3.2	3.6	55.6	34.6

WINLOCK SERIES.

The types in the Winlock series have dark-brown, dark-gray, or black surface soils and brown to dark-brown, compact subsoils. They occupy flat upland terraces where, owing to the inadequate drainage, much organic matter has accumulated. In origin, mode of formation, character of underlying material, and other features they are similar to the soils of the Salkum series. The native forest growth consists principally of fir, cedar, and spruce.

WINLOCK SILTY CLAY.

The surface soil of the Winlock silty clay consists of about 12 inches of a dark-gray to dark-brown silty clay of a mellow, friable structure. The reddish color of the soils of the Salkum series is nearly always absent from the type. The subsoil consists of brown to dark-brown or mottled gray and yellowish-brown silty clay, with

frequent markings of orange-colored iron stains. From 4 to 10 feet below the surface is found a mass of partially weathered basalt and gravel. On account of the level topography many of the low areas are wet until late in the spring, with the result that farming operations are somewhat delayed. In such areas the soil, where dry, is apt to clod, making it difficult to secure a mellow seed bed. The type is found associated with the Salkum silty clay, which it resembles in origin.

All of the areas mapped are confined to Lewis County. Extensive areas are found on both sides of the Cowlitz River in the vicinity of Toledo. Smaller areas occur near Salkum, west of Ethel, and northeast of Winlock.

The type as a whole has a very level or slightly undulating topography. On the higher elevations the natural drainage is adequate, but many of the low areas along drainage channels could be much improved by open-ditch or tile drains.

The Winlock silty clay occupies outwash plains and owes its origin largely to the weathering of the underlying glacial gravel. A part of the surface material, however, has probably been derived from silt and clay deposited as a shallow covering over the coarser glacial formation.

The original forest growth consists chiefly of fir, cedar, and spruce. South of the Cowlitz River and along all of the smaller streams this growth was unusually heavy, while on the large body occupying the high level plateau north of Toledo the trees were never large. This in a measure is undoubtedly responsible for the fact that practically all of the land in this vicinity is under cultivation, although the level topography and high productivity of the soil have also been important factors in its development.

The Winlock silty clay is an excellent soil and is held in high esteem for general farming. It is well adapted to hay and small grains as well as to fruit. Clover and timothy yield from 1 to 2 tons, with an average of 1½ tons per acre. Oats yield from 60 to 100 bushels, with an average of about 75 bushels per acre. Potatoes yield on an average about 150 bushels per acre, and other crops in like proportion.

Well-drained, improved areas of the Winlock silty clay are valued at $100 to $200 an acre. Unimproved land of this type remote from the railroads is on the market at from $25 to $50 an acre.

The results of mechanical analyses of samples of the soil and subsoil of this type are given in the following table:

Mechanical analyses of Winlock 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.*
25279	Soil	0.0	1.4	0.8	1.9	3.0	60.3	32.2
25280	Subsoil	.0	2.1	1.3	3.3	4.7	57.6	30.6

SPANAWAY SERIES.

The Spanaway series includes types having dark-brown to black soils and gray to light-brown subsoils. Usually there is an excessive quantity of decaying organic matter in the soil. The surface soil is usually gravelly, and the subsoil consists mainly of rounded gravels and cobbles, with comparatively little interstitial material finer than sand. Such material extends to an undetermined depth, and the types are porous and leachy.

The Spanaway series occurs on treeless or sparsely timbered level to undulating plains. The surface is usually hummocky and with low, rounded mounds, shallow basins, and low, flat-topped terraces. It is often strewn with cobblestones. The series is derived from glacial outwash material. Although often occurring in regions of moderately heavy rainfall, the types are excessively drained and subject to drought. The lighter and shallower members are not adapted to farming without irrigation. In favorable seasons and under intensive cultivation the heavier and deeper soils yield fair crops of small fruits, vegetables, oats, barley, and hay. Under irrigation the soils are adapted to a wide range of crops, including truck crops and fruits.

SPANAWAY GRAVELLY SANDY LOAM.

Where typically developed the soil of the Spanaway gravelly sandy loam consists of 10 to 18 inches, with an average of 12 inches, of black, medium-textured sandy loam, carrying a considerable quantity of glacial gravel. The soil always contains a relatively large proportion of organic matter, giving it the prevailing black color. It also modifies the texture, making the soil appear much more loamy than it really is, as determined by mechanical analysis. A few small water-worn bowlders are frequently scattered over the surface and disseminated through the soil. The subsoil, which is grayish in color, consists principally of glacial gravel and bowlders of all sizes up to a foot or more in diameter, with which is mingled sand of various grades, such finer material constituting a comparatively small proportion of the entire mass.

The deposits from which this soil is derived were laid down as glacial outwash plains in the Skookum Chuck and Chehalis River

Valleys. The relatively small quantity of fine material in the subsoil is probably due to the assorting in swift glacial waters.

The character of the surface material has subsequently been modified by large accumulations of decayed vegetation. All the type occurs in the northern part of Lewis County in the vicinity of Centralia, where three bodies, with a combined area of about 8 square miles, have been recognized.

The Spanaway gravelly sandy loam occupies level to gently rolling plains, which are only a few feet higher than the recent alluvial soils. On account of the extremely porous nature of the subsoil, drainage is excessive, and in order to insure any degree of success in growing crops every precaution must be taken to conserve the soil moisture. As the type is level, well drained, and free from large rocks, all kinds of improved farm machinery can be used on it.

Areas occupied by this soil are locally termed "prairie" and are either treeless or else support only a sparse and stunted growth of fir and oak.

Only a small part of the type is at present under cultivation, the greater part of it being used for pasture. In extremely favorable seasons moderate yields of grain and potatoes have been secured, but attempts at cultivation will probably never be really successful until the soil is irrigated. The greater part of the type is favorably situated for irrigation and with an abundance of water large yields of hay, grain, potatoes, vegetables, and fruits would be insured.

On account of its proximity to the city of Centralia, the value of the greater part of the type is based more on its value as building lots than as farming land.

Hesson Series.

The types placed in the Hesson series consist of dark reddish-brown surface soils and compact, yellowish-brown to reddish-brown subsoils. Gravel and small bowlders of quartzite or basalt frequently occur on the surface and occasionally in the soil and subsoil. Such coarse material is most plentiful on the steeper slopes.

The Hesson series occupies eroded terraces of undulating to rolling character, usually elevated several hundred feet above the present valley floors. The material has been derived mainly from quartzites and basalt and consists chiefly of old alluvial or possibly marine deposits. It includes locally some later colluvial and residual material.

The soils of this series are well drained, though retentive of moisture. They were originally heavily forested with fir and hemlock.

The series possesses many of the characteristics of the Olympic and Aiken series, but is readily distinguished from these by the presence of the waterworm quartzite gravel.

HESSON CLAY LOAM.

The soil consists of a brown to dark reddish-brown clay loam, which has an average depth of 10 or 12 inches, resting on a compact, light brown to dark reddish-brown clay, which becomes heavier with depth. Rounded quartzite gravel occur scattered over the surface, though seldom found in the soil or subsoil. The quantity of such surface deposits is not uniform and small areas occur at intervals which have the characteristics of a gravelly clay loam. Adjacent areas may be almost free from either gravel or small bowlders. The greater accumulations always occur on the steeper slopes bordering the small stream courses.

Extensive areas of the Hesson clay loam occur in the southeastern part of Clarke County and in the western part of Skamania County. The topography now varies from almost level to gently rolling, though the areas have the appearance of having once been comparatively level terraces. Their present configuration has resulted from activities of the many small streams that traverse this region. The summits of the low hills are comparatively level, and small level benches occur at frequent intervals, but the slopes bordering the numerous small stream valleys are often steep. This topography insures good surface drainage, but the internal drainage is retarded by the heavy subsoil, and the loss of moisture is not so excessive as is so commonly the case with the upland types underlain by coarser material.

The large quantity of waterworn quartzite pebbles in this soil indicates that it is derived from material primarily laid down by water. The areas occupied were probably found as terraces along the course of the Columbia River during an earlier period; but they have subsequently been much eroded, and there is no indication of stratification, except when gravel beds outcrop along the steep slopes bordering some of the small stream courses. The soil has many of the characteristics of the residual types placed in the Olympic and Aiken series, which are derived from the underlying basalt. In some areas the material derived from the weathering of these rocks has entered to some extent into the formation of the Hesson soil.

The Hesson clay loam is well adapted to general farming and to fruit growing. A large acreage is now in prune orchards, which always produce large yields. Pears, cherries, and apples, grown to a less extent, do exceedingly well.

Oats ordinarily produce from 40 to 60 bushels per acre, and during especially favorable seasons much larger yields are obtained. Potatoes are one of the principal crops and produce on an average 200 bushels per acre. Where dairying is practiced a considerable acreage

is utilized for grass, clover, timothy, and forage crops, and large yields are always secured.

The average results of mechanical analyses of samples of the soil and subsoil of this type are given in the following table:

Mechanical analyses of Hesson 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.*
5509131, 5509137...	Soil.....	2.4	5.5	5.5	11.1	6.9	39.2	29.1
5509132, 5509138...	Subsoil.....	2.4	6.0	5.1	10.6	6.8	34.5	34.7

LAUREN SERIES.

The Lauren series includes types with reddish-brown or light-brown to dark-brown soils and light-brown or brown, sometimes slightly mottled, subsoils, underlain by a porous substratum of stratified sand and fine gravel, with occasional pockets or strata of coarse gravel. A characteristic of the types is the presence of soft, iron-cemented pellets on the surface.

This series occupies elevated terraces lying adjacent to and above present stream valleys. These terraces are probably formed by ancient alluvial or possibly marine sediments, derived mainly from basaltic rocks. Since their formation the terraces have been subjected to much erosion and the former level surface has been changed to one ranging from gently sloping to undulating or rolling. Deep, narrow stream valleys cut these terraces in many places.

The soils are well drained and of low moisture-retaining power. They occur under humid climatic conditions, and in their native condition are forested. The dominant forest growth consists of fir and hemlock with a scattering growth of cedar.

LAUREN GRAVELLY COARSE SANDY LOAM.

The soil to an average depth of 12 inches is a light-brown to slightly reddish-brown coarse sandy loam, containing relatively large proportions of fine and coarse gravel. The gravel content often varies considerably over local areas. Small areas frequently occur in which only a little gravel is present on the surface or mixed with the soil while the surface of adjacent areas may be almost covered with it.

The subsoil consists of a coarse sandy loam of light-brown color, also containing a large quantity of fine and coarse gravel. As in the soil, the gravel content is variable. In some places the entire subsoil to a depth of several feet consists of a compact mass of gravel, with little interstitial fine material. In adjacent areas the soil may be underlain by a coarse to medium sand or sandy loam, containing com-

paratively little coarse material. At depths varying from 4 to 6 feet the type is uniformly underlain by stratified deposits of coarse sand and fine gravel. The strata are often cross-bedded, and some have a dip of about 20 degrees, while the overlying or underlying strata may lie horizontally. Pockets of coarse gravel occur throughout this deeper formation. The sand found in these deposits seems to have been derived largely from basalt.

The larger areas of Lauren gravelly coarse sandy loam occur in the southern part of Clarke County. Smaller areas are also found in the central and northwestern part of this county. The type occupies level to very gently rolling upland benches and terraces and has good surface drainage. The coarse, porous character of the subsoil often causes the internal drainage to be excessive, and it is necessary to use methods of cultivation which will tend to conserve the soil moisture in order to get the best results from the crops grown.

This type is derived from deposits of sand and gravel originally laid down by the waters of the Columbia River and now forming a part of the broad terraces that border the present valley of this stream.

A large acreage has been planted in prune orchards and when thoroughly cultivated the trees are thrifty and produce good yields. Pears, apples, and cherries also do well. Small fruits, potatoes, and vegetables are grown to a small extent. Properly managed, these crops produce very fair yields. Oats and hay are grown on a limited acreage, and during an average season very fair yields are obtained.

The results of mechanical analyses of typical samples of the soil and subsoil of this type are given in the following table:

Mechanical analyses of Lauren gravelly coarse 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.*
5509107	Soil	13.5	18.2	7.3	11.6	8.7	30.0	11.0
5509108	Subsoil	14.4	23.3	8.2	10.9	7.1	25.5	10.9

LAUREN SANDY LOAM.

The soil of the Lauren sandy loam consists of 12 to 15 inches of a brown to reddish-brown sandy loam, containing a considerable proportion of coarse sand, resting on a subsoil of light-brown or brown sandy loam, which becomes lighter in color and slightly coarser in texture as the depth increases. At an average depth of 4 to 6 feet below the surface the subsoil grades into a compact but pervious stratified deposit of coarse loamy sand and fine gravel. This stratum

underlies the entire area occupied by the type and has a depth of many feet.

The largest unbroken area of the Lauren sandy loam occurs in the southwestern part of Clarke County, and other smaller areas are found in the southern part. The topography as a whole is gently rolling, but extensive level to very gently undulating areas occur at frequent intervals. The deep deposits of coarse sand and fine gravel allow the free internal movement of moisture, and drainage is very thorough, but when proper methods of cultivation are practiced there is no difficulty in conserving a sufficient moisture supply for the successful growing of crops.

The soil is derived from alluvial deposits of silt, sand, and fine gravel laid down along an old flood plain of the Columbia River. These deposits now form part of a broad bench or terrace bordering the present valley of the river.

When thoroughly cultivated, the Lauren sandy loam is very productive and is well adapted to the growing of orchard fruits, small fruits, and vegetables. It is also well suited for the production of clover, timothy, and other forage crops.

The fruit grown consists mainly of prunes, but a small acreage is in apple, pear, and cherry orchards. These require thorough cultivation, but when well cared for the trees do exceedingly well. Strawberries are grown on a small acreage, and the soil seems well adapted to this crop. Other small fruits, such as raspberries and blackberries, are grown to a limited extent and produce very profitable yields. The yields of early vegetables are good. Clover and timothy produce from 2 to 3 tons of hay per acre. Kale is grown as a forage crop, the yield being heavy.

The results of mechanical analyses of samples of soil and subsoil are given in the following table:

Mechanical analyses of Lauren 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.*
509115	Soil	5.1	19.6	10.3	13.7	12.8	26.2	14.3
5509116	Subsoil	8.1	29.4	10.6	9.2	7.7	22.0	13.4

LAUREN FINE SANDY LOAM.

The soil of the Lauren fine sandy loam to a depth of 10 to 15 inches is a brown to slightly reddish or dark-brown fine sandy loam, composed largely of fine sand, very fine sand, and silt, underlain by a light-brown or slightly mottled gray and brown fine sandy loam, which becomes heavier as the depth increases and grades into a

heavy silty clay loam or silty clay at an average depth of 3 to 5 feet below the surface. A large quantity of small mica flakes is found mixed with the silt and clay which forms the deeper subsoil.

In some localities the surface of the areas occupied by this soil is a series of small, shallow depressions, with a darker colored soil and low mounds on which the soil is typical in color, the two phases occurring in about equal proportions in areas of only a few square rods in extent.

The larger areas of Lauren fine sandy loam occur in the central part of that portion of Clarke County included within the survey. Small bodies are also found in the southern and northwestern parts of the county. The surface in general appears almost level, but the numerous small basins and mounds and ridges give in detail an undulating to very gently rolling topography. The natural drainage of the greater proportion of the areas is well established, but artificial drainage would increase the value of many of the more level areas and of the areas where depressions are numerous.

The Lauren fine sandy loam is an intermediate type between the Lauren sandy loam and the Felida silt loam. The material from which it is derived was originally laid down by the waters of the Columbia River, but the deposits now lie far above the level of this stream, forming a high terrace or bench.

Dairy farming is practiced on this soil extensively and a large acreage is utilized for growing hay and forage crops. Clover and timothy produce from 2 to 3 tons per acre, and kale, an important forage crop, does well. The average yield of oats is estimated at 40 to 50 bushels per acre, although larger yields are frequently obtained. When well cultivated the type produces from 150 to 300 bushels of Irish potatoes per acre. A considerable acreage is used in fruit growing, prunes being the leading crop. When well cared for the orchards always produce heavily. Small fruits also do well, but are grown only to a small extent.

This soil is productive and is well adapted to dairying and to the general farm crops, but a large proportion of it is still undeveloped.

