SOIL SURVEY

Newaygo County Michigan

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UNITED STATES DEPARTMENT OF AGRICULTURE

Agricultural Research Administration

Bureau of Plant Industry, Soils, and Agricultural Engineering

In cooperation with the

MICHIGAN AGRICULTURAL EXPERIMENT STATION

How to Use THE SOIL SURVEY REPORT

FARMERS who have lived in one locality for a long time come to know about the soil differences on their own farms and on those of their immediate neighbors. What they do not know, unless a soil survey has been made, is how nearly their soils are like those at experiment stations or in other localities from which higher yields are reported. They do not know whether these higher yields are from soils like their own or so different that they could not hope to get equally high ones, even if they adopted the practices followed in these other places. The similarities and differences among soils are known only after a map of the soils has been made. Knowing what kind of soil one has and comparing it with soils on which new developments have proved successful will remove some of the risk in trying new methods and varieties.

SOILS OF A PARTICULAR FARM

To find what soils are on any farm or other tract of land, locate it on the soil map, which is in the envelope inside the back cover. This is easily done by finding the township, section, and quarter section the farm is known to be in and locating its boundaries by such landmarks as roads, streams, villages, and other features.

Each kind of soil is marked with a symbol on the map; for example, all soils marked Ia are of the same kind. To find the name of the soil so marked, look at the legend printed near the margin of the map and find Ia. The color where Ia appears in the legend will be the same as where it appears on the map. The Ia means Isabella loam. A section of this report (see table of contents) tells what Isabella loam is like, for what it is mainly used, and some of the uses to which it is suited.

How productive is Isabella loam? Find this soil name in the left-hand column of table 7, and note the estimated yield for different crops opposite and how these compare with yields for other soils in the county.

Read in the section on Soil Types and Phases to learn what are good uses and management practices for Isabella loam, and refer to the section on Soil Association Groups for additional general information on use and management.

SOILS OF THE COUNTY AS A WHOLE

If a general idea of the soils of the county is wanted, read the introductory part of the section on Soils. This tells where the principal kinds are found, what they are like, and how they are related to one another. Then study the soil map and notice how the different kinds of soils tend to be arranged in different localities. These patterns are likely to be associated with well-recognized differences in type of farming and land use.

A newcomer who considers purchasing a farm in the county will want to know about the climate as well as the soils; the types and sizes of farms; the principal farm products and how they are marketed; the kinds and conditions of farm tenure; kinds of equipment and machinery; availability of schools, highways, railroads, and telephone and electric services; water supplies; industries; and cities, villages, and population characteristics. This information will be found in the sections on General Nature of the Area and on Agriculture.

Students and others interested in how the soils of the county were formed and how they are related to the great soil groups of the world should read the section on Morphology and Genesis of Soils.

This publication on the soil survey of Newaygo County, Mich., is a cooperative contribution from the—

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SOIL SURVEY OF NEWAYGO COUNTY, MICHIGAN

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United States Department of Agriculture, in cooperation with the Michigan Agricultura Experiment Station

CONTENTS

AGRICULTURE is the principal industry in Newaygo County, both in value of products and in the number of people employed. At first the county was exploited for its timber resources, but farming became important as an adjunct to lumbering and continued on the better soils after the stands of timber were depleted. The present agriculture is diversified; the types of farms are (1) orchard; (2) general crops; (3) dairy and cattle; (4) subsistence; and (5) specialized crops. Livestock raising and dairying are major occupations. Corn, wheat, oats, potatoes, and hay are staple crops. Acreages of alfalfa have increased rapidly in recent years. Market vegetables, onions, and fruits are grown on specialized farms, or on general farms as a supplemental source of income. Apples are the main orchard crop. Much of the milk, fruit, and vegetables produced are processed within the county. To provide a basis for the best agricultural uses of the land cooperative soil research and mapping of the soils was begun in 1939 by the United States Department of Agriculture and the Michigan Agricultural Experiment Station.

GENERAL NATURE OF THE AREA

LOCATION AND EXTENT

Newaygo County is in the west-central part of the Lower Peninsula of Michigan (fig. 1) and is separated from Lake Michigan by Oceana and Muskegon Counties. It is rectangular, 36 miles long and 24 miles wide, with a total area of 857 square miles, or 548,480 acres. White Cloud, the county seat, is 85 miles northwest of Lansing, the capital of the State, and 40 miles north of Grand Rapids.

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

The county is located in the central upland division of the State, which is covered by a thick deposition of glacial drift, and in the last

FIGURE 1.—Location of Newaygo County in Michigan.

glaciation most of it was probably covered by the Lake Michigan ice lobe.[1] Surface features are therefore of glacial origin, showing considerable variety in relief but no great range in elevation.

The major topographic divisions are (1) rolling or hilly plateau uplands and (2) plains. The uplands, or moraines, are an accumulation of materials deposited by glaciers, and the general direction of their longer axis is north and south. The plains are made up of glacial outwash, ice-laid till, and lacustrine (lake) deposits.

The location of the plains and uplands is difficult to visualize from a written description, as they are irregular in shape, size, and occurrence. Locating the various areas on the soil map as they are dis-

[1] LEVERETT, F., and TAYLOR, F. B. THE PLEISTOCENE OF INDIANA AND MICHIGAN AND THE HISTORY OF THE GREAT LAKES. U. S. Geological Survey Monog. 53, 529 pp., illus. 1915.

cussed in the following paragraphs will make their arrangement and relation more easily understood.

Stream dissection has not greatly modified the land surface, except in the Muskegon Valley, and the land surface is largely constructional. It remains in its configuration much as it was left when the last glaciers receded.

The secondary topographic features are those normally found in areas where there are moraines, till plains, outwash plains, and old glacial drainage valleys. These consist of (1) rounded hills; (2) basins; (3) dry valleys; (4) a complexity of short slopes related to the constructional features of glacial origin rather than to geologic erosion or stream dissection; (5) stretches of smooth and pitted dry sandy and gravelly plains; (6) low gravelly knolls and ridges; (7) rounded depressions or pot holes; (8) shallow swales and complementary swells of upland; (9) widely distributed large and small swamps, complex in outline; and (10) lakes of various shapes and sizes.

The two major topographic divisions can be subdivided into three types of hill land and four types of plains. These features are described in some detail in the following paragraphs.

The hilly uplands, morainic in origin, that rise from 20 to 250 feet above the bordering plains consist of ridges, hummocks, knobs and complementary basins, valleylike depressions, and sags. Some of the sags are occupied by lakes and swamps while others are dry. Some depressions are small obstructed valleys that were possibly once occupied by streams; others are merely rounded and saucerlike. Slopes are either simple and uniform, like those in the smooth uplands, or short, complex, and variable, like those in the more rugged uplands. The gradient usually does not exceed 15 percent, and most slopes are gently rounded. Small level areas of outwash, old stream terraces, and narrow filled-in valleys are numerous. In a few places streams have cut sharply defined trenches in the valley floors and plains, but these stream-cut slopes seldom exceed 20 feet in depth.

Rough broken upland occurs locally throughout the hilly areas. The slopes are irregular, those with a gradient in excess of 15 percent forming conspicuous features of the landscape. Kamic gravelly hills and small steep-sided pot holes are numerous.

The gently rolling uplands are, in contrast, characterized by smooth slopes, a relief interval of not more than 20 feet, and shallow, poorly drained depressions. These areas are dominantly ground moraines and shallow outwash deposits over clayey drift.

The four types of plains are: (1) Wet plains with a dominantly mucky surface; (2) smooth dry sandy plains; (3) sandy lake-bed plains trenched by streams; and (4) deeply pitted sandy and gravelly plains.

The plains consist chiefly of glacial-outwash sand and gravel underlain at varying depths by clayey till. Narrow, conspicuous sand ridges and other topographic features suggest that temporary lakes were impounded in some places during or after the glacial recession. Some areas of outwash have been exposed to wind action, possibly before they were covered with vegetation, resulting in a billowy topography.

The most continuous and elevated upland lies 150 to 250 feet above the adjacent plains. It comprises a large part of the northeastern quarter of the rectangular county, including parts of Barton, Norwich, Goodwell, and Big Prairie Townships. According to Leverett,[2] the hills of this upland southwest of Hawkins reach an altitude of more than 1,200 feet. From this high point of the upland to the plain on the south and west the decrease in elevation is 150 to 250 feet. In the central part north of White Cloud are the headwaters of the White River and its tributary, Mullen Creek, both flowing southward. The headwaters of the northward-flowing Little South Branch Pere Marquette River also are in this plain. In Monroe Township the plain is marked by a great number of pitlike depressions, many of which are occupied by lakes and peat bogs.

On the west a bold front of another upland bounds the plain just described and still farther to the west the upland gives way to the lowland around Biteley. The roughest part of this highland is southwest of Indian Lake, where steep slopes and a local relief interval of more than 100 feet dominate the landscape. The drop from the upland to the plain is approximately 100 feet.

The plain around Biteley is followed by another upland and then the lowland of Troy Township, which is in the northwestern corner of the county. This lowland, which extends south to the plain of the White River Valley, is the swampy headwater of the Big South Branch Pere Marquette River.

From the western county line near Allen Creek an irregular, discontinuous highland mass of glacial drift extends southeastward to Grant. The elevation of this extensive upland does not exceed 900 feet. It is cut at Hesperia by a valley plain occupied by the White River, and again at Newaygo, by the valley of the Muskegon River. Both streams flow southwest. On its eastern front this upland area is low, except north of Aetna, north of Dutch Lake, and near Newaygo. In those places the upland is rough and broken and descends abruptly to the plain. The rough uplands north of Newaygo, north of Fremont, and northwest of Huber are characterized by relatively strong relief, kamic hills, and steep-sided depressions occupied by lakes. On both sides of the White River Valley and the small valley plain east of Dayton Center are comparatively bold fronts, but the upland is not extremely hilly once the sharp abutments have been crossed. In contrast to these hilly uplands are areas of smooth upland south of Volney, south of Fremont, and at Ashland Center.

Bridgeton Township and parts of Sheridan and Garfield Townships in the southwestern part of the county comprise a plain having an elevation of about 800 feet. The Muskegon River flows southwest through this plain in a trenched valley 80 to 100 feet deep. Small tributaries have cut back from the river-valley lowland and have developed deep, steep-sided ravines, with little or no valley filling. Ravines only a few hundred yards long are frequently cut to depths of 30 to 40 feet.

Another highland area extends north through Ensley into Croton Township, where it terminates at the Little Muskegon River Valley. At Croton, as at Newaygo, the upland has considerable elevation above the plain; in addition, the river has cut to a depth of more than 100

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[2] LEVERETT, F., and TAYLOR, F. B. MAP OF THE SURFACE FORMATIONS OF THE SOUTHERN PENINSULA OF MICHIGAN. U. S. Geol. Survey. 1924.

feet. Consequently, where the uplands adjoin the valley, relief intervals from the river to the hilltops may exceed 200 feet. South of Ensley Center the upland is knobby and broken, but eastward it smooths out so that the southeastern part of Ensley Township has the appearance of a plain with a very even skyline. This plain is characterized, however, by a large number of irregular, steep-sided, pitlike depressions. Conover, Baptist, and Englebright Lakes occupy the largest of these basins. Elsewhere the depressions are much smaller. Locally they are so numerous and so closely associated that the topography is apparently rough and not very different from the upland to the west.

The poorly drained plain between Ensley Center and Grant forms the headwater of the Rogue River. West of Ransom Lake a broad depression in this plain was formerly occupied by Rice Lake, a shallow body of water recently drained to make the peat and muck soils of its basin available for cultivation.

The Muskegon River Valley is an outstanding physical feature of the county. This valley is 1 to 3 miles wide and across the entire county has cut to depths of 100 feet or more below the adjacent lands. At Croton and near Oxbow dams have been constructed across the valley to create hydroelectric power. These have impounded water for some distance upstream, forming artificial lakes. Below Croton Dam the river channel is 200 to 300 feet wide.

Flood plains in the valley of the Muskegon River are for the most part fragmentary. They extend intermittently along the channel, alternating from one side to the other as the river meanders. Three distinct sandy and gravelly terraces can be traced, although they are not everywhere continuous and well defined but have been considerably cut and reworked by the meandering stream. The first terrace lies at 10 to 20 feet above the present channel; the second, 25 to 40; and the third, about 80 feet. All three are composed of loose stratified sand and gravel, 2 to 40 feet thick and resting on older sandy drift or, in places, on beds of ice-laid or lacustrine clay. At the Muskegon County line the river valley has an elevation of less than 600 feet. From this point, the lowest in the county, to the high hill southwest of Barton Township there is a difference in elevation of more than 600 feet.

Lakes of both the pit and the kettle type are well distributed throughout the county, although most large bodies of water are located within 10 miles of the town of Newaygo. They are irregular in outline and commonly possess neither inlet nor outlet. Twenty lakes cover more than 160 acres; some have sandy beaches that provide excellent resort facilities. More than 100 smaller lakes all possess desirable recreational features, but a few are swampy, muck-filled, inaccessible, or otherwise unfit as resort sites. In addition there are numerous small intermittent and permanent ponds. Lake waters are generally clear, alkaline in reaction, and of varying degrees of hardness. Kettle lakes, particularly where they are associated with calcareous moraines, are often underlain by marl, which serves in some places as a convenient source of liming material. Pit lakes, especially those on the sandy plains, are seldom marly, and the water in those surrounded by leatherleaf bogs is likely to be neutral or slightly acid.

Permanent streams are not numerous. All the large streams are tributary to rivers that flow into Lake Michigan. The principal river is the Muskegon. A few small streams, mostly intermittent, feed into local lakes and ponds.

WATER SUPPLY

The ground-water table varies greatly in depth. On the poorly drained plains it is present at a depth of a few feet. In the uplands and on the dry plains a water supply is obtained from wells 30 or 40 feet to 200 feet deep. The supply thus obtained is dependable. In hardness the water varies from 10 to 25 grains to the gallon. In a few places there are flowing wells. In others are springs and seeps, where a hanging water table emerges on the ground surface.

CLIMATE

The climate of Newaygo County is continental. Winters are fairly long and cold, and summers are short and mild. Seasons change gradually, the average difference in temperature being 20° F. between winter and spring, 24° between spring and summer, 19° between summer and fall, and 23° between fall and winter. Both spring and fall are characterized by sharp freezes and cold waves, but extremes of temperature are more frequent in spring, and the maximum fluctuations occur in that season. Spring is somewhat colder than fall. Fall approaches gradually and is usually the pleasantest part of the year.

The mean winter temperature is 23.4° F., but fluctuations from 59° to −37° have been recorded. Summers are mild, the average temperature being 68.1°. There are occasional hot spells, however, during which a maximum temperature of 102° has been recorded. These hot days may be oppressive because of high humidity.

The average frost-free period at Croton Dam generally extends from May 17 to September 26, making a growing season of 132 days. This is ample for the production of a wide range of crops. The frost-free period varies considerably, however, with elevation and air drainage. In many places frost may occur any month of the year. Killing frosts have been recorded as late as June 23 and as early as September 10. Along the west side of the county the tempering influence of Lake Michigan is evident in a frost-free period that is several days longer than in the eastern part.

The average annual precipitation is 31.14 inches, including melted snow. The yearly snowfall averages 40.5 inches. Snow sometimes accumulates to a depth of 2½ or 3 feet and may always be depended upon to protect fall-sown grain crops. Melting snow and ice in spring cause the only major variations in stream levels. Precipitation is fairly well distributed throughout the year and is sufficient for high crop production. General crop failures due to a deficiency or excess of water have never occurred, although rainfall shows considerable annual and seasonal variation. On sandy soils, however, crops may suffer from a lack of moisture because of infrequent rains during critical growing periods. Summer precipitation is frequently in the form of thundershowers; some hail may fall but seldom so severely as to cause serious crop damage.

The prevailing winds are westerly. They rarely attain high velocity and are therefore seldom destructive to crops or to soils other than dry muck and loose incoherent sands in exposed positions. Tornadoes are uncommon, but some of limited intensity and extent have occurred. Cold spells are often accompanied by blizzards.

Weather data compiled from records of the United States Weather Bureau station at Croton Dam are presented in table 1. These figures are probably fairly representative of conditions that prevail over a large part of Newaygo County, although there are marked local differences in susceptibility of crops to frost damage.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Croton Dam, Newaygo County, Mich.*

[Elevation, 722 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year [1]	Total for the wettest year [2]	Average snowfall
	° F.	° F.	° F.	*Inches*	*Inches*	*Inches*	*Inches*
December	26.4	57	−26	1.97	1.17	1.66	10.0
January	22.1	59	−32	1.82	2.86	1.94	11.6
February	21.8	57	−37	1.69	2.46	2.25	7.4
Winter	23.4	59	−37	5.48	6.49	5.85	29.0
March	31.2	77	−18	2.08	1.38	1.21	7.1
April	44.0	85	−2	2.98	1.48	4.68	1.1
May	56.1	94	20	3.16	2.05	5.69	.1
Spring	43.8	94	−18	8.22	4.91	11.58	8.3
June	65.6	97	31	3.13	2.02	4.97	0
July	70.6	102	38	2.74	.86	2.14	0
August	68.2	98	37	2.65	.78	1.27	0
Summer	68.1	102	31	8.52	3.66	8.38	0
September	61.3	95	29	3.23	2.20	5.26	0
October	49.7	86	16	3.11	1.78	7.33	.3
November	37.3	70	5	2.58	1.14	4.00	2.9
Fall	49.4	95	5	8.92	5.12	16.59	3.2
Year	46.2	102	−37	31.14	20.18	42.40	40.5

[1] In 1930. [2] In 1911.

VEGETATION

Forest originally covered more than 96 percent of the entire county—all parts except small open marshes and scattered areas in the dry plains of Big Prairie and Croton Townships. Early settlers found four associations of forest on the uplands: (1) Extensive stands of white and red pines, in which were included oak and aspen; after lumbering and burning, the pine did not reproduce, and the land now supports oak, aspen, and red maple, and a ground cover of sweetfern and grasses. (2) Chiefly hardwood of hard maple, beech, yellow birch, and hemlock; small virgin stands of this forest still exist, and the second growth is similar to the original but often includes red maple, white birch, and aspen as dominant species. (3) An open sparse stand of jack pine and oak, with a ground cover of grasses and shrubs; being of slight commercial importance, this original cover has been relatively undisturbed. (4) A mixed forest of white pine, hemlock, yellow birch, elm, ash, and other hardwoods; after lumbering and repeated burning the second growth is mainly aspen.

On the dry sandy plains of Croton and Big Prairie Townships there was a cover of grass and associated herbaceous plants, such as bluestem (*Agropyron*), asters (*Artemisia*), leadplant, sedge (*Carex*), and scattered clumps of prickly-pear cactus.

On wet lands and swamps occurred five kinds of cover associations: (1) On areas originally covered dominantly with white pine, a growth, since lumbering, of aspen, white birch, briers, willows, and swamp shrubs; (2) on wet clay lands, a growth of elm, black ash, red maple, basswood, and aspen mixed with conifers; (3) on peat soils, dense stands of tamarack, arborvitae, and black spruce; (4) on marshes, an association made up of marsh grasses (wiregrass and bluejoint), sedges (*Carex*, *Scirpus*, and *Cyperus*), cattails (*Typha*), and rushes (*Juncus*); and (5) on leatherleaf bogs, mosses (*Hypnum* and *Sphagnum*), sedges, blueberries, cranberries, and an occasional black spruce or tamarack.

EARLY SETTLEMENT, POPULATION, AND PUBLIC FACILITIES

Newaygo County is in a section of Michigan that was first exploited for its timber. As early as 1837, a settlement was established at the junction of Bigelow Creek and the Muskegon River north of the present site of Newaygo. Ten years later a settlement supported by lumber mills at the present site of Croton was sufficiently important to justify the building of a road to Grand Rapids. The land units then were large, and the owners were interested chiefly in selling timber. Some subsistence farming was practiced, first by laborers who remained on the cut-over land and later by settlers who moved in as the lumbering industry declined. A few staples, including corn and potatoes, were produced for home consumption, but a great part of the year was spent in clearing land and in working in lumber camps and mills.

The first permanent settlements were established between 1840 and 1850 by pioneers from New England, New York, Pennsylvania, Ohio, and southern Michigan. These families depended upon lumbering and trapping for their cash income, which was supplemented by produce from a mixed system of farming.

The influx of settlers was rapid and steady until 1890 when the rural population reached a peak of 20,476. Ten years later it had declined to 17,673, after which it remained relatively constant. In 1940 the total population was 19,286, of which 16,766 was rural. Most of the population is in the southern part of the county, chiefly on the upland extending from Volney to Grant. Fremont, the largest center, has a total of 2,520. Other villages of considerable size are White Cloud (the county seat), Newaygo, Hesperia, and Grant.

The county is served by two railroad lines. A network of improved gravel and concrete roads makes all parts readily accessible. Public schools are well distributed. The larger villages have high schools, and rural churches are conveniently situated. Rural electrification has made electric power available to a large proportion of the farmsteads, and telephone lines reach all the settled areas.

AGRICULTURE

Agriculture is the principal industry in Newaygo County, both in value of products and in the number of persons engaged. Much of the farm produce is consumed within the county. Exported products, chiefly fruits and vegetables, are shipped by truck and railroad to the larger cities of Michigan, Ohio, Wisconsin, Indiana, and Illinois. Considerable quantities of potatoes and apples are sold to truckers at the farms, but a few farmers market their own produce in Grand Rapids, Muskegon, and Chicago. Large quantities of fruits and vegetables are processed in Fremont for distribution throughout the United States. Cream and milk also are processed within the county.

EARLY AGRICULTURE

Early agricultural use of the land was purely exploitative. In a sense, this is still generally true, although increasing numbers of farmers are becoming conscious of the desirability and necessity of planning to maintain or increase the natural productivity of their soil. Much land is inefficiently used or is deteriorating because of economic conditions beyond the control of the occupants. Temporary occupancy, low land values, and the fact that the size of the farms and the type of farming have not been adjusted to the natural character of the land are among the negative economic factors.

Early settlers were not guided in their selection of land. Further, the rectangular system of surveying and consequent homesteading and sale according to arbitrary units, regardless of natural boundaries, resulted in waste of both land and human effort. The less fertile and less durable soils were sometimes deliberately selected because they were easier to clear and till and offered more healthful living sites.

Farming became more commercialized as the population increased and markets developed. When lumbering passed its climax, farmer-laborers dependent on this industry for a cash income were forced to do more farming. They established orchards and planted greater acreages to beans, wheat, and corn.

