RECONNOISSANCE SOIL SURVEY OF THE EASTERN PART OF THE PUGET SOUND BASIN, WASHINGTON.

By A. W. MANGUM and Party.

INTRODUCTION.

The area surveyed comprises an area of about 3,467 square miles. It extends from the Canadian boundary line on the north to the southern boundary of Pierce County, including all of the townships in Whatcom, Skagit, Snohomish, King, and Pierce counties which lie west of range 7 east, except those townships of Pierce County which

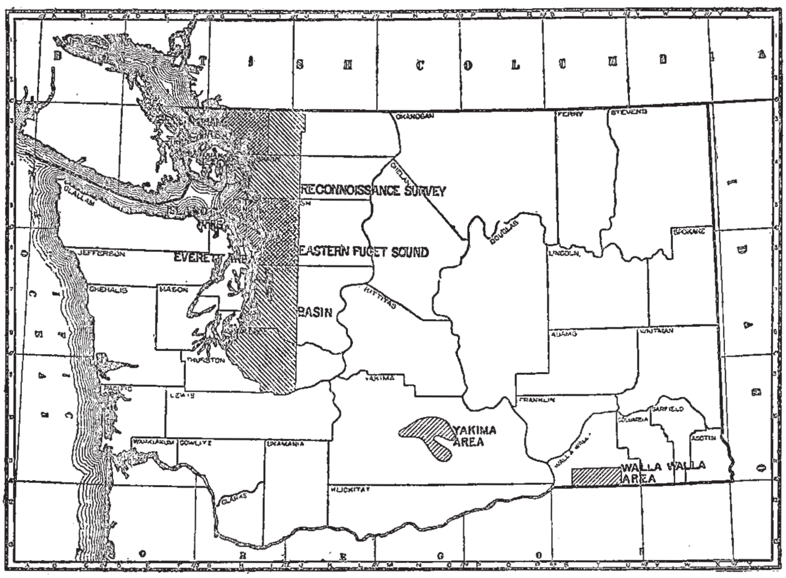

FIG. 48.—Sketch map showing location of the eastern part of the Puget Sound basin, Washington.

lie on the western side of Puget Sound. It also includes the small islands which form parts of the counties mentioned above.

The soil map represents a reconnoissance survey of the soils of this region. It shows the character of the soils which occur in every locality embraced by the survey, and although no attempt was made to indicate small isolated areas of the various types, which occupy only a very limited acreage, the soils of the area have been mapped in sufficient detail to show the character of the soil which occurs in every section in all of the townships surveyed. In the case of the rough mountainous and nonagricultural lands less detail was employed in the separation of the types than in the remainder of the area.

The land-classification map of the region shows by means of colors approximately the extent of the areas of "logged-off" or "burned-over" lands, from which the merchantable timber has been removed by the lumberman or by forest fires; the areas still covered by virgin forests; the areas which have been developed agriculturally; and the marsh lands, which support no timber and are at present too poorly drained to be used for agricultural purposes.

A considerable proportion of the land-classification map, especially that which covers the uplands, was constructed from data obtained from the county assessors of the counties embraced by the survey. The map of those districts for which no accurate data could be obtained was constructed by the parties in the field, who, wherever possible, also revised the data obtained from the counties, making such changes as were necessary on account of recent agricultural development or logging operations. The exact size of many of the small areas of timbered, logged-off or cultivated lands was estimated, as it was impracticable to make actual measurements of the acreage covered by each, but the map has been constructed in sufficient detail to show as nearly as possible on a map of the scale used, what proportion of each section of land is logged off, cultivated, or timbered.

The extent of the prairie region of Pierce County, the Indian reservations, and the city limits of the larger towns and cities are also indicated on the land-classification map.

The land over the entire region surveyed has been further classified into seven different groups, and these have been shown on the land-classification map by means of symbols: (1) Land adapted to general farming and justifying immediate agricultural development; (2) lands adapted to intensive farming, fruit growing, and pasturage; (3) land which can be utilized for orchards and pasturage, but not well adapted to farming; (4) nonagricultural lands, suitable for reforestation only; (5) mixed land, or areas where small tracts of agricultural land are scattered throughout more extensive areas of nonagricultural land; (6) sparsely timbered gravelly prairie; and (7) areas of forests, unclassified. In this broad classification of the lands of the area several types of soil are often included in the same general class. This is especially true of classes 1 and 2. This does not mean that all of the types of soil in any one class are equally productive, but it indicates that in the areas where these types are included in the same class they are adapted to the same general type of agriculture. The relative agricultural value of the different soils is taken up more in detail in the chapter on soils and in the description of each individual soil type mapped in the area.

Class 1 includes the alluvial soils occupying the river valleys and the broad level delta flats found at the mouth of the larger rivers. It also includes several upland types, such as the Whatcom silt loam and Buckley loam. Many of the soils, occupying the shallow upland basins, which occur frequently in the rolling uplands of the area, are also included in this class. The topography of the soils included in class 1 is usually level to gently rolling, and the subsoil of the upland types contain a sufficient amount of silt and clay to aid in the conservation of the soil moisture and to prevent the excessive natural drainage characteristic of the upland soils underlain by coarser material.

Class 2 includes the greater proportion of the rolling to hilly uplands. The soils in this class are mainly of a light sandy, gravelly or sandy loam mixture, and the subsoils contain a large percentage of coarse material, causing the natural drainage of the land to be excessive. The crops grown on the land of this class require constant cultivation and the continued use of such methods as will aid in the conservation of the soil moisture is necessary in order to get good results.

Class 3 includes those soils whose coarse porous texture makes them unsuited for the growing of crops which require constant tillage. These lands usually contain a large amount of gravel and are of little agricultural value, though they can be utilized with a fair degree of success as pasture and orchard lands.

The soils of class 4 either contain such a large amount of rock and gravel in both soil and subsoil or have such a rough and broken topography that they are not adapted to agriculture and are recommended for reforestation.

Class 5 includes certain limited areas where small tracts of sandy loam or silt loam, which might be profitably cultivated, occur at frequent intervals, scattered over larger areas occupied by soils which are either too stony or too rough to be of any agricultural value.

Class 6 includes the gravelly upland prairie belt of Pierce County.

Class 7 comprises the larger areas which are still covered by virgin forests.

The land classification is intended to show in a general way the relative agricultural value of the lands in every locality surveyed. Where small isolated areas of 40 to 160 acres, which would come under one class, occur in extensive areas of some other class, it was found impracticable to make a separation of the small tracts and the whole area falls into the class represented by 80 per cent or more of the land.

DESCRIPTION OF THE AREA.

TOPOGRAPHY.

The principal topographic features of the region surveyed consist of (1) the rolling uplands, which comprise the greater proportion of the entire area; (2) the rough mountainous districts; (3) the extensive delta flats and broad alluvial valleys of the larger rivers; (4) the shallow depressions which occur at intervals in the rolling uplands, representing the former basins of small lakes or upland marshes; (5) the level to gently rolling upland plain situated in the southwestern part of the area; and (6) the comparatively level plateaus which occupy more or less extensive areas in the uplands. The rolling uplands comprise the lower hills and ridges occurring between the rough mountainous region on the east and Puget Sound on the west. The topography of this region is quite rolling. The elevation gradually increases to the eastward, some of the foothills in the southeastern part of the area reaching an elevation of 600 to 800 feet above sea level. Except where broad delta flats have been formed at the outlet of the rivers, the uplands extend out to the waters of Puget Sound, with only a narrow strip of Coastal beach bordering the shore line. When the uplands extend out to the Sound, or where they border the broad alluvial valleys, the slopes are usually very abrupt, often forming steep, precipitous bluffs, but over the greater part of the area the slopes are seldom steep and the hilltops are flat or gently rolling, forming small, irregular-shaped upland plateaus. In Whatcom County the uplands lying west of the mountains have a more gently rolling topography than those in the other counties included in the survey. In this locality the rounded hills and ridges seldom reach an elevation of more than 300 to 400 feet above sea level, and, with the exception of the steep bluffs along the shores of Puget Sound, the hillsides slope gently to the broad alluvial valleys or to the intervening basinlike depressions.

Small areas of typical kame and kettle topography occur in many localities throughout the rolling upland districts of the area.

The northeastern and southeastern parts of the region surveyed are rugged and mountainous. In these districts the topography is very rough and broken, causing the greater proportion of the land to be unfit for agricultural purposes. The slopes are steep and rocky and the intervening valleys are narrow and V-shaped. Small, comparatively level plateaus or bench lands occur at intervals, but they are of limited extent, and the rough character of the surrounding areas cause many of them to be almost inaccessible. The higher mountains are found in the southeastern part of the area, where some of the peaks reach an elevation of 6,000 feet above sea level.

The river valleys are narrow in the mountainous and hilly country, along the eastern boundary line, but they rapidly become wider on reaching the more gently rolling country nearer the coast, often having an average width of from 2 to 4 miles. At the outlets of all of the larger rivers that empty into Puget Sound, the valleys widen out into extensive level "flats," which have been formed as deltas or by the filling of shallow bays with material brought down by the waters of the streams. These areas have only a slight elevation above sea level, and where they border on the waters of Puget Sound are frequently in a semimarshy condition and are known as tide flats. The largest of the delta flats occurs in the northwestern part of the area, extending from the lower valley of the Stilaguamish River in the northern part of Snohomish County to the outlet of the Samish River near the southern boundary of Whatcom County. Both river valleys and delta "flats" are in general almost level, but low, rounded elevations and shallow depressions give them locally a gently undulating topography.

The more or less extensive basins which occur in the upland districts have an almost level topography. These broad depressions were formerly occupied by shallow lakes or marshes. They are almost entirely surrounded by rolling hills and ridges and the natural drainage is usually very poor.

The surface of the extensive plain locally known as the "Prairie," which is located in the southwestern part of Pierce County, is gently rolling. The principal topographic features of this prairie region consist of low mounds, shallow basins, and more or less extensive terraces, which form flat-topped embankments from 1 to 20 feet in height. Sharp rounded ridges, which rise 75 to 100 feet above the level of the surrounding plain, occur at frequent intervals. With the exception of these ridges, which support a heavy growth of timber, the plain is treeless, or at most supports only a sparse growth of stunted fir, pine, or oak.

The plateaus, which are found at intervals in the uplands, vary in size from a few acres to areas several square miles in extent. The larger ones occur along the eastern boundary of the area in the vicinity of the towns of Buckley and Enumclaw. The surface of these plateaus is level to gently rolling, but they are usually bounded by steep slopes or precipitous bluffs.

Drainage.

The area surveyed is well drained by the numerous rivers which rise in the mountains to the eastward and empty into Puget Sound. The Nooksack and Sumas are the principal streams in that part of Whatcom County included in the survey. The Nooksack enters the area from the east and empties into Puget Sound at Bellingham Bay.

The Sumas rises in the foothills of the mountains, within the boundaries of the survey, and flows in a northerly direction, emptying into the Fraser River at a point some distance across the Canadian boundary line.

The greater part of the area surveyed in Skagit County is drained by the Skagit River and its small tributaries. The Skagit is the largest river in the five counties surveyed. It crosses the eastern boundary of the area at Hamilton and flows across the western part of the county in a general westerly direction. On reaching the broad delta flats near the coast it divides into several smaller channels, which empty into Puget Sound southwest of Mount Vernon. The Samish River, which crosses the northwestern part of the county, and Pilchuck Creek, which rises in the mountains near the Snohomish County line, also drain considerable areas.

In Snohomish County the principal streams within the boundaries of the survey are the Stilaguamish and Snohomish rivers. The north and south forks of the Stilaguamish unite near Arlington, and flow westward into Puget Sound at Stanwood. The Skykomish and Snoqualmie unite just within the eastern boundary of the survey forming the Snohomish, which flows into Puget Sound at Everett.

The northern part of the King County division of the area is drained by the numerous small streams which empty into Lake Washington or Lake Sammamish. The southern part, however, is drained by several large streams and their tributaries.

The White River enters the area near Buckley and flows in a northwesterly direction, forming the boundary line between King and Pierce counties for some distance. A branch of this stream then turns to the south into Pierce County and is known as the Stuck River, emptying into the Puyallup near Sumner, while the other branch which only contains water at times of flood, turns to the north and uniting with the Green River near Auburn continues in a general northerly direction under the name of White River. The Cedar River crosses the eastern boundary of the survey near Maple Valley and flows into the White River a short distance west of Renton, forming the Duwamish, which empties into the Sound at Seattle.

The portion of Pierce County included in the survey is drained principally by the Puyallup and Nisqually rivers and their tributaries, but the White River also drains a considerable area along the northern boundary of the county. The Puyallup enters the area near the southeastern corner and flows in a general northwesterly direction, emptying into the Sound near Tacoma. Its main tributaries within the area are the Carbon and Stuck rivers. The Nisqually forms the southern boundary of the county, and together with its smaller tributaries drains the upland plain region and a large proportion of the southeastern corner of the area surveyed.

A number of lakes occur scattered over the entire region surveyed, Lake Washington and Lake Sammamish, in King County, and Lake Whatcom, in Whatcom County, being the largest.

SETTLEMENT.

The area surveyed is as a whole sparsely settled, and a large proportion of it is still in the undeveloped condition, known as "logged-off" land, while other extensive areas are still covered by virgin forests.

Settlement has progressed most rapidly in the alluvial valleys and in the broad delta flats at the mouths of the larger rivers. This is especially true of the valleys of the White and Puyallup rivers, in King and Pierce counties, and of the La Connor flats, in Skagit County, which are at present comparatively thickly settled. In the vicinity of the cities and larger towns the settlement of the rolling uplands is progressing rapidly in every county included in the survey, but over the remainder of the area the greater proportion of the population is found in the small towns which have grown up along the railroads or larger streams as a result of the lumber industry. Large areas in the rough mountainous regions, however, are at present practically uninhabited. Two large cities, Seattle and Tacoma, are located within the area, while Everett and Bellingham are also cities with from 25,000 to 35,000 inhabitants. Many smaller towns of considerable local importance, having 500 to 3,000 inhabitants, are found in almost every part of the area, so that every locality, with the exception of some of the rough mountainous districts, is within easy reach of some local market and shipping point.

TRANSPORTATION.

The transportation facilities are excellent in every part of the region surveyed. Three transcontinental railroads—the Great Northern, Northern Pacific, and the Chicago, Milwaukee and Puget Sound—traverse parts of the area, and almost every locality within the boundaries of the survey is within easy reach of a branch of one of these lines, or of one of the less important local lines. Electric railways connect Seattle and Tacoma with the more important towns adjacent to these cities and an electric line is now completed between Seattle and Everett. The cities of Tacoma, Seattle, Everett, Bellingham, and Blaine, all have excellent harbors and small steamboats run regularly between these ports, while the larger ocean steamers furnish cheap transportation for the products of the area to all parts of the world.

MARKETS.

Seattle and Tacoma furnish a ready market for all the products of the area not marketed in the smaller towns. The dairy products not handled by the creameries and condensed milk factories find a ready market in the larger cities.

A large percentage of the fruit crop is also marketed at Seattle and Tacoma, but in recent years a large quantity of fruit has been annually shipped to larger cities in the middle western States and to Alaska.

CLIMATE.[a]

The object of this part of the report is to make the reader familiar with the average atmospheric conditions which constitute the climate of the area covered in the general report, and also to call attention to the departures from these average conditions which are the result of irregular changes in the weather. The general data used are taken from the annual summaries of the Climatological Service of the Weather Bureau for Washington, for the years 1898 to 1908, inclusive. These annual summaries are compiled from the daily reports sent to the central Weather Bureau station at Seattle by cooperative observers at the different stations throughout the section. Additional data were obtained from records at the Seattle Weather Bureau station, to which access was had through the courtesy of the section director.

The climate of any section is determined by its latitude; its general topography, including altitude, direction, and relation of slopes; its proximity to the sea or other large body of water; the direction of the prevailing winds; and the movement of low-pressure or storm areas and of high-pressure or clear weather areas over the locality.

CLIMATIC CONDITIONS OF PUGET SOUND BASIN.

The latitude of the section under discussion is the same as that of Montana, North Dakota, and Minnesota, and the conditions would be similar if latitude alone were effective in determining the climate. But situated as it is, on the west slope of the Cascade Mountains, in the path of the prevailing westerly winds, facing Puget Sound and the Pacific Ocean, the moderate winter and summer climate characteristic of large ocean areas is brought to the section by the moisture-bearing winds from the Pacific. If the winds were from the east this moderating effect of the ocean would scarcely be felt. The west winds are aided by the Rocky Mountains, the Cascade Mountains, and the mountains of British Columbia, which serve as barriers, protecting the area from the climatic extremes characteristic of the interior

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

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 or storm areas across the State from west to east. Toward these areas the air moves from all sides and passes spirally upward. The moisture that is present in the air may be condensed in the form of clouds and cause rain or snow. If these storm areas pass north of the section, the winds are from the south, are warm, and cause heavy precipitation, but if they pass south of the section the winds are from the north, are cooler, and cause less precipitation. The low-pressure areas are preceded or followed by high-pressure areas from which the air is moving outward in all directions. They bring with them clear weather, cold in winter and warm in summer. Thus the weather conditions during any month or season will vary with the intensity, number, and relation of the low-pressure and high-pressure areas which pass over the coast in their journey eastward.

PRECIPITATION BELTS OF WESTERN WASHINGTON.

The relations of the larger physiographic divisions of the State have such an important bearing on the general distribution and amount of rainfall in this section that it may be well to notice these general relations before describing in detail the precipitation of the area.

West of the area under discussion the Olympic Mountains, a high rugged mass, with slightly longer northwest and southeast axis, extend southward along the coast from the Strait of Juan de Fuca, gradually becoming lower to the south and west until they give place to the broad, low gap occupied by the Chehalis River and Grays Harbor. South of the gap the mountains are of rather low relief, and are therefore less effective than the northern portion as a climatic factor. The warm, moisture-laden winds from the Pacific Ocean, moving landward under the influence of the cyclonic areas and the prevailing westerlies, are forced up the western and southern slopes of the Olympics. In thus ascending the air is cooled and the moisture contained is largely condensed, resulting in a precipitation of 60 to 100 inches a year in an irregular belt near the coast. This has been called the wet belt.

Between the Olympic Mountains on the west and the high Cascade Mountains on the east lies the Puget Sound Basin, a broad, trough-like depression extending southward to the Columbia River. The eastward-moving air coming into this valley after it has parted with a large share of its moisture in passing over the slopes of the Olympics or through the Chehalis River Valley causes much lighter precipitation than in the coastal belt. The annual precipitation in the basin ranges from 25 to 60 inches, and it has been called the moist belt.

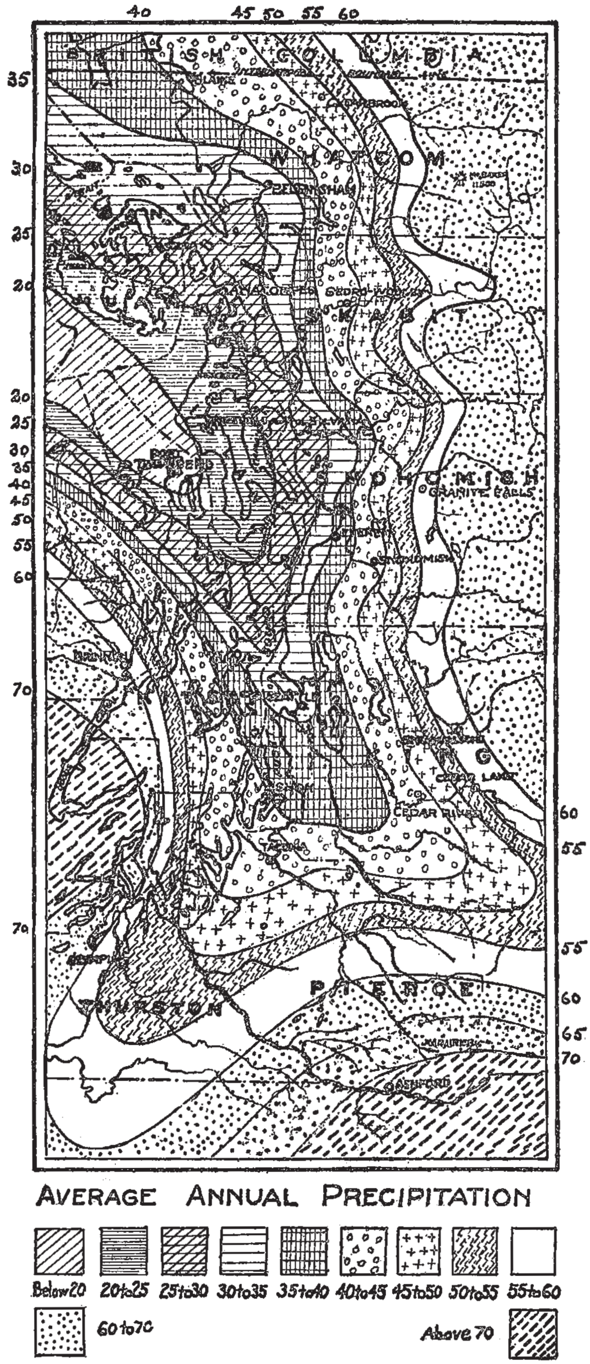

FIG. 49.—Sketch map showing annual precipitation.

As the air moves on east of the Sound Basin it is forced up the steep western slope of the Cascade Mountains, and the precipitation gradually increases until in a narrow irregular belt toward the summit of the range it exceeds 60 inches. Thus a second wet belt is produced, and from this belt most of the rivers flowing through the area under discussion obtain their supply of water. These slopes are well wooded and the character of the soil is such that the water is largely absorbed in it, thus keeping the rivers well supplied with water even during the drier summer season.

PRECIPITATION.

The average annual precipitation for different parts of the area is shown in 5-inch variations in figure 49. There is a marked decrease from 60 inches, in the southern portion of the area along the Sound, to 25 inches in the northern part. This is explained by the presence of the Chehalis River gap, which allows the southwest winds, still laden with moisture, to find their way into the lower Sound country. Precipitation takes place in gradually decreasing amounts as the air loses its moisture in passing northward. Thus the annual precipitation at Olympia is 55 inches, at Tacoma 45 inches, at Seattle 35 inches, at Anacortes 25 inches.

There is a decided increase in the precipitation as the air moves inland and is forced up the slopes of the Cascade Mountains. The effect of the broad, low river valleys, which extend for some distance inland, is shown by the slow increase in precipitation up the river valleys as compared with the increase on the intervalley upland spurs. The annual precipitation at Silvana is 30.4 inches, at Granite Falls about 60 inches, at Baker, along the Skagit River, much farther back in the mountains, only 60 inches, and at Lester, still farther back, only 46 inches. This difference would be much more apparent in the diagram if there were along the valleys a greater number of stations from which data could be obtained.

The average monthly precipitation at the different stations in the section is shown in figure 50. A study of this map shows that very little rainfall occurs at any of the stations during July and August and that June and September have a small rainfall compared with the winter months. The heaviest precipitation occurs during November, December, and January, and for many of the stations the maximum occurs in November.

At the northern stations, where the total precipitation is less than elsewhere in the section, 85 per cent of the total occurs in eight months between October and May, inclusive, and 70 per cent in six months between November and April, inclusive. At the southern stations, about Seattle and Tacoma, 90 per cent of the total precipitation occurs in the eight months, October to May, inclusive, and 75 per cent in the six months between November and April, inclusive.

