

UNITED STATES DEPARTMENT OF AGRICULTURE

Soil Survey
of
Mille Lacs County, Minnesota

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COUNTY SURVEYED

Mille Lacs County is in the east-central part of Minnesota. (Fig. 1.) Milaca, the county seat, which is located near the center of the southern part of the county, lies 62 miles northwest of St. Paul and Minneapolis and 106 miles southwest of Duluth. Two-thirds of the northern boundary of the county lies in Mille Lacs Lake, one of the largest lakes lying wholly within the boundaries of Minnesota. The county is 47 miles long from north to south. Its northern boundary is 18 miles long, a width of three townships, and its southern boundary is 12 miles long, the width of two townships. The land area of the county is 583 square miles, or 373,120 acres, and the water area is approximately 117 square miles, or 74,880 acres.

Mille Lacs County lies mainly within the region covered by the early Wisconsin glaciation. At the southern end of the county, however, the early Wisconsin drift has been for the most part covered and altered as a result of the late Wisconsin glaciation. Deposits of wind-blown sand, outwash plains and terraces, a glacial lake deposit, and small patches of till are of late Wisconsin age.

The two glaciations and the ensuing action of water and wind have greatly influenced the physiography of the county. The northern quarter is hilly and rough, owing to the wide early Wisconsin moraine which follows the southern, western, and parts of the southeastern shores of Mille Lacs Lake. The large central part of the county is gently undulating, undulating, or in places slightly rolling, and is part of the early Wisconsin till plain. It is crossed, here and there, by broken chains of eskers which rise from 5 to 25 feet above the plain. The relief of the southern quarter is more variable, owing to the different geological formations present. In the extreme southeastern part are undulating sand hills, and in the south-central part, sandy outwash plains. Between the sandy region and the large,



FIGURE 1.—Sketch map showing location of Mille Lacs County, Minn.

central early Wisconsin till plain proper, is a strip of land of variable relief. A part consists of an old lake plain which is strongly dissected and hilly adjacent to the river valley, but elsewhere is flat or very gently undulating; the other part includes an uneven area of drift, which in places is morainic, of both early and late Wisconsin deposition, and of terrace remnants, locally choppy and knobby.

The valley of Rum River, which extends from Mille Lacs Lake in the north through the middle of the county passing out at Princeton at the extreme southern end, is a pronounced topographic feature. In the northern part of the valley the river banks are low, but they gradually increase in height until, at the northern end of Page Township, they are from 30 to 40 feet above the level of the river. They reach their highest elevations in Page and Milaca Townships and continue at heights ranging from about 15 feet at Milaca to 35 feet at Princeton, at which point the river leaves the county. The valley of West Branch Rum River extends approximately parallel to the larger valley and west of it, and it is not so deep as the main river valley. The river banks of both valleys are in most places steep. Numerous other valleys of various depths extend back into the flat areas and slight depressions of the till plain.

Terraces of stratified sand and gravel occur along the valleys of both Rum River and its west branch. These are particularly well developed in Milaca, Milo, and Bogus Brook Townships in the southern part of the county and in Onamia Township in the northern part. Some of the tributary valleys and old abandoned river channels are bordered by similar pronounced terraces. Such terraces are especially noticeable in Bradbury and Lewis Townships, in the northern part of the county, and in Milaca, Milo, and Greenbush Townships, in the southern part. Recent alluvial deposits covering areas of variable width occur along Rum River and West Branch Rum River, but they are of no great extent.

Elevations within the county range from 947 feet above sea level at the lowest point, on Rum River below Princeton, to more than 1,300 feet in the hills of the moraine south and southwest of Mille Lacs Lake. The average elevation of the county is between 1,000 and 1,200 feet. The surface of Mille Lacs Lake is about 1,250 feet above sea level.¹ The lake is held in position by moraines in Mille Lacs, Crow Wing, and Aitkin Counties and by underlying crystalline rock² which is near the surface in northern Mille Lacs County.

Rum River, which rises in Mille Lacs Lake, carries practically all the drainage of Mille Lacs County. From its source to Onamia Lake the current is sluggish; below that it is stronger. Its total fall within the county is 305 feet over a course of 73 miles, or an average of 4.2 feet a mile, according to the State Drainage Commission Survey of 1909-1912.

Adjacent to Rum River, along most of its course, the land is fairly well drained, but owing to the generally shallow valleys and to the

¹ RALPH, G. A. REPORT OF COOPERATIVE TOPOGRAPHIC MAPPING IN MINNESOTA. Minn. State Drainage Comm. Bien. Rpt. 2: [5]-7. 1913.

HERRON, W. H. REPORT OF TOPOGRAPHICAL SURVEYS IN COOPERATION BETWEEN THE UNITED STATES GEOLOGICAL SURVEY AND THE STATE OF MINNESOTA FOR THE PERIOD BEGINNING JANUARY 1, 1911, AND ENDING DECEMBER 31, 1912. Minn. State Drainage Comm. Bien. Rpt. 2: 8-136, illus. 1913.

² SARDESON, F. W. HISTORY OF MILLE LACS COUNTY, MINNESOTA. Pan-American Geol. 40: 181-196, illus. 1923.

sluggish character of the tributary streams, with their (in many places) ill-defined channels, natural drainage of the greater part of the county is poor.

Water power was developed in the past on West Branch Rum River at two sites not far from its mouth. None is now utilized in the county, on account of the low volume of water in Rum River and its tributaries during the drier years.

The first white men known to have visited the territory now included in Mille Lacs County were Duluth, in 1679, and Father Hennepin, in 1680.³ With the exception of some of the early explorers and missionaries no others came until the fall of 1847, when a timber-survey party ascended Rum River, from its mouth, by canoe, following it and several of its tributaries in Mille Lacs County to their sources. This party was in charge of Daniel Stanchfield, a Maine lumberman, who 52 years later read a paper before the Minnesota Historical Society dealing with his early explorations for timber.⁴ An extract from his report is of interest because of the light which it throws on the original vegetative cover of the region, of which little now remains. He said, in describing his journey up Rum River:

A large tributary, the most northern entering [Rum River] from the west, which was afterwards called Bradbury brook, had the finest pine I had seen. * * * The pine on the main river reached from the shore, on each side, as far as the eye could see from the top of the highest tree, along all its extent of fifty miles or more from the mouth of the West branch to Mille Lacs.

Between 1847 and 1857 the settlers came chiefly from Maine and other Eastern States, and they were engaged almost entirely in the lumber industry.

The county was established by legislative enactment on May 23, 1857, one year before Minnesota was admitted to the Union, and the first election of county officers was held in 1867. The village of Princeton was platted in 1855, assumed business proportions in 1856, was incorporated in 1877, and was made the first county seat. The earliest development of the county was slow, owing, in part, to the greater interest in lumbering activities than in agriculture, and in part to the financial crisis in 1857 and to the Civil War.

No population figures are recorded prior to 1860, in which year the number of inhabitants was 731. The population increased gradually until 1890, more rapidly in the following decade, and steadily until 1920. The 1930 census⁵ reports 14,076 inhabitants in the county, a slight increase since 1920, all classed as rural. In 1870 the population consisted chiefly of Americans from elsewhere in Minnesota and from New York, Wisconsin, Ohio, Pennsylvania, and Illinois. These people were largely of English descent. The small foreign population at that time included Canadians, Swedes, Norwegians, Germans, Irish, English, Scotch, Danes, and French. About 1885 the proportion of foreign-born residents from Sweden, Norway, Germany, and Canada

³ FOLWELL, W. W. A HISTORY OF MINNESOTA. v. 1, 533 p., illus. St. Paul, Minn. 1922.

⁴ STANCHFIELD, D. HISTORY OF PIONEER LUMBERING ON THE UPPER MISSISSIPPI AND ITS TRIBUTARIES, WITH BIOGRAPHIC SKETCHES. Collect. Minn. Hist. Soc. 9: [325]-362, illus. Minneapolis. 1901.

⁵ Soil survey reports are dated as of the year in which the field work was completed. Later census figures are given whenever possible.

greatly increased. Until then agricultural settlement had taken place only in Princeton, Greenbush, and Milo Townships, in the southern part of the county. By 1890, settlement was pushing north in the wake of the lumber camps, farm communities growing up in Milaca, Borgholm, Bogus Brook, and northern Milo Townships. North of the village of Milaca, however, little development, apart from the lumbering industry and a few isolated farms along Rum River, occurred until much later. The townships of Lewis, Mudgett, Kathio, Dailey, East Side, and Bradbury are still sparsely settled. At the present time the population is distributed most densely in the six most southerly townships, and near Mille Lacs Lake in the northern part of the county, in South Harbor and Isle Harbor Townships. The present population is composed chiefly of native-born Americans and people of northern European origin, the Americans coming from the Northeastern States and Canada, and the Europeans from Sweden, Germany, Norway, the Netherlands, Denmark, Czechoslovakia, Finland, England, Ireland, Scotland, and Poland. The descendants of settlers from the Scandinavian countries, from Germany, and from the Netherlands are in the majority.

Princeton, with a population of 1,636 in 1930, is the oldest and largest village and lies just within the county at its extreme southern end. Milaca, the present county seat, situated about 15 miles south of the geographic center of the county, has a population of 1,318. Onamia, having a population of 514, lies near the center of the northern part of the county, within 4 miles of Mille Lacs Lake. Isle, in the northeastern part on Mille Lacs Lake, has a population of 523. Wahkon, Bock, Foreston, and Pease are smaller villages. With the exception of Wahkon, all the towns named have cooperative creameries, that at Milaca being one of the largest, noncentralized cooperative creameries in the State, with a weekly butter production ranging from 20,000 to 30,000 pounds. A small independent cheese factory is located at Princeton, and several local cream and poultry buyers operate in the county. Princeton, Milaca, Onamia, and Isle are the largest shipping centers for farm produce. In addition to the creameries and feed mills are a brick plant at Brickton, small pickle factories at Milaca and Wahkon, a granite cutting and polishing mill at Wahkon, with a quarry near by, and small sawmills at Onamia, Isle, and Wahkon. Portable sawmills operate at several points in the wooded northern townships, and small quantities of forest products are still shipped from the three northern villages. Several small summer resorts and many cottages and hotels are located on the shore of Mille Lacs Lake.

Transportation facilities are good in the more thickly settled parts of the county. A branch line of the Great Northern Railway, extending from St. Cloud to Sandstone and Duluth passes from west to east through Foreston, Milaca, and Bock. The Minneapolis to Milaca branch of the same railway joins with the first-mentioned branch at Milaca, connecting with Pease, Long Siding, Brickton, and Princeton to the south. The northern part of the county is served by a branch line of the Minneapolis, St. Paul & Sault Ste. Marie Railway from Brooten to Moose Lake and Duluth. This branch also passes through Johnsdale in the northwestern part of the county, and Wahkon and

Isle in the northeastern part. Few farms in the county are more than 10 miles from a shipping point, the average distance in the southern part being between 5 and 7 miles.

Most of the farms of Mille Lacs County are well placed with respect to State Highway No. 18 and State Highway No. 23, which traverse the county from north to south and from east to west, respectively. State Highway No. 18 passes around the southwest side of Mille Lacs Lake, thence south through Onamia to Milaca and Princeton, making automobile road connection with the towns of Brainerd and Aitkin, to the northwest and north, and with Elk River, Anoka, and the Twin Cities to the south and southeast. State Highway No. 23 passes through Bock, Milaca, and Foreston, giving those places good connection by graveled roads with Mora and Duluth to the east and northeast and St. Cloud to the west. In addition to these trunk highways, several almost equally good graveled roads are maintained by the county, connecting the more outlying parts. Good roads are less common in the more sparsely settled northern townships. The more important dirt roads are graded and kept dragged by the townships in which they occur. A total of 550 miles of graveled road is maintained in the county. Bus and truck services connect Isle, Wahkon, Onamia, Page, Milaca, and Princeton with Minneapolis and St. Paul. Rural mail delivery and telephone facilities serve most of the farms in the county. There are 78 schools, of which 7 are consolidated, 2 are high schools, and 4 are graded schools with high-school departments.

Minneapolis and St. Paul are the chief markets for the products of the county. All the butter, except that used for local consumption, is shipped to Minneapolis by railroad, the livestock by truck and railroad to South St. Paul, and potatoes by railroad to Minneapolis or St. Paul, for reconsignment to Chicago and Southern and Eastern States.

CLIMATE

The climate of Mille Lacs County is characterized by wide extremes in temperature. The mean temperature for January, the coldest month, is 8.5° F. and for July, the warmest, is 68.6°. The lowest temperature recorded at Milaca is -44° and the highest 98°. The average date of the last killing frost is May 15, and of the first is September 17, giving an average frost-free period of 125 days. The latest recorded killing frost occurred on June 5, and the earliest, on August 31.

The mean annual precipitation is 26.3 inches, two-thirds of which falls during the spring and summer. The rainfall gradually increases during the spring months and remains fairly uniform during the months of May, June, July, August, and September. It diminishes again during the late fall and is lowest during the winter. The winter precipitation is chiefly in the form of snow.

Table 1, compiled from records of the Weather Bureau station at Milaca, gives the more important climatic data for Mille Lacs County.

TABLE 1.—Normal monthly, seasonal, and annual temperature and precipitation at Milaca, Minn.

[Elevation, 1,072 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1898)	Total amount for the wettest year (1903)
	° F.	° F.	° F.	Inches	Inches	Inches
December.....	14.1	52	-31	0.49	0.00	0.63
January.....	8.5	47	-44	.54	.00	.20
February.....	10.7	42	-30	.84	.40	.36
Winter.....	11.1	52	-44	1.87	.40	1.19
March.....	26.9	81	-22	.98	.20	2.47
April.....	42.1	84	5	1.98	.60	6.02
May.....	54.5	91	21	3.44	2.91	4.53
Spring.....	41.2	91	-22	6.40	3.71	13.02
June.....	63.5	97	30	4.12	1.97	2.72
July.....	68.6	98	39	4.21	2.63	11.41
August.....	66.0	92	32	2.89	2.38	3.96
Summer.....	66.0	98	30	11.22	6.98	18.09
September.....	57.5	89	25	3.06	1.04	5.43
October.....	45.8	84	7	2.50	5.36	3.47
November.....	30.3	92	-12	1.25	.90	.40
Fall.....	44.5	92	-12	6.81	7.30	9.30
Year.....	40.7	98	-44	26.30	18.39	41.60

AGRICULTURE

Agriculture began in Mille Lacs County at about the time of the establishment of the village of Princeton in 1855. The first farms were located in the present township of Princeton, near the village of that name. Farming gradually spread over into the adjoining townships of Greenbush and Milo and by 1885 was pushing northward into the townships of Bogus Brook, Borgholm, and Milaca. North of the last two townships agricultural development is very much more recent, and, at the present time, with the exception of the townships of South Harbor, Isle Harbor, and parts of East Side, it rapidly diminishes to the northward. The southern half of the county and a 4 or 5 mile strip adjacent to the southeast and east sides of Mille Lacs Lake are agriculturally the better-developed parts. Of these, the area 6 miles or more in width, which lies just to the north of the sandy lands, is in the most advanced stage of development and is, in general, the most prosperous in appearance. This is partly because this area is among the oldest settled in the county and is partly owing to soil conditions. The northern half of the county, with the exceptions already mentioned, is still very largely in a wild state. The larger and more abundant areas of peat, which occupy a large percentage of the northern half of Mille Lacs County, isolating "islands" of upland, making road construction more expensive, and detracting from the appearance of the countryside agriculturally, are undoubtedly important factors in hindering the development of this section.

Table 2 gives the acreage and production of the leading crops in Mille Lacs County, as reported by the last six censuses.