Much of the sloping land and a large part of the sandy land that is now marginal, the Big Prairie, for example, once afforded good subsistence farming and a measure of prosperity. Now many of these light-textured soils have been abandoned or are, at most, furnishing only scant subsistence. Their natural fertility has been depleted and the land surface has deteriorated through wind and water erosion. These soils cannot compete with the heavier textured more durable and productive soils that were cleared later.

There has been a general adjustment to changing economic conditions and some conformity between agricultural practice and the natural environment. There are, however, numerous lags in adjustment and many individual instances of misuse and abuse of land. Ideal soil conservation and complete efficiency in the use of land for individual profit are hardly to be expected, but a better understanding of natural conditions, of the kinds of soil and land and of their geographic distribution, could result in better land use if the knowledge were applied. Such knowledge may be utilized as changing conditions cause new adjustments in agricultural procedures and land ownership. It may also prove of value in the management of land not cleared for agricultural use.

Competition may possibly limit crop production to the best land and leave a large aggregate acreage for forestry, grass, and pasture or some similar use. Whether the trend is toward an increase or a decrease in the acreage used for farm enterprises, a wider knowledge of the nature of soils should contribute to a better understanding of agricultural problems and aid in planning future land use.

LAND USE

The total land in farms and the number of farms reached a maximum in 1910, after which there was a decline in both, comparable to the decline in population. In 1940 the 2,799 farms averaged 100.2 acres each. About half the land in farms was classified as available for crops. About the same methods are followed and the same crops grown from year to year. The average value of the land, buildings, and implements and machinery on each farm was $3,617. The stability of farming is indicated by the fact that in 1940 there were 2,004 farms operated by full owners, and of these, 1,045 were free from mortgage debt. There were 2,425 automobiles, 441 trucks, and 763 tractors on farms. Of the 2,799 farms in the county, 818 were equipped with telephones. A total of 1,672 farm dwellings were lighted by electricity. Farm laborers earned $194,573 on 992 farms in 1939. The trend in number, value, size, and tenure of farms is indicated in table 2.

TABLE 2.—*Farm areas, values, and tenure in Newaygo County, Mich., in stated years*

Year	Farms				Land in farms		Farms operated by—		
	Number	Average size	Average value of land per acre	Average value of all farm property	Percentage of county area	Percentage of improved farm land	Owners	Tenants	Managers
		Acres	*Dollars*	*Dollars*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1850	(1)	(1)	(1)	(1)	0.3	51.6	((1)	(1)	(1)
1860	(1)	(1)	(1)	(1)	3.0	38.0	(1)	(1)	(1)
1870	516	190.6	(1)	[2] 511	18.1	22.3	(1)	(1)	(1)
1880	1,667	88.0	(1)	1,858	27.0	42.5	89.3	10.7	0
1890	2,284	82.0	(1)	1,998	34.2	48.4	90.5	9.5	0
1900	2,846	98.9	11.21	1,969	51.7	48.7	89.1	10.2	.7
1910	3,130	104.1	21.43	3,942	59.8	51.0	89.1	10.2	.7
1920	2,836	111.8	27.07	5,902	58.2	52.8	85.1	13.8	1.1
1930	2,335	112.3	40.45	5,878	48.2	54.0	85.5	13.8	.7
1940	2,799	100.2	31.46	4,189	51.1	57.7	83.8	16.0	.2

[1] Not available.
[2] Implements, machinery, and domestic animals only.

CROPS

Newaygo County has been relatively uninfluenced by the industrial expansion and growth of cities in Michigan because it is too remote from urban centers to be invaded by part-time suburban farmers. Urban and industrial growth in southern Michigan, however, has created a demand for farm products and thereby has indirectly brought about the development of truck-crop farming, dairying, livestock raising, and such specialized agricultural activities.

The agriculture is diversified. On nearly all farms there are several crops and sources of income. Five types of farms can be recognized as follows: (1) Farms, few in number, on which the chief source of income is fruit crops; (2) general farms that depend on hay, grain, potatoes, and a few dairy cows for income, and on which lima beans or peas are often raised as an additional cash crop; (3) farms used primarily for dairying, which in 1939 was the most important undertaking in the county from the standpoint of cash income; (4) small subsistence and part-time farms, usually on the poorer land, that have a few acres of various crops, one or two cows, a few chickens, and for a cash income a small plot of beans, cucumbers, or other special crops; and (5) specialized farms (mainly on muck land) on which are grown onions, spinach, table beets, celery, carrots, and other truck crops.

Corn, wheat, oats, hay, and potatoes have always been staple crops, and since 1880 rye has increased in importance. The wheat and oat acreage has declined in the past few years, while that in alfalfa has rapidly increased. Total acreages in hay have shown a rather steady increase since 1879. In 1939 snap beans were produced to the value of $16,583; green lima beans, $21,373; dry onions $176,955; and green peas, $1,518. Tomatoes, cabbage, spinach, and table beets were also important truck crops. The principal orchard crop has always been apples, although a few peaches, pears, and cherries are grown. Grapes are being produced in increasing quantities. The acreages of the principal crops and the number of bearing fruit trees and grapevines are given in table 3.

TABLE 3.—*Acreage of principal crops and number of bearing fruit trees and grapevines in Newaygo County, Mich., for stated years*

Product	1879	1889	1899	1909	1919	1929	1939
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Corn, all purposes	5, 934	8, 886	22, 516	19, 572	18, 030	14, 046	17, 645
Wheat, threshed	9, 229	11, 138	17, 985	7, 534	9, 348	3, 777	3, 477
Oats, threshed	2, 848	6, 692	3, 083	11, 601	15, 553	12, 720	8, 804
Buckwheat	293	1, 442	1, 383	1, 169	643	339	148
Barley	161	184	84	95	539	460	340
Rye	332	1, 617	8, 934	9, 675	18, 520	5, 974	2, 074
Sugar beets	[1]	[1]	101	84	17	[1]	[1]
Potatoes	1, 562	3, 022	5, 256	7, 899	5, 378	3, 128	2, 546
Dry edible beans	934	[1]	637	3, 512	6, 512	7, 136	6, 659
Soybeans, vetches, and Canada and other ripe field peas	[1]	[1]	122	643	91	59	73
All hay	[1]	[1]	19, 598	28, 370	31, 383	33, 969	34, 515
Alfalfa	[1]	[1]	3	96	537	5, 161	18, 297
Timothy and timothy and clover	[1]	[1]	[1]	24, 776	25, 817	20, 542	12, 844
Clover	[1]	[1]	989	1, 865	1, 168	7, 483	326
All other cultivated and wild grasses	[1]	[1]	18, 106	1, 463	2, 041	494	1, 861
Grains cut green	[1]	[1]	500	170	1, 670	231	1, 013
Legumes for hay	[1]	[1]	[1]	[1]	150	58	174
Vegetables	[1]	[1]	[1]	1, 481	1, 652	2, 183	3, 380
Strawberries	[1]	[1]	31	30	89	89	37
Raspberries	[1]	[1]	23	25	45	102	42
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Apples ... trees	[1]	55, 823	109, 752	104, 191	115, 194	92, 139	68, 957
Peaches ... do	[1]	3, 270	163, 615	195, 325	9, 310	8, 003	8, 598
Pears ... do	[1]	1, 117	4, 605	4, 166	3, 347	1, 432	1, 179
Plums ... do	[1]	1, 505	14, 589	4, 488	1, 865	1, 441	361
Cherries ... do	[1]	4, 155	7, 951	5, 247	8, 297	3, 041	10, 625
Grapes ... vines	[1]	[1]	8, 663	12, 624	5, 363	27, 211	52, 746

[1] Not available.

The values of the various agricultural products are shown in table 4.

TABLE 4.—*Value of agricultural products in Newaygo County, Mich., in stated years*

Product	1909	1919	1929	1939
Cereals	$565, 473	$1, 739, 636	$422, 781	$439, 148
Other grains and seeds	62, 891	299, 070	249, 329	188, 489
Hay and forage	401, 500	1, 008, 130	626, 525	495, 052
Vegetables and potatoes	194, 153	1, 010, 515	329, 417	487, 544
Fruits and nuts	257, 901	540, 240	144, 581	118, 177
Other crops	134, 731	11, 791	11, 657	6, 656
Forest products	(1)	(1)	183, 051	[2] 17, 902
Animals sold and slaughtered	[3] 378, 552	(1)	(1)	[4] 372, 934
Dairy products sold	356, 132	656, 224	798, 942	728, 699
Wool	17, 446	23, 541	5, 602	3, 794
Poultry and eggs	168, 737	330, 161	645, 096	289, 841
Honey	4, 789	3, 360	5, 773	1, 145

[1] Not reported.
[2] Forest products sold.
[3] Includes cattle, swine, sheep, goats, horses, mules, burros.
[4] Cattle, swine, and sheep only.

LIVESTOCK

The 1940 census reported 21,423 cattle and calves over 3 months old, of which 11,991 were cows and heifers milked in 1939. There were 4,401 horses and colts over 3 months old; 13,673 cows and heifers; 2,063 sheep and lambs over 6 months old; 4,649 swine over 4 months old; 132,288 chickens over 4 months old; and 1,209 turkeys over 4 months old. Considerable numbers of ducks, geese, and other fowls are raised.

FERTILIZERS

In an effort to increase crop yields and maintain productivity the use of local deposits of marl as a liming material is becoming an accepted practice, especially in the production of alfalfa. Commercial fertilizer also is generally used. The tendency is toward the use of fertilizer for all crops and the employment of more concentrated mixtures, though many farmers still depend largely on barnyard manure. On muck lands, potash alone or mixtures containing large quantities of potash are in common use for truck crops; other amendments, such as copper sulfate and manganese sulfate also are employed. Careful seed selection and the employment of recommended tillage methods are additional evidence that the purely exploitative phase of agriculture is in its decline. In late years an increasing number of farmers have become aware of the need for conservation, especially in preventing erosion. They are following methods of crop rotation and cultivation that aid in maintaining the fertility and productivity of the land. The trend in use and cost of commercial fertilizer are shown in table 5.

TABLE 5.—*Use and cost of commercial fertilizer in Newaygo County, Mich., in stated years*

Year	Farms reporting	Percentage of farms in county	Cost of fertilizer used	
			Total	Average per farm
	Number	*Percent*	*Dollars*	*Dollars*
1910	73	2. 3	1, 952	26. 74
1920	423	14. 9	20, 784	49. 13
1930	610	26. 1	32, 874	53. 89
1940	662	23. 7	50, 915	76. 91

SOIL SURVEY METHODS AND DEFINITIONS

In making a soil survey the soils are examined, classified, and mapped in the field and their characteristics recorded, particularly in regard to the growth of various crops, grasses, and trees.

The soils and underlying formations are examined systematically in many locations. Test pits are dug, borings made, and highway or railroad cuts and other exposures studied. Each reveals a series of distinct soil layers, or horizons, termed collectively the soil profile. Each horizon, as well as the underlying parent material, is studied in detail, and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stones are noted. The chemical reaction of the soil and its content of lime and salts are determined by simple tests.[3] Other features taken into consideration are drainage, both internal and external, the relief, or lay of the land, and the interrelations of soil and vegetation.

The soils are classified according to their characteristics, both internal and external, with special emphasis upon the features that influence the adaptation of the land to the production of crop plants, grasses, and trees. On the basis of these characteristics the soils are grouped in the following classification units: (1) Series, (2) types, (3) phases, (4) complexes, and (5) miscellaneous land types.

The series is a group of soils having the same genetic horizons, similar in important characteristics and arrangement in the profile and having similar parent material. Thus, the series comprises soils having essentially the same color, structure, natural drainage, and other important internal characteristics. The texture of the upper part of the soil, including that commonly plowed, may differ within a series. The series are given geographic names taken from localities near which they were first identified. Emmet, Kalkaska, and Isabella are names of important soil series in Michigan, all named for the counties in which they were originally distinguished.

Within a soil series are one or more soil types, defined according to the surface texture—sand, loamy sand, sandy loam, loam, silt loam,

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

clay loam, silty clay loam, or clay. This term is added to the series designation to give a complete name to the soil type. Oshtemo sandy loam and Oshtemo loamy sand are soil types within the Oshtemo series. Except for the texture of the surface soil these types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the unit to which agronomic data are definitely related. In comparisons of the type and phases of that type, to avoid repetition of their complete names, the type is sometimes referred to as the normal phase.

A soil phase specifically named is a variation within the type, differing from the normal phase of the type in some feature, generally external, that may be of special practical significance but not differing in the major characteristics of the soil profile. For example, within the total range of relief of a soil type some areas may have slopes that allow the use of machinery and the growth of cultivated crops and others may not. Differences in relief and degree of accelerated erosion may be shown as phases. Even though no important differences may be apparent in the soil profile or in its ability to produce native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such instances the more sloping parts of the soil type may be shown on the map as a sloping or a hilly phase. Bellefontaine sandy loam, hilly phase, is an example of a phase in the Bellefontaine series.

In this part of Michigan, the glacial drift is generally a complex mixture of various textures. In some places, two or more soil units may be in such intimate or mixed pattern that they cannot be clearly shown separately on a small-scale map but must be mapped as a complex. Examples of soil complexes are found in Isabella-Iosco sandy loams and in Isabella-Montcalm sandy loams.

Some areas of land that have little or no true soil are termed miscellaneous land types. Examples in this county are Burned peat and muck over sand, and Rough broken land (Arenac and Plainfield soil materials).

SOILS

The soils of Newaygo County show great variations in texture, structure, chemical composition, fertility, and moisture-retaining capacity. Diverse soils are intimately associated within a small area, and extreme variations may occur within short distances. These characteristics are common to the State as a whole and are inherent in regions covered with deep glacial drift.

The plow layer ranges from loose incoherent nearly pure sand to moderately heavy silt loam and clay loam. In acreage, loamy sands and sandy loams are the dominant textures. Roughly three-fourths of the agricultural soils are loamy and free-working under all conditions. Minor areas of stony or heavy clay lands are difficult to till, and the muck and peat lands have their own peculiar tilth characteristics.

The soils are dominantly of types that have a low organic-matter content in the plow layer—less than 2 percent by weight. It is estimated that 70 percent are of this kind. Some of the remaining soils

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are intermediate to high in organic content, the range being from 2 to 4 percent. Others, including muck and peat soils, have an organic-matter content of more than 4 percent. The humus layer in well-drained virgin soils is not more than 3 inches thick, and there is little organic coloring in cultivated areas below 6 or 7 inches. These soils can be penetrated to considerable depth, since the parent material of unconsolidated glacial drift is many feet thick. Nearly all the well-drained soils are acid just beneath the humus layer. When plowed, the plow soil is usually slightly to strongly acid. At a depth of less than 48 inches, however, approximately 95 percent contain sufficient calcium, magnesium, or other bases to give an alkaline reaction. The remaining 5 percent, sandy upland soils, may have an acid reaction to a depth of 6 to 8 feet or more.

The reaction in the surface layers of the imperfectly and poorly drained mineral soils is usually nearly neutral. A large proportion of the muck and peat is nearly neutral or slightly acid. Exceptions are found in some mucks of the Rice Lake area, which are extremely alkaline; the leatherleaf bogs in the northern townships are in contrast very strongly acid.

In productivity the agricultural soils are medium. They range, however, from very low to high. Part of the county, including the areas of well-drained sands and loamy sands, is naturally low in productivity because of both a lack of moisture and a scarcity of available plant nutrients. Some areas are low in mineral elements, particularly potassium. In others, unless the water table is controlled, there is either too much moisture or not enough. Muck and peat lands are among those having such deficiencies.

SOIL ASSOCIATION GROUPS

The soil association groups of Newaygo County are considered from the standpoint of land management and crop adaptation, because physical features other than the surface soil influence land values and land uses. Important features are shallow depressions occurring on both uplands and plains; deep basins or pot holes containing lakes and swamps; and kamic hills, old glacial drainage valleys, and complex slopes formed by the glaciers that once covered this part of the State. Slopes seldom conform to the valleys; but they do conform to the depressions, which may be circular, elliptical, or irregular in outline.

The depressions may be dry or filled by ponds that support a growth of cattails, sedges, and other marsh plants, or shrubs and trees. Slope surfaces around the deep basins are seldom even and smooth. Instead, the longer slopes of the hilly uplands are made up of innumerable billowy, choppy, or undulating smaller slopes, bewildering in their complexity and occurring without any order or regularity.

For the purpose of discussing land management and crop adaptation, the soils of the county are grouped in five associations. In addition to these five, muck and peat swampland is a conspicuous feature of the landscape. Because of the size of the separate bodies and, in some places, because of their intricate association with the higher land, this kind of land has been a factor in the development of the county. It has not only restricted settlement but also influenced land use and the nature of the crops grown. The swamps occur as narrow and elongated areas in valleys, as extensive plains or large basins spotted with islands of dry land, or as small separate bodies, representing former lake sites in the uplands.

GROUP 1

The soils in group 1 are nearly level to undulating loams and silt loams underlain by lacustrine clay, silt and sand, or clay till. This group is an association of Kent silt loam and nearly level areas of Isabella loam. It also includes small areas of Arenac fine sandy loam, Ottawa loamy fine sand, Munuscong sandy loam, and Bergland clay loam. Soils in this group are confined mainly to the smooth upland areas near Fremont, Ashland Center, and Volney, but other small bodies are in Bridgeton Township.

Some of the most durable and valuable soils in the county are included in group 1. Although well suited to general farming, most of the depressions require artificial drainage for efficient agricultural use. The heavy-textured surface soil presents a problem in plowing and other tillage because it can be worked only within a narrow moisture range. Fall plowing often proves satisfactory because freezing and thawing of the overturned furrow aids in promoting good tilth. Fall plowing combined with spring plowing serves as a partial control of quackgrass, which is generally a nuisance on land in this group. Slopes, however, are more susceptible to erosion losses, when the soil is plowed in fall than in spring. Turning under sweetclover may be beneficial because the addition of organic matter tends to make the soil loose and friable.

Crop rotation and land use are the same as for group 2.

GROUP 2

The soils of group 2 are undulating to hilly sandy loams underlain by a great diversity of drift deposits, the dominant texture being light sandy clay or clayey sand. Isabella loam, Isabella-Montcalm sandy loams, Isabella-Iosco sandy loams, and Emmet sandy loam together with Washtenaw soils, undifferentiated, Bergland loam, and muck-filled depressions make up this group. A large part of the upland that extends south from Volney through Beaver, Denver, and Dayton Townships and through Sherman, Granfield, Ashland, and Grant Townships is an association of soils in group 2. The topography is that of the smooth hilly uplands, but a small part is rough. The rougher more broken bodies are north of Fremont and near Mountain Hill in Beaver Township.

This land is durable where properly managed and in many respects is the most satisfactory for general or diversified farming. Inherent productivity is high, natural drainage is sufficient, except in a few depressions that must be tiled, and moisture retention is good. Furthermore, the textural and structural characteristics are such that no serious tillage problems are encountered. Slopes are susceptible to serious erosion, however, and lack of soil uniformity is a depreciating factor for some uses.

Crop adaptation and land use for groups 1 and 2 are considered together because they include most of the heavier textured surface soils of the county—the soils that support most of the successful farms. General farming, with some specialization in cannery crops, and livestock raising and dairying, or combinations of the two, are common farm operations. All the orchards in the county are on soils of groups 1 and 2.

The more successful farmers use some form of crop rotation. In their rotations a considerable acreage is used for alfalfa, which thrives on these calcareous drift soils. The surface layers in these groups are high in organic-matter content, which is well maintained by green manuring or by applications of barnyard manure. Ground limestone and marl also are used. Applications of commercial fertilizer usually bring marked crop responses, particularly if the fields are well drained, limed, and in good tilth.

GROUP 3

Morainic diversified hilly sandy soils underlain mainly by sands, but in some places by gravelly drift, comprise group 3. They form most of the hilly uplands of Lilley, Monroe, Lincoln, Merrill, Barton, Norwich, Goodwell, and Big Prairie Townships and small areas west of Newaygo in Garfield Township. There are many soils in this group. In the northern part of the county, Roselawn fine sand, Montcalm-Roselawn complex, and Emmet loamy sand are dominant; Echo loamy sand occupies the depressions. The plow layer and the underlying material are predominantly sandy, but variation in texture is pronounced. Tracts of 40 to 160 acres will contain a few scattered patches of clay an acre or more in extent.

The heavier textured and level areas are suited to small self-sufficient farms and special crops, as cucumbers and beans. Sand and loamy sand are usually so deficient in nutrients and organic matter that only the better areas can be farmed. Much of this land is not well suited to the prevailing types of general farming. It might better be used for extensive sheep and cattle grazing or for forests and recreation.

GROUP 4

In group 4 are the dry soils of the nearly level sandy plains—Grayling sand, Rubicon sand, Kalkaska loamy sand, Plainfield sand, Sparta loamy sand, and Ottawa loamy fine sand. All these soils are poorly suited to farming at the present time. Their organic-matter content is low, except in Sparta loamy sand, and wind erosion has completely removed their surface soil in places. Because of droughtiness and low productivity for most farm crops, forestry is probably the only practical use for a large part of these soils.

Most of the farms abandoned in Newaygo County are on the light-textured, well-drained soils of the third and fourth groups. Lack of fertility and a low moisture-holding capacity are their most serious disadvantages, and under cultivation the greatest problem is the correction of these two faults. For special crops and under special circumstances, irrigation may be practicable but for only a small part of the total acreage. A partial solution is the maintenance of a large supply of organic matter in the surface soil. Manure is valuable for this purpose. Alfalfa and sweetclover are satisfactory green-manure crops and can be used at frequent intervals in the rotation. Not more than two or three crops should intervene between legume seedings. Alfalfa is ordinarily cut for hay one year and plowed under the next, the quantity of growth plowed under being as great as the demand for hay will allow. To obtain good stands of leguminous crops, these light-textured acid soils are usually limed. Lime benefits not only the legume but also the succeeding crops. Although alfalfa and sweetclover are often sown, a successful seeding is seldom obtained when these legumes are sown with a grain crop on the lightest and most depleted soils. Rye, soybeans, and vetch are more satisfactory green manures for these soils.

A crop rotation successfully employed on sandy soils of moderate to high fertility is corn, wheat, oats, clover, or alfalfa. For sandy soils, three successful rotations are: (1) Sweetclover, wheat, corn, alfalfa; (2) rye, sweetclover, corn, alfalfa, grain; and (3) wheat to rye, corn to rye, sweetclover, potatoes, corn to rye, oats. In the last rotation, rye is sown as a catch or cover crop after both wheat and corn.

The low fertility of sandy soils is caused by a deficiency in the organic matter in which nitrogen is stored, and a lack of the minerals that supply potash and phosphorus. Commercial fertilizer usually produces crop increases in years of favorable rainfall.