The results of mechanical analyses of samples of the soil and subsoil of this type are given in the following table:

Mechanical analyses of Lauren 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.*
5509113	Soil	0.9	3.1	7.6	24.4	20.5	29.8	13.4
5509114	Subsoil	.0	2.8	7.9	24.6	17.7	29.5	17.4

LAUREN SILT LOAM.

The Lauren silt loam is a brown or dark-brown to slightly reddish-brown silt loam to silty clay loam, 10 to 12 inches deep, underlain by a compact, yellowish-brown silt loam or silty clay loam to a depth of 3 feet or more. Exposed sections show that beds of gravel and cobbles occur at depths of 20 to 30 feet. The soil is friable and easily cultivated.

Only one body of the type was mapped in the area. This occupies a high terrace near Cathlamet in Wahkiakum County and contains about three square miles.

The general topography and the underlying bed of gravel, containing large quantities of rounded quartzite, indicate that the type is an old alluvial terrace, which was formed from material brought down by the Columbia River when it flowed at a higher level.

The type as a whole has the topography of a terrace, having a nearly level surface and slopes of medium declivity toward the types on the west and north and toward the streams traversing the type. The terrace lies from 250 to 300 feet above the Columbia River and is separated from the river by a perpendicular bluff of basalt. Drainage is well established.

Some areas support a growth of fir, spruce, hemlock, alder, and maple. A small acreage is under cultivation to oats and hay. Good yields are secured. The soil is productive and a valuable type for general farming and dairying.

The value of land of this type ranges from $75 to $150 an acre.

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

Mechanical analyses of Lauren 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.*
550903	Soil	0.4	2.3	2.0	3.2	3.3	72.4	16.2
550904	Subsoil	.0	.6	.9	3.5	7.0	70.3	17.4

CAMAS SERIES.

The soils of the Camas series are light brown to dark brown in color and contain numerous small iron pellets. The subsoils are light brown to reddish brown in color, shallow, and underlain by a substratum of stratified gravel and bowlders. Both soil and subsoil contain variable quantities of rounded or subangular gravel and bowlders. Some of these are quartzite, but the material giving rise to the series is probably derived mainly from basaltic rocks.

Areas of the Camas soils form recent alluvial terraces or alluvial fans. The surface is level to gently sloping or undulating. Outcrops of basalt and angular fragments of this rock occasionally occur on the steeper slopes. The areas are free from overflow and are well and sometimes excessively drained.

A light forest of fir, hemlock, and some cedar covers much of the land.

The series occupies a lower position and is of much more recent origin than the Lauren and associated series.

CAMAS STONY GRAVELLY LOAM.

The soil of Camas stony gravelly loam consists of 8 to 12 inches of a light-brown, reddish-brown, or dark-brown loam or clay loam containing considerable quantities of gravel and small subangular rock fragments. It is underlain by a reddish-brown or light-brown loam or clay loam, which usually contains more gravel than the soil. From 40 to 90 per cent of the soil and subsoil consists of basaltic bowlders of various sizes, the largest having a diameter of 2 to 3 feet or more. At times the surface material to a depth of 2 or 3 feet or more consists entirely of bowlders and coarse gravel, with no fine soil particles. In other cases the soil may be covered by a mass of bowlders, as it may be underlain at comparatively shallow depths by the substratum of gravels and bowlders usually occurring in this series. Some small areas included with this type have considerable quantities of sand intermingled with the rock fragments.

The type occupies low terraces and alluvial fans at the mouths of creeks which rise in the rough, mountainous districts of Skamania County and empty into the Columbia River. The beds of these streams over the greater part of their course are very steep, and during times of high water they are able to carry large quantities of very coarse material. When these streams reach the more level terraces along the Columbia they spread out; and the flow being checked, the load is deposited in more or less fan-shaped areas. This material is modified at various times by the addition of clays and silts eroded from the adjacent uplands. Three small bodies of the Camas stony gravelly loam have been mapped in Skamania County. Two of these occur along creeks in the vicinity of Butler and the other along Rock Creek just west of Stevenson.

The topography is usually uneven, owing to the frequent occurrence of shallow depressions and small, rocky mounds, but it is never rough and hilly. The drainage in these areas, consisting largely of gravel and rocks, is naturally excessive, but where there is a considerable proportion of fine material the type retains moisture fairly well.

The Camas stony gravelly loam supports only a stunted and sparse growth of fir, with a few oaks. The very rocky areas, however, are practically devoid of vegetation. None of the soil is under cultivation and the greater part is too stony to be of any value for agriculture. Some small areas could be used for growing fruit.

CAMAS GRAVELLY SANDY LOAM.

The Camas gravelly sandy loam consists of 6 to 12 inches of a dark-brown sandy loam, usually containing a small quantity of rounded or subangular gravels, underlain by a lighter brown sandy loam. The deeper subsoil to 10 feet or more is a coarse sand or loamy coarse sand of imperfect stratification, which carries a much higher percentage of gravel than the soil.

The surface soil nearly always contains enough clay to make it sticky and in some cases the proportion becomes locally so high as to give the surface a rather heavy texture. Small quantities of mica are usually present. The rock fragments strewn over the surface and distributed through the soil are seldom sufficient to interfere seriously with cultivation.

In the vicinity of Homevalley there is a small area mapped with this type which differs considerably from the soil as described. Here the soil is a sandy loam and the subsoil a sand or loamy sand, neither showing the bowlders and gravel found in the typical soil. The area was too small, however, to warrant a separation.

The Camas gravelly sandy loam occupies recent river terraces and is derived from alluvial material. Earlier deposits laid down by swift waters when the adjacent streams flowed at a much higher level than at present were later covered with a thin layer of finer sands, silts, and clays, apparently in comparatively quiet waters. The surface soil has also been modified to some extent by the addition of fine material washed from the slopes of the adjacent uplands and by the accumulation of organic matter from the growth and decay of trees and plants.

Four bodies of Camas gravelly sandy loam are mapped in Skamania County. All except one small area near Homevalley are found in the vicinity of Cascades. The largest area contains approximately 2 square miles and the combined area of the four bodies is about 3 square miles.

As a whole, the type is level, though shallow depressions occur at intervals. The body in the vicinity of Homevalley has a more noticeable slope than the greater part of the type. Owing to its topography and the very porous nature of the subsoil, the drainage is excessive and crops are almost certain to be injured by drought unless irrigated.

A scattering growth of fir of inferior quality now covers most of the type. Practically none of it is in cultivation, and under present

conditions it is doubtful if the returns would justify the outlay necessary to prepare the land for ordinary farming. The two larger bodies, however, are so situated that they could be irrigated at a comparatively low cost, and a variety of crops, particularly fruits, could be profitably grown. In some cases the type furnishes good pasture during the rainy season.

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

Mechanical analyses of Camas gravelly 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.*
550969	Soil	9.2	16.1	15.4	18.8	9.2	21.6	10.0
550970	Subsoil	9.6	15.0	12.6	20.6	9.4	23.4	8.7

CAMAS SILT LOAM.

The Camas silt loam, to an average depth of 12 inches, consists of a light-brown to medium-brown silt loam, often carrying considerable quantities of small water-worn gravel on the surface and in the soil mass. The gravel, however, does not occur uniformly throughout the surface soil and is never sufficiently plentiful to give the soil the characteristics of a gravelly silt loam. Small bowlders also occur embedded in the soil at frequent intervals, though seldom found on the surface, except over a few isolated areas only a few square rods in extent, where they are numerous enough to interfere with cultivation. The areas thus affected were too small to be indicated on the map.

The subsoil is a heavy, compact silt loam, becoming heavier in texture as the depth increases and grading at about 24 inches into a light yellowish-brown silty clay loam. A small quantity of gravel and a few rounded bowlders also occur throughout the subsoil. At an average depth of from 4 to 6 feet below the surface the subsoil is underlain by an imperfectly stratified substratum of gravel and bowlders which has a thickness of from 15 to more than 40 feet.

The Camas silt loam occurs in the southeastern part of Clarke County, occupying a broad bench or terrace near the outlet of the confluence of Washougal and Columbia Rivers. A narrow strip of this soil also extends for some distance up the valley of the Washougal. The topography of the greater proportion of this soil is level to very gently rolling. Just north of Camas, however, the soil occupies a higher terrace, which extends from the river to the outlet of La Camas Lake, and the slope from the higher to lower terrace which borders the Columbia and Washougal Rivers is here often abrupt.

The drainage of the type as a whole is good. The heavy, silty subsoil enables it to conserve a sufficient amount of moisture for the growing of crops, and the coarse gravel deposit underlying the type insures good subdrainage, and even in the more level areas and shallow depressions artificial drainage is unnecessary.

Two distinct stages in the formation of this soil are apparent. First, the deposit of coarse gravel and small bowlders that forms the deeper subsoil was laid down upon the old flood plain of the Columbia and Washougal Rivers. Upon this coarser material a later deposit of fine sand, silt, and clay was deposited by the waters of these streams. Both these depositions are old and the rivers now flow at much lower levels.

The Camas silt loam is a productive soil and seems well adapted to a great diversity of crops. Dairying is one of the chief industries carried on in this section of the area and a considerable acreage of this type is utilized for growing grasses and forage crops. Clover, timothy, and kale are grown extensively and produce large yields. Small fruits, such as loganberries, blackberries, raspberries, currants, and strawberries, do exceedingly well, but up to the present very little attention has been given to the production of these crops. Orchard fruits are grown to a small extent and under proper management are profitable. Prunes occupy the largest acreage, but there are also a few small orchards of apples, pears, and cherries. Oats yield about 50 bushels per acre. A considerable acreage is annually planted to Irish potatoes, the yield ranging from 150 to 300 bushels per acre.

Camas silt loam, porous subsoil phase.—The porous subsoil phase of the Camas silt loam consists of 10 to 12 inches of a light-brown to medium-brown silt loam, overlying a light-brown to yellow silt loam or silty fine sand which rests upon bedrock or gravel at depths ranging from two to several feet. The soil usually contains small, rounded gravel and iron pellets, but this coarser material is seldom found in the subsoil. Fine particles of mica occur in both soil and subsoil, while outcrops, angular fragments of basalt, and closely related volcanic rocks are frequently encountered along the slopes. These have exerted very little influence on the composition of this soil.

This phase, like the typical soil, is confined to river terraces and consists chiefly of fine sands and silts deposited over the underlying rock formation by the Columbia River when it flowed at a much higher level than at present.

Areas of this soil occur only in Skamania County. Two areas of 1¼ to 1½ square miles each are situated near Butler. Other small areas occur in the vicinity of Cape Horn, Prindle, and Stevenson. The surface is more or less rolling and nearly always has a decided

slope toward the river. Over the greater part of the type the drainage is excessive, and crops must be cultivated frequently in order to insure the best results.

Forests of fir, with a scattering stand of hemlock and cedar, originally covered the land. These have been removed to a large extent, though some areas still support small blocks of merchantable timber.

By giving careful attention to the preparation and subsequent cultivation of the soil it would seem that such fruits as pears, apples, and prunes would do well on this soil. It is also quite probable that general farm crops and truck crops could be made profitable. A few English walnuts have been planted and are making a thrifty growth.

The principal crops grown at present are hay, grain, potatoes, fruit, and a few vegetables. All of these seem to do well.

Undeveloped tracts of this phase of the soil are held at $40 to $50 an acre.

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

Mechanical analyses of Camas 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.*
5509105	Soil	0.3	1.5	1.6	4.6	12.9	66.1	13.1
5509106	Subsoil	.3	1.1	1.2	4.1	10.6	72.9	9.7

KELSO SERIES.

The Kelso series have grayish-brown to reddish-brown soils and light-brown to reddish-brown subsoils, often mottled with gray and underlain by a substratum of stratified gray silt, clay, and sand containing occasional pockets of fine water-worn gravel. The series occurs upon moderately recent and rather narrow alluvial terraces, usually lying 40 or more feet above the present flood plains of the streams. The surface is level to gently sloping or undulating. The material forming these terraces has been derived in part from glacial deposits and in part from areas occupied by the residual Olympic and Melbourne series.

The Kelso soils are generally well drained, but retentive of moisture. They are forested with a heavy growth of fir, with a scattering of hemlock and cedar. Only one type in this series was encountered in the present survey.

KELSO SILTY CLAY LOAM.

The Kelso silty clay loam consists of 12 to 18 inches of a grayish-brown to reddish-brown silty clay loam resting upon a light-brown

to reddish-brown or mottled gray and brown, rather compact silty clay loam. This is underlain by alternating strata of gray clay, silt, and fine sand, which frequently extend to a depth of 50 feet or more, though small areas are encountered where bedrock, consisting of basalt, is either exposed or else covered only by a very shallow layer of these deposits. The soil seldom contains any large quantity of gravel, but pockets and strata of compact gravel sometimes occur at varying depths below 3 feet. The area mapped near Olequa, however, contains considerable quantities of such gravel deposits in both the soil and subsoil. The type includes a rather distinct phase in the vicinity of Toutle, Shanghai, and along the Coweman River east of Kelso. Here the soil has a dark-brown to reddish-brown color, with a more or less mottled reddish-brown subsoil, changing to a light-brown to gray at about 3 feet. As these areas are very similar in texture, topography, mode of formation, and crop adaptation, the variation in color alone seemed hardly sufficient to justify a separation.

In general, small depressions included with the type have a relatively high organic matter content, giving the soil in such places a very much darker color. The dry cultivated surface nearly always has a grayish appearance. The soil is generally mellow and free from stones and can be readily cultivated under a wide range of moisture conditions.

The Kelso silty clay loam is a river-terrace soil. It is derived from silts, clays, and fine sands deposited in comparatively quiet waters at a time when the streams flowed at a much higher level than at present. The deposits consist in part of material derived from the residual uplands occupied by the Olympic and Melbourne soils and in part of material brought down from the glaciated regions to the east. Some small areas are found, however, that are derived almost entirely from the reworked material washed from the Olympic soils.

All the type mapped in this survey is found in Cowlitz County, where it occurs as rather narrow strips bordering the recent alluvial soils of the Cowlitz River along a large part of its course through the county. Smaller and less typical areas occur in the vicinity of Toutle, Shanghai, and Woodland. The areas have in general a level to rolling topography. The level areas, however, are frequently marked by low mounds, ridges, shallow depressions, and gentle slopes, which cause the surface to be somewhat undulating. Owing to the comparative level topography and the compact structure of the soil and subsoil and underlying strata, the type retains moisture to a remarkable degree, and when given the proper care crops are seldom seriously affected by the long dry periods common during the grow-

ing season. Some of the flatter areas and the shallow depressions would undoubtedly be benefited by artificial drainage.

The native vegetation consists of a heavy stand of fir, scattering cedar, and hemlock, and a dense undergrowth of salal and vine maple. The timber has been removed from a large part of the type and many small tracts have been placed under cultivation. The soil seems very well adapted to potatoes, hay, grain, tree fruits, small fruits, and truck crops. In fact, when given the proper attention, almost any crop that is successfully grown in the region can be made to yield profitable returns on this type. The leading crops at present are hay, oats, potatoes, and strawberries. Hay yields 1½ to 2½ tons per acre, oats 60 to 100 bushels, and potatoes 150 to 300 bushels per acre. Tree fruits, truck crops, and several varieties of berries are also being grown on a small acreage. In many cases the yields could be increased by the application of lime and stable manure and by more thorough cultivation.

Undeveloped tracts of this soil are held at $40 to $100 an acre, and cultivated areas are valued at $100 to $200 an acre.

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

Mechanical analyses of Kelso silty 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.*
550979	Soil	0.5	2.6	1.7	2.9	3.6	60.1	28.5
550980	Subsoil	.2	1.5	1.1	2.1	2.0	71.1	21.8

WIND RIVER SERIES.

The Wind River soils are of light-brown to brown color and contain soft weathered basaltic fragments and small pellets or aggregates of mineral particles cemented by iron. The subsoils are light brown to yellowish brown and underlain usually at a depth of 4 to 50 feet by basalt. Frequently a stratum of stratified gravel rests upon the bedrock. Subangular to rounded bowlders and gravel commonly occur in the soil and subsoil.