The reasons for the concentration of the precipitation in the winter months are: (1) The cyclonic or storm areas passing over the Sound Basin 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. 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 heavy precipitation similar to that which occurs in the winter. This effect is empha-

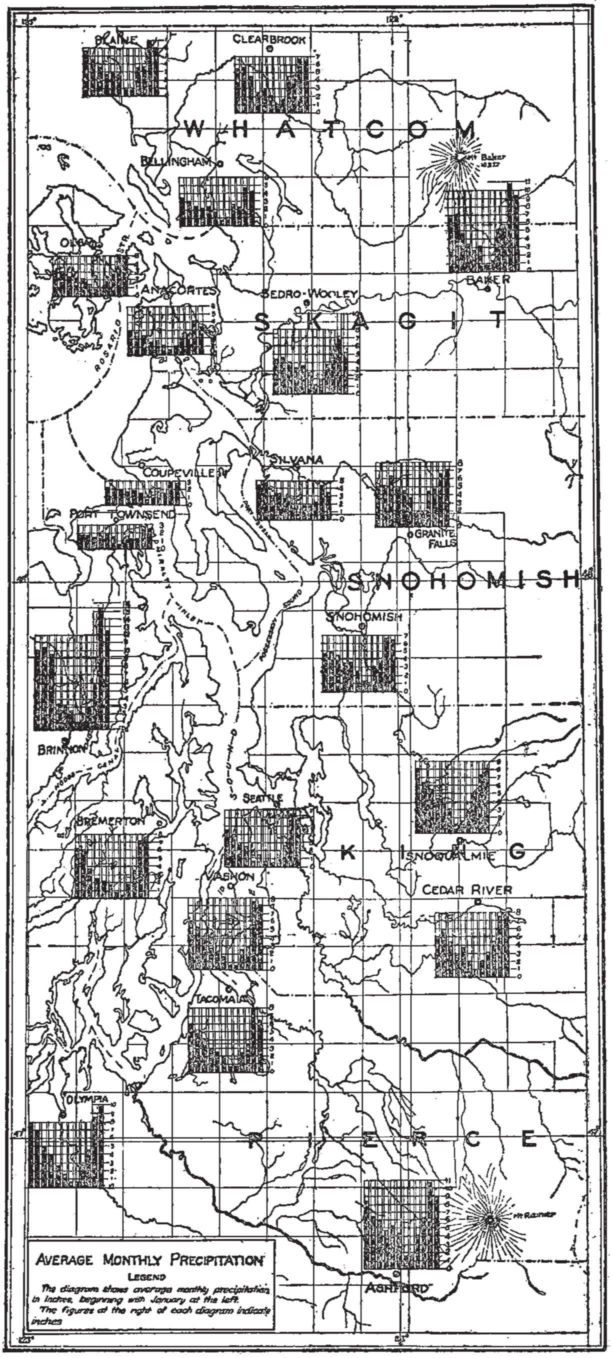

FIG. 50.—Diagram showing average monthly precipitation.

sized by the fact that the winter winds along the coast are prevailingly from the southwest and become cooler as they blow northward, while in the summer they are prevailingly from the northwest, becoming warmer as they blow southward and inland. Condensation is increased in either case also if the air is forced to ascend rapidly by passing over mountains.

The annual snowfall is very light at all stations in the coastal belt of the area, the average ranging from 6 inches at Anacortes to 13.7 inches at Tacoma. The absolute annual maximum for the ten-year period is 30 inches, at Snohomish. The snow remains on the ground for only a very short time, and has therefore little effect on vegetation or climate. Farther back from the coast the amount gradually increases, and at Ashford there is an average fall of 67 inches, with an absolute annual maximum of 161 inches. At Lester, a short distance east of the area, the annual average is 84 inches.[a]

Figure 51 shows the average number of days per year on which the precipitation, including rain and melted snow, was 0.01 inch or more. The highest average for any station is at Snoqualmie Falls, 171 days. The lowest average is at Silvana, 113 days. The average for the whole section is 146 days.

The average number of clear days for each station is also shown in figure 51. The highest average is at Vashon with 160 clear days, the lowest at Tacoma and Snohomish with 78 clear days. For the whole section the average year has 125 clear days, 100 partly cloudy days, and 140 cloudy days.

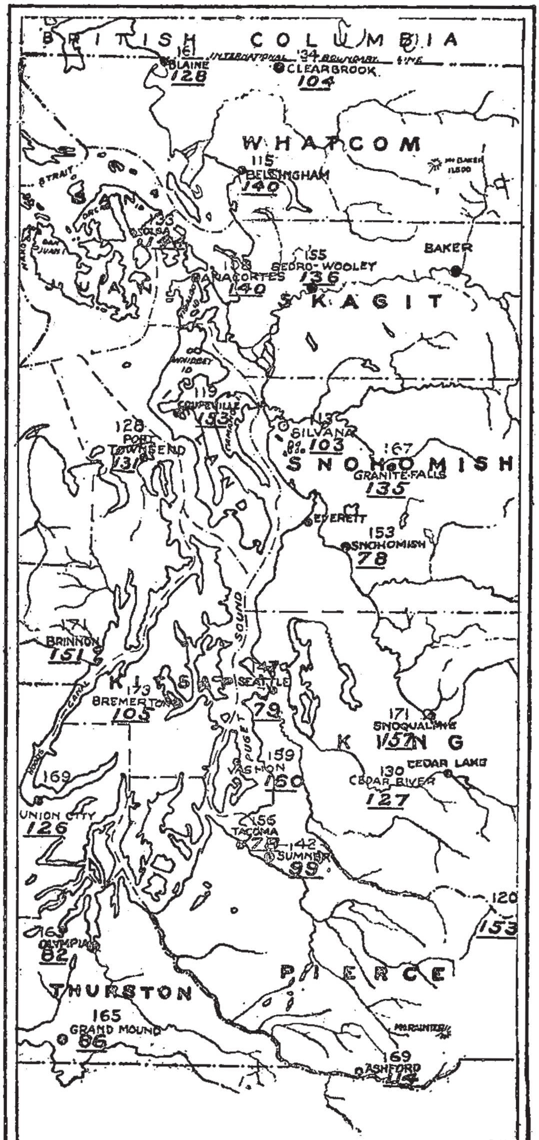

FIG. 51.—Number of clear days and number of days with rain. (Numbers underscored show rainy days.)

The distribution of precipitation during the day or during the twenty-four hours has not been worked out for the whole section, but observations at the Weather Bureau office at Seattle show that between 70 and 75 per cent of the total precipitation occurs during the night hours between 5 p. m. and 5 a. m.

[a] In considering snowfall in the total precipitation, 10 inches of snow is estimated to equal 1 inch of rain.

TEMPERATURE.

The general uniformity characteristic of marine climate is shown in the temperature conditions throughout the section. The mean annual temperatures at the different stations show a variation of only 3° for the whole belt, being 48.6° at Clearbrook, in the northern part, and 51.7° at Seattle, in the central part of the belt. For this reason and also because the mean annual temperatures signify little as regards the real distribution of temperature, no map has been made to show these conditions.

The average annual range, or the difference between the average temperature of the coldest month and the average temperature of the warmest month, is small, varying from 21° to 25°. The greatest annual range is 25° at Snohomish, with an average temperature of 63.5° for July and 38.5° for January. The smallest range is 21° at Bellingham and Coupeville, both of which show an average temperature of 40° for January and 61° for July. The average temperature for January, the coldest month in the year, varies from 40.5° at Seattle and other southern points to 36° at Blaine, in the northern part of the section, and 38.5° at Snohomish and other inland points. The average for July, the warmest month of the year, varies from 61° at Blaine to 64.1° at Seattle and 63.5° at Snohomish.

The average daily range of temperature at Seattle, which may be used as a fair average for the section, is 9° during the winter months and 18° during the summer months. The greatest daily ranges are from 25° to 30° during the summer months, while the least daily range occurs in the winter and is 3°. The mean daily variability or change of mean temperature from day to day is only 3.2° in January and 2.6° in July.

This remarkable uniformity is accounted for by the fact that the prevailing westerly winds come from the Pacific Ocean, which is warmer in the winter and cooler in the summer than the adjacent land areas, and consequently cause higher winter temperatures and lower summer temperatures in the coastal belt than would otherwise occur. The condensation of the moisture carried by these moisture-laden winds also causes a slight raising of the temperature of the air in which it is taking place, and thus increases the effect of the warm winds in the winter. For the latter reason the rainy days, which accompany the cyclonic or storm areas, and of which there are a large number during the winter months, are particularly mild and enjoyable, especially when the rain is unaccompanied by strong winds. The clouds produced by condensation are effective also in helping to keep the air cool in the summer, and in preventing rapid radiation and cooling at night and in the winter.

This moderating effect of the west winds, and of condensation, is noticeably absent during the passage of the anticyclonic or clear dry weather areas. At such times the air, coming from the interior over the Cascade Mountains, is sharp and frosty in the winter, but warm and dry in the summer.

The averages of the lowest and of the highest temperatures recorded during the ten-year period are shown in figs. 52 and 53. The maps indicate the lowest and highest temperature that may be expected in the respective belts. The lines of equal extremes of temperature follow the Sound in general, but are modified in much the same way as the lines of equal rainfall by the presence of the broad, low valleys extending inland between the undissected uplands.

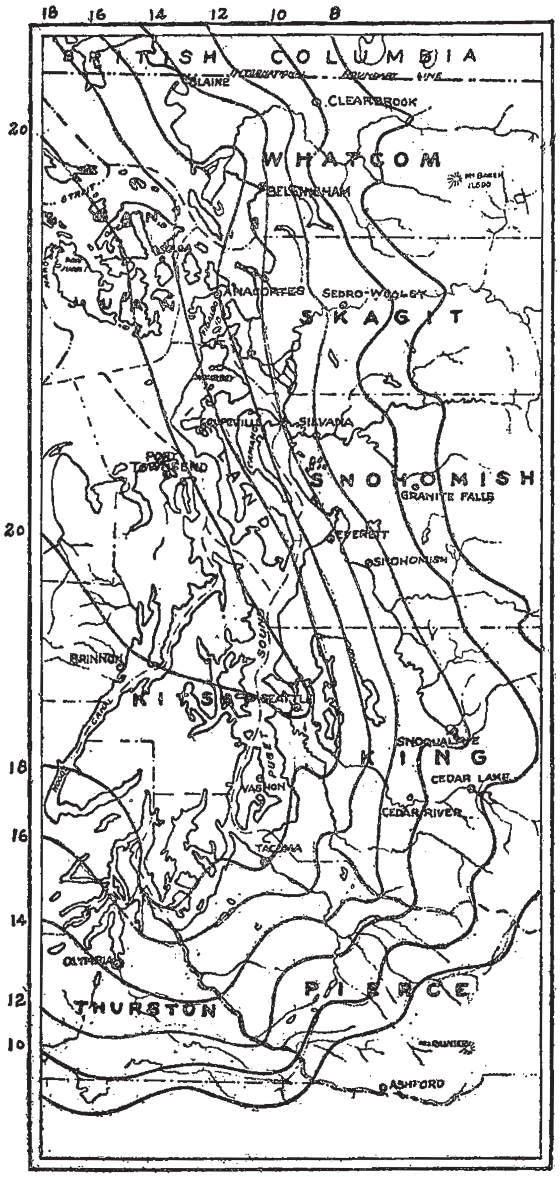

FIG. 52.—Average lowest temperatures.

The average of the lowest temperatures varies from 21° at Seattle and other Sound stations to 9° or 10° at Clearbrook and other stations farther back from the Sound. The lowest temperatures recorded since the establishment of the Weather Bureau stations were in January, 1893, when the thermometer fell to −6° at Blaine, −3° at Olga, 1° at Snohomish, 3° at Bellingham, Anacortes, and Seattle, and 5° at Tacoma. Such low temperatures are not at all common, and temperatures below 32° occur on the average only about twenty days each year.

The average of the highest temperatures varies from 82° at Olga and 84° at Blaine, to 91° at Seattle and 97° at Snoqualmie Falls and Olympia. The highest temperatures ever recorded at the stations were 104° at Snoqualmie Falls and Olympia, 98° at Tacoma, 97° at Snohomish, and 96° at Seattle and Bellingham. Most of these high marks were reached in July, 1906. While such high temperatures are occasionally reached, most of the Sound stations have only one or two days annually on which the temperature goes above 90°.

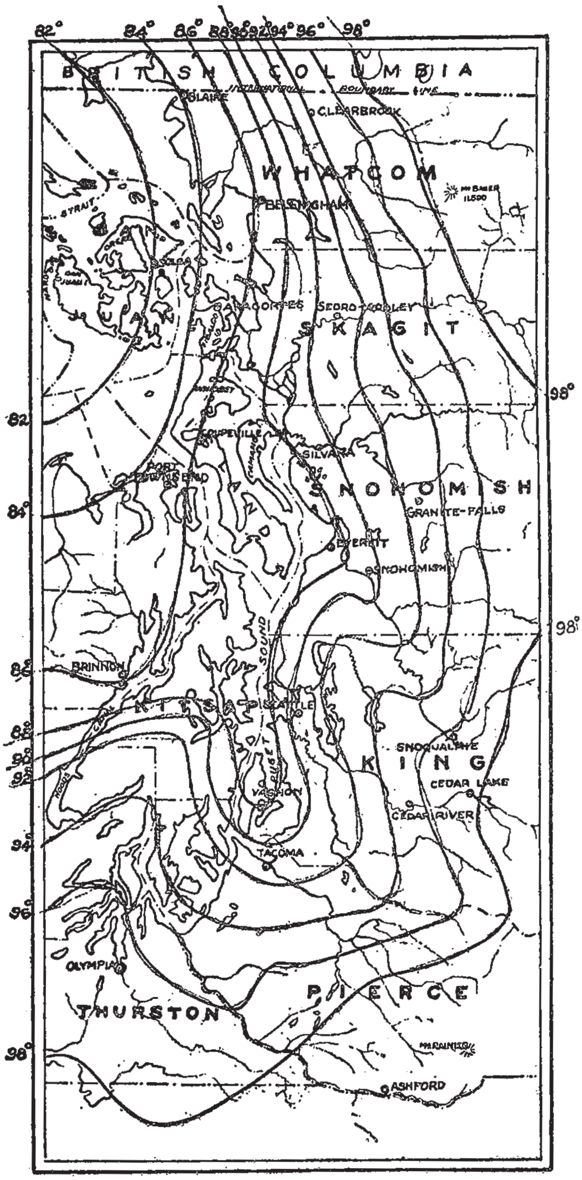

Fig. 53.—Average highest temperatures.

Killing Frosts.

The average of the dates on which the earliest killing frosts in the fall and the latest killing frosts in the spring have occurred is shown in figures 54 and 55. While there is great irregularity in the dates in different years these maps indicate approximately for the different belts the dates between which the earliest and latest frosts, respectively, may be expected. As the frosts usually occur under the influence of the irregular anticyclonic areas, which may cover the greater part of the Sound Basin, the dates in any particular year are apt to be the same for a number of stations.

The marine influence is shown on the maps by the general parallelism of the belts to the Sound. The irregularities are due largely to the river valleys, on account of the difference in elevation of the valley floors and the upland spurs between them. Occasionally, if the valleys are wide and flat, the colder and therefore heavier air collects in the valleys, causing earlier fall and later spring frosts than on the adjacent uplands. But if these valleys have sufficient slope to cause a good drainage of the air in them it tends to prevent frost, while on the uplands the stronger radiation may produce frost.

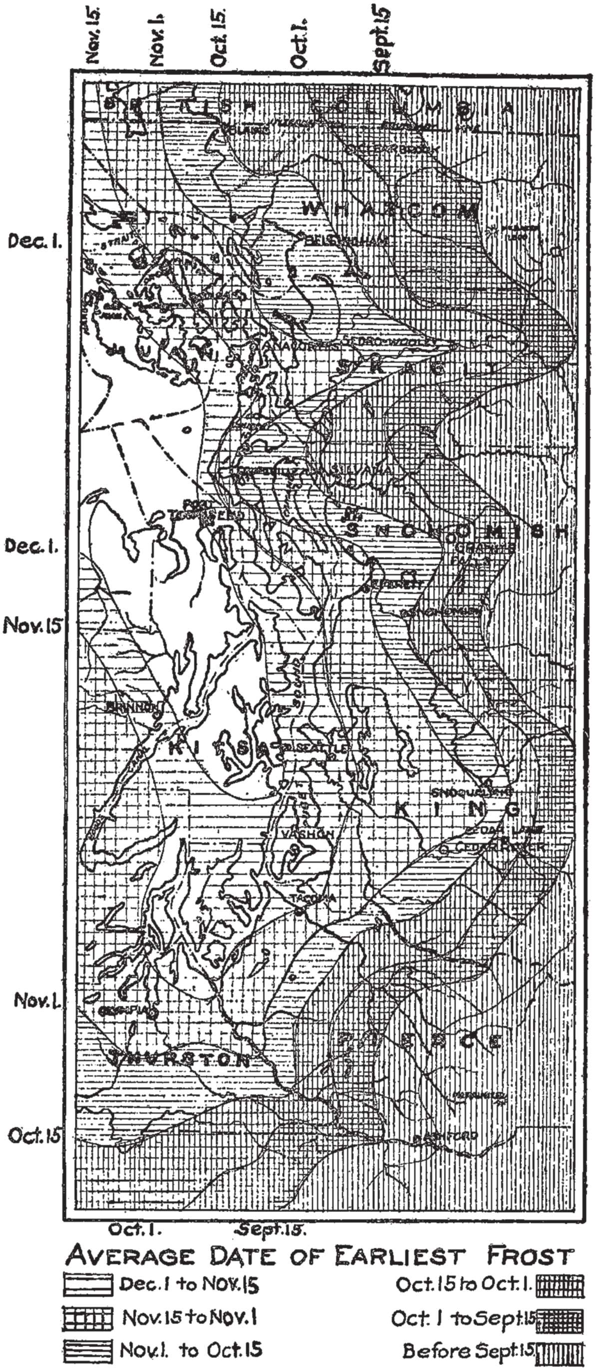

FIG. 54.—Sketch showing average dates of earliest frosts in fall.

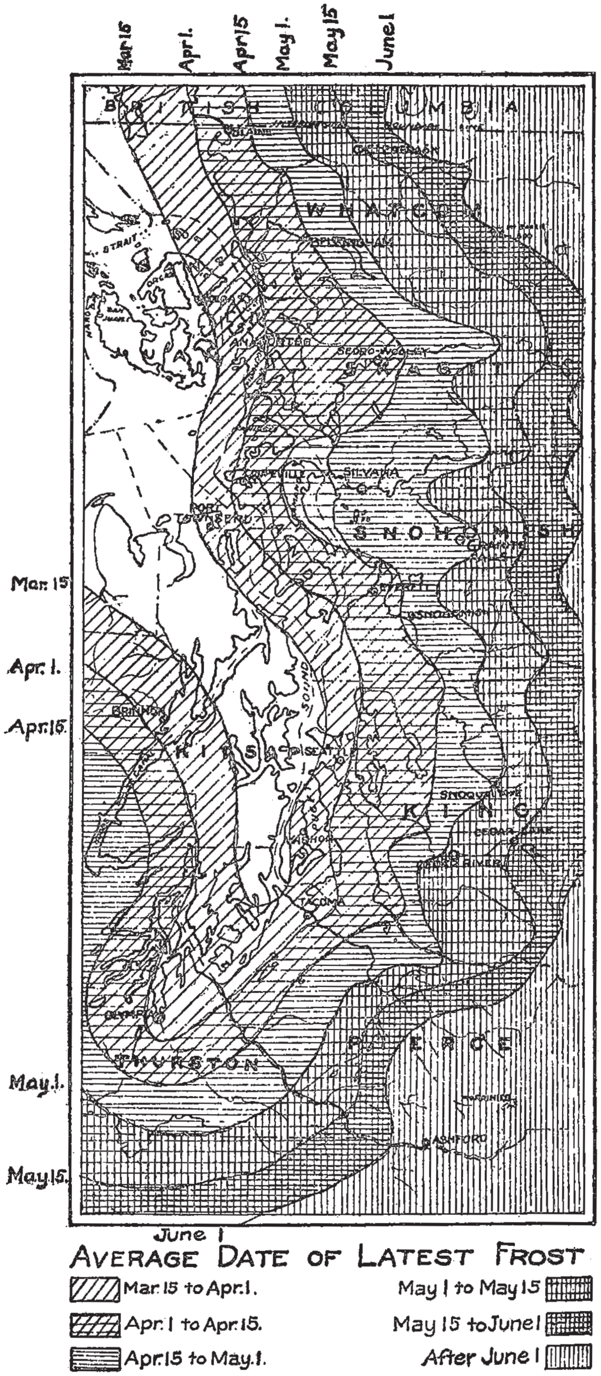

FIG. 55.—Sketch showing average dates of latest frosts in spring.

The earliest frosts in the fall occur at those stations farthest north and farthest from the marine influence of the Sound. The average date for Clearbrook and Granite Falls is between October 1 and October 15, while the date for Seattle, Tacoma, and other central Sound points is between November 15 and December 1. The earliest killing frost recorded at Blaine and Clearbrook is September 12, and at Snoqualmie Falls and Snohomish September 25, while in Seattle and Tacoma the earliest is October 18.

The average date for occurrence of the last frost in the spring at Clearbrook is between May 15 and June 1, at Snoqualmie Falls between April 15 and May 1, and at Seattle and other stations along the Sound between March 15 and April 1. The latest killing frost recorded at Clearbrook in the north is June 2. At Snohomish and Snoqualmie Falls, in 1901, frost occurred as late as July 12, but in Seattle and Tacoma the latest recorded is about April 1.

WINDS.

The winds of this section are prevailingly from the west, but they are modified in summer and winter by the different relations of high and low pressure areas over the Pacific Ocean and the interior of the continent in the two seasons. In the summer they are more commonly from the northwest and in the winter from the southwest. The direction of the winds is also interfered with and changed by the passage of the large cyclonic areas. After the passage of an anti-cyclonic area a station may have strong winds from the east or north-east, and during the passage of a cyclonic area it may have southeast, southwest, or northwest winds, depending upon the position of the station in regard to the low-pressure center.

The topographic features are another important factor in determining the direction of the winds. At the northern stations along the Sound the winds are from the west, northwest, or north, while at the southern stations the winds are from the south and southwest, coming through the Chehalis gap and up the Sound valley.

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 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 throughout the section and especially along the Sound is marine in character. The evenness of the temperature conditions throughout the year, the slow and rather slight changes, and the decided winter maximum in precipitation are the most striking features of the climate. 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. The conditions from May to October are ideal, with only five to twelve rainy days per month, few hot days, and no oppressively hot nights.

Many have ascribed this equable climate to the Japan current, but, as has been shown, the prevailing westerly winds, the cyclonic storms, and the condensation of the moisture are the chief factors in causing these conditions. Changes of climate have also been explained by changes in the position of the Japan current. In the first place, no permanent change of climate is shown by the records, and any slight differences that may be observed between two winter seasons, or two summer seasons, or different months can be easily accounted for by irregular variations in the path of the cyclonic storms which pass over the area. If the storms pass south of the section, the winds will be from the north and cooler weather will be the result. If the storms pass north of the section, the winds will be from the south and warmer weather will be the result.

AGRICULTURE.

The settlement of the area surveyed began in the decade 1850 to 1860, but the population increased very slowly and little progress was made in the development of its resources until within the last thirty years.

The entire area, with the exception of the prairie region of Pierce County and the "tide flats," was originally covered by a dense forest of cedar and fir, and the lumber industry has been the main factor in the development of this region. Lumbering is still the principal industry and extensive areas of virgin forests are still found in various parts of every county surveyed. (See Plate XX, fig. 2, and Plate XXI, figs. 1 and 2.)

Small areas in the river valleys and delta flats, adjacent to the larger towns and cities, were first put under cultivation, as these lands could be cleared and made ready for farming at a comparatively small cost. The rapid growth of the towns and cities caused a great demand for farm produce, and the acreage of cultivated land in the alluvial valleys rapidly increased, until at the present time a large proportion of the land occupying the larger stream valleys and upland basins is utilized for farming or dairying purposes.