TABLE 2.—*Acreage and production of the leading crops in Mille Lacs County, Minn., in stated years*

Crop	1879		1889		1899	
	Acres	Bushels	Acres	Bushels	Acres	Bushels
Corn.....	658	23,669	1,557	38,712	2,925	91,290
Oats.....	563	18,571	1,468	46,496	2,319	80,390
Wheat.....	1,192	16,440	384	6,853	4,002	73,490
Barley.....	42	850	34	847	292	7,910
Buckwheat.....	18	195	82	1,131	25	320
Rye.....	172	1,850	259	4,397	1,177	19,590
Flaxseed.....		6		30		30
Potatoes.....		4,752	224	20,124	2,338	256,671
Hay.....	1,114	Tons 1,875	5,426	Tons 7,116	11,621	Tons 17,806
Clover alone.....						268
Other tame hay.....					3,584	5,307
Wild hay.....					7,676	11,839
Grains cut green.....					93	127
Coarse forage.....					5	19
Apples.....					Trees 2,323	Bushels 21
Plums.....					911	13

Crop	1909		1919		1929	
	Acres	Bushels	Acres	Bushels	Acres	Bushels
Corn.....	2,659	89,661	2,759	101,195	1,853	140,676
Oats.....	3,998	164,764	8,996	333,117	15,308	501,637
Wheat.....	2,427	53,533	3,601	42,394		
Barley.....	1,097	33,771	2,195	60,874	6,535	155,941
Buckwheat.....	12	128	58	696		
Rye.....	290	5,846	1,910	25,652	1,714	28,465
Flaxseed.....	57	496	62	669		
Potatoes.....	3,860	570,482	7,227	661,494	5,441	502,227
Hay.....	23,876	Tons 41,816	36,097	Tons 62,892	43,227	Tons 58,072
Timothy alone.....	5,298	9,189	808	1,246		
Timothy and clover mixed.....	9,277	17,780	19,400	36,337		
Clover alone.....	459	827	794	1,550		
Alfalfa.....			29	32		
Other tame hay.....	546	988	2,471	3,742		
Wild hay.....	8,224	12,904	12,054	19,150		
Grains cut green.....	72	128	218	339		
Legumes cut for hay.....			323	496		
Root forage.....			160	991		
Coarse forage.....	324	2,067	1,332	3,435	5,100	32,415
Silage crops.....			1,700	14,787		
Apples.....	Trees 4,018	Bushels 1,900	Trees 6,568	Bushels 4,964		
Plums.....	550	81	1,786	269		

¹ For grain.

² Corn only.

In table 3 are given selected data concerning farms in the county.

TABLE 3.—*Land, farm areas, and operation in Mille Lacs County, Minn., in census years*

Year	Farms	Operated by owners			Land in farms			Improved land in farms		
					Total	Percent- age of county area	Per farm	Total	Percent- age of farm land improved	Per farm
1880.....	104	101	97.1	19,324	5.2	186.0	6,696	34.7	64.4	
1890.....	180	169	93.9	30,111	8.1	167.0	10,926	36.3	60.7	
1900.....	1,022	950	93.0	95,660	25.6	93.6	31,406	32.8	30.7	
1910.....	1,278	1,157	90.5	123,647	33.1	96.8	48,438	39.2	37.9	
1920.....	1,898	1,691	89.1	178,550	47.9	94.1	79,548	44.6	41.9	
1930.....	2,025	1,593	78.7	203,006	54.4	100.2				

Examination of these tables, together with data reported in earlier censuses, enables conclusions to be drawn concerning the type of farming practiced in Mille Lacs County at the present time and also concerning the trend of agricultural development during the more important years of its farming history. In 1859 there were 1,303 acres in farm lands, of which 86 acres only were improved. During that year, 655 bushels of corn, 104 of oats, 84 of wheat, 45 of buckwheat, 10 of rye, 730 of potatoes, 12 of peas and beans, and 62 tons of hay were produced. There were 40 head of cattle in the county, of which 9 were dairy cows.

By 1869 the number of acres in farm land had greatly increased. Ninety-one farms were reported, with an average of 139 acres each and a total area of 12,651 acres, of which 14 per cent was improved. The grain acreage had increased tremendously, there being produced in that year more than 9,000 bushels each of corn and oats, nearly 8,000 bushels of wheat, and smaller, though greatly increased, amounts of rye, buckwheat, and barley. More than 5,000 bushels of potatoes and nearly 2,000 tons of hay were harvested. Great increases were also reported in the number of livestock kept, there being an average at that time of 1 horse, 8 cattle, including 2 or 3 dairy cows, 2 hogs, and 2 sheep, on each farm. The number of livestock kept (with the exception of hogs) has steadily increased, and in 1930 a total of 5,189 horses, 81 mules, 25,201 cattle (including 15,513 milk cows), and 3,204 hogs was reported by the census.

At the present time dairy farming is the prevailing type of agriculture. Mille Lacs County is situated approximately in the center of the dairy region of Minnesota, and its agricultural practices are designed to make the production of butterfat the leading enterprise on the farm. The income from the sale of cream is supplemented by that obtained from the production of potatoes, poultry, eggs, livestock, and some small grains. A somewhat different type of agriculture is conducted on the earlier, sandy soils of the extreme southern part of the county where more corn, rye, barley, and potatoes are produced, and somewhat more livestock is fed. In that section, potatoes are the leading cash crop in many years, but on the whole there is now rather wide diversification, and the tendency is toward more cream production, the income from cream sales being of great importance throughout the county.

Hay and forage are the most important crops grown. In 1929 the average yield of hay was 1.3 tons to the acre. The present tendency is toward more leguminous tame hay, with alsike as the most popular crop, followed by red clover and alfalfa. Less timothy is sown now than formerly. Alfalfa gives satisfactory yields on the heavier upland soils in years of favorable precipitation. The acreage is steadily increasing. The annual State crop census for 1925 reported 1,147 acres of alfalfa hay in the county, the equivalent of 5½ per cent of the tame-hay acreage, and its estimated extent at the present time (1927) is approximately 1,500 acres. Many cooperative liming tests and other trials with alfalfa are at present being conducted in the county by the Division of Soils of the University of Minnesota. Sweetclover is being used to an increasing extent as a pasture crop. Corn for silage is gaining greatly in popularity, as evidenced by the large acreage reported by the 1930 census. During years in which

the spring season is late or precipitation is subnormal, the forage-corn acreage is greatly increased. Root crops for forage are not extensively grown. Millet and Sudan grass are used to some extent on the lighter-textured soils, millet being fairly common when a rapidly maturing forage crop is required. All the hay crop is fed within the county. In years of insufficient rainfall the crop is insufficient to feed the local livestock, and at such times it is necessary to ship feed into the county.

The leading grain crop is oats. Most of the crop is fed on the farms where grown. Medium early maturing varieties of oats are the most popular, chief among which are Swedish Select, Victory, Big Four, Roosevelt, and Swenson. The most extensively grown early varieties are Iowa 105 and Gopher. White Russian is a later variety which is grown less extensively.

Corn ranks third among the crops of the county in acreage. It is a rather uncertain crop in this locality. With more intensive feeding methods demanded by the dairy industry, however, its use for silage and fodder has increased, and according to the State census for 1924, 10,905 acres, or 19.5 per cent of the plowland, exclusive of pasture, was planted to corn. This was the highest recorded acreage for the county, a slight decrease taking place in the following year. A comparatively small amount of the corn is allowed to mature, except on the earlier, lighter-textured soils about Princeton, where ripe corn is fairly certain each year and is used for finishing hogs and cattle for market to a greater extent than elsewhere in the county. By far the greater part of the corn crop is used as fodder and silage corn, and a steady increase in the number of silos in the county is noticeable each year. Silage corn is most extensively grown in the southern and south-central townships. Farther north, in the newer sections, the proportion of fodder corn is greater. Medium and early varieties are grown, Minnesota 13, yellow-dent varieties (mixed), and Minnesota 23 being most common. For silage, Minnesota 13 and a rapid-growing so-called fodder corn, consisting of a seed-house selection, are very popular. The general practice is to plant ear and forage corn together each year, with the hope of being able to save sufficient for seed if the season is favorable for carrying the crop to maturity. Very little corn is shelled, and none is marketed.

Potatoes rank next in acreage. The present tendency is toward a rather more conservative production of potatoes in the county as a whole, although they are by far the most important supplementary cash crop. Particularly on the lighter soils and to a limited extent on the peat land and some of the stone-free soils, the potato acreage is comparatively large, and the crop is more important as a cash crop than on the heavy, stonier soils farther north. In places, potato production exceeds cream production as the main farm enterprise. Equal proportions of early, medium, and late potatoes are produced, the most common varieties being Triumph, Irish Cobbler, Early Ohio, Russet Burbank, Rural New Yorker, and Green Mountain. The potatoes are marketed at the village warehouses whence they are billed by freight to Chicago, but they are usually held at Minneapolis or St. Paul for reshipment to points in the Southern States.

Barley is second only to oats as a small-grain crop. This crop is increasing in importance, at present occupying about 8 per cent of the plowland on the farm and being used extensively as ground feed to replace shelled corn in the ration for cattle and hogs. Six-rowed barley of no particular variety is commonly used.

Wheat is diminishing in relative importance. In the early days, this was a widely grown crop in the southern part of the county, occupying the largest acreage of the small grains. Its acreage has rapidly diminished with the development of more specialized agriculture. Wheat production received a slight impetus during the World War period, but it has decreased again of late years. Owing to climatic conditions and diseases, its production has not proved satisfactory.

The acreage in winter rye is at present about equal to that in wheat, with a slight tendency to increase. Rye is produced almost entirely on the sand soils, and it is used mainly as hog feed, though to some extent as a cash crop. Common rye, chiefly, and some Rosen rye are grown.

A little flax is grown, usually on new ground, poorly drained mineral soils, and peat. Buckwheat and beans are grown in small patches throughout the county for home use and for local disposal. Tobacco is produced to a very limited extent by a few farmers, and the fields observed during the course of the survey appeared thrifty. Soybeans are occasionally planted with corn for silage. Sugar beets are grown by a few farmers. The total acreage of flax, buckwheat, field beans, soybeans, tobacco, and sugar beets amounted to less than 75 acres in 1925.

Most farms have a small orchard of apples and plums. The small fruits are less commonly grown, but good yields are obtained by farmers who pay attention to the production of raspberries and strawberries for local and tourist trade. Practically every farm includes a garden in which vegetables are grown for home consumption.

The increasing importance of the dairy industry in Mille Lacs County may be readily seen by referring to Table 4 which gives creamery statistics for Mille Lacs County in stated years.

TABLE 4.—Creamery statistics for Mille Lacs County, Minn., in stated years¹

Year	Cooperative creameries	Independent creameries	Patrons	Milk received	Cream received	Butter made	Amount paid patrons for butterfat	Amount received for butter
	Number	Number	Number	Pounds	Pounds	Pounds	Dollars	Dollars
1910.....	6	3	1,005	79,794	3,585,575	1,202,803	303,582.88	-----
1915.....	7	1	1,421	18,200	5,369,141	1,729,621	408,648.25	457,412.51
1920.....	8	-----	2,036	116,492	7,040,812	2,209,294	1,200,469.73	1,301,733.31
1925.....	7	-----	2,031	97,550	9,573,444	3,236,428	1,236,807.97	1,393,406.76
1926.....	8	-----	-----	94,109	11,409,090	3,834,680	-----	-----
1927.....	-----	-----	-----	57,211	11,217,211	3,829,877	1,500,095.54	1,618,964.02
1928.....	-----	-----	-----	63,971	12,050,780	3,900,741	1,648,082.76	1,762,686.01
1929.....	-----	-----	-----	67,878	12,046,497	3,895,226	1,556,649.78	1,692,205.88

¹ Data from records of Minnesota Cooperative Reporting Service and bulletins of State Department of Agriculture.

During 1925, as may be deduced from the figures given, an average of \$609 was paid to each of the 2,031 patrons of the cooperative creameries for butterfat. Two of the creameries draw appreciably

on territory outside the county, but approximately nine-tenths of the butter produced represents production within Mille Lacs County. The milk is separated on the farm and the cream delivered at the local creamery each day. Holstein and Guernsey grades, mixed breeds, and a few purebred herds of Holsteins, Guernseys, and Jerseys are kept. The cows are pastured in summer largely on wild land—brushy and stump land pasture that has been partly seeded to white Dutch and alsike clover. Late in the summer and early fall the animals are run on the meadows and stubble fields. No additional feed is given until late fall and during the winter months, when mixed clover and timothy hay, clover hay alone, or alfalfa hay, corn silage or fodder corn, and some grain are fed. An average of 10 or 12 cows are milked by each of the creamery patrons. All the butter manufactured, except the small amount used locally, is shipped to distributing houses in the Twin Cities.

Hog production is of secondary importance. From 5 to 10 hogs are kept on every farm. They are generally pastured on wild pasture, rape, small grains, or alfalfa in the summer and fed skim milk and some ground barley or rye the year round. They are marketed throughout the year. A considerable proportion of the number raised is hauled directly to South St. Paul by the producer, and some hogs are marketed through local shipping associations. The most common breeds are grades of Duroc-Jersey, Poland China, and Chester White. More attention is paid to hog raising on the lighter soils of the southern part of the county where the animals are largely corn fed.

Sufficient horses are raised for local needs only, some farmers preferring to buy them when urgently needed rather than keep them on the farm. Three or four horses a farm is the average number for the county. Percheron and Belgian grades are most popular.

Both wool and mutton sheep are raised, largely in the newly settled and rougher sections of the county. They are marketed locally and shipped by truck to South St. Paul.

Little attention is paid to the beef-cattle industry. Small herds and a few animals kept for home use are all that are raised. More beef cattle are raised in the southern than in other parts of the county. The few animals sold are disposed of locally or shipped by truck or through a shipping association to South St. Paul.

Every farmer keeps a flock of poultry. In 1930, 131,529 chickens were reported in the county. The eggs are shipped chiefly through the local creameries, but most of the fowls are disposed of by truck to the Twin Cities. Bees are kept on about half the farms of the county.

In a general way the farmers recognize the more outstanding crop adaptations of the various soil types. The finer-textured wetter soils and the undrained and poorly drained peats are considered better suited to hay and pasture crops than to cultivated crops. The deep sandy soils are recognized as well adapted to alfalfa, and the importance of drainage on the finer-textured upland soils is seldom overlooked for this crop. The production of flax is largely limited to the heavier soils. It is well understood that corn matures much more frequently on the sandy soils than on the heavy upland soils, although yields are generally lighter. The sandy soils are also well

suiting to early potato production, and rye is the most successful small-grain crop on such soils. The sandy soils suffer from insufficient moisture in some seasons. However, their regional and restricted distribution allows the farmers little choice as to their particular suitability, and a system of agriculture has developed on these soils in which mature corn plays a more important part than on the heavier later soils elsewhere.

The value of crop rotations is generally recognized, but definite systems are not universally followed as weather conditions and market prices vary greatly. The cropping practices commonly followed conform more or less to a rotation as follows: (1) Oats, seeded down to alsike or red clover, (2) hay, followed by (3) corn and potatoes. Variations from this rotation consist of lengthening the period during which the land is left in hay meadow, using clover and timothy mixtures to replace clover alone, and repeating the corn and potato crops. When alfalfa is used instead of clover, it is allowed to remain from three to five years or longer. Oats or barley (grown alone) or a small grain followed by corn may intervene after the corn crop on sod and before the land is again seeded to a hay crop. Under such conditions the hayfield is left unplowed for a second and occasionally a third season. Barley, rye, and sometimes wheat may replace oats as a nurse crop, rye being preferred on the very sandy lands.

In preparation for a corn or potato crop the land, which is commonly clover sod, is usually fall plowed, disked, and harrowed. On the lighter soils spring plowing is preferred by many farmers, as this avoids danger of surface blowing during the winter. The sandy land is left rougher than is considered desirable for the heavy soils. Except on the lighter soils, corn is usually drilled in rows, between May 12 and May 31. On the sands the check method is more common, and planting is from one to two weeks earlier. In certain seasons replanting is necessary and may continue until the middle of June. Most of the corn is used for silage, and the time of cutting is governed largely by the date of the first damaging frost which may occur as early as the middle of August, but usually silo filling does not take place until September 7 or thereabouts. The corn is hauled direct from the field to the silage cutter as soon after cutting as possible. Corn harvested for grain is cut when hard, shocked, and husked from the shock in the field. Potatoes are ordinarily planted between May 7 and May 31 and during the latter part of April on certain soils, particularly the sands. Harvesting with a potato digger may commence any time after September 1, depending on the season and the variety of potato grown. The potatoes are sacked and hauled to local warehouses by truck.