The Wind River series is developed east of the crest of the Cascade Mountains, where it occupies stream terraces well elevated above present flood plains. The region is subhumid or semiarid. The terraces are level to undulating and marked by steep, rocky slopes. The series is formed of material derived mainly from basaltic rocks. The soils are well drained and rather sparsely forested.

WIND RIVER GRAVELLY SANDY LOAM.

The soil of Wind River gravelly sandy loam, to a depth of 12 to 18 inches, is a brown to slightly reddish light-brown heavy sandy loam, carrying varying quantities of angular gravel and a large content of small, concentrically weathered basaltic fragments and soft, shotlike, iron-cemented pellets. The subsoil is a light-brown or yellowish sandy loam, also containing some gravel, rock fragments, and pellets, but in much smaller quantities than the soil. As a rule the quantity of gravel decreases and the percentage of silt increases with depth, until at 30 inches the gravel is hardly noticeable and the texture is that of a silt loam. This material may rest directly upon bedrock of basalt at 4 to 50 feet or more or it may be underlain by a coarse mass of gravel, cobbles, and bowlders resting upon the basalt. Small quantities of fine mica particles and a few rounded cobbles are usually found in both soil and subsoil. Limited areas of a stony character occur where the cobbles and bowlders are strewn over the surface and distributed through the soil in large numbers. Small, undifferentiated bodies of a soil almost free from gravel and having the texture of a heavy silty loam or silty clay loam have been included with the type. Such areas often have a yellowish-colored surface soil and a light-yellow subsoil. There are also some areas of this soil that contain a relatively high percentage of humus in the first 6 to 8 inches, giving the soil in such places a dark-brown color and a silty texture. While bodies of these different phases occur at frequent intervals they were not considered extensive enough to justify any attempt at a further separation in a survey of this character.

The Wind River gravelly sandy loam consists of material brought down from the mountainous country to the north and deposited as terraces by the swift waters of the Wind and Little White Salmon Rivers at a time when they flowed at a much higher level. These terraces are found at all elevations ranging from 10 feet above the creek bed in the upper courses of these streams to 200 to 400 feet in the lower courses, where the rivers have cut deep canyons in the underlying basalt.

Two bodies of this soil have been mapped in that part of the survey included in Skamania County. These occur along the Wind and Little White Salmon Rivers as strips from one-fourth to 1 mile wide. The type is generally fairly level, but in some cases low mounds, ridges, and shallow depressions cause the surface as a whole to be gently undulating. Along some of the smaller streams and in going from a higher to a lower terrace there is frequently considerable slope, but such areas are of very small extent.

Owing to the loose, incoherent nature of the soil and subsoil of the greater part of the type, the natural drainage is inclined to be

excessive, and crops are usually affected to some degree by the long dry periods that occur during the growing season, even when every possible precaution is taken to conserve the soil moisture.

The original forest growth, which consisted chiefly of fir, with a scattering stand of hemlock and cedar, has nearly all been removed, but only a comparatively small proportion of the type is at present under cultivation. Very recently, however, considerable development has taken place on that part of the type lying along the west side of the Little White Salmon River. In this section it has been possible to divert the water from some of the smaller streams and turn it on the land at a very low cost. The greater part of this tract is being planted to fruit, chiefly apples. A few acres of such crops as oats, hay, and potatoes are grown on this type, but the areas thus used are so limited that no satisfactory information regarding yields was obtainable. The best results, however, can not be expected until water is applied artificially, and there is no reason why this could not be profitably done. The surface is favorable, and the streams will furnish an abundance of water. Under irrigation the type should give very profitable returns in growing alfalfa, strawberries, and tree fruits.

About the minimum price for undeveloped tracts of this type is $40 an acre.

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

Mechanical analyses of Wind River gravelly 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.*
550981, 550985.....	Soil.....	7.2	15.7	9.7	13.5	8.6	31.9	13.6
550982, 550986.....	Subsoil.....	4.5	13.4	9.1	12.9	7.2	39.1	13.8

WIND RIVER SANDY LOAM.

The Wind River sandy loam consists of 15 to 24 inches of a brown to light-brown sandy loam of medium texture, overlying a light-brown or yellowish-brown sandy loam or loamy sand, which extends to a considerable depth, being finally underlain by gravelly deposits. In a few places, however, the gravel substratum is absent and the soil is underlain at a depth of 6 to 10 feet by Basaltic bedrock. Both the soil and subsoil contain a small quantity of fine mica particles and a few small, rounded basalt fragments or iron-cemented pellets.

Areas of a gravelly sandy loam too small to differentiate on a map of this scale have been included with the type.

The Wind River sandy loam owes its origin to the deposition of material by the Wind River before the stream had cut to its present level. The greater part of this material was carried by the river for considerable distances and laid down in waters which were quieter than those in which the gravelly loams were deposited.

The only body of this soil occurring within the limits of the survey lies in Skamania County about one-half mile north of Carson. It contains a little more than 1 square mile.

The type occupies stream terraces having a slightly higher elevation than the fine sandy loam and gravelly loam of the series. These terraces, as a whole, are fairly level, though shallow depressions and low ridges cause the surface in detail to be gently undulating. The drainage is very thorough, but profitable yields are secured where the crops are thoroughly and frequently cultivated.

Practically all the timber has been removed from this type and a considerable area placed under cultivation. Some small tracts are devoted to the growing of fruit, but the greater part of the cleared land is used for the production of hay and oats. In favorable seasons oats yield 30 to 60 bushels per acre and hay from 1 ton to 2 tons. The soil is probably best adapted to fruit, potatoes, and such other crops as can be given frequent cultivation. The land lies favorably for irrigation and with an adequate supply of water would undoubtedly give much larger yields than can be secured under existing conditions.

Undeveloped land of this type of soil is held at about $100 an acre, while the greater part of the cleared tracts is valued at $200. These high values are in part due to the fact that the land is situated near a town and railroad.

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

Mechanical analyses of Wind River 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.*
550939	Soil	3.5	15.0	16.4	20.2	8.9	25.0	11.3
550940	Subsoil	2.7	14.6	16.1	21.5	8.7	25.7	10.7

WIND RIVER FINE SANDY LOAM.

The soil of the Wind River fine sandy loam consists of 8 to 12 inches of a light-brown, sometimes mottled brown, fine sandy loam. The subsoil is a light-brown or yellowish-brown loam, also slightly mottled with other shades of brown and yellow. This material

becomes somewhat heavier and more compact at 30 inches and rests upon stratified deposits of gravel at a depth of 10 feet or more. Both soil and subsoil contain many fine mica particles and small basalt rock fragments and iron-cemented pellets. The latter are frequently soft or so thoroughly weathered that they may be crushed between the fingers. A few angular basalt fragments are found on the surface, especially along the steeper slopes.

A small area included with this type near Homevalley lies at a much lower level, is much heavier in texture, and has a darker color than the typical soil.

The type occupies a terrace about 300 to 400 feet above the channel of Wind River. A large part of the material, originally derived from basalt, was brought down by the stream when it flowed at a much higher level and deposited in comparatively quiet waters. The only body of this soil encountered in the survey lies on the east side of Wind River about 1½ miles east of Carson. The topography as a whole is level to rolling, with a pronounced slope toward the river. Owing to the rather compact structure of the soil and subsoil, the type retains moisture better than the other soils of this series, so that with proper cultivation crops that would be seriously damaged by drought on the more porous soils can here be successfully grown.

The greater part of the merchantable timber has been removed, but the type still supports a second growth, consisting chiefly of fir.

At the present time so little of this type is under cultivation that no satisfactory information regarding its productiveness is obtainable. It may safely be assumed, however, that the yield of hay and oats would be fully as large as on other soils in this region. With proper management the type should give profitable returns from tree fruits, especially apples. Strawberries should also do well on this soil.

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

Mechanical analyses of Wind River 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.*
550949	Soil	1.0	5.9	9.3	20.2	20.1	27.9	15.6
550950	Subsoil	.3	4.5	7.8	20.2	16.7	31.8	18.8

WIND RIVER GRAVELLY LOAM.

The Wind River gravelly loam consists of 12 to 18 inches of a brown to light-brown loam of rather silty texture, containing a rela-

tively large quantity of organic matter and considerable quantities of subangular to rounded gravels. The subsoil, consisting of a light-brown or yellowish-brown loam of silty texture, also carries a high percentage of gravel, but is usually somewhat heavier in texture and lighter in color than the soil. At 5 to 6 feet or more this material rests upon a substratum of stratified gravel.

A few bowlders and cobbles are usually found on the surface and distributed throughout the 3-foot section of the type. Such bowlders are very numerous along stream slopes where the surface material has been eroded away. Both soil and subsoil contain noticeable quantities of fine particles of mica.

The type occurs as a stream terrace having an elevation of 300 to 500 feet or more above the present floor of the river. It is composed chiefly of material transported from the mountanious regions to the north and laid down by Wind River at an earlier period.

Only one body of the soil has been mapped in the area. This occurs in Skamania County in the vicinity of Carson and contains approximately 2 square miles. Though the stream slopes are sometimes steep the type as a whole has a level to gently-rolling topography. The drainage while thorough is not excessive, and very profitable yields of crops are secured when proper cultivation is practiced.

Very little of the original forest growth, which consisted chiefly of fir, remains, but much of the type is still in an undeveloped state. When the proper precautions are taken for conserving the soil moisture the type is fairly well adapted to a variety of crops, but more particularly to fruit. Peaches and cherries do very well, but it is quite probable that large returns can be secured from apples. There is nearly always a good demand for the latter crop at fair prices, and it has the advantage over most other tree fruits in keeping qualities. In order to insure the best results the land must be frequently cultivated and the trees carefully pruned and sprayed. However, the greatest success in fruit growing will not be attained until irrigation facilities are provided. As the land lies favorably and as the Wind River furnishes an abundance of water, it is quite probable that a system of irrigation will eventually be installed.

The principal crops grown at present are hay and oats, though a few orchards have been planted.

As all of this type is located near town it is held at a rather high price. Undeveloped land is held at $100 to $150 an acre, and cleared tracts are valued at $200 to $300 an acre.

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

Mechanical analyses of Wind River gravelly 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.*
550935, 550937.....	Soil.....	8.3	9.1	5.7	9.7	11.3	41.2	15.3
550936, 550938.....	Subsoil.....	7.7	8.9	5.1	9.7	10.5	44.2	13.8

WIND RIVER LOAM.

The soil of the Wind River loam consists of 16 to 18 inches of brown loam of fine silty texture, carrying rounded gravel and angular fragments and bowlders of basalt or related rocks. The subsoil, where an underlying mass of bowlders is not too close to the surface, is similar in texture and of lighter brown color and more compact structure than the soil. Deep exposures along the canyon of the White Salmon River show stream-laid sand, gravel, and bowlders to a depth of many feet.

The only area of this type occupies a high bench in the extreme southeastern part of Skamania County, about 250 feet above the level of the Columbia and White Salmon Rivers. The bench is an old stream terrace, which was formed by the White Salmon River when it flowed at a much higher level.

The surface is sloping or nearly level to undulating. The descent to the Columbia and White Salmon Rivers is precipitous and rocky.

Uncleared parts of the type support a scattering growth of scrub oak and small pine. The greater part of the development has taken place in the last two or three years, and the land is being rapidly cleared and set in orchards, which appear very thrifty. Orchards in bearing indicate that the deeper portions of the type are adapted to the growing of apples, peaches, and other fruits without irrigation. Although the shallower and more rocky areas are apt to suffer from drought, fruit could be successfully grown on them with irrigation. The type produces good garden crops.

Undeveloped land of this type is valued at $175 to $200 an acre. No sales of developed tracts are reported.

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

Mechanical analyses of Wind River 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.*
550925.....	Soil.....	0.8	4.8	5.5	9.7	18.4	43.3	17.6
550926.....	Subsoil.....	.6	5.0	5.3	10.0	15.3	45.1	18.6

NASEL SERIES.

The types included in the Nasel series have dark-brown to black soils, containing a large amount of organic matter, and light-brown to yellow or gray subsoils, often mottled and of heavy texture. At less than 6 feet from the surface a compact substratum of rounded gravels, cobbles, and bowlders, with some interstitial sandy material, is found. In some types the true subsoil is absent, and the gravel immediately underlies the soil.

The series occurs upon old alluvial terraces along streams, traversing areas occupied by the Olympic and Melbourne soils. The terraces are usually elevated from 10 to 40 feet above the adjacent valley bottoms and are above overflow. Their surface is level to gently undulating or gently sloping, though the descent to adjacent bottoms or lower terraces is steep.

The deposits giving rise to these soils include some colluvial material, and in any case are derived mainly from the region of residual soils. The Nasel soils are well drained and support a growth of fir, hemlock, cedar, and spruce. They retain moisture rather poorly and are droughty during the summer season. Under favorable moisture conditions they are adapted to oats, hay, and forage crops, potatoes and other vegetables, and small fruits.

NASEL GRAVELLY CLAY LOAM.

The soil of the Nasel gravelly clay loam is a dark-brown to black clay loam, carrying small quantities of cobbles and gravel on the surface and frequently intermingled with the soil. This is underlain at a depth of 12 to 18 inches by a mass of water-worn gravel and cobbles, with a small quantity of interstitial sand and finer material of a yellowish color. On the slopes the surface soil is particularly gravelly and stony.

This is a type of small extent. It is found on narrow terraces along the Nasel River and Trap and Forks Prairie Creeks, in Pacific County, and along the Alochaman and Grays Rivers, in Wahkiakum County. It lies from 10 to 25 feet above the present flood plain of these streams.

The Nasel gravelly clay loam is an old alluvial soil composed of material brought down from the uplands by the streams. The dark color is due to an accumulation of organic matter. The type differs from the Nasel silty clay chiefly in having the substratum of gravel and cobbles within 12 to 18 inches of the surface.

It is droughty and is used for grazing during a part of the year. Practically none of the type is under cultivation. Under irrigation it would be a valuable soil for fruit and truck crops.

The value of the land is the same as that of the surrounding logged-off areas, from $25 to $40 an acre.

NASEL SILTY CLAY.

The Nasel silty clay is a dark-brown to black silty clay, with a depth of 16 to 24 inches, resting on a subsoil of mottled, light-brown, yellow, and gray clay, very compact and slightly plastic when wet. At or below a depth of 3 feet a bed of stream-laid gravel and cobbles is encountered. In a few cases this gravelly substratum occurs at a depth of 30 inches. The soil checks and cracks when dry, but breaks up readily when cultivated at the proper time. The soil contains a relatively high percentage of organic matter. Small, undifferentiated areas of a grayish-black clay occupy a few poorly drained depressions near the upland margin of the type. In a few cases limited quantities of basaltic gravel are found on the surface of the type.

The Nasel silty clay occupies benches or second bottoms along some of the streams of Pacific and Wahkiakum Counties. Areas too small to show on a map of this scale occur along some of the streams of these counties. The largest area of the type lies in the Willapa Valley, in Pacific County.

The surface of the Nasel silty clay is typically level, but some areas have a very gradual slope toward the streams. It lies from 10 to 20 feet above the first bottom. Where no first bottom has been developed the streams are deeply intrenched in the type. The terraces or benches occupied, especially in the Willapa Valley, lie at different levels, but the type is nowhere subject to overflow, except in case of extremely high floods. On account of the impervious subsoil and level topography, the drainage is imperfect.

The Nasel silty clay is formed from sediments deposited by streams draining the uplands occupied by the Melbourne and the Olympic soils. Parts of the type have been modified by colluvial material from the slopes of the adjacent uplands. The appearance of the type indicates that at some time it has been subjected to swampy conditions.

The Nasel silty clay was formerly covered with a forest of fir, cedar, hemlock, and spruce, but practically all this forest has been removed.

Outside of the Willapa Valley only a few small isolated patches of this soil are under cultivation. In this valley the greater part is cultivated to oats and grass. The expensive clearing and the slowness with which the type responds to cultivation have retarded its development. Light yields are the rule for the first two seasons, after which good yields of hay, oats, kale, and potatoes are secured in favorable seasons. A small acreage is devoted to strawberries and to truck crops. During the summer months of some seasons crops are apt to suffer from drought. The logged-off areas furnish fair pastur-

age. Dairying is the chief source of income to the farmers located on this type.

The value of uncleared areas of the type varies from $10 to $50 an acre. Improved areas bring from $100 to $200 an acre.