The difficulty in clearing the uplands of the logs, stumps, and underbrush, after the merchantable timber has been removed, has greatly retarded the agricultural development of these sections of the area, and only a very small percentage of this land is under cultivation. (See Plate XX, figs. 1 and 3.) The cost of clearing the logged-off uplands by the method in use at the present time is so

FIG. 1.—SHOWING CONDITION OF THE LAND AFTER IT HAS BEEN LOGGED-OFF AND BURNED OVER.

FIG. 2.—LOGGING OPERATIONS. GETTING OUT THE MERCHANTABLE TIMBER ON THE UPLANDS OF WHATCOM COUNTY.

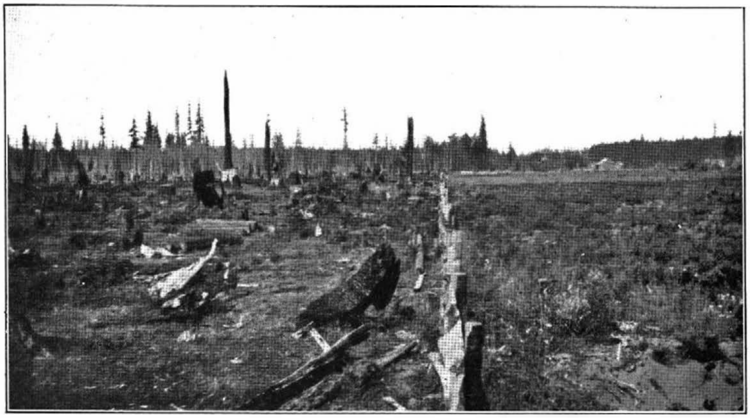

FIG. 3.—A CLEARED AND A PARTIALLY CLEARED FIELD IN UPLANDS.

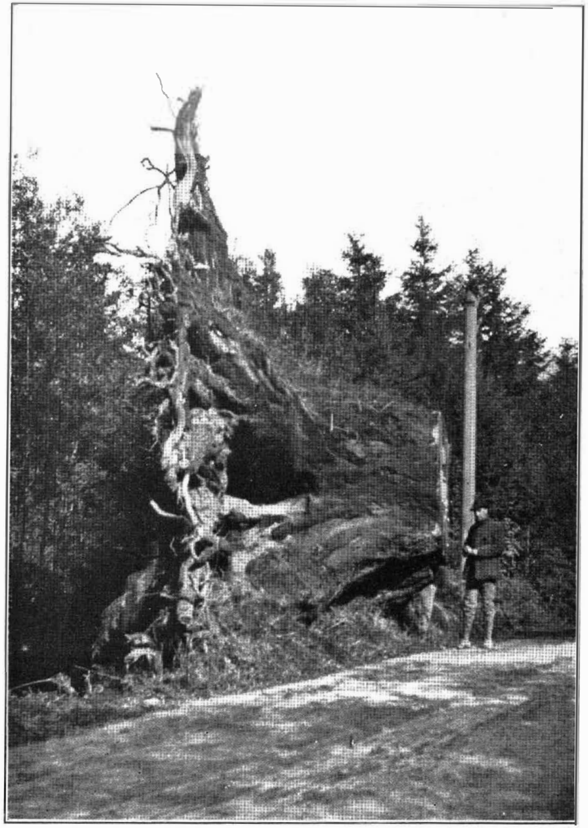

FIG. 1.—SHOWING THE SHALLOW ROOT SYSTEM OF THE RED FIR.

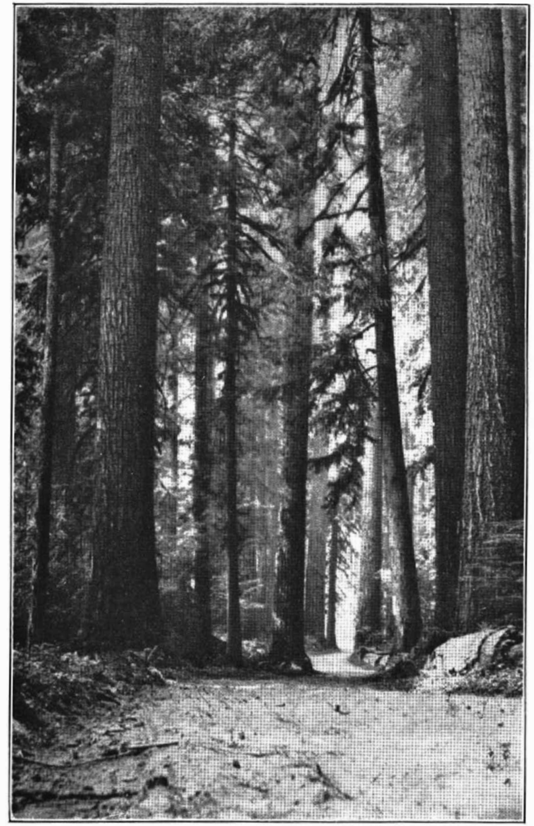

FIG. 2.—TYPICAL UPLAND FOREST GROWTH.

great that only the intensive cultivation of small areas has proved profitable.

During the early stages in the agricultural development of the area hops were grown extensively in many localities, but the uncertainty of securing good prices for this crop has resulted in a steady decrease in the acreage devoted to it and a proportional increase in the acreage of such staple crops as oats, hay, and potatoes. Hops are still grown to a limited extent in some localities, but over the greater part of the area the crop has been almost entirely discontinued.

Oats, hay, and potatoes were among the first crops grown in the area, and these continue to be the staple products. The growing of orchard fruits and small fruits is now one of the principal industries of the region, and the acreage devoted to these crops is annually increasing.

In the river valleys, delta flats, and on some of the larger upland basins, such as the Lynden Prairie, in Whatcom County, where the land could be cleared and put under cultivation at a comparatively small cost, such crops as oats, hay, and Canada field peas are profitably grown, but on the rolling uplands more intensive methods of agriculture are practiced, and the limited acreage of cleared land is usually cultivated to such crops as potatoes and small fruits.

Dairy farming is practiced on a more or less extensive scale in almost every part of the area and has become one of the most profitable industries of the whole region. The mild winters make it unnecessary to provide warm shelter for the stock and very fair pasturage is available during every season of the year. Most of the dairy cattle are of low grade. They are gradually being displaced by herds of highly improved breeds.

The raising of poultry is proving very profitable in the area, especially where this industry is combined with the growing of small fruits. Poultry farming is also practiced very successfully on some of the rough, gravelly, or nonagricultural lands adjacent to some of the larger cities.

The oats grown in the area are of good quality and very large yields are always secured. In the river valleys the yields usually range from 60 to 90 bushels per acre, but a yield of more than 100 bushels per acre is not uncommon. On the delta flats of the Skagit River the average yield is about 100 bushels per acre, and an average yield of more than 150 bushels per acre has been secured on a small acreage during a favorable season.

Wheat is grown to a limited extent on the alluvial soils of the river valleys and delta flats, and also on the Whatcom silt loam. It produces large yields, but the berry is too soft for milling purposes and is used mainly for chicken feed. The yields usually range from 50

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to 75 bushels per acre, but limited acreages in the delta flats have produced yields estimated at more than 100 bushels per acre. Canada field peas are grown quite extensively in some parts of the area. The crop is usually thrashed, and produces 40 to 50 bushels per acre.

Clover and timothy do well on both the upland and alluvial soils. In the uplands these crops are grown only to a limited extent on small areas utilized as pasture land for stock, but on the alluvial soils and on the soils occupying some of the larger upland basins they are grown on a more extensive scale and yield from 3 to 5 tons per acre.

One of the most profitable crops grown in the area is Irish potatoes. This crop is grown successfully on every type of soil suitable for agricultural purposes, and when properly cultivated large yields are always secured. A good quality of potato is produced on both the upland and alluvial soils. The yields obtained vary from 150 to 500 bushels per acre, depending largely on the cultivation of the crop and on the character of the soil.

Small fruits do exceptionally well on many types of soil and are grown more or less extensively in many parts of the area. In parts of the White and Puyallup river valleys and on Vashon Island the small-fruit industry has reached its greatest development within the area, and large shipments from these localities are annually sold on the larger markets at good prices.

The berries successfully grown for the markets consist mainly of blackberries, raspberries, and strawberries. On Vashon Island more attention is given to the growing of strawberries than to any other crop. The berries are grown on the upland gravelly and sandy loams, and when proper methods of cultivation are used they produce yields of 250 to 500 crates per acre. When properly cared for, orchards do well on the soils suitable for agriculture in every part of the region surveyed. The trees grow rapidly and begin bearing at an early age. The fruit is seldom, if ever, damaged by late frosts or cold weather. At the present time more attention is given to the growing of tree fruits in Whatcom County than in any other locality included in the survey, but this industry is developing rapidly and the area planted in orchards is annually increasing throughout the whole area. Apples, pears, cherries, prunes, and plums are all grown on a commercial scale and the fruit is of good quality.

Many varieties of vegetables are very successfully grown on both the upland and alluvial soils for the local markets.

Such a small proportion of the area has been developed agriculturally that very little is known concerning the adaptation of the various types of soil to the different crops grown. This is especially true of the upland sections of the area, where such a small percentage of the land is under cultivation. In the river valleys and delta flats, where a large proportion of the land is cultivated, the farmers prefer the heavier types of soil, such as the Puget silty clay and Puget silt loam for the grain and hay crop, while the lighter fine sandy loam soil seems well adapted to the growing of small fruits and vegetables.

On the upland types the success or failure of the crops grown depends largely on the methods employed in the cultivation of the land. When the land is cleared for farming the burning of the stumps, logs, and underbrush destroys the shallow covering of vegetable matter which prevents excessive evaporation and aids in the conservation of the soil moisture. A large amount of the humus in the soil is also destroyed by the fire and when the land is ready for cultivation it is usually in an impovershed condition and very careful methods of cultivation are necessary to restore its productiveness and to get it in condition for the successful growing of crops. Large applications of barnyard manure and the turning under of a crop of clover or field peas has proved very beneficial in restoring the soil to a state of productiveness. The topography of the rolling uplands and the porous character of the subsoils of the majority of the soils of this region result in a considerable loss of soil moisture by excessive natural drainage.

When thoroughly cultivated, however, the upland soils produce very fair yields of the crops grown. Frequent shallow surface cultivation, such as will keep a dust mulch on the surface and reduce the loss of moisture by evaporation, is necessary in order to protect the crops from serious damage by drought.

In a great many cases, no attempt has been made to restore the newly cleared land to a productive state. The crops are only given an occasional cultivation and brakes and weeds are allowed to grow profusely with the growing crops. Such methods always result in very poor yields and often in a total crop failure. The necessity for the thorough cultivation of the land utilized for orchards is now beginning to be recognized by the more successful fruit growers of the area.

No regular system of rotation of crops is practiced in the area, either in the valleys and delta flats or on the uplands. When grain and hay are the principal crops the usual rotation is oats, followed by timothy or field peas and back to oats again, but the fields are often planted to the same crops for many consecutive years.

The majority of the farms are operated by the owners and very little land is rented for farming purposes. The larger farms are located in the river valleys and delta flats, where they contain from 40 to 320 acres. In the uplands the farms seldom exceed 20 to 30 acres, and only a part of each tract is under cultivation. In many localities near the larger markets the land is being taken up in 5 to 20 acre tracts.

The labor employed on the farms is efficient, but owing to the fact that higher wages can be obtained in the lumber mills, logging camps, and in other industrial lines, there is usually a scarcity of farm labor, especially during the season for harvesting the hay and grain crops.

The value of the farming lands of the area varies considerably according to its location in relation to the larger cities, to the character of the soils, and to the extent of the improvements. Some of the highly improved valley lands adjacent to the larger markets are valued at $300 to $800 an acre, while unimproved upland tracts vary from $15 to $150 an acre.

A systematic rotation of crops, the more general use of barnyard manure, and frequent shallow cultivation of the surface soil are suggested for the improvement of the agriculture of the area.

FLORA CHARACTERISTIC OF THE DIFFERENT SOILS.[a]

Four general soils may be recognized by their flora. These are the gravelly prairie soil, embracing the Spanaway gravelly sandy loam; ordinary fresh-water bogs, included with the soils mapped under the head of Peat and Muck; peat bogs, also included under the head of Peat and Muck; and saline bogs, embracing in the main the soil type mapped as Tidal marsh. These cover a comparatively small area of the region included in the survey. While the plants vary much on the other soils, one can not draw from the vegetation definite conclusions concerning the kind of soil. The water content of a soil seems to be the greatest factor in determining the plant growth, and the ability of a soil to conserve moisture depends directly on the texture of the soil and subsoil. We may therefore learn something of this by the plants.

FRESH-WATER BOG.

A typical fresh-water bog has considerable water flowing or draining into it, and again out of it, so that the water is changing. This insures the removal of a considerable part of the soluble products of decomposition, such as acids, and the carrying of oxygen to the decomposing vegetation, so that the decomposition may be more rapid and more complete than where the water is stagnant, The drainage from such a bog may be subterranean, as in some of the depressions in the prairies about Tacoma, where the gravel permits downward or lateral movement of the water. The fresh-water bogs grade into peat bogs on the one hand as the out-flow of water is less, and into salt-water bogs on the other as the sea-water has access. Among the plants characteristic of such bogs are the following:

The cat-tail (1)[b] is known to everybody.

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[a] Prepared by T. C. Frye, of the Washington Geological Survey.

[b] The figures in parentheses refer to a list of scientific names of the plants given at the end of this chapter.

The tule (2) is a rush with round leafless stems, 3 to 6 feet high, and often used in life-preservers.

Purple marsh-locks (3) has compound leaves and almost prostrate stems as thick as a finger.

The buck bean (4) also has a stem the size of a finger, but has three leaflets to its leaves.

The water-shield (5) has oval floating leaves 2 to 6 inches long and the leafstalk from the center.

The common water lily (6).

Bladderwort (7) is floating and has its leaves split into threadlike segments.

Pond weeds (8) have either submerged or floating and shiny leaves.

Sedges (9) are grasslike in appearance, but with solid and often three-angled stems.

Dulichium (10) has a grasslike appearance, but with short leaves forming three distinct rows to the top of the tall stem.

The arrow grass or wapato (11) has large arrowheadlike leaves. This is the plant whose tubers the Indians used for food.

The bur reed (12) has leaves like the cat-tail, but the fruit is a bur about the size of the end of a man's thumb.

Fresh-water ponds and small lakes slowly fill with plant remains and sediment and become fresh-water bogs. The margins have their fresh-water bog vegetation, which is carried out by the water and settles in the deeper parts. Where the shore is lined with plants with strong fibrous stems, such as purple marsh-locks (3) and the buck bean (4) the mass of decomposing vegetation is densely interwoven. The marsh gas formed in decomposition is unable to penetrate such a mass rapidly and collects under it. A storm often causes such masses to loosen and move away as floating islands, like floating manure heaps, supported by marsh gas formed by their own decomposition. These fill up the deeper parts as they sink. Thus a fairly deep fresh-water area of small extent becomes a fresh-water bog. When a bog is filled with decomposing vegetation the surface becomes firmer. On such bogs sedges, rushes of the tule form, and dulichium (10) seem to form the chief flora. The sedges and dulichium are cut for hay on some such marshes in the vicinity of Tacoma, even though the surface is barely firm enough to support horses. These fresh-water bogs, when old and solid, or when drained, form some of the best soil in the survey—the black Muck.

Peat Bog.

This is characteristically an undrained bog. There must be an influx of water, either from the surrounding sloping shores or from some small streamlet, or the water would evaporate and the bog disappear; however, there can be but little outflow. The incomplete decomposition of the vegetation gives rise to acids which are in solution in the water and are not carried away. The acidity or some other condition hinders further decomposition, probably by preventing the growth of the proper bacteria. The lack of movement of the water prevents the carrying in of oxygen. The presence of little oxygen again hinders decomposition, and also causes the formation of more acid in decomposition. Thus we have a bog whose water contains comparatively high concentrations of humic acid in solution. The acid or some other substance is injurious to many plants. It is not known exactly what it is in peat-bog water which makes it difficult for plants to get water. If the roots of a plant can not get water, the plant suffers from drought whether the roots be submerged or not. We may thus have plants with water all about them and with their roots in it and yet have them suffering drought, somewhat as shipwrecked sailors may die of thirst while pitching about on the waves in a boat. This water difficulty makes a peat bog a desert so far as the water-absorbing power of the roots is concerned, although it is a very humid region so far as the atmosphere surrounding the leaves is concerned. Hence we find the flora different from that in fresh-water bogs and also from that on dry land. In fact the peat bogs, often many miles apart and quite disconnected, from the Atlantic to the Pacific, and from Alberta to Oklahoma, have pretty much the same plants, and most of these plants are found only in these acid bogs. This makes it easy to recognize such bogs. The following are some of the characteristic plants:

Labrador tea (13) is an evergreen shrub. Its leaves are covered beneath with long brownish hairs and are rolled back at the edges. It was formerly used for tea, being shipped from Labrador to England; hence the name.

Swamp laurel (14) is an evergreen shrub with leaves distinctly whitish beneath, but not hairy to the naked eye.

Hard-hack (15) is a bunched bushy shrub 10 feet or less tall, with very hard stems. The chief work in clearing a peat bog lies in the pulling of the bunches of this plant. It has pyramidal bunches of red flowers, which remain as dark-brown bunches of seed.

The cranberry (16) grows close to the ground on a bed of moss as a small, creeping, vinelike, but shrubby plant with evergreen leaves one-fourth to one-half inch long.

Peat moss (17) forms most of the soft bed or bottom of the swamp. Its leaves have a high water-holding capacity. It decomposes below while it grows above, and so grows year after year. When dry it has a whitish appearance.

Sundew (18) is a small plant 6 inches high or less, with a rosette of basal leaves of a red color. It is the only insectivorous plant in this region and it grows in these peat bogs only.

The dwarf birch (19) is found only in peat bogs. Its twigs are covered with small glandular raised spots about one-fourth the size of a pin head.

As has been said, peat bogs probably contain too much acid for most plants, and hence have a flora all their own. It is unfavorable to nearly all crops. The soil needs drainage to remove the acidulated water. It is well known that peat burns readily, since it is used for fuel in some countries. By lowering the water in a peat bog and burning away the top enough alkali is formed to counteract the acid of the soil. This practice is resorted to in Whatcom County. If, however, the water is too far down, and the bog burns to the bottom, the good soil is all burned away and the land is ruined. A peat bog which has been drained or has had its acidity destroyed assumes conditions similar to those found in reclaimed fresh-water bogs.

There are many intermediate grades between fresh-water bogs and peat bogs, and the determining factor is the outflow. In the intermediate bogs there is an intermingling of the two floras, and according to the degree of acidity the one or the other flora predominates.

Salt-water Bog.

The saline marshes or salt-water bogs cover only a small area of the region included in the survey, and these are restricted to the shores of Puget Sound and are confined there chiefly to areas near the mouths of rivers. At high tide, sometimes only at the very highest tides combined with a storm, the water backs into such places and is left to drain out slowly or evaporate. Such marshes are sometimes dry during the summer season. They are usually bare of trees and shrubs unless the water is only very slightly brackish. The plants of salt marshes find difficulty in getting water, just as do those of peat bogs, but for a different reason. Peat-bog water is poisonous to most plants, but it has not a high osmotic pressure. The water of the salt marshes along the seashore is poisonous to many plants and has a relatively high osmotic pressure as well. The presence of salt, therefore, makes it difficult for most plants to secure water. Hence most plants find a salt marsh physiologically too dry for them, i. e., they can not get water. Plants of saline marshes, like those of peat bogs, find their roots in physiologically dry conditions and their leaves and stems in humid air. The plants which inhabit these salt-water marshes are mostly specially adapted to such places and are not found elsewhere. The flora is therefore distinctive. Among the plants usually found are the following:

Salt grass (20) is a low-growing harsh, dry grass, with short two-ranked leaves and short wheatlike heads. It is not greatly relished by stock, although it is eaten in times of scarcity of more palatable feed. In case stock is salt hungry the grass is readily eaten, for it contains enough salt to be quite salty to the taste. The seed even has a salty taste. A stand of salt grass comes as near affording a useful crop in a salt marsh as anything growing in it in this region.

Saltwort or glasswort (21) is a fleshy leafless plant with distinctly jointed stems growing about a foot high. The fleshiness of the plant is evidently designed to conserve water, as does the cactus, because of the conditions of drought. It is distinctly salty to the taste and harmless; in fact, its fleshy joints are sometimes used for pickles. But cattle do not eat it in our experience. This plant and the preceding one form the great bulk of the vegetation, and they grow only in salt bogs or along seashores. With them are other plants in lesser abundance.

Atriplex (22) is a rigid, much-branched plant, kneehigh, with a few large, blunt lobes or teeth to its leaves.

Goosefoot (23) is a plant very similar to atriplex, but with a more red-striped stem. The leaves have suggested the imprint of a goose's foot.

Gum weed (24) is a plant 2 to 3 feet high, with yellow heads of flowers about an inch in diameter. The head outside below the petals is gummy. This is not eaten by cattle. The gum has a disagreeable taste.

Seaside buttercup (25) is a small fleshy plant 6 to 10 inches high, with small heads of butter-yellow flowers. This plant is not indigenous, having been introduced in ballast, but is now common.

Beard-grass (26) has lobed heads somewhat like those of a foxtail grass.

Jaumea (27) is a fleshy plant with rather large heads of yellow flowers.

The effect of salt on cultivated plants is, of course, like that on wild ones. A few can do well in the presence of a moderate quantity, though most can not. Asparagus, beets, and celery do fairly well in saline soil. Of course with the drainage of salt marshes the rains gradually carry the salt out of the soil.

Prairie.

The natural prairies of the region, such as those about Tacoma, are for the most part too well drained for trees. The soil is almost pure gravel to a considerable depth and retains very little water. The plants are thus largely those which can complete their growth during the rainy spring season or very shortly after. The chief plants are the following:

Silvery hair-grass (28) is an annual. This grows to a height of 3 to 8 inches and is quite dead by the middle of the summer. It is a fair grass for cattle, so far as it goes, but the yield is very small. The seed is good food, but like the grass is small. This dry grass, together with other dry plants, makes prairie fires a menace on these prairies in the summer and fall.

One of the smaller lupines (29) grows in abundance among the grass. This penetrates to some distance with its roots and can stand more drought. Its leaves are protected by a hairy covering.

The camas (30) is abundant. It is a plant with somewhat onion-like leaves and a bunch of white flowers on a leafless stem. This is the camas so much gathered by the Indians for food during and before pioneer days and cooked somewhat as we cook potatoes.

The blue violet (31) and the hairy yellow violet (32) are abundant, as is a lamb's lettuce (33).

The prairie buttercup (34) is a small plant with butter-yellow flowers about three-fourths inch in diameter. This is abundant in the spring among the grass.

Shooting star (35) is a plant with a rosette of entire leaves and a stem 1 to 2 feet high, with a bunch of flowers. The central part of the flower projects as a point.

Along the borders of these prairies are scattered oaks (36), among which is growing the shiny Oregon grape (37). This Oregon grape is the one whose roots are used in medicine. It is an indication of rather poor soil within this region, since it likes rather gravelly soil.

The oaks seem to be a vanishing genus in western Washington, where they once were undoubtedly much more widely spread. They are being crowded out by the red fir. This is to be seen at almost any place along the borders of these prairies. In passing from prairie to woods among the oaks one finds thrifty young red firs scattered here and there, often a red fir in a clump of oaks. Then farther in the woods one finds a stand of young red firs with dying oaks among them. Next one finds red firs a foot or more in diameter, with only scattered dead oaks among them. Then come large red firs, with an occasional decaying oak log. Lastly, one finds himself in the normal red-fir forest. The trunks and limbs of the oaks are covered with lichens and mosses to such an extent as probably to injure them. We know at least that when an orchard of apple trees is covered with lichens, as are these oaks, it is of little good, since the twigs die. The red firs are not so affected. Fungi, perhaps, do not like the resin. The oak is not necessarily dependent upon root-fungi (mycorrhiza), while the red fir is. These root-fungi probably find the soil rather dry, and hence do not do well; thus the red fir finds difficulty. But the oaks, with deeper roots, can stand drier soil, and possibly find less lichen troubles in the dry region. Their decaying leaves furnish the humus for other plants and eventually for the red fir.

