

SOIL SURVEY

Steele County Minnesota



UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service
In cooperation with
MINNESOTA AGRICULTURAL EXPERIMENT STATION

Issued August 1973

Major fieldwork for this soil survey was done in the period 1946-62. Soil names and descriptions were approved in 1966. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1967. This survey was made cooperatively by the Soil Conservation Service and the Minnesota Agricultural Experiment Station. The survey is part of the technical assistance furnished to the Steele County Soil and Water Conservation District.

Either enlarged or reduced copies of the soil map in this publication can be made by commercial photographers, or they can be purchased on individual order from the Cartographic Division, Soil Conservation Service, United States Department of Agriculture, Washington, D.C. 20250.

HOW TO USE THIS SOIL SURVEY

THIS SOIL SURVEY contains information that can be applied in managing farms and woodlands; in selecting sites for roads, ponds, buildings, and other structures; and in judging the suitability of tracts of land for farming, industry, and recreation.

Locating Soils

All the soils of Steele County are shown on the detailed map at the back of this publication. This map consists of many sheets made from aerial photographs. Each sheet is numbered to correspond with a number on the Index to Map Sheets.

On each sheet of the detailed map, soil areas are outlined and are identified by symbols. All areas marked with the same symbol are the same kind of soil. The soil symbol is inside the area if there is enough room; otherwise, it is outside, and a pointer shows where the symbol belongs.

Finding and Using Information

The "Guide to Mapping Units" can be used to find information. This guide lists all the soils of the county in alphabetic order by map symbol and gives the capability classification of each. It also shows the page where each soil is described and the page for the capability unit in which the soil has been placed.

Individual colored maps showing the relative suitability or degree of limitation of soils for many specific purposes can be developed by using the soil map and the information in the text. Translucent material can be used as an overlay over the soil map and colored to show soils that have the same limitation or suitability. For example, soils that have a slight limitation for a given use can be colored green, those with a moderate limitation can be colored yellow, and those with a severe limitation can be colored red.

Farmers and those who work with farmers can learn about use and management of the soils from the soil descriptions and from the discussions of the capability units.

Game managers, sportsmen, and others can find information about soils and wildlife in the section "Use of the Soils for Wildlife."

Engineers and builders can find, under the section "Engineering Uses of the Soils," tables that contain test data, estimates of soil properties, and information about soil features that affect engineering practices.

Scientists and others can read about how the soils formed and how they are classified in the section "Formation and Classification of the Soils."

Newcomers in Steele County may be especially interested in the section "General Soil Map," where broad patterns of soils are described. They may also be interested in the information about the county given at the beginning of the publication and in the section "General Nature of the County."

Contents

	Page		Page
How this survey was made	1	Descriptions of the soils—Continued	
General soil map	2	Moland series.....	37
1. Webster-Clarion-Nicollet association.....	2	Muck.....	38
2. Lester-Webster-Le Sueur association.....	3	Newry series.....	39
3. Lerdal-Kilkenny-Shields association.....	3	Nicollet series.....	39
4. Hayden-Webster-Lester association.....	3	Salida series.....	40
5. Maxcreek-Moland-Merton association.....	3	Shields series.....	41
6. Bixby-Dakota-Biscay-Estherville association.....	4	Sparta series.....	42
Descriptions of the soils	4	Storden series.....	42
Alluvial land.....	6	Talcot series.....	43
Biscay series.....	6	Terril series.....	44
Bixby series.....	7	Udolpho series.....	44
Blooming series.....	8	Wadena series.....	45
Burnsville series.....	9	Waukegan series.....	46
Calco series.....	10	Webster series.....	47
Canisteo series.....	10	Use and management of the soils	47
Chelsea series.....	12	Use of the soils for crops and pasture.....	47
Clarion series.....	12	Capability grouping.....	49
Colo series.....	14	Management by capability units.....	50
Dakota series.....	15	Predicted yields.....	57
Dickinson series.....	16	Use of the soils for wildlife.....	57
Dundas series.....	17	Engineering uses of the soils.....	60
Estherville series.....	18	Engineering classification systems.....	60
Glencoe series.....	19	Estimated engineering properties.....	61
Hanska series.....	19	Engineering interpretations.....	61
Havana series.....	20	Engineering test data.....	61
Hayden series.....	21	Formation and classification of the soils	88
Hayfield series.....	23	Formation of the soils.....	88
Kato series.....	23	Parent material.....	88
Kato series, calcareous variant.....	24	Climate.....	89
Kilkenny series.....	25	Plants and animals.....	89
Lake beaches.....	26	Relief.....	91
Lamont series.....	26	Time.....	91
Lemond series.....	27	Processes of soil formation.....	91
Lerdal series.....	28	Classification of the soils.....	92
Lester series.....	29	General nature of the county	94
Le Sueur series.....	31	Physiography, relief, and drainage.....	94
Lura series.....	32	Water supplies.....	94
Madelia series.....	33	Climate.....	97
Marna series.....	34	Social and industrial development.....	99
Marsh.....	34	Farming.....	99
Maxcreek series.....	34	Literature cited	100
Mayer series.....	35	Glossary	100
Merton series.....	36	Guide to mapping units	Following
			102

This page intentionally left blank.

SOIL SURVEY OF STEELE COUNTY, MINNESOTA

BY JOSEPH F. CUMMINS, CARROLL R. CARLSON, GRENFALL F. HARMS, AND D. KIRK WOODWORTH, SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, IN COOPERATION WITH THE MINNESOTA AGRICULTURAL EXPERIMENT STATION

STEELE COUNTY is in the south-central part of Minnesota (fig. 1). Owatonna, the county seat, is about 60 miles south of Minneapolis and St. Paul and about 40 miles north of the Iowa line. The county has a total land area of about 427 square miles, or 272,880 acres.

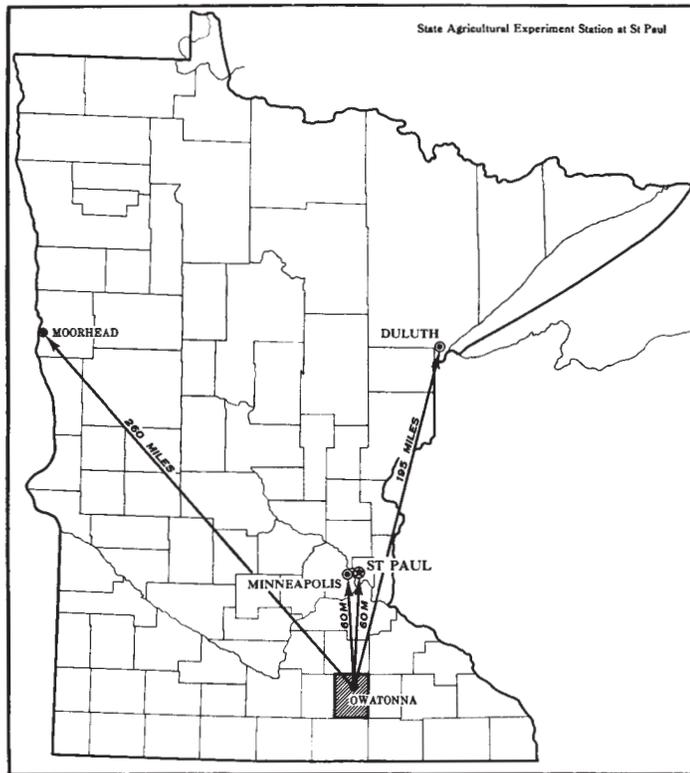


Figure 1.—Location of Steele County in Minnesota.

Of this, 96 percent is land in farms. In 1960, approximately 85 percent of the land in farms was used for crops, mainly corn and soybeans. Dairying and the raising of hogs are the principal livestock enterprises.

How This Survey Was Made

Soil scientists made this survey to learn what kinds of soil are in Steele County, where they are located, and how they can be used. The soil scientists went into the county

knowing they likely would find many soils they had already seen and perhaps some they had not. They observed the steepness, length, and shape of slopes, the size and speed of streams, the kinds of native plants or crops, the kinds of rock, and many facts about the soils. They dug many holes to expose soil profiles. A profile is the sequence of natural layers, or horizons, in a soil; it extends from the surface down into the parent material that has not been changed much by leaching or by the action of plant roots.

The soil scientists made comparisons among the profiles they studied, and they compared these profiles with those in places more distant. They classified and named the soils according to nationwide, uniform procedures. The *soil series* and the *soil phase* are the categories of soil classification most used in a local survey.

Soils that have profiles almost alike make up a soil series. Except for different texture in the surface layer, all the soils of one series have major horizons that are similar in thickness, arrangement, and other important characteristics. Each soil series is named for a town or other geographic feature near the place where a soil of that series was first observed and mapped. Lester and Nicollet, for example, are the names of two soil series. All the soils in the United States having the same series name are essentially alike in those characteristics that affect their behavior in the undisturbed landscape.

Soils of one series can differ in texture of the surface soil and in slope, stoniness, or some other characteristic that affects use of the soils by man. On the basis of such differences, a soil series is divided into phases. The name of a soil phase indicates a feature that affects management. For example, Clarion loam, 2 to 6 percent slopes, is one of several phases within the Clarion series.

After a guide for classifying and naming the soils had been worked out, the soil scientists drew the boundaries of the individual soils on aerial photographs. These photographs show woodlands, buildings, field borders, trees, and other details that help in drawing boundaries accurately. The soil map in the back of this publication was prepared from the aerial photographs.

The areas shown on a soil map are called mapping units. On most maps detailed enough to be useful in planning the management of farms and fields, a mapping unit is nearly equivalent to a soil phase. It is not exactly equivalent, because it is not practical to show on such a map all the small, scattered bits of soil of some other

kind that have been seen within an area that is dominantly of a recognized soil phase.

Some mapping units are made up of soils of different series, or of different phases within one series. Two such kinds of mapping units are shown on the soil map of Steele County: soil complexes and undifferentiated groups.

A soil complex consists of areas of two or more soils, so intermingled or so small in size that they cannot be shown separately on the soil map. Each area of a complex contains some of each of the two or more dominant soils, and the pattern and relative proportions are about the same in all areas. The name of a soil complex consists of the names of the dominant soils, joined by a hyphen. An example is Clarion-Storden complex, 6 to 12 percent slopes, eroded.

An undifferentiated group is made up of two or more soils that could be delineated individually but are shown as one unit because, for the purpose of the soil survey, there is little value in separating them. The pattern and proportion of soils are not uniform. An area shown on the map may be made up of only one of the dominant soils, or of two or more. The name of an undifferentiated group consists of the names of the dominant soils, joined by "and." Lester and Hayden loams, 18 to 25 percent slopes, is an example.

In most areas surveyed there are places where the soil material is so rocky, so shallow, or so severely eroded that it cannot be classified by soil series. These places are shown on the soil map and are described in the survey, but they are called land types and are given descriptive names. Alluvial land, occasionally flooded, is a land type in Steele County.

While a soil survey is in progress, samples of soils are taken, as needed, for laboratory measurements and for engineering tests. Laboratory data from the same kinds of soil in other places are assembled. Data on yields of crops under defined practices are assembled from farm records and from field or plot experiments on the same kinds of soil. Yields under defined management are estimated for all the soils.

But only part of a soil survey is done when the soils have been named, described, and delineated on the map, and the laboratory data and yield data have been assembled. The mass of detailed information then needs to be organized in such a way as to be readily useful to different groups of users, among them farmers, managers of woodland and rangeland, and engineers.

On the basis of yield and practice tables and other data, the soil scientists set up trial groups. They tested these groups by further study and by consultation with farmers, agronomists, engineers, and others, then they adjusted the groups according to the results of their studies and consultation. Thus, the groups that are finally evolved reflect up-to-date knowledge of the soils and their behavior under present methods of use and management.

General Soil Map

The general soil map at the back of this survey shows, in color, the soil associations in Steele County. A soil association is a landscape that has a distinctive propor-

tional pattern of soils. It normally consists of one or more major soils and at least one minor soil, and it is named for the major soils. The soils in one association may occur in another, but in a different pattern.

A map showing soil associations is useful to people who want a general idea of the soils in a county, who want to compare different parts of a county, or who want to know the location of large tracts that are suitable for a certain kind of land use. Such a map is a useful general guide in managing a watershed, a wooded tract, or a wildlife area, or in planning engineering works, recreational facilities, and community developments. It is not a suitable map for planning the management of a farm or field, or for selecting the exact location of a road, building, or similar structure, because the soils in any one association ordinarily differ in slope, depth, stoniness, drainage, and other characteristics that affect their management.