Doty Series.

The Doty series comprises terrace types having light-brown or yellowish-brown to reddish-brown surface soils, carrying rounded gravel and cobbles, and yellowish-brown to reddish-brown subsoils. They are underlain, like the Nasel soils, at a depth of 3 to 6 feet by a substratum of rounded cobbles, bowlders, and gravels, mainly of basalt, and are distinguished from the Nasel series by their darker color, larger content of organic matter, and coarser character of the underlying stratum.

The Doty series occurs upon level to undulating terraces, is well drained, and usually free from overflow. The material of which the soils are composed has been derived mainly from the region of the residual Olympic and Melbourne series. The series is developed in a humid region and supports a forest mainly of fir, hemlock, and cedar. The soils are adapted to dairy farming and the production of oats, hay, and potatoes. Only one type was mapped in the present survey.

Doty silty clay loam.

The Doty silty clay loam consists of a light-brown or sometimes light reddish-brown silty clay loam, with a depth of 12 to 18 inches, resting on a subsoil of yellowish-brown to reddish-brown silty clay loam or clay, extending to a depth of 3 feet or more. At 3 feet or deeper a bed of rounded gravel and cobbles with a very small quantity of interstitial fine material is found. Small level areas or slight depressions have a dark-brown to black soil, underlain by a mottled yellow, brown, and gray subsoil.

A gravelly phase of this type, indicated upon the soil map by symbols, is found near Boistfort, Pe Ell, and Doty. The soil of this phase is a reddish-brown gravelly silty clay loam, underlain by a yellowish-brown gravelly clay loam or clay, resting upon a substratum of gravel and cobbles at or below a depth of 3 feet. Considerable quantities of gravel are frequently found on the surface, but in some cases little gravel occurs in the subsoil.

East of Curtis and also north of Adna areas have been modified by alluvial material derived from the adjoining Melbourne silty clay loam.

North of Dryad the soil is a brownish-red clay loam, underlain by a reddish clay loam subsoil, which at a depth of 8 to 10 feet rests upon a bed of more or less angular fragments of basalt, gravel,

and cobbles. This phase has been modified by material from the Olympic silty clay loam on the north.

The Doty silty clay loam occupies more or less pronounced terraces in the valleys of the Chehalis and Newaukum Rivers, and of some of their tributaries, in Lewis County. The most extensive area lies west of Forest, in the Newaukum Valley.

This soil comprises the remnants of alluvial terraces which formerly occupied extensive areas along the stream mentioned. They were formed from material brought down by the streams from the residual uplands.

The surface of the type is nearly level and lies from 8 to 25 feet above the present bottoms along the Chehalis and Newaukum Rivers. Very little of the land is overflowed, but water stands on parts of it during the rainy season.

Much of the type is cleared and used in the production of the general farm crops or for pasture. The yields of oats range from 40 to 75 bushels per acre. Hay yields from 1½ to 2½ tons per acre. Potatoes are grown chiefly for home consumption. Dairying is the chief source of income of the farmers.

The value of land of this type varies from $50 to $150 an acre, depending upon the improvements and state of cultivation.

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

Mechanical analyses of Doty silty 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.*
550989	Soil	0.8	3.2	3.4	8.5	7.7	52.7	23.8
550990	Subsoil	.2	1.9	2.1	6.5	6.7	46.4	35.9

SIFTON SERIES.

The Sifton series is another group of soils found on terraces in this general region. The terraces are ancient and may either have been laid down by the rivers now flowing in adjacent valleys or may have had a marine origin. In general mode of occurrence and appearance the soils resemble the Spanaway soils, which are classed as glacial outwash types, for like the latter they are sparsely timbered, are known locally as prairies, and are excessively drained.

The types are distinguished by dark-brown, dark-gray, or black soils and coarse, porous subsoils consisting mainly of stratified deposits of gravel and cobblestones, with little interstitial material. The soils contain a large proportion of organic matter and have evidently been subject at some time to swampy conditions.

One type in this series is found in the region covered by the present survey—the gravelly sandy loam. It is used extensively in the production of prunes.

SIFTON GRAVELLY SANDY LOAM.

The soil of the Sifton gravelly sandy loam is a dark-brown or dark-gray to black sandy loam, 10 to 12 inches deep, carrying a large quantity of rounded gravel both on the surface and mixed with the soil mass. The gravel varies in size from fine particles to fragments several inches in diamter. A relatively high content of organic matter gives the soil its characteristic dark color. The subsoil is a compact mass of gravel and small, rounded cobbles, mixed with a medium to coarse sandy loam or loamy sand of brown color. In some places the interstitial material is almost wholly lacking.

Areas of this type occupy two large, sparsely timbered tracts in the southwestern part of Clarke County, locally known as the Fourth Plain and Mill Plain. Another small area occurs just east of the town of Vancouver. These areas were easy to clear and were among the first in the entire area to be farmed. Small areas have been under cultivation for more than 50 years. In general the surface of the area is level, but in detail numerous low mounds and ridges, with broad, shallow depressions intervening, give the type as a whole a gently undulating topography. The coarse, gravelly subsoil causes excessive internal drainage, and it requires very careful methods of cultivation to conserve a sufficient supply of moisture for the crops which mature late in the season. The deposit of sand and gravel from which this soil is derived was originally laid down upon an old flood plain of the Columbia River. Since then the river has cut its channel to a depth of many feet, and the type now occupies a part of the broad terrace lands which border the present valley of the stream.

A comparatively large area of the Sifton gravelly sandy loam is under cultivation. The success or failure of the crops depends largely on the methods used in their cultivation. Every precaution must be taken to conserve the soil moisture if profitable yields are to be secured. A large acreage is in prune orchards. When well cultivated and vetch or some other green manure crop is grown and turned under, these orchards do well and produce large yields, but with inefficient management they give very poor results. Early vegetables do well, but all crops that mature late in the season are often damaged by drought. Strawberries do well, and a good crop is almost always secured. Irish potatoes when thoroughly cultivated produce from 150 to 200 bushels per acre.

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

Mechanical analyses of Sifton gravelly 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.*
5509103	Soil	20.2	7.8	3.0	8.5	10.6	33.4	16.6
5509104	Subsoil	33.4	9.3	3.3	8.1	7.7	26.9	11.7

FELIDA SERIES.

The Felida series comprises types with grayish-brown to dark-gray surface soils and light-brown or mottled gray and brown compact subsoils. The soils are usually free of gravel, but a deep substratum of compact stratified silts, clays, and fine sands, with occasional pockets of rounded gravel, underlies the series.

The Felida soils occupy elevated, eroded terraces, which are cut by deep valleys of minor streams. In the general features of origin, mode of formation, and topography the soils are similar to those of the Lauren series, from which they differ in color and in the character of the substratum. The areas are well drained, except for occasional local depressions, but the soils are retentive of moisture and productive.

FELIDA SILT LOAM.

The soil of the Felida silt loam to a depth of 12 to 15 inches consists of a grayish-brown to dark-gray silt loam, containing a few small, rounded, iron-cemented pellets. The soil is composed mainly of silt, but it contains enough clay to cause the formation of compact clods if cultivated when wet. The subsoil is a light-brown or slightly mottled brown and gray heavy silt loam that grades usually into a silty clay loam at a depth of 3 to 4 feet below the surface. A considerable quantity of fine mica particles is always present in the subsoil; a few small pockets of gravel occur in the soil and subsoil, but as a whole the type is free from coarse sandy gravel or bowlders. The subsoil is underlain by a compact deposit of silt, silty clay, and fine sand. This deposit is stratified, and at a depth of from 10 to 20 feet below the surface distinct strata of silt or fine sand several feet in thickness sometimes occur.

The larger body of the Felida silt loam occurs in the western part of Clarke County, extending from the South Fork of the Lewis River to Vancouver on the Columbia River. Several smaller areas are found in the southeastern part of Clarke County and in the western

part of Skamania County. The topography varies from comparatively level to gently rolling. Some of the areas which border the valley of the South Fork of the Lewis River and the areas just west and northwest of Manor have a more rolling topography, but the hills are rounded and the slopes are never steep enough to interfere with cultivation or to subject the land to damage by erosion. Many of the small streams which traverse the areas occupied by this type have cut deep, narrow valleys, and the slopes bordering the stream courses are often steep.

The type as a whole has good natural drainage. The heavy character of the subsoil, however, does not permit the excess water to drain off rapidly and some of the more level areas and shallow depressions remain in a cold, wet condition during the early spring months. The agricultural value of these small areas would be greatly increased by artificial drainage. The soil is derived from deposits laid down upon an old flood plain of the Columbia River. These deposits now have an elevation of many feet above the present flood plain and form one of the more recent elevated terraces of the Columbia Valley.

Where proper methods of cultivation are used the Felida silt loam produces yields equal to those obtained from any upland terrace soil in the area. A large acreage is utilized for the growing of prunes. The soil seems well adapted to this fruit and when well cared for the orchards do exceptionally well. Cherries, apples, and pears are also grown to some extent with good results. Small fruits, such as strawberries, blackberries, and raspberries, also do well, but are grown only in a small way.

This soil is well adapted to the production of grass and forage crops. Clover and timothy yield 3 to 4 tons per acre. Kale is grown as a forage crop and produces a large tonnage per acre. The oat crop is one of importance. (See Pl. II, fig. 1.) During ordinary seasons the yields range from 50 to 75 bushels per acre and larger yields are not uncommon. Irish potatoes do well, producing from 200 to 400 bushels per acre. A small acreage in alfalfa has demonstrated that this crop can also be successfully grown. The topography, natural drainage, and general productiveness of this soil make it one of the best types for general farming in the area. The land is valued at $100 to $400 an acre, the value depending on the location of the land and the extent to which it has been improved.

The results of mechanical analyses of samples of the soil and subsoil are given in the following table:

Mechanical analyses of Felida 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.*
5509111	Soil	0.4	3.2	1.7	3.3	11.9	63.6	15.8
5509112	Subsoil	.0	1.0	.6	2.2	10.7	69.7	15.7

SOILS OF THE RECENT FLOOD PLAIN AND DELTAS.

PUGET SERIES.

The Puget series includes the recent alluvial soils occupying the valleys and delta flats of the rivers which traverse the glaciated region of the Puget Sound Basin. The types of this series are quite uniform in color, texture, and topography in all parts of the Puget Sound region. They are derived from glacial material which has been brought down by the rivers and deposited over the valleys or in the shallow bays at the mouths of the streams in times of flood, eventually building up broad, level delta lands. The types are characterized by flat to gently-sloping topography and by brown to drab or gray friable soils, usually with a high organic matter content, underlain by light-brown to drab material, ranging from porous sands to compact silt or silty clay subsoils.

The lighter-textured types of the series occur near the main stream channels where the coarser material was deposited by the swifter currents. Farther back from the stream the sandy deposits have been covered by finer sediments of silt and clay, which were laid down in the quieter waters. In depressions, which remained flooded for long periods in each overflow, the sediments of silt and clay are often many feet deep, giving rise to the heavier types of the series. Over the greater part of the valleys the underlying sandy deposits are encountered at from 10 to 30 inches below the surface.

PUGET FINE SANDY LOAM.

The Puget fine sandy loam consists of 12 to 15 inches of light-brown to light grayish-brown fine sandy loam, which frequently has a thin covering of silt where the type occurs adjacent to the silt loam of this series. The texture of the type in this area is in general somewhat finer than the average. The subsoil is lighter in color and texture than the soil and consists of a fine sand, which gradually gives place to a medium sand in the deeper subsoil or substratum. Both the soil and subsoil are slightly mottled with iron stains.

This type includes many areas along the immediate banks of the streams, where the texture is much lighter than the typical soil, being either a loamy sand, a loamy fine sand, or even a fine sand. In such

places the subsoil, too, is generally coarser and more porous. Other local, undifferentiated areas occur in some of the large bends of the Cowlitz River, where the soil is made up almost entirely of river wash, consisting of gravel and the coarser grades of sand with practically no fine silty material.

As a whole, the type is mellow and friable and can be cultivated under a wide range of moisture conditions.

The Puget fine sandy loam owes its origin to the deposition of material by streams which have their source in glaciated regions. This material, held in suspension, is assorted by currents of varying velocities, the coarser particles being laid down near the stream banks where the waters are swift and the finer sands and silts farther back in comparatively quiet waters.

The greater part of the Puget fine sandy loam borders the Cowlitz River, where it occurs as a strip from a few rods to a mile or more wide along nearly its entire course. A number of small bodies are also found along the Kalama and Lewis Rivers and one body along the South Fork of the Toutle River. Two of the largest and most important areas are in the vicinity of Kelso and Woodland.

The surface is generally level, though it is frequently interrupted by abandoned stream channels, low mounds, and shallow ridges, causing the topography in detail to be gently undulating. The loose, incoherent structure of the soil and subsoil insures good natural drainage. Some of the areas are subject to overflows, but only during seasons of unusual floods. These occur at seasons of the year when the crops are not likely to suffer any great injury. On some of the lighter phases crops are frequently damaged by drought.

The original forest consisted of a mixed stand of fir, spruce, cedar, cottonwood, alder, and willow. The greater part of this has been removed and nearly all the land placed under cultivation. The type is well adapted to berries and other small fruits and tree fruits, especially pears, prunes, and cherries. Little truck is grown on this soil, though it would seem that profitable returns could be secured from such crops in favorably situated areas. The larger tracts are devoted principally to the production of hay and grain, and the crops, while smaller than on the silt loam of the series, are usually profitable. The yield of hay ranges from $2\frac{1}{2}$ to $3\frac{1}{2}$ tons and of oats from 60 to 125 bushels per acre. Potatoes are also successfully grown, from 200 to 400 bushels per acre being the ordinary range in yields. The area used for the production of fruit is gradually extending, especially in the vicinity of Toledo, Kelso, and Woodland, where excellent results have been secured.

Improved areas of the Puget fine sandy loam near towns are valued at $150 to $250 an acre. Some small, undeveloped tracts in the more remote districts could probably be purchased for $25 to $50 an acre.

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

Mechanical analyses of Puget 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.*
25254	Soil	0.4	0.3	1.8	24.0	20.3	43.1	10.0
25255	Subsoil	.1	.3	3.1	66.7	21.0	6.7	1.7

PUGET SILT LOAM.

The Puget silt loam consists of 10 to 24 inches of light grayish-brown or slightly mottled gray and brown silt loam, frequently carrying a relatively high proportion of very fine sand. The subsoil is a light-gray, grayish-brown, or mottled gray and brown fine sand or silty fine sand, becoming gradually coarser as depth increases, and at about 3 feet being displaced by a gray or grayish-brown medium-textured sand. This coarser material is also usually more or less mottled with brown iron stains.

In a few poorly drained basins areas of a silty clay, which are not underlain by sand within 3 feet, have been included with this type.

Puget silt loam, dark phase.—An important dark phase of this type occurs in the vicinity of Woodland, where two bodies have been indicated on the map by means of hachures. In these areas the upper 4 to 6 inches consists of a black silt loam containing a relatively large proportion of organic matter and rests upon a layer of gray or mottled gray and brown fine sand or fine sandy loam 6 to 8 inches thick. This material is underlaid by a heavy silt loam or silty clay loam having a gray or mottled gray and brown color. The subsoil may extend to a depth of 3 feet or more or it may rest upon deposits of sand at a somewhat shallower depth. The dark color of the surface soil in these areas is probably due to the fact that they were formerly rather swampy, thus favoring the accumulation of large quantities of decaying vegetation.

The type owes its origin chiefly to the deposition of fine alluvial material brought down from the glaciated regions near Mount St. Helens and Mount Rainier by the Cowlitz, Lewis, and Kalama Rivers. The valleys in which this type occurs were formerly covered by a deposit of sand, and this now forms the subsoil of the type. The soil proper represents more recent deposits laid down in quieter waters. In some cases this material has been modified by the addition of material from the adjacent upland soils of the Olympic series. The topography is generally level, though low mounds, shallow basins, and old stream channels are found at intervals, giving the surface a gently undulating appearance.

Areas of this soil usually occur at somewhat lower elevations than the surrounding types, and for this reason water stands on parts of it during the rainy season. Some of these areas would be benefited by artificial drainage, thus making it possible to commence farm operations earlier in the spring, but the natural drainage of the greater part of the type is very good.