Mycorrhiza (root-fungi) is a word derived from *myco*=fungus and *rhiza*=root. Many of our common large fungi, such as mushrooms and toadstools, have an abundance of fine, cobweblike threads interwoven in the soil and extending throughout it to a considerable distance from the "umbrella" portion. These threads digest partly decomposed organic matter in the soil, such as wood, leaves, and other plant remains, and thus get the food which results in the spore-forming part or "umbrella." These threads often live in the soil from year to year and spread if they find sufficient decomposing matter. The threads of some fungi seem to like to grow on the delicate tissue of the tips of young roots of certain plants. In some plants the fungal threads are closely interwoven over the surface of the root tips, making them appear woolly to the naked eye or with a hand lens. In other cases, as in the beech, the fungal threads penetrate the root tips and live partly within the cells. In either case the threads radiating from the root tips serve the plant as root hairs in the absorption of water, and at least in some cases the plant derives the greater part of its food from the fungus, as in the Indian pipe. The fungal threads get some benefit from the root tips, so both the fungi and the plants on which they grow are benefited.

Perhaps the driest of the prairie regions is between Hillhurst and Roy. Here we find the yellow pine (38) and a species of *Hookera* (39). These two are characteristic plants of eastern Washington.

The prairies need humus. Possibly one could get a stand of the native wild lupine as a protection to a stand of young alfalfa. The deep roots of alfalfa might stand the summer drought, but this has not been proven.

Common Forest Areas.

The soils of these areas are hardly distinguishable by the plant covering, since the distribution of the plants depends more upon soil water than soil composition and texture. However, since the difference between a good soil and a poor one is often merely a difference in the power of retaining water, we may get some suggestions from the plant covering. Some of the conspicuous plants will, then, be taken up and discussed from the view point of their relation to water.

The red fir (40) prefers a fairly well-drained soil, and yet a moist one. This is easily understood from the presence of root-fungi (mycorrhiza) on its roots, which probably aid in the absorption of water or food substances or both. These root-fungi apparently determine the distribution of the fir to a considerable extent; the conditions under which they can not thrive are the conditions under which the fir apparently does not thrive. The mycorrhiza of the red fir do not thrive in water, nor in soil thoroughly water-logged, nor in acid soil like that of peat bogs, nor in soils from which the water drains very rapidly, leaving it dry most of the time, and possibly not in soil which contains very little or no decomposing vegetation. In other words, conditions good for soil mushrooms or toadstools are the conditions good for red fir mycorrhiza, and hence the conditions good for the red fir. This tree is then absent from swamps, from the immediate or low shores of lakes and rivers, and from the dry, gravelly prairies of the Tacoma region. It is an inhabitant of fairly well-drained areas.

The white fir (41) is an occasional tree rather than an abundant one. It also has mycorrhiza and is therefore subject to the same restrictions concerning soil and water.

The giant cedar (42) is a tree which likes a wet region, but not one of acid water; hence it does not grow in peat bogs, though it does well in bogs which are between peat bogs and fresh-water bogs; that is, in those having a fair amount of drainage. It occupies areas quite level and hence boggy. Within the region surveyed, it also inhabits wet ravines, and west of the Coast Range, where the rainfall is much greater, it creeps up the sides of the ravines and grows over the hills, competing with the red fir. Cedar land is good land, but usually needs draining.

The western hemlock (43) has no mycorrhiza, although they are present on the eastern hemlock. In its desire for water it stands between the red fir and the cedar. The hemlocks accompany the cedars in ravines, but do not seem to do so well in the bogs approaching acidity as do the cedars. This is illustrated in the "alder bottoms." They do grow as scattered, but rather scrubby trees in peat bogs. This seems curious unless one recalls that the roots of a tree can not get water readily from a peat bog, and it is therefore physiologically a drier place than a fresh-water bog, so far as the tree is concerned. Hemlock contains much tannin. The decaying wood seems to have an injurious effect on crops. Some farmers claim the tannin is the cause of it. West of the Coast Range the greater rainfall causes the hemlock to predominate over hill and valley in certain regions. In the Puget Sound region it grows more abundantly in higher altitudes. Between 1,800 and 4,000 feet it is in many places the most abundant species. Hemlock, then, indicates more water in the soil than red fir and less than cedar, except in case of its presence in a peat bog.

The birches are different in their requirements. The western birch (44), with smooth twigs, likes wet soil. It accompanies the giant cedar in the swampy regions of Whatcom County, where it seems to be especially abundant. It indicates, therefore, soil with much water and usually only fair drainage. The dwarf birch (19), with warty glandular twigs, is a peat-bog plant only, as has been said, preferring the acid soil. The two birches thus indicate very different soil conditions.

The red alder (45) is a tree with a liking for dampness, but adjusting itself to almost any condition, exclusive of very dry regions or peat bogs. It seeds prolifically, and the seeds germinate and form dense growths where they can reach the soil, whether the decaying leaves be removed by stirring of the soil or by burning. It grows rapidly, probably because the roots bear large root tubercles in abundance. From the fact that these alders will form dense thickets 6 feet high in two years from the seed, on soil which is known to be too poor to raise oats in a climate adapted to this crop, one is led to surmise that these root tubercles fix the free nitrogen of the air, as do those of the clover. In the uplands the red firs soon overtop the alders, and the latter are left to fill the openings here and there or to occupy the hollows and shores of streams and lakes too wet for the red fir, but in the fresh-water bogs, where the water is not deep or not permanent, the alder accompanies the cedar and birch, sometimes forming the predominating tree. In the upland the red fir conquers; in the wet bottoms the alder remains. These bottom areas, "alder bottoms," are considered among the best soils of the region. Possibly the root tubercles have something to do with this.

Cottonwoods (46) are an indication of sandy soil with water in the subsoil. They are chiefly trees of river bottoms.

The vine maple (47) disputes the ground with the alder and cedar if the water is quite near or at the surface. Vine maple is said to indicate good soil, and such is usually the case; but this is due to the presence of water rather than the nature of the soil, for it will grow in pure gravel or in clefts on a rock wall as well as in good soil, provided the water is there.

The shore pine (48) is a plant of dry regions. It grows chiefly on sandy soil. In the Puget Sound region it grows on the tops of dry, gravelly, or rocky hills, and in prairies and in peat bogs. The hills occupied are poor in water, and are considered of little value agriculturally, as are the prairies. The peat bogs are likewise a dry region, so far as the trees are concerned, but apparently removing the acid makes this soil good. Hence the plant indicates either good or poor soil, depending upon whether it finds its physiologically dry situation on a hill, on a prairie, or in a peat bog. This tree also grows in sand along the shore of the ocean, finding there its required dry soil. It may be recognized by the fact that it has only three needles in a bunch.

Salal (49) likes good drainage, but very great humidity. It will therefore grow almost anywhere throughout the region surveyed.

The Sitka spruce (50) is a tree by which one can conclude very little. It grows on the level rich soil of the Puyallup River, in rather soggy soil, at the heads of ravines in various places, and along the seashore; also occasionally in peat bogs.

The madroña (51) should be considered with manzanita (52), which has reddish bark, that peels off like the madroña, but has leaves only about 1 to 2 inches long and slightly hairy, and with the evergreen huckleberry (53), and mountain balm (54), the last of which has broad, sticky green leaves with a pleasant sweetish odor. The last four plants mentioned prefer very well-drained gravelly or sandy soil, on a south slope, or where they get the sun. They are plants of poor soil, as a rule—poor because of deficiency of water.

The following is a table in which some of the trees and shrubs are roughly placed in the order of their desire for water. These plants will not always be found in the conditions given, but they seem to prefer such conditions.

	Soil.	Subsoil.		Soil.	Subsoil.
Cedar	Soggy	Soggy.	Shore pine	Dry	Damp.
Vine maple	do	Do.	Mountain balm	do	Do.
Hemlock	Wet	Wet or soggy.	Evergreen huckleberry.	do	Dry.
Alder	do	Do.	Manzanita	do	Do.
Salal	Damp	Wet.	Madroña	Very dry	Do.
Red fir	do	Do.	Oak	do	Do.
Dull Oregon grape	do	Do.	Yellow pine	do	Do.
Cottonwood	Rather dry	Damp.			
Shiny Oregon grape	do	Do.			

WEEDS.

The Canada thistle is a very common weed in certain regions, especially in the lower valleys of the Nooksack and Duwamish rivers. This differs from our other thistles in that it spreads by subterranean shoots (rootstocks). These can send up a new plant at every joint; therefore plowing spreads the plant. The leaves and heads of flowers resemble those of the common thistle, but both are somewhat narrower. The seed is carried by the wind, as is that of the common pasture thistle. This is one of the most effective means for a plant to get itself well sown over a given territory. It is therefore the means of dispersal of the worst weeds of the State. The Washington laws, which compel the cutting of these thistles, are very seldom enforced, and likely will not be, unless the farmers themselves insist upon it. One may be sure that if his neighbor leaves his thistles uncut that one will also have them within a few years, from seed blown upon his farm. It is decidedly a farmer's business to cut his own Canada thistles, and also to see that his neighbors cut theirs. Since they grow well in meadows as well as pastures and cultivated fields, they are distributed along the highways by hay-wagons, and through manure from barns where such hay is fed. This is one of the worst weeds in the United States.

The Scotch thistle or bull thistle (56) is a common one in pastures in some parts of the State, conspicuously so about Lynden. It spreads by wind-blown seed, as does the Canada thistle, but does not multiply by underground shoots. Cutting an inch or two beneath the surface of the ground will kill it. It is permitted to grow along the public roads, and thus copiously to seed the neighboring pastures and meadows. This thistle will not stand cultivation, and thus gives trouble only in pastures, mowings, waste land, and along roadsides. The leaves have exceedingly sharp prickles, which prevent cattle eating the grass about the plants and which also trouble stock in eating hay containing them. Some pastures were observed on land worth at least $100 an acre which were so full of thistles that it was estimated one-third of the grass could not be secured by the stock—clearly a waste of one-third the value of the land. In this case, as with the Canada thistle, it requires cooperation among the farmers of a community to get rid of the weed.

In new land the common brake (57) is a bad weed. This gradually disappears with cultivation, and is not one of the weeds of the State that will prove troublesome in the future. The stem is a black root-like structure the thickness of a finger and 6 to 10 inches under ground. From it are sent up into the air the large leaves, appearing with their tips coiled. The food supply is stored in the subterranean stem. Since leaves rarely give rise to new plants or new leaves, cutting the brake ends the life of the leaf which is cut. While the leaves are still coiled at the tip they are soft as asparagus and may be easily knocked off with a stick, which ends them, just as cutting does. New leaves will be sent up by the subterranean stems, but they will have less and less vitality. Hence successive cuttings or knocking off of the leaves for a few years will exhaust the food supply in the stems and the brake will disappear. When once eradicated from cultivated ground, it will not again appear.

Cat's-ear (58), sometimes called false dandelion, is in many places a bad pasture and lawn weed. As a lawn weed it is not so troublesome as the dandelion, since the flowers do not grow up so rapidly, and hence frequent cutting of a lawn prevents the formation of seed by the plant. In pastures it is worse because it forms a dense covering of straggling stems 1 to 2 feet high and thus shades the grass, takes its moisture, and interferes with grazing. Its leaves are similar to those of the dandelion, but rough and hairy; its stems are leafless but branched; its flowers and heads of seeds are very near to the dandelion in general appearance, and it has, like the dandelion, a long thick taproot, enabling it to get water from considerable depth. This weed will not withstand cultivation. In pastures it may be kept down by mowing before it seeds, although some seed will be formed later from new shoots. This plant reached us from Peru through ballast. In the last seven years it has multiplied enormously in the Sound country.

The tar weed (59) is a common roadside weed in Whatcom County and is becoming fairly abundant in other counties. This has sticky hairs on its stems, narrow leaves, and small yellow flowers in a flask-shaped green cup (involucre). It grows about kneehigh. Except along roadsides it is not a bad weed, although in very thinly grassed pastures or meadows it is occasionally troublesome.

The oxeye daisy (60) has been introduced from the East, either as a beautiful flower or in hay, and has become a farmyard weed here and there. While in the East this is said to be a very bad weed it does not seem to thrive so well in Washington. In no place where it was seen does it promise to become a bad weed.

Corn spurry (61) is rapidly becoming a weed in oat fields in certain regions. This is an introduced plant 1 to 2 feet high, with rather inconspicuous flowers. The striking thing about it is the fleshy linear or narrowly cylindrical leaves, six to ten of which spring from each joint of the stem. This was introduced in grains from the eastern United States and Europe, where it is common. It is not as bad as some other weeds, but it seems that it takes to the climate of the Sound region very well. Six years ago it was practically unknown in western Washington, now it is fairly common. It is distinctly a field weed and an annual.

The burdock (62) is common in some places, especially in vacant lots in cities. This is a hard weed to get rid of outside of cultivated areas. It is a plant of waste land and fences. The burs get into the wool of animals, tails of horses and cattle, and the clothes of man, and are a source of much trouble. This weed may be looked for in great abundance in ten years unless steps are taken to keep it down. It is not a field weed. It has large leaves, somewhat like rhubarb, and a perennial root like a Scotch thistle.

The prickly lettuce (63) has been introduced from the East, likely in hay or in grass seed. This is a very bad roadside and waste-land weed in the East, and is so here in places. Six years ago this was a very rare plant. Its seeds are carried by the wind, as are those of the dandelion, and it is rapidly becoming more abundant. The leaves are weak-prickly at the edges and on the back of the mid-vein. The leaves have a tendency toward vertical edges.

On the whole there are a few weeds which need to be carefully watched, for example, Canada thistle, Scotch thistle, and perhaps the oxeye daisy, since they are very bad weeds in some other places. Great care should be exercised in the sowing of grains from other regions. Otherwise the bad grain weeds from those regions are sure to be introduced. Careful inspection of the grain for foreign seeds does not take long and may prevent much work in eradication of weeds later. Hay is least watched in regard to its weeds and is one of the most common means of dispersal of bad weeds. Man himself is the greatest distributor of weeds and he can blame only himself and his careless neighbors if he finds his farm overrun with them.

SUMMARY.

Fresh-water bogs may readily be distinguished from peat bogs by the plants in them.

A fresh-water bog is good soil as soon as it is drained.

Most plants find difficulty in getting water from a peat bog, and from peat-bog soil when newly drained, even though there is plenty of water present.

The substances which hinder plants from getting water from peat-bog soil slowly wash out after drainage.

Burning a peat-bog soil helps it, but is a little dangerous.

Most plants have great difficulty in getting water from salty soil.

Salt is also more or less poisonous to most plants.

Well-drained salty soil will gradually have the salt washed out.

The reasons why the prairies of the Tacoma region are prairies is because the water drains away so rapidly through the gravelly soil that only those plants can do well which can either mature during the short spring rainy season or can send their roots to deeper waters.

The red fir is encroaching upon the prairies and smothering the scattered oaks.

The red fir gets water through fungi on its roots, and thus thrives best on soil in which fungi do well.

Cedars and hemlocks indicate plenty of water in the soil, and for this reason usually good soil.

Alders do not always indicate good soil. But large alders with cedar, with little or no red fir, on level land indicate a good supply of water in the soil.

Maples usually indicate good soil, because they indicate plenty of soil water.

Oak, madroña, and evergreen huckleberry indicate poor soil; the first two practically always, the last usually when abundant.

Abundant shore pine indicates poor soil, or sandy soil, or a peat bog.

It would be a good thing for farmers to cooperate in the fighting of weeds.

Certain bad weeds are well established and rapidly spreading.

Scientific names of plants referred to in this chapter.

(1) *Typha latifolia.*
(2) *Scirpus occidentalis.*
(3) *Comarum palustre.*
(4) *Menyanthes trifoliata.*
(5) *Brasenia schreberi.*
(6) *Nymphaea polysepala.*
(7) *Utricularia.*
(8) *Potamogeton.*
(9) *Cyperaceæ.*
(10) *Dulichium arundinaceum.*
(11) *Sagittaria latifolia.*
(12) *Sparganium.*
(13) *Ledum groenlandicum.*
(14) *Kalmia glauca.*

Scientific names of plants referred to in this chapter—Continued.

(15) *Spiraea douglasii.*
(16) *Oxycoccus oxycoccus intermedius.*
(17) *Sphagnum.*
(18) *Drosera rotundifolia.*
(19) *Betula glandulosa.*
(20) *Distichlis spicata.*
(21) *Salicornia ambigua.*
(22) *Atriplex patula littoralis.*
(23) *Chenopodium humile.*
(24) *Grindelia oregona.*
(25) *Cotula coronopifolia.*
(26) *Polypogon littoralis.*
(27) *Jaumea carnosa.*
(28) *Aira caryophyllea.*
(29) *Lupinus lepidus.*
(30) *Quamasia quamash.*
(31) *Viola canina.*
(32) *Viola nuttallii.*
(33) *Valerianella congesta.*
(34) *Ranunculus occidentalis.*
(35) *Dodecatheon latifolium.*
(36) *Quercus garryana.*
(37) *Berberis aquifolium.*
(38) *Pinus ponderosa.*
(39) *Hookera howellii.*
(40) *Pseudotsuga mucronata.*
(41) *Abies grandis.*
(42) *Thuja plicata.*
(43) *Tsuga heterophylla.*
(44) *Betula occidentalis.*
(45) *Alnus oregona.*
(46) *Populus trichocarpa.*
(47) *Acer circinatum.*
(48) *Pinus contorta.*
(49) *Gaultheria shallon.*
(50) *Picea sitchensis.*
(51) *Arbutus menziesii.*
(52) *Arctostaphylos tomentosa.*
(53) *Vaccinium ovatum.*
(54) *Ceanothus velutinus.*
(55) *Carduus canadensis.*
(56) *Carduus lanceolatus.*
(57) *Pteridium aquilinum pubescens.*
(58) *Hypochaeris radicata.*
(59) *Madia madioides.*
(60) *Chrysanthemum leucanthemum subpinnatifidum.*
(61) *Spergula arvensis.*
(62) *Arctium minus.*
(63) *Lactuca scariola.*

SOILS.

A reconnoissance survey of the area classifies the soils broadly into 26 types, including Peat and Muck, Swamp, Tidal marsh, and Rock outcrop. This separation of the soils is based on their texture, origin, agricultural value, and topography. Minor differences in texture or topographic features occur in some of the types which influence the natural drainage and agricultural value of limited areas to a sufficient extent to warrant their separation in the event of a more detailed survey, but in a reconnoissance survey of this character no attempt could be made to go into the detail necessary to show each minor phase or modification of the principal types of soil. Extensive areas also occur in some localities, such as the rough mountainous regions, which are of such low agricultural value that a detailed soil map showing each local variation would be of little or no value. However, the soils have been classified in sufficient detail to show the location and extent of all the principal types and to show the types suitable for agricultural purposes and those which are of little or no agricultural value without attempting the separation of local modifications of the main types.

The soils of the area, owing to natural physiographic or geological features, have been divided into six groups: (1) Those derived

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directly from the weathering of deposits of glacial drift; (2) those derived from recent alluvial deposits; (3) those derived from material deposited in the basins of shallow lakes or swampy depressions; (4) soils of the rough mountainous region; (5) beach deposits formed by the action of the waves; and (6) soils derived from material deposited as glacial outwash.

The first group comprises soils occupying the rolling uplands and lower foothills of the rough mountainous region. The greater proportion of the soils of the first group are derived from glacial drift which has been more or less modified by the action of glacial waters, and consists mainly of deposits of sand and gravel, with an occasional bed or pocket of compact silt or silty clay. The surface soils of these types are quite sandy and usually contain a considerable amount of small gravel, but there is enough fine material mixed with the coarser sand and gravel to give them a loamy texture. The subsoil consists of beds of sand and gravel which often have the appearance of being stratified.

In some localities the glacial deposits consist of a heavy compact silty loam or silty clay, containing a little gravel and a considerable proportion of rock fragments. This material is found underlying the soils of the level plateaus near Buckley. The surface soils have a silty texture and the level topography, together with the imperviousness of the subsoil, causes the natural drainage of the land to be very poor. The decomposition of the rank vegetation under the condition of inadequate drainage has resulted in the accumulation of a large amount of organic matter, which gives the soils their characteristic dark color.

The glacial material forming the greater part of the rolling uplands north of the range of hills that crosses the southwestern corner of Whatcom County differs from the drift forming the uplands of the counties south of these hills. In this locality the till consists of a compact mass of silt, clay, and fine sand, containing only a small amount of gravel and an occasional bowlder. The soils of this region are uniformly silty in texture, and the heavy impervious subsoil prevents the excessive natural drainage characteristic of the majority of the upland soils in the remainder of the area surveyed. More or less extensive deposits of sand, gravel, and small bowlders also occur in this section of the area, but the interstitial material in the surface soils is of a fine silty texture, and a shallow covering of heavy silt loam often overlies the coarser material.

The recent alluvial deposits which occupy the valleys of the larger streams consist mainly of fine sands and silt. The valleys were first covered by deposits of sand, but with the exception of narrow areas bordering the stream channels, the sand has been covered by more recent sediments of silt and clay laid down at times of overflow. In

FIG. 1.—STONY SOIL BETTER ADAPTED TO REFORESTATION THAN TO AGRICULTURE.

FIG. 2.—SHOWING STUNTED TREE GROWTH, WHERE THE TIMBER IS ENCROACHING ON THE GRAVELLY PRAIRIES.

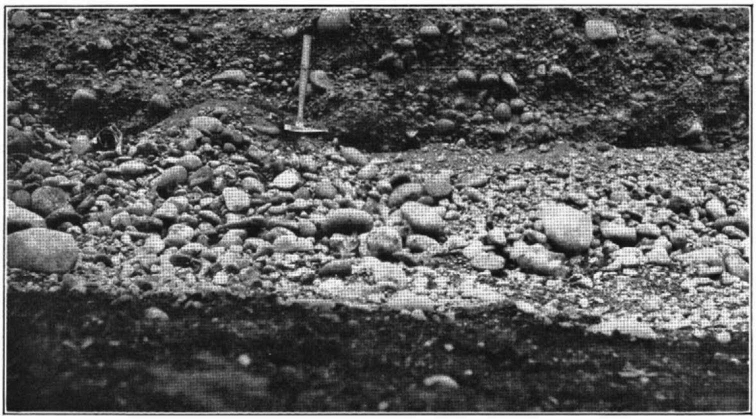

FIG. 3.—SECTION OF GRAVELLY PRAIRIE. (SPANAWAY GRAVELLY SANDY LOAM.)

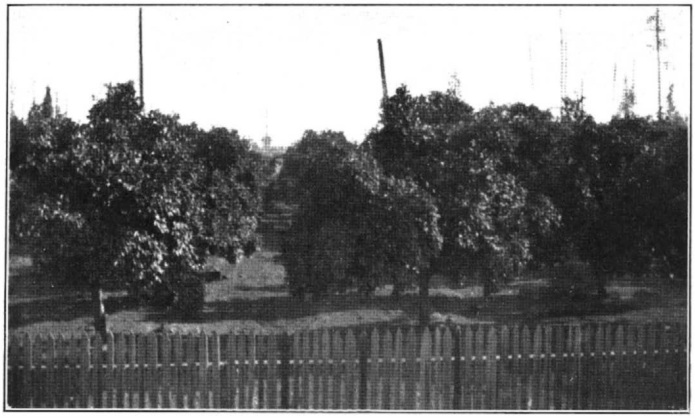

FIG. 1.—PRUNE ORCHARD ON WHATCOM SILT LOAM IN SEC. 20, T. 39, R. 3 E.