The six soil associations in Steele County are each described in the following pages. The terms for textures used in the descriptive heading for several of the associations apply to the surface layer. For example, in the title for association 1, the word "loamy" refers to texture of the surface layer.

The names of soil associations in Steele County do not match those of Dodge County, the adjoining county to the east, because of refinements in classification and redefinition of series descriptions. Soils along the county line are similar except for the difference in name.

1. Webster-Clarion-Nicollet association

Poorly drained to well-drained, nearly level to rolling, loamy soils

This association consists of nearly level to rolling or undulating soils that have short, complex slopes. These soils are intermingled with soils in depressions and in low-gradient swales. Summits of the rises commonly are only 10 to 20 feet higher than the bottoms of the swales. Areas of this association in southwestern Berlin Township contain somewhat circular hills that have smooth side slopes and nearly level tops. A small lacustrine area is west and south of Havana station. This association occupies about 26 percent of the county.

The major soils formed in calcareous, loamy glacial till, and they have a black or very dark brown surface layer. The poorly drained, nearly level Webster soils occupy about 31 percent of the association; the well-drained, gently undulating and rolling Clarion soils occupy about 28 percent; and the moderately well drained or somewhat poorly drained, gently undulating and nearly level Nicollet soils occupy about 14 percent. The calcareous Storden soils occur with the Clarion soils in some of the steeper areas where the slopes are convex.

Very poorly drained Glencoe soils in depressions occupy about 10 percent of the association. The remaining 17 percent of the association consists of small areas of poorly drained and very poorly drained Biscay, Canisteo, Madelia soils and Muck; well-drained Dakota, Lester, and Wadena soils; somewhat excessively drained Estherville and Storden soils; and moderately well drained or somewhat poorly drained Le Sueur soils.

Corn and soybeans are the principal field crops, and canning peas and asparagus are grown as special crops.

Management needs consist of controlling erosion and the height of the water table, keeping the surface layer in good tilth, and properly fertilizing the organic soils.

2. *Lester-Webster-Le Sueur association*

Well-drained to poorly drained, nearly level to rolling, loamy soils

This association consists of gently undulating, rolling, and nearly level soils that have short slopes and that are intermingled with soils in depressions and in low-gradient swales. Summits commonly rise 10 to 40 feet above the low areas. In southwestern Berlin Township, there are somewhat circular hills with smoothly sloping sides and nearly level tops. This association occupies about 35 percent of the county.

The major soils formed in calcareous, loamy glacial till, and they have a very dark gray or black surface layer. The well-drained, gently undulating to rolling Lester soils occupy about 34 percent of the association. The calcareous Storden soils occur with the Lester soils in some of the steeper areas where slopes are convex. The poorly drained, nearly level Webster soils occupy about 24 percent of the association, and the moderately well drained to somewhat poorly drained, nearly level to gently undulating Le Sueur soils occupy about 16 percent.

Glencoe soils make up about 6 percent of the association. The remaining 20 percent consists of poorly drained Biscay and Dundas soils; very poorly drained Muck; well-drained Bixby, Hayden, and Wadena soils; and somewhat excessively drained Burnsville, Storden, and Estherville soils.

Corn, soybean, oats, and alfalfa are the principal field crops, and canning peas and asparagus are grown as special crops. Management needs consist of controlling erosion and the height of the water table, keeping the surface layer in good tilth, and properly fertilizing the organic soils.

3. *Lerdal-Kilkenny-Shields association*

Poorly drained to well-drained, nearly level to rolling, loamy and clayey soils

This association consists of nearly level, rolling, and gently undulating soils that have short, complex slopes. These soils are intermingled with soils in depressions and low-gradient swales. Summits of the rises commonly are 10 to 20 feet higher than the nearly level soils and swales in the more sloping areas and 2 to 10 feet above them in the more nearly level areas. This association makes up about 4 percent of the county.

The major soils formed in 3 to 10 feet of shaly, calcareous, fine-textured till. Their surface layer is black or very dark gray. The somewhat poorly drained, gently undulating Lerdal soils occupy about 25 percent of the association; the well-drained, gently undulating to rolling Kilkenny soils occupy about 20 percent; the somewhat poorly drained and poorly drained, nearly level Shields soils occupy about 12 percent; and the poorly drained, nearly level Marna soils occupy about 11 percent.

The remaining 32 percent of the association consists of poorly drained Canisteo, Dundas, and Webster soils; very poorly drained Glencoe and Lura soils and Muck;

moderately well drained and somewhat poorly drained Le Sueur soils; and well-drained Lester and Hayden soils.

Corn, soybeans, alfalfa, and oats are the main crops. Management needs consist of controlling erosion and the height of the water table and keeping the surface layer in good tilth.

4. *Hayden-Webster-Lester association*

Well-drained and poorly drained, nearly level to steep, loamy soils

This soil association consists of nearly level, gently undulating, rolling, and steep soils that have short, complex slopes. These soils are intermingled with soils in depressions and in low-gradient swales. Summits of the rises commonly are from 15 to 40 feet higher than the bottoms of the swales. Adjacent to the valley of the Straight River, slopes are longer and are dissected at intervals by deep, narrow ravines. This association occupies approximately 13 percent of the county.

The major soils formed in calcareous, loamy glacial till. They have a dark grayish-brown, very dark gray, or black surface layer. The well-drained, gently undulating to steep Hayden soils occupy about 44 percent of the association; the poorly drained, nearly level Webster soils occupy about 14 percent; and the well-drained, gently undulating to steep Lester soils occupy about 10 percent.

The remaining 32 percent of the association consists of well-drained Bixby and Lamont soils; somewhat excessively drained Burnsville, Estherville, and Storden soils; excessively drained Chelsea soils; moderately well drained to somewhat poorly drained Le Sueur soils; poorly drained Dundas and Canisteo soils; and very poorly drained Glencoe soils and Muck.

Corn, soybeans, alfalfa, and oats are the principal crops. Management needs consist of controlling erosion and the height of the water table, keeping the surface layer in good tilth, and properly fertilizing the organic soils.

5. *Maxcreek-Moland-Merton association*

Poorly drained to well-drained, nearly level to gently undulating, mainly silty soils

This soil association consists of nearly level, gently undulating, and rolling soils that are intermingled with soils in moderate-gradient swales and in a few closed drainageways. Summits commonly are from 5 to 15 feet above the swales. This association occupies approximately 7 percent of the county.

The major soils formed in a silty mantle and the underlying friable, calcareous loam or light clay loam till. A coarse-textured layer, or pebble band, commonly separates these two materials. The major soils have a black surface layer. The poorly drained, nearly level Maxcreek soils occupy about 31 percent of the association. The well-drained Moland soils occupy about 18 percent; they are gently undulating in most places but are nearly level near the village of Blooming Prairie. The moderately well drained, nearly level to gently undulating Merton soils occupy about 17 percent of the association.

The well-drained, gently undulating to rolling Blooming soils occupy about 10 percent of the association and

occur near lakes and major drainageways. The remaining 24 percent consists of poorly drained Canisteo soils, somewhat poorly drained Havana soils, and moderately well drained to somewhat poorly drained Newry soils.

Corn and soybeans are the principal field crops, and canning peas and asparagus are grown as special crops. Management needs consist of controlling erosion and the height of the water table and keeping the surface layer in good tilth.

6. Bixby-Dakota-Biscay-Estherville association

Poorly drained to somewhat excessively drained, nearly level, loamy soils

This association consists dominantly of nearly level soils that are intermingled with soils in swales and depressions. Slopes are gently undulating and rolling in a few areas near streams and drainageways and where the broad areas of nearly level, well-drained and excessively drained soils border the broad areas of nearly level, poorly drained soils. This association occupies about 15 percent of the county.

The major soils formed in medium-textured and moderately coarse textured material and the underlying sand or sand and gravel. They have a dark grayish-brown to black surface layer. Soils that have a surface layer of dark grayish brown are mostly along the eastern edge of the county. The well-drained Bixby, Dakota, Wadena, and Waukegan soils and the moderately well drained to somewhat poorly drained Hayfield soils occupy about 29 percent of the association; the poorly drained Biscay, Colo, Hanska, and Kato soils and the somewhat poorly drained to poorly drained Udolpho soils occupy about 23 percent; and the somewhat excessively drained Estherville, Burnsville, and Dickinson soils occupy about 20 percent.

The poorly drained to very poorly drained, calcareous Kato, Calco, Lemond, and Mayer soils occupy about 10 percent of the association; and Alluvial land and the Terril soils occupy about 10 percent. Muck occupies about 8 percent of the association and, in a few places, is in tracts about 600 acres in size. In most places many of the soils, including droughty and wet soils, are intermingled, but a few large areas of nearly level soils are made up dominantly of one or two soils. The Hayfield, Kato, and Waukegan soils are along the eastern edge of the county.

Corn, soybeans, alfalfa, and oats are the principal crops. The larger areas of Muck and Estherville soils are used for truck crops. Management needs consist of adequate drainage where needed, control of soil blowing, irrigation, diversification of crops and crop use, and proper fertilization of mucky and calcareous soils.

Descriptions of the Soils

This section describes the soil series and mapping units in Steele County. The acreage and proportionate extent of each mapping unit are given in table 1.

Each soil series is described in considerable detail, and then each mapping unit in that series is described briefly. Unless the description of a given mapping unit specifically mentions otherwise, the reader should assume that what is stated about the soil series holds true for the mapping

units in that series. Thus, to get full information about any one mapping unit, it is necessary to read both the description of the mapping unit and the description of the soil series to which it belongs.

An important part of the description of each soil series is the soil profile, that is, the sequence of layers from the surface downward to rock or other underlying material. Each series contains two descriptions of a profile that is representative for the series. The first description is brief and in terms familiar to the layman. The second description is of the same profile; it is detailed and in technical terms, and is for scientists, engineers, and others who need to make thorough and precise studies of soils. Unless otherwise stated, the colors and the consistency given in the descriptions are those of a moist soil.

As mentioned in the section "How This Survey Was Made," not all mapping units are members of a soil series. Alluvial land, occasionally flooded, for example, does not belong to a soil series, but nevertheless it is listed in alphabetic order along with the soil series.

Following the name of each mapping unit is a symbol in parentheses. This symbol identifies the mapping unit on the detailed soil map. Listed at the end of each description of a mapping unit is the capability unit in which the mapping unit has been placed. The page for the description of each capability unit can be found by referring to the "Guide to Mapping Units" at the back of this survey.

Many of the terms used in describing soils can be found in the Glossary at the end of this survey, and more detailed information about the terminology and methods of soil mapping can be obtained from the Soil Survey Manual (12).¹

Soil texture is one of the dominant soil properties that the soil scientist uses in classification. Texture is an expression of the interrelationship of the three main groupings of particle size: sand, silt, and clay.

Sand ranges in effective diameter from 2.0 to 0.05 millimeter. Other major properties of sand are low water-holding capacity, low compressibility, relative inelasticity, and chemical inactivity.

Silt ranges in effective diameter from 0.05 to 0.002 millimeter. Other major properties of silt are high water-holding capacity, high compressibility, moderate elasticity, and low chemical activity.

Clay has mostly platy structure; the plates are less than 0.002 millimeter thick. Other major properties of clay are high water-holding capacity, high compressibility, high elasticity, and chemical activity.

Gravel ranges from 2 millimeters to 3 inches in diameter and is used in the name of textural classes as a modifier, for example, gravelly sandy loam or gravelly loamy sand. Organic matter tends to modify field judgment; sandy textures feel finer, and clayey textures feel less sticky.

The proportionate amounts of sand, silt, and clay in a soil determine its texture, for example, loamy sand, sandy loam, silt loam, clay loam, or clay.

A given soil series in this county may be identified by a different name in a recently published soil survey of an adjacent county. Such differences in name result from

¹ Italic numbers in parentheses refer to Literature Cited, p. 100.