A large part of the Puget silt loam occurs in the Cowlitz Valley, in Cowlitz County, where many bodies, ranging in extent from a few acres to 1 square mile, have been mapped. These areas are found wherever the river makes a big bend. There are also a few small bodies along the Lewis River in Clarke County, in the vicinity of Woodland in Cowlitz County, and one small area exists at the mouth of the Kalama River.

Nearly all of the native vegetation, which consisted of fir, cedar, spruce, hemlock, willow, and alder, has been removed, and practically all the type is under cultivation. Its level surface allows the use of all kinds of farm machinery. It is considered one of the best soils in the area for general farming, and when well cultivated is adapted to nearly all the crops grown in the region. It is especially suited to small fruits and truck crops. The principal crops now are hay, oats, and potatoes. In favorable seasons 2½ to 3½ tons of hay per acre are secured. Oats yield from 60 to 125 bushels and potatoes from 200 to 400 bushels per acre.

As nearly all of this land is favorably situated as regards markets, its value is based primarily upon the extent to which it has been developed. Highly improved tracts near town are held at $150 to $250 or more an acre, while some of the less desirable tracts can be secured at a much lower figure.

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

Mechanical analyses of Puget 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.*
25258	Soil	0.0	0.2	0.1	2.0	4.4	82.7	10.5
25259	Subsoil	.1	.4	3.5	37.4	22.9	32.5	3.7

COLUMBIA SERIES.

The soils of the Columbia series are of grayish-brown to light-brown or buff color; the subsoils of light-gray to buff, or sometimes mottled yellow and brown color. A substratum of fine sandy material is usually present. They are micaceous, free from gravel, and high in organic matter.

The soils of the Columbia series occupy present or recent river flood plains, low stream terraces, and estuarine delta plains. They are sometimes subject to overflow, and the lower depressions are poorly drained. The surface varies from level to irregular, with sloughs and lagoons of frequent occurrence. The series differs from the Puget series in the conspicuous mica content and in the origin of the parent material, which is more heterogeneous. Much of it has been transported great distances.

In the vicinity of stream channels the soils usually support a growth of cottonwood and willows. They are adapted to grazing and to hay crops and, when not too poorly drained or subject to overflow, to vegetables or truck crops.

As mapped, the series includes considerable areas of the darker colored soils belonging to the Sacramento series. But one type, the Columbia fine sand, is found in the present survey.

COLUMBIA FINE SAND.

The soil of the Columbia fine sand is a light-brown to grayish-brown or gray fine sand, frequently of rather heavy, silty texture, with a depth of 3 feet or more. The texture of the type is subject to considerable variation, and as mapped it includes some small, undifferentiated areas of loamy fine sand and fine sandy loam which could not well be shown on a map of the scale used in the present survey. The depth of the soil decreases toward the adjoining areas of Sacramento silty clay loam, and frequently the soil of the latter type becomes the subsoil of the Columbia fine sand. Both soil and subsoil contain a high percentage of mica. The subsoil is often very compact. Near Ilwaco the type is a dark-brown fine sand, underlain by a light-colored fine sand. Narrow strips of this soil lie along the river side of several of the areas of Sacramento silty clay loam in Clarke and Cowlitz Counties. Some of the small islands in the Columbia River also have a narrow fringe of the type surrounding the Sacramento silty clay loam. Other areas occur along the Columbia River between Megler and Ilwaco in the southern part of Pacific County, and several small bodies are found along the Columbia River in Skamania and the eastern part of Clarke Counties. Other areas too narrow to show have been included with the Sacramento silty clay loam.

The type is alluvial in origin and was formed by the deposition of sediment by the Columbia River at flood stages. It is level and lies slightly higher than the adjacent bottom soils.

Cottonwoods, willows, and native grasses are the chief vegetation. The greater part of the type is used for grazing. Small areas are in alfalfa, truck, and grass crops. Two cuttings of hay—one in May,

another in August—are secured, but the yields are rather light. Tomatoes are being successfully grown on Bachelors Island.

Land of this type is usually held, along with tracts of the Sacramento silty clay loam, at $40 to $60 an acre.

Sacramento Series.

The soils placed in this series have been mapped extensively in the interior valleys of California. In the present area the one type mapped occurs under widely different climatic conditions, but in character of material from which it is derived, mode of formation, color and character of soil and subsoil, and topographic features it resembles the types previously recognized under this name.

It includes in this area some areas of undifferentiated soils of the Columbia series which differ from those of the Sacramento series in the lighter color of the soil and subsoil material.

The soils are of dark-gray to drab or black color and often contain a large amount of organic matter. Where previously mapped, they usually extend to a depth of 6 feet or more, with but little variation in the subsoil, but are sometimes underlain at less depth by subsoils of variable character, ranging from gravels and sands to heavy, compact material, usually of silty texture. In this area the deeper subsoil occurring at a depth of 3 to 6 feet is usually a fine sand. The subsoils are usually of drab or brown color and may be mottled. The series occupies stream bottoms and river flood plains, often marked by sloughs, and are frequently subject to overflow where not protected by levees. The lighter members usually occupy the slightly higher elevations of natural stream-built levees. The surface varies from irregular to smooth. The series consists of recent alluvial flood-plain material deposited from shifting stream currents or from slack flood waters. The material, which has been transported long distances, comes from both quartz-bearing and quartz-free igneous rocks and metamorphic rocks, and to some extent from sedimentary rocks and glacial material. In the vicinity of stream courses a growth of timber usually occurs. When protected by levees and favored by climatic and drainage conditions, the soils are usually productive and adapted to general farm crops and to the intensive production of sugar beets, truck crops, beans, hops, potatoes, alfalfa, or prunes, pears, and other fruit.

Sacramento silty clay loam.

The soil of the Sacramento silty clay loam is a dark-gray to dark-brown or drab silty clay loam often containing much surface organic matter and becoming nearly black in color. It extends to an average depth of 18 inches and often shows yellowish mottlings. A thin

mantle of more recent sediment of a mottled yellow and brown color covers the surface of portions of the type. The subsoil is a bluish-drab, mottled with yellow and brown silty clay loam, with a depth of 3 feet or more. The intensity of the mottling varies with the position of the type, being less pronounced in the better drained areas. The type is always underlain by sand at a depth of 3 to 5 feet below the surface, and occasionally the sand is encountered at a depth of 30 to 36 inches. Both soil and subsoil contain small quantities of mica. The texture is noticeably lighter near sloughs and streams. Frequently there is a thin covering of muck on the surface of small areas, and pockets of peaty material occur in both the soil and subsoil. Local undifferentiated strips of Columbia fine sand along some of the sloughs and rivers were included with this type when they were too narrow to show on a map of the scale used in the present survey. In Wahkiakum County the color of the surface is very dark, and the soil and subsoil have very little mottling.

The Sacramento silty clay loam occupies the greater part of the bottom land along the Columbia River in Skamania, Clarke, Cowlitz, and Wahkiakum Counties. The most extensive areas occur in the western part of Clarke County, near the mouth of the Cowlitz River in Cowlitz County, and near the mouth of the Alochaman River in Wahkiakum County. Puget Island, in the Columbia River off Cathlamet, and included within Wahkiakum County, is entirely covered by the type and constitutes another large area of the soil.

The surface is generally level, but low ridges and somewhat higher areas along the river banks and numerous sluggish sloughs occur, and in detail it has a very gently undulating topography. Old stream channels and basinlike areas between the sloughs and ridges often contain shallow lakes, lagoons, or marshes, especially in the western part of Clarke County, where Vancouver, Shillapool, and several smaller lakes occur. The areas in Wahkiakum County are more level, as they have no ridges and only slightly higher strips along some of the sloughs and river banks. Although the greater part of the type lies along the portions of the Columbia River subject to tides, the water of the Columbia River and of the sloughs is fresh.

The type lies from 3 to 10 feet above the normal level of the Columbia River and is overflowed during a part of the rainy season and again in June and July. At other seasons the ground-water level varies with the level of the river, but it is never far below the surface. The better drained parts of the type are on the ridges and near the sloughs and rivers. The type as a whole is very poorly drained and has marshy areas.

The Sacramento silty clay loam is formed largely from the finer sediments deposited by the Columbia River during floods. The Lewis, Kalama, Cowlitz, and Alochaman Rivers have each aided materially in the formation of the areas near their respective mouths. Although these areas have some of the characteristics of deltas, the greater part of the sediment which forms the soil and subsoil was deposited by the Columbia River.

Cottonwoods, alders, and willows grow on the ridges and along the sloughs and rivers, and the more level areas support a good growth of wild grasses.

Thus far there has been very little development of this type. Small cultivated fields occur, but the majority of them are along the sloughs and rivers on strips of the Columbia fine sand, which were too narrow to map. These fields often extend for a short distance into the typical Sacramento silty clay loam. The largest cultivated area lies west of Vancouver, in Clarke County. At present hay is the most certain crop grown, for it is less subject to damage by the late spring floods. Yields of 2½ to 4 tons per acre are secured. A considerable acreage of wild hay is cut during the latter part of August and early in September. The greatest handicap to hay farming is the danger of unsettled weather during the haying season. The type is used largely for grazing during the greater part of the year. Good yields of wheat are secured on a limited acreage on Bachelors Island. It is used for feed, as the grain is too soft for milling purposes. Oats are grown on parts of the areas lying south of Vancouver Lake and also on Bachelors Island. It is a rather uncertain crop, as the seed is likely to be damaged by standing water or by sediments deposited during the spring floods. The yields range from 60 to 100 bushels per acre, depending upon the season. One tract on one of the islands west of Cathlamet has been diked and is producing good yields of truck crops.

As may be seen from the yields stated, the type is very productive and, if protected from overflow by dikes and drained, would give profitable yields not only of the general farm crops, but of truck crops. It has cheap transportation facilities to nearby markets and would justify a considerable expense for diking and draining. Under the present conditions of drainage and the liability of damage to crops by late spring floods, it is best adapted to dairy farming.

Unimproved land of this type is held at $40 to $60 an acre; small areas of improved land are valued at $200 to $500 an acre.

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

Mechanical analyses of Sacramento silty 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.*
550901, 550927....	Soil.....	0.0	0.3	0.6	1.7	0.8	72.2	24.1
550902, 550928....	Subsoil.....	.1	.5	.6	1.1	1.3	70.3	25.9

CHEHALIS SERIES.

The Chehalis series consists of recent alluvial soils, occupying the valleys of streams that traverse humid regions of residual soils from basalt and sedimentary rocks. The Chehalis types vary considerably in color, but the majority are gray or drab to reddish brown. Some of the heavier types contain much organic matter and are dark brown to black. The subsoils are yellow, gray, sometimes mottled, light brown, dark brown, or black. They vary much in texture. The material has been eroded mainly from fine-textured soils occupying the uplands and deposited in the river valleys during times of flood. Some of the areas are at present subject to overflow, and new material is being added from time to time.

The topography of the Chehalis soils is almost level, but sloughs or abandoned stream channels are frequent, and the greater proportion of the land has a sufficient elevation above the present level of the stream channels to insure good natural drainage. The soils are very productive.

CHEHALIS LOAM.

The Chehalis loam consists of a light-brown to slightly reddish-brown loam, 15 inches deep, underlain by a darker-colored fine sandy loam to a heavy loam, or sometimes clay loam. Near the stream banks the soil is often a fine sand or loamy fine sand. The soil gradually becomes heavier as the distance from the streams increases, until it merges into the heavy silty clay loam of the series.

The type is of recent alluvial formation and represents materials deposited by currents of moderate movement in times of overflow.

Only one area of this type was recognized. This occurs as a strip about 2 miles long and one-fourth to 1 mile wide along the Chehalis River just northwest of Centralia. Nearer the river, where the soil is more sandy, the surface is slightly rolling. Farther back it is nearly level. The drainage as a rule is good.

The soil is well adapted to fruits and to such truck crops as are not injured by light midsummer frosts. Hops do well, but the profits of this crop are uncertain. The land is practically all under cultivation. Values range from $100 to $200 an acre. The high price is partly due to the nearness of the city of Centralia.

CHEHALIS SILTY CLAY LOAM.

The Chehalis silty clay loam is a brown to reddish-brown silty clay loam, with a depth of 14 to 18 inches, underlain by a light-brown to reddish-brown silty clay loam or silty clay extending to a depth of 3 feet or more. In lower and poorly drained portions of the type the soil is noticeably darker in color and the subsoil is heavier and usually mottled. The soil is friable and easily cultivated.

A valuable phase of the type occurs in the vicinity of Ceres, Adna, and in the east one-half of Section 11, T. 13 N., R. 3 W., in Lewis County. Here the type consists of a dark-brown to dark silty clay loam about 15 inches deep, resting upon a dark-colored silty-clay loam of rather compact structure. At Littell a distinct soil occurs, which is also included with the type because of its small extent. The material consists of about 6 inches of a black clay loam overlying a dark reddish-brown to black silty clay loam.

The areas of the type, which occur along many of the streams of Pacific and Wahkiakum Counties, consist of about 16 inches of a light yellowish-brown clay loam, underlain by a more compact light-brown clay loam to a depth of 3 feet or more. The lighter color of the phase is due chiefly to the fact that a large part of the material forming it is derived from the adjacent Melbourne silty clay loam, and also to the small amount of organic matter in the soil. In some cases, where the streams drain areas underlain by Tertiary sandstones, these bottoms have a lighter textured soil, often approaching a silt loam or loam. Beds of watern-worn gravel are found at shallow depths on the upper parts of the areas occupying bottoms along streams which rise in the Olympic loams.

In Lewis County a narrow strip of a light-brown or yellowish-brown fine sandy loam to loam often occurs along areas of the type which border the Chehalis and Newaukum Rivers. These areas are widest on the inside of the bends of the rivers. They have been included with the type as they were too narrow to show on a map of this scale.

The Chehalis silty clay loam is the most widely distributed and most extensive alluvial soil of the area. It is found in Pacific, Wahkiakum, Lewis, and Cowlitz Counties, where it occupies first bottoms from one-eighth to 1½ miles wide along the principal streams and some of their tributaries which rise in the soils of the Olympic series or in the Melbourne silty clay loam. Isolated patches and narrow bottoms too small to show on the map occur along many of the smaller creeks. The largest areas of the type are found along the West and South Forks of the Chehalis River, along the Chehalis and Newaukum Rivers and Lucas Creek in Lewis County, along the Willapa and Nasel Rivers in Pacific County, and along Grays River and Skomaukee Creek in Wahkiakum County.

The topography of the type is practically level. The narrow areas have a marked slope downstream, but the slope of the larger areas is hardly noticeable. Old-stream channels traverse some of the wider bottoms of the type. As a whole the type is well drained, but on the wider bottoms small, poorly-drained depressions often occur near the uplands. Although the larger streams are deeply intrenched, their channels are not large enough to carry off the flood waters, and nearly all of the type is overflowed during some part of the rainy season.

The Chehalis silty clay loam is composed of material from the upland portions of the valleys of the streams along which it occurs. The chief source of such material in this area is the Melbourne silty clay loam and the soils of the Olympic series. During a part of the rainy season the channels of the streams are not able to carry off the flood water, and this water spreads out over the bottoms along their lower courses. On account of their decreased velocity the streams are unable to carry their load of sediment. This sediment is carried out and deposited in the comparatively still water of the flooded areas. The type is the result of the slow accumulation of such deposits through a long period of time. It is still in the process of formation.

Very little of the original timber growth remains. The type was one of the first ones to be cleared, and nearly all of it is at present under cultivation. It is recognized as one of the most valuable soils of the area. It is used in the production of a wide range of crops, including oats, hay, wheat, hops, and potatoes. The yields of oats range from 60 to 125 bushels per acre, with an average yield of 70 to 80 bushels. The higher yields are secured on the better portions of the type. In Pacific and Wahkiakum Counties a large part of the oats is cut for hay. Winter wheat yields from 30 to 50 bushels per acre, but the grain is soft and is used for feed. The yields of hay vary from 2 to 3 tons per acre. Clover does especially well. Potatoes produce from 200 to 300 bushels per acre. A considerable acreage along the Chehalis River near Chehalis, Klaber, and Ceres and along the Newaukum River near Agate is devoted to the growing of hops. The yields range from 1,200 to 2,000 pounds per acre. Flax and hemp are grown to a limited extent in the vicinity of Chehalis. Dairying is the chief source of income of the majority of the farmers living on the type. Well-drained areas are adapted to alfalfa, but the stand is seriously damaged by excess water during the rainy season.