The corn and potato ground may or may not be plowed for the following crop of grain, depending on the condition of the land and the progress of the season's work. If plowed, this is usually done in the spring. The plowed or unplowed ground is disked and harrowed. The small grains are drilled in, between April 7 and April 30, and the clover or grass seed is broadcast or sown with a seeder attachment or wheelbarrow seeder. Rye is sown on grain stubble during September, and if hay is desired as the next crop, the seed

is broadcast on the rye land in the spring. Small-grain harvest begins the third week in July and continues until August 15 or 20. Alfalfa is usually seeded with an accompanying crop of grain, the grain being drilled in at a much lighter rate than ordinarily. The practice of sowing alfalfa alone on carefully prepared clean ground is becoming more popular, however, and has distinct advantages.

Farm buildings and equipment vary greatly within the county. In the southern and south-central townships, and particularly on the better soils, the farm homes and barns are of moderate size and well kept. Frame houses are most numerous, although many brick houses are in the vicinity of Princeton and Long Siding. The general-purpose type of barn, of frame construction, is used on most farms. Silos are built of wooden staves, cement, and hollow tile. In the more remote parts of the county, where clearing has only just commenced, and on the newer farms in the older settled parts, pioneer conditions are common. The houses consist of 2 or 3 rooms, and many of the barns are small and built of logs. Empty houses in a poor state of repair are frequently seen in the newer sections. All farms are fairly well supplied with machinery, many of the more expensive implements, such as binders and silage cutters and occasionally drills, being owned cooperatively. Many farms have tractors and small gasoline engines for separating cream and pumping water.

Good water is abundant at depths ranging from 25 to 60 feet, and each farm has one or more wells. According to the 1930 census the average value of land and buildings is \$6,789 a farm.

All the barnyard manure is utilized, ordinarily being applied to the hay or small-grain stubble fields in late summer, fall, or winter, and plowed under in preparation for corn and potatoes. A few farmers use grain straw and cornstalks as a means of increasing the organic-matter content of the sandy soils and to offset the danger of blowing. Very little green manuring is practiced. On a few reclaimed peat bogs commercial phosphate and potash fertilizers are used in amounts and proportions which vary with the requirements of the peat. Lime is necessary on some peats and is used on such soils and also, to a limited extent, on the acid upland soils where alfalfa is to be grown.

On the majority of farms, work is done by members of the family, and arrangements are made with neighbors to exchange help when extra assistance is needed for work of a pressing nature. The occasional local help that must be hired is fairly abundant and reliable. From \$2 to \$3 a day, with board, is the common wage. A few men are engaged by the month at prices ranging from \$45 to \$55 with board. For harvesting special crops, such as potatoes, higher prices are paid.

Of the 2,025 farms reported by the census, nearly 90 per cent are between 20 and 175 acres in extent. Smaller holdings are operated in the vicinity of the towns and lakes. Since 1900 the percentage of farms operated by owners has gradually decreased, and tenancy has increased from 7 to 21 per cent. Rental contracts vary considerably. When an entire farm is rented the tenant commonly pays on the share basis, the proportion of the products due the owner ranging from one-

third to two-thirds, depending on the details of the agreement as to provision of seed, implements, and other necessities. The agreement in most common use calls for one-half the products to the owner, the renter supplying everything. Cash rental is usually paid for hay and pasture lands. When a farm with considerable plowland is rented for cash, the tenant pays from \$2 to \$10 an acre depending on the location and condition of the land, the kind of improvements, and the character of the soil. The average cash rental ranges from \$3.50 to \$4.50 an acre. The average value for all farm land, exclusive of buildings, is reported by the 1930 census as \$67.82 an acre, but there is a wide range in the price of land in various parts of the county. Comparatively little land is changing hands at the present time. Wild cut-over land, situated from 5 to 12 miles from a town, may be purchased at prices ranging from \$10 to \$40 an acre. A few tracts of wild land, supporting a heavy growth of virgin timber, command very much higher prices. Improved land throughout the county, exclusive of buildings, sells at prices ranging from \$60 to \$125 an acre, depending on soil types and distance from town.

SOILS

As discussed fully in the report, great differences in degree of agricultural development exist in the northern and southern parts of Mille Lacs County. The northern part consists of less fully developed, less thickly populated, cut-over country, and the southern part of more thickly settled and more extensively cleared farm lands. In the southern half of the county a detailed soil survey was conducted, and in the northern half a detailed survey was made of the cleared⁶ areas only. A less detailed, or reconnaissance, survey was made of the uncleared⁷ parts.

Two groups of well-drained upland soils are represented in Mille Lacs County. The first group consists of upland soils which show the characteristics of soils developed under rather humid conditions, in regions of low winter temperatures, and in situations where the vegetation was once a forest of mixed conifers and deciduous trees. These are podzolized soils, so-called from the ash-gray color of the surface soil. The soils of the second group have characteristics more similar to those of soils developed under conditions of rather lower humidity and similar winter temperature, but under prairie vegetation. These are prairie soils. The first group is by far the more important, as it includes almost all the upland soils of the county. The second group is inextensively and not typically represented by a series of soils occurring in the southern part of the county and another occurring as small scattered areas among the more extensive soils of the first, or podzolized, group.

In the detailed description of any soil the term "soil profile" is used. This term simply refers to the aggregation of natural layers of soil material which occur one below the other, from the surface of the layer of accumulated organic débris at the top downward into the unchanged substratum from which most of the soil as it now exists

⁶ Cleared land is land from which the brush has been burned or cut off. Brush-free stump land and wooded but brush-free pasture is classed as cleared land.

⁷ Uncleared land is forested land from which the brush has not been removed.

has been developed by the various agencies of soil formation. In some places, the deeper layers in the profile are unrelated to the upper part of the soil mass, which has weathered from overlying sediment of a different character. In the most detailed and complete study of a soil profile, physical, chemical, and biological characteristics are taken into consideration. During the soil survey, however, only the most important and conspicuous characteristics, which can be readily recognized in the field, are examined.

The typical podzolized soil profile includes the following layers: (1) A layer of leaf mold; (2) a thin dark-colored humous layer consisting of a mixture of well-decomposed organic matter and mineral particles; (3) a very well-leached gray or brownish-gray layer of uniform-textured material, very low in content of organic matter; (4) a darker-colored layer, with more clay than the layer immediately above and in many places somewhat cemented; and (5) the unweathered parent material, or substratum, from which most of the soil has been derived, which continues downward for indefinite or variable depths and which in this region is usually rather coarser textured than any of the layers above. The upper four layers are usually acid in reaction. The podzolized soils of Mille Lacs County have profiles corresponding very closely to this description.

The profile of the typically developed prairie soils includes layers having the following outstanding characteristics: (1) A deep dark-colored humous layer consisting of an intimate mixture of decomposing organic matter and mineral particles; (2) a layer in which accumulations of carbonate of lime are most abundant and conspicuous; and (3) the more or less calcareous parent material. The profiles of the prairielike soils of Mille Lacs County agree imperfectly with the typical prairie soil profile, but sufficient points of similarity are present to justify their classification with the prairie soil group.

Associated with the upland soils of these two groups are soils occurring in positions in which drainage is such that the typical soil profile of the region has been hindered in its development. Such soils are physically and chemically different from the typical well-drained soils. These differences are important and are recognized in the soil survey. It may happen that poorly drained soils associated with the soils of both the upland groups are so controlled in their development by imperfect drainage that points of dissimilarity, which mark the upland soils, have not developed. This is true of Isanti loamy fine sand which has been mapped in association with the upland soils of both groups.

In addition to soil differences which are readily recognizable and are caused by drainage conditions, is another set of factors, which makes it necessary to distinguish further soil differences within any soil group. These differences are owing to variations in the character of the parent material itself. Minor variations in the composition of the parent rock may be disregarded. Outstanding variations must be recognized, however, as they commonly affect the physical and chemical character of the soil, frequently to a very marked degree. It is clear, that for soils developed side by side, under the same, or very nearly the same, conditions of climate, drainage, and vegetation, the differences in their profiles due to differences in parent

material will be least noticeable in the surface layers and most pronounced in the deeper layers. Noticeable profile differences frequently occur in the soils of any group, which can not readily be attributed to climate, drainage, geologic substratum, or vegetation, and for which at present there is no certain explanation. These are also recognized, and soils having such profile peculiarities are separated from the other soils during the course of the soil survey.

Separations made on the basis of any of the differences mentioned give rise to what are known as soil series. Variations in the profile of the soils of a given series, which are insufficient to cause the formation of a new soil series but which nevertheless make for significant soil differences, allow subdivision of the soils of a series into soil types. The most common distinction made between different types of a given soil series is variation in texture of the soil profile, particularly of the surface soil layers.

Mille Lacs County lies within that part of Minnesota in which glacial drift is the surface soil geological formation. Two kinds of drift, of slightly different age, have been deposited in the county. These are the early Wisconsin, or Patrician, drift and the late Wisconsin drift. The early Wisconsin drift, is also called the "young red drift," on account of the reddish-brown color of the unweathered drift material and because it is the more recent of two glacial deposits in Minnesota which are of very similar character. The early Wisconsin drift is the result of an ice invasion from the northeast, when the flowing ice ground up crystalline rocks and on melting deposited a till formed largely from these rocks. The late Wisconsin drift is commonly referred to as the "young gray drift," owing to the brownish-gray or yellowish-gray color of the unweathered till. It is the younger of two very similar drifts, both of which have resulted from ice invasions entering the State from the northwest, which caused the deposition of material derived chiefly from the grinding up of limestones and shales. The young red drift is stony, usually rather coarse-textured material, and in its upper layers it is low in lime; the young gray drift is less stony, usually finer-textured material, and in its upper layers it is higher in lime than the young red drift. By far the greater part of Mille Lacs County is covered by young red drift, only a few patches of young gray drift occurring in the southern part. In addition to these two drift formations are wind-blown sand deposits, terraces, outwash plains, a lake plain, and peat bogs, on all of which various soils have been formed. The unconsolidated geological deposits are of variable thickness. Except in the northern part of the county, where small outcrops of gray granite and other crystalline rocks occur and where the drift layer is shallow, and in a few places along the stream channels, the drift and other deposits form deep layers overlying the bedrock.

The better-drained soils of the podzolized group belong to the Milaca, Onamia, Santiago, Greenbush, Bradford, Brickton, Zimmerman, and Berrien series.

The soils of the Milaca series (fig. 2) have the following profile characteristics: (1) A layer of dark-brown or black leaf mold (A_0), from 1 inch to 3 inches in thickness; (2) a very thin layer (A_1) of mellow nearly black or very dark brown soil, rich in humus, from one-quarter to three-quarters of an inch thick; (3) a strongly acid



A, Freshly picked stones on Milaca very fine sandy loam. The farmstead is fairly typical of those in the south-central part of the county; B, fairly typical farmstead on the red drift till plain, composed of Milaca very fine sandy loam, Adolph silty clay loam, and Freer silt loam; C, typical stumpy poplar and birch upland pasture on Milaca very fine sandy loam



A, Potatoes on Milaca very fine sandy loam; B, crops on a dairy farm on Greenbush very fine sandy loam

leached or podzolized layer (A₂) of medium texture, ranging in color from gray or yellowish gray to very pale brown and here and there slightly mottled with rust brown and gray, and varying in thickness from 4 to 12 inches; (4) a 5 to 10 inch layer of strongly acid finer-textured weakly cemented material, mottled light brown and gray, comprising the upper part of the concentration zone (B₁); (5) a transitional zone (B₂), from 10 to 20 inches in thickness, of yellowish-brown or slightly reddish-brown or mottled brownish-gray, more stony, coarser-textured, weakly cemented material which is medium in acidity; and (6) the slightly altered parent rock of young red

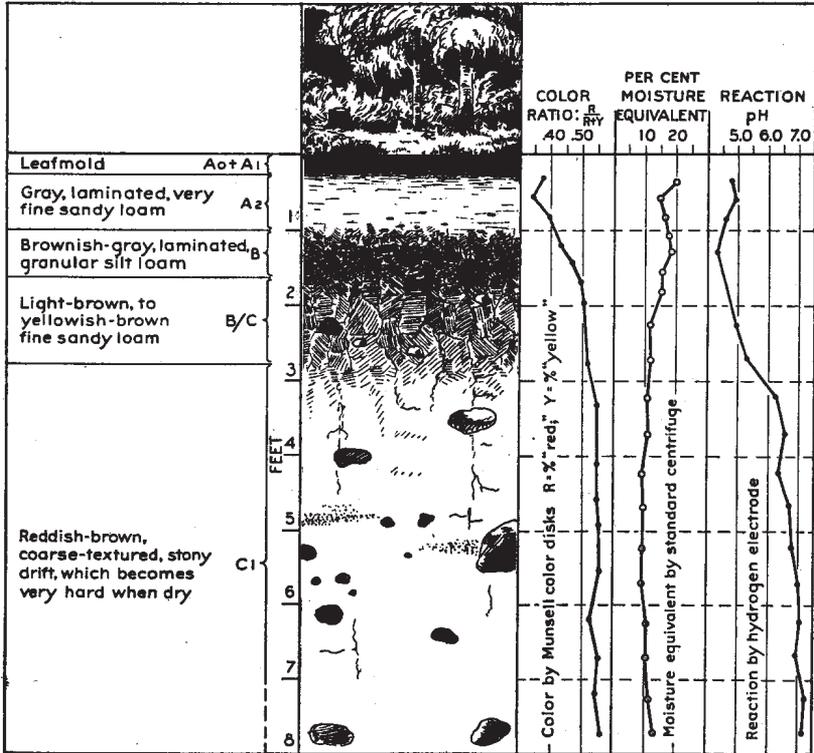


FIGURE 2.—Profile of Milaca very fine sandy loam: The description and diagram indicate the general character of the soil horizons. The color measurements are averages of many samples; those of moisture equivalent and acid reaction are of a single profile set. Slight variations from the data shown are to be expected

drift, consisting of reddish-brown stony sandy or medium textured material which contains a few sand pockets and thin sand or gravel strata. The parent material is almost invariably slightly or medium acid to a depth ranging from 6 to 10 feet below the surface. The relief of the Milaca soils ranges from very gently to strongly undulating.

To a depth ranging from 15 to 36 inches, the profile of the Onamia soils is very similar to that of the Milaca soils. At that depth stratified cobbly gravel and gravelly sand is reached. The layer im-

mediately above the gravel tends to be coarser textured than the corresponding layer in the Milaca soils. The concentration zone is also coarser in texture. The Onamia soils are acid in reaction throughout. Their relief is, in general, level or gently undulating, and in the rolling phase it is hilly.

The Santiago soils have light-gray or brownish-gray surface soils underlain by a yellowish-brown or brown concentration zone, ranging in thickness from 10 to 20 inches. The soil material is very much finer textured and yellower than in the corresponding layer in soils of either of the preceding series. Beneath this layer is the parent material of red drift which is identical with that underlying the soils of the Milaca series. The Santiago soils are gently or strongly undulating.

The soils of the Greenbush series differ from the Santiago soils chiefly in that they are underlain by stratified pebbly gravel at a depth ranging from 20 to 36 inches, and the layers immediately above the gravelly substratum are less fine textured. The surface layer, beneath the leaf mold and humous layer, is in many places somewhat browner. Like the gravel layer in the soils of the Onamia series, the reaction of the corresponding layer in the Greenbush soils is usually strongly acid to a depth of more than 6 feet. Most of the Greenbush soils have developed on outwash terraces derived from the young red drift, and accordingly calcareous rocks are lacking within a depth of 10 feet. The relief of these soils is level or undulating.

The soils of the Bradford series (fig. 3) have a thin layer of leaf mold underlain by 3 or 4 inches of gray, dark-gray, or, in some places, black fine-textured material fairly well supplied with organic matter, beneath which lies a light-gray or brownish-gray slightly coarser leached layer. At a depth ranging from 12 to 20 inches a yellowish-brown or dark-brown heavy clayey layer begins, and it extends, with increasing fineness of texture and stickiness, to a depth ranging from 4 to 5 feet. These soils are acid or strongly acid from the surface down to the lower part of this zone of concentration. The parent material, which lies from 4 to 5 feet from the surface consists of the light yellowish-brown calcareous slightly or moderately stony rather fine-textured young gray drift. Areas of these soils are undulating.