TABLE 1.—Approximate acreage and proportionate extent of soils

Soil	Area	Extent	Soil	Area	Extent
	<i>Acres</i>	<i>Percent</i>		<i>Acres</i>	<i>Percent</i> ⁽¹⁾
Alluvial land, occasionally flooded	501	0.2	Lake beaches	119	
Alluvial land, frequently flooded	2,770	1.0	Lamont sandy loam, 2 to 6 percent slopes	491	.2
Biscay loam	3,320	1.2	Lamont sandy loam, 6 to 12 percent slopes	315	.1
Biscay loam, depressional	1,200	.4	Lamont sandy loam, 12 to 18 percent slopes	159	.1
Bixby loam, 0 to 2 percent slopes	568	.2	Lemond loam	529	.2
Bixby loam, 2 to 6 percent slopes	612	.2	Lerdal silty clay loam, 2 to 6 percent slopes	1,795	.7
Bixby loam, 2 to 6 percent slopes, eroded	1,766	.6	Lerdal silty clay loam, 2 to 6 percent slopes, eroded	1,048	.4
Bixby loam, 6 to 12 percent slopes, eroded	324	.1	Lester loam, 2 to 6 percent slopes	7,127	2.6
Bixby loam, 12 to 18 percent slopes, eroded	96	(1)	Lester loam, 2 to 6 percent slopes, eroded	18,075	6.6
Blooming silt loam, 2 to 6 percent slopes, eroded	1,761	.6	Lester loam, 6 to 12 percent slopes	820	.3
Blooming silt loam, 6 to 14 percent slopes, eroded	246	.1	Lester loam, 6 to 12 percent slopes, eroded	6,560	2.4
Burnsville sandy loam, 2 to 6 percent slopes	224	.1	Lester loam, 12 to 18 percent slopes, eroded	1,046	.4
Burnsville sandy loam, 6 to 12 percent slopes	106	(1)	Lester-Estherville-Storden complex, 2 to 6 percent slopes, eroded	286	.1
Calco silty clay loam, very wet	813	.3	Lester-Estherville-Storden complex, 6 to 18 percent slopes, eroded	472	.2
Canisteo silty clay loam	2,300	.9	Lester and Hayden loams, 18 to 25 percent slopes	875	.3
Canisteo silty clay loam, depressional	1,347	.5	Lester and Hayden loams, 25 to 35 percent slopes	661	.2
Canisteo clay loam	6,404	2.4	Lester-Storden complex, 6 to 12 percent slopes, eroded	585	.2
Canisteo clay loam, depressional	5,108	1.9	Lester-Storden complex, 12 to 18 percent slopes, eroded	270	.1
Chelsea loamy fine sand, 2 to 18 percent slopes	192	.1	Le Sueur clay loam, 0 to 2 percent slopes	9,480	3.5
Clarion sandy loam, 2 to 6 percent slopes, eroded	228	.1	Le Sueur clay loam, 2 to 4 percent slopes	6,208	2.3
Clarion loam, 2 to 6 percent slopes	5,058	1.9	Lura silty clay loam	174	.1
Clarion loam, 2 to 6 percent slopes, eroded	11,817	4.3	Madelia silty clay loam	512	.2
Clarion loam, 6 to 12 percent slopes, eroded	4,354	1.6	Marna silty clay loam	1,239	.5
Clarion-Storden complex, 6 to 12 percent slopes, eroded	606	.2	Marsh	990	.4
Clarion-Storden complex, 12 to 18 percent slopes, eroded	851	.3	Maxcreek silty clay loam	4,890	1.8
Colo silty clay loam, occasionally flooded	624	.2	Maxcreek silty clay loam, swales	1,156	.4
Colo silty clay loam, frequently flooded	210	.1	Mayer loam	1,744	.6
Dakota sandy loam, 0 to 2 percent slopes	349	.1	Merton silt loam, 0 to 2 percent slopes	2,700	1.0
Dakota sandy loam, 2 to 6 percent slopes	915	.3	Merton silt loam, 2 to 4 percent slopes	505	.2
Dakota sandy loam, 6 to 14 percent slopes	637	.2	Moland silt loam, 0 to 2 percent slopes	633	.2
Dakota loam, 0 to 2 percent slopes	528	.2	Moland silt loam, 2 to 6 percent slopes	1,124	.4
Dakota loam, 2 to 6 percent slopes	923	.3	Moland silt loam, 2 to 8 percent slopes, eroded	1,739	.6
Dickinson sandy loam, terrace, 0 to 2 percent slopes	1,096	.4	Muck	7,907	2.9
Dickinson sandy loam, terrace, 2 to 6 percent slopes	1,062	.4	Muck, calcareous	638	.2
Dundas silt loam	2,232	.8	Muck, sandy substratum	255	.1
Estherville sandy loam, 0 to 2 percent slopes	2,023	.7	Muck, loamy substratum	8,556	3.1
Estherville sandy loam, 2 to 6 percent slopes	2,715	1.0	Newry silt loam, 0 to 3 percent slopes	1,944	.7
Estherville sandy loam, 6 to 12 percent slopes	576	.2	Nicollet clay loam, 0 to 2 percent slopes	7,356	2.7
Estherville sandy loam, 12 to 18 percent slopes	177	.1	Nicollet clay loam, 2 to 4 percent slopes	2,797	1.0
Glencoe clay loam	15,293	5.6	Salida gravelly loamy sand, 12 to 25 percent slopes	142	.1
Hanska loam	426	.2	Shields silty clay loam	1,389	.5
Havana silt loam	1,165	.4	Sparta-Dickinson complex, 2 to 6 percent slopes	373	.1
Hayden sandy loam, 2 to 6 percent slopes, eroded	504	.2	Sparta-Dickinson complex, 6 to 12 percent slopes	248	.1
Hayden sandy loam, 6 to 12 percent slopes, eroded	281	.1	Sparta-Dickinson complex, 12 to 25 percent slopes	171	.1
Hayden loam, 2 to 6 percent slopes	2,394	.9	Talcot clay loam	1,575	.6
Hayden loam, 2 to 6 percent slopes, eroded	8,090	3.0	Terril loam, occasionally flooded	566	.2
Hayden loam, 6 to 12 percent slopes	731	.3	Terril loam, frequently flooded	128	(1)
Hayden loam, 6 to 12 percent slopes, eroded	3,338	1.2	Udolpho silt loam	499	.2
Hayden loam, 12 to 18 percent slopes	297	.1	Wadena loam, 0 to 2 percent slopes	1,305	.5
Hayden loam, 12 to 18 percent slopes, eroded	733	.3	Wadena loam, 2 to 6 percent slopes	1,748	.6
Hayfield silt loam	1,137	.4	Wadena loam, 6 to 12 percent slopes, eroded	178	.1
Kato silty clay loam	1,958	.7	Waukegan silt loam, 0 to 2 percent slopes	1,525	.6
Kato silty clay loam, swales	662	.2	Waukegan silt loam, 2 to 6 percent slopes	930	.3
Kato silty clay loam, calcareous variant	453	.2	Webster clay loam	51,146	18.8
Kato silty clay loam, calcareous variant, depressional	264	.1	Gravel pits	415	.2
Kilkenny clay loam, 2 to 6 percent slopes, eroded	1,260	.5	Lime quarry	27	(1)
Kilkenny clay loam, 6 to 12 percent slopes, eroded	1,110	.4	Total ²	272,880	100.0

¹ Less than 0.05 percent.² Includes 880 acres of meandered land, now drained and cropped.

changes in the concepts of soil classification since publication of the previous survey. The characteristics of a soil series described in this county are considered to be within the range defined for that series. In those instances where a soil series has one or more features outside the defined range, the differences are explained.

Alluvial Land

Alluvial land consists of well drained or moderately well drained, very dark gray or very dark brown material recently deposited by streams. It is nearly level and occupies areas adjacent to the Straight River and its tributaries. The surface layer is dominantly loam, but some areas have a surface layer of loamy sand or sandy loam of varying thickness. Remnant meander channels occur in some areas. Reaction is neutral. Permeability is moderately rapid in most places. The available water capacity is variable. The content of organic matter is high, and natural fertility is medium.

Alluvial land, occasionally flooded (Ad) is on the higher bottom lands along the Straight River and its major tributaries. It is subject to occasional flooding and scouring. This land is used principally for corn and soybeans. Variations in the texture of the alluvial deposits cause wide variations in yields during periods of drought. (Capability unit IIw-3)

Alluvial land, frequently flooded (Af) is adjacent to the Straight River and its major tributaries. It is subject to frequent flooding, scouring, and stream cutting. Because of the hazard of flooding, this land is used principally for undeveloped pasture. (Capability unit VIw-1)

Biscay Series

The Biscay series consists of nearly level, poorly drained, loamy soils that are moderately deep over coarse sand and fine gravel. These soils formed in 2 to 3 feet of loamy sediment over coarser textured material. The native vegetation was principally water-tolerant grasses.

In a representative profile, the surface layer is loam about 16 inches thick. The upper part is black, and the lower part is very dark gray and contains streaks of grayer material from the layers below. The subsoil is mottled, olive-gray, friable sandy clay loam about 16 inches thick. The underlying material is olive-gray, loose coarse sand and fine gravel that is mottled with olive and dark grayish brown.

Where these soils are drained, permeability is moderate in the upper part of the profile and rapid in the sandy underlying material. Runoff is slow to ponded. Available water capacity is moderate. The water table is at a depth of 0 to 3 feet. The organic-matter content is high, and natural fertility is medium.

In areas where these soils are undrained, they are poorly suited to crops grown in the county. If adequately drained, the soils are well suited to most of the commonly grown crops, and large acreages are used for corn and soybeans.

Representative profile of Biscay loam, in Owatonna Township, 200 feet north and 300 feet east of the southwest corner of SW $\frac{1}{4}$ sec. 31, T. 107 N., R. 20 W.:

Ap—0 to 8 inches, black (N 2/0) loam; weak, medium, subangular blocky structure; friable; neutral; abrupt, wavy boundary.

A1—8 to 12 inches, black (N 2/0) loam; weak, medium and coarse, subangular blocky structure; friable; neutral; abrupt, wavy boundary.

A3g—12 to 16 inches, very dark gray (10YR 3/1) loam, high in content of sand; few streaks of gray (5Y 5/1) and dark gray (5Y 4/1); weak, medium and coarse, subangular blocky structure; friable; neutral; gradual, irregular boundary.

B21g—16 to 20 inches, olive-gray (5Y 5/2) sandy clay loam; many, fine, faint, olive (5Y 5/3) and light olive-gray (5Y 6/2) mottles; weak, coarse, subangular blocky structure; friable; neutral; clear, wavy boundary.

B22g—20 to 32 inches, olive-gray (5Y 5/2) sandy clay loam; few tongues of olive (5Y 5/4); weak, fine and medium, subangular blocky structure; friable; calcareous; mildly alkaline; clear, wavy boundary.

IICg—32 to 60 inches, olive-gray (5Y 5/2) coarse sand; many, medium, faint, olive (5Y 5/3) and dark grayish-brown (2.5Y 4/2) mottles; single grain; loose; few fine pebbles; calcareous; mildly alkaline.

The Ap and A1 horizons range from 10 to 16 inches in combined thickness. Reaction in these horizons commonly is neutral but ranges from slightly acid to mildly alkaline. The A3 horizon ranges from 3 to 6 inches in thickness. Reaction of that horizon commonly is neutral but in places is mildly alkaline. There are black tongues in this horizon in some places.

The B horizon ranges from 12 to 24 inches in thickness. It contains distinct, light olive-brown mottles in some places. Texture of the B horizon commonly is sandy clay loam but ranges to heavy loam or sandy loam.

The IIC horizon in some areas is fine and medium sand, together with some coarse gravel. The IIC horizon is commonly mildly alkaline but is neutral in the upper part in some depressions. Depth to the IIC horizon ranges from 24 to 40 inches.

Biscay soils are associated with the Hanska soils. They have a higher content of clay in the A and B horizons and have coarser material in the C horizon than the Hanska soils. The Biscay soils contain more sand and less silt than the similar Kato soils.

Biscay loam (0 to 2 percent slopes) (Bc).—This nearly level soil occupies 3-acre to 100-acre tracts, mostly on broad sand flats but also in small upland draws. Its profile is the one described as representative of the series.

Included with this soil in mapping are areas of Mayer and Hanska soils that are too small to be mapped separately. Also included, in Summit Township, are areas of Biscay soils that are underlain by fine sand in many places. In places the surface layer is calcareous. Clay loam till is at a depth of 60 to 72 inches in some areas.

This soil is wet. Runoff is slow, and depth to the water table ranges from 1 to 3 feet in undrained areas. Drainage is needed for this soil to be dependable for the commonly grown crops. Tile drains and open ditches effectively control the level of the perched water table. Maintenance of tilth and fertility are minor management needs. (Capability unit IIw-1)

Biscay loam, depressional (Bd).—This soil is in depressions; in long, winding, narrow swales; and in broad shallow sloughs. Size of the areas in depressions is 3 to 5 acres, and size of the areas in swales and sloughs is 15 to 60 acres. The profile is similar to that described as representative for the series, except that the black part of the surface layer is somewhat thicker and the content of clay is higher.

Included in mapping, along the rims of the swales and depressions, are areas of Mayer soils and of Biscay soils that have a calcareous surface layer.