Tillage practices also must be considered in planning rotations for sandy soils and loamy sands. Plowing does not have the same beneficial effect as on heavier soils. Because plowing is not so beneficial the seedbed is frequently prepared by a disk or a spring-tooth harrow, unless a quantity of plant material is to be turned under. A firm compact seedbed is essential to insure a good moisture contact between soil and seed. This is accomplished by rolling the land. Where intertilled crops are planted, they are cultivated only enough to eliminate weeds.

GROUP 5

In group 5 are the imperfectly drained and wet soils, which are of some value for pasture and in a few places are used for special crops. The soils of this group are Arenac fine sandy loam and loamy sand, Ottawa loamy fine sand, Saugatuck sand, and Ogemaw sandy loam, all of which occur in the drier areas; and Munuscong sandy loam, Newton loamy fine sand, and Granby sandy loam in the wettest parts. The imperfectly drained areas are used with some success for general farming, particularly where clay is near the surface.

Fair yields of beans, potatoes, and timothy and clover hay are not uncommon. In the northern part of the county, where the deep sands predominate, the land is used for pasture or for wild hay. Drainage on Newton and Granby soils would be of doubtful value because the subsoil has a low water-holding capacity. Furthermore, the surface organic matter is quickly exhausted under cultivation, leaving only a gray infertile sand that becomes droughty when the water table recedes in midsummer. These low-lying plains are extremely subject to frosts. Because of these disadvantages, large acreages in the northern townships remain in second-growth timber.

SOIL TYPES AND PHASES

In the following pages the soil types,[4] phases, complexes, and land types are described in detail and their agricultural relations discussed. Their location and distribution are shown on the soil map (in envelope, p. 3 of cover), and their acreage and proportionate extent are given in table 6.

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[4] When a soil type is subdivided into phases, that part of the type having no phase name is considered the normal phase of the type.

TABLE 6.—*Acreage and proportionate extent of the soils of Newaygo County, Mich.*

Soil [1]	Acres	Percent
Antrim sandy loam	4, 198	0. 8
Arenac fine sandy loam	2, 156	. 4
Arenac loamy sand	9, 119	1. 7
Bellefontaine sandy loam	678	. 1
Hilly phase	893	. 2
Undulating phase	135	[2]
Bergland clay loam	553	. 1
Bergland loam	4, 139	. 8
Burned peat and muck over sand	191	[2]
Carlisle muck	9, 320	1. 7
Shallow phase	1, 304	. 2
Echo loamy sand	4, 644	. 8
Edwards muck	1, 800	. 3
Shallow phase	748	. 1
Emmet loamy sand	3, 677	. 7
Eroded phase	401	. 1
Eroded undulating phase	20	[2]
Hilly phase	208	[2]
Undulating phase	2, 731	. 5
Emmet sandy loam	5, 882	1. 1
Hilly phase	112	[2]
Undulating phase	3, 716	. 7
Fox sandy loam:		
Sloping phase	923	. 2
Undulating phase	3, 635	. 7
Genesee sandy loam	769	. 1
Granby sandy loam	10, 609	1. 9
Gravel or marl pits	206	[2]
Grayling sand	24, 860	4. 5
Rolling phase	107	[2]
Undulating phase	5, 624	1. 0
Greenwood peat	3, 124	. 6
Griffin loam and clay loam, undifferentiated	880	. 2
Griffin sandy soils, undifferentiated	9, 324	1. 7
Houghton muck	3, 652	. 7
Shallow phase	632	. 1
Isabella-Iosco sandy loams	2, 486	. 5
Isabella loam	21, 543	3. 9
Hilly phase	1, 222	. 2
Rolling phase	5, 979	1. 1
Isabella-Montcalm sandy loams	16, 366	3. 0
Hilly phases	1, 365	. 2
Rolling phases	5, 633	1. 0
Kalkaska loamy sand	2, 064	. 4
Kent-Arenac complex	2, 115	0. 4
Kent silt loam	3, 192	. 6
Kerston muck	4, 906	. 9
Maumee fine sandy loam	3, 558	. 6
Montcalm-Roselawn complex	28, 575	5. 1
Hilly phases	5, 324	1. 0
Undulating phases	17, 078	3. 1
Munuscong-Maumee soils, undifferentiated	1, 436	. 3
Munuscong sandy loam	5, 336	1. 0
Newton loamy fine sand	37, 547	6. 9
Drained phase	272	[2]
Ogemaw sandy loam	4, 666	. 9
Oshtemo loamy sand:		
Sloping phase	316	. 1
Undulating phase	864	. 2
Oshtemo sandy loam	10, 661	1. 9
Gently sloping phase	181	[2]
Ottawa loamy fine sand	3, 089	. 6
Sloping phase	19	[2]
Plainville sand	38, 079	7. 0
Eroded undulating phase	83	[2]
Rolling phase	4, 398	. 8
Undulating phase	4, 273	. 8
Rifle peat	11, 746	2. 1
Shallow phase	1, 502	. 3
Roselawn fine sand	47, 308	8. 6
Eroded phase	297	. 1
Eroded undulating phase	199	[2]
Hilly phase	9, 766	1. 8
Undulating phase	44, 709	8. 2
Roselawn gravelly fine sand, undulating phase	1, 790	. 3
Rough broken land (Arenac and Plainfield soil materials)	3, 717	. 7
Rubicon fine sand	616	. 1
Rubicon sand	33, 752	6. 2
Eroded phase	242	[2]
Undulating phase	1, 482	. 3
Saugatuck fine sand	55	[2]
Drained phase	249	[2]

See footnotes at end of table.

TABLE 6.—*Acreage and proportionate extent of the soils of Newaygo County, Mich.*—Continued

Soil [1]	Acres	Percent	Soil [1]	Acres	Percent
Saugatuck sand	19, 111	3. 5	Wallace-Weare fine sands	1, 772	0. 3
Drained phase	837	. 2	Wallkill loam	2, 158	. 4
Sparta loamy sand	7, 815	1. 4	Washtenaw soils, undifferentiated	4, 568	. 8
Eroded phase	871	. 2			
Eroded undulating phase	106	(2)			
Undulating phase	207	(2)	Total	548, 480	100. 0

[1] Where data are given for a phase only, the normal type is not mapped in the county.
[2] Less than 0.1 percent.

Antrim sandy loam.—This soil occurs on gravelly plains and on low terraces in the valleys. The bodies are small and irregular, except those on the plain on which Hesperia is located and those on a slightly higher and drier plain northeast of White Cloud, which are associated with the Oshtemo soils. The surface is nearly level to gently undulating. The original forest vegetation was hardwoods and hemlock, with some white pine admixed.

The surface soil is dark-gray or dark-brown friable slightly acid sandy loam, relatively high in organic-matter content, and underlain by a grayish- or brownish-yellow loamy sand to a depth of 2 feet or more. In places there is a deep subsoil of reddish-brown clayey sand or sandy clay over calcareous cross-bedded sand and gravel. The soil is slightly darker and moister than other similar dry, sandy, and gravelly soils, because of a topographic position that allows some drainage from higher land or because of shallow depth to the clay substratum.

This soil may be productive, but it is not very durable under cultivation unless highly manured. The staple crops, as corn, oats, rye, potatoes, alfalfa, and sweetclover, can be grown, but yields are generally not high.

Arenac fine sandy loam.—Old lake beds and other plains having 3 to 4 feet of sand over impervious clay are occupied by this soil. Natural drainage is sufficient in most places for field crops and small fruits. Runoff is slow, but the upper part of the soil is sufficiently pervious to allow water to penetrate readily to the clay substratum. Although it is nearly level in most places, occasionally there are slopes as steep as 7 percent surrounding depressions. Most of the soil occurs in Sheridan and Bridgeton Townships, although small bodies are widely distributed throughout the southern half of the county. The original cover was a forest of hard maple, beech, hemlock, basswood, ash, elm, cherry, and white pine, but probably 95 percent of the total area has been cleared and cultivated.

Under virgin conditions there is a 2-inch layer of slightly acid dark grayish-brown loam made up of well-decomposed organic matter mixed with fine sand. The next layer, 2 to 6 inches thick, is light-gray or ashy-gray strongly acid loamy sand in which there is a high content of fine sand. This is underlain by 8 to 10 inches of acid yellowish-brown loamy sand to sandy loam, slightly indurated in spots. The subsoil is grayish-yellow sand, in places mottled at depths of 2 to 3 feet. A moisture-retaining layer of reddish-brown calcareous heavy silty clay, silt, and very fine sand is 3 to 5 feet below the surface. Under cultivation the upper two layers are mixed to form a grayish-brown light sandy loam plow soil.

This soil and Ogemaw sandy loam are closely associated on the imperfectly drained plains. In fact, small areas of both Ogemaw and Munuscong sandy loams are included. The Ogemaw soil is not so well drained as this one. It has a conspicuous induration in its brown layer that this soil lacks. The depth to the impervious layer in its subsoil is also less.

General farming and raising beef and dairy cattle are the two main uses of this soil. About one-fourth of the cultivated area is in corn, and large areas are in rye and wheat. Corn yields 20 to 35 bushels an acre; rye, 10 to 25; wheat, 10 to 25; oats, 10 to 20; and potatoes, 75 to 300. About 20 percent of the total area is in alfalfa or other hay crops, from which fair yields are obtained. String beans, peas, cucumbers, and small fruits do well and return a good income when prices and other economic conditions are favorable.

Some type of 3- to 5-year crop rotation is practiced on most farms, the clean-cultivated crops being followed by sod or noncultivated crops. Barnyard manure is ordinarily applied once or twice in the rotation, and commercial fertilizer is generally used with cash crops. An application of 1 to 3 tons or more of lime is necessary for a good stand of alfalfa. Aside from these precautions to maintain fertility, there are no serious problems in tillage and management.

Arenac loamy sand.—This soil is formed under drainage conditions intermediate between those of Ottawa and Saugatuck sand. There are small included bodies of these two and of the Rubicon and Kalkaska soils. Small to medium-sized areas of this soil occur in the central and southwestern parts of the county, particularly in Wilcox and Bridgeton Townships. Most of it is on nearly level or undulating outwash plains and lake plains where a sand covering overlies a clayey substratum. Slopes are usually under 8 percent, but a few steeper areas around depressions are included. Most of the native forest has been cut; it probably consisted of pines with some admixture of hardwoods.

The 4- to 6-inch surface soil is light grayish-brown loamy sand, strongly acid, and low in organic-matter content. The 4- to 8-inch subsoil is reddish-brown to brownish-yellow strongly acid loamy sand. Beneath this there is a pale-yellow medium sand that shows some evidence of impeded drainage in the form of brown streaks and mottlings at depths of 3 to 4 feet. From 4 to 6 feet below the surface is either the water table or a moisture-retaining layer of sandy clay, heavy clay, or silt that retards downward water movement. Included is a very small total area like this soil that lies 10 to 20 feet above the valley bottom on the discontinuous sandy terrace in the Muskegon Valley. In this variation the mottling in the sandy subsoil indicates that the water table is within 5 feet of the surface for a large part of the year. The agricultural value of this inclusion is less than that of the type.

Arenac loamy sand is third class in agricultural value. Under optimum conditions, fair returns are obtained from general farm crops, small fruits, cucumbers, peas, and string beans. Without heavy applications of manure and good management, yields rapidly diminish. Soil blowing is a menace under clean cultivation.

Bellefontaine sandy loam.—The topography of this type is rolling, and there are a large number of short slopes that vary from 8 to 15 percent in gradient. Surface drainage is therefore rapid and erosive. Internal drainage is free because the substratum is gravelly. Plant growth seldom suffers from lack of moisture, however, because of the retentive properties of the surface soil. Considerable variation in texture is common; and gravel and boulders occur throughout the soil. Patches of Roselawn fine sand, undulating phase, and Isabella loam too small to be mapped separately are included in mapped areas of this type. The largest and most continuous body is on a range of hills that enters Newaygo County on the south border east of Rogue River; other very small areas are scattered over the hilly uplands.

In undisturbed areas the surface material is a 2- to 3-inch layer of forest litter and leafmold and dark-colored humus soil, underlain by yellowish friable loamy sand or sandy loam. These sandy top layers are mixed by plowing to form a fairly heavy grayish-brown sandy loam. Between 2 and 3 feet below the surface a reddish-brown slightly sticky clayey layer is usually found. This marks the transition to an underlying unchanged heterogeneous mass of sand, gravel, boulders, and clay. The upper or top layers are slightly acid. As the depth increases the reaction becomes more alkaline. A large percentage of limestone gravel is present in the parent material.

The agricultural value of this soil is somewhat less than that of the undulating phase, and a larger proportion remains in forest cover. Difficulty is encountered in working the steep slopes, and water erosion losses are severe. The soil is better suited to trees and pasture than to cultivated crops.

The soil is easily handled, and only the lighter agricultural implements are required for cultivation. The chief need is an increase in the content of organic matter. The use of commercial fertilizer is limited, although some farmers make heavy applications on grain and potato crops. A cover crop of clover or rye is sometimes plowed under. Small fruits are grown commercially, but tree fruits are grown mostly in small home orchards. Bluegrass, which appears to be well adapted to this soil, makes fair pasture.

Bellefontaine sandy loam, hilly phase.—This soil is confined to a few steep slopes and small areas of high knolls, sharp ridges, and steep depressions in the hills east of Rogue River. It is closely associated with other phases of the type, but because of its choppy topography, it has less agricultural value. The soil was cultivated at one time, but erosion eventually removed much of the surface soil. Now, it supports a second growth of oak or poor pasture.

Bellefontaine sandy loam, undulating phase.—The principal difference between this soil and the normal phase is topography. This soil occupies smooth gentle slopes and hilltops where agricultural machinery can be used with little difficulty. The slopes are seldom in excess of 7 percent, whereas those of the normal phase range from 8 to 15 percent.

This soil is of only moderate agricultural importance. Approximately 75 percent of it is cleared for farming. The woodland on the rest includes beech, hard maple, hickory, red, black, and white oaks, and elm. The soil is better adapted to special crops than to general farming, but fair yields are obtained from staple crops in favorable years, if management is good. Yields average higher than those from Roselawn fine sand.

A wide fluctuation in yield over the same field is caused mainly by the depth of the sandy cover over the subsoil, the texture and thickness of the surface layer, the fertility of the land, and moisture conditions.

Bergland clay loam.—On the low wet plains this heavy-textured dark-colored poorly drained type occurs in close association with the Kent, Munuscong, Ogemaw, and Arenac soils. It is formed in low places where there is no sandy covering over the clayey materials. The relief is nearly level or gently undulating (0 to 3 percent). Drainage is poor, and runoff is slow, even where aided by ditches, because of the slight slope of the land and the depressional positions in which it is located. Internal drainage is very slow because the texture of the soil is heavy and structural development in the profile is poor. A high water table is the chief impediment to the downward growth of plant roots, since roots readily penetrate the clayey substratum when the soil is drained. Stones and boulders are not numerous. This soil is found mainly in Sheridan Township. The acreage is not large, and the individual bodies are small and widely separated. The original forest cover was principally elm, ash, red and silver maples, swamp oak, and basswood.

The surface soil is dark gray or nearly black and granular. The texture varies considerably, but it is dominantly a clay loam 8 to 12 inches thick that contains a large proportion of organic material. This layer is underlain by 2 to 10 inches of gray loam to sandy clay soil intensely mottled with spots and streaks of yellow, brown, red, and even white. At depths of 8 to 30 inches is a yellowish-brown or brown sandy clay or clay, grading into a heavy very tight and impervious gray clay. The entire profile is ordinarily neutral or slightly alkaline.

This soil is susceptible to early and late frosts; the range of crops is therefore limited, and the risk involved in producing them is greater than on higher and drier land. About 80 percent is cleared, but because of the danger of frost, the expense of draining, and the small size and irregular shape of the areas, most of this soil is left in permanent pasture, despite its high inherent fertility. On drained land, corn produces 25 to 40 bushels an acre; wheat, 20 to 40; oats, 30 to 45; rye, 15 to 30; hay, 2 to 3 tons; alfalfa, 2 to 4 tons; and beans, 5 to 15 bushels. Potatoes yield only 50 to 100 bushels and are likely to be ill-shaped and of poor quality.

Although this soil does not require amendments, the sandy inclusions usually need manure, lime, and commercial fertilizer. Considerable care must be taken to avoid working this soil when it is too wet.

If this is done it will puddle and become hard and difficult to till for several seasons.

Bergland loam.—Like the Washtenaw and Wallkill soils, this soil occurs in basins, at the foot of slopes, along drainageways, or where associated with Kent silt loam and Isabella loam, as small, low, nearly level to gently rolling plains. It is a fertile soil but requires artificial drainage for crop use. Because of the small size of separate bodies and their irregularity, this is not an important agricultural soil. Most of it is cultivated as an integral part of the Kent or Isabella types.

The surface layer consists of 6 to 18 inches of dark-gray granular loam or silt loam, neutral to slightly alkaline. In the lower part granulation becomes less marked, and the fertile dark surface layer grades into the underlying light-gray mottled clayey subsoil. In a few places an intervening grayish-white waterlogged compact soil, sand to sandy loam in texture, separates the surface soil from the clayey material underneath. At 3 to 4 feet below the surface, substratum materials of the kinds common to such associated soils as Isabella loam or Kent silt loam are encountered.

Burned peat and muck over sand.—These are areas where muck or peat has burned to leave a 1- to 3-foot layer of mucky organic material mixed with ashes upon a sandy substratum. The land for the most part supports weeds or grasses or a scant brushy cover of aspen and willow. The land may produce fair crops for a few years if properly managed, but is not likely to remain productive. Where not too brushy, it furnishes fair pasture.

Carlisle muck.—This black or brownish-black granular loamy organic soil is chiefly in the southern part of the county. Except for an extensive area in Grant Township, it occurs as small bodies in the depressions and stream valleys. The relief is nearly level. The muck contains woody fragments but little admixed mineral material, and the high ash content indicates a comparatively advanced stage of decomposition. Physical changes in the plant material of the soil are so advanced that botanical identification is impossible.

The original forest vegetation was dominantly elm in association with red maple, ash, swamp white oak, hemlock, basswood, aspen, and white pine. White-cedar (arborvitae) was also common, particularly in the northern part of the county. The major part of this muck has been cut-over, and it is now pastured where the individual bodies are large enough and suitably located. Some areas are brushy, with a dense cover of grasses or sedges, or they support a second-growth cover similar to the original.

The surface layer is usually more than 8 inches deep and may extend downward 2 to 3 feet before the less decomposed, more fibrous, brown or yellow peaty [5] material is reached. The reaction of the surface layer is nearly neutral or slightly acid. In places the muck is underlain by marl, but the substratum is more often a sandy or clayey drift. Under natural conditions the water table is probably 18 to 30 inches below the surface.

A large area of this soil is in the artificially drained basin of Rice Lake, in Grant Township. It is the most productive soil in the

[5] Highly decomposed organic soils are termed "mucks"; raw or slightly decomposed organic soils, "peats."

county for growing onions, producing more than 1,200 bushels an acre under good management. If it is overdrained, deficiency in moisture becomes the chief factor limiting plant growth. Dry muck also suffers severe losses from wind erosion. Valuable fields are therefore protected by windbreaks. A few of the smaller bodies are planted to vegetables for home use. These small areas, however, are unfavorably located with regard to air drainage. They are subject to frost, therefore, and this is a disadvantage in their use for the intensive production of truck crops. The soil supports a fair pasture when cleared and is capable of producing a more vigorous growth of trees than any other organic soil in the county. In the northern part of the county it[6] is left uncleared for the production of pulpwood and fence posts. In addition to truck crops, corn, timothy, alsike hay, and barley are grown to a limited extent on this soil.

Carlisle muck, shallow phase.—A few areas of Carlisle muck are less than 2 feet deep. These areas are mapped as the shallow phase and are mainly brushy wasteland.

Echo loamy sand.—In the bottoms of dry hollows and valleys this loose soil occurs in association with Emmet loamy sand, Montcalm-Roselawn complex, and all phases of Roselawn fine sand. The slope does not exceed 3 percent. As lack of moisture is less a limiting factor than it is on the adjoining slopes, this is the soil that usually produces a livlihood for those families who prefer to live in the sand hills or are forced to live there by circumstances.

The original cover was similar in most places to that of the surrounding slopes, and some of the trees, particularly the pines, attained their greatest size in these depressions. In association with the Roselawn sand hills, however, it appears that many of these depressions never supported a forest cover but formed, instead, small grass-covered clearings.

The surface soil is a dark-gray to grayish-brown loamy acid sand, 4 to 18 inches in depth and relatively high in organic matter that is washed down from the surrounding slopes. The underlying layer may be a pale-yellow, grayish-yellow, or brownish-yellow loamy sand showing some evidence of a coating around the sand grains. This loamy sand grades into a layer of light-yellow or pale grayish-yellow sand mottled at depths of 4 to 5 feet.

A few of the openings in the forest were once cultivated, but because of their small size, irregular shape, and inaccessibility, they are now abandoned or used for pasture.

Edwards muck.—The surface layer of this organic soil resembles Carlisle muck, but the substratum is marl. The marl is 10 inches to 3 feet below the surface and is readily removed for agricultural use. The reaction is commonly nearly neutral to slightly alkaline. The largest body was mapped in the Rice Lake area. The soil equals Carlisle muck in fertility and productivity but under cultivation is likely to become excessively alkaline sooner. This normal phase has a greater depth of organic soil material above the substratum of marl and is therefore more productive than the shallow phase.

[6] A similar organic soil in Mason County, Mich., has been mapped as Lupton muck.

Edwards muck, shallow phase.—This soil occurs in several places where the lowering of lake levels or the complete disappearance of a lake has exposed marl accumulations 1 to 20 feet deep. The marl is usually topped with 1 to 10 inches of loamy mucky material containing considerable sand in some locations. The largest body of this phase is in the basin of Rice Lake.

The surface layer is nearly black, granular, and alkaline. After burning, or after a few years of cultivation, the gray or whitish marl, loose and ashlike in consistence, appears at the surface. This marl is very unbalanced in plant nutrients.

Attempts at raising onions or other truck crops have never been so successful as on other mucks, probably because of the excessively high alkalinity. Drainage is required for cropping. At present, the soil supports a weedy grass cover in which bluegrass, quackgrass, a few sedges, and goldenrod dominate.

The marl is an excellent source of liming material, particularly where it is found in highland positions, and is generally of a good grade for agricultural use.

Emmet loamy sand.—In topography and related characteristics, this loamy sand differs from the undulating phase. Slopes vary from 8 to 15 percent, whereas the gradient of the undulating phase does not exceed 7 percent. The soil layers are thinner and not so well developed. Moreover, erosion by wind and water has removed most of the original surface soil. As a result, the plow layer in areas where cultivation is attempted is a grayish-yellow acid sand that contains little organic matter. Agriculturally the soil is of little value other than for pasture. The individual bodies are widely distributed in association with other phases of the type.