The Brickton series includes soils very closely related to those of the Bradford series. Practically the only difference lies in the character of the parent material and in the degree of fineness of texture of the material in the concentration zone. It is distinctly finer than that in the corresponding layer of the Bradford soils, and it is relatively much finer than that in the dark-gray humous and leached layers of the surface soil. The parent material is a gray or brownish-yellow strongly calcareous uniformly fine-textured lacustral deposit which consists largely of silt and very fine sand and includes a few veins of darker-brown silty clay. The relief of these soils is undulating or gently rolling.

The soils of the Zimmerman series are developed on fine-textured wind-shifted sands. Beneath the surface inch of forest litter and leaf mold lies the dark-brown humous layer which varies in thickness from a fraction of an inch to more than 2 inches. This layer is

underlain by light brownish-gray or grayish-brown fine sand which extends to a depth ranging from 3 to 5 feet. Beneath this layer occur horizontal veins of light-brown or dark-brown rather firmly cemented material which may total 2 or even 3 feet in thickness. The underlying parent rock is looser and lighter in color, and it consists of incoherent medium-textured sand of quartz, feldspars, and ferromagnesian minerals. Throughout the profile the reaction is of varying degrees of acidity, the intensity decreasing with depth.

The soils of the Berrien series are closely associated with those of the Zimmerman series but differ from them in that the Berrien

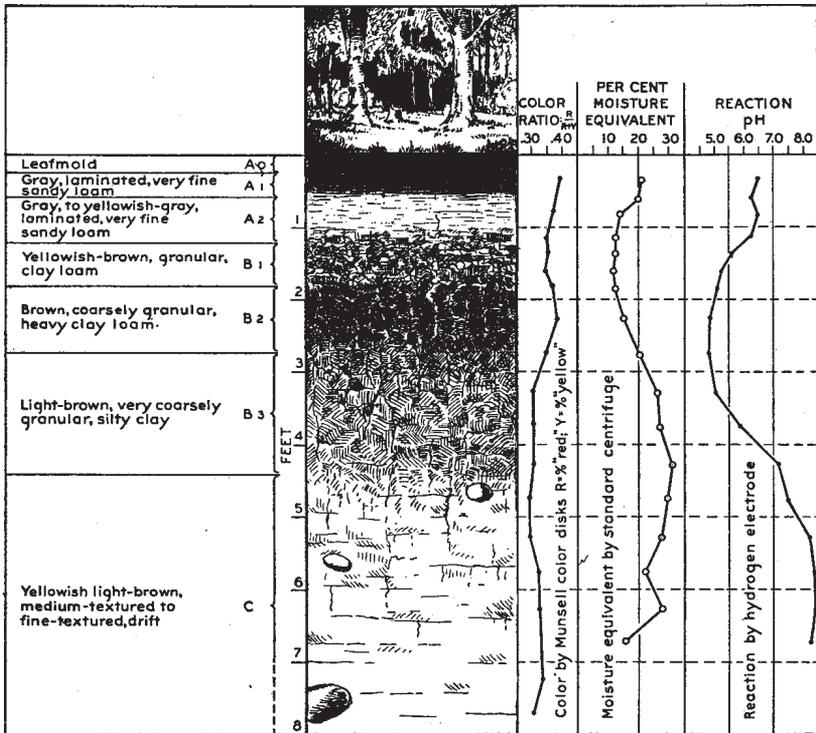


FIGURE 3.—Profile of Bradford very fine sandy loam: The description and diagram indicate the general character of the soil horizons. The color measurements are averages of many samples; those of moisture equivalent and acid reaction are of a single profile set. Slight variations from the data shown are to be expected

soils are somewhat coarser textured and overlie calcareous sandy grayish-brown drift at a depth ranging from 2 to 6 feet. These soils occur along the edge of the old sand-dune region.

The group of prairie soils is represented by one well-drained soil series, the Hubbard. The Emmert soils, which have poorly developed soil profiles, may be regarded as transitional between soils of the podzolic and prairie groups.

Soils of the Hubbard series have brown or dark-brown fine sandy surface soils extending to a depth ranging from 3 to 5 or more feet. Beneath this material lies a somewhat mottled brown transitional zone, from 12 to 24 inches in thickness, which in turn overlies the

light-brown loose sandy parent material. These soils range from medium or strongly acid in the surface soil to slightly acid in the unweathered material below. They differ from the Zimmerman and Berrien soils in having a very much deeper humous surface soil and in lacking a clearly defined concentration zone above the parent rock. The relief of the Hubbard soil areas is level or gently undulating.

Soils of the Emmert series have rather dark colored stony coarse-textured surface soils, overlying, at a depth ranging from 1 to 8 inches, yellowish-brown more or less stratified stony sandy gravel which shows some very weak cementation in its upper layers. The profile is medium acid throughout. The relief of the Emmert soils is in most places ridgy and hilly and in a few places undulating or slightly rolling.

Soils of the Adolph, Freer, Kanabec, and Isanti series are all poorly drained.

The Freer series typically includes poorly drained soils which are associated with the Milaca soils. They have thicker leaf-mold and humous layers than have the Milaca soils, the depth of these two layers combined in many places amounting to 6 or more inches. Below these layers is a foot or so of leached dark brownish-gray medium-textured soil which overlies a 2-foot layer of mottled brown finer-textured material. This layer grades, at a depth ranging from 3 to 4 feet, into the slightly weathered stony and rather sandy red drift. An acid reaction persists throughout the profile but is particularly pronounced in the upper $3\frac{1}{2}$ feet. The Freer soils occupy depressions and level or slightly undulating areas of inadequate drainage.

The Adolph soils are more poorly drained and less mature than those of the Freer series. They have a deep dark fine-textured humous layer extending to a depth ranging from 8 to 15 inches, which may or may not underlie a layer of leaf mold, depending on the present natural cover. A coarser-textured mottled gray and brown layer, from 20 to 30 inches in thickness, is next reached. Beneath this is a layer of pinkish-brown material intermittently saturated with water, which is mottled with gray and is similar in texture to the layer immediately above. At a depth of 4 or more feet the material of this layer grades into the water-logged coarser-textured slightly weathered stony red drift. These soils are strongly acid to a depth extending well into the parent rock. A very shallow layer of peat above the humous layer is a common variation which occurs in soils of the Adolph series.

Soils of the Kanabec series are geologically similar in many respects to the Brickton soils. The Kanabec soils, however, are poorly drained, are level or slightly undulating, and are underlain at a depth ranging from 4 to 8 feet by stratified pebbly sand and gravel. The finer-textured layers above the gravel are strongly or medium acid in reaction, and the gravel itself is neutral or slightly acid in the upper part of the substratum.

The Isanti soils are weakly podzolized sands which have developed in the depressions and poorly drained areas, about which the Zimmerman and Berrien soils are the associated upland soils. The Isanti soils are acid light brownish-gray soils which become progressively more distinctly mottled between depths ranging from

4 to 8 inches and 3 feet. Beneath the mottled layer is a dark-brown slightly cemented sand layer, underlain by firmly cemented veins of the same material. The light-brown neutral or slightly acid parent material is not reached above a depth ranging from 5 to 7 feet.

The alluvial deposits occurring adjacent to Rum and West Branch Rum Rivers are of variable texture. The finer-textured members are deep and brown, whereas the more sandy soils are lighter in color. All are underlain by lighter-colored deposits which in many places become sandy or gravelly at a depth ranging from 2 to 4 feet from the surface.

Immature brown coarser-textured soils are developed on the old beach sands surrounding Mille Lacs Lake, and peat deposits are scattered throughout the area. The peat areas vary in character of material, degree of decomposition, and natural vegetation. Both deep and shallow phases of peat are mapped.

In the following pages the various soil types mapped are described in detail and their agricultural value is discussed. Their distribution in Mille Lacs County is shown on the accompanying soil map, and their acreage and proportionate extent are indicated in Table 5.

TABLE 5.—*Acreage and proportionate extent of the soils mapped in Mille Lacs County, Minn.*

Type of soil	Acres	Per cent	Type of soil	Acres	Per cent
Milaca very fine sandy loam.....	119, 296	32. 0	Berrien loamy fine sand.....	1, 792	0. 5
Milaca silt loam.....	6, 400	1. 7	Freer silt loam.....	42, 560	11. 4
Milaca fine sandy loam.....	9, 664	2. 6	Adolph silty clay loam.....	30, 528	8. 2
Milaca loam.....	8, 768	2. 4	Kanabec silt loam.....	1, 152	} . 4
Onamia very fine sandy loam.....	13, 632	} 4. 3	Depressional phase.....	384	
Rolling phase.....	2, 368		} 3. 5	Isanti loamy fine sand.....	1, 280
Santiago silt loam.....	10, 112	} 1. 1		Hubbard fine sand.....	5, 120
Level phase.....	3, 072		} . 1	Emmert stony fine sandy loam.....	1, 856
Greenbush very fine sandy loam.....	4, 096	} . 1		Emmett fine sand.....	1, 448
Greenbush gravelly fine sandy loam.....	320		} . 4	Alluvial soils, undifferentiated.....	6, 464
Bradford very fine sandy loam.....	1, 664	} . 4		Beach sand.....	2, 816
Bradford fine sandy loam.....	1, 408		} 1. 5	Peat.....	79, 168
Brickton silt loam.....	5, 504	} 1. 3		Shallow phase.....	8, 320
Zimmerman fine sand.....	4, 928			Total.....	373, 120

MILACA VERY FINE SANDY LOAM

Virgin areas of Milaca very fine sandy loam are covered by a 1½ to 3½ inch layer of dark-brown leaf mold. Beneath this, and almost inseparable from it, is a very thin humous soil layer (A₁) from one-half to three-quarters of an inch in thickness. This is underlain by a well-podzolized layer (A₂) from 6 to 12 inches thick, consisting of gray or light brownish-gray very fine sandy loam, slightly mottled with faint rust-brown markings. The material is strongly acid in reaction. This layer is invariably very finely laminated in the undisturbed condition, and is noticeably vesicular. On crushing, the almost dry soil breaks down very readily into a silty, powderlike mass. A rather inconspicuous layer of accumulation (B₁) occurs next. It is from 4 to 8 inches thick and consists of strongly acid gray, brownish-gray, or light yellowish-brown silt loam which is extensively mottled with rust-brown. The laminated arrangement of the upper

layer persists, but a faintly nutlike structure is also noticeable, owing to a slight cementation of the soil particles. Under pressure the small weakly coherent nutlike granules are readily broken down into a finely granular almost structureless mass. Beneath this is a 6 to 20 inch transitional layer (B_2) of yellowish-brown or grayish-brown fine sandy loam or sandy loam, mottled with rust-colored patches and pinkish-gray tonguelike markings. The material is irregularly laminated, weakly cemented, and contains pebbles and stones. The material in this layer is usually more coarsely nutlike in structure than in the overlying layer, although this characteristic may be almost lacking. The upper layer (C_1) of the parent rock is reached at a depth ranging from 24 to 40 inches. It consists of slightly weathered reddish-brown stony glacial till which, when dry, becomes indurated and very difficult to penetrate by pick or soil auger. The texture of this material ranges from sandy clay to clayey sand, but fine sandy loam and sandy loam predominate. In many places dark stains are noticeable in the cracks and fissures in the upper part of this layer, and sand and gravel veins and pockets are common. Granite, gneiss, basalt, schist, and gabbro stones and boulders are abundant. An occasional ferruginous sandstone fragment is found, but limestones and shales are lacking. The reaction of this material is slightly or very slightly acid but changes abruptly to alkaline at a depth ranging from 6 to 11 feet. A rather more purple tinge frequently occurs in the reddish-brown color at this depth and the vesicular pores are not present, otherwise the characteristics of the less-weathered drift are similar to those of the layer above. Boulders and stones of all sizes are scattered abundantly over the surface of the ground and in a few places are so numerous as to prevent cultivation. (Pl. 1, A.) In cultivated fields the surface soil consists of 6 to 9 inches of light brownish-gray or grayish-brown structureless or very finely granular very fine sandy loam or silt loam.

Milaca very fine sandy loam is the most extensive soil in the county and forms the predominant upland soil of the till plain area (pl. 1, B), reaching from a few miles south of Milaca north to Onamia. The relief is gently undulating or undulating and in a few places gently rolling. In wet years the natural surface drainage of the flatter areas is somewhat deficient, but on the whole drainage of this soil compares favorably with that of the better-drained soils of the county. Internal drainage is fair.

At one time this soil supported an excellent stand of white pine, together with mixed hardwoods. The pine has been almost entirely cut off, however, and in many places the succeeding growth has been repeatedly burned over. The present vegetation includes poplar (aspen), ironwood, white birch, red oak, bur oak, basswood, red maple, sugar maple, mountain maple, ash, elm, several varieties of dogwood and willow, and a few white pine. (Pl. 1, C.) Norway pine and white spruce occur to less extent.

From 20 to 25 per cent of the land is under cultivation. This is a productive soil for the crops commonly grown and is well suited to dairying which is the prevalent type of farming. The leading crops are hay, oats, potatoes (pl. 2, A), corn, and barley. Hay yields from 1 to 3 tons to the acre; oats, from 40 to 75 bushels; potatoes, from 100

to 150 bushels; barley, from 35 to 60 bushels; and corn, which is grown chiefly for silage, from 6 to 10 tons. From 35 to 40 bushels to the acre of ear corn are obtained during favorable seasons.

The soil is naturally low in nitrogen and shows marked response to applications of barnyard manure, to legumes in the rotation, and to nitrates for most of the ordinary crops. Barnyard manure is the only kind of soil enrichment used to any extent, and its value is well recognized. This is used about once in every four or five years, or as frequently as the supply will allow.

The selling price of this soil (1927) varies greatly, depending on improvements and the usual local conditions, such as nearness to town, kind of roads, distance from school, and other features.

MILACA SILT LOAM

Beneath the layers of leaf mold and humus, the surface soil of Milaca silt loam is very strongly acid light-gray laminated vesicular silt loam which extends to a depth ranging from 4 to 6 inches. Below this layer is a 6 or 8 inch layer of slightly cemented brownish-gray material of somewhat finer texture, which may show slight gray and brown mottlings in its lower part. This layer also is very strongly acid in reaction. At a depth ranging from 12 to 15 inches from the surface a more pronounced dark reddish-brown or coffee-colored material, constituting the concentration zone has developed. This material is very strongly acid coarsely granular clay loam of nutlike structure, in which the granules become hard when dry. The upper strata of slightly weathered parent material lie at a depth ranging from 24 to 36 inches from the surface, and they consist of reddish-brown rather coarsely laminated heavy clay loam or silty clay loam, which is strongly acid in its upper layers but gradually becomes decreasingly acid with depth until, at a depth ranging from 6 to 8 feet from the surface, the calcareous rich reddish-brown till is rather abruptly reached. The texture of the till is variable, and it may be very sandy. Very fine veins of calcium carbonate occur along the fissures and cracks in the drift mass.

An important difference between Milaca very fine sandy loam and Milaca silt loam lies in the lower stone content of the silt loam both on the surface and throughout the soil. Neither limestone nor shales have been observed, but all the rock varieties present in the very fine sandy loam occur in the silt loam also. Cultivation disseminates the leaf mold and tends to darken the uppermost 6 or 8 inches of soil.

This soil occurs to a small extent in South Harbor and Isle Harbor Townships, in the belt of morainic drift which follows the south shore of Mille Lacs Lake. The relief is gently rolling or rolling. Surface drainage is good, and underdrainage is fair. A dense stand of mixed hardwoods and an occasional white pine once covered much of this soil and is still standing in places. Sugar maple, basswood, ash, elm, and red oak are particularly abundant and appear to have reached much greater size than on Milaca very fine sandy loam to the south.