This depressional Biscay soil is wet. Runoff is slow to ponded, and depth to the water table ranges from the surface to 3 feet in undrained areas. Drainage is needed if this soil is to be dependable for the commonly grown crops. Surface waterways are used to prevent ponding. Tile drains and open ditches effectively control the level of the perched water table. Maintenance of tilth and fertility are minor management needs. (Capability unit IIIw-1)

Bixby Series

The Bixby series consists of nearly level to moderately steep, well-drained, loamy soils that are moderately deep over sand or sand and gravel. These soils formed in 24 to 36 inches of loamy sediment and the underlying coarser textured material. They are in 5-acre to 15-acre areas on circular hills; in 20-acre to 200-acre areas on broad, gently undulating outwash plains; and in 3-acre to 20-acre tracts on the side slopes of hills associated with the less sloping areas. Areas of these soils on circular hills near the eastern and northern edges of the Straight River are commonly underlain by sand. The native vegetation was principally oak and brush.

In a representative profile, the surface layer is very dark grayish-brown loam about 4 inches thick. The subsurface layer is dark grayish-brown loam about 3 inches thick. The subsoil is about 27 inches thick. It is dark-brown, brown, and dark yellowish-brown silty clay loam, clay loam, and sandy clay loam in the upper 18 inches, and it is dark reddish-brown loamy sand in the lower part. The upper 13 inches of the underlying material is brown and dark-brown loamy sand. Below a depth of about 47 inches, the material is calcareous, yellowish-brown and light olive-brown sand and gravelly coarse sand.

Permeability is moderate to a depth of about 25 inches and rapid below that depth. Runoff is slow to rapid, depending on the slope. The water table is below a depth of 10 feet. The available water capacity is moderate. The organic-matter content is moderate in uneroded areas and low in eroded areas. Natural fertility is medium.

These soils are moderately well suited to most of the crops commonly grown in the county. Most areas are used for cultivated crops, but some of the more sloping areas are wooded. Moderate available water capacity, the hazards of soil blowing and water erosion, and the poor tilth of the surface layer are the principal concerns of management. In areas where a seedbed has been prepared, this soil tends to slake and settle on wetting and to crust on drying.

Representative profile of Bixby loam, 2 to 6 percent slopes, in Havana Township, in the southeast corner of SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 1, T. 107 N., R. 19 W.:

A1—0 to 4 inches, very dark grayish-brown (10YR 3/2) loam, grayish brown (10YR 5/2) when dry; moderate, fine, subangular blocky structure; friable; neutral; abrupt, smooth boundary.

A2—4 to 7 inches, dark grayish-brown (10YR 4/2) loam; moderate, medium, platy structure; many small

tubules; friable; slightly acid; clear, irregular boundary.

B1—7 to 12 inches, dark-brown (10YR 4/3) silty clay loam; faces of peds dark grayish brown (10YR 4/2), light brownish gray (10YR 6/2) when dry; moderate, fine and medium, angular blocky structure; friable; faces of peds are porous; medium acid; abrupt, wavy boundary.

B21—12 to 17 inches, brown (10YR 4/3) clay loam; faces of peds dark grayish brown (10YR 4/2); moderate, fine and medium, angular blocky structure; friable; faces of peds are porous; medium acid; abrupt, wavy boundary.

B22t—17 to 22 inches, dark yellowish-brown (10YR 4/4) clay loam; faces of peds dark yellowish brown (10YR 3/4); moderate and strong, fine and medium, angular blocky structure; friable to firm; many thin clay films on faces of peds; strongly acid; abrupt, wavy boundary.

B31t—22 to 25 inches, brown (7.5YR 4/4) sandy clay loam; weak, medium and coarse, subangular blocky structure; friable; common, thin, patchy clay films on faces of peds; strongly acid; clear, wavy boundary.

IIB32t—25 to 34 inches, dark reddish-brown (5YR 3/2) loamy sand; weak, coarse, subangular blocky structure; very friable; common clay bridges between sand grains; slightly acid; abrupt, wavy boundary.

IIC1—34 to 47 inches, variegated brown (7.5YR 4/4) and dark-brown (7.5YR 3/2) loamy sand with thin bands of sandy loam; weak, coarse, subangular blocky structure; very friable; slightly acid; abrupt, wavy boundary.

IIC2—47 to 60 inches, yellowish-brown (10YR 5/4 and 5/6) sand; single grain; loose; few fine pebbles; calcareous; mildly alkaline; abrupt, wavy boundary.

IIC3—60 to 65 inches, light olive-brown (2.5Y 5/4) gravelly coarse sand; single grain; loose; calcareous; mildly alkaline.

The A1 horizon is commonly loam but, in some places, is silt loam that has a high content of sand. Structure in this horizon is moderate, fine, subangular blocky or fine granular. The A2 horizon is dark grayish-brown or grayish-brown loam or silt loam 2 to 4 inches thick. Reaction is slightly acid or medium acid. The A1 and A2 horizons are incorporated into an Ap horizon in cultivated areas. The Ap horizon is dark grayish-brown or very dark grayish-brown loam or silt loam about 7 inches thick. Cultivated fields in many places have a weakly cloddy Ap horizon. In fields under long-time cultivation, this layer is medium acid.

The B1 and B2 horizons are commonly silty clay loam or clay loam but range to heavy silt loam or loam. Combined thickness of these horizons ranges from 12 to 24 inches. The B31t horizon does not occur in all areas of these soils. The combined thickness of the B31t and IIB32t horizons ranges from 5 to 25 inches. These horizons are hard and cohesive when dry and sticky when wet.

The IIC1 horizon is absent in some profiles. The Bixby soils on circular sandhills have a IIC horizon that consists only of sand. The lime in the IIC horizon is in the form of soft masses, concretions, threads, and coatings on the particles of gravel.

The Bixby soils have a thinner A1 horizon or a lighter colored Ap horizon than the similar Wadena and Waukegan soils. They have more clay in the B horizon than the Wadena soils, and they have more sand and clay in the B horizon than the Waukegan soils. They have more clay in the B horizon than the similar Lamont soils.

Bixby loam, 0 to 2 percent slopes (B/A).—This soil occupies 3-acre to 50-acre tracts. The smaller tracts are on the tops of circular sandhills. The larger tracts are associated with more sloping Bixby soils. This soil has a profile similar to that described as representative for the series, except that in cultivated areas the original surface and subsurface layers have been mixed together so that the present surface layer is very dark grayish brown or dark grayish brown.

This is a moderately droughty soil. Runoff is slow. Most areas are used for cropland. Soil blowing is a hazard in the larger areas. (Capability unit IIs-1)

Bixby loam, 2 to 6 percent slopes (BIB).—This soil occupies 3-acre to 200-acre tracts. The smaller tracts are on the side slopes of circular sandhills. The larger tracts occur in outwash areas. Slopes range from 50 to 125 feet in length. This soil has the profile described as representative for the series, but in cultivated areas the original surface and subsurface layers are mixed together and the present surface layer is very dark grayish brown or dark grayish brown.

The larger tracts of this soil are crossed by drainage-ways of a poorly developed drainage net. These drainage-ways are occupied by Kato, Hayfield, or Udolpho soils and were included in mapping.

This soil is moderately droughty. Runoff is medium, and water erosion is a hazard. Most of the acreage is used for crops, but some areas are wooded. (Capability unit IIe-4)

Bixby loam, 2 to 6 percent slopes, eroded (BIB2).—This soil occupies 3-acre to 200-acre tracts. The smaller tracts are on the side slopes of circular sandhills, and the larger ones are in outwash areas. Slopes range from 50 to 125 feet in length. This soil has a profile similar to that described as representative for the series, except that erosion, deep tillage, and removal of trees have mixed part of the brown subsoil with the remaining original surface layer. The resulting surface layer is browner and less friable than the original one. In some places the present surface layer is mostly brown material from the subsoil.

The larger areas of this soil are crossed by drainage-ways of a poorly developed drainage net. These drainage-ways are occupied by Kato, Hayfield, or Udolpho soils, which were included in mapping.

This Bixby soil is moderately droughty. Runoff is medium, and water erosion is a hazard. The content of organic matter is lower than in uneroded Bixby soils. Most of the acreage is used for crops. (Capability unit IIe-4)

Bixby loam, 6 to 12 percent slopes, eroded (BIC2).—This soil occupies 3-acre to 20-acre tracts that commonly lie below areas of less sloping Bixby soils. A few areas are small, irregularly shaped hills that are associated with the loamy upland soils. Slopes range from 50 to 100 feet in length. This soil has a profile similar to that described as representative for the series, except that erosion, deep tillage, and tree removal have mixed the original surface layer with part of the brown subsoil. The resulting surface layer is browner and less friable than the original one. In some places the present surface layer is chiefly material from the brown subsoil.

Included in mapping were some areas of uneroded Bixby soils.

This soil is moderately droughty. Runoff is medium, and there is a severe hazard of water erosion. The organic-matter content is lower than in uneroded Bixby soils. Most of the areas are used for crops, but a few are wooded. (Capability unit IIIe-4)

Bixby loam, 12 to 18 percent slopes, eroded (BID2).—This soil occupies 3-acre to 10-acre tracts that are on side slopes below areas of less sloping Bixby soils. Slopes

range from 50 to 100 feet in length. This soil has a profile similar to that described as representative for the series, except that its layers are somewhat thinner. In addition, erosion, deep tillage, and tree removal have mixed the original surface layer with part of the brown subsoil. The resulting surface layer is browner and less friable than the original one. In some places the surface layer is mostly material from the brown subsoil.

Included in mapping are some areas of uneroded soils and a few small areas of soils having slopes of 18 to 25 percent. Also included are a few small tracts of Burnsville soils.

This soil is moderately droughty. Runoff is rapid. The hazard of water erosion is very severe. The organic-matter content is lower than in uneroded Bixby soils. Most of the areas are used for crops, but some are wooded. (Capability unit IVe-2)

Blooming Series

The Blooming series consists of deep, gently undulating to rolling, well-drained, loamy soils that formed in a silty mantle and the underlying friable, loamy glacial drift. The native vegetation was oak and brush. The thickest stands of timber were near Rice and Oak Glen Lakes.

In a representative profile, the surface layer is very dark brown silt loam about 8 inches thick. This layer dries to a dark-gray color. The subsoil is about 40 inches thick. The upper 11 inches is brown silt loam that grades to dark yellowish-brown, friable loam. Sand content increases with depth. The middle 6 inches is yellowish-brown sandy clay loam. The lower part of the subsoil, about 23 inches thick, is light olive-brown, friable loam. The underlying material is calcareous, light olive-brown, friable loam.

Permeability is moderate, and runoff is medium. The available water capacity is high. The water table is at a depth below 10 feet. Organic-matter content and fertility are high.

These soils are well suited to the commonly grown crops, and most areas are used for crops. A few areas remain in trees or woodland pasture. Control of erosion and maintenance of fertility and tilth are the principal management needs.

Representative profile of Blooming silt loam, 2 to 6 percent slopes, eroded, in Blooming Prairie Township, in the northwest corner of SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 105 N., R. 19 W.:

Ap—0 to 8 inches, very dark brown (10YR 2/2) silt loam, dark gray (10YR 4/1) when dry; cloddy; friable; slightly acid; abrupt, smooth boundary.

B21t—8 to 15 inches, brown (10YR 4/3) silt loam; dark grayish-brown (10YR 4/2) ped faces; moderate, fine, sub-angular blocky structure; friable; few thin clay films on faces of peds; few, thin, porous coatings on faces of peds; slightly acid; clear, wavy boundary.

B22t—15 to 19 inches, dark yellowish-brown (10YR 4/4) loam; brown (10YR 4/3) ped faces; moderate, fine, sub-angular blocky structure; friable; few thin clay films on faces of peds; medium acid; clear, wavy boundary.

IIB23t—19 to 25 inches, yellowish-brown (10YR 5/4) sandy clay loam; brown (10YR 4/3) ped faces; weak, medium, prismatic structure parting to weak, medium,

subangular blocky; friable; few clay fillings in pores; medium acid; clear, wavy boundary.

IIB24t—25 to 35 inches, light olive-brown (2.5Y 5/4) loam; weak, medium, prismatic structure; friable; few clay fillings in pores and few thin clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.

IIB3t—35 to 48 inches, light olive-brown (2.5Y 5/4) loam; few, fine, prominent, dark-brown (7.5YR 4/4) mottles; weak, medium and coarse, prismatic structure; friable; few clay fillings in pores; about 4 percent coarse fragments; slightly acid; abrupt, wavy boundary.

IIC—48 to 60 inches, light olive-brown (2.5Y 5/4) loam; few, fine, prominent, dark-brown (7.5YR 4/4) mottles; massive; friable; about 4 percent coarse fragments; calcareous; mildly alkaline.