Emmet loamy sand, eroded phase.—Areas of this phase have lost the entire surface soil and part of the subsoil through the action of wind and water.

Emmet loamy sand, eroded undulating phase.—Badly eroded hillsides are invariably associated with all phases of this type. In this phase are differentiated small areas in the undulating phase that have been left barren and uncovered by the removal of the entire surface soil. In some places there are small areas of the original surface covered by 12 to 18 inches of sandy, wind-transported material. These are included in the phase because, from the standpoint of land use, they are as great a problem as the exposed sandy substratum. Reclamation of this soil has not been attempted, but at the time of survey quackgrass was spreading inward from the margins of the bare spots. Quackgrass thrives on this sandy soil and may, in time, afford a measure of stabilization.

Emmet loamy sand, hilly phase.—Slopes exceeding 15 percent gradient in areas of steep, abrupt topography differentiate this from the normal phase. The combined area is not extensive, and almost all the bodies occupy the steep slopes that occur within larger areas of this type and Emmet sandy loam.

Emmet loamy sand, undulating phase.—In the sand hills of the county this is the most important agricultural soil. Although widely distributed on hilltops and on broad gentle slopes in the uplands of the central and western parts, the total area is not large. The largest bodies occur in Beaver Township. Slopes do not exceed 7 percent.

The original cover was a hardwood forest similar to that found on Emmet sandy loam, but in all probability it was not so dense. Under cultivation, the plow soil is susceptible to damage by wind erosion, as it is a loose grayish-brown loamy sand. Water erosion can be a problem.

Under virgin conditions, this soil has a 4- to 6-inch layer of slightly acid or neutral dark-brown or nearly black organic matter. This is underlain by an 8- to 20-inch layer of strongly acid umber-brown, dark reddish-brown, or brownish-yellow loamy sand. The following layer of grayish-yellow or yellow medium sand gives way after a gradual transition to a grayish-yellow sand that lies 30 inches or less below the surface. This sand becomes alkaline 5 to 10 feet below the surface. A few pockets of pink clayey sand occur, and stones and boulders are fairly common. Within areas of this phase are included minor bodies of Emmet sandy loam, Montcalm-Roselawn soils, and in depressions, Washtenaw soils, undifferentiated, and Echo sandy loam.

Nearly all of this soil has been cleared and placed under cultivation. The land has produced good crops of beans, potatoes, corn, rye, and fruits, but poor management has finally depleted organic matter and fertility to such an extent that it has been abandoned or used only for pasture. Overgrazing followed by grasshopper invasions exposed the more southward sloping part to serious wind erosion, and as a result, a large aggregate acreage is nearly worthless.

Emmet sandy loam.—The topography of this soil is normally hilly, a large proportion of slope gradients ranging between 8 and 15 percent. Slopes may be irregular in direction, complex, and short; they therefore constitute a problem in soil management in cleared fields. In places stones and boulders are sufficiently numerous to interfere with cultivation. This is not an extensive type, most of it being confined to the uplands in the western part. It possesses a deep ash-gray and a conspicuous dark-brown layer, and some limestone in the parent drift. The soil was originally covered with a dense hardwood forest in which hard maple and beech were the dominant species. Hemlock, basswood, black cherry, white ash, elm, and red oak were scattered throughout or were locally dominant.

Described as it occurs under a virgin hardwood forest, the soil is covered by a 1- to 5-inch layer of undecomposed leaves and litter. Beneath the leaves and litter decomposing plant material forms a ½- to 1-inch layer that overlies ½ to 2 inches of highly granular well-decomposed black humus material in which grains of gray sand are conspicuous. These organic layers are neutral to slightly alkaline in reaction and well matted by myriads of fine fibrous roots. They can be rolled back to expose a grayish-white sandy loam, somewhat stained on top, but well leached and ashlike at depths of 1 to 2 inches.

The ashy layer is characterized by an indefinite platy structure and an acid reaction; it becomes more yellow with depth, and 8 to 20 inches below the surface firm very slightly indurated umber to coffee-brown sandy loam is encountered. This is underlain by pale-yellow fine sand and reddish sandy loam or sandy clay that continues downward to depths of 3½ to 4 feet. The substratum is a mixture of fine sand, silt, gravel pockets, and calcareous clayey layers and lenses. An alkaline reaction within 3 feet of the surface is characteristic.

In areas of this soil shown on the soil map there are small included patches of Isabella sandy loam, Emmet loamy sand, Montcalm sandy loam, Iosco sandy loam, and small poorly drained spots of Wallkill loam and Washtenaw soils, undifferentiated. Despite the wide variation indicated by these inclusions, Emmet sandy loam has a fairly definite character as a natural land division.

The soil has proved to be suitable for orchards, especially apples. Near Reeman, in Sheridan Township, a large proportion of the orchards are located on this type. Only a small part is being used for other purposes. The soil is fair for general farming, but yields are lower than those obtained on the undulating phase. Unless the soil is carefully managed, there may be destructive sheet erosion and gullying because of the steep slope and inherent erodibility. Erosion results in decreased yields and increased production costs.

Emmet sandy loam, hilly phase.—This soil differs from the normal phase, with which it it associated, in that it occurs on steep slopes where gradients are in excess of 15 percent. The solum is neither deep nor well developed. Agriculturally, these slopes are too steep to be profitably used for orchards. A large portion of this inextensive phase is pastured or left covered with a second growth of beech, hard maple, and red oak.

Emmet sandy loam, undulating phase.—The soil profile of this phase is similar to that of the more sloping normal phase, but its topography is smoother and more undulating. Slope gradients are from 4 through 7 percent. The soil occurs in association with the normal and the hilly phases of Emmet sandy loam and with Isabella-Montcalm sandy loams, which it nearly equals in agricultural value.

Because air drainage is not so good as on the more rolling normal phase, only a small acreage of this soil is in orchards. It is well adapted to general farming, however, and nearly all of it is under cultivation. Few difficulties in management are encountered because the surface soil retains moisture without being heavy. Stones and boulders are not numerous enough to constitute a nuisance, and the slopes are not too steep to be tilled with labor-saving machinery. Losses from sheet erosion may be detrimental unless preventative measures are taken.

Corn yields 25 to 50 bushels an acre; wheat, 10 to 35; oats, 20 to 40; rye, 15 to 25; beans, 10 to 20; and potatoes, 150 to 300. Alfalfa produces 1½ to 3 tons of hay, and timothy and clover 1 to 2 tons an acre.

Fox sandy loam, sloping phase.—The slopes of this phase seldom exceed 15 percent in gradient, and they surround numerous basinlike depressions on a pitted plain. The depressions are 25 to 30 feet deep on the western part of the plain and less than 10 feet on the smoother eastern part. The low spots or pits are dry for the most part. The soil at the bottoms contains somewhat more organic matter in the surface layer than that on the adjacent slopes and divides, and the subsoil is higher in content of moisture.

A few depressions contain muck or peat; others hold intermittent or permanent ponds. The largest pits or depressions on the plain are occupied by Baptist, Englebright, and Conover Lakes. The slopes surrounding the depressions are seldom steep enough to make cultivation impracticable. Moreover, they are small in size and so closely associated with the nearly level parts of the plain that little attempt has been made to isolate them for special crop uses. The slopes have been farmed in the same manner as the more level part. The fertile surface soil is washed into the bottoms of the depressions, and if erosion is allowed to continue, is covered with infertile sandy subsoil material (pl. 1, *A*).

The soil profile is very similar to that of the undulating phase. The friable surface layer is grayish-brown to yellowish-brown sandy loam or light loam. The compact subsoil is light yellowish brown in the upper part, and the reddish-yellow lower part is sticky when moist. The substratum is sand and gravel or clayey materials.

The agricultural value of a large part has been greatly reduced by erosion. The utilization of sod crops and alfalfa and the planting of only more level fields to beans and potatoes has proved of some benefit in ameliorating erosion. The tendency has too often been toward planting beans, potatoes, and other clean-tilled crops.

Fox sandy loam, undulating phase.—On the pitted plain in the eastern part of Ensley Township, areas of this phase[7] occupy the smooth or gently undulating divides that separate the depressions. The western side of the soil area grades into Bellefontaine and Montcalm soils, but no sharp division can be drawn.

Under an undisturbed forest cover the top 2 to 3 inches is a mixture of leafmold, plant roots, litter, and mineral matter, neutral to slightly alkaline in reaction. This is underlain by a dark-gray friable acid sandy loam 2 to 3 inches thick that grades into a compact light yellowish-brown sandy loam to clay loam acid soil. Plowing mixes these relatively thin layers, and the plow soil is a grayish-brown to yellowish-brown fine sandy loam or light loam. Between 2 and 4 feet from the surface there is a 6- to 12-inch layer of sticky compact reddish-yellow clayey gravelly sand that overlies a mixture of sand and gravel. The texture of the substratum varies considerably, the range being from clayey materials, like those found under Isabella sandy loam, to dry loose gravel and stratified sand.

This soil is intermediate in agricultural value, but nearly all of it is cleared and in pasture or under cultivation. Good yields of all staple crops are produced. Corn yields 15 to 30 bushels an acre; wheat, 10 to 25; oats, 25 to 50; rye, 15 to 25; beans, 10 to 15; and potatoes, 100 to 300. Excellent stands of alfalfa are obtained after applications of lime or marl; annual cuttings may average 3.6 tons an acre.

Beans, potatoes, and such clean-cultivated crops have been grown on this soil to the exclusion of sod and pasture crops, and this practice has encouraged both sheet and gully erosion. The soil is particularly susceptible to erosion because the compact subsoil impedes water infiltration, causes saturation of the plow layer, and facilitates runoff and mass movement of soil down the slopes.

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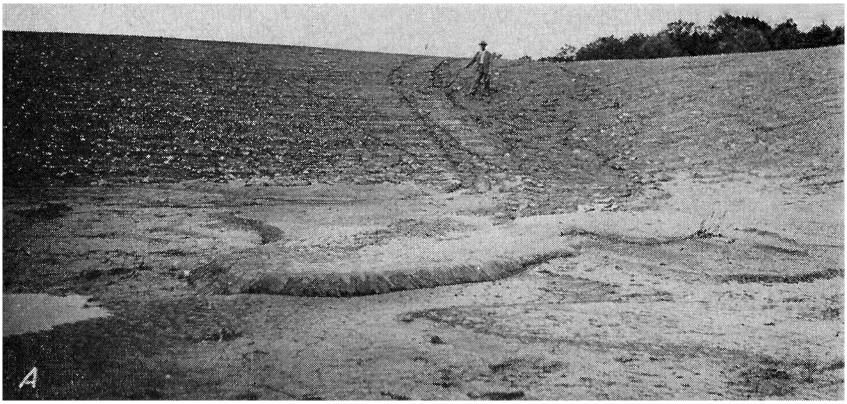
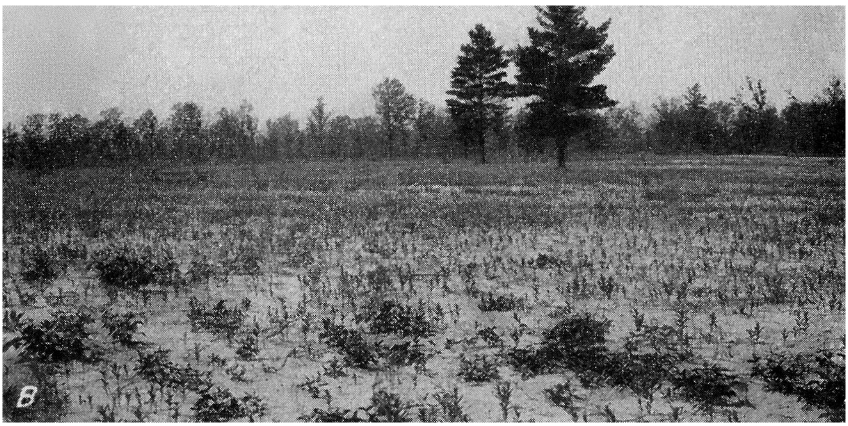
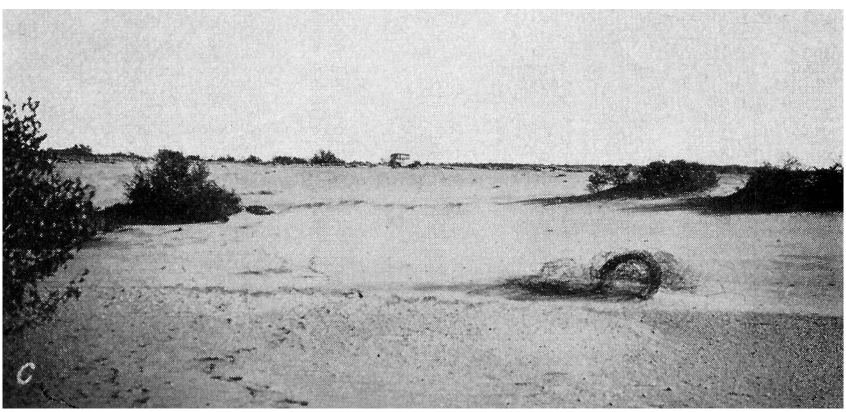
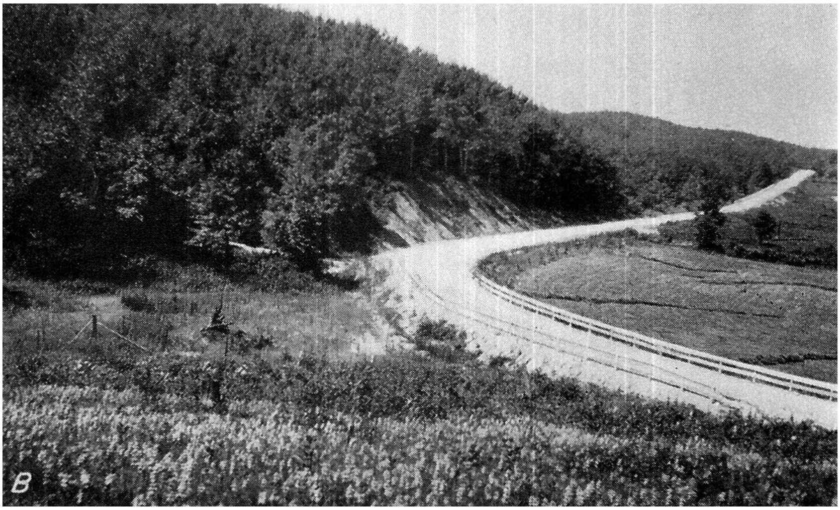
[7] Areas of Fox sandy loam, sloping phase, join Isabella loam in Kent County, which was mapped in 1926. Since that date the increasing detail in mapping has permitted a finer distinction in soil units. Hence, Fox sandy loam, undulating phase, is now differentiated from Isabella loam by its smoother, more plainlike topography, its browner surface layer, and its gravelly substratum.







A, Effects of water erosion on Fox sandy loam, sloping phase. The fertile surface soil in the foreground has been covered by sandy wash, leaving the subsoil exposed on the slopes.
B, Remnants of original pine cover in foreground and second-growth woodland on Rubicon sand and Saugatuck sand, drained phase, in background. The sparse vegetation in foreground has required 2 years to develop since the field was cultivated.
C, Desert on Sparta loamy sand formed by wind erosion.



A, Farmstead on Isabella loam.
B, Second growth of woodland on Montcalm-Roselawn complex to the left of the road; hayfield to the right on Isabella-Montcalm sandy loams.

Genesee sandy loam.—This soil of alluvial origin is not uniform in texture, but for the most part, sandy at the surface, light brown, and fairly well supplied with organic matter. It is better drained than the Griffin soils, alkaline in reaction, moderately fertile, and sufficiently retentive of moisture for plant growth. The original cover resembled that on the Griffin soils.

Agriculturally, this soil is not important. The individual bodies are relatively inaccessible, and the total extent is small. Small areas occur on the natural levees in the Muskegon River Valley, and there are a few patches elsewhere. Where it is included within farmed areas, this soil is used for gardens, cultivated crops, or pasture.

Granby sandy loam.—Parts of the wet undrained plains, particularly those adjoining the heavy-textured calcareous uplands, are occupied by this soil. A few small nearly level valleys associated with the upland Emmet soils in Beaver Township were also mapped as Granby soil, though the surface layer in these areas has a higher content of organic matter than is typical. Natural drainage is poor, and water remains near the surface most of the year unless the land is drained artificially. This is not an extensive type in the county.

The native cover was swamp hardwoods, dominantly elm, red maple, and black ash. About half of this soil has been cleared and sufficiently drained for the production of crops. Overdrainage has resulted in considerable damage to the surface through excessive drying and blowing.

The 4- to 6-inch surface soil is dark grayish-brown sandy loam, very high in content of organic matter, and ranging from slightly acid to slightly alkaline. The grayish-white to dingy-gray, mottled with rust brown, sandy subsoil extends to depths of 3 to 4 feet or more. This soil differs from Newton loamy fine sand in its heavier surface soil and in its neutral or alkaline instead of acid reaction. A few small patches of Saugatuck sand, Munuscong sandy loam, and muck are included.

Corn, beans, small grains, and hay are grown on the drained areas. The soil is subject to early and late frosts, however, and it is uncertain that potatoes, corn, and beans will mature before frost early in fall. The natural fertility is rapidly depleted under cultivation; consequently, programs for soil improvement are necessary if crop yields are to be maintained. Under optimum rainfall and frost-free conditions, corn yields 15 to 30 bushels; beans, 5 to 10; potatoes, 50 to 150; oats, 20 to 30; rye, 10 to 20; and timothy and alsike hay, 1 to 2 tons. String beans, cucumbers, other truck crops, and strawberries or other small fruits do well on the sites less subject to frost if fertility is maintained and the level of the water table can be controlled.

Gravel or marl pits.—Gravel pits are classified as a miscellaneous land type. Indicated on the map are the larger areas where gravel has been removed, or where a gravelly material still remains. Many pits are too small and unimportant to be shown on the map.

A few of the deposits of marl in the county have no soil over them, and in some places these are of sufficient size to be indicated on the map. The marl pits are a source of liming material and are therefore of some agricultural importance.

Grayling sand.—Except for the gray layer immediately below the surface and a more conspicuous brown layer, this soil is similar to

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Plainfield sand in that it occurs in large uniform bodies. These, however, are only on the dry sandy plains in the northern part of the county, while Plainfield sand is confined to the plains south of the Muskegon and White Rivers. The topography of Grayling sand is nearly level or but slightly undulating.

The original cover was largely jack pine, particularly in the northern part of the county. Most of this pine was not cut, but large areas were burned over. A few undisturbed thickets of mixed jack pine and oak remain. The ground cover consists of various native grasses, bluegrass, a sedge (*Carex* sp.), sweetfern, and mosses and lichens. In some places the predominant cover may be a sparse open stand of oak interspersed with fire cherry, willow, and aspen. In the southern parts of the soil area, cover resembling that of Plainfield soils commonly occurs. The present forest cover supplies some firewood and posts.

Under an undisturbed jack pine cover, the surface layer is chiefly needles in all stages of decay. There is ¼ to ½ inch of this litter. Below it there is about 1 inch of dark-gray loamy sand that overlies, in turn, a characteristic ashy-gray sandy layer 1 to 2 inches thick. For a distance of 4 to 6 inches, the following layer of sand is yellow or dull yellow when moist, but at depths of 18 to 20 inches the gradual change to a loose pervious pale-yellow or grayish sand is complete. The subsoil and the surface soil are both acid.

Only a small part of this soil is cultivated. Numerous abandoned clearings, farmstead ruins, deserted houses, and shacks are evidence of the impracticability of farming this dry infertile soil. Some pasture is available in spring and fall. Little reforestation has been attempted by individual owners. The chief deficiencies of this soil are a low content of moisture during the growing season, a low fertility, and high acidity.

Grayling sand, rolling phase.—This soil occurs on more rolling parts of the plains that were probably formed by wind action. The gradients range from 8 to 15 percent, and, aside from its sloping surface, the soil is similar to the normal phase.

Grayling sand, undulating phase.—This soil is similar to the normal phase but occurs on slopes where gradients range from 4 to 7 percent.

Greenwood peat.—This yellow or red-brown loose uncompacted stringy slightly decomposed and highly organic material occurs chiefly in the northern part of the county, where it occupies shallow depressions on the sand plains that once held lakes. The water table is at or within a few inches of the surface, except in very dry periods when it may drop to depths of 1 to 2 feet. This peat accumulates on the water of a lake as a floating mat. It shows very little surface decomposition. Many of the accumulations are uniform to depths of 6 to 8 feet; the ash content is low and reaction is strongly acid.

The characteristic cover is a dense mat of leatherleaf, uniform in height, that grows over the entire bog. Under the leatherleaf, but supported by its stems, spagnum and other mosses flourish. Other plants common to this type of bog are bog rosemary and the insectivorous pitcherplant, which is usually imbedded in the top of a sphagnum hummock. Around the margins where decomposition of plant material is more advanced, blueberry, laurel, cranberry, and cotton grass invade the bog. Occasional clumps of stunted tamarack and black spruce are present.

The land has no prospective agricultural value except for the remote possibility of producing such crops as blueberries and cranberries. The tree growth is of little or no value.

Griffin loam and clay loam, undifferentiated.—These poorly drained soils are similar to Griffin sandy soils, undifferentiated, except in texture. The surface is a dark-gray loam to clay loam overlying highly mottled fine-textured alluvium. Areas occur in stream bottoms and are subject to flooding. In character of native vegetation and agricultural possibilities they are similar to Griffin sandy soils, undifferentiated. In some places pasture is excellent.

Griffin sandy soils, undifferentiated.—The alluvium forming this separation is deposited in stream bottoms that are periodically overflowed. It consists mainly of dark-gray, yellow, and rusty-brown sands, but there is a great variation in the texture of the surface; fine sand, loamy sand, sandy loam, and some loam and silt loam are included. The water table is high, and in places the soil contains a high content of organic matter that was either developed in place or deposited as mucky alluvium. The soil is generally alkaline and, in places, calcium carbonate is present in the surface layer. This soil is fertile, but because of poor drainage and narrowness of the bottoms, it has little agricultural value except for pasture and woodland.

The bottoms originally supported a dense mixed stand of hardwood and coniferous trees and a shrubby undergrowth. On Maple Island in the Muskegon Valley of Bridgeton Township, there is a nearly virgin cover of red maple, white ash, black ash, black walnut, elm, swamp white oak, hackberry, basswood, hard maple, sycamore, and willow. Balm-of-Gilead poplar, aspen, black spruce, tamarack, and alder are also common species on the bottom land.