Dairying is the prevailing type of farming on this soil, and the kinds of crops as well as their relative importance and yields, are

similar to those on Milaca very fine sandy loam. At present the selling price of this land is somewhat less than that of Milaca very fine sandy loam.

MILACA FINE SANDY LOAM

In uncultivated areas the profile of Milaca fine sandy loam consists of four or five layers. Two inches of dark-brown leaf mold and humus overlie a 6 to 8 inch layer of leached light brownish-gray coarsely laminated fine sandy loam or loamy fine sand. This layer is strongly acid and is underlain at a depth ranging from 8 to 12 inches by gray very fine sandy loam having rust-brown stains and blotches. This layer has the platy structure so characteristic of all the forested soils of the region. It is very strongly acid and may extend to a depth ranging from 18 to 24 inches, where it is underlain by mottled rust-brown and gray laminated fine sandy loam or sandy clay loam which is also very strongly acid. Between depths of 30 and 36 inches the upper layers of the parent rock are reached. These consist of very pale reddish-brown or yellowish-brown faintly laminated slightly acid or neutral loamy sand or sandy loam, containing stones and gravel. The water table may reach within 7 or 8 feet of the surface of this soil, and stones are fairly numerous.

Milaca fine sandy loam is an inextensive soil scattered throughout the northern townships of the county. The relief is gently undulating, and drainage ranges from fair to good.

At the present time a large proportion of the land supports a good stand of mixed hardwoods, but white pine was abundant in the past. Sugar maple, ironwood, basswood, red oak, bur oak, hazel, pignut hickory, white and large-toothed aspen, red maple, mountain maple, white birch, and green ash have been observed growing on this soil. Red oak, ironwood, and sugar maple predominate.

A very small proportion of the land is under cultivation. It produces good yields of the common crops of the county. Land prices are similar to those asked for Milaca very fine sandy loam.

MILACA LOAM

The name Milaca loam is applied to groups of soils whose similarity lies in their geographic position within the county, their morainic "pot and kettle" relief, and their development from similar parent material consisting of variable morainic deposits of early Wisconsin drift. The areas so mapped are chiefly in Kathio Township in the northwestern part of the county, but also occur to a slight extent in East Side Township and in sections 13 and 23 of Bogus Brook Township.

No single soil profile may be considered representative of the group, as the soils vary greatly within short distances. All members of the Milaca series, previously described, are represented and in addition areas of light grayish-brown loamy fine sand of considerable depth, which in the lower, browner, layers have well-developed cemented ferruginous sandy loam and clayey sand veins and strata. Here and there more extensive areas of a definite soil type of the Milaca series are included with the loam. The areas are sharply rolling and are extremely cut up by numerous small and large irregularly shaped peat bogs. Both of these features affect the agri-

cultural value of the land. Drainage is good, except in the numerous potholes. Stones are fairly abundant.

White pine and Norway pine were once scattered over these soils, but the land has been burned over repeatedly and at present the rather sparse natural vegetation consists chiefly of white birch, pin cherry, hazel, poplar, red oak, bur oak, pin oak, scarlet oak, sumac, and dogwood. Very little of the land is under cultivation, and the selling price is low.

ONAMIA VERY FINE SANDY LOAM

Onamia very fine sandy loam under forest consists of the following layers: (1) A 1 or 2 inch layer of leaf mold; (2) a ½-inch layer of nearly black humous soil; (3) a layer of light brownish-gray laminated strongly acid very fine sandy loam, from 5 to 10 inches thick (4) a layer of brownish-gray slightly mottled laminated weakly cemented strongly acid very fine sandy loam, from 5 to 10 inches thick; (5) a layer of acid reddish-brown slightly cemented somewhat clayey gravelly sand from 3 to 10 inches thick, containing pebbles and small stones; and (6) strata of brown stony gravel or gravelly sand, lying at a depth ranging from 20 to 40 inches from the surface. The underlying coarse material is composed of water-worn, noncalcareous crystalline rocks and is strongly acid in reaction to a depth of more than 6 feet. The water table lies at a depth of 4 feet or more, the depth depending on the time of year and the position of the land with respect to stream channels. The gravel layer in most places is not water-logged above 6 or 8 feet from the surface, and in many places the depth to the water table is very much greater. Stones are few on this soil, in many places entirely lacking. The profile of the cultivated soil varies from the typical profile described only in the upper 6 to 10 inches, in which the material becomes darker in color with manuring and tillage.

This soil is distributed chiefly along Rum River, northwest of section 27, Bogus Brook Township, south of section 35, Page Township, and along West Branch Rum River in Milaca and Milo Townships. Scattered level areas are also distributed over outwash plains, dissected high terraces, and old stream channels in Milo, Milaca, Hayland, and some of the most northerly townships.

Surface drainage of Onamia very fine sandy loam is poor, and underdrainage in most places is very good. For these reasons, in a normal spring the soil can be worked somewhat earlier than soils having less perfect internal drainage, but in years of excessive moisture the poor surface drainage may seriously delay farming operations. Very little virgin timber remains on the land, the present natural vegetation consisting chiefly of poplar, birch, red oak, bur oak, hazel, and sumac. Norway pine and white pine were at one time abundant. Owing to its level relief and almost stone-free character, Onamia very fine sandy loam is usually one of the first soils to be cleared.

Farms consisting entirely of this soil are uncommon. Dairy farming is practiced by the few farmers who own no other upland soil and by those who farm this land in conjunction with the more extensive soils. Crop yields are reported as averaging slightly lower than those obtained on the near-by Milaca soils, and grain and hay crops

particularly are apt to suffer from drought during years of deficient moisture. No consistent farming methods are followed by farmers on this soil, although heavy applications of barnyard manure are recognized as being especially valuable and more necessary than on Milaca very fine sandy loam.

Very little land of this kind has changed hands in recent years. The selling price varies, depending on the extent of improvements and the location of the areas in the county.

Onamia very fine sandy loam, rolling phase.—The rolling phase of Onamia very fine sandy loam differs from the typical soil chiefly in relief, stoniness, surface drainage, and, to less extent, in the character of the substratum. Areas of the rolling phase range from undulating to rolling and in many places are hilly. Both surface drainage and underdrainage are excessive. The substrata are variable, in a few restricted areas being of much finer-textured material than typical. Soil of this phase is developed on morainic, eskerlike, and kamelike ridges.

Soil of the rolling phase is most abundant in Milaca Township northwest of the village of Milaca, although scattered small areas occur throughout the central and north-central parts of the county. In places, a fair stand of white pine and mixed hardwoods still grows on the land, but unimproved areas support chiefly a scrubby stand of birch, poplar, oak, sumac, pin cherry, and hazel. Little of the land is under cultivation, but it is largely reserved for grazing purposes, for which use it is best suited.

This is an inferior agricultural soil, owing to its rough relief and droughtiness. Areas included with the smoother, less droughty soils detract from the selling price of the farm.

SANTIAGO SILT LOAM

In the virgin condition the surface soil of Santiago silt loam is covered by a 2-inch layer of leaf mold and humous soil. Beneath this layer is a 6 or 8 inch layer of medium-acid light-gray very finely laminated vesicular silt loam. When dry this material is readily pulverized to a structureless mass. Beneath it is a 4 to 8 inch layer of strongly acid brown silt loam, slightly mottled with darker brown stains and having the same structure as the layer above. Colorless grains of very fine sand are abundant on the cleavage faces and fissures. A pronounced concentration zone occurs at a depth ranging from 12 to 16 inches and extends downward from 6 to 12 inches. This layer consists of strongly acid yellowish-brown or brown coarsely granular clay loam, in which the cleavage faces of the granules are dotted with colorless grains of very fine sand, giving them a mottled appearance. A cut or crushed granule from this layer presents a much lighter yellowish-brown color. The presence of this yellowish-brown accumulation zone is one of the most distinctive characteristics of the soil, and, in part, distinguishes it from Milaca very fine sandy loam. Beneath this layer is an acid transitional zone which extends from 8 to 12 inches downward into the substratum. It consists of brown weakly granular sandy loam or sandy clay loam, and the same peculiarity of color change occurs on crushing, though to a less marked degree than in the layer above. The substratum of

stony red drift lies at a depth ranging from 24 to 36 inches below the surface. Stones are not abundant, except in a few places where the substratum lies close to the surface. Under cultivation a grayish-brown or brownish-gray plowed layer is produced.

Santiago silt loam is the most important upland soil in southern Milo, Greenbush, and southwestern Bogus Brook Townships. Along the northern boundary of the areas, the soil gradually merges into Milaca very fine sandy loam. It is closely associated in Milo and northwestern Greenbush Townships with Greenbush very fine sandy loam, which it resembles throughout the upper 20 or 24 inches of its profile.

The relief of Santiago silt loam is undulating or gently rolling. Surface drainage is good and underdrainage moderately good.

Very little of this soil remains in virgin forest, but the few such areas support a heavy stand of large hardwood, such as sugar maple, basswood, ironwood, red oak, ash, elm, and poplar. A few white pine trees still stand in places.

From 75 to 85 per cent of the soil is now under cultivation. Owing to its geographic location it comprises some of the older farming lands of the county. Very good yields of the general farm crops of the county are produced. Hay, oats, corn, potatoes, and barley are the most important crops grown, and the yields are somewhat higher than those obtained on Milaca very fine sandy loam.

No special soil management methods are followed. Applications of barnyard manure and a leguminous hay crop are regularly used in the crop rotation. The selling price of this soil ranges widely, depending on improvements.

Santiago silt loam, level phase.—The level phase of Santiago silt loam is very closely associated with the typical soil and differs from it in profile, owing to the presence of conspicuous splotches and streaks of yellow and brown below the 8 to 10 inch surface layer. The unweathered red drift occurs at a slightly greater depth from the surface in the more level soil. As its name implies, the relief is nearly flat or gently undulating, and surface drainage is poor, but in all other respects the two soils are very similar. Scattered areas of the level phase are mapped throughout Greenbush Township. Agriculturally, this soil is treated in the same manner as Santiago silt loam.

GREENBUSH VERY FINE SANDY LOAM

Much similarity exists between the upper 2 or 3 feet of the soil profiles of Greenbush very fine sandy loam and Santiago silt loam. The uppermost layer of Greenbush very fine sandy loam consists of 1 or 2 inches of leaf mold. Beneath this is light-gray, light brownish-gray, or darker brownish-gray laminated very fine sandy loam extending to a depth ranging from 10 to 15 inches. This comprises the podzolized horizon, which is slightly darker in its upper part, owing to the presence of some organic matter. Immediately beneath the leached upper layer lies the yellow-brown coarsely granular silt loam or clay loam layer of accumulation, which in this soil is similar to that in the soils of the Santiago series, though in many places it is thinner. In most places this layer extends to a depth ranging from 18 to 36 inches and overlies a deep bed of brown stratified gravel and

gravelly sand. The reaction of the various layers is strongly acid throughout. Cultivation produces a slightly darker brownish-gray plow soil.

A slight variation from the profile described occurs in some of the flatter areas of this soil, particularly in southern Greenbush Township. Here the yellowish-brown clay loam layer is slightly mottled with small darker-brown patches, owing to somewhat inferior surface drainage.

This soil is rather extensively developed in certain parts of southern Milo, Greenbush, and Bogus Brook Townships. It occurs in level or undulating stone-free upland or terrace areas adjacent to existing or ancient stream channels. Surface drainage is fair or good, and underdrainage is excellent. This soil is of considerable agricultural importance, as it frequently occupies the greater part of a single farm and is distributed in the more highly developed parts of the county. From 50 to 60 per cent of the land is under cultivation, and the remainder is in woodland pasture. The natural vegetation consists of white pine, maple, basswood, elm, butternut, oak, and birch. Most of the crops common to the region are grown, and yields compare very favorably with the average for the county. (Pl. 2 B.) Owing to the moisture-retentive character of the upper 2 or 3 feet of this soil little difference in time of spring tillage, seeding, and harvest in comparison with Santiago silt loam are ordinarily observed. In exceptionally dry years crops growing on Greenbush very fine sandy loam are slightly handicapped on account of excessive underdrainage, but under ordinary conditions no difference in yields is evident. The usual crop rotations, more rigidly adhered to, are practiced on this soil.

GREENBUSH GRAVELLY FINE SANDY LOAM

The uppermost layer of Greenbush gravelly fine sandy loam consists of 1 or 2 inches of leaf mold. Beneath this is a layer, from 1 to 2 inches thick, of nearly black loose structureless sandy loam. This is underlain by a layer of light grayish-brown faintly laminated slightly cemented loamy fine sand or light sandy loam, from 6 to 10 inches thick, which is strongly acid in reaction and crumbles readily to a structureless mass. At a depth ranging from 12 to 15 inches a fairly well developed concentration zone occurs, in which the material is a mixture of sand and some fine gravel with sufficient clay to provide a coarse lumpy breakage and stickiness when moist. This layer is brown with rust-brown streaks and is strongly acid in reaction. At a depth ranging from 20 to 30 inches the material grades into beds of gravel and sand, which extend downward to various, but usually great, depths. Between depths of 35 and 50 inches the gravelly substratum contains limestone pebbles and is alkaline in reaction. Cementation occurs in places, owing to the deposition of calcite between adjoining pebbles and sand grains. Little or no clayey material is present in the substratum and very few large boulders. Excellent road material is afforded by the gravel, and gravel pits are common on this soil.

Greenbush gravelly fine sandy loam is not an extensive soil. It occurs in rather small scattered patches about the margin of the young gray drift sheet in southeastern Bogus Brook and northeastern Princeton Townships. The soil occupies an undulating upland or

plateaulike position, and the relief varies considerably from place to place, the smaller areas occurring as hills or knolls. Both surface drainage and underdrainage are thorough, and, from the point of view of agriculture, may be considered excessive.

The chief importance of this soil lies in its source of road material. About 25 per cent of the land is under cultivation; the remainder consists of woodland, used for grazing, and of gravel pits. The natural vegetation includes oak, ash, basswood, butternut, elm, and hazel.

No areas of this soil are large enough to comprise entire farms, and the land is cultivated and cropped along with the adjoining soils. Agriculturally the soil is of little value and has a tendency to detract from the sale value of surrounding soils.

BRADFORD VERY FINE SANDY LOAM

Bradford very fine sandy loam has formed as a result of the weathering of the young gray drift. In the virgin condition, a thin covering of dark-brown leaf mold occurs at the surface, overlying a 3 to 6 inch layer of light-gray very fine sandy loam. This light-gray layer has a laminated structure and is slightly vesicular, in position, but when dry it readily breaks down under pressure to a powdery mass. The material is slightly acid or medium acid in reaction. A well-leached light-gray or faint yellowish-gray layer occurs at a depth ranging from 4 to 8 inches. The structure of this layer is almost identical with that of the layer above and with corresponding layers in the Milaca, Onamia, and Santiago soils. At a depth ranging from 10 to 15 inches from the surface the upper layer of the concentration zone is reached. This consists of 10 or 12 inches of light yellowish-brown or dark-brown medium granular clay loam of acid reaction. A finely jointed and fissured arrangement of the soil aggregates in the profile is responsible for the granular structure of the disturbed mass. An accumulation of colorless grains of very fine sand on the cleavage faces of the sharply angular fragments produces a slightly mottled appearance. At a depth of about 2 feet the soil texture becomes finer, the color much darker brown, and the granular structure of the soil mass more coarsely nutlike, and larger more cubical fragments break when the mass is disturbed. The same mottled appearance as in the layer above is noticeable, and the soil remains acid. At a depth of about 3 feet the accumulation of colloidal material is even more pronounced, the material here being of silty clay texture, massive or very coarsely jointed in structure, and light brown or yellowish brown in color. The reaction is acid or neutral. Throughout the three layers of accumulation the freshly cut surface of the nutlike granules is brownish yellow. At a depth ranging from 4 to 5 feet the parent material is reached. This consists of friable finely granular calcareous light yellowish-brown clay loam or loam. A few stones are present in the parent material, mainly limestones and shales, but in the upper layers only noncalcareous crystalline rocks were observed.

This soil is not widely distributed, and occurs chiefly, together with Bradford fine sandy loam, in southern and southeastern Bogus Brook and northern Princeton Townships. Because of the undulating relief, surface drainage is good but underdrainage is somewhat deficient.