The Ap horizon ranges from very dark brown to very dark grayish brown in color. Its texture is commonly silt loam but in places is loam that has a high content of silt. Thickness of the Ap horizon ranges from 4 to 8 inches. An A2 horizon is present in uncultivated areas. It is dark grayish brown or very dark grayish brown and ranges from 1 to 4 inches in thickness. This horizon commonly remains in cultivated fields in the area of Rice and Oak Glen Lakes but has been incorporated into the plow layer over most of the acreage of these soils. Structure of the A2 horizon is weak, thin and medium, platy, and reaction is slightly acid to medium acid.

The B21t and B22t horizons are silt loam, silty clay loam, or loam that is high in content of silt. They are 6 to 16 inches in combined thickness. The IIB23t horizon is variable in texture, ranging from loam or sandy clay loam to sandy loam, loamy sand, or sand. It is 2 to 16 inches thick. In some places there are some pebbles, stones, or cobblestones in this horizon. The rest of the IIB horizon is loam, sandy clay loam, or clay loam and is 15 to 30 inches thick. There are porous grayish coatings on the faces of the prisms in some places, and these are pronounced in areas where the A2 horizon is thickest and where the Ap or A1 horizon is grayer.

The IIC horizon is loam or clay loam.

The Blooming soils have a thinner A1 horizon than the similar Moland soils and lack the dark-colored A3 horizon of those soils. The Blooming soils developed in multiple glacial materials, whereas the similar Lester soils developed almost entirely in glacial till. Blooming soils are not so poorly drained as the Havana, Maxcreek, and Newry soils.

Blooming silt loam, 2 to 6 percent slopes, eroded (BoB2).—This undulating soil occupies 3-acre to 80-acre tracts in uplands and is associated with Newry and Merton soils. This soil has the profile described as representative for the series.

Included in mapping are some areas of uneroded soils. Near Rice Lake and Oak Glen Lake, the surface layer is grayer and has poorer tilth than that in most areas of Blooming soils. West-facing, convex slopes have a loamy mantle and a few cobblestones on the surface in some places. In some areas the convex knobs have a gravelly layer on the underlying drift. In some places there are small sand and gravel beds at a depth below 6 feet.

Runoff is medium. The hazard of erosion is moderate. Most of the areas are used for crops, but a few remain in trees or woodland pasture. (Capability unit IIE-1)

Blooming silt loam, 6 to 14 percent slopes, eroded (BoC2).—This sloping soil occupies 3-acre to 20-acre upland tracts. It has a profile similar to that described as representative for the series, except that in some areas the present surface layer is material from the mostly brownish subsoil.

Included in mapping are some uneroded areas. Also included are a few areas where slopes are between 18 and 25 percent. There are a few cobblestones on the surface of some eroded slopes.

Runoff is medium. The hazard of erosion is severe. Most areas of this soil are used for crops, but a few remain in trees or woodland pasture. (Capability unit IIIe-1)

Burnsville Series

The Burnsville series consists of gently sloping to sloping, somewhat excessively drained soils that are shallow over calcareous, stratified sand and gravel. These soils formed in 12 to 24 inches of loamy sediment and the underlying coarser textured material. Slopes are simple. The native vegetation was principally oak and brush.

In a representative profile, the surface layer is dark grayish-brown sandy loam about 7 inches thick. The subsoil, about 31 inches thick, is dark-brown and dark yellowish-brown, friable loam and sandy loam in the upper 17 inches. The lower part is dark yellowish-brown, loose gravelly coarse sand. The underlying material is calcareous, light olive-brown, loose gravelly coarse sand.

Permeability is moderate in the upper part of the subsoil and rapid at a depth below 24 inches. Runoff is slow to medium, and the water table is at a depth below 10 feet. The available water capacity is low, organic-matter content is moderate, and fertility is low to medium.

Most areas of these soils are used for crops, but some are wooded. These soils are poorly suited to corn and soybeans because of the low available water capacity. Also, water erosion and soil blowing are hazards.

Representative profile of Burnsville sandy loam, 2 to 6 percent slopes, in Blooming Prairie Township, 200 feet north of the southwest corner of SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 5, T. 105 N., R. 19 W.:

Ap—0 to 7 inches, dark grayish-brown (10YR 4/2) sandy loam; weak, fine, subangular blocky structure and some platy structure; very friable; medium acid; abrupt, smooth boundary.

B21t—7 to 13 inches, dark-brown (10YR 3/3) loam, dark yellowish brown (10YR 4/4) when rubbed; moderate, fine and medium, subangular blocky structure; friable, sticky; common thin clay bridges between sand grains; few clay films in pores; medium acid; clear, wavy boundary.

B22t—13 to 20 inches, dark-brown (10YR 3/3) gravelly sandy loam; weak, medium and coarse, subangular blocky structure; friable; medium acid; few thin films in pores and few thin clay bridges between sand grains; clear, wavy boundary.

B23t—20 to 24 inches, dark yellowish-brown (10YR 4/4) sandy loam; a few streaks of dark brown (7.5YR 4/4); weak, coarse, subangular blocky structure; very friable, sticky; few gravel particles; medium acid; abrupt, wavy boundary.

IIB3—24 to 38 inches, dark yellowish-brown (10YR 4/4) gravelly coarse sand; weak, coarse, subangular blocky structure; loose, sticky; slightly hard; slightly acid; clear, wavy boundary.

IIC—38 to 60 inches, light olive-brown (2.5Y 5/4) gravelly coarse sand; structureless (single grain); loose; calcareous; mildly alkaline.

The Ap horizon commonly is dark grayish brown or very dark grayish brown and dries to light grayish brown or grayish brown. Its texture is sandy loam or loam, and its thickness ranges from 6 to 9 inches. In uncultivated areas these soils have an A1 horizon that is 3 to 4 inches thick and an A2 horizon that is 2 to 3 inches thick. The A horizon is very friable or friable and slightly acid to medium acid.

The B2 horizon is sandy loam, gravelly sandy loam, or loam and is 6 to 18 inches thick. The content of clay is greater

than in the A horizon. There are porous grayish coatings on the faces of peds in the upper part of the B2 horizon in some profiles. Reaction is medium acid or strongly acid in the B2 horizon. The IIB3 horizon is gravelly loamy coarse sand, loamy coarse sand, coarse sand, or gravelly coarse sand and is 5 to 15 inches thick.

The IIC horizon is coarse sand or gravelly coarse sand. Calcium carbonate is present in this horizon as concretions, soft masses, and threads and as coatings on the gravel.

Burnsville soils have a thinner A1 horizon than the similar Estherville soils.

Burnsville sandy loam, 2 to 6 percent slopes (BuB).—This soil occupies 3-acre to 80-acre tracts. The smaller tracts are associated with the loamy Bixby, Hayden, and Lester soils. The larger tracts are primarily associated with Bixby soils. This soil has the profile described as representative for the series.

Included in mapping are some areas where part of the brownish subsoil has been mixed with the original surface layer. The broader areas are crossed by drainageways of a poorly developed drainage net. These drainageways are occupied by Hayfield, Kato, or Udolpho soils, which are included. Salida soils are included on some of the small convex knobs.

This soil is droughty. Runoff is slow. Soil blowing and water erosion are hazards. Most of the acreage is used for crops, but a few areas are in woodland. (Capability unit IIIe-3)

Burnsville sandy loam, 6 to 12 percent slopes (BuC).—This soil occupies 3-acre to 20-acre tracts. It occurs below areas of less sloping Burnsville or Bixby soils and is associated with Hayden and Lester soils.

Included in mapping are some areas where part of the brownish subsoil has been mixed with the original surface layer. Salida soils are included on a few of the small convex knobs.

This soil is droughty. Runoff is medium. Soil blowing and water erosion are moderate hazards. Most of the acreage is used for crops, but some areas are wooded. (Capability unit IVe-2)

Calco Series

The Calco series consists of deep, nearly level, very poorly drained, silty soils that formed in silty alluvium. These soils occupy seepy bottom lands. The native vegetation was water-tolerant grasses, shrub willow, and sedges.

In a representative profile, the surface layer is calcareous silty clay loam about 36 inches thick. The upper part is black, and the lower part is very dark gray. The subsoil is dark olive-gray silty clay loam that is about 10 inches thick and contains olive-gray mottles. The underlying material is dark greenish-gray, calcareous silty clay loam.

Permeability is moderately slow in drained areas. Runoff is slow to ponded. The water table is at a depth of 1 to 3 feet or where the soils are drained, near tile depth. The available water capacity is high. Organic-matter content and fertility are high.

Most areas are idle or are used as native pasture. Calco soils are naturally too wet for most cultivated crops presently grown in the county.

Representative profile of Calco silty clay loam, very wet, in Summit Township, 600 feet east of the north-west corner of SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 13, T. 105 N., R. 20 W.:

Ap—0 to 6 inches, black (N 2/0) silty clay loam; weak, fine, granular structure; slightly plastic; calcareous; mildly alkaline; gradual, wavy boundary.

A1—6 to 16 inches, black (N 2/0) silty clay loam; weak, fine, granular structure; plastic; calcareous; mildly alkaline; gradual, wavy boundary.

A3—16 to 36 inches, very dark gray (5Y 3/1) silty clay loam; common strong-brown (7.5YR 5/8) coatings along root channels; weak, fine, granular structure; plastic; calcareous; mildly alkaline; gradual, wavy boundary.

Bg—36 to 46 inches, dark olive-gray (5Y 3/2) silty clay loam; many, medium, faint, olive-gray (5Y 4/2) mottles; common light olive-brown (2.5Y 5/4) coatings along root channels; massive; plastic; neutral; gradual, wavy boundary.

Cg—46 to 60 inches, dark greenish-gray (5GY 4/1) silty clay loam; massive; plastic; calcareous; mildly alkaline.

The Ap and A1 horizons are silty clay loam or heavy silt loam and have a combined thickness of 14 to 24 inches. Their structure is weak, fine, granular or subangular blocky. The A3 horizon is silty clay loam or heavy silt loam and is 15 to 25 inches thick. Its structure is weak, fine, granular or subangular blocky. The Bg horizon is dark olive gray, olive gray, or olive and contains mottles. It is silty clay loam, clay loam, silt loam, or loam and is 10 to 20 inches thick. Reaction is mildly alkaline or neutral. The Cg horizon is dark greenish gray or dark gray. Its texture is commonly silty clay loam but ranges to clay loam or loam. There are thin seams of sand or sand and gravel in some places.

Calco soils are associated on the landscape with Colo soils and Alluvial land. Calco soils have lime in the A horizon, but the similar Colo soils lack lime in the A horizon.

Calco silty clay loam, very wet (0 to 1 percent slopes) (Cc).—This nearly level soil is on bottom lands along streams.

This is a very wet soil. It has a constant high water table and is subject to flooding. The surface generally is hummocky or boggy. Extensive outlet development or installation of pumps and dikes is needed to make this soil suitable for commonly grown crops. Most of the areas are idle or are used as native pasture. (Capability unit VIw-1)

Canisteo Series

The Canisteo series consists of deep, nearly level, poorly drained, calcareous soils that formed in silty and loamy glacial drift. These soils occupy broad upland tracts, shallow draws, and rims of depressions and drainageways. The native vegetation was water-tolerant grasses and sedges.

In a representative profile, the surface layer is calcareous clay loam about 20 inches thick. The upper part of this layer is black, and the lower part has mixed colors of very dark gray, black, and dark gray. The subsoil is dark-gray to olive-gray, calcareous, friable clay loam about 11 inches thick. The underlying material is mottled olive-gray and olive, calcareous, friable clay loam.

Permeability is moderate in drained areas. Runoff is slow to ponded. The water table is at a depth of 0 to 3 feet or near tile depth in drained areas. The available water capacity is high. The organic-matter content and fertility are high.

In their natural state, these soils are only moderately well suited to poorly suited to crops grown in the county.

If adequately drained, they are well suited to most crops common in the county, and most areas are used for cropland. Special fertility treatments are beneficial for most crops because of the high concentration of lime carbonates.