Houghton muck.—This type is found in former lake sites overgrown and filled with the accumulated remains of marsh grasses, sedges, cattails, rushes, and other water-growing plants. The finer texture is the principal basis for its differentiation from Carlisle muck. The water table is permanently high, the depth from the surface varying from 18 to 20 inches. Except for an occasional small aspen, willow, or tamarack, trees have not invaded these marshy areas.

The surface deposit is a 6- to 8-inch layer of brown or nearly black fine-granular well-decomposed organic matter containing a large quantity of matted roots. The reaction is neutral or slightly acid. The underlying material is a yellowish-brown spongy or feltlike peat composed mostly of the remains of grasses and sedges.

A slightly different type was mapped in the drained basin of Rice Lake. It exhibits a more definite brown in the surface layers. Decomposition has not progressed so far nor extended so deep as in the typical. The underlying layers exhibit in places a peculiar gelatinous pasty consistence. This highly colloidal material becomes very hard when dry and breaks with a definite conchoidal fracture. The soil, actually less suitable for production of truck crops than either the Carlisle or the more typical Houghton mucks, can doubtlessly be utilized for high-acre-value truck crops if it can be sufficiently drained and if it is highly fertilized.

Very little of this muck is under cultivation because drainage and the control of the water table is difficult. It is capable of producing truck and other crops under favorable conditions. Native grasses, often harvested for hay, furnish fair pasture in some places.

Houghton muck, shallow phase.—This organic deposit is similar to the normal phase, but the surface is less than 2 feet in total depth. These shallow deposits are less durable as muck soils because they tend to become mineral soils after drainage and a few years of cultivation.

Isabella-Iosco sandy loams.—At the foot of slopes where there are bodies of Isabella-Montcalm sandy loams, small irregularly shaped intermediately drained areas of soil occur in which a hardpan layer is frequently conspicuous. These, together with small areas of Isabella sandy loam, form this complex. The complex often occupies a transition zone between the higher lying Isabella, Montcalm, or Emmet soils and the poorly drained soils at the bottoms of the depressions. It is distinguished from the lower lying Ogemaw sandy loam by its sloping topography and better drainage; from the higher lying Emmet sandy loam by its poorer position and drainage. About half the individual areas are Isabella sandy loam and half Iosco sandy loam.

Iosco sandy loam usually contains more organic matter and has a darker color than the soils of the better drained slopes above. In addition, it has a 2- to 10-inch layer of harsh ash-gray sand, and finally the dark-brown indurated loamy sand that forms the hardpan. The brown layer is not everywhere continuous. The substratum is a great variety of materials common to the Isabella and Montcalm soils, but it may differ from them in showing some evidence of poor drainage—a grayer color or rusty mottling.

Isabella sandy loam is grayish brown in the upper part of the surface soil and light gray in the lower. The reddish-brown subsoil is plastic when wet; the substratum is sandy clay till. The sandy layers are usually acid in reaction, but the underlying sandy clay is neutral or alkaline.

Agriculturally this complex is just as productive as Isabella-Montcalm sandy loams. In many places, however, it is not cultivated but included with the poorly drained soils that lie in the bottoms of depressions. Where this complex is farmed, the individual bodies are usually so small and intricately associated with other soils that they are not managed separately but cropped and cultivated in the same manner as the dominant soil types with which they occur.

Isabella loam.—For both orchard and general farming, this moderately extensive soil is probably the most productive in the county (pl. 2, *A*). The principal and most uniform areas are distributed over the uplands that extend from Volney through Grant. Marginal areas occur along the upland; the smaller bodies scattered over the rest of the county are less uniform in physical characteristics. The relief is favorable to cultivation because slopes do not exceed 7 percent in gradient.

The original vegetation was hardwood forest, principally hard maple and beech, with smaller numbers of hemlock, white ash, elm, basswood, yellow birch, and a few scattered white pine. Only a few culled virgin stands remain, as nearly all the land is under cultivation.

Under an undisturbed forest cover the surface 2 to 4 inches is a mixture of litter, leafmold, and mineral material in which there is a high content of humus. The black humus color fades through a transition layer of less than ½ inch, after which there is a gray ashy silty and sandy layer 2 to 6 inches thick. Plowing mixes the surface layer with most of the gray layer to produce a friable grayish-brown loam. The organic content in the plow soil is not high, but it can be considered good in comparison with that of others in the county, and considerably better than that of the well-drained sandy soils. The plow soil is generally heavy enough to retain large quantities of moisture.

The reaction of the humus layer is nearly neutral or alkaline, but the lighter colored material underneath is generally slightly acid. The humus layer is granular and loose; the gray layer, though porous, is very compact and commonly exhibits a definite and conspicuous platy structure, particularly in the upper part, that breaks horizontally into numerous flakelike pieces when pressure is applied. Close examination reveals an open structure having many minute continuous holes and channels. In the lower part of the gray layer there are more dense and compact yellowish-brown or pinkish-brown lumps. These become more numerous with depth and mark, at depths of 8 to 16 inches, the transition from the gray layer to a moderately compact acid yellowish-brown or pinkish-brown sandy to silty clay loam.

The heaviest and most compact layer is generally encountered at depths of 14 to 30 inches. This is reddish-brown, sticky and plastic when wet, and conspicuous because of its well-developed nutlike structure. Individual blocks vary from a fraction of an inch to more than an inch in diameter and are characterized by numerous convex angular facets, sharp edges, and pointed corners. There may be a suggestion of vertical orientation, or in other words, there may be dominant cracks and crevices 6 to 12 inches apart, extending downward. The sides of these cracks, and the surfaces of the adjoining structural blocks are coated with a thin layer, darker in color than that found inside the blocks. Plant roots penetrate the more or less permanent openings between the blocks. Larger roots develop in the major cracks, and the smaller rootlets spread over the surface of the minor shrinkage or joint cracks. Tree roots are frequently concentrated in this heavy but penetrable layer. The numerous cracks, crevices, and channels allow free water percolation through this otherwise compact layer so that the profile has every appearance of good internal drainage. The reaction commonly varies from slightly acid to slightly alkaline, although no free carbonates can be detected.

The nutlike structure becomes less apparent and the color becomes lighter as depth increases. If the texture remains sufficiently like that in the upper part, a few large dark-surfaced cracks may persist to depths of 12 to 14 feet. Aside from these cracks, the soil materials show little evidence of weathering below depths of 4 to 6 feet. The substratum is dominantly a massive calcareous pale-red till, hard when dry, but sticky and plastic when wet. Carbonates, beginning at depths of 3 or 4 feet, are mostly in the form of limestone, which occurs either finely divided or as nodules the size of a pebble or larger.

Carbonates are also present as an accretionary coating on the faces of blocks and as filling in the lower parts of the numerous cracks and channels.

Stones are common both on the surface and throughout the substratum, but are seldom numerous enough to interfere with tillage. No difficulties are encountered in the use of farm machinery because the topography is rolling and the relief moderate. Slopes are sufficient, however, to bring about good surface drainage, and long rows running up and down the slope would permit erosion.

Within areas the plow soil is not everywhere of the same color or texture. In a single field there may be many variations in both the chemical and the physical properties. In a few places as much as 25 percent of the surface soil of an area mapped as Isabella loam may actually be a sandy loam. The sandy loam texture may result either because of a greater quantity of sand in the original material or because of a superficial 6- to 12-inch sandy covering over the heavier textured till.

Included in mapped areas of this soil are small closely associated areas of Roselawn fine sand, Montcalm-Roselawn complex, Emmet sandy loam, Isabella sandy loam, or Isabella-Iosco sandy loams. These inclusions are the result of abrupt differences in the texture of the glacial drift, which in many places may change either vertically or horizontally from plastic clays to loose sands within an interval of a few inches or a few feet. Within areas of Isabella loam may be also small inclusions of Bergland loam, Munuscong sandy loam, and Washtenaw soils, undifferentiated. These develop at the foot of slopes, or in the bottom of a small depression, or in other places where both the surface and internal drainage are poor. Few farms of more than 40 acres are composed entirely of Isabella loam, and therefore, as farm land, it must be evaluated according to the soils it is associated with and the area it covers on the individual farm.

The crop yields on Isabella loam are usually the best in the county and good in comparison with other productive soils of the State. Corn produces 35 to 60 bushels an acre; beans, 10 to 20; wheat, 20 to 40; oats, 30 to 60; rye, 15 to 25; timothy and clover hay, 1 to 3 tons; and alfalfa, 2 to 4 tons. Although this soil is considered too heavy to produce well-shaped tubers, 100 to 200 bushels an acre of marketable potatoes can be obtained by careful management. Where air drainage is favorable, there are fruit farms on this soil. Apples are the major crop, but peaches, cherries, and pears also are grown. Yields of these fruits are fair to good. In the vicinity of Fremont large cash returns are often obtained from crops of garden peas, string beans, lima beans, tomatoes, and other vegetables grown for canneries under contract.

Successful farmers employ a 3- to 5-year crop rotation, and they ordinarily grow generous acreages of alfalfa with cash and feed crops. Experience shows that the use of stable manure and commercial fertilizer throughout the rotation generally gives increased profits. Liming is also profitable, but good alfalfa stands may be obtained sometimes on uniform fields without lime applications. This is not true of the invariably acid sandy inclusions; they require 1 to 2 tons of lime an acre for a satisfactory seeding of alfalfa.

Few tillage problems are encountered. If the soil is worked when too wet, however, clods may develop on drying. If this happens, the field will be difficult to handle for several seasons. The surface also shows a tendency to crust after a hard rain. Invisible but serious sheet erosion is taking place, even on gentle slopes.

Isabella loam, hilly phase.—This is found in association with the normal and rolling phases of Isabella loam in the rough upland areas, and where stream cutting has resulted in the formation of steep slopes. Slope gradients in the uplands usually vary between 16 and 25 percent; those formed by streams commonly exceed 30 percent. Tractors, binders, hay loaders, and other large machinery are seldom used on these steep slopes; cultivation of any kind is difficult in many places, even with horse-drawn implements. In addition, severe erosion resulting from cultivation would increase costs and prevent the profitable production of general farm crops. Despite its wide distribution over the uplands of the county this soil is inextensive in area.

The danger of erosion on this hilly soil is increased because the combined depth of the shallow surface layers is commonly not more than 5 or 6 inches. The entire profile is seldom developed to a depth of more than 15 inches. Plowing therefore mixes part of the lower compact layer with those above, and the resulting plow soil is largely a slightly acid or neutral reddish-brown heavy loam to clay loam, which is underlain by alkaline clay loam.

The soil is best suited to alfalfa. Another obstacle to economic agricultural production is the occurrence of large numbers of boulders and stones on the surface and throughout the soil. The original hardwood cover has been cut from about 75 percent of the land; much of the cut-over land has been farmed but is now abandoned. At the present time, this phase is used chiefly for growing hay or for pasture.

Isabella loam, rolling phase.—Most of this inextensive phase is found in Barton and Norwich Townships. It occurs in association with the normal phase, and the principal difference is the steeper gradient of its slopes, 8 to 15 percent, as compared with a maximum of 7 percent for the normal phase. Most of the soil can be cultivated with labor-saving machinery, though handling of tractors is difficult in some places.

Sheet erosion is destructive. At the crest of the hills and in many other places the surface soil has been washed away completely. Where this has occurred, a layer of heavy compact clay is exposed that is difficult to cultivate. Gullies are not frequent, but they develop rapidly under careless management.

The cropping adaptations are similar to those of the more gently sloping normal phase, but the productivity is somewhat less. Production costs are slightly higher because the steeper slopes are harder to farm. These factors, together with the fact that good alfalfa stands can be obtained on the exposed calcareous clay of eroded slopes, encourage hay production and livestock farming. A large acreage is in alfalfa and pasture.

Isabella-Montcalm sandy loams.—In this complex are two closely associated irregularly intermixed soil types—Isabella sandy loam and Montcalm sandy loam. They are mapped together as a complex because they are intricately associated. There are a great variety of textures in the substratum. All variations from loamy sand through clayey sand and sandy clay were observed. The moisture-retaining red clayey sand or sandy clay of Montcalm sandy loam is distributed in thin layers and lenses throughout the substratum, but the texture is dominantly more sandy. Despite the variation in the substratum, the plow soil is generally a fairly uniform light grayish-brown sandy loam, slightly acid to neutral, and somewhat deficient in organic matter.

The complex is fairly extensive, and occurs principally on the uplands extending from Beaver through Dayton, Garfield, and Grant Townships, but smaller, more irregular bodies are found on the other uplands. The topography is gently sloping to undulating, with slopes of 4 to 7 percent in gradient. The relief is not great, nor are stones and boulders numerous enough to interfere with cultivation.

The original vegetation on this complex was a mixed forest of hardwood and white pine. The size and distribution of the stumps that remain indicate that the pine flourished on these sandy soils. Early settlers often selected the hardwood openings in the forest for farms because the hardwoods indicated that clay was at or near the surface. The hardwood stumps also rotted more rapidly than the pine, so that fields could be cleared more quickly and easily. Although this land is relatively productive, it has not been so extensively cleared as the heavier Isabella loam. Perhaps 10 percent remains in second-growth forest of oak, aspen, soft maple, cherry, white ash, Juneberry, and pine, the undergrowth being witch-hazel, sassafras, viburnum, blackberry, dwarf-recumbent dogwood, and honeysuckle. Wintergreen, bracken, false Solomonseal, and grasses compete for ground space. An additional 10 percent is utilized only as stump pasture land.

The following profile observed in a patch of undisturbed forest is considered representative of Isabella sandy loam. A litter accumulation about an inch thick is underlain by a black granular humus layer 1 to 2 inches thick containing a few scattered particles of white sand. This organic layer is slightly alkaline in reaction and is heavily matted by the fibrous roots of the small plants that grow on the forest floor. A thin dark-gray transitional mineral layer over a strongly podzolized acid nearly white ashy gritty fine sand to sandy loam 3 to 6 inches thick is exposed when the mat is removed. As in Isabella loam, this light-colored layer is fairly compact; it shows a weak platy structure and there are numerous minute channels, passages, and worm holes filled with dark material from the upper layers. In many places, where the forest cover has long since been cut and grass has invaded the forest floor, the light podzol layer is less evident. Instead, the 8-inch layer directly under the thin deposit of litter is a grayish-brown relatively compact sandy loam. Slight pressure causes this loam to break into poorly defined fragments that possess no characteristic or distinct shape; the soil granules merely adhere in shapeless moderately firm irregular aggregates.

Underlying the light-gray, or the gray-brown, layer is a 4- to 8-inch layer of light-brown fine sandy loam to loam, also compact, that shows little evidence of structural development. This layer is ordinarily replaced abruptly by a light-gray sandy loam or fine sandy loam with a pinkish cast. This is acid to neutral in reaction and 12 to 24 inches thick. Close observation discloses a coarse blocky structure in which horizontal cleavages dominate. A gradual change through a

1- to 3-inch transition zone terminates in a slightly cemented compact layer similar to that in Isabella loam in all respects but its greater depth (18 to 40 inches below the surface) and its lighter texture, which is generally a clayey sand to sandy clay.

The blocks are large, massive, and angular, and the faces have dark-brown coatings. Considerable fine gravel and coarse sand may be present, and therefore the blocks are not so hard when dry as those of Isabella loam. They crumble and show that the coarse particles are covered with reddish-brown clay. When wet, the color is more pronounced and the clay material is sticky and plastic. This layer is from 3 to 4 inches thick. The dark-reddish color gradually fades with increasing depth, and below 6 to 8 feet there is no other evidence of weathering. The heavy dark material is extremely variable in depth. Long pointed tongues were observed that extended 6 or 7 feet below the surface. The substratum is generally a calcareous pale reddish clayey sand or sandy clay, but pockets of sand and silt, and lenses of impervious massive clay are common.

Included bodies of Isabella loam and Roselawn fine sand are marked by differences in the texture of the plow soil. Some small areas of Iosco sandy loam are included in places where the drainage is imperfect because of seepage. Poorly drained spots of Washtenaw soils, undifferentiated, Wallkill loam, and in dry valleys, Echo loamy sand, were also included if they were not of sufficient size to be mapped separately.

The agricultural use of this complex is similar to that of Isabella loam, but yields are somewhat smaller. Corn produces 30 to 50 bushels an acre; beans, 10 to 20; wheat, 20 to 35; oats, 25 to 40; rye, 10 to 20; timothy and clover hay, 1 to 3 tons; and alfalfa, 1 to 3 tons. This is potentially a good potato soil in spite of the fact that average yields have been only 100 to 175 bushels an acre. Some orchard fruits are successfully grown, particularly where Emmet sandy loam is closely associated.

Fairly large increases in crop production can be obtained by the use of commercial fertilizer and liming material. Liming is considered necessary if satisfactory seedings of alfalfa are to be obtained. Successful farmers generally follow some method of crop rotation and are careful to avoid the planting of intertilled crops on the same field in successive years, and thereby the danger of serious erosion is reduced. Spring plowing of slopes, cultivation across the slope instead of up and down, and use of sod waterways are aids in preventing serious erosion losses.

Isabella-Montcalm sandy loams, hilly phases.—This complex occupies slopes that are usually between 16 and 25 percent in gradient, but some may exceed 30 percent. The soil is not cultivated, but a small acreage is used for pasture and grazing.

Isabella-Montcalm sandy loams, rolling phases.—This complex includes areas with rougher more broken surfaces where gradients vary from 8 to 15 percent. The dark reddish-brown sandy clay layer is nearer the surface on the sidehills than it is in the normal phases of the complex, even under a forest cover. This indicates that the soil-forming processes were such that they did not allow development of a deep solum. Under cultivation, erosion on the steepest slopes rapidly removes the thin top layers and leaves the sandy clay on the surface.

This inextensive complex is associated with other Isabella soils and often occupies the transitional zones between Isabella soils and Montcalm-Roselawn complex or Roselawn fine sand. Cropping adaptations are similar to those of Isabella-Montcalm sandy loams, but the productivity is not so great and production costs are higher. Erosion is serious in cultivated fields, and on steeper slopes it can be prevented only by keeping the soil in sod or cover crops.

Kalkaska loamy sand.—This is not an extensive soil in the county. It occurs on flat benches with associated Emmet soils and on nearly level dry sandy plains. The largest body is located east of Hesperia on the plain of the White River Valley. The original cover consisted dominantly of hard maple, beech, yellow birch, hemlock, elm, and ironwood, with a few scattered pines admixed.

Under a second-growth hardwood forest the surface layer is composed of litter and leaves in all stages of decomposition. It is 1 to 3 inches thick and slightly alkaline in reaction. Underlying this is an acid ashy-gray sand that may extend as deep as 18 inches. This conspicuously light-colored layer is underlain, in turn, by an acid dark coffee-brown loamy sand, often slightly indurated, and 3 to 12 inches thick. The brown color fades through a thin transition layer, and an acid pale-yellow loose deep sandy substratum is next encountered. The visible difference between this soil, which was originally covered with hardwoods, and the soils of the pine plains is in the thickness of the gray and the brown layers. A few small areas resembling Arenac loamy sand or Saugatuck sand and low nearly level ridges of Wallace-Weare fine sands are included.

Nearly all of this soil has been cleared for cultivation, but a small acreage supports a hardwood second-growth cover. Under cultivation the plow soil is grayish-brown loose loamy sand. The organic content is rapidly depleted, and the result is a rather infertile soil that retains a trifle more moisture than Rubicon sand. Under good management fair yields of all staple crops are obtained. Wind erosion, however, has removed a large part of the original surface soil of this type.

Kent-Arenac complex.—This is an intricate association of Kent silt loam and Arenac fine sandy loam, both of which are described elsewhere in this report. On the smooth upland of Sheridan Township, and in a few other places in the county, the calcareous silty lacustrine clay typical of the Kent soils is characterized by a smoothly undulating surface. The depressions in the clay plain are filled with sand, so that the surface is nearly level. In the deepest parts of the sand-filled pockets, which seldom exceed an acre in extent, a typical Arenac profile has developed. Around the margins, the sand covering the clay is often only of plow depth. Strips of silt loam or loam from 50 to 100 feet or more in width separate the discontinuous Arenac areas. These strips that border the sand-filled clay spots may be Kent silt loam, Arenac fine sandy loam, or Ogemaw sandy loam.

Inextensive areas of another arrangement of these soils in a complex are encountered. In these the nearly level calcareous clay plain was covered with low narrow discontinuous ridges of sand to produce an undulating topography. The typical Arenac soil is situated only on the deepest parts of the ridges and sandy mounds; Kent silt loam occupies the broad intervening spaces. Wind erosion often removes the surface soil from the ridges and spreads that sandy material over the silt loam in the lower areas.

Agriculturally, the complex is of a value intermediate between Kent silt loam and Arenac fine sandy loam. The crops are naturally very spotty on such variable fields. Under good management, soil amendments are intensified on the sand spots to insure uniform production.

Kent silt loam.—The relief of this soil is undulating to gently sloping, and there are no slopes sufficiently steep to prevent the use of tractors and other labor-saving machinery. It occupies high, smooth, heavy-textured till plains or old lake-bed plains. Natural drainage is slow, both surface and internal, but it is sufficient for the growth of all general crops without artificial drainage. Tiling, however, is advisable for best results, especially in the swales or depressions. Nearly all of the soil has been cleared, but it originally supported dense forests consisting largely of hard maple, beech, elm, ash, basswood, and hemlock. The largest and most uniform areas are in the smooth upland near Fremont, on the trenched plain in Sheridan Township, and near Volney. The total area is not large.

Under virgin conditions the surface layer consists of 1 to 2 inches of nearly black decomposed and disintegrated leaves and woody material. Following this is a leached thin gray layer, the texture of which varies from sandy loam to silt loam. Next in order is a reddish-brown or yellowish-brown clay 6 to 8 inches thick and strongly acid, into which numerous tongues or streaks of the preceding light-gray sandy loam extend. This soil therefore has a grayish-brown or dark-gray finely granular heavy silt loam plow soil that is medium to strongly acid. At a depth of 10 to 20 inches there is a dark yellowish-red heavy clay or silty clay. This clay is plastic when wet, but when dry it readily breaks or crumbles into small blocks or cubes ¼ to ½ inch in diameter. The reaction of this blocky layer is medium acid. At depths of 20 to 24 inches there is light yellowish-red heavy calcareous clay containing numerous light-gray streaks and a few rust-brown mottlings. In places, small areas of Ogemaw sandy loam, Bergland loam, and Munuscong sandy loam are included with areas of this soil, but as a whole it has a uniform loam or silt loam surface soil over a heavy silty clay.