Although the type as a whole is well drained, artificial drainage of the larger areas would be found profitable, as it would aid in carrying off the flood waters and thus enable the earlier planting of crops. In an average season the type suffers very little from drought. Some areas lying only a few feet above the streams are subirrigated. Por-

tions of the type, especially the light-colored phases, are deficient in organic matter and would be benefited by the plowing under of green crops.

The value of farms composed of this type of soil varies according to the market facilities, improvements, and state of cultivation. Well-improved farms, with nearby markets, are held at $200 to $300 an acre. Less desirable areas are valued at $100 to $200 an acre.

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

Mechanical analyses of Chehalis silty 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.*
25180	Soil	0.0	0.1	0.1	2.6	5.8	64.8	26.4
25181	Subsoil	.0	0.0	.2	1.9	1.0	64.7	32.1

CHEHALIS CLAY LOAM.

The soil of the Chehalis clay loam consists of from 12 to 20 inches of grayish-brown or drab to light-brown heavy clay loam, with an average depth of 15 inches. The typical color of the surface when dry is ashy gray, but when wet it is considerably darker. In places the soil is sufficiently heavy to clod if plowed too wet or too dry, but ordinarily the material breaks down into a fine, mellow tilth.

The subsoil consists of grayish-brown or mottled gray, yellow, and yellowish-brown silty clay or silty clay loam. A compact gray or drab clay is frequently encountered at varying depths below three feet. Occasionally, however, this material occurs at 15 to 20 inches below the surface. This type is closely associated with the Chehalis silty clay loam. It is distinguished from the latter by a lighter colored surface and a heavier subsoil.

The type is alluvial, the material of which it is composed representing the finer particles carried in suspension and deposited in comparatively quiet waters. Along the smaller streams the soil consists in part of material washed down from the adjacent slopes.

The Chehalis clay loam is found chiefly in the vicinity of Chehalis, in the Chehalis River Valley, in Lewis County, and along some of the smaller tributaries. Bodies are also found along some of the small streams that empty into the Cowlitz River. It usually occurs at the base of the hills bordering the valleys, lies at a lower elevation than the soils nearer the river bank, and is subject to inundation. The surface is nearly level and seldom has sufficient slope to give good drainage. This, combined with the impervious nature of the subsoil, causes the water to stand on the ground till late in spring,

with the result that early plowing or seeding is impossible. In nearly every case, however, the bodies could be cheaply drained by ditching, as the elevation is considerably above that of the river at mean water level. Areas along the smaller streams usually have a greater slope, but even here artificial drainage would prove beneficial.

Forested areas support a heavy stand of fir, cedar, alder, and vine-maple, with a luxuriant undergrowth of brakes, salal, and "devil's club." Only near Chehalis is a large part of the type cleared and under cultivation. The soil is well adapted to oats, barley, wheat, and the various grasses. Except in the well-drained areas, attempts to grow clover have proved unsuccessful until artificial drainage has been provided. Owing to the fact that much of the type is waterlogged till late in spring, the preparation of the seed-bed is frequently delayed, with the result that the growing grains are not sufficiently advanced to give the best results before the dry weather of July and August comes on. For this reason the type is not well adapted to potatoes and other long-season crops. Timothy and native grasses are the leading hay crops, and oats the chief grain grown at the present time. Yields of from 1 to 2 tons of hay per acre are secured with an average of 1½ tons. Much of the oat crop is cut for hay; but when thrashed 60 to 75 bushels per acre are secured, and yields of 80 to 100 bushels are not uncommon. Artificial drainage would make it one of the most valuable soils in the region. The land is held at $25 to $100 an acre, depending on location and improvements.

CHEHALIS SILTY CLAY.

The Chehalis silty clay consists of 16 inches of grayish-brown sticky silty loam, underlain by a bluish-gray to slate-colored, slightly plastic silty clay to a depth of 3 feet or more. Yellow mottlings and brown iron stains are common in both soil and subsoil, but are more pronounced in the former. Both soil and subsoil contain varying quantities of undecomposed vegetable matter, the soil having the greater amount. Thin layers of peaty material and partially decomposed pieces of driftwood are encountered in both soil and subsoil.

When diked and put under cultivation the soil becomes light-brown to brown, mottled with yellow in color, and all traces of undecomposed organic matter disappear. It also loses its tenaceous character and pulverizes very readily.

The Chehalis silty clay is locally known as "tide flats." The type occurs along the estuaries and lower courses of the tidewater streams that empty into Willapa Bay in Pacific County, and into Grays Bay in Wahkiakum County. Usually the type does not extend as far up

these streams as the tide flows. An extensive area also occurs in the vicinity of the Wallacut and Chinook Rivers in the southern part of Pacific County. There are other areas about the south end and in some of the reentrant curves of Willapa Bay.

The fine sediments, chiefly silt and clay, which are carried in suspension by the streams draining the residual uplands, are deposited in the quiet waters of their lower or tidewater courses and as deltas at the heads of shallow bays. By a long continuation of this process more or less extensive areas of tidal flats have been built up and are still being added to at times of extremely high tide.

The Chehalis silty clay has a level topography. The larger areas are slighly higher near the banks of the streams and very little above high-tide level. They are traversed by numerous brackish sloughs, and the greater part of the type is inundated at times of extremely high tides and during a large part of the rainy season. The water table is so close to the surface that diking and draining are necessary before the type can be put under cultivation.

A large percentage of the type is covered with a heavy growth of marsh grasses and the remainder has a sparse and stunted growth of fir, cedar, spruce, alder, and willows.

At present a comparatively small percentage of the type is under cultivation. When diked and drained it is a valuable soil for general farming. One rather extensive area about 1 mile northwest of South Bend was diked about 20 years ago. For several years a considerable acreage was sowed to oats, producing as high as 146 bushels per acre. It was then seeded to timothy, alsike clover, and Italian rye grass, and since that time has been used for hay and pasturage. The stand is very thick and, although the fields have not been reseeded for at least 12 years, the yields are said to be heavier than during the first few years after seeding. The fields are pastured during the whole year, with the exception of from 4 to 6 weeks before the haying season. The grass is cut during the latter part of July and yields from 3 to 5 tons of hay per acre. Other small areas, which have been diked and drained, produce good yields of potatoes and other truck crops.

Quite extensive areas of the type are being diked along the Wallacut, Deep, Palux, and South Nemah Rivers.

Land of this type is very productive and justifies a considerable expense for diking and draining. The dikes should be strong and high enough to prevent overflow at the high-water level. The problem of diking and draining is a matter to be handled in large tracts. Cooperation between owners of adjoining tracts or between the owners and either the county or State would reduce the cost of reclamation and hasten the development of the type. Much of the land is held at too high a price to encourage immediate development, being

valued at $50 to $75 an acre. Reclaimed land is held at $200 to $300 an acre.

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

Mechanical analyses of Chehalis 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.*
25182	Soil	0.1	0.7	0.3	0.5	1.2	65.4	31.4
25183	Subsoil	.0	.4	.2	.4	.2	69.8	28.9

CHEHALIS CLAY.

The Chehalis clay consists of 10 to 12 inches of a dark-gray or drab to black, heavy, tenacious clay, mottled with yellow and orange. When dry the surface varies from dark-gray to slate color, and when wet it is decidedly black. In the latter condition the material is dense and sticky. On drying it becomes sun cracked, compact, and baked, and difficult to flow. In the lower places considerable organic matter is found in the soil, which makes cultivation somewhat easier. The subsoil from 12 to 36 inches consists of a mottled gray and orange waxy clay, underlain by a compact gray clay. Sometimes the subsoil is dark-drab to slate color with slight mottlings of reddish-brown iron stains in the lower depths.

All this type mapped in the area lies in Lewis County. The largest body occurs along Lincoln Creek, northwest of Centralia. A small area is found along Hanford Creek, northeast of this city, and in addition several small bodies have been indicated in the Chehalis River Valley in the vicinity of Chehalis.

The soil is entirely alluvial in origin and consists largely of material derived from the upland soils of the Salkum and Melbourne series. The absence of any noticeable quantity of sand indicates that the material was laid down in very quiet waters.

The surface is uniformly level, and as the areas occupy the lowest depressions in the stream valleys the greater part of it is inundated during the rainy season. Because of its low position and the impervious nature of the subsoil the surface remains sticky and wet for a considerable time after the floods recede. Practically all of the type would be benefited by tile drainage.

The greater part of the Chehalis clay is used for the production of small grains, oats being the leading crop. The soil produces a heavy growth of straw, which gives a high tonnage when cut for hay. When the crop is allowed to mature, as it usually is, the yield ranges from 60 to 100 bushels per acre. The soil is well adapted to grasses

of all kinds and yields of 2½ tons of timothy and clover hay per acre are not uncommon.

Land of this type of soil is held at $75 to $125 an acre, depending on location and drainage.

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

Mechanical analyses of Chehalis 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.*
25188	Soil	0.0	0.1	0.1	0.7	0.2	24.0	74.6
25189	Subsoil	.0	.0	.0	.3	.5	20.7	78.3

TOWER SERIES.

In this series have been placed certain soils of lacustrine origin occurring in the nonglacial part of the area. They are similar in many respects to the Bellingham soils, but the latter series is restricted to the glaciated areas. The Tower soils are dark gray, drab, or black and contain an excessive quantity of organic matter, often sufficient to render them somewhat mucky. The subsoils are yellowish brown, gray, or drab and frequently mottled with reddish or yellowish iron stains. Pockets or strata of sand and gravel and some diatomaceous earth are found. The mineral constituents of the soil are mainly nonglacial and probably derived principally from basalt.

The series occupies shallow depressions or lake basins in the uplands and poorly drained flats on old terraces. The surface is level to hummocky. Drainage is usually inadequate. A growth of shrubs and bushes, with scattering trees, constitutes the typical vegetation. When drained the soils are productive.

TOWER FINE SANDY LOAM.

The soil of the Tower fine sandy loam to a depth of 10 to 15 inches consists of a dark-gray to black fine sandy loam, containing a large percentage of decomposed organic matter. A few small pockets of gravel are found, but as a whole the soil contains little or no coarse sand or gravel.

The subsoil is a light-brown loam, grading into a silty clay loam at a depth of about 36 inches.

Two small areas of this type occur in the northeastern part of that portion of Clarke County included within the survey. The larger of these is known as the Amboy prairie. It has the general appearance of being a broad, comparatively level basin, almost wholly surrounded by rolling uplands. The surface in detail, however, is

hummocky. Many low mounds and ridges occur and between these lie broad, winding, shallow channels or "swales."

Two small streams traverse the areas of Tower fine sandy loam, and the greater proportion of the type has fairly good drainage. Artificial drainage, however, would improve the soil occupying the swales or shallow depressions. The material from which this soil is derived is thought by geologists possibly to have been laid down by glacial ice, although this is uncertain. A small tongue of glacial ice may have extended into the valley from the ice sheet which came down the Lewis River Valley. In such case the material is of local origin and derived from adjacent basaltic areas. Until the two small streams which traverse this valley had cut out their channels the drainage was restricted, and the land probably remained in a swampy or poorly drained condition for a long period of time. The decay of the native vegetation under these poorly drained conditions gave rise to the large quantity of organic matter found in this type. This soil is very productive, and a large proportion of it is under cultivation. The principal crops are oats and hay. Oats produce 40 to 60 bushels per acre. The hay consists mainly of clover and timothy, the yield being 2 to 3 tons per acre. Dairying is the principal industry in this section of the area, and a considerable acreage is utilized for growing kale and other crops for forage. Irish potatoes produce 150 to 300 bushels per acre. Vegetables and small fruits are grown to a small extent and do well.

Tree fruits are not grown on a commercial scale, but there are a number of small orchards on this type which produce good yields of apples, pears, and cherries.

TOWER CLAY LOAM.

The soil of the Tower clay loam to an average depth of 10 inches consists of a dark-gray, drab, or grayish-brown clay loam of rather silty texture. In some areas, especially where the soil has not been cultivated and where the drainage is poor, the surface 4 to 6 inches contains considerably more organic matter than usual, giving the soil a dark-brown color. The subsoil is a gray or grayish-brown to drab clay loam or clay, sometimes mottled, which becomes very hard and compact when in a dry condition. Thin strata or pockets of sand or gravel and local deposits of diatomaceous earth are sometimes encountered in the deeper subsoil.

Small areas of this type varying from a few acres to about one square mile in extent occur at intervals throughout the rolling and gently rolling uplands in Clarke County. Other areas are found in the northern part of Cowlitz and the southern part of Lewis County. The soil occupies shallow basins almost entirely surrounded by lands having a rolling to gently rolling topography. It also occupies

broad, level valleys which border the courses of some of the small streams. The small creeks that now traverse these valleys, however, are seldom large enough to furnish adequate drainage for the adjacent lands.

The topography of the Tower clay loam is level to very gently undulating. The natural drainage is as a whole very poor. The relatively low position of these basins causes them to receive the drainage waters from the surrounding lands, and they usually remain in a wet or flooded condition during the greater part of the winter and spring months. Artificial drainage is always necessary in order to get the land in a condition suitable for farming. This is usually accomplished by means of open ditches, but tile drainage has been used on a few small areas with more satisfactory results.

The soil is derived from material washed from the surrounding hills and ridges and deposited in these low basins during periods when they were in a flooded or swampy condition.

The success or failure of the crops grown on this soil depends largely on the drainage. Where no adequate drainage has been provided and where poor methods of cultivation are in use the soil remains in a cold, wet condition until late in the spring, and when plowed it breaks up into clods. Under these conditions the yields obtained are usually small. Where the soil is well drained and thoroughly cultivated it is very productive and is well adapted to oats and hay. Hay is the principal crop, the ordinary yields ranging from 2 to 3 tons per acre. Oats also do exceedingly well on the better drained areas, yielding from 50 to 75 bushels per acre, with 100 bushels per acre in very favorable seasons. Irish potatoes are grown to a small extent and on well-drained soils produce from 150 to 200 bushels per acre.

Values placed on land of this type of soil range from $50 to $200 an acre, depending on location and improvements.

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

Mechanical analyses of Tower 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.*
5509123	Soil	0.4	0.9	0.7	8.6	16.7	43.1	29.5
5509124	Subsoil	.1	.7	.6	9.7	13.1	48.4	27.0

TOWER CLAY.

The Tower clay consists of 10 to 15 inches of dark-gray, grayish-brown or drab, waxy, compact clay, more or less mottled with red-

dish-brown iron stains, underlain by a sticky, heavy, compact clay of a gray or drab color mottled with brown, usually lighter than the soil. This material frequently rests upon compact deposits of gravel and sand at about 30 inches. In some cases there is 4 to 10 inches of organic matter overlying the soil, and pockets of this same material are sometimes encountered in the subsoil. Where the covering of humus is absent the surface is very sticky when wet, but as it dries it bakes and cracks. Over parts of the type a few porous andesitic bowlders are found on the surface.

Because of the very high percentage of clay in this soil, it is rather difficult to manage unless tiled when the moisture conditions are just right. The type consists chiefly of fine sediments carried down from the adjacent upland soils (Olympic series) and deposited in the quiet, shallow water that covers the basin areas during the rainy season. Only two bodies of this soil, with a combined area of about 1 square mile, have been mapped in this survey. Both of these occur in Cowlitz County in the vicinity of Silver Lake. The type occupies flat areas which are almost entirely surrounded by higher lands and as a result is it poorly drained. The compact structure of the soil and subsoil prevent the percolation of water, which stands on the surface a large part of the year.

The native vegetation consists of alders, willows, and swamp grass. None of the type is under cultivation, and the greater part is not adapted to farming in its present condition. During the summer months it furnishes considerable pasturage. If it were artificially drained, however, it would probably be adapted to the production of grass and small grains.

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

Mechanical analyses of Tower 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.*
550973	Soil	0.2	0.6	0.8	4.2	11.9	25.8	56.5
550974	Subsoil	.3	.7	.5	8.7	10.4	34.5	44.8

SOILS OF THE MARINE BEACH AND EOLIAN DEPOSITS.