Representative profile of Canisteo clay loam, in Owatonna Township, 400 feet west and 100 feet south of the northeast corner of sec. 24, T. 107 N., R. 20 W.:

- Ap—0 to 10 inches, black (N 2/0) clay loam; very dark gray (10YR 3/1) when dry; weak, fine, subangular blocky structure; friable; about 2 percent coarse fragments; calcareous; mildly alkaline; abrupt, smooth boundary.
- A1—10 to 13 inches, black (N 2/0) clay loam; weak, very fine, subangular blocky structure; friable; about 2 percent coarse fragments; calcareous; mildly alkaline; clear, irregular boundary.
- A3g—13 to 20 inches, very dark gray (10YR 3/1) clay loam; few tongues of black (N 2/0) and dark gray (10YR 4/1); weak, very fine, subangular blocky structure; friable; about 2 percent coarse fragments; calcareous; mildly alkaline; gradual, irregular boundary.
- B21g—20 to 24 inches, dark-gray (10YR 4/1) clay loam; common, fine, faint, dark grayish-brown (2.5Y 4/2) mottles; few tongues of very dark gray (10YR 3/1) and grayish brown (10YR 5/2); weak, very fine, subangular blocky structure; friable; about 2 percent coarse fragments; calcareous; mildly alkaline; clear, wavy boundary.
- B22g—24 to 31 inches, olive-gray (5Y 5/2) clay loam; weak, fine, subangular blocky structure; friable; about 2 percent coarse fragments; calcareous; mildly alkaline; clear, wavy boundary.
- Cg—31 to 60 inches, olive-gray (5Y 5/2) and olive (5Y 5/3) clay loam; few, fine, distinct, light olive-brown (2.5Y 5/6) mottles; massive; friable; about 2 percent coarse fragments; calcareous; mildly alkaline.

The Ap and A1 horizons are black when moist but are very dark gray or dark gray when wet. The profiles with the dark-gray color have a higher content of lime than those with the very dark gray color. Texture of these horizons commonly is clay loam or silty clay loam, but it ranges to loam. Structure is weak, very fine or fine, granular or subangular blocky. Thickness of these horizons ranges from 10 to 20 inches. The A3 horizon is loam, clay loam, or silty clay loam and ranges from 4 to 8 inches in thickness. Calcium carbonate equivalent ranges from 5 to 15 percent in the A horizon.

The B horizon is dark gray, dark grayish brown, olive gray, or grayish brown in color. In most places these soils are loam or clay loam in the B horizon. In other places, however, they are silt loam or silty clay loam in the upper part of the B horizon; loam in the middle part; and sand with some gravel, loamy sand, sandy loam, sandy clay loam, or loam in the lower part. Horizons having a texture coarser than loam are 1 to 20 inches thick, are commonly about 4 inches thick, and are massive in places. The B horizon commonly is mildly alkaline and calcareous, but in some areas the lower part of the B horizon is neutral and noncalcareous. Calcium carbonate equivalent ranges from 0 to 15 percent and is commonly about 15 percent in the B horizon.

The C horizon is loam or clay loam. It is massive or has weak, subangular blocky structure. Calcium carbonate equivalent is 10 to 25 percent.

The Canisteo soils have lime in the A horizon, but the associated Maxcreek and Webster soils lack lime in that horizon.

Canisteo silty clay loam (0 to 2 percent slopes) (Cc).—This soil occupies 3-acre to 10-acre tracts on rims of depressions and swales and on slight rises that are within and adjacent to areas of Maxcreek soils. This soil has a profile similar to the one described as representative for the series, except that the surface layer is silty clay loam and in most areas a coarser textured layer separates the silty material from the underlying glacial drift.

Included in mapping are small tracts of Maxcreek soils, particularly those that have a calcareous surface layer.

This soil is wet. Depth to the water table ranges from 1 to 3 feet in undrained areas. Drainage is needed if this soil is to be dependable for crops. Tile drainage effectively controls the perched water table. This soil has a high concentration of lime carbonates. Concentrations generally are greatest on rims of depressions and are lower in the broad, nearly level tracts. The content of lime carbonate exceeds 15 percent on a few rims and rises. Most of the acreage is used for crops. (Capability unit IIw-2)

Canisteo silty clay loam, depressional (Cd).—This soil occupies 10-acre to 20-acre areas in long, winding, low-gradient drainageways. It has a profile similar to the one described as representative for the series, except that the surface layer is silty clay loam and in a few areas there is a thin mat of organic material on the surface. In many areas a coarser textured layer separates the silty material from the underlying glacial drift.

Included in mapping are small areas of Maxcreek silty clay loam, swales, particularly those where the surface layer is calcareous. The flat areas near Havana station and southwest of Hope have inclusions in which a thick sandy substratum is near a depth of 5 feet. Along the eastern edge of the county, stones are at the surface of the underlying loam in a few places.

This soil is very wet. Depth to the water table ranges from the surface to 3 feet in undrained areas. Drainage is needed if this soil is to be dependable for crops. This soil contains a high concentration of lime carbonates. Accumulations are commonly lower in the depressions than on adjacent rims, and a high percentage is remnants of snail shells. Most of the acreage is used for crops. (Capability unit IIIw-3)

Canisteo clay loam (0 to 2 percent slopes) (Ce).—This nearly level soil occupies 10-acre to 100-acre tracts. It has the profile described as representative for the series.

Included in mapping are small tracts of Webster soils, particularly those having a calcareous surface layer.

This soil is wet. Depth to the water table ranges from 1 to 3 feet in undrained areas. Drainage is needed if this soil is to be dependable for crops. Tile drainage effectively controls the perched water table. This soil has a high concentration of lime carbonates. Concentrations generally are greatest on rims of depressions and are lower in the broad, nearly level tracts. The content of lime carbonate exceeds 15 percent on a few rims and rises. Most of the acreage is used for crops. (Capability unit IIw-2)

Canisteo clay loam, depressional (Cf).—This soil occupies 3-acre to 5-acre depressions and 5-acre to 30-acre areas in long, winding, low-gradient drainageways. It has a profile similar to that described as representative for the series, except that there is a thin mat of organic material on the surface in some areas.

Included in mapping are small areas of a Glencoe soil, especially in the center of the depressions.

This Canisteo soil is very wet. Depth to the water table ranges from the surface to 3 feet in undrained areas. Drainage is needed if this soil is to be dependable for crops. This soil has a high concentration of lime

carbonates. Accumulations commonly are lower in the depressions than on adjacent rims, and a higher percentage is remnants of snail shells. Most of the acreage is used for crops. (Capability unit IIIw-3)

Chelsea Series

The Chelsea series consists of deep, gently sloping to moderately steep, excessively drained, sandy soils. These soils formed in sandy sediment in which sand commonly is medium and fine. They occupy 5-acre to 15-acre side slopes and circular sandhills within the loamy glacial uplands. The native vegetation was oak and brush.

In a representative profile, the surface layer is dark grayish-brown loamy fine sand about 8 inches thick. The subsoil, about 38 inches thick, is brown and yellowish-brown sand interlayered with $\frac{1}{8}$ - to $\frac{1}{4}$ -inch, wavy bands of dark-brown loamy sand and sandy loam. The underlying material is pale-brown, loose sand.

Permeability is rapid. Runoff is slow to medium, depending on slope. The water table is below a depth of 10 feet. The available water capacity is very low or low. The organic-matter content and fertility are low.

These soils generally are farmed with other soils in the field. The very low to low available water capacity, the low fertility, and the hazard of soil blowing are major limitations for crop production. These soils are better suited to permanent vegetation, especially conifers, than to crops that require cultivation.

Representative profile of Chelsea loamy fine sand, 2 to 18 percent slopes, in Owatonna Township, in the SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 16, T. 107 N., R. 20 W.:

- Ap—0 to 8 inches, dark grayish-brown (10YR 4/2) loamy fine sand; single grain; loose; medium acid; abrupt, smooth boundary.
- B21—8 to 14 inches, brown (10YR 5/3) and yellowish-brown (10YR 5/4) sand; a few, wavy, nearly horizontal bands of dark-brown (7.5YR 3/4) loamy sand $\frac{1}{4}$ inch thick; structureless (single grain); loose between the bands; bands are weakly coherent; medium acid; clear, wavy boundary.
- B22—14 to 27 inches, brown (10YR 5/3) and yellowish-brown (10YR 5/4) sand; few wavy bands of dark-brown (7.5YR 3/4) sandy loam; single grain; loose between the bands; bands are weakly coherent; they are more numerous than in the horizons above and below and are mostly $\frac{1}{8}$ to $\frac{1}{4}$ inch thick; medium acid; clear, wavy boundary.
- B23—27 to 46 inches, brown (10YR 5/3) and yellowish-brown (10YR 5/4) sand; few wavy bands of dark-brown (7.5YR 3/4) sandy loam; single grain; loose between the bands; bands are slightly coherent; they are mostly $\frac{1}{8}$ to $\frac{1}{4}$ inch thick; medium acid; clear, wavy boundary.
- C—46 to 72 inches, pale-brown (10YR 6/3) sand; few yellowish-brown (10YR 5/4) streaks; single grain; loose; slightly acid.

The Ap horizon is dark grayish brown or brown in color and ranges from 6 to 9 inches in thickness. Its reaction is medium acid to slightly acid. The B horizon ranges from 35 to 50 inches in thickness. The bands in this horizon range from sand or fine sand, each high in content of clay, to loamy sand, loamy fine sand, sandy loam, or fine sandy loam. The rest of this horizon is sand or fine sand. The bands are mostly $\frac{1}{8}$ to $\frac{1}{4}$ inch thick but in places are as much as 2 inches thick. These bands are most common at a depth between 14 and 48 inches and have a total thickness of about 6 to 8 inches. In places there is a 2- to 3-inch horizon of sandy

loam just below the Ap horizon. The C horizon is sand or fine sand. Its reaction is slightly acid or neutral.

The Chelsea soils have a thinner and lighter colored A horizon than the similar Sparta soils, which also lack bands in the B horizon. Chelsea soils have a B horizon in the form of bands, whereas the similar Lamont soils have a B horizon that is continuous vertically.

Chelsea loamy fine sand, 2 to 18 percent slopes (ChD).—This soil occupies 10-acre to 40-acre sandhills. Its upper layers commonly are disturbed by rodent burrowings. It is associated with the Hayden and Lester soils and, in places, with the Lamont soils. This is the only Chelsea soil mapped in the county.

Included in mapping are a few areas where slopes are between 18 and 25 percent. Soil blowing has removed part or all of the original surface layer on these steeper slopes.

This soil is droughty, and it also is susceptible to soil blowing and water erosion. Some areas are cultivated with associated soils, but this soil is better suited to permanent vegetation than to crops that require cultivation. (Capability unit VI1-1)

Clarion Series

The Clarion series consists of deep, gently undulating to moderately steep, well-drained, loamy soils that formed in loamy glacial till. These soils are in the uplands on knolls and on the side slopes of hills. In places they have a thin mantle of sandy loam. Some areas of these soils are so intermingled with areas of Storden soils that it was impractical to separate them, and these areas were mapped as complexes. The native vegetation was tall prairie grass and a few thin stands of oak or brush.

In a representative profile, the surface layer is very dark brown and dark-brown loam about 11 inches thick. The subsoil, about 25 inches thick, is dark yellowish-brown and brown, friable loam in the upper 15 inches. The lower part is grayish-brown and light olive-brown loam. The underlying material is calcareous, grayish-brown and light olive-brown, friable loam.

Permeability is moderate. Runoff is medium to rapid, depending on slope. The water table is at a depth below 10 feet. The available water capacity is high. The organic-matter content commonly is high but is lower in eroded areas. Fertility is high.

Most areas of these soils are used for crops and are well suited to this use. A few areas are in trees or permanent pasture. The hazard of erosion is the main limitation.

Representative profile of Clarion loam, 2 to 6 percent slopes, in Owatonna Township, in the southwest corner of SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 12, T. 107 N., R. 20 W.:

- Ap—0 to 8 inches, very dark brown (10YR 2/2) loam; weak, medium, subangular blocky structure; friable; about 2 percent coarse fragments; slightly acid; abrupt, smooth boundary.
- A3—8 to 11 inches, dark-brown (10YR 3/3) loam; moderate, fine and medium, subangular blocky structure; friable; about 2 percent coarse fragments; slightly acid; clear, wavy boundary.
- B21—11 to 16 inches, brown (10YR 4/3) loam, dark yellowish brown (10YR 4/4) when rubbed; moderate, fine and medium, subangular blocky structure; friable; about 2 percent coarse fragments; slightly acid; clear, wavy boundary.

- B22—16 to 26 inches, dark yellowish-brown (10YR 4/4) loam, brown (10YR 5/3) when rubbed; moderate, fine and medium, subangular blocky structure; friable; about 2 percent coarse fragments; slightly acid; clear, wavy boundary.
- B3—26 to 36 inches, light olive-brown (2.5Y 5/4) and grayish-brown (2.5Y 5/2) loam; weak, coarse, prismatic structure; about 2 percent coarse fragments; neutral; abrupt, wavy boundary.
- C—36 to 60 inches, light olive-brown (2.5Y 5/4) and grayish-brown (2.5Y 5/2) loam; massive; friable; about 2 percent coarse fragments; calcareous; mildly alkaline.