Small grains, corn, beans, red clover, and alfalfa hay are the chief crops grown, and of these, hay occupies the largest acreage. Corn yields 20 to 40 bushels an acre; oats, 20 to 50; beans, 5 to 15; and alfalfa, 2 to 4 tons. Sweetclover is grown frequently for pasture and for soil improvement and is occasionally grown for hay. In some places it is possible to obtain stands of alfalfa without the use of lime, but it is ordinarily necessary to use large quantities of barnyard manure. All crops respond well to commercial fertilizer, but in general, most of the fertilizer used during the rotation is applied for the wheat crop.

Kerston muck.—Because it is located on stream-valley bottoms that are subject to flooding and to poor drainage, this organic soil is of low agricultural value.

The surface soil contains considerable alluvium because it is flooded in a manner similar to the Griffin soils. Except for the admixed mineral matter, this dark-colored muck or peat resembles Carlisle muck, Rifle peat, or Houghton muck. The organic accumulation is seldom deep. Near stream banks as much as 60 to 70 percent of the mineral material may be admixed as lenses or layers. For the most part, the surface is 1 to 3 feet above stream level.

This soil type generally supports a fairly vigorous cover of white-cedar, tamarack, alder, willow, aspen, birch, elm, ash, and red maple. The ground cover is often dominated by a heavy growth of ferns. When cut over, the land will support a good pasture. Poor location and drainage give a low farming value, though the natural fertility may be as high as that of other organic soils.

Maumee fine sandy loam.—Transition zones between better drained mineral soils and the muck lands are very often occupied by this soil. An example is the wide belt that nearly surrounds the drained area of Rice Lake. There, some of this fine sandy loam is cultivated, but elsewhere the bodies are too small and show too little evidence of durability to justify the expense of both drainage and clearing. The individual bodies are nearly level, and under natural conditions the water table is at or near the surface much of the year.

The slightly acid surface layer, 4 to 12 inches thick, is a loamy mixture of finely divided organic matter and white sand. In places the surface is nearly pure muck; in others it is nearly a sandy loam. The subsoil is a gray waterlogged sand, slightly acid to slightly alkaline in reaction.

Cleared areas provide good pasture, and the carrying capacity through the summer is likewise good. If this soil is skillfully managed, particularly if heavy applications of commercial fertilizer are applied, it can be used for truck crops. It is generally less valuable for truck crops, however, than the well-decomposed mucks; and for the staple low-acre-value general farm crops, much less durable and productive than the drained soils of heavier texture, for example, Bergland clay loam.

Montcalm-Roselawn complex.—Intricately associated Roselawn loamy sand and Montcalm sandy loam comprise this complex. The Roselawn member has a plow soil of a light-gray acid loamy sand that is underlain by the materials of the kind described for Roselawn fine sand. A great degree of variation exists in both of the component soil types, and inclusions of Roselawn fine sand may amount to as much as 15 to 20 percent of the total area. Another extreme variation occurs chiefly on slopes, where a stiff reddish-brown clay is exposed as a result of severe erosion. A heavier surface texture is also characteristic in places where there are included areas of Isabella loam and Isabella sandy loam, both of which possess a more clayey substratum. Other imperfectly drained inclusions resemble Iosco sandy loam. The poorly drained bottoms of depressions and pot holes are either Washtenaw soils, undifferentiated, or Wallkill loam.

The topography of this complex is more rolling and hilly than that of Isabella loam or Isabella-Montcalm sandy loams. Slopes commonly vary from 8 to 15 percent; they are usually complex and irregular, seldom smooth. Labor-saving machinery can be employed in all but a few places. Stones and boulders are numerous but not a serious obstacle to cultivation.

The complex is relatively extensive. It is widely distributed on the uplands in nearly every township and is closely associated with the rolling phases of Isabella loam and Isabella-Montcalm sandy loams and the undulating phase of Roselawn fine sand.

The original vegetation was similar to that on Isabella-Montcalm sandy loams but probably contained a larger proportion of both red and white pines (pl. 2, *B*). This was one of the best pine soils, according to information furnished by the early settlers, and the remaining stumps make evident the large size and density of the forest. The present growth resembles that on Isabella-Montcalm sandy loams. Sixty percent of this soil was estimated to be under cultivation at the time of survey.

The surface layer of Montcalm sandy loam, under the litter of a second-growth forest, is intermingled gray sand and finely divided black granular organic matter that together form a loamy layer 1 to 2 inches thick. This overlies a 2- to 3-inch layer of gray strongly acid medium sand to loamy sand, the structure of which is platy and porous. Underneath is a light-brown or yellowish-brown strongly acid loamy sand 5 or 6 inches deep. When dry this layer appears to be slightly cemented. Cultivation mixes these top layers to produce an acid gray or grayish-brown light sandy loam that is deficient in organic matter.

Below a depth of 18 to 24 inches is light friable strongly acid brownish-red clayey sand to sandy clay that is plastic and sticky when wet but crumbly when dry. This clayey moisture-retaining layer is massive and compact. It may extend downward for several feet, but more often it is only 8 or 10 inches thick.

The substratum is generally a light-brown or yellowish-brown medium loamy sand containing thin distributed layers of pink clayey materials. Lenses of sand, silt, and heavy clay occur often. The upper part of the substratum is slightly acid, but at a depth of 4 or 5 feet it becomes neutral to alkaline in reaction.

Crop yields vary widely according to the management the soil receives. The land is well drained; it warms up early in spring, and yet it has a fair moisture-retaining capacity. It cannot withstand a prolonged summer dry spell, however, and the natural fertility is not high. Efficient farmers are able to make a fairly good living by growing well-adapted crops and using stable manure, green manure, commercial fertilizer, and lime. Poor managers, at the opposite extreme, generally have difficulty in meeting the requirements of bare subsistence, especially on the lighter soil phases.

Among the grain crops, rye yields 8 to 12 bushels an acre; wheat, 5 to 20; oats, 20 to 35; corn, 20 to 40; beans, 5 to 20; potatoes, 75 to 150; alfalfa, 1 to 2 tons an acre; and clover and timothy hay, ½ to 2 tons. String beans, cranberry beans, kidney beans, and cucumbers often produce good yields and are regarded as fairly certain cash crops by the subsistence farmers.

Sheet erosion losses on this soil are severe, even on moderate slopes, and on the steep slopes erosion losses are so great that cultivation soon becomes unprofitable. Some areas have been overgrazed and are now extensively covered with worthless sweetfern. In other places where the sod has been destroyed, wind erodes the sandy spots and causes blow-outs and bare fields. Careless management often leads to gullying. In these clayey sand materials this is serious because the gullies grow rapidly once cutting starts. The planting of cover crops, the use of proper rotations, the prevention of overgrazing, and other good soil management practices reduce erosion losses.

Montcalm-Roselawn complex, hilly phases.—This complex is associated with Montcalm-Roselawn complex and differs only in its rougher and more broken topography. Slope gradients exceed 15 percent, except in a few small incidental nearly level areas that occur in such places as narrow valley floors and hilltops.

In the heavier textured type the ashy-gray leached layer and thin humus accumulation under an undisturbed forest cover is only ½ to 1½ inches thick. The underlying yellowish-brown loamy sand seldom exceeds 4 inches in thickness. Brownish-red sandy clay is frequently encountered between 5 and 10 inches below the surface, and a great variety of materials of the kinds described for Montcalm-Roselawn complex make up the substratum. In the roughest places, considerable gravel is distributed in both the surface soil and the subsoil, and stones and boulders are numerous.

Although this complex occurs chiefly in the rough uplands, there are small acreages scattered throughout the uplands. The small areas are especially prevalent where the less steep uplands have been cut by streams.

Approximately 85 percent of this soil supports a second-growth cover similar to that on the normal phase of the complex. Sassafras and sumac dominate the most open areas, which were at one time grazed. The rest is used chiefly as stump pasture. Cultivation is prohibited because the steep slopes prevent the use of machinery. Erosion losses would be too high to permit profitable farming if cultivation were feasible. This soil produces fair pasture, and it should support profitable wood lots under good management.

Montcalm-Roselawn complex, undulating phases.—Except for a milder more undulating topography, a smaller relief interval, and smoother slopes, this is similar in chemical and physical characteristics to Montcalm-Roselawn complex. The topographic differences, however, are reflected in a slightly better developed profile, more organic matter in the surface soil, decreased susceptibility to erosion losses, a trifle higher natural fertility, and greater ease of cultivation. This soil, therefore, has a greater inherent productivity and will grow crops more economically. Variations in soil texture are neither so frequent nor so extreme as those in the Montcalm-Roselawn complex.

The total area is not large but the individual bodies are widely distributed over the uplands. About 90 percent of the total area is cleared and cultivated. The small nearly level areas usually occur where the hills interfere with their agricultural use and therefore are not so well utilized as many less productive soils that have the advantage of being in larger bodies. This undulating land is usually found in association with other phases of Montcalm-Roselawn complex, and it is managed in much the same manner to produce crop yields 15 to 20 percent higher.

Munuscong-Maumee soils, undifferentiated.—In the lowland plain of Rice Lake a mixture of soils has been designated as Munuscong-Maumee soils, undifferentiated. The slopes do not exceed 3 percent in gradient.

This diversified soil is characterized by a black mucky sandy loam surface layer 6 to 14 inches deep over a sandy and clayey subsoil. Both the surface soil and substratum are neutral to alkaline.

Some of the soil is black mucky sand over gray waterlogged sand like that of the Maumee and Granby soils, and some is included that consists of a dark-colored clay or silt loam at the surface and, at depths of 12 to 18 inches, wet sand or interstratified sand, silt, and clay.

This land has little agricultural value, but it can be used for both general farm and truck crops. The principal depreciating factors are a lack of uniformity and difficulty in drainage caused by extreme variations in texture. About 15 percent is in pasture. The rest is covered with a growth of aspen, alder, willow, elm, ash, red maple, and various shrubs.

Munuscong sandy loam.—With reference to the depth to the clay layer, this soil is intermediate between Bergland loam and Newton loamy fine sand or Granby sandy loam. Small bodies of Bergland loam, Saugatuck sand, and sandy loams of the Ogemaw and Granby series are included in areas of this soil. Munuscong sandy loam is not extensive. The largest and most continuous bodies are located on the smooth upland and plain in Sheridan, Garfield, and Bridgeton Townships.

The soil occupies low-lying lake-bed plains and low pockets and depressions in moraines and till plains. The surface is nearly level. Surface runoff is slow, and internal drainage is poor because of the underlying clay. Tile and open ditches are employed to facilitate drainage. The native forest consisted of a mixed stand of red maple, elm, swamp white oak, basswood, ash, hemlock, white pine, and white-cedar.

The plow soil is a dark grayish-brown to dark-gray loose slightly granular sandy loam, neutral or slightly acid. It overlies 12 to 36 inches of slightly acid loamy sand or sandy loam, dingy gray to dark grayish brown and mottled with reddish brown and yellow. This layer is abruptly underlain by an impervious neutral to alkaline bluish-gray silty or sandy clay mottled with rust brown, red, and yellow.

This soil has high fertility, but only 60 percent of it has been drained and cleared. Because of its low position, crops are menaced by both late and early frosts, and therefore the use is largely restricted to grains, hay, and pasture. Timothy and alsike clover return good yields. In favorable locations excellent yields of beans and potatoes are obtained. Beans yield 10 to 25 bushels an acre. Oats produce well, yielding from 25 to 50 bushels an acre. Probably 50 percent of the cleared acreage remains in pasture. The chief factors limiting a more extensive use of this soil are the cost of drainage and the lack of frost-resistant cash crops.

Newton loamy fine sand.—A lighter textured surface soil and a more acid reaction throughout differentiate this soil from Granby sandy loam. It occupies a large part of the poorly drained sandy plains, where the water table is near the surface a large part of the year. Though the area covered by this soil is extensive, only a small part is cleared and drained. The native cover was similar to that of Granby sandy loam, but aspens became the dominant tree growth after cutting and burning. Some pulpwood is obtained from the forest cover.

The surface soil under a second-growth cover is decomposing leaves and litter mixed with mucky material and sand to depths of 3 to 4 inches. A layer of drab-brown or dirty-gray sand, acid in reaction, is the only other layer above the dingy whitish-gray waterlogged sands that extend to depths of 3 to 4 feet or more. This type is closely associated with Saugatuck sand, of which there are many inclusions.

Under cultivation, the land generally fails to produce profitable yields of any staple field crops after a few years of cropping. It is subject to frost in most places, and this is an additional handicap. Overdrainage is a disadvantage because the surface layers are not retentive of moisture. Most of the soil remains in permanent pasture. It is fair for this purpose, but it has little agricultural value for low-cost production of staple general farm crops. With skillful management some of the favorably located bodies may have some potential value for truck crops, but they would require drainage.

Newton loamy fine sand, drained phase.—Differentiated in this phase are several areas on the well-drained sandy plain in Lilley Township and a few small areas elsewhere that possess a profile similar to the normal phase except for the surface soil, which contains less organic matter, and the water table, which lies at a greater depth. The tree cover consists of scattered oak and aspen. This phase has little agricultural value for cultivated crops, but it produces some hay and pasture.

Ogemaw sandy loam.—Light sands overlying clay on smooth poorly drained plains are identified in this type. The relief is nearly level to undulating, and surface drainage is slow. Although moisture readily penetrates the upper part of the soil, the downward movement of water is impeded by the clay substratum. The total acreage is made up of widely distributed individual bodies. The original forest cover was white pine with admixed hardwoods.

The plow soil, a dark-gray or grayish-brown loose sandy loam fairly high in organic matter and strongly acid, is underlain by 4 to 8 inches of grayish-white harsh loamy sand. Below the sand is the characteristic dark-brown hardpan, a layer 2 to 12 inches thick of sand cemented by organic compounds and iron oxide. The hardpan may be relatively soft or earthy, or hard and rocklike. Underneath the indurated layer is 4 to 8 inches of dingy-gray sand, mottled with bright brown and yellow, that gives way to a stiff heavy impervious calcareous clay.

The total thickness of the sandy layers is 18 to 36 inches, but in small included areas the clay is close enough to the surface to form Bergland clay loam. In other places slight differences in drainage result in the formation of small areas of Munuscong sandy loam or Arenac fine sandy loam. Small inclusions of these are common in areas of this type.

About 65 percent of the land has been cleared and cultivated. Some type of artificial drainage is needed for best results from most farm crops. Artificial drainage systems consist chiefly of shallow open ditches that empty into larger ditches. Owing to the difficulty of working around them, feeder drains are shallow, inefficient, and seldom adequate in number. They are being replaced by tile to some extent.

Corn yields 15 to 30 bushels an acre; wheat, 5 to 20; oats, 15 to 45; rye, 5 to 20; potatoes, 75 to 300; and beans, 5 to 15. Alfalfa produces 1 to 3 tons an acre, but it does not thrive so well as on the better drained soils.

Oshtemo loamy sand, sloping phase.—Except for its lighter texture and lower agricultural value, this soil is similar to Fox sandy loam, sloping phase. It occurs in association with the undulating phase. The normal phase is not mapped in the county.

About half of the soil remains in pasture and forest cover. Runoff is decreased both by the vegetative cover and the porous subsoil, and therefore the soil has not been extensively damaged by water erosion. Slope gradients are from 8 to 15 percent.

Oshtemo loamy sand, undulating phase.—Fairly large bodies of this phase are distributed over the central and northeastern parts of the pitted plain in Ensley Township. The soil is similar to Fox sandy loam in many respects; its principal difference is a lighter texture. The slopes range from 4 to 7 percent. The plow soil is a loamy sand that is in places sandy enough to resemble the Plainfield. The substratum is sandier and less calcareous than in Fox sandy loam.

The same crops are grown and nearly the same farm practices are followed as for Fox sandy loam, but in spite of the fact that erosion has not been so destructive, this soil is of less agricultural value. Possibly one-fourth of the total area remains in second-growth timber.

Oshtemo sandy loam.—East of White Cloud an extensive uniform body of this soil is being successfully farmed. General crops are grown, and the yields average slightly less than those on Arenac fine sandy loam. The original cover on this body of soil was a dense stand of white and red pines. Elsewhere in the county the soil is drier. It supported less pine and the value for farming is low. Slope gradients do not exceed 3 percent.

The virgin soil consists of ½ to 1½ inches of a dark-gray acid sandy loam mixed with well-decomposed brown organic materials, litter, and leafmold. This is underlain by 3 or 4 inches of grayish-brown acid light sandy loam that grades into a yellowish-brown or brownish-yellow loamy sand. These three layers all contain considerable coarse sand, and the color of each seems to be imparted by a coating around the individual sand particles. Under cultivation, the surface layer is a grayish-brown light sandy loam, deficient in organic matter.

At depths of 2½ to 4 feet there is a thin layer of reddish-brown sticky clayey sand or clayey gravel. This layer is massive, hard, and cemented when dry, but is not uniform in thickness, and is entirely missing in some places. The substratum is stratified sand and calcareous gravel. The gravel seldom exceeds 1½ inches in diameter. There may be a few cobbles and boulders scattered through the soil profile. Small areas of a gravelly Plainfield soil and Plainfield sand occur as inclusions, and in depressions there may be included areas of Antrim sandy loam.

Oshtemo sandy loam, gently sloping phase.—This is similar to the normal phase in all properties except topography. Instead of having a nearly level surface, this soil is characterized by slopes varying from 4 to 7 percent. Some areas of this phase are cultivated, and others support a second growth of oak.

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Ottawa loamy fine sand.—This soil occurs on nearly level sandy outwash and old lake plains chiefly in the southwestern part of the county. The surface is low in moisture-holding capacity, but lenses of clayey material or a clay substratum retain moisture 3 to 5 feet from the surface. The original forest vegetation was white pine, or a mixture of pine, hemlock, hard maple, and beech.

The plow soil is a light grayish-brown loamy fine sand, loose, mellow, and easily worked. The subsoil, which extends to depths of 15 to 20 inches, is a strongly acid light yellowish-brown loamy sand. The substratum is yellowish-gray sand, acid in reaction, and shows yellow and rust-brown mottling at depths of 4 to 5 feet. At depths of 3 to 4 feet throughout the sands, there are less pervious lenses of reddish-brown clayey sand and silt, and heavy limy clay is encountered at depths of 5 to 6 feet. Included with this type are a few acres on the more rolling parts of the outwash and lake plains that have slopes up to 8 percent in gradient.

Nearly all of this easily worked soil has been cultivated at one time, but a part of it has been abandoned, and nearly all of the rest is in permanent pasture. Where the soil is cultivated, rye, beans, and corn are the chief crops. A large quantity of stable manure or green manure is required to make this soil highly productive. Under continuous clean cultivation considerable damage results from wind erosion.

Ottawa loamy fine sand, sloping phase.—In this phase are differentiated areas having slopes in excess of 8 percent. This soil occurs chiefly around depressions occupied by the normal phase. The steepest slopes in the normal phase, even with the small more sloping inclusions, do not exceed 7 percent. In this phase gradients are up to 15 percent.

Plainfield sand.—This is the driest soil of the dry plains in the southern part of the county. It occurs in large uniform bodies that have a nearly level surface. Judging from the stumps, the original forest cover was a thin stand of white and red pines, probably interspersed with oak. A second growth of scrubby oak, pin cherry, and sumac covers some of this soil; in other places there is only a sparse cover of grasses and weeds.

An undisturbed surface layer under a second-growth cover consists of 1 to 2 inches of loamy sand in which there is a moderate proportion of humus and admixed leafmold and a few roots. This is underlain by 1 to 2 inches of light grayish-brown sand that grades into a pale brownish-yellow sand in which the individual grains are slightly coated. This layer may be 2 to 12 inches thick. The substratum is a loose pervious pale-yellow sand. With the exception of the organic layer, which is nearly neutral, all of the layers are acid and there is no evidence of carbonates within 4 or 5 feet of the surface. The plow soil is light grayish-yellow sand containing little organic matter.

This is not an agricultural soil, but a few acres are planted to cucumbers and green beans for cash crops, or to vegetables for home use. Rye, timothy, beans, and potatoes do fairly well in wet years after heavy applications of lime, manure, and commercial fertilizer. The pervious nature of the substratum, lack of plant nutrients, and low moisture-retaining properties are the chief disadvantages.

The necessity for careful management apparently was not well understood by the early settlers, many of whom preferred the sandy plain soils because they were easily cleared and worked. More abandoned farms can be seen on this soil than on any other in the county. Judging by the ruins of the buildings that remain on the abandoned land, some of the farms were originally successful. The most practical use seems to be grazing in spring and late fall in conjunction with more poorly drained soils, or the planting of pines or other conifers.

Plainfield sand, eroded undulating phase.—Wind erosion has removed the surface layers on part of this phase. The only plants existing on these bare wind-swept spots are sandbur, milkweed and, in a few places, quackgrass. These areas are of no apparent agricultural value.

Plainfield sand, rolling phase.—A few stream-cut slopes are found on the deep sand plains adjacent to large stream valleys; this phase is mapped where the gradient ranges from 8 to 15 percent. It is chiefly grass- and shrub-covered and has no agricultural value.

Plainfield sand, undulating phase.—Where a few inextensive areas of the normal phase have an undulating surface not exceeding 7 percent, this phase is mapped. The land is of no apparent agricultural value.

Rifle peat.—The surface layer is a dark-brown or black, nearly pure organic material formed from partly to highly decomposed leafy or woody accumulations. At depths of 6 to 20 inches there are fibrous coarse-textured masses of brown very slightly decomposed plant material. Many woody roots are above the water table, which varies from 10 to 20 inches from the surface. The reaction of the organic layers is slightly to strongly acid. The substratum is either sand or clay.

The vegetation is ordinarily a dense growth of white-cedar, black spruce, and tamarack, with an occasional white pine. A few scattered elm, red maple, and aspen are not uncommon. In some places the burned-over and logged-off swampland has grown to dense thickets of aspen, alder, willow, and a few scattered white birch. Leatherleaf, blueberry, laurel, and such vegetation of the more acid bog types are occasionally associated with the growth of trees. Open areas support a heavy cover of sedge and bluejoint.

This peat has little agricultural value, but a few areas support pasture, and others furnish hay. The greatest value of the soil is probably in the growth of trees it produces and, indirectly, in the game shelter the cover provides.

Rifle peat, shallow phase.—These numerous organic accumulations, generally in the bottom of small depressions, possess a typical Rifle peat surface but are less than 2 feet deep. They have no value aside from the cover they may afford game. They may depreciate the value of adjoining land because they are not tillable and interfere with laying out rectangular fields.

Roselawn fine sand.—Extensive bodies of this sandy soil of the rolling to hilly pinelands occur on all the upland areas, particularly in the northern part of the county. They have formed on sandy moraines, and the topography is generally gently rolling or rolling

(8 to 15 percent). Internal and external drainage are both good because of the looseness and perviousness of the soil material and the nature of the topography.