COASTAL BEACH AND DUNESAND.

Coastal beach and Dunesand consist of gray to white sand of various grades. The areas represent shore-drift material which has been built up above sea level by the combined action of waves and wind. The materials are closely associated with the Westport fine sand and have a similar though more recent origin.

Two areas of Coastal beach and Dunesaid occur in the western part of Pacific County. (See Pl. II, fig. 2.) They occupy spits on each side of the entrance to Willapa Bay and narrow strips on the seaward side of a part of the areas of Westport fine sand. The sandy beaches occupy only a small area and have been included with the Dunesand for this reason.

The greater part of the Coastal beach and Dunesand lies above high tide and is inundated only during heavy storms. Areas mapped under this head have no agricultural value.

WESTPORT FINE SAND.

The Westport fine sand consists of a gray to light yellowish-gray incoherent fine sand, with a depth of 12 to 14 inches, underlain by a mottled yellow, gray, and brown fine sand, extending to a depth of 3 feet or more. The immediate surface of virgin areas contains a small percentage of organic matter, which gives it a darker color and a slightly more loamy texture than the soil at greater depths. The color of both soil and subsoil varies with their position. On the ridges the soil and subsoil are lighter in color and looser in texture, and in the depressions between the ridges the soil is a dark-gray or mottled yellow and brown in color, slightly loamier in texture, and the subsoil is a dark brown, mottled with yellow and gray. A few small level areas occur within the type where the surface is hummocky and the soil a grayish black, while the subsoil is marked by the presence of a dark-brown sandy hardpan at depths between 12 and 24 inches, beneath which occurs the typical mottled subsoil. The soil is easily cultivated, but drifts unless protected by vegetation.

The type in this area is confined to the western part of Pacific County. The largest area occupies the greater part of the sand spit, which extends from a point near North Head northward for nearly 20 miles, and which separates Willapa Bay from the ocean. Other areas occur in the northwestern part of Pacific County as a narrow strip between the uplands and the drifting beach sands, and also as small mud spits on the north side of Willapa Bay.

The Westport fine sand is marked by a series of low, rounded ridges from 5 to 25 feet high, with corresponding depressions between them. The ridge topography is more noticeable on the ocean side of the type. Long, narrow, marshy areas of Muck and Peat usually occupy parts of the depressions and shallow lakes often occur within the areas of Muck and Peat. The type as a whole lies very little above sea level and the water table is close to the surface. During the rainy season a considerable part of the type is flooded and artificial drainage is necessary before the low-lying areas can be put under cultivation.

The Westport fine sand is of Eolian origin and represents material derived from beach deposits. The smaller sand spits on the north side of Willapa Bay are of similar origin, while the strip along the uplands in an old beach deposit.

The native vegetation on the long sandy areas consists of a stunted growth of fir, with a dense undergrowth of salal, while on the more moist and low-lying areas a mixed growth of fir, spruce, cedar, alder, and willows, together with a dense undergrowth of small shrubs, is found.

Only a small part of the type is under cultivation. With the present methods of cultivation oats, hay, potatoes, and truck produce fair yields in favorable seasons. Cut-over and sparsely timbered areas give fair pasturage during the greater part of the year. The type is deficient in organic matter and has a low moisture-holding capacity, but by the plowing under of green crops, by fertilization, and other improved methods of farming it could be made to produce good yields of truck, potatoes, hay, and small grains. An abundance of good water for irrigation is available by pumping from shallow wells and this practice would prove profitable for the growing of truck crops on small tracts for near-by markets.

The value of land of this type varies from $50 to $100 an acre, depending upon location and improvements.

SOILS DERIVED MAINLY FROM ORGANIC DEPOSITS.

MUCK AND PEAT.

Muck and Peat are so closely related and so frequently grade into each other that it was found impracticable to attempt their separation in this area. They represent accumulations of organic matter in various stages of decomposition, with only a slight admixture of mineral material. In the Muck this process is so far advanced that nearly all traces of vegetable fiber have been destroyed and the incorporation of a small percentage of silt and clay with the decomposed organic matter has given the soil more body. In the case of the Peat decomposition has not progressed far enough to destroy the vegetable fiber and it is a more or less compact mass of organic material, whose original character is quite easily recognized.

The areas in the western part of Pacific County consist of a few inches of coarse vegetable fiber, brown in color, underlain by 18 to 20 inches of grayish-black to black Muck, which in turn rests upon a bed of Peat. Frequently the peaty surface is lacking. The type is underlain by fine sand at a depth of 3 to 5 feet. The deposits in these areas are thickest near their center and gradually thin out toward their margins, where the underlying sand is encountered at

a less depth. Near their borders a small quantity of sand is mixed with the surface material. The other areas of Muck and Peat occur on the terraces or on the uplands and are underlain by an impervious clay.

Muck and Peat occupy poorly drained basins where the conditions are favorable for the growth and preservation of rank water-loving vegetation. The greater part of these organic soils occurs within the Westport fine sand in the western part of Pacific County, where they occupy long, narrow areas inclosing shallow lakes. These areas are flat and lie only a few feet below the level of the surrounding type. They are poorly drained and are covered with water during a part of the year. Other areas too small to show on the map occur within the same type.

Two areas of the type were mapped in Clarke County, one about 3 miles southwest of Amboy, in T. 5 N., R. 2 E., and another a short distance northwest of Manor, in T. 3 and 4 N., R. 2 E. Other areas occur in Cowlitz County, where they nearly surround Silver Lake. The remaining area lies just north of the city limits of Chehalis in Lewis County.

A small part of the Muck and Peat area is used for pasture and for growing oats and hay. The yields are good in favorable seasons. Some areas are well adapted to cranberries. Approximately 100 acres on the "North Beach Peninsula" in the western part of Pacific County is in cranberries, and a considerable acreage is being prepared for this crop. The yields range from 75 to 130 barrels per acre. Strawberries for the winter market are also being grown successfully. The growing of truck crops for the local summer market is profitable.

Land of this type suitable for cranberries is valued at $150 to $300 an acre. Other areas are held at $50 to $150 an acre.

CHEMICAL ANALYSES OF SOILS.[1]

In addition to the physical analyses of typical samples of the soils of the area, chemical analyses were also made. For this purpose samples were taken by means of a soil auger to the depths indicated in the following table and were sent to the laboratory at the University of Washington. Generally these samples were taken from uncultivated fields, but in many cases the soils had been modified by the effects of fires which had previously burned over portions of the area. Aside from physical and biological changes in the soil due to the destruction of organic matter on the surface by fires, it is to be expected that the lime, potash, and phosphoric acid percentages might be increased in some cases and the nitrogen reduced, while the loss on ignition might be very much increased by the presence of charcoal in large quantity but in a finely divided condi-

[1] By H. K. Benson, of the Washington Geological Survey.

tion and so masked by a coating of fine soil particles as to escape the attention of the analyst. In such cases nitrogen and humus may be very low as compared with the loss on ignition independently of water-holding constituents.

It has come to be generally recognized that the mineral elements in the soil which are of the most interest to the agriculturist are calcium, potassium, phosphorus, and nitrogen. For technical reasons, which need not be explained here, these are generally spoken of as lime (calcium oxide), potash (potassium oxide), phosphoric acid (phosphorus pentoxide), and nitrogen, which is sometimes called ammonia. The last is undoubtedly present in the soil in various combinations, as are also calcium, potassium, and phosphorus. Nitrogen, potash, and phosphoric acid are the constituents which it is sought to add to the soil in commercial fertilizers, calcium going in incidentally as a carrier of phosphoric acid and sometimes of nitrogen. Lime, gypsum, ground limestone, etc., are, however, regarded as a fertilizer by most farmers. The rôle of lime in the soil will be briefly referred to presently. Other mineral elements are undoubtedly needed by growing plants, but they have been considered always abundantly present in the soil and to have no great importance in fertilizer practice, although the chemical, physical, and physiological action of these in the soil and in the plant furnish a wide field for investigation.

Besides analyzing the soil for the above constituents, it is now recognized that the chemist can add important information by determining the lime requirements of a soil; that is, the amount of lime which must be added to render the soil certainly neutral or slightly alkaline. The action of the lime is probably quite complex in most cases, neutralizing any acids which may be present, inducing a much better flocculation or crumbling of the soil, improving its tilth, aeration, etc., which functions are most important for the growth of desirable kinds of bacteria in the soil, and especially those kinds which gather nitrogen from the air and grow in "symbiosis" or association with certain leguminous crops, as alfalfa, the clovers, peas, etc. Moreover, it is possible that lime may have a specific effect on some plants, and it is held by many fruit growers that an ample amount of lime will cause the production of sweeter fruit. Potash is largely active in the production of stem and is believed to be of special importance in the production of starch in the growing plants, and phosphoric acid to be important mainly in the formation of seeds or grain, although undoubtedly having other functions in the growing plants. Nitrogen is believed to be taken from the soil, mainly in the form of nitrates. It is especially active in the production of foliage and is elaborated or made over in the plant into various substances, especially the proteids—substances which are best

known in the muscular tissues of animals. No substance in the soil produces a more rapid or decided response in the crop than does nitrogen. A ready supply of nitrates is of the utmost importance to green crops, especially during the periods of most rapid growth, and it is desirable to have nitrogenous organic substances in the soil to furnish nitrates by the process of decay, especially for plants other than leguminosæ, and even for these a small amount of available nitrogen is considered advantageous in the early stages of growth.

The methods employed in the analyses of the soils are those of the Association of Official Agricultural Chemists, although a few modifications of procedure which our own experience justified were introduced. The analytical work was done by Mr. F. W. Ashton, assistant chemist, under the supervision of the author. The soil samples were pestled and sifted through a 1-mm. sieve, the fine earth only being used in the analysis. The loss on ignition of the soil was generally determined to obtain an approximate idea of the organic matter present. The determination is open to objections, especially where much clay, water-holding minerals, and charcoal are present, and consequently in a few cases the "humus" or dark organic coloring matter in the soil was also determined. In the case of much charcoal it is to be expected that a low humus content might be associated with a high loss on ignition. The presence of a good supply of humus in the soil is believed to be of great importance, as it tends to promote a proper aggregation or clustering of the soil grains, favoring good tilth, the water-holding capacity of the soil, its aeration, and the power to absorb or retain from leaching the dissolved mineral plant nutrients. The formation of humus in the soil from the organic remains of plants or other organisms is supposed to be facilitated by lime, and this view is supported by the figures in the following analyses.

Effect of lime on the formation of humus.

Type.	Lime.	Phosphoric acid.	Potash.	Loss on ignition.	Humus.	Lime requirement.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sand	0.08	0.10	0.10	2.51	0.25	0.0214
Sandy loam	.54	.24	.52	7.96	3.68	.0114

The results of the analyses of the various soil types are given in the accompanying table, which is for the most part self-explanatory. The column headed "Lime requirement" gives the percentages of lime that are necessary to give the soils a neutral reaction, and for convenience there has been computed the corresponding amounts of limestone, which are given in the last column. Other analyses of soils from the area are to be found in Bulletins Nos. 13, 55, and 85, State College Experiment Station, Pullman, Wash.

Analyses of soils of southwestern Washington.

Laboratory No.	Soil type.	Location.	Depth of sample.	Lime.	Phosphoric acid.	Potash.	Nitrogen.	Loss on ignition.	Lime requirement.	Limestone per acre for neutralization.
			Inches.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*
39	Wind River fine sandy loam	NE. ¼ NE. ¼ sec. 34, T. 3, R. 8	.....	0.26	0.22	0.19	.....	4.80	0.0165	577.5
40	.....do	NE. ¼ sec. 27, T. 3, R. 8	0–12	.28	.19	.21	0.0784	6.30	.150	5,250
41	Wind River sandy loam	NE. ¼ sec. 19, T. 3, R. 8	0–15	.36	.31	.22	.....	7.40	.0225	900
42	.....do	NE. ¼ sec. 20, T. 3, R. 8	0–14	.34	.40	.18	.....	8.34	.0250	1,000
43	Wind River gravelly sandy loam	From U. S. Forest Service Nursery Tract. (See Van Dyne for description.)	0–14	.34	.30	.38	.1631	14.96	.0925	3,600
44	.....do	.....do	0–14	.42	.37	.42	.....	16.57	.1325	5,300
45	.....do	.....do	0–14	.42	.34	.39	.....	17.94	.1625	6,500
46	Wind River gravelly loam	SE. ¼ SE. ¼ sec. 20, T. 3, R. 8	0–14	.85	.34	.18	.....	18.88	.0150	600
47	.....do	SE. ¼ sec. 19, T. 3 R. 8	0–12	.68	.30	.17	.....	15.90	.0200	800
48	Westport fine sand	Sec. 16, T. 10, R. 11	0–8	.55	.03	.15	.....	4.28	.0600	2,400
49	.....do	Sec. 15, T. 10, R. 11 E	0–12	.43	.03	.16	.0916	3.90	.0650	2,600
50	Olympic loam	SE. ¼ SE. ¼ sec. 16, T. 5, R. 3 E	0–12	.32	.33	.14	.....	16.86	.0350	1,225
51	.....do	SE. ¼ NW. ¼ sec. 13, T. 3, R. 7 E	0–16	.36	.10	.17	.....	14.10	.0500	1,750
52	.....do	E. ½ sec. 8, T. 5, R. 2	0–12	.23	.15	.15	.1871	12.28	.0525	1,837.5
53	Underwood loam	SE. ¼ sec. 16, T. 3, R. 10 N	0–14	.57	.09	.25	.0916	7.10	.0150	525
54	.....do	NE. ¼ NE. ¼ sec. 20, T. 3, R. 8	0–14	.32	.16	.20	.....	11.70	.0300	1,050
55	Tower clay loam	Sec. 11, T. 5, R. 3	0–14	.19	.18	.15	.....	30.70	.0650	2,112.5
56	.....do	SE. ¼ NW. ¼ sec. 15, T. 5, R. 3	0–14	.17	.17	.10	.8229	32.36	.0550	1,787.5
57	.....do	SE. ¼ NE. ¼ sec. 12, T. 5, R. 3	0–14	.23	.18	.43	.....	18.49	.0250	812.5
58	Tower clay	NE. ¼ sec. 36, T. 10, R. 1 W	0–14	.30	.11	.20	.....	17.12	.1975	6,418.75
59	Toutle very fine sand	E. ½ sec. 7, T. 10, R. 2 W	0–14	.36	.32	.19	.....	3.24	.0275	1,100
60	.....do	NE. ¼ sec. 2, T. 9, R. 2 W	0–14	.36	.31	.21	.0436	3.94	.0150	600
61	Toutle coarse sandy loam	SE. ¼ sec. 2, T. 10, R. 1 W	10–36	.45	.14	.18	.....	7.90	.0150	600
62	.....do	.....do	0–12	.40	.15	.18	.....	9.10	.0150	600
63	Toutle gravelly coarse sand	NE. ¼ sec. 16, T. 10, R. 1 E	0–12	.83	.11	.19	.0369	2.30	.0150	600
64	.....do	E. ½ sec. 25, T. 10, R. 1 W	0–14	.38	.02	.16	.....	4.30	.0100	400

Analyses of soils of southwestern Washington—Continued.