The Ap or A1 horizon is black, very dark brown, or very dark gray in color and ranges from loam to light clay loam in texture. It ranges from 7 to 12 inches in thickness. Reaction is slightly acid or medium acid. The A3 horizon is dark brown or very dark brown and ranges from loam to light clay loam. It is 3 to 6 inches thick. Structure is weak or moderate, medium to very fine, subangular blocky or is weak, fine, granular. Reaction is slightly acid or medium acid.

The B2 horizon is dark brown, brown, or dark yellowish brown in color and is loam or light clay loam in texture. It ranges from 15 to 30 inches in thickness. Structure is weak or moderate, fine or medium, subangular blocky. Reaction is slightly acid or medium acid in the upper part and is commonly neutral in the lower part.

The C horizon is grayish-brown, light olive-brown, or yellowish-brown loam.

Clarion sandy loams in this county have a texture of sandy loam in the A1 or Ap horizon and, in some profiles, in the A3 horizon. Such soils have weakly developed structure in these horizons and are coarser textured in these horizons than the defined range for the series, but this difference does not alter the usefulness or behavior of the soils.

The Clarion soils have an A3 horizon rather than an A2 horizon that is in the similar Lester soils. They have more sand and less silt in the A horizon and in the upper part of the B horizon than the similar Moland soils. They have a B horizon, whereas the associated Storden soils lack a B horizon. Free carbonates are leached to a depth of 2 feet or more in the Clarion soils, but in the Storden soils they occur in all horizons.

Clarion sandy loam, 2 to 6 percent slopes, eroded (Ck2).—This gently undulating soil occupies 5-acre to 10-acre knolls associated with Clarion loam. Slopes are 80 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that the upper layers are sandy loam and soil blowing and water erosion have removed much of the original surface layer. In cultivated areas the surface layer is more brownish and is lower in content of organic matter than in noncultivated areas.

Included in mapping are areas of soils that have a lighter colored surface layer because they developed under timber. Also included are a few areas of uneroded soils.

This soil is moderately droughty. Runoff is medium, and the hazards of soil blowing and water erosion are moderate. Most of this soil is used for crops, but a few areas are in trees. (Capability unit IIe-1)

Clarion loam, 2 to 6 percent slopes (C1B).—This soil occupies 5-acre to 20-acre knolls and rises. Slopes are convex and concave and are 75 to 150 feet long. This soil is associated with Nicollet and Webster soils, and in some places it occurs above more sloping Clarion soils. This soil has the profile described as representative for the series. The layers are thinner on the convex slopes.

Included in mapping are small areas of Nicollet soils. Narrow draws and small depressions are occupied by Webster and Glencoe soils. Some of these are identified on the soil map by symbols for drainageways or depres-

sions. A symbol for gravel spot identifies small pockets of gravel.

Runoff is medium. The hazard of erosion is slight. This soil is used mostly for crops and is well suited to this use. (Capability unit IIe-1)

Clarion loam, 2 to 6 percent slopes, eroded (C1B2).—This soil occupies 5-acre to 20-acre knolls and rises. Slopes are convex and concave and are 75 to 150 feet long. This soil is associated with Nicollet and Webster soils, and in some places it occurs above more sloping Clarion soils. This soil has a profile similar to that described as representative for the series, except that erosion and deep tillage have caused a mixing of the original dark-colored surface layer with part of the brownish subsoil. In a few areas the present surface layer consists mostly of material from the brownish subsoil. This layer is less friable and contains less organic matter than the original surface layer. Layers are thinner where slopes are convex.

Small areas of Nicollet soils are included. Webster and Glencoe soils are included in narrow draws and small depressions. Also included are small areas of Storden soils in areas where slopes are convex. A symbol for gravel spot on the soil map identifies small pockets of gravel.

Runoff is medium. The hazard of erosion is moderate. This soil is used mostly for crops. It is well suited to crops commonly grown in the county. (Capability unit IIe-1)

Clarion loam, 6 to 12 percent slopes, eroded (C1C2).—This soil occupies 5-acre to 30-acre knolls of irregular shape where slopes are concave and convex. It also is in 5-acre and 15-acre, irregularly shaped areas on hillsides. Slopes are 75 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that erosion and deep tillage have caused a mixing of the original dark-colored surface layer with part of the brownish subsoil. In a few areas the present surface layer is mostly material from the brownish subsoil. This layer is less friable and contains less organic matter than the original surface layer. The layers in this soil are thinner than typical and are thinnest where slopes are convex.

Included in mapping are some areas where the surface layer is sandy loam. In a few areas slopes are more than 12 percent. Also included, at the base of some slopes, are small areas of a soil that has a thicker surface layer than this Clarion soil. Narrow downslope drainageways and small depressions contain Webster and Glencoe soils. Also included are small areas of Storden soils and small pockets of gravel.

Runoff is medium. The hazard of erosion is moderate. Most of this soil is used for crops. (Capability unit IIIe-1)

Clarion-Storden complex, 6 to 12 percent slopes, eroded (Cs2C2).—This complex occupies 5-acre to 30-acre, irregularly shaped knolls where slopes are concave and convex (fig. 2). It is about 70 percent Clarion loam and 30 percent lighter colored Storden loam. These soils have profiles similar to those described as representative for their respective series. In the Clarion soil, however, erosion and deep tillage have caused a mixing of the original dark-colored surface layer with part of the brownish



Figure 2.—A recently cultivated field. Light-colored, calcareous Storden soils occupy the knoll in the background, dark-colored Clarion soils are adjacent to the Storden soils, and a nearly level Webster soil is in the narrow draw in the foreground.

subsoil. This layer is less friable and contains less organic matter than the original surface layer.

Included in mapping are a few areas where slopes are less than 6 percent and more than 12 percent. Also included, at the base of some slopes, are small areas of a soil that has a thickened surface layer. Small spots of gravel also are included.

Runoff is medium. The hazard of erosion is moderate. Temperature variations are greater on south- and west-facing slopes than on north- and east-facing slopes. Special fertility treatments are beneficial on the calcareous Storden soil. Most of this complex is used for crops. (Capability unit IIIe-1)

Clarion-Storden complex, 12 to 18 percent slopes, eroded (CsD2).—This complex occupies 5-acre to 30-acre areas of irregular shape on knolls and hillsides. Slopes are 75 to 150 feet long. The complex is about 70 percent Clarion loam and 30 percent lighter colored Storden loam. The Storden soil has convex slopes. Both soils have profiles similar to those described as representative for their respective series, but in the Clarion soil, erosion and deep tillage have caused a mixing of the original dark-colored surface layer with part of the brownish subsoil. This layer is less friable and contains less organic matter than the original surface layer.

Included in mapping are a few areas where slopes are less than 12 percent and more than 18 percent. Also included, at the base of many slopes, are small areas of a soil that has a thickened surface layer. Small gravelly spots are marked on the soil map by gravel-spot symbols.

Runoff is rapid. The hazard of erosion is severe. Temperature variations are much greater on south- and west-facing slopes than on slopes that face north and east. Special fertility treatments are beneficial on the calcareous Storden soil. Most of this complex is used for crops. (Capability unit IVe-1)

Colo Series

The Colo series consists of deep, nearly level, poorly drained, silty soils that formed in loamy alluvial deposits. These soils are on bottom lands. The native vegetation was water-tolerant grasses.

In a representative profile, the surface layer is black silty clay loam about 27 inches thick. Below this is a layer of mottled, very dark gray and gray, friable clay loam about 10 inches thick. The underlying material is mottled, gray, friable loam.

Permeability is moderately slow. Runoff is slow to ponded. The water table is at a depth of 1 to 4 feet. The available water capacity is high. Organic-matter content and fertility are high.

Many areas of these soils are used for crops, but some are in native grass that is pastured. If properly drained and protected from flooding, these soils are well suited to most crops grown in the county, especially corn and soybeans. Wetness and the hazard of flooding are the major limitations to their use.

Representative profile of Colo silty clay loam, occasionally flooded, in Meriden Township, 100 feet east and 10 feet south of the corner of NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 1, T. 107 N., R. 21 W.:

- Ap—0 to 7 inches, black (N 2/0) silty clay loam; cloddy; friable; neutral; abrupt, smooth boundary.
- A11—7 to 17 inches, black (N 2/0) silty clay loam; weak, fine, subangular blocky structure; friable; neutral; clear, wavy boundary.
- A12—17 to 27 inches, black (N 2/0) silty clay loam; weak, medium, subangular blocky structure; friable; neutral; clear, irregular boundary.
- ACg—27 to 37 inches, very dark gray (5Y 3/1) clay loam; few tongues of gray (5Y 5/1); few, fine, prominent, red (2.5YR 4/8) mottles; weak, fine, subangular blocky structure; friable; neutral; gradual, irregular boundary.
- Cg—37 to 60 inches, gray (5Y 5/1) loam; few tongues of black (10YR 2/1); few, fine, prominent, red (2.5YR 4/8) mottles; weak, fine, subangular blocky structure; friable; neutral.

The A1 horizon has a total thickness of 18 to 20 inches. The ACg horizon ranges from 6 to 20 inches in thickness. Tongues of black are in some profiles. The Cg horizon is loam, clay loam, or silty clay loam. Reaction is neutral to mildly alkaline. In some profiles the lower part of the Cg horizon contains lime.

Colo soils contain more silt and less sand than the similar Glencoe soils. Colo soils lack lime in the A horizon, whereas the similar Calco soils have lime in the A horizon. They contain more silt and less sand and are wetter than the similar Terril soils.

Colo silty clay loam, occasionally flooded (0 to 1 percent slopes) (Ct).—This soil occupies bottom lands adjacent to the smaller streams. Meander channels are few. This soil is occasionally flooded. It has the profile described as representative for the series.

Included in mapping are small areas of Calco and Terril soils and Alluvial land. Also included are some areas of soils that have a calcareous surface layer. In some places there is sand below a depth of 60 inches.

This Colo soil is wet. Depth to the water table ranges from 1 to 4 feet and is usually controlled by streamflow. Flooding occurs principally during spring snowmelt and occasionally during periods of high or extended rainfall in June and early in July. Some areas are tiled. Tile functions satisfactorily except when streams are at or near flood flow. Most of this soil is used for crops. (Capability unit IIw-1)

Colo silty clay loam, frequently flooded (0 to 1 percent slopes) (Cu).—This soil occupies bottom lands adjacent to stream channels, and it is frequently flooded. Meander channels are common.

Included in mapping are small areas of Calco soils and Alluvial land. Also included are some areas of soils that have a calcareous surface layer. In some places there is sand below a depth of 60 inches.

This Colo soil is wet. Depth to the water table ranges from 1 to 4 feet and is controlled by streamflow. Extensive development of outlet ditches is needed to make this soil suitable as cropland. Some of the acreage is used for crops, but much of it is in native grass pasture. (Capability unit VIw-1)

Dakota Series

The Dakota series consists of nearly level to sloping, well-drained, loamy soils that are moderately deep over sandy material. These soils formed in loamy sediments 24 to 36 inches thick and in the underlying sandy material. They occupy broad flats, narrow ridges, and short steep slopes within the glacial outwash plains and stream terraces. They also occur as small hills within the rolling uplands. Slopes are simple. The native vegetation was grass and a few thin stands of oak or brush.

In a representative profile, the surface layer is loam about 13 inches thick. The upper part is very dark brown, and the lower part is very dark grayish brown. The subsoil, about 23 inches thick, is brown and yellowish-brown loam and sandy clay loam in the upper 13 inches. The lower part of the subsoil is dark yellowish-brown loamy sand. The underlying material is light brownish-gray and pale-yellow, loose fine sand and coarse sand.

Permeability is moderate in the subsoil and rapid below a depth of about 28 inches. Runoff is slow to medium, depending on slope. The water table is at a depth below 10 feet. The available water capacity is moderate to low. The organic-matter content is high. Fertility is medium.

Most areas of these soils are used for crops. The soils are moderately well suited to that use. They are moderately droughty, and at times plant growth is limited by lack of available water. Droughtiness and the hazards of soil blowing and water erosion are the major limitations to use of these soils for crops.