FIG. 2.—POTATOES ON WHATCOM SILT LOAM. SECOND-GROWTH TIMBER IN THE BACKGROUND. SEC. 23, T. 39, R. 1 E.

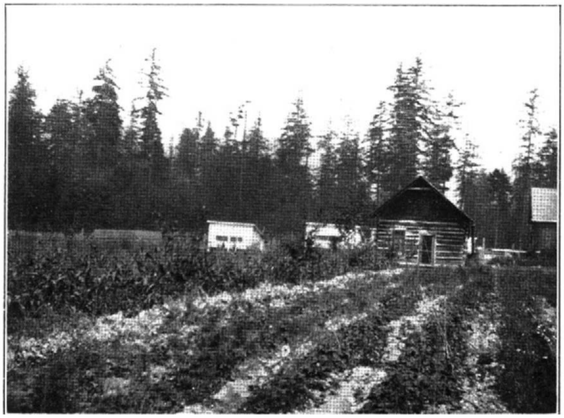

FIG. 3.—STRAWBERRIES ON SILTY UPLAND SOIL.

FIG. 1.—OATS IN SKAGIT RIVER VALLEY.

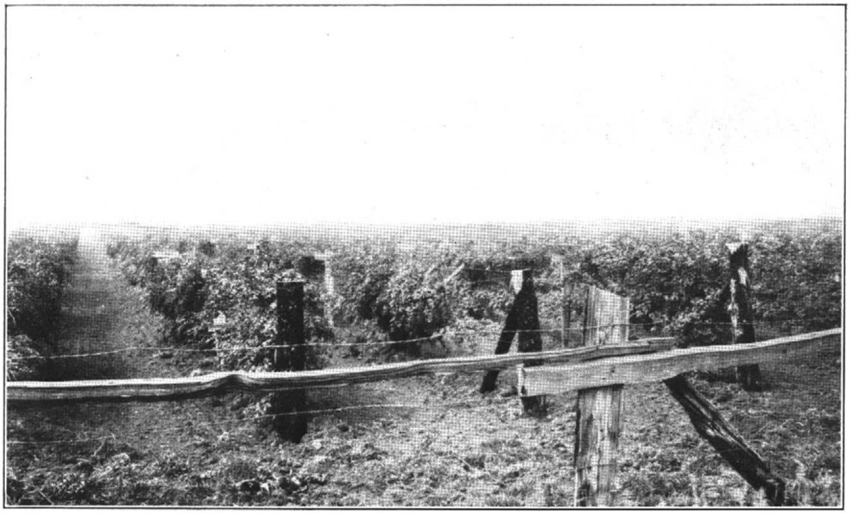

FIG. 2.—EVERGREEN BLACKBERRY ON MUCK.

the shallow depressions where water has collected and stood for long periods, the silt deposits are often several feet in thickness, but over the greater part of the valleys it forms only a shallow covering over the underlying sand. The broad delta flats formed at the mouths of the rivers are composed of material similar to that forming the river valley soils. The fine sand, silt, and clay held in suspension by the waters of the streams was deposited in the shallow bays at the outlet of the rivers, eventually forming extensive tidal marshes, which were gradually built up above tide level by the continued depositions of material brought down by the streams. During the formation of these delta flats, the finer material settled in the quieter waters, forming extensive deposits of silt and clay, which often have a thickness of many feet above the underlying sand. The soils occupying the shallow basins and depressions found in various parts of the area surveyed always contain a high percentage of organic matter. The texture of these soils varies from a light silty loam containing a large amount of fine sand to a heavy silty loam or silty clay, but the surface soil always contains a high percentage of silt.

Some of the poorly drained depressions are covered by a deep deposit of Peat or Muck, while in others more or less extensive deposits of diatomaceous earth are found at a shallow depth below the surface. These basins were formerly small lakes or ponds, but they have been gradually filled up by material washed into them from the surrounding uplands. In some of the larger basins, such as those occupied by the Custer silt loam or Custer loam, the silty soil is underlain by a deposit of sand, but the majority of the basin soils have a heavy silty to silty clay subsoil.

The soils occupying the mountainous parts of the area vary in texture from a sandy loam to a heavy loam or silty loam and contain a large quantity of small bowlders and rock fragments. There occur small areas that are comparatively free from stones, but they are of limited extent and are surrounded by large areas of nonagricultural land. The steep and broken topography of this region and the large quantity of stones found scattered over the surface and in the soils cause this land to be of small agricultural value. (See Plate XXII, fig. 1.)

The material from which these mountain soils are derived is chiefly of glacial origin, but the drift is often very shallow, and the material derived from the weathering of the underlying rock, which outcrops along the steeper slopes, has also entered into the composition of the soils, especially on the slopes of some of the higher mountains.

The beach deposits in the area are very limited in extent. They consist of a narrow strip of sand and gravel laid down along the shores of small inlets and bays by the action of the waves.

The greater part of the upland plain in the southwestern part of the area is covered by a deposit of gravel and small rounded cobbles many feet in thickness. These coarse glacial deposits have been washed clean by the action of glacial waters and contain little or no fine interstitial material. Overlying the coarser gravel and cobbles is a shallow covering of sand and fine gravel, which has an average thickness of 8 to 20 inches. In other sections of this plains region deep deposits of sand occur. The sand becomes coarser in texture at a depth of 10 feet or more below the surface, but it is almost entirely free from gravel or small bowlders. The soil derived from this sandy deposit has a much higher agricultural value than that derived from the coarse gravelly formations.

The different types of soil encountered in the area vary considerably in agricultural value. The alluvial types occupying the river valleys are very productive and are considered the most valuable farming lands of the area. The soils of the delta flats are equal in productiveness to those of the river valleys, but it is often necessary to dike or drain the land before it can be profitably cultivated. In the rolling uplands the silty types of soil that have a heavy, compact subsoil, such as the Buckley loam and Whatcom silt loam, can be cultivated with more certainty of securing profitable yields than the other upland soils. (See Plate XXIII, fig. 3.) The sandy loams and gravelly sandy loams are also successfully cultivated, but the coarse, porous subsoils of these types cause the natural drainage to be excessive, and the crops grown on them are liable to be damaged by the lack of sufficient moisture during the growing season. However, when these lighter textured soils are thoroughly cultivated and such methods are employed as will tend to conserve the soil moisture very profitable yields are secured.

The gravelly soils on the whole are not productive, as they are excessively drained and their coarse gravelly texture makes it difficult to cultivate them properly. In areas where the gravel content is comparatively small or where the interstitial material consists of a fine silty loam, such as in the type mapped as Lynden gravelly loam, these coarse-textured soils have been very successfully utilized for orchards and to a limited extent for general farming purposes.

The soils occupying the upland basins are on the whole well adapted to agriculture. They can be cleared and put under cultivation at a comparatively small cost, but the natural drainage of these types is very poor and artificial drainage is necessary before they can be farmed successfully.

The stony loam types of soil are of small agricultural value and the greater part of the area occupied by them is suited only for reforestation.

The limited areas of Coastal beach are not adapted to farming and are classed with the nonagricultural land.

The coarse gravelly soil of the plains region is too excessively drained to be valuable for farming purposes, as the lack of soil moisture during the growing season results in a total or partial loss of the crops. However, the sandy loam type found in this region produces very fair yields of all crops grown.

The following table gives the name and extent of each of these soils and the proportion each type forms of the total area surveyed:

Areas of different soils.

Soil.	Bellingham sheet.	Seattle sheet.	Total.	Per cent.
	Acres.	*Acres.*	*Acres.*	
Everett gravelly sandy loam	288,384	429,568	717,952	31.4
Everett stony loams	400,192	154,176	554,368	24.3
Everett gravelly loamy sand	39,808	111,552	151,360	6.6
Whatcom silt loam	140,480	....	140,480	6.2
Puget fine sandy loam	60,992	40,320	101,312	4.4
Spanaway gravelly sandy loam	....	100,608	100,608	4.4
Puget silt loam	54,784	29,120	83,904	3.8
Puget silty clay	75,712	7,488	83,200	3.6
Lynden sandy loam	51,264	512	51,776	2.2
Muck and peat	35,840	14,208	50,048	2.2
Everett loamy sand	8,000	36,608	44,608	2.0
Bellingham silt loam	12,224	17,408	29,632	1.3
Buckley loam	....	27,904	27,904	1.2
Lynden silt loam	22,144	....	22,144	1.0
Everett loam	....	21,632	21,632	.9
Everett stony sandy loam	....	21,440	21,440	.9
Lynden gravelly loam	20,928	....	20,928	.9
Lynden fine sandy loam	19,904	....	19,904	.9
Tidal marsh	1,472	7,744	9,216	.4
Custer silt loam	8,960	....	8,960	.4
Custer loam	8,704	....	8,704	.4
Orting loam	....	4,480	4,480	.2
Spanaway fine sandy loam	....	3,712	3,712	.1
Coastal beach	2,496	....	2,496	.1
Swamp	2,240	....	2,240	.1
Rock outcrop	512	....	512	.1
Total	1,255,040	1,028,480	2,283,520	....

EVERETT SERIES.

The soils of the Everett series occupy rolling uplands and are derived from glacial drift, which in many cases has been more or less modified by the action of glacial waters. The material consists mainly of deposits of sands and gravels, with occasional beds of silt or clay, which often have the appearance of having been laid down in strata.

The surface soils of this series, with the exception of the Everett loam, are quite sandy and usually contain a considerable amount of small gravel. However, the soils contain enough fine material, mixed with the coarse sand and gravel, to give them a loamy texture. The soils of this series have uniformly a light-brown to reddish-brown color. The subsoils are usually lighter in color, varying from light brown to gray. The natural drainage of the soils of the series, after the land has been cleared for agriculture, is usually excessive. The Everett soils support a heavy growth of timber, principally red fir. Red cedar, spruce, and hemlock are also found on these soils.

EVERETT GRAVELLY SANDY LOAM.

The Everett gravelly sandy loam occupies the greater proportion of the rolling uplands in Skagit, Snohomish, King, and Pierce counties. The soil, to an average depth of 0 to 15 inches, consists of a light-brown to reddish-brown sandy loam, containing a large number of small, rounded iron concretions, which weather rapidly on being exposed on the surface, often becoming soft enough to crush between the fingers. The presence of these small concretions has given the soil the local name of "shot clay." The soil also contains a large amount of rounded gravel varying in size from coarse sand particles to pieces 4 or 5 inches in diameter. The gravel content of the soil is always large, but there is not a sufficient quantity to cause the soil to be classed as a gravelly loam, but rather as a sandy loam containing enough gravel to influence its texture to a considerable extent.

The subsoil consists of a mass of rounded glacial gravel embedded in a medium to coarse gray sandy loam. The texture of the subsoil frequently varies considerably over very limited areas owing to the heterogeneous character of the deposits. Gravel, coarse sand, fine sand, or silt often occur in more or less extensive beds or pockets or in layers varying from 1 to 5 feet in thickness, and sometimes the subsoil has the appearance of being stratified.

There are several more or less extensive areas, located in various parts of the area surveyed, which are occupied by a phase of the type differing slightly from the typical soil. In these areas the soil contains a higher percentage of sand, is slightly lighter in texture, and is not as loamy as the typical soil. The subsoil also contains less gravel and a higher percentage of coarse sand. This phase represents the gradation between the Everett gravelly sandy loam and the Everett loamy sand, but a large amount of gravel is present in both soil and subsoil. The larger areas of this phase of the soil are found in Snohomish County between Everett and Edmonds, in King County northeast of Greenlake, and in the vicinity of Sunnydale, but other areas of limited extent occur at intervals through all the larger areas occupied by this type.

The Everett gravelly sandy loam occupies the greater proportion of the bench lands, hills, and ridges that lie between the mountainous region and Puget Sound. The topography, on the whole, is gently rolling to rolling, but near the foothills it becomes more rough and hilly. The rolling topography, together with the open, porous character of the subsoil, causes the natural drainage to be excessive, and when cleared for cultivation the soil can not retain sufficient moisture for the growing of crops, unless every precaution is taken for the conservation of the soil moisture. The Everett gravelly sandy loam is not adapted to general farming, and must be utilized for the growing of such crops as will give large returns from the intensive cultivation of a limited acreage.

The soil is derived from the weathering of the glacial drift, which covered the underlying rock formation to a considerable depth. This drift is composed mainly of various grades of sand and gravel, and in many localities irregular bands of gravel and sand occur in the subsoil, indicating that these deposits have been more or less modified by the action of glacial waters.

The agricultural value of this soil varies considerably in different localities. Where the topography is steep or broken and the drainage is excessive, and where the land has not been thoroughly cultivated, the soil does not produce profitable yields, but, on the other hand, where the topography is rolling or gently rolling, and where small areas are cultivated very intensively, profitable yields of potatoes, fruits, and strawberries and other small fruits are secured. Where very intensive methods of cultivation are practiced this soil has produced large yields of strawberries, and on Vashon Island it is considered well adapted to the growing of this crop. Only a very limited area of this soil is under cultivation, the greater proportion being still in the logged-off state, while larger areas are still covered by the original forest growth. The logged-off land is valued at $25 to $500 an acre, according to its location in relation to Seattle, Tacoma, or some of the other large towns or cities.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Everett gravelly sandy loam:

Mechanical analyses of Everett 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.*
14085, 14087, 22082, 22084	Soil	2.7	8.2	6.1	21.0	15.5	32.4	13.6
14086, 14088, 22083, 22085	Subsoil	2.5	8.4	7.5	21.2	18.5	29.4	12.4

EVERETT STONY LOAMS.

The soil of the Everett stony loams consists of a light-brown to reddish-brown loam to silty loam, with an average depth of 10 to 15 inches. A large amount of gravel and small glacial bowlders are found scattered over the surface and mixed with the soil, and more or less extensive areas often occur, where from 30 to 60 per cent of the surface is covered by bowlders of various sizes.

The texture of the soil varies to some extent with the topographical position. On many of the more level bench lands, terraces, or lower ridges the soil is deeper, more silty in texture, and contains a comparatively small quantity of rock and gravel, while on the steeper mountain slopes the soil is shallow and contains a higher percentage of sand, rock, and gravel. Along some of the steeper slopes the soil has been entirely removed by erosion and more or less extensive areas of Rock outcrop occur.

The soil occupying the steeper slopes is always lighter in texture and contains a larger quantity of rock and gravel than that found on the bench lands and less precipitous slopes. The subsoil is a heavy sandy loam or loam containing a large quantity of gravel, small stones, and bowlders. The gravel in the deeper subsoil often occurs in irregular bands or pockets, and pockets of heavy silty glacial till, comparatively free from stones or gravel, are also found occasionally in the deeper subsoil on the bench lands and lower ridges.

The Everett stony loams occupy the rough mountainous sections of the area, the larger unbroken areas being found in the northeastern and southeastern parts of the region surveyed. The topography is very rough and broken, some of the higher peaks reaching an elevation of 6,000 feet above sea level. The rough topography of this type makes the greater proportion of the land of little or no agricultural value, and it is valued mainly for the heavy growth of timber it supports. Owing to the rough character of the country and to the difficulty of getting out the timber, lumbering has not progressed very rapidly in these mountainous sections of the area, and a large percentage of the land is still covered by the original forests.

Even when the timber is removed the greater proportion of the land is of such low agricultural value that the best plan will be to reforest it. At intervals on the bench land or on the flat tops of some of the lower hills and ridges occur small areas that are comparatively level and free from large bowlders, and these could be profitably utilized for farming. Such areas, however, are of limited extent and the topography of the surrounding country is so rough that they are usually almost inaccessible. The natural drainage of the type as a whole is excessive, and when the timber and underbrush is removed the soil moisture is carried off by evaporation and by seeping through the porous subsoil, so that both the soil and subsoil remain in a very dry condition throughout the summer months.

In these mountainous sections of the area small, poorly drained depressions are sometimes found which are almost entirely surrounded by hills and ridges. These small basins are usually occupied by Peat and Muck, and where they are of any considerable extent they have been indicated on the map.

The drainage of the bench lands and more level areas is not so excessive as that of the more hilly section, and when the soil is properly cultivated it will retain a sufficient amount of moisture for the growing of crops.

The Everett stony loams are derived mainly from the weathering of the glacial drift, which covers this entire region, but the drift is often very shallow on the higher mountains, and areas of Rock outcrop occur frequently. On the steeper slopes and mountain sides the material derived from the weathering of the underlying rocks has in many cases entered into the composition of the soil to a considerable extent.

Only a very limited acreage of the Everett stony loams is cultivated, as the rough and broken topography limits the acreage suited for agriculture. However, some of the more level areas have been utilized very successfully for the growing of fruits, and when the land is well cultivated the small orchards of apples, pears, plums, and other deciduous fruits do exceedingly well. Good yields of clover, timothy, and oats have been secured on the limited acreage cultivated to these crops, and with thorough cultivation large yields of Irish potatoes have been obtained. At the present time the value of the greater part of this mountainous land depends largely on the amount of standing timber and on its accessibility.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Everett stony loams:

Mechanical analyses of Everett stony loams.

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.*
14105, 14107, 17713.	Soil.........	3.6	7.5	4.1	10.9	15.1	44.7	17.1
14106, 14108, 17714.	Subsoil......	4.5	9.0	5.4	14.9	17.5	36.0	13.1

EVERETT LOAMY SAND.

The soil of the Everett loamy sand consists of a light-brown light sandy loam or loamy sand having an average depth of 10 to 15 inches. The texture of the sand content is medium to fine, and a few rounded gravel are found on the surface and mixed with the soil. On the hillsides, especially on the steeper slopes bordering small streams where the soil has been slightly eroded, the texture is often lighter and the soil has the characteristics of a loamy sand. The subsoil is coarser in texture than the surface. It consists of a gray coarse to medium sand, containing some small rounded gravel. Small pockets or thin layers of fine sand, coarse sand, or gravel often occur in the deeper subsoil, giving it a stratified appearance. An extensive area occurs on the east shore of Lake Washington, near Bellevue, where a larger proportion of gravel than is typical is found in both the surface soil and subsoil. A similar area is found on the west side of Vashon Island. These gravelly areas have been indicated on the soil map by means of a symbol.

This soil occupies the gently rolling uplands and also frequently occurs as a narrow strip along the hillsides bordering the stream valleys. Owing to its topographical position and to the porous character of the subsoil, the natural drainage is excessive, but when cultivated intensively the more level to gently rolling areas produce very fair yields. The soil is derived from the weathering of deposits of glacial drift which were more or less modified during the period of deposition by the action of glacial waters.

Only a small percentage of this type is under cultivation, the greater proportion being still in the undeveloped state known as "logged-off land." The crops grown are liable to be injured by the lack of moisture during the growing season, but where very intensive methods of cultivation are used, small areas have been profitably cultivated to orchard fruits, small fruits, and to potatoes and other vegetables. The Everett loamy sand is not adapted to general farming and is suited only to very intensive methods and special crops.

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

Mechanical analyses of Everett loamy 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.*
22072	Soil	1.9	16.1	21.0	26.1	13.1	10.4	11.4
22073	Subsoil	.5	10.6	27.9	47.5	5.3	4.5	3.8

EVERETT GRAVELLY LOAMY SAND.

The surface soil of the Everett gravelly loamy sand, to an average depth of 10 inches, is a light-brown sandy loam or loamy sand containing from 40 to 60 per cent of medium to coarse gravel. This is underlain by a gray medium to coarse sandy loam which also contains a very high percentage of gravel and small bowlders. The gravel in the subsoil often occurs in compact beds or pockets many feet in thickness.

More or less extensive areas of this soil occur in the rolling uplands in almost every part of the area surveyed. The topography varies from nearly level, in the areas bordering some of the smaller stream courses, along the margin of small lakes, or on the small upland plateaus, to rough and hilly in the areas found along the steeper slopes of the upland ridges. The soil is derived mainly from the coarser glacial deposits of sand and gravel which were laid down by the waters of the melting ice, but some of these gravelly areas probably represent the glacial drift, modified by the action of glacial waters, which have removed the finer material and left the coarser sand and gravel deposited in beds, pockets, and strata of various degrees of thickness. The drainage of this type of soil is too thorough. The coarse gravelly subsoil allows 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 usually damaged by drought.

The coarse gravelly texture of the land interferes to some extent with cultivation, and it is not well adapted to the growing of crops which require thorough tillage. Small areas, however, have been used for fruit growing with fair success. It is often difficult to get the fruit trees established owing to lack of sufficient moisture. During the earlier spring months, when there is usually a considerable amount of rainfall, the soil supports a good growth of grass, and considerable areas have been utilized very profitably as pasture lands.

The Everett gravelly loamy sand seems better adapted to fruit growing and pasturage than to the growing of crops which require constant cultivation of the soil. During a very favorable season moderate yields of potatoes and early truck crops have been secured, but crops which mature late in the season are usually a failure on account of the inadequate moisture supply. Only a very small percentage of the type is at present under cultivation, the greater part being undeveloped or covered by a heavy growth of timber.

The value of the land varies according to its location in the area and to the quantity and quality of the timber standing on it.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Everett gravelly loamy sand:

Mechanical analyses of Everett gravelly loamy 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.*
14101, 14103	Soil	6.9	21.6	12.7	22.0	11.1	17.4	8.0
14102, 14104	Subsoil	7.9	31.7	12.6	25.7	7.3	9.3	5.3

EVERETT LOAM.

The soil of the Everett loam, to an average depth of 12 inches, consists of a grayish loam to a silty loam, ranging in color from gray to yellow. Some areas also occur which have a yellowish-brown color. The surface when wet is a dark bluish gray in color, but on drying it becomes a light ashy gray. The subsoil as a rule is of about the same texture, but usually lighter in color and frequently mottled with yellow iron stains. However, small areas in which the soil becomes increasingly sandier below 12 inches are not uncommon. The type as a whole differs from the other soils of the Everett series in the absence of gravel and glacial bowlders, but resembles them in the presence of a few small iron concretions. A few rock fragments are found at the base of steep slopes and near the higher knobs where the bed rock comes very near to the surface.

Only three bodies of Everett loam have been mapped, all of which are found in the extreme southeastern part of the area. These vary in size, the smallest being very little over 1 square mile in extent, while the largest covers several square miles. Other bodies are found in this same locality, but they were too small to indicate on a map of the scale used.

The topography of the Everett loam is rolling to almost mountainous, with precipitous bluffs, deep ravines, and high elevations, but more or less extensive comparatively level areas occur at intervals.

The surface configuration insures good drainage, and where not too steep the type is easily cultivated. Up to the present time very little of the Everett loam has been cleared of timber, and only a few small areas have been cleared and put under cultivation. The forested areas support a heavy stand of fir and cedar.

When properly cultivated the more level areas of this soil should equal if not exceed in productiveness the other soils of the Everett series. It is especially adapted to grasses for hay and pasturage. Fruit, potatoes, and grain should also prove profitable crops.

The present value of Everett loam is based largely on the stand of timber. Some of the logged-off areas can be purchased for $25 to $50 an acre. Timbered areas bring prices considerably higher than this.

The following table gives the results of chemical analyses of the soil and subsoil of the Everett loam:

Mechanical analyses of Everett 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.*
22074	Soil	1.9	5.9	3.7	13.9	14.1	38.3	22.1
22075	Subsoil	3.8	7.2	5.0	13.6	21.4	27.9	20.9

EVERETT STONY SANDY LOAM.