None of the original forest of white and red pines remains. Instead, the soil supports a second growth of oak, aspen, pin cherry, red maple, and a few scattered pine. The ground cover is chiefly sweetfern, bracken, witch-hazel, blueberry, and grass. Numerous depressional areas support a grass cover, and many old clearings that were once farmed are now grown over with grass and sweetfern.

Under virgin conditions there is a thin layer of leaves, twigs, and pine needles on the surface. This overlies 1 to 2 inches of acid dark-gray loamy sand. Underneath is a thin ash-gray layer, an inch or two thick, that is not everywhere evident, even under a second-growth cover, and is seldom found under a heavy sod. The next is a 5- to 6-inch layer of strongly acid brownish-yellow or yellowish-brown loose loamy sand. Under close inspection the sand particles are covered by a brown organic coating. The two upper layers and a part of the third become mixed when cultivated, and the resulting plow soil is light grayish brown, acid, and low in organic matter.

The substratum in most places consists of a pale-yellow sand that extends to depths of several feet. This droughty sand is dominant in the substratum but in places a few lenses and bands of pink clayey sand or silt may be evident, and gravelly pockets are not uncommon. Large rounded masses of heavy calcareous sandy and silty clay sometimes occur, their shape suggesting that they were transported by ice in the manner of boulders.

Within areas of this soil are included bodies of Montcalm, Emmet, and Isabella sandy loams; and in the accompanying depressions, Echo loamy sand and Washtenaw soils, undifferentiated. There are areas of the soil that have a larger proportion of gravel. These are shown on the map by gravel symbols. Gravel in this soil usually indicates a little more clay in the subsoil.

Only a few areas of Roselawn fine sand are cultivated. Inherent low fertility, low productivity, and susceptibility to drought are obvious to all but the inexperienced. Good yields of truck and early maturing staple crops may be secured for a season or two after clearing, if there is sufficient rainfall. The supply of organic material is soon depleted, however. In spite of the fast and apparently vigorous growth of corn in spring, a week or more without rain early in July will ordinarily dry up most of the crop. Where it appears that farms are successful, crops are not actually grown on this soil, but in small depressional areas where lack of moisture is not so much a limiting factor.

Where it occurs in conjunction with better farming land, the soil can be pastured with fair success in spring and fall. Under good management it supports some livestock in summer, but wells are necessary for watering the livestock. Large tracts are unfit for anything except recreational use and forestry. If fires are prevented, a good second-growth forest can be established. Under a different type of management the soil may be more valuable for game propagation and hunting land than for forestry and agriculture.

Roselawn fine sand, eroded phase.—This phase is inextensive. It occurs in a few areas where, due to improper use for farming or to overgrazing, the surface has been left unprotected by either sod or forest and severe erosion by wind-blowing has resulted. Some of these wind-blown areas are still barren, and some blow-outs are present, but in other places sweetfern, weeds, and grass have become established and are effecting a measure of stabilization.

Roselawn fine sand, eroded undulating phase.—Differentiated in this phase is a large part of the undulating phase of Roselawn fine sand that was pastured after being cut over. A good second-growth forest never became established.

The high price of wool in the early twenties stimulated sheep raising and indirectly led to overgrazing on many tracts. The result was destruction of the scanty original sod cover, and finally wind-blowing of the surface soil. Some of the wind-blown areas are still barren, but sweetfern, weeds, and grass have invaded other bare spaces and effected a measure of stabilization.

Roselawn fine sand, hilly phase.—Included in this phase are areas having slope gradients of 16 to 25 percent or more, a rugged abrupt topography, and a comparatively strong relief. The profile under virgin conditions is similar to that of the normal phase. The native forest was largely red and white pines. Some of the trees grew very large, particularly those located in depressions.

Some areas have been cleared, but after a few years of cultivation and the accompanying washing and blowing, there remains only a yellow dunelike sand, on the surface of which there is a little scattered gravel. Areas of this soil containing considerable gravel are indicated on the map by gravel symbols. None of the soil is now cultivated. Areas once farmed are now worthless eroded wasteland, and the rest is in second-growth timber mainly of oak and aspen. The land is well adapted to recreational use where it occurs near lakes, as in the vicinity of Newaygo. The ruggedness is there considered an asset because it helps to make the landscape picturesque.

Roselawn fine sand, undulating phase.—Differentiated in this phase are the smoother more nearly level parts of the sandy uplands. There are no significant differences in profile development between this and the normal phase. From the standpoint of land use, however, this undulating soil possesses a slightly greater productivity and usually supports better pasture, particularly where it occupies the floors of depressions. The depressional areas, though dry, suffer less from lack of moisture than the surrounding slopes. Because of its greater productivity, a larger proportion has been cleared and pastured.

In connection with fur farming, resort management, and such lines of endeavor, a small acreage is farmed to subsistence crops of potatoes, rye, buckwheat, beans, and garden vegetables. Under proper management some of the smoothest parts in the southwestern part of the county might be used for orchards, particularly peaches. Even with large applications of manure and commercial fertilizer, yields are limited by the low moisture-holding capacity of the soil.

Roselawn gravelly fine sand, undulating phase.—In smooth nearly level areas of the hilly uplands this phase is associated with other Roselawn soils that have slopes of up to 7 percent and seldom less than 4 percent. The surface and substratum contain a large quantity of gravel. The soil supports a fair pasture and a good second-growth forest containing a large proportion of oak.

Rough broken land (Arenac and Plainfield soil materials).—Steep stream-cut slopes and steep slopes bordering depressions in the sand plains are combined and mapped as this miscellaneous land type. Very steep slopes of Arenac, Plainfield, Grayling, and Rubicon sands, and Oshtemo sandy loams are included. This type has virtually no value for crops or pasture because the slopes are 25 percent or more in gradient. Most of the slopes bear trees or shrubs. Forest should be maintained on these areas to prevent the accelerated headward cutting of ravines.

Rubicon fine sand.—Along the Muskegon River on the dry terraces there are several small areas of this type. The relief is nearly level or gently undulating, and the soil is ordinarily separated from other types by steep stream-cut slopes that are 10 to 40 feet long.

Under virgin conditions the surface is covered by 1 to 2 inches of dark-brown or black forest litter; the lower part of which is finely granular, well-decomposed, and nearly neutral in reaction. Following in the profile is a thin but conspicuous layer of ashy-gray strongly acid fine loamy sand, slightly stained by organic material in the topmost part. A 4- to 6-inch dark coffee-brown layer is present in some places but is not a persistent feature. The underlying light-yellow acid fine sand contains a few layers of silt. Along the river are included several narrow strips, 30 to 60 feet wide, of a lower and wetter soil, consisting of 2 to 3 inches of muck over gray fine sand.

Some of this soil has been cleared and is now used for pasture. It is somewhat superior to Rubicon sand in fertility and water-holding capacity, but has little agricultural value. Only a small area is under cultivation because of the unfavorable location and small size of the separate bodies. Some small and inaccessible areas have an almost undisturbed cover of hemlock, white birch, white pine, red maple, aspen, and elm.

Rubicon sand.—This soil occurs mostly in large uniform bodies on the dry sand plains where the topography is nearly level or only gently undulating. There are a few inclusions of Grayling and Plainfield sands and of Arenac loamy sand.

The original forest cover was a dense stand of white and red pines, but no completely undisturbed areas can now be found (pl. 1, *B*). Most of the present cover consists of a few scattered pine, quaking aspen, bigtooth aspen, clumps of red maple, and oak. Abandoned fields grow up to sumac, sassafras, and raspberry, with which are admixed witch-hazel, sweetfern, bracken, blueberry, grasses, and many colorful weeds, as Indian paintbrush, butterflyweed, and milkweed.

Under virgin conditions the soil is characterized by a thin layer of dark-gray, grayish-brown, or black forest litter, loosely bound together with fine roots. Next lower in the profile is a thin layer of grayish-brown stained sand. This does not exceed 1½ inches in thickness and is underlain by 1 to 4 inches of harsh ashy-gray sand. The harsh sand grades into a 2- to 8-inch layer of brownish-yellow loamy sand. The substratum is grayish-yellow medium sand to depths of at least 5 or 6 feet. The entire profile is acid, except for the top layer of litter, which is neutral.

This soil is low in plant nutrients and moisture-holding capacity. Only small areas are farmed, and these mainly with heavier or more poorly drained soils. Small yields of corn, rye, beans, and alfalfa hay are obtained. Fair spring and fall pasture can be obtained after heavy application of lime and manure.

Rubicon sand, eroded phase.—At one time a considerable acreage of Rubicon sand was cultivated. The meager fertility and low supply of organic matter were soon depleted, and a large part of the surface soil was removed by wind. Where most of the surface soil has been removed, this phase is mapped. Some of these eroded spots have been reforested in recent years with fair success.

Rubicon sand, undulating phase.—This soil occurs on slopes and gently undulating plains in association with the normal phase, from which it differs only in topography. Gradients commonly range from 4 to 7 percent. At the base of slopes the surface soil is more retentive of moisture and usually contains more organic matter than that on the slopes. When reforested, the trees in the depressions seem to thrive; those at the top of the slope are slow growing.

Saugatuck fine sand.—Small areas of this type occur in Sheridan Township. The soil is poorly drained, and in places has a brown firmly cemented layer. It differs from Saugatuck sand in that both its surface and substratum are fine sand. The reaction of the surface layer is neutral or only slightly acid.

Saugatuck fine sand, drained phase.—This soil is associated with and similar to Saugatuck sand, drained phase. The texture throughout is fine sand. Lenses of very fine sand and silt occur in the substratum. The productivity and value for farming purposes is slightly higher than that of Saugatuck sand, drained phase. The soil is nearly all cultivated, or in pasture. It is similar to Granby sandy loam in agricultural value and tillage requirements.

Saugatuck sand.—A unique surface feature of this soil (and Ogemaw sandy loam) is the cradle-knoll topography formed by the frequent uprooting of large trees. The trees are subject to uprooting because the hardpan and water table prevent roots from growing very deep. Rains have washed out the earth enmeshed by the exposed roots of the fallen trees and left it in a gravelike mound along the side of the cavities or pits that mark sites where the trees stood. These pits and mounds occur in no order. The microrelief interval averages 18 to 24 inches, but in some places it may approach 4 feet. This local relief is related to the water table, as it has controlled both the depth of the tree roots and the hardpan. The deeper the hardpan, the larger the roots and the greater the mound when a tree is uprooted. The mounds in turn determine the microrelief.

The original forest consisted of large shallow-rooted white pine in association with elm, ash, red maple, hemlock, aspen, and birch. After cutting and burning, the pine did not reproduce; instead, a second growth of aspen and oak predominates, and the ground cover is hypnum moss, and wintergreen, and obscuring the microrelief, a dense growth of bracken.

Under an undisturbed cover, the soil has a thin surface layer of undecomposed litter underlain by 2 to 3 inches of strongly acid dark grayish-brown well-decomposed organic matter firmly matted by plant roots and fibers. The underlying mineral layer is harsh slightly compact light-gray to nearly white strongly acid sand, slightly streaked with brown, and ranging from 2 to 10 inches in thickness. In some places, however, it may be as much as 18 inches thick. The characteristic hardpan layer following is coffee-brown cemented loamy sand, the color being imparted by the colloidal indurating material, which is probably made up of both organic compounds and iron oxide.

Over large areas this cemented layer ranges from 6 to 18 inches in thickness and is so hard that roots penetrate it with great difficulty. In other places the cementation is weak, and water and roots pass through it easily. Still other areas show only a vestige of the hardpan—a thin brown loamy layer of sand. The substratum is an acid dingy-gray or grayish-brown waterlogged sand to a depth of more than 3 feet.

The soil occurs in places where the water table has persisted for a long time just below the surface. Although water seldom stands on the surface, artificial drainage is required for successful cultivation. Newton loamy fine sand is invariably associated with this type, and in some places there are small included areas of Arenac loamy sand, Rubicon sand, and narrow ridges of Wallace-Weare fine sands. This association of soils is characteristic of the poorly drained plains of the county.

Despite its interesting ecology and large area, Saugatuck sand is not an important agricultural soil. Even with an expensive artificial drainage system, it warms slowly in spring. If the ditches are deep enough to drain the soil early in summer, the surface becomes too dry later in the season. The hardpan prevents deep rooting, and consequently crops are injured even during short droughts. In addition to these negative factors, the soil is susceptible to both late and early frosts because of its low position. The gray and brown sandy subsurface material is also deficient in plant nutrients. Only small areas are still used for farming. These are a few more favorably located fields that occur in association with heavier upland soils in the southern townships.

The largest acreage is planted to corn, which yields 15 to 20 bushels an acre in good years; in many years it fails to make grain and produces only forage. Oats yield 15 to 45 bushels an acre; rye, 10 to 20; beans, 5 to 10; and potatoes, 50 to 150. Attempts to grow alfalfa or wheat are seldom made. String beans, cucumbers, and strawberries make fair cash crops, and farmers ordinarily plant small fields to each. Fair pasture is produced, and this is particularly useful when this soil is associated with the drier sands. Large areas of this land might be better used for pulpwood production and game refuges.

Saugatuck sand, drained phase.—Several of the streams in the trenched plain of Bridgeton and Sheridan Townships have cut through plains that were undrained during some earlier period—plains on which a Saugatuck profile dominated. Because the water table was lowered through natural drainage, the original Saugatuck soil degraded. It now resembles Rubicon sand in many respects. The difference is the presence of a relict hardpan that occurs 2 to 3 feet from the surface. The hardpan, in places 18 to 24 inches thick, outcrops on the bluffs along the ravines, some 20 to 30 feet above stream levels. The soil color, a yellowish brown, is lighter in most places than typical of Saugatuck sand. The top of the hardpan is light colored and crumbles easily under pressure; the dark-brown coating around the sand particles that causes induration in Saugatuck sand has almost disappeared. The lower part, being protected by its position, has retained its color and firmness. The sand substratum below the hardpan layer and above the deep clay floor has entirely lost its gray waterlogged appearance and is similar to the substratum of Rubicon, Arenac, or Plainfield sands.

The area of this soil is small and only a small acreage is farmed. Some fields have been well managed, and these have produced fair yields of the general farm crops and of special crops, such as potatoes, and beans for canneries. The soil is not good for grass or small grain, and if it is to be kept productive, it must be heavily manured.

Sparta loamy sand.—Most of this soil occurs in the dry plains of Big Prairie and Croton Townships. It occupies a large aggregate area.

The 6- to 18-inch surface layer is a mixture of sand and finely divided well-decomposed dark-brown or black organic matter. Following this is a brownish transition layer of loose sand that grades into a gray or pale-yellow sandy substratum. Throughout its profile, the soil is acid, loose, pervious, and unconsolidated. It originally supported a grass rather than a forest cover.

This was one of the first soils to be farmed in the county. It was easy to cultivate, and clearing was unnecessary, but it did not prove durable under the farming practices of the early settlers. The first crops were profitable enough to lead to the building of what were then comfortable if not pretentious farmsteads. After 10 to 15 years of continuous cropping, however, the productivity declined, and wind erosion removed part of the surface soil over a large area (pl. 1, *C*). The moisture-holding capacity of the subsoil was also found to be insufficient for crop needs in dry seasons.

Some of the 20 to 30 farms originally operated were already deserted in 1900. Lack of moisture, a poor cropping system, and loss of surface soil by blowing were the chief factors leading to abandonment. Only one or two farms are now worked; the rest are either entirely abandoned or cropped at infrequent intervals. Under present economic conditions, the land cannot be utilized for pasture because associated more poorly drained soils are lacking. Experiments in forestation indicate that pines may make a fairly rapid growth, even in the driest locations.

Sparta loamy sand, eroded phase.—The surface soil, and in places the subsoil to a depth of 2 or 3 feet, has been entirely removed from several large tracts on the plain in Big Prairie Township. The largest of these eroded areas includes over 1,000 acres.

Extreme wind erosion has resulted in a few places in the formation of a "desert floor" of gravel that varies from 1/4 to 3/4 inch in diameter. Elsewhere the sand has a rippled surface and is still shifting. The amount of material removed from this plain, which was nearly level according to local residents, is indicated by a few remaining grass-covered hummocks that rise 3 to 6 feet above the wind-swept floor. Two or three feet of wind-blown sand has accumulated above the original surface on these mounds. This sand is held by grass that grows through each layer as it is deposited.

Experiments in reforesting this sand have shown that there is enough retained moisture for the growth of pines. The "desert" is considered a tourist attraction, however, and possibly has greater value as scenery than as forest land.

Sparta loamy sand, eroded undulating phase.—This separation includes wind-eroded undulating and sloping parts of the Sparta plains. Slope gradients vary from 4 to 7 percent. Included are the dunelike accumulations of wind-transported sand. These dunes are formed from soil blown from the eroded plain to the west.

Sparta loamy sand, undulating phase.—This phase includes the more sloping undulating part of the treeless Sparta plains. Slope gradients vary from 4 to 7 percent.

Wallace-Weare fine sands.—Linear ridges scattered over the plains make up this complex. The ridges, 100 to 200 feet wide and 5 to 30 feet high, occur in association with all the sandy plain soils.

Wallace fine sand, one of the two types in the complex, has a cemented coffee-brown or reddish-brown sandy layer 7 to 12 inches beneath the gray sand of the surface layer. Weare fine sand, the other type, has 6 to 8 inches of light-gray fine sand over 4 to 5 inches of brownish-yellow loamy sand. The loamy sand shows little or no cementation. Both soils have a substratum of loose or slightly coherent sand.

The complex supported a pine cover at one time, but after cutting and burning blow-outs rapidly developed. A large part of the land surface, perhaps 50 percent, has been altered by wind action. A few of the ridges are somewhat stabilized by a second-growth cover of aspen, pin cherry, sumac, briers, and grasses. Agriculturally, this complex is not important, because of its small total area and other unfavorable characteristics.

Wallkill loam.—Numerous small bodies of this soil occur in the bottoms of basins and pot holes, at the base of slopes, as narrow strips, and as deltas at the outer borders of peat or muck swamps.

This is not a uniform soil type. On the contrary, it is characterized by many textural and other variations. It frequently consists of dark-gray or blackish loamy mineral accumulations as much as 2 or 3 feet thick that overlie muck or peat. The high organic-matter content and the muck and peat under the mineral layer distinguish this soil from the Washtenaw.

Though the occurrence of this soil in association with the upland soils is widespread, the individual areas are so small and numerous that it was impractical to show all of them on the map or to distinguish them accurately from Washtenaw soils, undifferentiated, in all places.

When drained, this soil is generally productive, and it is especially suited to truck and small garden plots. Much of it remains as wasteland because of the small size of the separate bodies, or because artificial drainage is impracticable. Many of the small pot hole inclusions of the soil depreciate the value of otherwise uniform land. Cattail or buttonbush ponds have some value as cover and sources of food for wildlife.

Washtenaw soils, undifferentiated.—This association of dark-colored moist and wet soils occurs in pot holes, lake basins, and swales. Variations in depth, color, texture, organic-matter content of the surface layer, and the nature of the substratum are characteristic.

The bodies are small bcause they are limited to the size and shape of the depressions in which they occur. Some are in small basins that have no outlets; others are deposited in narrow mostly intermittent drainageways. There are many separate areas, but they are often of such small size that it is not practical to show all of them on a soil map. They are especially numerous in association with Isabella, Emmet, and Montcalm soils in the hilly and more rolling parts of the county.

A large part of the surface soil has been washed in from the adjacent slopes. Because of this, the characteristics of the soil are related to the slopes that furnish the alluvium and, indirectly, to the use of these slopes. Cultivation on the slopes accelerates erosion and the consequent deposition of a relatively light-colored infertile material on the original surface soil. The dark color tends to disappear as erosion increases on the adjacent slopes. The wash has accumulated to depths of more than 3 feet in some places. Locally, small deltas of subsoil sand, gravel, and clay have recently been washed from gullies that lead back to higher land. In a few places, muck and peat soil remain in the center of pot hole depressions that originally held lakes.

The small size of the separate bodies, their irregular pattern and relation to the associated soils, and their inadequate drainage for some crops lower the value of this land for agricultural use. Furthermore the optimum time for plowing this soil and the time crops mature on it are seldom the same as for the adjacent land.

ESTIMATED CROP YIELDS

Estimates of average per acre crop yields to be expected over a period of years under common or prevailing farm practices are given in table 7 for each soil mapped in Newaygo County.