A very heavy and dense hardwood forest with a few scattered pines once covered the soil. Remnants of the original stand include the following trees: Red oak, bur oak, basswood, butternut, black ash, aspen, ironwood, white birch, elm, and sugar maple.

The soil is largely under cultivation, the wooded and stump-land areas being used as pasture. Clover, potatoes, corn, oats, and barley are the chief crops grown, and all these crops produce well. Hay yields from 2 to 3 tons to the acre; potatoes, from 90 to 150 bushels; corn, which is used chiefly for silage, from 10 to 16 tons; oats, from 50 to 75 bushels; and barley, from 45 to 65 bushels. This is excellent farming land and commands a price considerably above the average for the county.

BRADFORD FINE SANDY LOAM

The profile of Bradford fine sandy loam is very similar to that of Bradford very fine sandy loam. The most outstanding difference between the two soils lies in the coarser-textured surface layer of the fine sandy loam, beneath the humus and leaf mold, which consists of finely platy light-brown fine sandy loam, of strongly acid reaction, extending to a depth ranging from 6 to 10 inches. This material is underlain by a somewhat coarser-textured faintly mottled layer from 10 to 15 inches thick. The finer-textured dark-brown laminated and slightly jointed strongly acid concentration layer begins at a depth ranging from 20 to 25 inches from the surface and continues, with slight modification in color and structure, to the parent rock which lies at a depth ranging from 4 to 6 feet and consists of calcareous glacial till, with abundant limestone pebbles and concretions of calcite in the cracks and fissures of the till. The whole profile is more or less influenced by the presence of a higher proportion of sand in the upper layers. Besides its effect on the texture of the leached layers, the most important result of the sand content seems to be the development of a more permeable, less highly colloidal concentration layer which fails to show such pronounced nutlike structure and jointed cubelike cleavage lines as occur in Bradford very fine sandy loam. In a few areas, chiefly in the more sharply undulating areas in the vicinity of Mud Lake, in both Princeton and Bogus Brook Townships, this soil has a rather high proportion of pebbles and small stones on the surface.

Bradford fine sandy loam occurs in association with the Brickton and Berrien soils and with Bradford very fine sandy loam. The areas are more strongly undulating or rolling than areas of Bradford very fine sandy loam. Surface drainage is good and internal drainage fairly good. This is not an extensive or an important soil. It is all included in farm lands, and most of it is cultivated. The farming methods practiced and crop yields produced on this soil are similar to those on the other member of the Bradford series, with the possible exception of the small areas of more rolling relief, which are of slightly inferior agricultural value. Selling prices are similar to those asked for Bradford very fine sandy loam.

BRICKTON SILT LOAM

Brickton silt loam, where uncultivated, has a 1 or 2 inch surface layer of leaf mold, beneath which is a layer of dark-gray laminated

vesicular silt loam extending to a depth of 6 or 8 inches. This layer contains considerable organic matter and is neutral in reaction. It is underlain by a pale brownish-gray podzolized layer of the same texture and similar, though more pronounced, structure. The material in this layer is of medium acidity, has a thickness ranging from 3 to 7 inches, and extends downward to the layer of accumulation, which in most places lies from 10 to 15 inches below the surface. The layer of accumulation consists of coarsely granular clay loam or silty clay which is light brown with yellowish-brown markings in its upper part and which becomes much darker brown and more coarsely granular at greater depths. A brownish-yellow color is apparent on examination of the freshly cut surface of the granules. A nutlike structure, similar to that of Bradford very fine sandy loam, is also noticeable, though more pronounced, in this soil. The coarse granules, of irregular, roughly cubical shape, are very tough and coherent when moist and hard when dry. The material in this layer of accumulation, which is from 24 to 40 inches in thickness, is distinctly acid throughout. At a depth ranging from 3 to 4 feet the parent material, which consists of highly calcareous brownish-yellow very fine sandy loam or silt loam of very uniform texture, is reached. Layers of dark-brown silty clay are common at different levels in the parent material. Concretions of impure calcium carbonate occur in irregular layers between depths of 4 and 5 feet, the nodules ranging from a fraction of an inch to more than 3 inches in length. Stones, pebbles, and gravel are lacking throughout the profile.

Brickton silt loam is the predominating upland soil of the northwest quarter of Princeton and the adjoining parts of Greenbush and Bogus Brook Townships. Erosion along the valley of Rum River has produced a very rolling, hilly relief, and the surface soil is well drained immediately adjacent to that stream. Farther away from the river the soil, in places, is somewhat deficient in drainage. In most places, the relief is undulating or gently rolling, and the soils have rather good surface drainage and fair internal drainage. A variation in soil profile is noticeable in the steeper sloping areas of Brickton silt loam. In such places erosion has removed much of the surface soil, and as a result the heavy subsoil lies closer to the surface of the ground.

The natural vegetation on the soil is a hardwood forest (pl. 3, A), far denser and including much higher trees than those commonly found on the red drift soils to the north. The following trees were at one time abundant: Red oak, basswood, American elm, ironwood, sugar maple, butternut, black ash, bur oak, and wild plum. From 60 to 75 per cent of the land is now under cultivation, and it is one of the most productive soils of the region. Corn, grown chiefly for silage, yields from 12 to 15 tons to the acre; oats, from 45 to 90 bushels; barley, from 35 to 65 bushels; potatoes, from 100 to 250 bushels; red clover, from 2 to 3 tons; and alfalfa, from 2½ to 4 tons. The rotation most widely practiced consists of oats or barley, clover, potatoes, and corn. The potato and corn ground is plowed in the fall or spring, preferably in the spring, in order to avoid baking, and the ground for smaller grains is commonly only disked. Dairying is the predominant type of farming, with potatoes as an important supplementary cash crop.

ZIMMERMAN FINE SAND

The soil profile of Zimmerman fine sand is remarkably uniform within the area of its occurrence in Mille Lacs County. This is largely due to the assortment given the parent material at the time of its original deposition by wind. The soil profile consists of the following layers: (1) An inch or two of leaf mold; (2) a 2 to 4 inch layer of dark-brown structureless loam containing much well-decomposed organic matter; (3) a layer of gray or grayish-brown structureless fine sand, strongly acid in reaction, from 15 to 24 inches thick; (4) a layer of light-brown or faint yellowish-brown structureless fine sand, which is streaked here and there with darker-brown or yellow markings, of strongly acid reaction and extending to a depth ranging from 4 to 6 feet; and (5) a bright yellowish-brown loamy fine sand or loamy sand layer containing many thin horizontal veins of cemented sand of a coffee-brown color. These veins are from one-tenth to 1 inch in thickness, and usually occur at intervals of a few inches. In a few places, however, they are superimposed on one another in such a manner as to make an almost continuous laminated cemented layer, from 2 to 3 feet thick, which is slightly acid in reaction. The slightly weathered, slightly acid, medium sand, which comprises the parent material, lies at a depth ranging from 5½ to 7 feet. It is of mixed mineralogical composition, quartz, feldspars, and dark-colored minerals being present in such proportions as to give a light brownish-gray appearance to the mass. Cultivation mixes the uppermost three layers of the profile, producing a plowed layer of uniform grayish-brown color.

Zimmerman fine sand occupies a total area of a few square miles to the east, northeast, and north of the village of Princeton, where it is the prevailing upland soil. This land has the abruptly undulating relief typical of wind-blown sands. Both surface drainage and underdrainage are excellent. At the western edge of the areas there is imperceptible gradation into Hubbard fine sand, and the separation of the two soils is more or less arbitrary.

About 85 per cent of the land is under cultivation and the remaining areas are in woodland and are used chiefly for grazing. The virgin forest consisted of jack pine, bur oak, scarlet oak, pin oak, aspen, large-toothed aspen, white birch, pin cherry, chokecherry, hazel, and sumac. In some places jack pine is most abundant, and in other places pin oak is predominant.

Mixed farming, potato growing, and dairying are carried on by the farmers on this soil. More attention is paid to corn and potato production and to the feeding of hogs and other livestock on a small scale than elsewhere in the county. The earliness of the soil, which favors the production of matured corn and early potatoes, and its nearness to market are both responsible for the agricultural tendency of this locality. The crop rotation most closely followed consists of oats, rye, or barley, followed by clover, potatoes, and corn. Fair yields of these crops are obtained. Alfalfa is being more extensively grown, instead of red clover, by the more progressive farmers.

This is a droughty soil, and during windy dry periods in the spring great damage is done to all unprotected young crops by sand drifting. This may be overcome, in part, by careful tillage and



A, Dense mixed hardwood forest on Brickton silt loam; B, burned-over peat swamp in northern part of Mille Lacs County

the more extensive use of cornstalks, straw, and barnyard manure on the most exposed areas. Spring plowing and leaving the ground ridgy and lumpy at the surface are favored by many farmers, in order to avoid winter and early spring soil blowing. Ground limestone is used for alfalfa, but barnyard manure is practically the only material used for soil enrichment.

The most serious problems to be met by the farmers on this soil are the upkeep of the organic-matter content, the prevention of soil blowing, the production of profitable crops in years of drought, and the maintenance of adequate pasture. More importance should be attached to the utility of alfalfa in the rotation. A somewhat prevalent impression that the layer of cemented sand, which occurs from 4 to 6 feet below the surface and which is locally known as hardpan, is detrimental to crops, lacks confirmation at present.

BERRIEN LOAMY FINE SAND

The profile of Berrien loamy fine sand is variable in different areas. A fairly representative description follows: Beneath a thin cover of leaf mold the surface soil consists of 6 or 8 inches of strongly acid dark-gray loamy fine sand which is underlain by a somewhat paler grayish-yellow or yellowish-gray strongly acid loamy fine sand, extending to a depth ranging from 15 to 22 inches. Beneath this is a 10 to 20 inch layer of grayish-yellow or drab acid fine sandy loam, in which the soil material may be weakly cemented and slightly mottled with yellow and brown stains. This layer, in turn, is underlain by light brownish-gray or yellowish-gray mottled rather tough calcareous sandy clay or sandy loam. Pebbles occur here and there throughout the profile.

Areas of Berrien loamy fine sand range from nearly flat, relatively low areas to undulating wide ridges. Drainage ranges from somewhat poor to adequate. The most pronounced variations from the typical soil occur in section 1; the northeast, west, southwest, and southern parts of section 12; the east-central part of section 11; the southwestern corner of section 13; the southeastern corner of section 15; the northeastern part of section 22; and the northwestern and western parts of section 23, T. 36 N., R. 26 W. Here the surface soil and deep subsoil approach loamy sand in texture, and the relief is stronger, thus providing more perfect drainage.

Both the typical and less typical areas of this soil are probably developed on water-laid and wind-laid deposits of variable thickness overlying the calcareous young gray drift. The coarser-textured variations show greater susceptibility to drought, but the more numerous finer-textured areas are more seriously affected by wind blowing. The soil is inextensive and not of great agricultural importance, in this regard being intermediate between the Zimmerman and Bradford soils, although it is far less productive than the Bradford soils.

The forested areas support a growth of mixed deciduous trees. The land is farmed in the same manner as the soils lying adjacent to it, and selling prices are similar to those asked for Zimmerman fine sand.

FREER SILT LOAM

The uppermost layer in virgin areas of Freer silt loam consists of a 2-inch layer of dark-brown leaf mold which is acid in a few places. Beneath this is a very dark brown, almost black, 3 to 5 inch layer of silt loam which is rich in well-decomposed organic matter. When partly dry the material in this layer assumes a finely granular, bird-shotlike structure. It ranges from medium to strongly acid. Beneath this is an 8 to 10 inch layer of strongly acid finely laminated dark brownish-gray, in a few places light-gray, very fine sandy loam or silt loam, which becomes darker gray, mottled with brown, in its lower part. A heavier layer, the concentration layer, is reached in most places within 15 inches from the surface. This consists, in its upper part, of strongly acid brownish-gray heavy silt loam or clay loam, mottled with rust brown, and in its lower part the material (stony clay loam) becomes much brighter and more pinkish brown with orange-brown markings, is somewhat less acid, and includes many stains and rust-margined layers bordering old root passages. In the upper part a fine distinctly nutlike structure is apparent, in addition to the horizontal, vesicular laminations. The breakage is finely granular. In the lower part of the layer a more coarsely nutlike, but still laminated, structure exists, the material breaking down to coarser granules on being disturbed. The total thickness of the concentration layer is between 25 and 30 inches. This layer grades into reddish-brown slightly acid or medium acid laminated and slightly vesicular stony sandy loam at a depth ranging from 3 to 4 feet from the surface. Cultivation mixes the uppermost 6 to 10 inches of soil, producing dark brownish-gray silt loam soil. An occasional but important variation from the typical soil is characterized by the presence of calcareous clay at a depth ranging from 8 to 12 inches from the surface and continuing for 12 or 15 inches into the lower strata of the soil. This is particularly noticeable in sections 20 and 21 of Borgholm Township. Similar variations occur in the southern part of the county where the soil is mapped in association with the Bradford and Brickton soils, the calcareous material lying at a greater depth in such places. Other striking variations of the typical soil are in parts of Borgholm and Milaca Townships, where the soil in places consists of a brown loam or silty loam deposit overlying sandy material, evidently of lacustral formation. In many places old beaver dams are partly responsible for these variations.

Freer silt loam is an important soil which occurs in close association with the upland soils of the Milaca and Santiago series and the very poorly drained soils of the Adolph series. In general, it is intermediate in drainage characteristics between the first-mentioned soils and the last. The chief development of this soil is in the depressions and in flat or undulating poorly drained areas of the early Wisconsin till plain which covers the greater part of the county, but it also occurs in old bottom-land positions adjacent to Onamia very fine sandy loam. In such places the surface layers are thicker and gravelly strata are present here and there in the deep subsoil. This association and these variations are particularly noticeable in Milaca Township and in other places where Onamia very fine sandy

loam and Freer silt loam adjoin each other. Both surface drainage and under drainage are deficient, and stones are numerous throughout the soil.

From 10 to 15 per cent of the land is more or less improved, and probably less than half the improved land is under the plow. The uncleared land in many places consists of willow, dogwood, and alder thickets, or it may be covered by fair-sized trees of elm, basswood, ash, sugar maple, red oak, bur oak, and an occasional white pine. Poplar thickets are common on the burned-over areas.

Freer silt loam is farmed in conjunction with the adjoining upland soils, where only small areas of it occur as depressions and strips dissecting such soils. Many of the larger, wider draws and flats are reserved for meadow and pasture. Where more extensive areas of this soil comprise the greater part of a single farm, as in sections 5 and 6 of Borgholm Township, farming methods similar to those prevailing on the near-by better-drained soils are practiced. Excellent yields of the common farm crops are obtained, although some trouble is experienced with lodging of grain. Silage corn yields from 10 to 16 tons to the acre; ear corn, of which but little is grown, from 40 to 60 bushels; oats, from 60 to 90 bushels; barley, from 35 to 50 bushels; potatoes, from 125 to 175 bushels; and alfalfa or clover hay, from 2 to 3½ tons. The present drainage of this soil is inadequate for the most successful production of alfalfa and losses from winter killing are serious. However, during the drier seasons, yields superior to those commonly obtained on the better-drained soils can be expected.

ADOLPH SILTY CLAY LOAM

Under hay meadow the surface soil of Adolph silty clay loam is dark-brown or black somewhat laminated finely granular silty clay loam which is covered in a few places by a few inches of peat. When partly dry the granules are readily shaken apart and may be compared in size and shape to angular bird shot. The material in this layer, which ranges from 8 to 15 inches in thickness, is medium acid in reaction. Proximity of the soil to active stream channels results in a deeper surface layer, owing to an occasional silt deposition. This layer is underlain by gray very fine sandy loam or silt loam of pronounced laminated structure and very strong acidity. Vertical dark-brown stains are most conspicuous in this part of the profile. Small, more or less vertical, animal burrows have been found, filled with dark-brown or black silty clay loam, evidently washed in from the layer above. At a depth of 2½ or 3½ feet a pinkish-brown layer of fine sandy loam or clayey fine sand occurs. This layer is mottled with gray and, like the layer above, it may contain both animal burrows and conspicuous vertical dark rust-colored stains. The stains, which range in diameter from one twenty-fifth to three twenty-fifths of an inch, are caused by concretions of iron occurring about living and dead grass roots. Their formation in these layers is probably brought about by the alternate oxidation and reduction of iron compounds following the frequent saturations and partial drainage to which the soil is so commonly subjected. Below a depth of 4 feet, a more or less permanently water-saturated layer is present. This is a mottled reddish-brown and gray somewhat cemented and

laminated strongly acid stony gravelly sandy loam. This soil includes some of the stoniest land in the county. Reddish-brown sandy or gravelly strata underlie it in a few places. Beaver dams, which blocked the old drainage ways, on which much of this soil has formed, have caused marked local variations in some places.