The soil of the Everett stony sandy loam, to an average depth of 12 inches, consists of a yellowish-brown gravelly coarse sandy loam. Large quantities of glacial bowlders of all sizes up to 2 or 3 feet in diameter are strewn over the surface and distributed through the soil. The subsoil is composed of 40 to 70 per cent of rounded glacial rocks, with a grayish coarse gravelly sand for interstitial material. As a rule, very little fine material is found in the subsoil, but the type includes some small areas where there are large numbers of glacial bowlders imbedded in a sandy loam which carries more or less silty material. A few small depressions of a silty soil are included in this type.

Several bodies of this type, most of which are several square miles in extent, have been indicated on the map. With the exception of the one tract found in the southern part of King County, all of this type of soil occurs in that part of the area included in Pierce County. In topography the areas vary from a nearly level or gently rolling surface to very steep and precipitous slopes along the stream valleys. Generally speaking, however, the type is quite rolling, the surface being made up of many rounded hills and intervening depressions. Owing to the character of the topography and the extremely porous nature of the subsoil, the drainage is excessive, and when once the forest covering has been removed the soil becomes very dry and unproductive.

The Everett stony sandy loam is a glacial sediment from which the waters of the melting ice have washed a great proportion of the finer materials. The characteristic forest covering consists 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.

The very stony character of this soil practically prohibits the growing of crops that require cultivation, and as a result very few attempts have been made to farm it. Possibly some of the less stony and more level areas could be utilized to a limited extent for pasturage and fruit growing, but the greater part of the type is fit only for reforestation. Land of this type of soil ranges in value from $10 to $100 an acre, depending on location and stand of timber.

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

Mechanical analyses of Everett stony 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.*
22076, 22078......	Soil........	7.4	15.8	16.5	19.9	16.1	14.9	9.7
22077, 22079......	Subsoil......	13.6	19.8	17.7	21.4	11.8	9.5	6.3

Lynden Series.

The soils of the Lynden series occupy gently rolling uplands and broad, comparatively level plains that represent the flood plains of glacial streams. The soils are derived principally from more or less stratified deposits of sand and gravel which were laid down over the broad valleys and along the lower bench lands by the waters of glacial floods or were deposited in various parts of the gently rolling uplands in the form of glacial outwash. They have uniformly a sandy or gravelly subsoil, and the natural drainage is usually excessive. The characteristic color is light brown to reddish brown, but the lighter textured sandy types are often light gray on the surface. The areas support a heavy growth of fir and other timber. Four types in this series were mapped in the present survey.

LYNDEN SANDY LOAM.

The surface soil of the Lynden sandy loam is a light-brown light sandy loam having an average depth of 10 to 15 inches. This is underlain by a gray loamy sand which has a more or less stratified structure and often contains pockets or thin beds of fine gravel. The sand content of the soil varies to some extent with its topographical position. Along some of the gentle slopes, where the soil has been slightly eroded, a small amount of the coarser sand composing the subsoil has become mixed with the surface soil, causing it to have a slightly coarser texture than the soil occupying the more level areas.

The Lynden sandy loam occurs in more or less extensive bodies in various parts of Snohomish, Skagit, and Whatcom counties. The larger areas, however, are found in the west-central part of Whatcom County and north and east of Marysville, in Snohomish County. The topography varies from almost level to gently rolling, but the low knolls and ridges are not steep enough to cause the land to be damaged by erosion.

The sandy texture of both soil and subsoil results in rapid and thorough drainage of this type, and in most cases it is even excessive. As a result crops are frequently damaged on account of the lack of sufficient moisture during the growing season.

The material from which the soil is derived was probably laid down by the waters of glacial floods, as the uniformity in the topography and texture of the type and the stratified structure, seen in the deeper cuts, indicate deposition by water.

The yields obtained on this soil depend largely on the methods used in its cultivation. Where a small acreage is thoroughly cultivated, and when the soil is kept in a productive state by the use of barnyard manure or the growing and turning under of clover or peas, very good results are secured. On the other hand, when the land is planted to general farm crops and poorly cultivated a large amount of the moisture supply is lost by evaporation and by leaching out through the loose sandy subsoil, and the yields obtained are light. A very intensive system of farming is necessary and where such is followed the type seems well adapted to the growing of early potatoes and other vegetable crops that mature early in the season. A limited acreage of the soil has been irrigated by sprinklers, and the results obtained demonstrate that the soil will produce very profitable yields if a sufficient supply of moisture is furnished the crops. When intensive methods of cultivation are practiced, the soil will conserve, during a season of average rainfall, moisture enough for most crops without the aid of irrigation.

LYNDEN FINE SANDY LOAM.

The surface soil of the Lynden fine sandy loam, to an average depth of 15 to 20 inches, is a light-brown fine sandy loam containing a considerable quantity of silt, which causes it to have a fine loamy texture. The subsoil, to a depth of 36 inches, is a light-brown to gray fine sandy loam which contains a large amount of silt in the upper 10 to 15 inches but gradually becomes lighter in texture as the depth increases, grading at about 30 to 36 inches into a fine loamy sand. The deeper subsoil is usually quite sandy and sometimes contains small pockets of fine gravel. Both soil and subsoil are comparatively free from glacial gravel and bowlders.

No extensive areas of the Lynden fine sandy loam occur in the area surveyed, but several small areas are found occupying the bench lands of the Snohomish and Stilaguamish valleys, in Snohomish County, while other bodies comprising a total of several square miles are located in the western and northwestern parts of Whatcom County. The soil occurs along the outer border of some of the broad valleys which probably served as an outlet for the glacial waters during the period of the ice invasion. It is the intermediate type between the coarser sandy deposits forming the Lynden sandy loam and the fine silty glacial drift that forms the Whatcom silt loam. It owes its origin to the finer sediments—fine sand and silt—which were laid down along the outer border of the old valleys by the waters from the melting glaciers.

The topography is level to gently rolling and the slopes from the bench lands to the adjacent valleys are never steep enough to cause any damage by erosion. The natural drainage is good, but the fine texture and compact structure of the subsoil prevents the excessive drainage common to many of the sandy upland soils.

A heavier phase of the soil occurs in the more level areas. Here the soil contains a larger amount of silt and organic matter than the greater part of the type, causing the surface to have the characteristics of a silty loam. On the other hand, the soil occupying the low knolls and ridges contains a higher percentage of sand and is slightly lighter in texture than the type as a whole.

It is estimated that less than 5 per cent of the area occupied by this type of soil is under cultivation. When well cultivated it produces very profitable yields of all crops. Oats have been grown on a limited acreage, the yields ranging from 50 to 60 bushels per acre. The soil, however, is better adapted to the intensive cultivation of such crops as potatoes, small fruits, and early truck crops, rather than to the general farm crops.

Cabbage, cauliflower, carrots, pumpkins, garden peas, cucumbers, and other vegetables do well, when carefully cultivated. Canada field peas produce an average yield of 50 to 60 bushels per acre. There are a number of small orchards located on this soil, and where they are well cared for they do exceedingly well.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Lynden fine sandy loam:

Mechanical analyses of Lynden 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.*
14091, 14093, 17733.	Soil.........	1.2	6.2	5.8	22.4	18.8	33.7	11.6
14092, 14094, 17734.	Subsoil......	.7	3.9	4.9	18.5	19.5	39.1	13.3

LYNDEN SILT LOAM.

The soil of the Lynden silt loam consists of 15 to 20 inches of light-brown silt loam to silty fine sandy loam, containing a considerable quantity of organic matter. A small amount of fine gravel is usually present in the soil, but not in sufficient quantities to influence its texture. The subsoil consists of a compact mass of gravel and sand. The gravel particles vary in size from small pebbles to rounded cobbles several inches in diameter, while the sandy interstitial material varies in texture from fine to coarse, the latter, however, predominating.

The larger areas of this soil are found in the western and northwestern parts of Whatcom County. Another area of considerable extent is located on Lummi Island. The topography of the greater part of these areas is rolling, but the surface is never so rough as to interfere with the agricultural development of the land. The hills are low and rounded, and more or less extensive upland plateaus, whose surfaces are gently rolling to almost level, occur at intervals. This rolling topography, together with the porous character of the subsoil, insures good natural drainage. On the slopes of the rounded hills and ridges the drainage is often too thorough and unless proper methods of cultivation are used and care is taken to conserve the soil moisture the crops are liable to be damaged by droughts.

The soil is derived from the weathering of glacial deposits of fine sand and silt which were laid down upon coarser glacial material, consisting of coarse sand, gravel, and small rounded bowlders. The greater proportion of the area occupied by the Lynden silt loam has been cleared of merchantable timber, but on only a small percentage have the stumps and underbrush been removed and the land put under cultivation.

Crops grown on this soil produce larger yields during wet seasons than during seasons of average rainfall. This is due to the fact that a large part of the water absorbed by the surface soil is rapidly carried off through the coarse porous subsoil. Frequent shallow cultivation, keeping a dust mulch on the surface, has proved effective in maintaining a sufficient store of moisture in the soil to carry the crops through seasons of scanty rainfall. The soil seems well adapted to fruit growing, especially when the orchards are cultivated during the dry summer seasons. Apples, pears, plums, cherries, and prunes are all grown successfully, and the fruit is of fine quality. Small fruits have also been grown to a limited extent and produce very fair yields. Strawberries do especially well, when thoroughly cultivated, often producing yields equal to those obtained from any other type of soil in the area surveyed. Both clover and timothy have been successfully grown on a limited acreage, and after the underbrush is cleared off the land can be profitably utilized as pasture land before the stumps are removed, and it is made ready for cultivation. When well cultivated, Irish potatoes of fine quality have been grown, the yields averaging about 200 bushels per acre and much larger yields being obtained during favorable seasons.

The following table gives the results of mechanical analyses of the soil and subsoil of the Lynden silt loam:

Mechanical analyses of Lynden 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.*
17705	Soil	6.0	8.4	1.0	1.6	19.1	53.3	9.8
17706	Subsoil	19.3	43.6	6.0	6.9	4.0	14.7	4.6

LYNDEN GRAVELLY LOAM.

The surface soil of the Lynden gravelly loam consists of a light-brown loam or silty loam, 10 to 15 inches deep, containing a large quantity of rounded glacial gravel. The gravel content of the surface soil often varies considerably within small areas. Along some

27511°—11——99

of the steeper slopes, where a great amount of erosion has taken place, from 40 to 60 per cent of the surface is often covered by gravel and small rounded bowlders, while in adjacent areas the gravel occurs in compact beds just below the surface and is covered by from 4 to 6 inches of a brown loamy soil, which is comparatively free from coarse material.

The subsoil is a compact mass of sand, gravel, and small cobbles, the materials often occurring in layers, beds, or pockets, causing the whole mass to have a more or less stratified appearance. The fine earth composing the surface soil of this type contains a larger quantity of silt and is much heavier in texture than that which forms the soil of the Everett gravelly loamy sand.

The Lynden gravelly loam occurs mainly in Whatcom County. The two larger bodies are found in the extreme northwestern part of the area surveyed, and smaller areas are found in various parts of the rolling upland region of the western part of Whatcom County. The topography of the larger areas is quite rolling, but some of the smaller areas found upon broad terraces or small upland plateaus have a comparatively level or gently rolling surface. The soil is derived from coarser glacial deposits of sand and gravel, probably laid down by the water from the melting ice as glacial outwash. This coarser material was later covered by a deposit of fine sand and silt, which form the fine earth in the surface soil.

No large areas of this type have been cleared for agricultural purposes, the greater proportion being covered by the underbrush and remnants of the forests left by the lumbermen. When well cultivated the soil seems well adapted to orchard fruits and the acreage planted in orchards is annually increasing. The gravelly texture of the soil makes it poorly adapted to the growing of crops which require frequent turning of the soil. During a favorable season very fair yields of Irish potatoes have been secured.

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

Mechanical analyses of Lynden 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.*
17729	Soil	7.6	19.1	7.9	9.8	3.0	40.1	12.2
17730	Subsoil	16.7	43.9	14.1	15.1	1.9	3.6	4.0

PUGET SERIES.

The Puget series comprises the alluvial soils occupying the stream valleys and the broad delta land found at the mouths of some of the larger rivers. The types of this series are quite uniform in texture, color, and topography in all sections of the Puget Sound region. They have been formed of material carried down by the rivers and deposited over the valleys at times of flood or in the shallow bays at the mouths of the rivers, eventually building up extensive level delta lands. The lighter textured soils occur near the main stream channels where the coarser particles are laid down by the swifter currents. Farther back from the streams the coarser sandy deposits have been covered by a layer of a finer silty material laid down in the quieter waters. In depressions where water has collected in time of flood and remained for long periods the sediments of silt and clay are usually many feet deep and no coarse sandy material is found in the subsoil to a depth of 3 to 5 feet. In the delta land this assorting of the material by the swift or slow currents has also taken place, the lighter textured soils having been deposited where the currents were swifter and the heavier soils in areas covered by quieter waters.

The heavier soil, known as the Puget silty clay, is sometimes a heavy silty loam and differs from the Puget silt loam mainly in that the silt deposit has a thickness of 3 feet or more above the underlying sand, while in the Puget silt loam the underlying sand is encountered at a depth of 10 to 20 inches below the surface. The delta lands are not heavily timbered, and it is often necessary to drain and dike them before they can be farmed. They often support a growth of coarse marsh grasses. The soils of the river valleys often support a growth of cedar and other timber, but the land is not so difficult to clear as the uplands.

The soils of this series are very productive and are classed among the best agricultural soils of the Puget Sound region.

PUGET SILTY CLAY.

The soil of the Puget silty clay consists of 10 to 15 inches of drab to slightly mottled silty clay containing a relatively large proportion of organic matter in various stages of decomposition. This surface material is underlain by a heavy silty loam or silty clay subsoil, slightly mottled with iron stains and very similar in texture to the surface soil, but containing a smaller amount of organic matter.

The larger bodies of the Puget silty clay are found in the alluvial flats or deltas near the outlets of the larger rivers, but smaller areas occur in many of the river valleys at a distance from the delta flats. The largest areas are found in the broad flats which extend from the outlet of the Stilaguamish River in northwestern Snohomish County to the northwestern part of Skagit County, including the broad La Connor Flats at the outlet of Skagit River. The topography is nearly level, and many of the larger areas have only a slight elevation above the level of the stream channel. This low position causes much of the area to be subject to overflow at times of high water, and near the mouth of the river it is often necessary to dike the land before it can be successfully used for farming. The soil as a whole has very poor natural drainage, and artificial drainage is necessary to enable cultivation. Open ditches are used to carry off the excess water, but even with these the subsoils in some of the areas occupying shallow basins remain in a saturated condition during the greater part of the year.

The Puget silty clay is derived from the finer sediments of silt and clay deposited in the shallow water at the mouth of the river. The smaller areas farther up the river valley owe their origin to the silt and clay deposited at times of overflow by the quiet waters at a distance from the main channels of these streams.

This land is not so difficult to clear as the upland soils, and a comparatively large proportion of it is now under cultivation. When thoroughly drained the soil is very productive and is considered one of the most valuable soils in the area for general farming. The soil is well adapted to oats and is utilized extensively for the growing of this crop. The better drained areas produce from 90 to 125 bushels per acre, and yields of 150 bushels per acre have been reported. Barley has been grown to a limited extent and yields 40 to 50 bushels per acre. Wheat also gives exceptionally large yields, but the product is too soft for milling purposes. Clover and timothy do well, producing from 3 to 5 tons per acre. Potatoes, vegetables, and small fruits are grown with good results. The small orchards of apples, pears, plums, and cherries which have been located on better drained areas do exceedingly well. Tile drainage is recommended to improve the agricultural value of the soil. Tile drains were seen in a few small areas and apparently were giving no trouble. In a soil of silty texture, however, there is always more or less danger of the tiles becoming clogged with the fine particles, and in installing systems of any considerable extent it will be well to guard against this contingency by placing silt boxes at proper intervals and even by keeping permanently in the tiles cables to which cleaning brushes may be easily attached if the necessity arises.

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

Mechanical analyses of Puget 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.*
14073, 14075, 16986, 17721, 22063, 22065.	Soil.....	0.1	1.1	0.5	1.2	3.2	63.5	30.4
14074, 14076, 16987, 17722, 22064, 22066.	Subsoil...	.2	.7	.4	.9	5.0	66.0	26.4

PUGET SILT LOAM.

The Puget silt loam, to an average depth of 8 to 20 inches, is a light-brown to drab silt loam, containing a considerable amount of fine and very fine sand. This is underlain by a light-brown to gray fine sandy loam subsoil, which is often slightly mottled with yellow iron stains.

This is the principal river valley soil of the area. It occurs extensively in the valleys of all of the larger streams and also in the delta flats found at the mouths of many of the rivers. The topography is locally level, but low mounds and shallow basins are found at intervals, causing the surface, as a whole, to be gently undulating.

Large areas of the Puget silt loam bordering the stream courses are subject to overflow at times of high water, but the natural drainage of the greater proportion of it is very good. Artificial drainage is necessary, however, in many of the basins or shallow depressions, where water collects during the winter and early spring months and often remains for long periods of time. The soil owes its origin to the deposition of fine sand, silt, and clay by the streams. The valleys in which the type occurs were formerly covered by a deposit of fine sand and this now forms the subsoil; the soil represents more recent deposits laid down by quieter waters.

A large proportion of this type is under cultivation and it is considered one of the most valuable soils in the area for general farming. The land can be cleared for farming at a comparatively small cost, and its fine silty texture makes it easy to cultivate. When well cultivated the soil is very productive of all crops grown in the area. In the Skagit River Valley large areas are devoted to oats and produce an average yield of more than 100 bushels per acre. (See Plate XXIV, fig. 1.) In the White River Valley extensive areas are used for growing blackberries, raspberries, and other small fruits, and the large yields obtained have demonstrated that the soil is well adapted to these crops and the industry has developed very rapidly. Potatoes, vegetables, Canada field peas, clover, and timothy also yield heavily. Orchards located on this type, where well cared for, are in a flourishing condition.

The value of this land depends on its location in the area and on the extent to which it has been developed agriculturally. The price ranges from $75 to $100 an acre, for tracts at a distance from the larger cities, to from $500 to $800 an acre for land located in the White River Valley, which has been highly developed agriculturally and is utilized for the growing of small fruits.

The table following gives the average results of mechanical analyses of the soil and subsoil of the Puget silt loam.

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.*
14069, 14071, 17717, 22059, 22061.	Soil.....	0.1	0.8	0.3	3.0	13.8	67.9	14.2
14070, 14072, 17718, 22060, 22062.	Subsoil..	tr.	.8	1.4	29.7	34.8	27.4	5.5

PUGET FINE SANDY LOAM.

The soil of the Puget fine sandy loam is a dark-gray to light-brown fine sandy loam usually containing a relatively large proportion of silt. The silt content is greater along the boundary between this type and the Puget silt loam, as the sandy loam slowly merges into the finer-textured silty soil. At an average depth of 12 to 15 inches the soil grades into a fine sandy loam subsoil, which is both lighter in color and in texture than the surface soil. Both the soil and subsoil are often slightly mottled with iron stains. The subsoil contains a higher percentage of sand and less silt than the soil, but an occasional thin layer of silt or clay is often found at a depth of 2 to 3 feet below the surface.

Areas of this type occur in the valleys of all the larger streams and rivers. It occurs usually as a comparatively narrow strip, varying in width from a few rods to a mile or more, which borders the present channels of the streams. The loose, incoherent structure of the soil and subsoil insures good natural drainage. Some of the areas are subject to overflow, but only during times of unusual floods. These overflows, however, occur at such seasons of the year as not to injure the crops to any great extent.

The soil is derived from the finer sand and silt which has been deposited along their banks by the swifter currents of the rivers and their larger tributaries during times of overflow. The land is mostly cleared and a large proportion of the type is at present under cultivation. In some localities the soil has been utilized extensively for growing forage crops. In the White River Valley extensive areas have been cultivated to vegetables, orchard fruits, and small fruits, and the yields are in all cases very profitable. Where the natural drainage is not impeded, the soil seems well adapted to small fruits, especially blackberries and raspberries. The average yield of raspberries is estimated at from 500 to 800 crates per acre. When thoroughly cultivated and when such methods are in use as will tend to conserve the soil moisture potatoes do well, averaging from 240 bushels to 300 bushels per acre. Timothy, clover, and oats are grown on limited areas of this type and produce very profitable yields. The areas of the soil which are located nearer the larger markets should be utilized more extensively for growing early truck crops.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Puget fine sandy loam:

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.*
17741, 22055, 22057.	Soil.........	0.1	0.3	0.4	18.5	39.6	35.1	5.7
17742, 22056, 22058.	Subsoil......	.0	.5	2.5	37.5	34.8	20.8	3.5

CUSTER SERIES.

The Custer series comprises the sedimentary glacial basin soils which are underlain by sandy material. These soils occupy shallow basins which were formerly small lakes or ponds and have been formed by the gradual filling up of these ponds by material washed from the surrounding glacial uplands. The earlier deposits were mainly sand which now forms the subsoil of the series, upon which was deposited later finer material, consisting mainly of find sand, silt, and clay. The silt and organic matter content of these soils is always high. The subsoil material contains a high percentage of iron, which frequently cements the sand into a compact mass. Small iron concretions are of common occurrence throughout the soil mass, while beds of bog iron ore are occasionally encountered in the subsoil.

The large amount of organic matter present in the soil is derived from the slow decay of the rank growth of vegetation which flourished during the later stages of the change from a water to a land surface. In some localities the quantity is so great as to give a shallow deposit of peat or muck. The surface of these basins is level to gently undulating and artificial drainage is necessary on all the soils of the series before they can be profitably utilized for agriculture.

CUSTER LOAM.

The soil of the Custer loam consists of a gray to dark-brown loam, with an average depth of 10 to 15 inches. The upper 2 to 6 inches contains a large amount of silt and in the uncultivated areas the silty material forms a shallow surface covering, seldom more than a few inches deep. When cultivated this surface material becomes mixed with the coarser material and forms a friable, loamy soil, easily reduced to a state of good tilth. The subsoil is a compact loamy sand, usually slightly mottled with iron stains. Pockets of gravel sometimes occur in the subsoil and in some small areas the sand has been cemented with iron into a hard, compact mass. Small beds of bog iron ore and pockets of iron concretions are sometimes found in the subsoil.

This soil contains a large amount of organic matter. In some small areas it is covered by a shallow deposit of peat, but over the greater part of the type the organic matter has become thoroughly decomposed and is mixed with the silty surface layer.

This type occupies small basins or more or less extensive poorly drained depressions which are usually surrounded by rolling uplands occupied by one of the light sandy types of soil. The surface soil has been formed from sediments of silt, clay, and fine sand washed from the uplands and deposited upon the materials forming the bottoms of the earlier lakes and ponds. The late deposition has taken place in quiet water, which accounts for the uniform fineness of the surface. The large content of organic material is the result of the accumulation of the remains of rank water-loving vegetation.

Only a small proportion of this type is under cultivation, the greater part being used mainly for pasture land. Where well drained it produces very fair yields of potatoes and other vegetables and small fruits. Oats and hay, now the principal crops, produce good yields, except on small areas where accumulations of iron have caused the formation of small deposits of bog iron ore or of hardpan in the subsoil.

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

Mechanical analyses of Custer 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.*
14065, 14067	Soil	0.3	2.5	2.5	20.2	15.8	37.4	21.1
14066, 14068	Subsoil	2.4	18.9	16.2	32.7	12.7	11.3	5.7

CUSTER SILT LOAM.

The surface soil of the Custer silt loam is a gray to light-brown silt loam, with an average depth of 15 to 20 inches. The soil contains a large quantity of organic matter and in some areas the surface is covered by a shallow deposit of peat. The texture of the soil becomes more sandy as the depth increases, slowly grading into a compact sandy subsoil. The subsoil material is usually quite uniform in texture, but sometimes contains pockets of gravel or thin strata or bands of silty clay. It also carries relatively large quantities of iron, which often cements the sand particles into a hard compact mass. The soil and subsoil are in many places slightly mottled with iron stains, and iron concretions and small beds of bog iron ore are sometimes found in the subsoil.