TABLE 7.—*Estimated average acre yields of the principal crops on each soil in Newaygo County, Mich., over a period of years under common farm practices*

[Absence of yield data indicates that the crop is not ordinarily grown on the particular soil]

Soil	Corn	Wheat	Oats	Rye	Mixed timothy and clover hay	Alfalfa	Field beans	Potatoes
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Tons*	*Tons*	*Bu.*	*Bu.*
Antrim sandy loam	30	12	25	15	1. 1	2. 2	10	140
Arenac fine sandy loam	25	12	30	20	2. 1	2. 6	15	100
Arenac loamy sand	15	7	15	12	1. 1	. 8	7	100
Bellefontaine sandy loam	10	3	5	3	. 4	. 2	5	60
Hilly phase								
Undulating phase	20	10	25	10	. 9	1. 6	7	120
Bergland clay loam	15	7	20	10	1. 9	3. 6	12	40
Bergland loam	20	10	20	10	1. 9	3. 2	12	60
Burned peat and muck over sand								

TABLE 7.—*Estimated average acre yields of the principal crops on each soil in Newaygo County, Mich., over a period of years under common farm practices*—Continued

Soil	Corn	Wheat	Oats	Rye	Mixed timothy and clover hay	Alfalfa	Field beans	Potatoes
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Tons*	*Tons*	*Bu.*	*Bu.*
Carlisle muck	40	----	----	----	1. 8	----	----	----
Shallow phase	35	----	----	----	1. 8	----	----	----
Echo loamy sand	----	----	----	----	1. 0	----	----	----
Edwards muck	20	----	----	----	1. 4	----	----	----
Shallow phase	5	----	----	----	. 2	----	----	----
Emmet loamy sand	----	----	----	----	. 5	----	----	----
Eroded phase	----	----	----	----	----	----	----	----
Eroded undulating phase	----	----	----	----	----	----	----	----
Hilly phase	----	----	----	----	----	----	----	----
Undulating phase	20	5	10	15	. 9	1. 4	10	100
Emmet sandy loam	20	10	20	10	1. 6	3. 2	10	60
Hilly phase	----	----	----	----	. 5	----	----	
Undulating phase	30	15	30	20	1. 3	3. 6	15	180
Fox sandy loam:								
Sloping phase	15	7	20	10	1. 0	2. 4	7	100
Undulating phase	25	12	30	20	1. 0	3. 6	15	140
Genesee sandy loam	20	10	20	12	1. 3	1. 6	7	80
Granby sandy loam	15	5	5	15	. 7	. 8	----	80
Grayling sand	----	----	----	----	----	----	----	----
Rolling phase	----	----	----	----	----	----	----	----
Undulating phase	----	----	----	----	----	----	----	----
Greenwood peat	----	----	----	----	----	----	----	----
Griffin loam and clay loam, undifferentiated	----	----	----	----	1. 0	----	----	----
Griffin sandy soils, undifferentiated	----	----	----	----	1. 0	----	----	----
Houghton muck	25	----	----	----	1. 6	----	----	----
Shallow phase	20	----	----	----	1. 2	----	----	----
Isabella-Iosco sandy loams	25	15	35	20	1. 1	2. 2	15	180
Isabella loam	40	25	40	20	1. 8	3. 6	15	140
Hilly phase	----	----	----	----	----	----	----	----
Rolling phase	35	20	35	20	1. 4	3. 6	15	140
Isabella-Montcalm sandy loams	35	23	30	18	1. 4	2. 1	15	130
Hilly phases	----	----	----	----	----	----	----	----
Rolling phases	20	10	20	10	1. 4	2. 8	10	60
Kalkaska loamy sand	20	5	15	10	. 2	----	10	80
Kent-Arenac complex	30	18	35	20	1. 5	3. 0	15	120
Kent silt loam	40	25	40	20	1. 8	3. 6	15	100
Kerston muck	25	----	----	----	1. 0	----	----	----
Maumee fine sandy loam	25	----	----	----	1. 0	----	----	----
Montcalm-Roselawn complex	20	7	20	10	. 9	1. 6	7	100
Hilly phases	----	----	----	----	----	----	----	----
Undulating phases	20	10	20	10	1. 2	2. 6	7	60
Munuscong-Maumee soils, undifferentiated	25	10	15	20	1. 3	1. 6	----	120
Munuscong sandy loam	25	12	30	12	1. 9	1. 8	17	140
Newton loamy fine sand	----	----	----	----	. 7	----	----	----
Drained phase	15	3	20	7	. 8	----	5	40
Ogemaw sandy loam	20	10	20	17	1. 3	1. 6	7	100
Oshtemo loamy sand:								
Sloping phase	10	3	10	5	. 6	. 2	7	60
Undulating phase	15	7	15	11	. 6	. 4	6	40

TABLE 7.—*Estimated average acre yields of the principal crops on each soil in Newaygo County, Mich., over a period of years under common farm practices*—Continued

Soil	Corn	Wheat	Oats	Rye	Mixed timothy and clover hay	Alfalfa	Field beans	Potatoes
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Tons*	*Tons*	*Bu.*	*Bu.*
Oshtemo sandy loam	20	7	15	12	0. 9	0. 4	7	40
Gently sloping phase	10	3	15	7	. 6	----	7	60
Ottawa loamy fine sand	20	5	10	15	. 9	1. 2	10	100
Sloping phase	----	----	----	----	----	----	----	
Plainfield sand	----	----	----	----	----	----	----	
Eroded undulating phase	----	----	----	----	----	----	----	
Rolling phase	----	----	----	----	----	----	----	
Undulating phase	----	----	----	----	----	----	----	
Rifle peat	----	----	----	----	1. 4	----	----	
Shallow phase	----	----	----	----	. 8	----	----	
Roselawn fine sand	----	----	----	----	. 4	----	----	
Eroded phase	----	----	----	----	----	----	----	
Eroded undulating phase	----	----	----	----	----	----	----	
Hilly phase	----	----	----	----	----	----	----	
Undulating phase	----	----	----	----	. 5	----	----	
Roselawn gravelly fine sand, undulating phase	10	----	----	5	. 6	----	5	60
Rough broken land (Arenac and Plainfield soil materials)	----	----	----	----	----	----	----	
Rubicon fine sand	----	----	----	----	. 6	----	----	
Rubicon sand	----	----	----	----	----	----	----	
Eroded phase	----	----	----	----	----	----	----	
Undulating phase	----	----	----	----	----	----	----	
Saugatuck fine sand	----	----	----	----	----	----	----	
Drained phase	20	7	10	12	. 8	. 6	3	60
Saugatuck sand	15	----	----	10	. 7	----	10	
Drained phase	15	3	20	10	. 8	----	5	80
Sparta loamy sand	5	3	5	5	. 2	----	----	
Eroded phase	----	----	----	----	----	----	----	
Eroded undulating phase	----	----	----	----	----	----	----	
Undulating phase	----	----	----	----	----	----	----	
Wallace-Weare fine sands	----	----	----	----	----	----	----	
Wallkill loam	----	----	----	----	1. 0	----	----	
Washtenaw soils, undifferentiated	25	20	25	12	1. 9	2. 0	7	60

The natural factors influencing the productivity of land are mainly climate, drainage, and relief or lay of the land. In addition to these are the factors of land management and soil amendments. Whenever available, crop yields over a long period furnish the best summation of these productivity factors. A low yield for any particular crop may be due to some local condition of unfavorable relief, drainage, or climate rather than to lack of soil fertility. The drainage considered in these estimates is that practiced in this county and is not necessarily the optimum drainage, which would change the yields of some soils. Likewise, irrigation would probably raise the level of yields on some of the sandy soils.

In interpreting the yields in table 7 it should be borne in mind that the estimates are based on data gathered in interviews, during observations made in the course of the survey, and on information supplied by local agricultural leaders. Estimates were necessary because definite measurements and, particularly, accurate methods of obtaining yields were lacking on the many soil types. The estimates indicate the productivity of the various soil types under the management practices ordinarily used.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of weathering and soil development acting on the parent material deposited or accumulated by geologic agencies. The characteristics of the soil at any given point depend on (1) the physical and mineralogical composition of the parent material; (2) the climate under which the soil material has accumulated and has existed since accumulation; (3) the plant and animal life in and on the soil; (4) the relief, or lay of the land; and (5) the length of time the forces of development have acted on the material. The climate, and its influence on soil and plants, depends not only on temperature, rainfall, and humidity but also on the physical characteristics of the soil or soil material and on the relief, which, in turn, strongly influences drainage, aeration, runoff, erosion, and exposure to sun and wind.

Newaygo County is in the west-central part of the Lower Peninsula of Michigan and all of it was probably covered by the Lake Michigan ice lobe in the last glaciation.

There are two broad groups of soils: (1) Mineral soils, developed from glacial material; and (2) organic soils, composed of plant residues in various stages of decomposition and accumulated in undrained or poorly drained areas. The mineral soils are divided into two broad groups according to moisture conditions within the solum. These are (1) zonal or well-drained soils and (2) hydromorphic soils—those in which water exists permanently or for considerable periods to the point of complete saturation and waterlogging. The organic soils are classified according to the extent of decomposition and chemical reaction of the surface layers.

From the standpoint of texture, the most extensive parent materials are sand and gravel, and from these most of the plains soils and several of the hill soils are developed. The glacial streams sorted, reworked, and redeposited the sand and gravel as outwash plains. In a few places wind erosion of the plains resulted in the formation of low dunelike hills; in others, a readvance of the ice pushed up sandy ridges and formed rough abrupt sandy moraines. The readvancing ice also brought with it an assorted mass of stones, boulders, and boulderlike chunks of clay till, and when this was deposited on the sandy moraines a great heterogeneity of parent materials resulted.

Another parent texture is represented by boulder clay containing a sufficient proportion of sand to make possible a marked development of an eluviated sandy horizon in the soil profile. The soil profile varies in detail but makes a relatively uniform soil in that a clayey subsoil horizon is everywhere present.

Calcareous clays and clay till form a fine-textured group of parent materials that may occur separately or in combination with other textures. In fact, all the textures may be found alone or in various combinations.

The glacial drift was laid down during the Late Wisconsin or last stages of glaciation and consequently the land surface is comparatively young. Except in the Muskegon River Valley, the topographic forms are constructional because streams have not had time to form dendritic systems and to dissect the surface left by the receding glaciers. Large areas of land are flat and undrained and large bodies of soil have therefore developed under conditions of high moisture. On the other hand, the perviousness and great thickness of many deposits have allowed the development of soils under low moisture conditions despite the level land surface. Various wet and dry conditions on the upland moraines are largely the result of differences in the texture of the glacial debris and the constructional variations, such as depressions, which naturally receive surface drainage from the surrounding slopes.

The diversity of the soil types in the county and their intricate association in small bodies can usually be attributed to: (1) Heterogeneity in the mineral accumulations; (2) differences in thickness of pervious over impervious materials, which results in a wide range of moisture conditions; and (3) great diversity of topography—moraines, outwash plains, till plains, dunelike ridges, and depressions.

From the accumulated parent materials, soil-forming processes have developed three classes of soils in Newaygo County—mineral, organic, and water.[8] These three occupy approximately 78, 20, and 2 percent, respectively, of the total area. The lithological, mineralogical, and chemical character of the parent mineral accumulation is related directly to the continental glaciers that advanced over this area and indirectly to the old underlying geological formations.

A large part of the parent material, or drift, deposited by the ice sheet was from local sources, but a considerable admixture of detritus undoubtedly came from regions to the north. The deposit is 50 to 200 feet or more thick, and therefore the bedrock underneath nowhere directly influences the soil. The drift is characterized by a great variety of rocks without a marked dominance of any particular kind. Limestone is present in all the deposits but probably nowhere exceeds 10 percent of the mass of coarser materials, and the proportion is generally much smaller. The clay ice-laid drift is invariably calcareous, and so are the lacustrine clays. In general the boulder clay is pink or faded red where unweathered and red or reddish brown where weathered. The stratified sandy deposits of the moraines, outwash plains, and lake plains are dominantly gray and faintly reddish. They contain a large percentage of quartz and are less calcareous than the clay and gravel.

Except for small areas of prairie and marsh, all the county was once forested. A dense stand of hardwood grew on the more fertile moisture-retaining heavy-textured soils, pine and oak grew on the sands, and mixed hardwoods and white pine on the soils of intermediate texture. Nearly all the species were widespread. They grew on a large number of different soils, but there were differences

[8] A number of different types of water-formed soils can be distinguished on the basis of differences in the subaqueous layers, which may be clay, marl, sand, or peat. The classification of water soils, however, is in a rudimentary stage.

in the relative abundance, form, and size of growth under the influence of the differing soil environments.

The native vegetation was related to the characteristics of the soil on which it grew, and the vegetative cover, in turn, influenced the development of the soil profile. The physical and chemical characteristics of the organic surface layers are directly related to the original vegetative cover. The forest cover influenced not only the nature of the organic accumulation on the surface but also the depth and color of the leached layer of mineral soil directly beneath it. On well-drained sites the leached layer is thinner where conifers predominated and thicker under the hardwoods, since this forest type produced a greater thickness of organic matter on the surface.

Areas covered by grass are characterized by a deep layer of finely divided organic matter mixed with loamy sand. Some of this material was probably inherited from organic matter accumulated when the areas were in a previous undrained condition, but a large proportion undoubtedly had its source in the decaying grass roots, which extend to considerable depth. In fact, where grasses invade cut-over lands the leached gray layer common to many forest soils is obliterated by decaying grass roots.

The soils have developed under a cool moist climate that is somewhat influenced by the proximity of the Great Lakes. The mean annual precipitation of approximately 30 inches is fairly uniform in all seasons but somewhat less in winter than in summer. The winters are fairly long and cold and the summers short and mild. The climate is transitional between that in the Podzol soil region and that in the Gray-Brown Podzol soil region of the central and east-central parts of the United States.

Under the prevailing climate podzolization is the dominant soil-forming process. This has resulted in leaching, particularly of calcium and magnesium carbonates, together with the translocation and removal of sesquioxides, from the surface layer. The extent of podzolization is indicated by a reddish-brown color moderately developed in the illuviated horizon; a moderate humus layer accumulated at the surface; a gray, ashy, podzolized layer, not intensely developed; and an underlying brown orterde layer, more characteristic of Podzol soils, that is not generally conspicuous. In the solum, the quantity of residual clay formed in place through weathering is probably slight in comparison with soils derived from the weathering of bedrock or coarse glacial debris containing a large quantity of limestone and basic igneous rock. Most of the clay in these soils is derived as such from parent drift material.

In the solum, or true soil, the dominant soil-forming processes have been eluviation and, to a lesser extent, illuviation. No other logical explanation has been advanced to account for the textural differences between the second, third, and fourth layers unless, of course, they are obviously beds of separate geologic deposition. It is improbable that much colloidal material has been translocated through the illuviated horizon. There is, however, an apparently slight precipitation of carbonates below the illuviated zone, particularly in such heavy-textured profiles as in Kent silt loam. The precipitated material may appear as an encrustation, cementation, or nodular accretion. It is debatable whether the precipitated layer is actually material removed from the solum above; instead, it may be a purely geologic phenomenon unrelated to soil formation. Close observation, however, particularly in the heavy-textured materials, usually reveals a concentration of carbonates below the illuviated zone.

The well-drained maturely developed mineral soils are pedalferic. The generalized profile of the virgin soils of this group consists of the following layers: (1) A very thin accumulation of litter and forest mold; (2) a thin layer of dark grayish-brown humus soil; (3) a highly leached (eluviated) acid ashy-gray to light grayish-brown light-textured layer; (4) an illuviated layer, containing an apparently high quantity of inorganic colloids, and therefore relatively heavy in texture; (5) the parent material, or geologic substratum.

In well-drained profiles the surface layers of litter, mold, and humus are layers of accretion or accumulation. Commonly the mold and humus do not exceed 2 or 3 inches in total thickness. The mold and humus layers are slightly acid to slightly alkaline and more alkaline than the underlying horizons of the solum. This is probably due to the return of bases to the surface by deeply penetrating plant roots. The leafmold is also high in nitrogen, phosphorus, and potassium in comparison with the underlying leached horizon. There is no appreciable return of these nutrients to the upper part of the solum, except as they infiltrate downward into the top part of the leached layer, because mineralization processes are extremely slow. The mineral layer, stained dark gray by organic materials, is seldom more than 3 or 4 inches thick.

The litter accumulation, the mold, the humus layer, and the stained mineral horizon increase in thickness as moisture conditions approach those of a swamp. On the other extreme, the dry sandy pine plains seldom possess more than 1 inch of litter and sandy mold; true humus is absent or developed only as a thin layer that is generally most noticeable where the soil is limy.

The leached, or podzolized, layer in the soil profiles varies in thickness with the texture of the parent material; it is thinnest in the more clayey soils and thickest in the sands. The typical appearance of this layer is given in the description of Isabella loam. The illuviated horizon contains the concentration of clay and colloids. Iron and alumina are abundant in this layer, which reaches its maximum development in the heavy-textured soil materials, probably because of the large proportion of collodial clay that has been inherited from its parent material.

In general the greater the thickness of the leached layer and the lighter its shade of gray, the more strongly and thickly developed is the underlying illuviated horizon. The two are ordinarily sharply divided, particularly in the sandy textures. The minimum development occurs in very dry sands. The maximum color development is seen at the top of the orterde and orstein layers in the sandy soils. In these layers the color fades gradually with depth, and the transition between them and the parent material is very gradual and poorly defined. Long tongues of the reddish clayey illuviated horizon commonly extend into the substratum, especially where the parent material is gravelly, as it is in the Bellefontaine and Fox soils.

Isabella sandy loam, one of the well-drained zonal soils, presents an interesting profile. The parent material is a pale-reddish clayey sand,

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sufficiently pervious to allow the rapid and nearly complete removal of the inherited colloidal materials to depths of 3 to 5 feet or more. At this depth an illuviated horizon is encountered that is representative of the zonal soils in all respects. It possesses a distinct nutlike to blocky structure and grades into the massive compact underlying substratum. In some places the solum has been so well leached of clay as to lead the casual observer to the false conclusion that the leached and illuviated layers represent a disconformity. After all clay was washed from the top parent material, a brownish-yellow loamy sand was left. This sand, leached of its inherited clay, was subjected to soil-forming processes, and as a result a thin podzolized horizon developed between the litter and humus layers above and the orterde layer below. The result is the phenomenon of two zonal profiles in the same parent material, one above the other.

In the evolution of soils in this area, some clay has been formed in place within the profile through the weathering of glacial rocks, but the quantity is less than that in the older unglaciated parts to the south. The gravelly calcareous deposits in particular show evidence of clay formation through postglacial weathering, and thus the clayey layer in Bellefontaine and Fox soils is explained. Most of the clay in soils such as Isabella loam, however, has been inherited from the parent material.

The soil-forming processes continue, and further evolution of the pedalferic profiles will probably result from continued leaching. The effects of this action will be expressed in the downward growth of the solum. In time, geologic erosion will result in further development of dendritic stream systems. These will increase soil drainage and lead to the development of a larger area of zonal, or mature, profiles. As zonal soil areas increase there will occur a complementary decrease in the area of poorly drained soils and a disappearance of organic and water soils.

In the past, changes in drainage have occurred. In fact, they have given rise to several apparent nonconformities in the classification of mineral soils according to zonal and hydromorphic categories. Sparta loamy sand, for example, although underlain by the yellow dry sandy substratum of the well-drained plains, possesses also the deep organic surface characteristics of poorly drained soils. Several highland marl deposits associated with Sparta loamy sand are proof of an ancient wet or marshy condition. It appears that the organic layer of this soil developed when the area was not so excessively drained as at present. A sudden lowering of the water table exposed the marsh surface to soil-forming forces. The original organic accumulation was deep enough to persist through the degradational processes that have operated on it since the recession of the water table. This theory of a sudden change from excessively wet to excessively dry conditions also affords an explanation of the failure of the forest to advance rapidly over the grass-covered Sparta plains. The grasses, of course, aided in preserving the organic matter in the surface layer

Another such nonconforming soil is Saugatuck sand, drained phase, in which an old, inherited indurated layer persists in a deep sandy profile some 20 to 30 feet above the present stream levels. This soil is explained as being a relict of an ancient undrained plain. Evidence of geologic erosion is close at hand in the form of deep ravines that cut through the plain. Newton loamy fine sand, drained phase, can be recognized as another soil that developed under conditions that no longer exist.

Soils developed under waterlogged or poorly drained conditions are characterized by the following general profile: (1) A dark-gray or black mucky surface layer that results from the accumulation and partial preservation of organic matters; (2) a gray or drab glei horizon, slightly stained by downward filtering organic matter; (3) a clayey horizon showing maximum plasticity and cohesion, and only slightly colored by ferric and humus stains; and (4) the substratum, or parent material.

Where developed from the same parent material as the well-drained zonal soils the hydromorphic soils are less completely leached of carbonates and generally contain more plant nutrients—nitrogen, phosphorus, and potassium. If the parent material is calcareous, poorly drained soils are generally alkaline from the surface downward. Where the parent material is sand, the solum is commonly acid, its second layer is conspicuously leached, and the third is often dark brown but not indurated. Typical soils of this nature are Newton loamy fine sand and Munuscong sandy loam.

Some soils have developed under an intermediate range of drainage. Where the water table fluctuates just below the surface, Ground-Water Podzols are formed. These are characterized by a very white leached layer underlain by a dark-brown hardpan. Soils of the Saugatuck and Ogemaw series are representative.

Increasingly better drainage conditions lead first to the development of soils of the kind typified by Arenac loamy sand, then to Ottawa loamy fine sand, Rubicon sand, and finally to Grayling sand. The soils of all the textural groups could be arranged in drainage series similar to this, but there would be fewer types recognized in each. For example, in the lacustrine textural group, Kent silt loam represents the well-drained member and Bergland clay loam the poorly drained.

Immature or incompletely developed soil profiles are formed almost entirely in recent alluvium in stream valleys. The alluvium is yellowish brown to grayish brown and derives its properties from the local soils and glacial drifts. In many places layers of alluvium alternate with layers of muck that may be either transported or accumulated in place. An immature profile is also found in recent accumulations of eroded material or colluvium that have been deposited in basins and drainage swales. Accelerated erosion caused by cultivation has created a large number of extremely small bodies of parent material on which the profile development processes have not yet operated. Large areas of the alluvial soils are subject to flooding and some occur in swampy or semiswampy places.

The organic soils, second in the broad soil classification, are similar in that they consist mainly of combustible accumulations of plant tissue. Nearly all the organic deposits have accumulated in lakes and marshes, but a few have developed in seepage areas. Those in marshes and swamps are relatively shallow, but the ones developed in lakes are ordinarily more than 3 feet deep and may reach as much as 50 feet.

The organic materials were preserved because the water prevented rapid oxidation. Anaerobic processes, however, cause some decomposition, even of submerged materials. The degree of decomposition is related both to the nature of the plant material and to the height of the water table. Acid accumulations of sphagnum moss and leatherleaf, commonly associated with sandy plains low in lime, have decomposed slowly because of their acidity, even though fluctuations in the water table are as great as those in the other deposits. In fact, sphagnum and leatherleaf accumulations show only slight discoloration and physical disintegration. The original plant material may often be recognized in the most decayed layers.

Organic deposits on drift having a high lime content are usually the remains of an entirely different association of plants. The underlying material more often contains marl, and decay of both the surface and underlying organic layers is more complete than in the leatherleaf and sphagnum accumulations.

In the development of the organic soils, it appears that the chemical reaction of the original lake waters influenced the type of plant growth. In turn, the type of plant growth caused variations in the residual material from which organic soils were derived. Finally, the decomposition of the various plant residues was affected by both the acidity or alkalinity of the preserving water and by fluctuations in its level. In some places it seems that the acidity of the organic soils is caused by the height of the present water table and the present stage of decomposition of the plant material. There is no apparent relation between the type of organic material deposited in these places and the mineral content of the adjacent soils, nor is there a relation between the reaction of organic material and the alkalinity or acidity of the water draining from these higher soils.

Concentric strips of various plant associations may be observed in some depressions. The type of organic soil underneath varies with the vegetative growth. At the margins, and often associated with marl, is the soil most highly decomposed—Carlisle muck, for example. Next occur woody deposits, perhaps identifiable as Rifle peat, and in the center of the depression, or advancing upon the open water, is an acid organic accumulation like Greenwood peat.

The present lake waters that support vegetation are clear and contain very little suspended mineral material. They are generally alkaline, owing to the presence of calcium and magnesium bicarbonates, but there is a wide range in hardness. The variation is from 2 or 3 grains to as much as 16 or 18 grains per gallon. In a few small lakes and ponds partly filled by leatherleaf and sphagnum moss the standing water, stained brown by organic matter, is acid. Most of the streams, even those originating in peat and muck swamps, are alkaline and comparatively clear throughout the year, although occasional hard rains flush out the brownish-tinted water that accumulates in the organic deposits.

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Areas surveyed in Michigan shown by shading—detailed surveys by northeast-southwest hatching; reconnaissance surveys by northwest-southeast hatching.

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