Laboratory No.	Soil type.	Location.	Depth of sample.	Lime.	Phosphoric acid.	Potash.	Nitrogen.	Loss on ignition.	Lime requirement.	Limestone per acre for neutralization.
			Inches.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*
65	Olympic clay, dark-colored landslide phase.	NE. ¼ sec. 36, T. 3, R. 7 E.	0–10	.62	.15	.31	.1351	15.46	.350	11,375
66	.....do.....	E. ½ sec. 36, T. 3, R. 7.	0–10	.60	.14	.20	.....	14.24	.0125	406.25
67	Olympic stony clay loam, dark-colored landslide phase.	SW. ¼ sec. 34, T. 3, R. 7.	0–10	1.64	.14	.23	.....	11.60	.0175	568.75
68	.....do.....	SW. ¼ sec. 35, T. 3, R. 7.	0–10	.43	.20	.19	.....	16.52	.1220	3,965
69	Olympic stony clay loam, light-colored landslide phase.	NW. ¼ sec. 27, T. 2, R. 6 E.	0–18	.26	.15	.16	.1699	16.14	.0100	325
70	Aiken stony clay.	Sec. 6, T. 2, R. 4.	0–10	.30	.07	.17	.....	19.40	.0200	650
71	.....do.....	SE. ¼ SE. ¼ sec. 21, T. 3, R. 3.	0–10	.21	.07	.12	[1].0917 .0939	11.76	.0950	3,087.5
72	.....do.....	Sec. 9, T. 2, R. 4.	0–10	.17	.13	.10	.....	28.34	.0425	1,381.25
73	Puget fine sandy loam.	SW. ¼ SW. ¼ sec. 26, T. 6, R. 3.	0–36	.64	.10	.05	.....	2.96	.0165	660
74	.....do.....	NE. ¼ SW. ¼ sec. 10, T. 9, R. 2 W.	0–15	1.10	.13	.13	.....	8.26	.0100	400
75	Toutle gravelly coarse sand.	SW. ¼ NW. ¼ sec. 3, T. 10, R. 2 E.	0–15	1.47	.15	.19	.....	10.94	.150	525
76	Puget silt loam.	NW. ¼ NW. ¼ sec. 6, T. 4, R. 1 E.	0–36	1.02	.09	.08	.....	2.66	.0300	1,050
77	Toutle coarse sandy loam.	SW. ¼ SW. ¼ sec. 26, T. 6, R. 3 E.	0–36	.72	.06	.09	.....	.82	.0100	400
78	Olympic stony loam.	Near center, sec. 26, T. 6, R. 3 E.	0–14	.36	.09	.08	.1934	27.10	.....	.....
79	Olympic silty clay loam.	NE. ¼ sec. 1, T. 9, R. 3 W.	0–14	.21	.31	.16	.....	12.36	.2100	7,350
80	Olympic silt loam.	Sec. 22, T. 8, R. 5 W.	0–14	.04	.20	.13	.1417	18.50	.0400	1,300
81	.....do.....	Sec. 2, T. 8, R. 5 W.	0–14	.13	.16	.15	.....	12.18	.0500	1,625
82	Olympic silty clay loam.	NE. ¼ sec. 34, T. 10, R. 1 W.	0–14	.26	.08	.13	.....	8.86	.0650	2,112.5
83	.....do.....	.....do.....	0–14	.19	.06	.10	.....	8.00	.0550	1,787.5
84	Nasel silty clay.	One mile south of Nasel (see field map).	0–14	.09	.06	.17	.4343	22.04	.9500	30,875
85	.....do.....	Sec. 24, T. 15, R. 7.	0–14	.23	.24	.19	.....	20.06	.5150	16,757.5
86	Nasel gravelly clay loam.	Sec. 6, T. 12½, R. 7.	0–14	.15	.32	.10	.....	34.92	.0750	2,437.5
87	.....do.....	Sec. 5, T. 12, R. 7.	0–14	.17	.28	.07	.....	33.96	.0700	2,275

88	Lauren gravelly coarse sandy loam	½ mile NE. of Elsworth (see field map)	0–14	.40	.32	.30	.5036	20.36	.0250	1,000
89	do	do	0–14	.30	.24	.17	.3729	16.90	.0250	1,000
90	do	NW. ¼ SW. ¼ sec. 7, T. 4, R. 1 E	0–36	.26	.32	.14		22.08	.0450	1,800
91	Lauren silt loam	NW. ¼ sec. 1, T. 8, R. 6 W	0–14	.15	.20	.19		22.96	.0750	2,437.5
92	Lauren sandy loam	SE. ¼ SE. ¼ sec. 2, T. 4, R. 2 E	0–24	.32	.24	.13		27.70	.0200	800
93	Melbourne silty clay loam	Sec. 33, T. 14, R. 7	0–14	.08	.08	.07		20.10	.2060	6,695
94	do	Sec. 5, T. 9, R. 6	0–12	.17	.06	.14	.0109	19.46	.3050	9,912.5
95	do	Sec. 18, T. 14, R. 9	0–14	.15	.09	.18		23.90	.4150	13,487.5
96	Kelso silty clay loam	SW. ¼ SW. ¼ sec. 3, T. 10, R. 2 W	0–15	.13	.45	.23		22.52	.1600	5,200
97	do	SE. ¼ sec. 2, T. 9, R. 2 W	0–14	.21	.16	.31	.0916	9.76	.1200	3,900
98	Wind River loam	NE. ¼ sec. 22, T. 3, R. 10 E	0–14	.34	.18	.17		10.34	.0050	175
99	do	SE. ¼ sec. 15, T. 3, R. 10 E	0–14	.38	.22	.22		10.00	.0050	175
100	Felida silt loam	Sec. 9, T. 2, R 3 E		.23	.12	.12		9.90	.0600	2,100
101	do	NW. ¼ sec. 32, T. 2, R. 4 E		.42	.10	.17	.03180	17.40	.0150	525
102	do	SW. ¼ sec. 29, T. 3, R. 1 E	0–18	.51	.34	.36		7.20	.0100	350
103	Doty silty clay loam	See field map	0–18	.53	.33	.19		17.04	.0450	1,462.5
104	Muck (cranberry marsh)	½ mile SE. of Long Beach (see map)		.15	.13	.13	2.420	85.66	.1250	
105	Muck	SE. ¼ NW. ¼ sec. 35, T. 5, R. 2 E	0–16	.25	.06	.16		10.66	.0450	
106	Chehalis clay loam	SE. ¼ NE. ¼ sec. —, T. 10, R. 3 W	0–15	.95	.16	.13	.1307	15.50	.0850	2,762.5
107	do	NW. ¼ sec. 36, T. 19, R. 6 W		.53	.13	.16		12.90	.1650	5,362.5
108	Chehalis silty clay loam	Sec. 24, T. 15, R. 7	0–14	.72	.10	.15		16.96	.2200	7,150
109	do	SW. ¼ SW. ¼ sec. 9, T. 9, R. 2 W	0–15	.57	.25	.13		17.20	.0200	650
110	Chehalis silty clay	Sec. 15, T. 13, R. 10	0–14	.40	.15	.48	.5714	22.10	.4200	13,650
111	do	NE. ¼ sec. 20, T. 14, R. 9	0–14	.28	.18	.91		28.82	.0200	650
112	do	SW. ¼ sec. 20, T. 14, R. 9	0–4	.51	.19	.40		15.20	.0700	2,275
113	do	NW. ¼ sec. 20, T. 14, R. 9	0–4	.36	.18	.36		15.20	.0650	2,112.5
114	Hesson clay loam	Sec. 22, T. 2, R. 3 E		.11	.16	.13		15.66	.0250	812.5
115	do	Sec. 34, T. 2, R. 3 E		.23	.20	.21		16.02	.0175	568.75
116	Columbia fine sand	NW. ¼ sec. 35, T. 4, R. 1	0–36	.77	.16	.32	.0829	6.82	Neutral.	
117	do	SE. ¼ SE. ¼ sec. 11, T. 4, R. 1 E	0–30	.60	.11	.16		8.70	.0250	1,000
118	Sacramento silty clay loam	NE. ¼ sec. 31, T. 7, R. 1 W		.70	.20	.23		13.76	.0075	243.75
119	do	SW. ¼ sec. 32, T. 8, R. 2 W	0–14	.98	.14	.16		10.58	.0500	1,625
120	do	Sec. 24, T. 4, R. 1 W	0–18	.72	.16	.28	.0209	13.00	.0100	325

[1] Check.

Analyses of soils of southwestern Washington—Continued.

Laboratory No.	Soil type.	Location.	Depth of sample.	Lime.	Phosphoric acid.	Potash.	Nitrogen.	Loss on ignition.	Lime requirement.	Limestone per acre for neutralization.
			Inches.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*
121	Olympic stony loam	NW. ¼ sec. 20, T. 3, R. 7 W	0–18	.30	.09	.15	.....	13.66	.0100	350
122	Camas gravelly sandy loam	E. ½ sec. 21, T. 2, R. 7 E	0–10	.76	.15	.19	.0178	12.50	.0375	1,500
123	.....do	W. ½ sec. 21, T. 2, R. 7 E	0–8	1.57	.10	.32	.....	2.46	.0550	2,200
124	Camas silt loam, porous subsoil phase	NE. ¼ sec. 34, T. 2, R. 6 E	0–12	.66	.41	.21	.0165	8.40	.0075	300
125	.....do	⅛ mile E. of Stevenson (see map)	0–12	.66	.27	.20	.....	7.70	.0075	300
126	Camas silt loam	SE. ¼ NE. ¼ sec. 11, T. 4, R. 2 E	.....	.68	.04	.37	.....	12.16	.2200	7,700
127	.....do	NW. ¼ sec. 16, T. 1, R. 4 E	0–14	.30	.42	.24	.....	10.40	.0075	2 2.5

These analyses show that the soils of the area compare well with the general run of soils in good agricultural areas of similar rainfall and other climatic conditions. It will be observed that the variations in the figures for any one type of soil are about the same as the variations between types. Consequently, so far as these analytical data show, the chemical composition of the soil is not a type characteristic. That is to say, the main differences in the soils of this area are in their physical and perhaps biological characteristics, and the chemical differences are of importance only in the individual fields, but not between types.

The interpretation of a chemical analysis of a soil is a matter of extreme difficulty. As stated above, these analyses show the soils of the area to be similar in composition as regards the content of lime, potash, and phosphoric acid to good soils of similar areas elsewhere. As a matter of general experience, some authorities, notably Hilgard [1] and Maercker,[2] have suggested arbitrary standards as to the quanti-

Grade of soil.	Potash.	Phosphoric acid.	Lime in sandy soil.	Total nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	
Poor soil	Below 0.05	Below 0.05	Below 0.05	Below 0.05
Normal soil	0.15–0.25	0.10–0.15	0.15–0.20	0.10–0.15
Rich soil	Above 0.40	Above 0.25	Above 0.30	Above 0.25

ties of the different constituents which soils of different textures should have. By these standards the above analyses show the soils of the area to be generally quite satisfactory. But it is impossible to apply such standards in a rigid manner, and it is quite possible for the inexperienced layman or farmer without the necessary technical training to draw quite erroneous conclusions. Therefore it has not been considered necessary or desirable to tabulate a direct comparison for this report, but to make the simple statement that the data given here, whether by comparison with data for other localities having similar climatic conditions or by other standard methods, show a generally satisfactory state of affairs as regards the chemical composition of the soils of the area.

On the other hand, while the data show that the soils of this area are not deficient in essential mineral constituents, they do not show any unusually large percentages of these constituents, and there is

[1] Soils, E. W Hilgard, p. 377. The average of the analysis of 696 samples of virgin soils taken from the humid region is here stated as follows: Lime, 0.13 per cent; phosphoric acid, 0.12 per cent; potash, 0.21 per cent; loss on ignition, 4.40 per cent.

[2] An arbitrary standard for the rating of soils by plant-food percentages was formulated for European soils by Prof. Maercker, of the Halle Station, Germany. While these ratings have failed of general acceptance, even by the soil chemists of Germany, they are here given for the purpose of indicating an approximation of the quantities of plant-food percentages in soils of various grades:

every reason to believe that the three important methods of soil control which have proved successful on similar soils under similar conditions elsewhere would prove effective in this area. Deep and thorough tillage, while improving the general physical, chemical, and biological conditions in these soils, is especially important for improving the aeration and counteracting the tendency toward sourness. To this end, also, it appears wise to lime these lands frequently. An application of 40 to 50 bushels of air-slaked lime or finely ground limestone every few years or perhaps once in every second rotation will probably prove very effective, and more so if a crop rotation is used in which grass or a clover or other like legume enters at intervals of three or four years. It is clearly desirable to have these soils at frequent intervals under a crop which does not require clean cultivation.

Finally, the third method of control—the use of fertilizers—would probably be found efficacious in the area. Besides as liberal a use as possible of stable manures and green manures, high-grade fertilizers should be used. The local differences for each field and crop make it hazardous to give general advice in this connection, and it will be wiser for the individual farmer to consult the authorities of the State experiment station for specific advice and assistance.

SUMMARY OF CHEMICAL ANALYSES.

(1) The data secured by the chemical analyses show the soils of this area to compare very favorably with soils in other areas under similar climatic conditions. The content of important mineral plant nutrients is generally somewhat above the average for soils from other localities.

(2) The variations within types as well as between types are of a local character and call for specific rather than general consideration.

(3) Deep and thorough tillage, a systematic crop rotation, and rational fertilizing are all indicated as necessary to the best use of the soils of the area.

SUMMARY.

The area surveyed is located in southwestern Washington and comprises a total of 4,136 square miles, or 2,647,040 acres. It includes all of Pacific and Wahkiakum Counties and parts of Lewis, Cowlitz, Clarke, and Skamania Counties. The unsurveyed areas within these counties consist mainly of rough mountainous lands still covered by a dense forest growth.

A general soil map and a land classification map of this area were constructed.

The topography of the western part of Cowlitz, the northwestern part of Clarke, and the northern part of Skamania Counties is rough and mountainous. Over the remainder of the area the topography of the uplands varies from gently rolling to hilly, while extensive, comparatively level areas occur in the valleys and on the terraces which border the valleys of the larger streams.

The regional drainage is mainly through the Columbia River and its many tributaries rising in the mountainous or hilly uplands.

Many of the larger streams in Pacific County, however, empty into Willapa Bay.

The alluvial valley and more level terrace lands along the principal streams are comparatively thickly settled, the hilly uplands are sparsely settled, and the rough mountainous districts are practically uninhabited.

The principal towns within the area are Centralia and Chehalis in Lewis County, Vancouver in Clarke County, and South Bend and Raymond in Pacific County.

The area is traversed by the main lines of the Northern Pacific, Union Pacific, and Great Northern Railroads. Several branch lines of these roads and many local logging railroads reach various parts of the area.

The greater proportion of the farm products of the area are sold in the local markets. Large shipments are made to Portland, Seattle, and other large cities along the coast.

Originally a large part of the area was covered by a heavy forest growth, and lumbering is still the principal industry in many sections. Most of the agricultural development has taken place in the alluvial valleys and on the more level terraces bordering them.

The high cost of clearing the land of the stumps and underbrush has greatly retarded the development in the uplands. Dairy farming is the principal agricultural industry in the logged-off districts of the uplands. General farming is practiced on the alluvial and terrace soils. Oats, hay, and potatoes are the principal crops grown. Fruit growing is becoming an important industry in all parts of the area. Prunes are grown extensively in Clarke County and to a less extent in other parts of the area. This product is dried and shipped to various parts of the United States. The climate and soils of eastern Skamania County seem well adapted to the production of apples. Small fruits are grown in all parts of the area and give excellent results. Winter strawberries are successfully grown in Pacific County. A large acreage of the Muck in Pacific County is cultivated to cranberries. Cranberry growing is proving very profitable.

Soils suitable for cranberry culture are becoming very valuable.

Irish potatoes are one of the staple crops in all parts of the area. They produce profitable yields on many types of soil.

Hops were formerly an important crop, but at present they are only grown on a small acreage in Lewis County.

Flax and hemp are minor crops in Lewis County. Clover and timothy do well on many types of soil. Alfalfa has been successfully grown on a small acreage. Dairy products are the chief source of revenue to the farmers of the area.

Fifty-four types of soil occur in the area. These may be separated into 6 groups: (1) Soils derived from the weathering in place of the underlying rock, (2) those derived from the old outwash plain and alluvial terrace formations, (3) those derived from ancient alluvial deposits, (4) those derived from material deposited in shallow lake basins, (5) marine beach and eolian deposits, and (6) those derived from accumulations of organic matter.

The soils of the first group have not been extensively developed, but are well adapted to dairy farming. Many types are also utilized successfully for fruit growing.

Soils of the second group are as a whole very productive and are utilized extensively for fruit growing, dairying, and general farming. The heavier silty loams of this group are among the most productive soils of the area.

Soils of the third group are very productive. They are utilized mainly for the growing of hay and grain crops. Dairy farming is also practiced extensively. Soils of the fourth group are as a whole poorly drained, but when drained artificially they produce large yields of hay and small grain. Soils of the fifth group, which includes the beach and wind-laid deposits, are of little agricultural importance.

Muck and Peat soils, placed in the sixth group, are very valuable for cranberry culture as well as for some other special crops and are rapidly being developed agriculturally.

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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.]

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