Adolph silty clay loam is widely scattered throughout the county, occupying the most poorly drained positions on the early Wisconsin till plain. It occurs in depressions, shallow valleys, along intermittent stream channels, and marginal to peat lands. The relief, in general, is flat or depressed, and in a few places is very gently undulating.

Very little of this soil is under cultivation. Most of the areas included in farm lands are devoted to pasture or the production of hay. Under natural conditions the land supports a forest of elm, ash, basswood, willow, alder, and poplar. The least well-drained areas are covered entirely by alder, willow, and swamp grasses.

The soil is highly productive when provided with adequate drainage which is the first essential in its reclamation. In a few places, drainage has been accomplished by open ditches, but none of the land has been tiled. Applications of barnyard manure are said to be particularly beneficial to this soil. Owing to its low-lying position the land is subject to early fall and late spring frosts. Well-drained areas are considered as desirable as the adjacent upland soils, and selling prices are largely based on the value placed on those soils.

KANABEC SILT LOAM

In pastured areas of Kanabec silt loam the 1 or 2 inch surface layer is dark-brown silt loam, well supplied with organic matter. Beneath this lie from 3 to 6 inches of pale brownish-gray slightly platy vesicular silt loam which readily pulverizes to an incoherent mass. A third distinctive layer is reached in most places at a depth ranging from 6 to 9 inches from the surface, and it consists of a mottled brownish-gray jointed medium, but weakly, granular silt loam layer. The material becomes heavier with depth, and at a depth of 12 inches yellowish-brown silty clay is present. This layer extends to a depth of more than 2 feet. It is strongly jointed and fissured in such a manner as to give a roughly cubical breakage, or coarse angular nutlike structure on being disturbed. The freshly cut surface of a single lump appears much yellower than the faces of the lump. The succeeding layer, which occurs between depths of 3 and 5 feet, consists of dark-brown silty clay which in a few places is interlain by oblique strata of yellowish-gray silt. There is a slight tendency toward horizontal lamination, but the outstanding structure is coarsely granular and nutlike, with more tendency to prismatic jointing and breakage, rather than cubical as in the layer above. The cleavage faces are brownish black, but the interiors appear much browner when freshly cut. At a depth ranging from $3\frac{1}{2}$ to 6 feet and deeper, stratified sand and gravel are reached, and this layer of coarse material extends downward to an indefinite depth. The soil is acid throughout, the degree of acidity being greater in the first and second foot from the surface. The gravel of the substratum reacts very slightly acid or neutral. Stones are lacking in any part of the soil lying above the gravel bed. Cultivation changes

the uppermost 8 inches of soil to light brownish-gray slightly granular material which becomes compact and rather hard on repeated wetting and drying.

Kanabec silt loam is inextensive in the county, occurring only in Bogus Brook Township bordering Rum River. Geologically, the material is a fine-textured lacustrine deposit laid down on outwash sand and gravels. Reestablishment of the prelacustral drainage system has effected some dissection and partial drainage of the lake plain. The late Wisconsin drift appears to have contributed chiefly to the lacustral clay from which the soil is derived, but owing, possibly, to the shallowness of the deposit and to the proximity to the gravel beneath, the soil has for the most part developed strongly acid characteristics. In the more southerly extension of this soil, where the lacustral deposit is deeper and the soil adjoins Brickton silt loam, it is possible that calcareous material still remains above the gravel, although the soil has not been explored at that depth. It is safe to say that fully half the soil is acid to a depth of more than 5 feet, and all of it is medium or strongly acid within a depth of 3 feet.

The land ranges from level to very gently undulating, and it is lacking in adequate surface and internal drainage. Immediately adjacent to the river escarpment in sections 22, 27, and 34, Bogus Brook Township, surface drainage is somewhat better, but very little of the soil is materially affected by the proximity of the river. The impervious highly colloidal material present in the second and third feet of the soil profile seriously hinders free downward movement of water.

The natural vegetation includes bur oak, red oak, basswood, ash, elm, and a few white pine. Almost all the Kanabec silt loam is improved, and a large proportion of it is under cultivation. Agricultural practices are similar to those carried out on Brickton silt loam which adjoins this soil on the south, and good yields of the common crops are obtained. Silage corn yields from 10 to 12 tons to the acre; ear corn, from 40 to 50 bushels; oats, from 35 to 75 bushels; barley, from 30 to 60 bushels; potatoes, from 90 to 125 bushels; and hay, from 1½ to 3 tons. Alfalfa does not do so well on this soil as on Brickton silt loam. Liming of the land seems to be necessary for the most successful production of alfalfa.

Kanabec silt loam, depressional phase.—A lower-lying soil surrounded by Kanabec silt loam but still more poorly drained than that soil has been separated during the course of the soil survey and indicated as Kanabec silt loam, depressional phase. The differences between the phase and the typical soil are due to differences in surface drainage, the phase, owing to its position, acting as a catch basin or shallow drainage way for run-off water from areas of Kanabec silt loam.

The surface soil is dark colored to a depth ranging from 5 to 12 inches and may be covered by an inch or two of peat. The successive layers in the second, third, and fourth feet of soil are more mottled, somewhat tighter in consistence, and more impervious. These very poorly drained areas are not extensive, but they detract from the agricultural value of the land with which they are associated, if they are locally numerous or larger than usual. Some

success in procuring drainage is had by boring holes to the gravel substrata in order to carry away the surface water. However, unless the holes are very numerous this method proves inadequate. The smaller bodies of the phase are included with the typical soil in cropping, farming operations, and general treatment, and the larger areas are largely reserved for hay meadow and pasture. The current selling price of this soil is somewhat less than for typical Kanabec silt loam.

ISANTI LOAMY FINE SAND

Isanti loamy fine sand has a very shallow surface layer of leaf mold which is underlain by a 2 to 6 inch layer of dark-brown slightly granular acid fine sandy loam. A faintly platy slightly vesicular podzolized light brownish-gray layer of the same texture is next in succession, extending from a depth of 3 to 12 inches from the surface. Beneath this is distinctly laminated mottled gray and brown loamy fine sand which becomes darker, more mottled, and less well oxidized with increasing depth, changing but little in texture. This continuation of the podzolized layer extends, with color changes, to a depth of more than 3 feet from the surface. In the lower part of the layer the dark-brown and orange-brown blotches become larger and more tonguelike in form, producing a marbled effect on the grayer background. A pronounced concentration layer occurs in the fourth foot. In the material of its upper part, which extends in tongues into the overlying layer, cementation is weak, but from 10 to 12 inches deeper an indurated vein of ferruginous loamy fine sand of variable thickness is reached. The brownish-yellow slightly mottled fine sand lying below this layer grades into the unweathered parent material at a depth ranging from 5 to 7 feet. This material consists of wind-blown sand which is apparently identical in color and mineralogical composition with the unweathered substrata of Zimmerman fine sand. The degree of acidity of the various layers gradually decreases with depth, the reaction of the least-weathered part ranging from neutral to very slightly acid. Cultivation alters the surface soil to a depth ranging from 6 to 10 inches by mixing the darker-colored surface layers with the more thoroughly leached lower layer. The degree of change depends largely on the amount of organic matter originally present and the subsequent treatment of the soil.

Owing to the association of Isanti loamy fine sand with both the Zimmerman and Hubbard soils, variations in profile characteristics occur. However, the greater part of the soil occurs in association with Zimmerman fine sand, and the profile description given may be considered fairly typical. Although the concentration layer is beyond the reach of the soil auger in most places, it is probable that this layer is very poorly defined or even lacking where the soil is mapped in association with the western part of areas of Hubbard fine sand.

Areas of Isanti loamy fine sand occur as depressions and small flats. Consequently they may receive some water by lateral movement and by run-off from the surrounding sandy upland. Under-drainage is fairly well provided by the porous substratum.

This is a rather inextensive soil, occurring only on the sandy plains of Princeton and Greenbush Townships. Most of the land is under

cultivation, although no single large areas are under the plow. The natural vegetation still standing includes bur, pin, and scarlet oaks as the predominant trees.

Cropping methods are similar to those followed on the Zimmerman soil. Because of the greater abundance of moisture in this lower-lying soil, it is more productive and crops growing on it are less liable to serious injury from drying winds. Land values are somewhat higher for Isanti loamy fine sand than for the Zimmerman and Hubbard soils.

HUBBARD FINE SAND

Hubbard fine sand, in the virgin condition, has a surface covering of 1 or 2 inches of leaf mold. This is underlain by a 6 to 12 inch layer of very dark brown structureless loamy fine sand, in which individual quartz sand particles may be readily distinguished and which contains a few pebbles of various noncalcareous crystalline rocks. Beneath this is a deep layer of structureless fine or medium fine sand, containing a few small pebbles, which extends to a depth ranging from $3\frac{1}{2}$ to $5\frac{1}{2}$ feet. The sand ranges in color from brown to dark brown, being lightest in the middle and lower parts of the layer where the material is also slightly mottled and stained. This layer is underlain by structureless light-brown sand which is composed largely of rounded quartz particles but also includes ferro-magnesian and feldspathic materials. The reaction varies from strongly acid in the uppermost part of the dark-brown layer beneath the leaf mold to medium acid in the middle part and slightly acid in the parent rock. Under cultivation the surface soil is uniformly brown throughout the plow layer.

The present natural vegetation consists chiefly of an open forest of bur oak, with a grassy undergrowth. A few groves of white pine occur.

Hubbard fine sand is the prevailing upland soil in the southwest corner of Princeton and the southeast corner of Greenbush Townships. The relief is rather milder than that of Zimmerman fine sand areas, and the areas are broader and more gently undulating than areas of that soil. With regard to drainage and droughtiness the two soils are very similar, although damage from wind is generally less common to young crops growing on Hubbard fine sand than those on Zimmerman fine sand. In cultivated fields the sandier areas of Hubbard fine sand have been, and still are, more or less shifted by the wind. However, it is probable that the greater part of this material was water-laid in contrast to the aeolian origin of the Zimmerman soil material.

Mixed farming is practiced on Hubbard fine sand, the farm income being sustained by the sale of dairy products, poultry and eggs, rye, hogs, and potatoes. The crop rotation most commonly, though but loosely, followed consists of corn; rye, wheat, or oats seeded to clover; hay; and potatoes. Manure is applied in the fall for the corn or potatoes, but the supply is usually inadequate. Straw is frequently plowed under, and occasionally a crop of medium red clover is used as green manure. Crop yields are fair and range as follows: Silage corn, from 5 to 7 tons to the acre; ear corn, from 10 to 30 bushels; oats from 25 to 60 bushels; barley, from 15 to 25 bushels; rye, from 10 to 25 bushels; potatoes, from 75 to 150 bushels; clover

hay, from three-fourths to 1 ton; and alfalfa hay, from 2 to 2½ tons. Sweetclover, fall rye, and oats are used to some extent for pasture. The alfalfa acreage is increasing, for use both as hay and as pasture. One of the most serious problems on farms composed of this soil is the production of sufficient feed. River-bottom lands and the lower-lying areas are utilized as much as possible, but hay has to be hauled by many farmers from the meadows of western Greenbush Township, and pasture is insufficient on most farms. Lime is used to some extent for alfalfa, although manure is at present more popular. Very small quantities of commercial fertilizer are used for potatoes. The suggestions offered for the improvement of Zimmerman fine sand apply also to this soil.

Very little Hubbard fine sand has changed hands recently. Land prices vary widely, depending on location of the land, associated soils, and improvements.

EMMERT STONY FINE SANDY LOAM

Emmert stony fine sandy loam has a shallow dark-colored surface layer which is in most places from 1 to 8 inches thick. The material in this layer is brownish-gray or dark-brown structureless gravelly sandy loam, containing an abundance of stones and small boulders. In a few places the surface layer is so stony that no dark soil has formed, the parent material lying exposed. When present the surface soil is underlain by a yellowish-brown slightly stratified layer of similar material which contains more gravel and less organic matter. Some very slight evidence of an iron accumulation exists in this layer which extends to a depth ranging from 12 to 16 inches before grading into the unchanged parent material, consisting of a mass of boulders, cobbles, gravel, and sand. The soil material is medium acid throughout.

Emmert stony fine sandy loam occurs only as eskers, eskerlike ridges, and kames. The areas are hilly and rough, and both surface and internal drainage are excessive. Small, more or less continuous, ridges on which this soil has developed occur scattered throughout the drift-covered part of the county. An especially conspicuous and extensive band of the soil extends, intermittently, from the southeast quarter of section 12, Hayland Township, southwest to the center of section 19, Milaca Township, a distance of about 15 miles. Many areas occur in association with Onamia very fine sandy loam, rolling phase, and along old glacial drainage channels and present stream valleys. In Greenbush Township, the surface soil is somewhat deeper and the substrata rather more sandy than is typical of the greater part of the soil.

Emmert stony fine sandy loam is of little agricultural value. Very little of the land is under cultivation, its main use being, in conjunction with other soils, to provide wild pasture. In the natural state it is sparsely wooded with scrubby birch, poplar, oak, and a few pine trees. For the most part, the land is covered with a fairly thick but stunted growth of hazel, sumac, pin cherry, and wild grasses. The main use of this soil is as a source of road-bed material.

EMMERT FINE SAND

Emmert fine sand, to a depth ranging from 3 to 6 inches, consists of dark-brown or grayish-brown loose fine sandy loam or loamy fine

sand, which overlies yellowish-gray sandy loam or loamy sand, extending to a depth ranging from 2 to 3 feet from the surface and becoming browner with depth. Beneath this is an unconsolidated mass which varies in texture from gravelly sand to sand and loamy sand and in color from light brown to dark brown and reddish brown.

This extremely variable soil occurs only on small kamelike, sandy dumps and knolls in Milo and Greenbush Townships, where it is associated with Santiago silt loam and Greenbush very fine sandy loam.

Comparatively little of the land is under cultivation. Where cultivated the methods of cropping and cultivation are similar to those for the adjoining soils. In agricultural value this soil is inferior to the finer-textured upland soils of the county, with which it is sold when farm land changes ownership.

ALLUVIAL SOILS, UNDIFFERENTIATED

The recent alluvium in the bottom lands of Rum River, West Branch Rum River, and some of the smaller streams is mapped as alluvial soils, undifferentiated. The profiles of these soils differ greatly, but the bottom lands along the upper reaches of Rum River from Onamia to within 1 mile of Princeton and along most of the west branch, consist chiefly of the finer-textured deposits. Owing to the occasional spring flooding, to which large areas of the bottom lands are subject, no definite soil profile has developed. The prevailing profile appears about as follows: (1) From 12 to 18 inches of brown very fine sandy loam or silt loam; (2) from 18 inches to 3 feet, grayish-brown or chocolate-brown fine sandy loam or loam; and (3) light-brown or grayish-brown fine sand or sand, in a few places changing to gravel in its lower layers. The deposits are usually more or less stratified throughout, and have a medium or finely granular structure. The soil reaction is variable and may be either acid or alkaline, though an acid reaction is more common and may persist to great depths. Stones are lacking in the soil to a depth ranging from 2 to 3 feet.