The type occurs in one large area in the northern part of Whatcom County. It occupies a broad level basin known as the Lynden

Prairie, which was formerly the bed of a shallow lake. This basin later passed through the stages of a poorly drained marsh, and the large amount of organic matter present is derived from the decay of swamp vegetation. The soil has been formed from the sediments of silt and clay which were deposited in the quiet water of the shallow lake as a fine silty layer, overlying coarser sandy deposits of an earlier period. The topography of this area is almost level and the natural drainage is very poor. Its position, however, is sufficiently elevated above the adjacent stream course to allow it to be artificially drained without difficulty, and a large proportion of this land has already been reclaimed and utilized for agriculture.

There were originally peat deposits over much of this area and over a large area the organic matter was in such a coarse fibrous condition that thorough cultivation of the land was very difficult. In the majority of cases where this condition pertained the peat was burned off as soon as the land had been thoroughly drained.

When well drained and thoroughly cultivated the soil is very productive and is considered very valuable land for general farming. The principal crops grown are oats and hay. The yield of oats usually ranges from 50 to 60 bushels per acre, with yields as high as 80 to 100 bushels per acre in favorable seasons. Timothy and clover also do well, producing large yields of hay of good quality. Canada field peas are also grown extensively and yield heavily. Irish potatoes are produced to some extent, yielding from 200 to 400 bushels per acre.

The following table gives the results of mechanical analyses of the soil and subsoil of the Custer silt loam:

Mechanical analyses of Custer 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.*
17709	Soil	0.3	1.4	2.2	8.6	14.2	55.2	17.5
17710	Subsoil	.9	15.1	19.5	31.9	10.8	15.3	6.6

SPANAWAY SERIES.

The region known locally as the Prairie is occupied by the Spanaway series. This series comprises the soils of the upland treeless or sparsely timbered plain. These plains are formed by deep beds of coarse glacial gravel containing little or no fine material and by beds of sand which contain only a small percentage of gravel. These deposits represent material left by the swift waters of subglacial streams under the partially submerged or floating ice front, or material laid down uniformly over the basin of an icebound glacial lake. The deep deposits of sandy material were probably formed as deltas by the glacial streams emptying into quiet waters.

The area occupied by these soils has the general appearance of a level plain, but low, rounded mounds, shallow basins, and low, flat-topped terraces give it as a whole a gently rolling topography. This plain is traversed by numerous narrow ridges which often rise 20 to 40 feet above the surrounding plain. The ridges are narrow and frequently several miles in length. They are not occupied by the soils of the Spanaway series and are covered with a heavy growth of timber, while the areas included in the Spanaway series are either treeless or support only a very sparse and stunted tree growth. (See Plate XXII, fig. 2.) The Spanaway soils are excessively drained and of low agricultural value. The coarser gravelly soils are not at present used for agriculture, but the sandy soils are used to some extent.

SPANAWAY FINE SANDY LOAM.

The Spanaway fine sandy loam, to an average depth of 12 inches, consists of dark-brown to black fine sandy loam, carrying a high percentage of organic matter and occasionally very small quantities of gravel. The subsoil, to a depth of several feet, is a grayish-brown slightly loamy medium sand, which becomes somewhat coarser in texture and lighter in color as the depth increases. The area of this soil which occurs just southwest of Dupont contains a higher percentage of coarse sand and gravel than is usually found in the type. In general the soil, being of a loose incoherent structure, is easily cultivated.

All of the bodies of the Spanaway fine sandy loam occur in the southwestern part of Pierce County. The largest area has an extent of approximately 2 square miles and is located west of Roy on the Nisqually River. In addition, four smaller bodies, ranging in extent from one-half to 1 square mile, are found in the same section. In nearly every case the soil is almost entirely surrounded by the Spanaway gravelly sandy loam and forms a part of what is locally termed the Prairie.

The greater proportion of each of the areas occupied by this soil is comparatively level, but the few low ridges, mounds, and gentle slopes give the type as a whole a slightly undulating topography. Although the type contains more fine material than the Spanaway gravelly sandy loam and is accordingly more retentive of moisture, yet the constant use of methods for conserving soil moisture is necessary to carry the crops successfully through periods of drought.

The Spanaway fine sandy loam is derived from extensive deposits of sand probably laid down as deltas where swift glacial streams emptied into the quiet waters of icebound glacial lakes. The greater part of the type is treeless, but there are some small areas of fir of an inferior quality.

Owing to the sparse timber growth, the type is easily cleared, and as a result much of it is already under cultivation. The yields secured are only fair, but they could undoubtedly be increased by the adoption of dry-farming methods. Oats produce from 18 to 20 bushels per acre and wheat 8 to 10 bushels per acre. Potatoes, truck, and fruit do fairly well when properly cultivated.

Land of this type ranges in value from $25 to $50 an acre or even higher, depending on location and amount of improvements.

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

Mechanical analyses of Spanaway 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.*
22070	Soil	0.6	2.9	6.6	41.8	25.0	12.2	11.0
22071	Subsoil	.4	2.9	5.9	43.3	22.6	15.5	9.5

SPANAWAY GRAVELLY SANDY LOAM.

The soil of the Spanaway gravelly sandy loam, to an average depth of 12 inches, is a very dark brown to black medium sandy loam, carrying considerable quantities of gravel and rock. It contains a relatively large proportion of organic matter, giving it the characteristics of a soil of much more silty texture. Where cultivated the dry surface is much lighter in color than the virgin areas, often approaching a gray. The subsoil consists chiefly of rounded waterworn rock fragments of all sizes up to 8 or 10 inches in diameter. It contains small quantities of coarse sand and fine gravel, but as a whole is characterized by the almost total absence of any very fine material below 18 inches from the surface. (See Plate XXII, fig. 3.)

This type includes some narrow areas along streams and small basins in which the soil is of a much finer texture, being either a fine sandy loam or a silty loam, but such areas are too small to indicate on a map of the scale used in this survey. In a few places large quantities of loose bowlders are found strewn over the surface, but the greater part of the type is comparatively free from such surface accumulations of rock.

There are two small areas in the uplands just east of Kent and two on the mountain road a short distance north of Tanwax Hall in which the soils differ somewhat from the type as found in the larger areas, but, as they bear a close resemblance in the general characteristics and agricultural value, they have been grouped with the Spanaway gravelly sandy loam.

The four small bodies previously mentioned embrace a total area of less than 2 square miles. The remainder of the type occurs as one continuous body, comprising several townships in the southwestern part of Pierce County. As a whole the type is not difficult to cultivate, except in those cases where underlying rocks are found so near the surface that they interfere with plowing.

The Spanaway gravelly sandy loam occurs as a broad level to gently rolling plain, having the characteristic glacial topography. The most striking features are low rounded mounds, shallow basins, and more or less extensive terraces, which form flat-topped embankments 1 to 20 feet high.

On account of the extremely coarse and porous nature of the subsoil the drainage of this type is excessive, and it is only during the winter, when frequent rains occur, that the soil contains sufficient moisture to keep the grasses and smaller vegetation in a green and growing condition. Shortly after the winter rains cease all the smaller plants become dry and withered.

The soil is derived from the coarse sand, gravel, and bowlders deposited by the glaciers. Swift glacial streams at work during the period of deposition of the subsoil washed out all of the fine material, leaving a mass of rock fragments. Subsequent deposition during a period of quieter currents probably gave the finer stratum which now represents the soil, though the difference between soil and subsoil is no doubt due in part to the weathering of the former since its deposition.

The Spanaway gravelly sandy loam is either treeless or for the most part supports only a sparse and stunted tree growth. Along the steeper terrace slopes, however, and on some of the low ridges there are found small areas of merchantable timber.

At present practically no attempt is made to cultivate the type, except in the shallow basins and small areas along the streams, where, owing to position and the presence of larger amounts of fine material, the soil is, in comparison to the main areas, retentive of moisture. On such areas, where dry-farming methods are employed, moderate yields of oats, wheat, and potatoes are secured, but over the greater proportion of the type the returns are not sufficient to justify the expenditure of time and money necessary to produce a crop. During the winter season, when the rains are abundant, these plains afford a fair amount of pasturage for the cattle and sheep.

Land of this type of soil ranges in value from $15 to $75 an acre, the difference depending chiefly upon location.

The table following gives the average results of mechanical analyses of typical fine-earth samples of the soil.

Mechanical analyses of Spanaway 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.*
22067, 22069.......	Soil.........	10.9	20.2	7.1	9.5	7.3	26.0	18.9

WHATCOM SILT LOAM.

The surface soil of the Whatcom silt loam is a light-brown to reddish-brown silt loam with an average depth of 15 inches. A few small iron concretions are present in the soil, but aside from these the material as a whole is free from coarse particles, such as coarse sand or gravel. The subsoil consists of a heavy silty loam or silty clay loam of a gray to drab color, plastic and sticky when wet and of a massive compact structure.

Relatively large areas of this soil occur in the western part of Whatcom County and several smaller areas, only a few square miles in extent, in the rolling upland section of Skagit County. The topography is rolling, but the hills are low and rounded and the slopes are never steep or eroded. In some localities there occur many small depressions nearly surrounded by low knolls of glacial drift, giving rise to typical kame and kettle topography. The soil in these depressions is darker in color than that found on the knolls and ridges, and where the areas are of sufficient extent they have been mapped as Bellingham silt loam.

Uncleared areas of Whatcom silt loam support a heavy growth of timber, and the difficulty of removing the stumps and underbrush after the merchantable timber has been cut has greatly retarded the use of the land for farming. Once it is reclaimed from its wild state this soil can be cultivated with more certainty of securing profitable yields than the greater proportion of the upland soils of the area surveyed, as its heavy compact subsoil enables it to maintain a good supply of moisture and the crops are not as liable to be damaged by droughts as on the types with coarser textured subsoils. Notwithstanding the difficulty of clearing a comparatively large area has been put under cultivation and the acreage cropped is steadily increasing. The soil is derived from the weathering of the glacial till, which in this part of the area surveyed consists of a compact mass of silt, clay, and fine sand, containing only a very small amount of gravel or small bowlders.

The Whatcom silt loam is well adapted to orchard fruits, apples, pears, plums, prunes, and cherries, and also to strawberries and other small fruits. Irish potatoes and the other vegetable crops grown in the area produce good yields on this type. (See Plate XXIII, figs. 1 and 2.) Oats, barley, clover, and timothy have been grown to a limited extent and give very profitable returns, but owing to the fact that the cost of clearing the land is high, the areas under cultivation are used chiefly for crops better suited to intensive farming.

Uncleared areas of Whatcom silt loam are valued at $20 to $100 an acre, according to their location with regard to the larger towns and cities. The cultivated land brings from $100 to $300 an acre, and some highly improved land near the larger cities is held at $500 to $700 an acre.

The average results of mechanical analyses of the soil, subsoil, and lower subsoil of the Whatcom silt loam are given in the following table:

Mechanical analyses of Whatcom 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.*
16976, 14095, 14099.	Soil	1.1	4.5	2.7	7.1	7.3	61.2	15.2
16977, 14096, 14098.	Subsoil	.8	3.6	2.7	9.1	10.0	52.0	21.9
16978	Lower subsoil.	1.5	5.4	4.1	15.6	10.3	48.5	14.7

BELLINGHAM SILT LOAM.

The soil of the Bellingham silt loam is a dark-brown to drab colored heavy silt loam, containing a relatively large though variable amount of organic matter. In some areas the soil is covered by a thin layer of thoroughly decomposed vegetable matter having the appearance of muck and in such areas the surface has a very dark brown to black color. In other areas, especially where the soil has been cultivated, the vegetable mantle has been mixed with the deeper soil and the surface is lighter in color. The subsoil is a heavy compact drab-colored silt loam, which becomes heavier in texture as the depth increases, until at 30 to 36 inches it has the characteristics of a silty clay. Deposits of diatomaceous earth are frequently found in the subsoil. All of the small upland basins, occurring at frequent intervals in the rolling upland of the entire region surveyed, are of this type of soil. These basins are almost wholly surrounded by rolling hills and ridges. The natural drainage is very poor and many of the depressions have no drainage outlet whatever.

The texture of the soil in the greater proportion of these basins is fairly uniform, but owing to the fact that the soil is derived largely from material washed down from the adjacent uplands there is some variation, which accords with the texture of the materials found on the surrounding hills. Some of the smaller basins are surrounded by the lighter textured upland soils and contain a higher percentage of sand than the typical Bellingham silt loam, and on the other hand small areas occur which have a higher clay content than the typical soil. In a reconnoissance survey it was not found practical to separate all of these local phases into separate soil types nor was it considered necessary, as the areas are very similar in agricultural value, drainage conditions, and origin.

The Bellingham silt loam is derived from material washed from higher land into basins, during the periods when they were small ponds or lakes or were in a wet, swampy condition. The large amount of humus in the soil is derived from the slow decomposition of the water-loving vegetation which flourishes in areas of poor drainage.

Areas of the Bellingham silt loam when well drained are very productive and can be profitably utilized for agricultural purposes. They can be cleared for cultivation at a comparatively small cost, but to this must be added the expense of artificial drainage, which is necessary before the type can be successfully used for farming. Open ditches are generally used to drain this land, but tile drainage has been used to a limited extent and has proved to be the most satisfactory.

The soil seems well adapted to both clover and timothy, and the yield of hay is estimated at 3 to 4 tons per acre. With thorough drainage very profitable yields of vegetables are secured. Irish potatoes in particular produce heavily. The oat crop has also been found profitable. The value of this land varies from $30 to $500 an acre, according to its location in the area, its condition as to drainage, and the extent of the improvements.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Bellingham silt loam:

Mechanical analyses of Bellinhgam 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.*
17725, 17727	Soil	0.3	1.3	0.4	2.8	8.3	68.7	18.1
17726, 17728	Subsoil	.2	.7	.5	4.1	8.5	72.1	13.9

ORTING LOAM.

The soil of the Orting loam, to a depth of 8 to 12 inches, consists of a dark-drab light but sticky loam containing small amounts of gravel, with occasional glacial bowlders. The type carries a high percentage of organic matter, which is largely responsible for the dark color of the soil when wet. The subsoil is a sandy loam or loam containing considerable coarse and medium sand and a varying amount of gravel, small rock fragments, and glacial bowlders. There is enough silt and clay present in the subsoil to make it decidedly sticky when wet. In color it ranges from gray to grayish brown, mottled with yellow iron stains. Only two areas of this type were mapped. In the smaller of these the soil contains more stones, less organic matter, and is less productive than the other, which is taken as the typical soil. However, in their general characteristics they are quite similar, and have therefore been grouped together in the map.

The Orting loam is found in the northern part of Pierce County. The larger area occurs as a broad level bench between the Puyallup and Carbon rivers, just before their junction, and on this body the town of Orting is located. The other body is a few miles farther up the valley of the Puyallup River.

In general the topography is level, but in detail low mounds and ridges give the surface a gently undulating appearance and relief enough to promote good natural drainage, notwithstanding the presence of a rather compact and heavy subsoil. From its position and from surface indications, the type would seem to be very similar to the more recent stream alluviums, but the heterogeneous mixture of coarse and fine material proves beyond a doubt that the type is of glacial origin, while the entire absence of stratification and assortment of soil particles goes to show that there has been very little change by water action since the materials were left by the ice.

The native vegetation consisted of forests of spruce, fir, cedar, and alder. At present, however, almost all the land is cleared and mostly under cultivation. It is easily handled and breaks into a loose, friable seed bed. Hops do very well and for several years this crop was the principal source of income, but as the prices diminished the crop became unprofitable and was gradually supplanted by oats, hay, and potatoes.

Both hay and grain do well on this soil. The yield of oats varies from 50 to 75 bushels per acre and a yield of 2 to 3 tons of hay per acre is not uncommon. Large yields of wheat can be secured, but as the grain does not harden sufficiently to permit milling, this crop is not extensively grown. Potatoes yield 200 to 300 bushels per acre and are of fine quality. All kinds of garden truck and small fruits flourish. Apples, pears, and cherries yield well, although early varieties are sometimes injured by frosts. Uncleared areas of Orting loam are valued at $25 to $50, while the cultivated lands range in price from $50 to $250 an acre.

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

Mechanical analyses of Orting 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.*
22053	Soil	4.3	13.2	8.1	17.4	11.2	26.8	18.8
22054	Subsoil	6.0	15.7	9.9	21.3	19.7	16.3	11.2

BUCKLEY LOAM.

The soil of the Buckley loam varies in texture from a loam to a silty loam. The surface material has an average depth of 10 inches and carries a relatively large quantity of organic matter and a small quantity of gravel. In a wet condition the soil has a decidedly black color, but the dry cultivated surface changes to a dark bluish gray. The subsoil is an impervious compact loam, possessing the characteristics of a much heavier soil and containing considerable quantities of coarse sand and fine gravel and more or less angular and subangular rock fragments and glacial bowlders. In color it is a bluish gray, mottled with yellow or brown iron stains. In some cases the soil consists largely of organic matter, with just enough soil to give it the characteristics of Muck, and where of sufficient extent such areas have been so classified, but several areas encountered were too small to be shown on a map of the scale used, and these have been included in the Buckley loam. The areas mapped also embrace a few small bodies of the Everett gravelly sandy loam.

At present a considerable part of this type is cleared and under cultivation. The uncleared areas still support a growth of fir, cedar, spruce, alder, and maple, with a dense undergrowth of salal, huckleberry, and brake.

Two large bodies and several small bodies of this type were mapped, all of which are located near the eastern border of the area. The principal one of the smaller bodies, comprising approximately one-half square mile, occurs as a bench in the valley near South Prairie. The two large areas, each of which is several square miles in extent, comprise the greater proportion of the two plateaus on which the towns of Enumclaw and Buckley are located and are separated only by the White River and the narrow strips of soil along its steep slopes. The surface is flat, or in a few instances interrupted by swells and ridges. The areas are frequently bordered by steep slopes. Owing to the topography and to the impervious nature of the subsoil, the natural drainage is rather poor, and only where artificial drainage has been resorted to have the best results been obtained. It is claimed by those who have had some experience that in order to drain the land properly the laterals should be no farther apart than 60 feet. When properly drained the soil becomes light and friable and is easily managed, although it is never possible to begin spring operations as early as on the more sandy and gravelly types.

The Buckley loam is derived from the Osceola till and has been formed directly from these deposits without the intervention of water action. In this it is unlike most of the glacial soils of the area. The rock fragments exhibit very little variety and from all indications were probably derived from rocks at no great distance. The silt which constitutes a large part of this soil is quite like the rock flour that the White River is carrying to-day.

Where this soil is cleared and properly drained it becomes one of the most productive upland types in the area. The yield of oats ranges from 50 to 85 bushels per acre. Large yields of wheat are secured, but the berry is not hard and the product is used mainly as chicken feed. The same difficulty is encountered in the growing of corn. Potatoes yield from 150 to 200 bushels and are of good quality. Late fruits have been successfully grown, but are injured by frosts in unfavorable seasons. The soil is unusually well adapted to hop culture and at one time was used almost exclusively in the production of this crop. However, owing to the low prices of recent years many of the hop fields have been plowed up, although some large fields still remain. Dairying is a very profitable source of income and it is probable that the soil is best suited to this type of farming, as it affords excellent pasturage, while the yields of hay are large, seldom being less than 2 or 3 tons per acre.

Logged-off areas of Buckley loam can be purchased for $25 to $50 an acre. Very little of the cultivated land is on the market, but it ranges in value from $125 to $250 an acre, depending on location and improvements.

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

Mechanical analyses of Buckley 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.*
22043, 22045	Soil	3.3	9.3	4.4	11.5	9.6	28.7	33.1
22044, 22046	Subsoil	5.0	12.9	6.7	16.1	16.0	24.1	19.6

SWAMP.

The areas mapped as Swamp represent lands which are too wet to be of any present agricultural value. Many of these swampy areas can be drained. The soils when reclaimed contain large quantities of decomposing organic matter and are usually very productive.

MUCK AND PEAT.

Areas of Muck and Peat occur in almost every part of the region surveyed. These areas represent deep accumulations of organic matter in various stages of decomposition. The greater proportion of this vegetable matter is thoroughly decomposed and has become mixed with silt and clay forming the typical Muck soil. In other areas the material has not been thoroughly decayed, is more fibrous, and has more of the characteristics of Peat than of Muck. These two stages in the decomposition of the deposits of vegetable matter are so closely related and grade into each other so frequently within small areas that no attempt was made to separate them in the general classification of the soils.

Muck and Peat deposits occupy low, poorly-drained basins and are formed from the decay of rank water-loving vegetation under conditions of poor drainage. When these deposits have a fibrous, peaty texture, they are very difficult to cultivate and are used mainly for pasture. Small areas of the Muck, on the other hand, have been drained and profitably cultivated to oats and, to a limited extent, to onions, cabbage, celery, and bramble fruit. (See Plate XXIV, fig. 2.) Hay gives larger yields on the better-drained areas, but it is usually of a poor quality on account of the coarse wild grasses mixed with it.

TIDAL MARSH.

The areas mapped as Tidal marsh occur along the coast near the outlets of some of the larger rivers. These areas have only a slight elevation above tide level and are traversed by numerous small brackish sloughs. They support a heavy growth of coarse marsh grasses, and the surface is sometimes composed of a thick layer of partially decomposed, fibrous organic matter formed from the decay of this vegetation. In some localities small areas of this land have been diked and drained and profitably utilized for agriculture.

Tidal marsh has been formed through the accumulation of the materials held in suspension by the water of the streams and deposited in the shallow waters of the bays into which the streams empty.

COASTAL BEACH.

The Coastal beach consists of either a gray coarse sand or a mixture of such sand with small gravel, which deposits are seldom wide enough to be indicated on a map of the scale used in the survey, as they usually form only a narrow strip along the shores. The type is purely a beach deposit formed by the deposition of sand and gravel by the action of the waves and is of such limited extent that it is of little or no importance.

ROCK OUTCROP.

Extensive areas of Rock outcrop occur in several parts of the region surveyed. Where these areas are of sufficient extent to be shown on the map they have been indicated by means of a symbol. One of the largest of these areas occurs on Cypress Island, Skagit County, while other areas of less extent are found upon adjacent islands and in the rough mountainous regions.

UNPRODUCTIVE AREAS.

Areas of more or less extent frequently occur in various types of soils, and especially on the lighter textured upland soils, on which the crops planted fail to produce profitable yields and usually result in a total failure. These areas often occur as small spots in fields which are producing good yields and there is little or no difference in the texture of the soil in the productive land and on the small areas which fail to give profitable yields.

On account of the land having been burned over, or on account of erosion, the soil has been left in an impoverished condition, and consists mainly of the mineral constituents of the soil, which act mainly as a support for the plant, while organic matter and other factors which make a productive soil are lacking. These areas must be fertilized heavily with either commercial fertilizer or large applications of barnyard manure in order to get them in a condition suitable for plant growth. With heavy applications of fertilizers or manure and with thorough cultivation of the soil, it is soon possible to get a good stand of clover or field peas on these areas and by plowing under these crops the land is soon restored to a productive state.

CHEMICAL ANALYSES OF THE SOILS.[a]

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 probably been somewhat modified by the effects of fires which had previously burned over portions of the area.

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. Nitrogen is also sometimes spoken of as ammonia, although undoubtedly present in the soil in other forms. These constituents are the ones which it is sought to add to the soil in commercial fertilizers. Other mineral elements are undoubtedly needed by growing plants, but they are always abundantly present in the soil and have no great importance in fertilizer practice.

[a] Prepared by H. K. Benson, of the Washington Geological Survey.

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 might 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 or the clovers. 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 believed to be of especial 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, 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.

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 there is much clay or water holding minerals present, and consequently in a few cases the "humus" or dark organic coloring matter in the soil was also determined. 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:

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 the various soil types of the eastern part of Puget Sound Basin, Washington.

Laboratory No.	County.	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.*
1	King	Everett gravelly sandy loam.	Sec. 8, T. 26, R. 6 E	0–12	0.11	0.18	0.68	0.186	10.02	0.0086	250
3	do	do	SE. ¼ sec. 17, T. 22 N., R. 5 E	0–12	.12	.05	.13		11.72	.0257	910
101	do	do	NE. ¼ sec. 4, T. 25, R. 4 E	0–4	.31	.08	.08	.150	13.27	.0179	630
112	do	do	Sec. 1, T. 23, R. 3 E	0–14	.24	.12	.16		14.31	.0043	140
117	do	do	Sec. 33, T. 22, R. 4 E	0–14	.26	.14	.11	.760	9.70	.0486	1,400
123	do	do	Sec. 28, T. 26, R. 5 E	0–14	.12	.07	.08		9.00	.0057	165
133	do	do	Sec. 28, T. 23, R. 4 E	0–14	.24	.18	.22		9.76	.0228	700
139	do	do	Sec. 18, T. 22, R. 3 E	0–18	.14	.11	.33		18.08	.0086	280
140	do	do	Sec. 18, T. 22, R. 3 E	0–18	.17	.08	.07		10.10	.0100	350
7	Pierce	do	Sec. 33, T. 20, R. 4 E	0–12	.38	.03	.14		6.58	.0071	245
50	do	do	NW. ¼ SE. ¼ sec. 32, T. 20, R. 3 E	0–14	.28	.05	.16		11.82	.0071	245
56	do	do	SW ¼, NW. ¼ sec. 2, T. 18, R. 5 E	0–14	.26	.07	.13		7.96	.00287	70
61	do	do	Sec. 6, T. 17, R. 5 E	0–18	.10	.12	.19	.190	12.64	.0143	490
94	do	do	Sec. 34, T. 20, R. 3 E	12–36	.11	.03	.14				
97	do	do	R. 4 E	0–18	.13	.14	.04		6.06	.0028	70
104	do	do	SE. ¼ sec. 11 T, 18, R. 4 E	0–20	.17	.03	.12		7.04	.1060	3,710
116	do	do	NE. ¼ NW. ¼ sec. 16, T. 19, R. 6 E	0–14	.11	.16	.29		12.31	.0170	595
85	Snohomish	do	Sec. 21, T. 32, R. 6 E	0–12	.18	.20	.24		10.03	.0114	385
25	Skagit	do	Sec. 1, T. 34, R. 1 E	0–20	.40	.02	.13	.223	4.68	.0029	98
72	do	do	Sec. 25, T. 33, R. 4 E	0–20	.41	.03	.13		15.92	.0572	1,750
122	do	do	Sec. 1, T. 34 N., R. 1 E	20–36	.16	.02	.10				
26	Snohomish	Everett gravelly loamy sand.	NW. ¼ sec. 11, T. 31, R. 5 E	0–6	.31	.19	.16		11.53	.0086	280
44	do	do	Sec. 24, T. 27, R. 3 E	8–24	.11	.19	.17				
45	do	do	SW. ¼ sec. 3, T. 28, R. 6 E	12–24	.15	.04	.05				
47	do	do	SW. ¼ sec. 3, T. 28, R. 6 E	0–12	.20	.06	.11		16.46	.0314	1,050

Analyses of the various soil types of the eastern part of Puget Sound Basin, Washington—Continued.

Laboratory No.	County.	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.*
87	Snohomish	Everett gravelly loamy sand.	Sec. 11, T. 31, R. 5 E	10–18	0.21	0.12	0.09		7.39		
128	do	do	Sec. 24, T. 27, R. 3 E	0–8	.17	.19	.16		6.18	0.0143	490
33	Skagit	do	SW. ¼ sec. 5, T. 36, R. 4 E	15–25	.26	.07	.11				
103	do	do	SW. ¼ sec. 5, T. 36, R. 4 E	0–15	.10	.04	.49	.387	15.99	.0100	350
105	King	do	NE. ¼ sec. 23, T. 21 N., R. 4 E	0–16	.38	.05	.13	.040	8.20	.0086	280
114	do	do	Sec. 19, T. 26, R. 5 E	0–14	.29	.19	.20		9.30	.0125	420
82	Pierce	Everett loamy sand	NW. ¼ sec. 6, T. 18, R. 5 E	0–14	.18	.31	.15		7.49	.0043	140
108	King	do	Sec. 20, T. 23, R. 4 E	0–14	.12	.13	.30		6.94	.0214	700
145	do	do	NE. ¼ sec. 25, T. 25, R. 4 E	0–14	.28	.07	.36	.240	9.62	.0079	245
146	do	do	NE. ¼ sec. 25, T. 25, R. 4 E	0–14	.52	.11	1.23	.230	8.66	.0105	210
14	Whatcom	Everett stony loams	Sec. 4, T. 40, R. 5 E	12–24	.46	.03	.17				
17	do	do	Sec. 4, T. 40, R. 5 E	0–12	.19	.13	.13		14.76	.0067	210
28	do	do	Sec. 25, T. 37, R. 4 E	12–18	.11	.07	.09				
34	do	do	Sec. 6, T. 38, R. 5 E	0–12	.32	.03	.18		8.35	.0529	1,650
121	Pierce	do	NW. ¼ sec. 21, T. 19, R. 6 E	0–14	.11	.04	.16		7.16	.0057	210
35	do	do	Sec. 36, T. 17 N., R. 4 E	0–18	.11	.12	.12		7.93	.0144	490
41	do	do	NW. ¼ sec. 33, T. 19 N., R. 6 E	0–14	.15	.10	.12		8.50	.0057	210
126	Whatcom	Lynden gravelly loam	NW. ¼ NE. ¼ sec. 5, T. 40, R. 1 E	0–14	.21	.04	.14		9.46	.0072	245
9	do	Lynden sandy loam	Sec. 2, T. 39, R. 2 E	0–14	.37	.08	.14		7.73	.0071	245
81	do	do	NE. ¼ NE. ¼ sec. 22, T. 40, R. 2 E	0–14	.17	.03	.15		11.39	.0215	700
20	Snohomish	do	Sec. 21, T. 31, R. 5 E	0–12	.11	.17	.06		7.00	.0043	140
38	do	do	Sec. 32, T. 31, R. 5 E	18–24	.19	.04	.10				
51	do	do	Sec. 21, T. 31, R. 5 E	18–24	.31	.02	.12				
79	do	do	Sec. 32, T. 31, R. 5 E	0–12	.10	.09	.19		11.50	.0343	1,050
84	do	do	NE. ¼ sec. 29, T. 32, R. 6	0–12	.15	.32	.14		11.44	.0271	945
118	do	do	Sec. 28, T. 30, R. 5 E	0–4	.19	.07	.11		10.54	.0408	1,400
125	do	do	Sec. 28, T. 30, R. 5 E	4–20	.11	.13	.08				

142	.....do.........	.....do......................	Sec. 21, T. 31, R. 5 E..................	0-12	.11	.17	.06	.095	7.00	.0043	140
143	.....do.........	.....do......................	Sec. 21, T. 31, R. 5 E..................	18-24	.31	.02	.12	....	....	....	....
74	Pierce..........	.....do......................	SW. ¼ SE. ¼ sec. 2, T. 19, R. 3 E.......	0-14	.18	.10	.14	....	7.79	.0220	770
29	Snohomish....	Lynden fine sandy loam..	SW. ¼ sec. 35, T. 31, R. 6 E...........	0-14	.11	.05	.17	.16	16.67	.0372	1,295
75	Whatcom......	.....do......................	SW. ¼ sec. 27, T. 39, R. 2 E...........	0-14	.13	.38	.34	....	11.26	.0172	595
92	.....do.........	.....do......................	SW. ¼ NE. ¼ sec. 9, T. 40, R. 1 E......	0-14	.17	.03	.11	....	8.21	.0057	175
10	.....do.........	Puget fine sandy loam....	....	0-12	.19	.08	.12	....	4.83	.0057	210
22	Pierce..........	.....do......................	NE. ¼ SE. ¼ sec. 34, T. 20 N., R. 6 E..	0-14	.21	.04	.14	....	7.64	.0072	245
49	.....do.........	.....do......................	Sec. 19, T. 20 N., R. 4 E..............	12-36	.37	.06	.42	....	....	....	....
100	.....do.........	.....do......................	SW. ¼ NE. ¼ sec. 34, T. 19, R. 5 E.....	0-14	.17	.05	.24	....	4.43	.0043	150
111	.....do.........	.....do......................	NE. ¼ sec. 18, T. 16, R. 3 E...........	0-14	.17 .13	.15 .14	.09 .11	....	20.68	.0615	2,100
70	Skagit..........	.....do......................	Sec. 31, T. 34, R. 4 E..................	0-12	.22	.14	.10	....	10.67	.0186	630
89	.....do.........	.....do......................	Sec. 35, T. 35, R. 4 E..................	0-20	.10	.15	.08	.57	43.74	.0071	245
141	Snohomish....	.....do......................	Sec. 5, T. 30, R. 5 E..................	6-24	.14	.15	.10	....	....	....	....
46	Skagit..........	.....do......................	Sec. 31, T. 34, R. 4 E..................	12-36	.34	.08	.17	.02	....	....	....
98	Pierce..........	.....do......................	Sec. 19, T. 20 N., R. 4 E..............	0-12	.17	.16	.21	....	7.09	.0164	560
24	.....do.........	Spanaway gravelly sandy loam.	NW. ¼ sec. 6, T. 19, R. 3 E............	0-14	.26	.04	.15	.220	12.25	.0100	350
43	.....do.........	.....do......................	Sec. 22, T. 18, R. 3 E..................	0-12	.28	.08	.13	....	29.26	.0229	770
86	.....do.........	.....do......................	Sec. 21, T. 19, R. 3 E..................	0-15	.65	.10	.13	.330	29.56	.0200	700
99	.....do.........	.....do......................	Sec. 34, T. 19 N., R. 2 E..............	0-10	.11	.09	.06	....	19.81	.0243	840
131	King............	.....do......................	SE. ¼ sec. 25, T. 22 N., R. 5 E........	0-10	.13	.13	.10	....	30.34	.0286	980
132	.....do.........	.....do......................	NW. ¼ sec. 20, T. 22 N., R. 6 E........	0-10	.12	.14	.23	....	36.15	.0214	735
71	Pierce..........	.....do......................	Cen. sec. 31, T. 18, R. 2 E............	0-12	.17	.10	.25	....	8.42	.0243	840
129	.....do.........	Spanaway fine sandy loam	Sec. 33, T. 18, R. 2 E..................	0-14	.44	.166	.14	....	....	.0057	228
11	Whatcom	Whatcom silt loam.........	....	0-12	.11	.09	.19	....	10.82	.0343	1,190
15	.....do.........	.....do......................	NE. ¼ NW. ¼ sec. 5, T. 40, R. 2 E......	0-14	.17	.03	.14	.071	9.11	.0543	1,890
18	.....do.........	.....do......................	SW. ¼ sec. 25, T. 39, R. 1 E...........	0-14	.18	.16	.26	....	11.97	.0043	150
57	.....do.........	.....do......................	NW. ¼ sec. 2, T. 38, R. 2 E............	18-30	.18	.12	.24	....	....	....	....
64	.....do.........	.....do......................	Sec. 23, T. 38, R. 2 E..................	0-14	.36	.13	.18	....	7.50	.0043	150
67	.....do.........	.....do......................	Sec. 32, T. 37, R. 4 E..................	0-14	.16	.16	.08	....	23.90	.0229	770
91	.....do.........	.....do......................	NW. ¼ sec. 35, T. 40, R. 5 E	0-12	.11	.09	.14	....	9.96	.0172	595
16	Snohomish....	.....do......................	....	0-10	.11	.11	.15	....	19.76	.1187	4,154
52	.....do.........	Lynden fine sandy loam..	NE. ¼ sec. 7, T. 31, R. 6 E............	0-12	.13	.18	.10	....	5.81	.0072	245

Analyses of the various soil types of the eastern part of Puget Sound Basin, Washington—Continued.

Laboratory No.	County.	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.*
36	Snohomish	Whatcom silt loam	Sec. 15, T. 30, R. 6 E	0–14	0.47	0.20	0.10		7.63	0.0644	2,100
37	do	do	Sec. 36, T. 32, R. 4 E	0–8	.29	.20	.11		21.77	.0243	840
52	do	do	NE. ¼ sec. 7, T. 31, R. 6 E	0–12	.16	.06	.29		12.83	.0286	980
119	do	do	Sec. 36, T. 32, R. 4 E	4–24	.23	.25	.16				
134	do	do	Sec. 35, T. 32, R. 6 E	12–18	.10	.06	.55				
19	Whatcom	Lynden silt loam	NE. ¼ sec. 33, T. 39, R. 1 E	0–14	.25	.30	.13		14.12	.0100	350
78	Snohomish	Custer loam	Sec. 4, T. 30, R. 5 E	0–6	.31	.03	.13		3.54	.0417	1,400
54	do	do	Sec. 5, T. 30, R. 5 E	6–24	.14	.15	.10				
109	do	do	Sec. 23, T. 31, R. 5 E	0–14	.41	.46	.36	.182	14.22	.0072	245
95	Whatcom	do	NW. ¼ NE. ¼ sec. 14, T. 39, R. 2 E	0–14	.11	.33	.06		18.68	.0129	455
110	do	Custer silt loam	NE. ¼ NW. ¼ sec. 15, T. 40, R. 2 E	0–14	.25	.01	.10		6.17	.0500	1,650
73	Pierce	Everett loam	NW. ¼ sec. 3, T. 15, R. 4 E	0–14	.21	.05	.15		7.62	.0222	770
68	do	do	Sec. 6, T. 15, R. 5 E	0–14	.22	.02	.10	.09	10.36	.0400	1,400
58	King	Bellingham silt loam	Sec. 1, T. 26, R. 4 E	0–12	.31	.08	.13	1.141	18.41	.0408	1,400
53	Whatcom	do	Sec. 36, T. 37, R. 3 E	3–14	.11	.04	.15		13.24	.0072	245
66	do	do	Sec. 34, T. 38, R. 3 E	0–14	.10	.03	.06		12.58	.0543	1,750
96	Pierce	do	Sec. 10, T. 15 N., R. 4 E	0–14	.10	.05	.12		12.96	.0887	3,080
113	do	do	Sec. 2, T. 15, R. 4 E	0–14	.16	.05	.16		12.34	.0100	350
2	King	do	SE. ¼ sec. 1, T. 25 R. 5 E	0–8	.28	.31	.44		5.8	.0858	2,975
76	Pierce	do	NE. ¼ SE. ¼ sec. 3, T. 19, R. 3 E	0–14	.20	.05	10	.53	22.98	.1144	3,850
8	do	Orting loam	NW. ¼ SE. ¼ sec. 32, T. 19, R. 5 E	0–14	.33	.08	.16		3.60	.0114	385
40	do	do	Sec. 18, T. 19, R. 6 E	0–14	.11	.11	26		28.68	.0114	385
120	do	do	NW. ¼ NE. ¼ sec. 3, T. 19 N., R. 6 E.	0–14	.13	.03	.08		19.04	.0072	245
136	do	do	Sec. 32, T. 19, R. 5 E	0–12	.14	.06	1.03		9.72	.0143	490
63	do	do	NE. ¼ sec. 31, T. 18, R. 5 E	0–16	.24	.13	.09		21.31	.0071	245
39	do	Buckley loam	Sec. 31, T. 20, R. 6 E	0–8	.18	.09	.14	.450	21.89	.0128	455
13	do	Puget silt loam	Sec. 29, T. 20 N., R. 4 E	18–36	.32	.06	.17				

48	.....do.........	.....do..................	Sec. 29, T. 20 N., R. 4 E..............	0–18	.29	.07	.20	.27	10.10	.0157	560
59	Skagit.........	.....do..................	Sec. 23, T. 34, R. 3 E................	0–14	.33	.03	.39	....	13.34	.0086	280
107	.....do.........	.....do..................	Sec. 23, T. 34, R. 3 E................	14–36	.16	.06	.05	....	....	....	....
135	Whatcom	.....do..................	Sec. 31, T. 39, R. 5 E................	0–10	.32	.17	.46	....	12.64	.0071	245
144	King...........	.....do..................	Sec. 36, T. 22, R. 4 E................	0–12	.28	.06	1.19	....	13.40	.0057	210
23	Snohomish....	Puget silty clay...........	Sec. 8, T. 31, R. 5 E.................	0–12	.18	.23	.24	....	10.11	.0386	1,235
55	.....do.........	.....do..................	Sec. 8, T. 31, R. 5 E.................	18–24	.24	.09	.24	....	....	....	....
83	.....do.........	.....do..................	Sec. 30, T. 32, R. 4 E................	10–36	.25	.13	.24	.029	....	....	....
130	.....do.........	.....do..................	Sec. 30, T. 32, R. 4 E................	0–10	.15	.07	.16	....	12.48	.0186	585
30	Skagit.........	.....do..................	NW. ¼ sec. 29, T. 33, R. 4 E..........	0–20	.17	.13	.43	.030	6.31	.0634	1,950
62	.....do.........	.....do..................	Sec. 19, T. 34, R. 3 E................	18–36	.20	.08	.17	....	....	....	....
102	.....do.........	.....do..................	Sec. 19, T. 34, R. 3 E................	0–18	.17	.14	.38	....	10.80	.0157	520
42	King...........	Peat and muck...........	SE. ¼ sec. 5, T. 26, R. 5 E...........	0–36	.25	.11	.21	....	80.84	.1001	3,500
124	....do.........	.....do..................	Sec. 4, T. 26, R. 5 E.................	0–36	.35	.09	.20	....	92.12	.0536	1,855
77	Pierce.........	.....do..................	NW. ¼ sec. 5, T. 19, R. 3 E...........	0–14	.28 .19	.09 .06	.17 .11	....	9.33	.0643	2,240
106	.....do.........	.....do..................	Sec. 13, T. 20, R. 4 E................	0–14	.16	.06	.24	....	83.92	.0068	224
115	.....do.........	.....do..................	NE. ¼ sec. 9, T. 19 N., R. 6 E........	0–14	.08	.23	.07	....	81.92	.0705	2,450
		Diatomaceous earth.......	....	....	.11	.05	.33	....	31.22	....	....
		Soil from diatomaceous earth.	....	....	.12	.05	.13	....	11.72	....	....

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[a] and Maercker,[b] have suggested arbitrary standards as to the amounts 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 any 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

[a] 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; potash, 0.21; loss on ignition, 4.40 per cent.

[b] An arbitrary standard for the rating of soils by plant-food percentages was formulated for European soils by Professor 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:

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 .40	Above .25	Above .30	Above .25

any unusually large percentages of these constituents, and there is 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) Speaking generally, the soils throughout the area would probably respond well to liming.

(4) 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 borders Puget Sound, Washington, extending from the Canadian boundary southward to the southern boundary of Pierce County. It embraces all the townships in Whatcom, Skagit, Snohomish, King, and Pierce counties lying west of Range 7 east, excepting the townships of Pierce County that lie on the west side of Puget Sound.

The soil map shows the location and extent of the principal types of soil, and the land classification map the extent of the logged-off land and the relative agricultural value of the lands.

The land has been grouped in seven classes, as follows: (1) Land adapted to general farming and justifying immediate agricultural development; (2) lands adapted to intensive farming, fruit growing, and pasturage; (3) lands which can be utilized for orchards and pasture, but are not well adapted to farming; (4) nonagricultural lands suitable for reforestation only; (5) mixed lands, or areas where small tracts of agricultural land are scattered throughout more extensive areas of nonagricultural land; (6) sparsely timbered gravelly prairies; and (7) areas of forests, unclassified.

The northeastern and southeastern parts of the area are rough and mountainous, but the topography of the greater portion of the upland is rolling. Broad, shallow depressions, the basins of former shallow lakes or ponds, occur at intervals on the uplands. An extensive sparsely timbered upland plain is found in the southwestern part of the area, and extensive level delta lands have been formed at the outlet of some of the larger rivers.

The drainage system of the region is formed mainly by the many rivers which rise in the mountainous regions to the eastward, traverse the area, and empty into Puget Sound.

The alluvial valleys and delta flats are comparatively thickly settled, and a large proportion of this land is cultivated. The uplands are sparsely settled, and the greater proportion is still in the undeveloped state, known as "logged-off lands." Extensive areas occur in the mountainous regions which are still covered by the original forest growth and are almost uninhabited.

The principal cities within the area are Seattle, Tacoma, Everett, Bellingham, and Mount Vernon.

Three transcontinental railroads traverse the area, and almost every locality is within easy reach of a branch of one of these roads, of one of the local railroads, or of an electric line.

A large proportion of the region surveyed was originally covered by a heavy growth of timber, and lumbering is still the principal industry of the area.

Agriculture has developed most rapidly in the alluvial valleys and tide flats. The cost of clearing the logged-off lands of the stumps, logs, and underbrush has greatly retarded their agricultural development.

Hops was once the principal crop grown in the area, but this crop is now grown only to a limited extent.

Oats, hay, and potatoes are the staple products of the region. The growing of orchard and small fruits is also becoming a very important industry.

The hay and grain crops are grown mainly in the alluvial valleys, while more intensive methods of farming are practiced on the upland soils and the small areas of cleared land are devoted to such crops as small fruits and potatoes.

Oats produce very large yields, and the quality of the product is good. Wheat also produces large yields, but the product is too soft for milling purposes.

Canada field peas do well on almost every type of soil and produce large yields. Clover and timothy are grown on both the upland and alluvial soils. Irish potatoes are one of the most profitable crops grown in the area and do well on every type of soil suited for agriculture.

Dairy farming is now a very profitable industry in the area.

The upland soils are excessively drained, and careful methods of cultivation are necessary to conserve the moisture.

Twenty-six types of soil occur in the area. These are separated broadly into six groups.

The first group includes the glacial upland types. It comprises the Everett series of soils, consisting of the Everett gravelly sandy loam, Everett loamy sand, Everett stony loams, Everett gravelly loamy sand, Everett stony sandy loam, and Everett loam. These soils are excessively drained. The stony members of this series are of low agricultural value, but when intensively cultivated the other members of the series can be profitably cultivated. The Whatcom silt loam, Buckley loam, and Orting loam, local types, also belong in this group. These are well adapted to agriculture, and are very productive.

The second group comprises the alluvial soils, the Puget silty clay, Puget silt loam, and Puget fine sandy loam, which occupy the river valleys and delta flats. These soils are very productive, and a large proportion of their area is under cultivation.

The third group comprises the sedimentary soils, or those derived from material deposited in glacial lakes or ponds. This group includes the soils of the Custer series. The Custer silt loam and Custer loam are the members having compact sandy subsoils, and when well drained these produce very profitable crops. The Bellingham silt loam is a local type included in this group, which is also very productive when properly drained.

The fourth group embraces the soils of the mountainous region. These soils are variable in texture, and owing to the rough topography and to the large amount of stones usually present in both soil and subsoil they are of small agricultural value.

The fifth group embraces the soils derived from material deposited as glacial outwash. This group includes soils of the Lynden series and the Spanaway series. The Lynden soils are excessively drained, but where intensively cultivated they produce very profitable yields. The Spanaway soils are also excessively drained, and the gravelly sandy loam is of little agricultural value.

The sixth group includes the beach deposits, which are of no agricultural value.

Chemical analyses show that the soils compare favorably with soils of other sections having similar climatic conditions.

Four soils are easily recognized by their flora: the gravelly prairie (Spanaway gravelly sandy loam), Muck and Peat, and Tidal Marsh. The other types show much variation in the character of the supported vegetation.

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