Most of the alluvial land is very much dissected by old river channels, oxbows, and backwater areas which are more or less waterlogged and may be partly filled with peat or silt. Textural variations are also very common within short distances. Immediately adjacent to the present and abandoned stream channels the surface layers are in most places more sandy. In a few places, such as in Bogus Brook and northern Princeton Townships, along Rum River, and in parts of Milo Township, along West Branch Rum River, wider and more uniform flood plains occur. Such areas are of greater agricultural value. Owing to the proximity of the streams and the low-lying position of the bottom lands, drainage is deficient and uncertain. Artificial drainage is very difficult, and both diking and drainage are expensive. It is doubtful whether such improvement would be justified despite the generally high productivity of these soils under favorable conditions. Very little of the alluvial land is under cultivation, and pasture and hay meadow occupy most of the improved land. Most of the areas are in woodland and support a mixed hardwood forest.

BEACH SAND

Beach sand occurs to greater or less extent along the shore of Mille Lacs Lake, on wave-washed ridges and flats extending back from the present lake shore to various distances inland. The total area is small, and four variations of the sand are noticeable. Owing to their inextensiveness, to their comparative unimportance, and to the heavily wooded character of the land, no separations into types have been made.

The most common profile shows an 18 to 24 inch layer of structureless medium sand, dark brown at the surface but becoming lighter colored with depth, overlying pale-brown slightly mottled structureless medium sand which extends downward to the water table, lying from 3 to 6 feet from the surface. No stones occur in the upper layers, but gravel and stones may be present in the lower part of the profile. The sand is medium acid to a depth of 6 feet. This variation of beach sand is moderately heavily wooded with basswood, oak, elm, ash, willow, sumac, and a few Norway pine, although much of the land is open meadow.

A less common variation consists of the following layers: (1) An inch or two of leaf mold, (2) from 6 to 10 inches of very dark brownish-black loamy fine sand or fine sand, and (3) light-brown fine sand which becomes more yellowish in color and distinctly streaked and stained with rust brown in its lower strata. The material is strongly acid to a depth of 5 feet. The land is densely wooded with a luxuriant growth of mixed hardwoods.

A third variation is characterized by a layer of beach sand over drift. In detail this includes layers as follows: (1) A layer of leaf mold, from 1 to 2½ inches thick; (2) an 8 to 12 inch layer of brownish-black loamy fine sand, containing a few stones; (3) a mottled dark-brown loamy sand layer, containing a few stones, which extends to a depth ranging from 18 to 24 inches; and (4) mottled brown and gray stony sandy loam which, between about 24 and 30 inches from the surface, develops into a mottled rust-colored and brownish-gray fine-textured layer. At a depth of 3 feet or thereabouts from the surface the slightly weathered and mottled reddish-brown stony young red drift is reached. The water table lies at a depth ranging from 4 to 7 feet from the surface. This variation is strongly acid at the surface, but the acidity decreases in the lower layers. A forest growth of mixed hardwoods, including ash, elm, oak, butternut, basswood, and a few white pine trees covers most of this soil.

The three better-drained variations of beach sand are used almost entirely as sites for lake-shore homes and summer camps. Practically none of the land is under cultivation except in small garden patches, for which the darker-colored sands are fairly well suited, though droughty. The addition of lime, barnyard manure, and nitrogenous fertilizers should prove highly beneficial for garden truck.

A fourth phase, or variation, of beach sand is distinguished chiefly because of its low position and unsuitability for lake-shore building sites. The soil is darker to greater depths and more highly mottled in the lower layers than is the higher-lying soil. Both surface and

internal drainage are very poor, because this variation occupies depressions and because of its proximity to the lake.

PEAT

Peat consists of an accumulation of more or less decomposed plant remains with which is mixed a small amount of mineral soil. The appearance of peat is largely dependent on the kind of vegetation which the peat bog supported during the process of its formation, and the duration of the various plant associations. The vegetation is to a greater or less extent dependent on the height of the water table and on the lime supply contained in the peat itself. During the course of the survey peat and a shallow phase of peat were recognized. Where the mineral substratum is below the depth which can be reached by the plow on breaking, the soil will remain peat until the upper layers decompose sufficiently to so lower the surface of the land that the plow will reach into the mineral soil on subsequent plowing.

By far the greater part of the peat areas in Mille Lacs County have developed under a forest vegetation and are dark-brown moderately well-decomposed woody peats which have formed in low-lying plains, in valleys, and in depressions. In the northern three-quarters of the county this type of peat (pl. 3, B) prevails almost entirely, and a few sedge and grass covered bogs occur in the more southerly townships.

In most places the unburned woody peats consist of several inches of loose, living mosses, chiefly Sphagnum, overlying a brown fibrous mossy woody mass which becomes more compact and may be more or less decomposed, and correspondingly darker or lighter in color, in the lower layers. Fragments of woody material are embedded in the moss in more or less abundance, and pieces of well-preserved roots are found in many places at various depths. The surface layer may consist of an interwoven mat of roots of such plants as leatherleaf and Labrador-tea, together with Sphagnum moss, and in such areas the peat is usually undecomposed. In the deeper substrata, layers of different plant remains occur in many places, representing different growth conditions which favored different types of plant associations.

The sedge and grass peats have been extensively affected by fire. To a depth of 1 or 2 feet they consist of rather coarsely fibrous undecomposed brown sedge peat and grass peat, underlain by finely divided well-disintegrated very dark brown or black more compact material which extends downward to the mineral stratum.

The character of the mineral material below the organic deposit depends on the adjacent mineral soil. Where the upland soils are derived from drift or other fairly fine-textured deposits, most of the mineral material beneath the peat is dark-gray or grayish-black silty clay or some other fine-textured comparatively impervious material. Where the upland soils are sands or are very sandy, the peat deposits are underlain in most places by gray or dark-gray sands.

The natural vegetation of the woody peats was largely spruce and tamarack, although basswood, elm, ash, birch, and poplar were not uncommon on the shallower more decomposed varieties. Destruction

of the tree cover by fire over large areas of peat makes it impossible to tell with certainty what were the predominating species. Such bogs, thick with windfalls of burned and dead poles, upturned roots, and partly burned stumps, and grown up to coarse sedges and grasses, present an unsightly appearance and make clearing expensive. In addition the surface of the peat has been lowered, causing it to become nearer to the water table, and the land is more likely to become flooded.

A few ash swamps occur, notably in Bradbury and Dailey Townships, and in these the peat is dark brown, fairly well decomposed, and contains large quantities of tree trunks in various stages of decomposition. Such swamps are usually very poorly drained. On the grass swamps the natural vegetation consists of grasses and sedges. Most of the peat in the county is strongly acid in reaction.

Very little of the total area of peat in Mille Lacs County is under cultivation. Crops produced on the cultivated areas include hay, potatoes, and oats. Satisfactory drainage arrangements, correct fertilization, careful seed-bed preparation, and tillage will result in good yields of the crops adapted to peat soils. Owing to the ever-present danger of serious summer frosts and the expense of providing adequate drainage for such naturally low-lying lands, the list of crops which can be safely produced is greatly curtailed. Hay and pasture are sure crops on properly fertilized and fairly well-drained peat; and it is for these that peat is ordinarily best suited. Peat soil is of particular value when situated on the same farm with sand or very sandy soils in the sandier sections of the county, where adequate production of hay and pasture is a serious problem.

Information concerning crop adaptations and probable lime and fertilizer requirements may be obtained from the Division of Soils of the University of Minnesota. It is unwise for persons to purchase peat lands or go to any expense in reclaiming them without first giving careful consideration to the character of the peat, its fertilizer requirements and cost, and the possibility and expense of providing sufficient drainage.

Peat, shallow phase.—The shallow phase of peat consists of 8 inches or less of fairly well-decomposed dark-brown peat overlying mineral material. The character of the underlying soil may be judged by determining the character of the associated upland. Practically all the shallow peat is underlain by a black, mucky, silty clay deposit, very similar to Adolph silty clay loam. Exceptions to this occur in those areas surrounded by Zimmerman and Hubbard soils, where the substrata are dark-gray sands.

The shallow phase of peat is not extensive, and it occurs in small scattered areas. It includes swampy areas of burned-over land from which the peat has been largely removed by fire, leaving hummocks of partly burned peat, boulders, and potholes. Such areas occur in the northwest part of Page Township and in adjoining sections in Dailey Township. In many places a rim of shallow peat surrounds the typical peat, but, owing to its occurrence in such narrow strips, it is not separated on the map. A higher proportion of the shallow phase is under cultivation than of typical peat, and the land is farmed in association with the low-lying mineral soils. The shallow

peat is less likely to be deficient in available plant nutrients and can ordinarily be reclaimed at less expense. Its range of crop adaptation is also wider. There is the same frost danger, however, that is experienced on typical peat areas, but the cost of drainage is slightly less on the shallow phase.

SUMMARY

Mille Lacs County is in the east-central part of Minnesota. Milaca, the county seat, is located in the southern part of the county, 62 miles northwest of St. Paul and Minneapolis, and 106 miles southwest of Duluth. The land area of the county is approximately 583 square miles, or 373,120 acres. Two-thirds of the northern boundary lies in Mille Lacs Lake, and several smaller lakes lie wholly within the county. The relief ranges from gently undulating to slightly rolling and is typical of glaciated terrain. The average elevation of the county is between 1,000 and 1,200 feet, and Milaca is 1,072 feet above sea level. Rum River, which rises in Mille Lacs Lake, runs southward the full length of the county, and, with its tributaries, drains almost the entire county.

The first settlement took place in the southern townships about 1850, but settlement gradually progressed northward following lumbering activities. At the present time 80 per cent of the farms are located in the southern half of the county; the northern half is still largely unsettled and consists of wild cut-over lands and unreclaimed peat areas. In 1930 the population was 14,076, all classed as rural. The majority of the inhabitants are of Scandinavian, German, and Dutch origin.

Two railroads serve the county, and two graveled trunk highways traverse its length and breadth. Well-maintained graveled and graded roads connect the outlying parts with the main highways.

The climate of Mille Lacs County is representative of a large area in central Minnesota. The summers are mild with cool nights, and the winters are cold. The average number of frost-free days is 125.

Dairy farming is the prevailing type of agriculture, butterfat being the chief dairy product sold. Potatoes are a very important supplementary cash crop. Side lines of varying importance, carried on in different parts of the county, are the sale of eggs, poultry, veal calves, and hogs. The chief crops grown are hay, oats, corn, potatoes, and barley.

In 1930 there were 2,025 farms in the county, averaging 100.2 acres in size, and amounting to 54.4 per cent of the land area of the county. Tenants occupy about 21 per cent of the farms.

The soils of Mille Lacs County belong chiefly to the large group of podzolic soils which are forested, gray soils. All of Mille Lacs County was at one time glaciated. Ground moraines, outwash plains, river terraces, glacio-lacustral deposits, and wind-blown sands all occur within the county, and soils have developed on all of them. Most of the soils are developed from the stony Patrician, or young red, drift of early Wisconsin age. This is a rather coarse-textured and very stony till of low lime content and reddish-brown color and is the product of the glaciation of noncalcareous crystalline rocks. Twenty soil types and three phases of types have been identified.

These are grouped in 14 soil series, depending on drainage, geological origin, and other important profile characteristics. In addition, three classes of miscellaneous deposits are mapped.

The better-drained soils of the podzolized group are included in the Milaca, Onamia, Santiago, Greenbush, Bradford, Brickton, Zimmerman, and Berrien series.

The Milaca, Santiago, Bradford, and Brickton series include brownish-gray medium-textured soils developed on glacial till. Soils of the first two series have formed on the stony young red drift and differ from each other in degree of stoniness and in character of the concentration zone. The Bradford and Brickton soils have developed on calcareous deposits of fine-textured young gray drift origin. The Brickton soils overlie a uniform, glacio-lacustral formation; the Bradford soils overlie till. All these soils are acid at the surface.

The Onamia and Greenbush soils are acid brownish-gray medium-textured soils that in most places overlie noncalcareous stony gravel strata. The Onamia soils are otherwise somewhat similar to the Milaca soils, and the Greenbush soils in many respects resemble the Santiago soils. One type of the Greenbush series is coarser textured and overlies more or less calcareous gravel.

The Zimmerman and Berrien soils are gray and brownish-gray sands, formed on wind-blown and glacial deposits, respectively. The Berrien soils are underlain by somewhat calcareous heavier material at a depth of 3 or 4 feet from the surface. Soils of the Zimmerman series are acid to considerable depths.

The prairie group of soils is represented by one well-drained soil, Hubbard fine sand, a dark-colored soil, developed on loose, uniform outwash sands. The Emmert soils, which are transitional between the podzolic and prairie soils, are developed on kames and eskerlike ridges, and they overlie stony gravel which outcrops at the surface in many places.

Soils of the Freer, Adolph, Kanabec, and Isanti series are poorly drained. The Freer and Kanabec series include heavy dark brownish-gray soils. The Freer soils have a fine-textured mottled slightly impervious concentration zone and overlie the stony red drift. The Kanabec soils are rather darker colored than the Freer and are exceedingly impervious in the lower layers. Beneath the concentration zone is an open stony gravel layer.

Soils of the Adolph series are very fine textured, dark-brown or black very poorly drained soils, and they are more or less waterlogged in their lowest layers. The Isanti series includes brownish-gray sands overlying mottled and deep-lying cemented layers of the same material.

The undifferentiated alluvial soils along the stream channels are brown, variable material. The finer-textured deposits predominate, but sandy alluvium occurs in small amounts. These soils are subject to occasional overflows. Beach sand occurs about Mille Lacs Lake. The peat soils are mainly dark-brown, woody and fibrous organic deposits which are acid in reaction and of very inadequate drainage.

[PUBLIC RESOLUTION—No. 9]

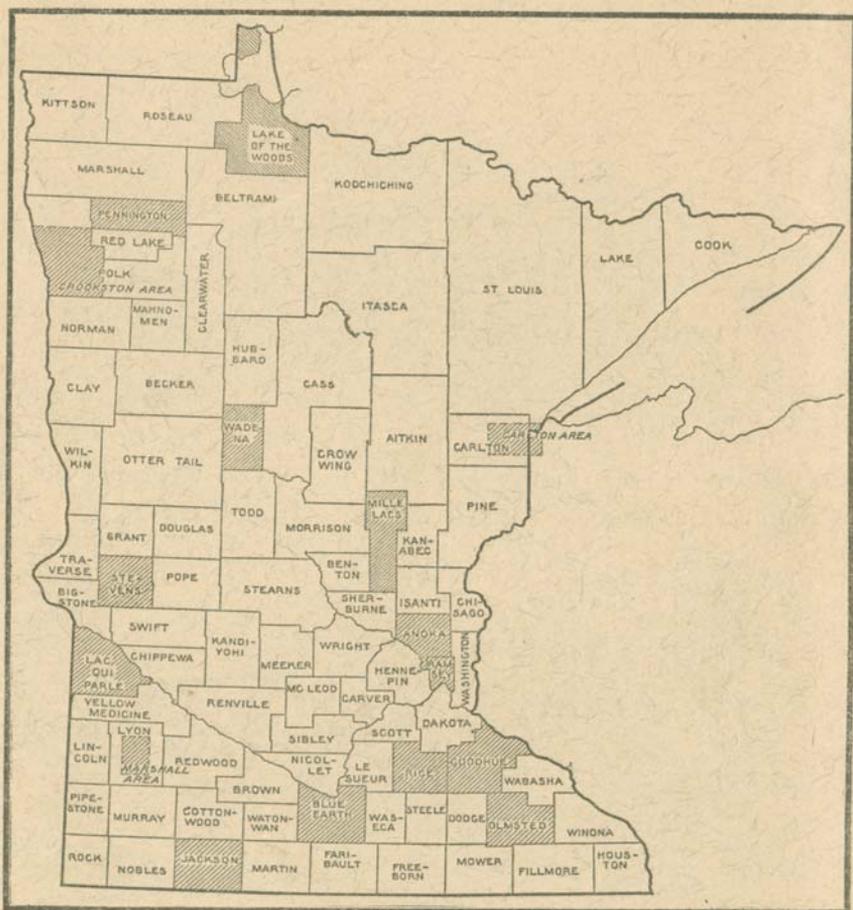
JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

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

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

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils, and on July 1, 1927, the Bureau of Soils became a unit of the Bureau of Chemistry and Soils.]



Areas surveyed in Minnesota shown by shading

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