Representative profile of Dakota loam, 2 to 6 percent slopes, in Merton Township, 200 feet southwest of the northeast corner of SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 28, T. 108 N., R. 19 W.:

- Ap—0 to 10 inches, very dark brown (10YR 2/2) loam; weak, fine, granular structure; very friable; slightly acid; abrupt, smooth boundary.
- A3—10 to 13 inches, very dark grayish-brown (10YR 3/2) loam; weak, fine, subangular blocky structure; very friable; slightly acid; abrupt, wavy boundary.
- B1t—13 to 18 inches, brown (10YR 4/3) loam; ped faces are dark brown (10YR 3/3); weak and moderate, fine and very fine, subangular blocky structure; friable; few thin clay films on sand grains; medium acid; clear, wavy boundary.
- B2t—18 to 26 inches, yellowish-brown (10YR 5/4) loam; ped faces are brown (10YR 4/3); moderate, fine, subangular blocky structure; friable; few thin clay films in pores and common clay bridges between sand grains; medium acid; abrupt, smooth boundary.
- B31—26 to 29 inches, yellowish-brown (10YR 5/4) sandy clay loam; ped faces are brown (10YR 4/3); moderate, medium, subangular blocky structure; friable; medium acid; abrupt, wavy boundary.

IIB32—29 to 36 inches, dark yellowish-brown (10YR 4/4) loamy sand; single grain; loose; few fine pebbles; medium acid; abrupt, wavy boundary.

IIC1—36 to 42 inches, light brownish-gray (10YR 6/2) fine sand; single grain; loose; slightly acid; abrupt, wavy boundary.

IIC2—42 to 60 inches, pale-yellow (2.5Y 7/4), stratified fine and coarse sand; single grain; loose; calcareous; mildly alkaline.

The Ap horizon and the A1 horizon, where present, range from very dark gray to very dark brown or black in color. Their texture ranges from sandy loam to loam, and their total thickness ranges from 7 to 12 inches. Structure commonly is weak, fine, granular but ranges to weak, fine, subangular blocky. Reaction is slightly acid or medium acid. The A3 horizon is very dark grayish brown, very dark brown, or dark brown and is sandy loam or loam. It is 3 to 8 inches thick. This horizon commonly is thicker in the Dakota sandy loams than in the Dakota loams. Reaction is slightly acid or medium acid.

The B1 and B2 horizons range from 10 to 25 inches in total thickness. Their texture is loam or sandy clay loam. The B31 horizon is sandy clay loam or sandy loam. Reaction ranges from slightly acid to medium acid in the B horizon.

The IIC horizon is yellowish brown or light brownish gray to pale yellow. It is mostly fine sand or sand, but this horizon is stratified with coarse sand in some profiles.

The Dakota soils have more clay in the B horizon than the similar Dickinson soils. They have finer sand in the profile than the similar Wadena soils and do not contain gravel in the IIC horizon as do the Wadena soils. Dakota soils have a darker colored A horizon and less abrupt increase in content of clay in the B horizon than the similar Lamont soils. They have more clay and sand in the B horizon than the similar Waukegan soils.

Dakota sandy loam, 0 to 2 percent slopes (D_aA).—This soil occupies tops of hills and ridges above sloping Dakota soils. It has a profile similar to that described as representative for the series, except that the surface layer is sandy loam.

Included in mapping in some areas are soils that have loamy till material at a depth of 4 to 6 feet. Subsoil colors are grayer in areas that have a loamy substratum. Also included are small areas where slopes are more than 2 percent.

This is a moderately droughty soil. Runoff is slow. There is hazard of soil blowing. This soil is used mainly for crops. (Capability unit IIIs-1)

Dakota sandy loam, 2 to 6 percent slopes (D_aB).—This soil is in 3-acre to 20-acre tracts. It is on short side slopes below nearly level Dakota sandy loams and on low ridges, hills, and side slopes adjacent to drainageways. Slopes are typically 60 to 125 feet long. This soil has a profile similar to that described as representative for the series, except that the surface layer is sandy loam.

Included in mapping in some areas are soils that have loamy till material or loamy strata at a depth below 5 feet. Also included are some areas of eroded soils in which part of the browner subsoil has been mixed with the original dark surface layer. Small areas where slopes are less than 2 percent and more than 6 percent also are included.

This soil is moderately droughty. Runoff is slow to medium. There are hazards of soil blowing and water erosion. Most of this soil is used for crops. (Capability unit IIIe-4)

Dakota sandy loam, 6 to 14 percent slopes (D_aC).—This soil occupies 3-acre to 15-acre tracts below less sloping Dakota soils and on slopes facing the larger

drainageways. Slopes are 60 to 100 feet long. This soil has a profile similar to that described as representative for the series, except that the surface layer is sandy loam.

Included in mapping are a few small tracts of Dakota loam and Dickinson sandy loam. A few areas have loamy till or bands below a depth of 5 feet. Also included, because of the small acreage, are a few areas where slopes are up to 25 percent. Some areas have been eroded, and in these the present surface layer is mostly material from the brownish subsoil.

This soil is moderately droughty. Runoff is medium. The hazards of soil blowing and water erosion are severe. South- and west-facing slopes have much wider fluctuations in soil temperature than east- and north-facing slopes. Most of this soil is used for crops. (Capability unit IVe-2)

Dakota loam, 0 to 2 percent slopes (DkA).—This soil occupies 3-acre to 20-acre tracts on tops of hills and ridges above more sloping Dakota soils. Included in mapping are a few areas that have loamy material below a depth of 5 feet.

This soil is moderately droughty. Runoff is slow. There is a hazard of soil blowing. Most of the soil is used for crops. (Capability unit IIs-1)

Dakota loam, 2 to 6 percent slopes (DkB).—This soil occurs in 3-acre to 20-acre areas on short side slopes below nearly level Dakota loam and on ridges and side slopes adjacent to drainageways. It is associated with Sparta soils in some areas. This soil has the profile described as representative for the series.

Included in mapping are a few areas that have loamy strata below a depth of 5 feet. A few areas of included soils formed in material high in content of very fine sand. A few areas are eroded, and here the present surface layer is a mixture of the original dark-colored surface layer and part of the brownish subsoil. These areas are lower in organic-matter content than this Dakota soil.

This soil is moderately droughty. Runoff is medium. The hazards of soil blowing and water erosion are moderate. Most of this soil is used for crops. (Capability unit IIe-4)

Dickinson Series

The Dickinson series consists of deep, nearly level to steep, somewhat excessively drained, loamy soils. These soils formed in sandy sediment in which the sand commonly is medium and fine. They are on broad outwash flats and small, rounded sandhills within the glacial uplands. The Dickinson soils on the small sandhills commonly occur in complexes with Sparta soils. Slopes are simple. The native vegetation was grass and a few thin stands of oak or brush.

In a representative profile, the surface layer is very dark gray and very dark brown sandy loam about 15 inches thick. The subsoil, about 30 inches thick, is brown sandy loam in the upper 7 inches and brown to dark yellowish-brown loamy sand in the lower part. The underlying material is yellowish-brown, loose loamy sand in the upper part and grayish-brown and olive-brown, loose sand below. There are discontinuous, thin, finer textured bands below a depth of 56 inches in some places.

Permeability is moderately rapid in the upper part of the profile and rapid below a depth of about 22 inches. Runoff is slow to medium. The water table is below a depth of 10 feet. The available water capacity is moderate to low. The organic-matter content is moderate, and fertility is medium to low.

Most areas of these soils are used for crops. However, those areas that occur in complexes with Sparta soils commonly are in permanent vegetation. The low available water capacity and hazard of soil blowing are the main limitations.

Representative profile of Dickinson sandy loam, terrace, 0 to 2 percent slopes, in Lemond Township, 300 feet north and 50 feet west of the southwest corner of SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 13, T. 106 N., R. 21 W.:

- Ap—0 to 8 inches, very dark gray (10YR 3/1) sandy loam; weak, fine, subangular blocky structure; very friable; slightly acid; abrupt, smooth boundary.
- A3—8 to 15 inches, very dark brown (10YR 2/2) and very dark gray (10YR 3/1) sandy loam; weak, coarse, subangular blocky structure; very friable; medium acid; clear, wavy boundary.
- B21—15 to 22 inches, brown (10YR 4/3) sandy loam; ped faces are very dark brown (10YR 2/2) and very dark grayish brown (10YR 3/2); weak, coarse, subangular blocky structure; very friable; medium acid; clear, wavy boundary.
- B22—22 to 34 inches, brown (10YR 4/3) loamy sand; ped faces are very dark grayish brown (10YR 3/2); weak, coarse, subangular blocky structure; very friable; medium acid; clear, wavy boundary.
- B3—34 to 45 inches, dark yellowish-brown (10YR 4/4) loamy sand; single grain; loose; medium acid; clear, wavy boundary.
- C1—45 to 48 inches, yellowish-brown (10YR 5/4) loamy sand; single grain; loose; slightly acid; clear, wavy boundary.
- C2—48 to 56 inches, grayish-brown (2.5Y 5/3) sand; single grain; loose; slightly acid; abrupt, wavy boundary.
- C3—56 to 60 inches, grayish-brown (2.5Y 5/2), olive-brown (2.5Y 4/4), and dark grayish-brown (2.5Y 4/2) sandy loam interbedded with thin seams of sand; single grain; loose; neutral; abrupt, wavy boundary.
- C4—60 to 72 inches, grayish-brown (2.5Y 5/2) and olive-brown (2.5Y 4/4) sand; single grain; loose; neutral.

The A horizon ranges from very dark gray or very dark grayish brown to very dark brown in color. Its texture ranges from heavy loamy sand to light loam, and its thickness ranges from 10 to 20 inches. Reaction is slightly acid to medium acid in the various subhorizons.

The B21 horizon is sandy loam or fine sandy loam, and the B22 horizon is loamy fine sand, loamy sand, sandy loam, or fine sandy loam. The B2 horizon is 8 to 30 inches thick. The B3 horizon is loamy sand or loamy fine sand. Reaction ranges from slightly acid to medium acid in the B horizon.

The C horizon is mostly loamy fine sand, loamy sand, sand, or fine sand. The sandy loam C3 horizon does not occur in all profiles. Reaction ranges from medium acid to neutral. Lime commonly is leached below a depth of 60 inches, except in areas where finer textured material deeper in the soil restricted leaching.

In this county the Dickinson soils mapped alone have discontinuous, thin (1-inch to 3-inch) bands of sandy loam or loam below a depth of 50 inches in some profiles. The Dickinson soils mapped in complexes with the Sparta soils have discontinuous bands of sandy loam, loam, clay loam, and silty clay, 1 to 6 inches thick, at a depth below 60 inches. A few areas have thin strata of coarse sand.

The Dickinson soils have less clay in the B2 horizon than the similar Dakota soils. They have finer sand in their solum than the similar Estherville soils and lack the gravel contained in those soils.

Dickinson sandy loam, terrace, 0 to 2 percent slopes (DtA).—This soil occupies 10-acre to 200-acre tracts on

stream terraces and broad outwash flats. It has the profile described as representative for the series.

Included in mapping are a few small areas of Biscay or Hanska soils. These soils occupy the drainageways of the poorly developed drainage net on broader areas of this Dickinson soil.

This soil is droughty. Runoff is slow. Soil blowing can be severe on unprotected fields during the spring months. (Capability unit IIIs-1)

Dickinson sandy loam, terrace, 2 to 6 percent slopes (D8).—This soil occupies 10-acre to 50-acre tracts. The larger tracts are associated with the Biscay and Hanska soils. The smaller tracts occur on short side slopes below nearly level Dickinson soils.

Included in mapping are a few areas of eroded soils where part of the browner subsoil has been mixed with the original surface layer. These eroded soils are lower in content of organic matter than normal for Dickinson soils.

This soil is droughty. Runoff is slow to medium. Soil blowing can be severe on unprotected fields in spring. There is a slight hazard of water erosion. Most of this soil is used for crops. (Capability unit IIIe-3)

Dundas Series

The Dundas series consists of deep, nearly level, poorly drained, loamy soils that formed in calcareous glacial deposits. These soils occupy gentle rises and shallow draws in uplands within the original woodland areas of the county. The native vegetation was dominantly oak.

In a representative profile, the surface layer is very dark gray silt loam about 8 inches thick. This layer has a distinctive gray color when dry. The subsurface layer is dark-gray silt loam about 4 inches thick. The subsoil is clay loam about 25 inches thick. There is a pronounced increase in content of clay in the subsoil about midpoint in depth. The upper and lower parts are friable, and the middle part is firm. Colors in the subsoil range from dark grayish brown in the upper part to light olive brown in the lower part. The underlying material is calcareous, mottled, olive-gray to light olive-brown clay loam and loam.

Permeability is moderately slow. Runoff is slow to medium. Depth to the water table ranges seasonally from 2 to 5 feet. The available water capacity is high. The organic-matter content is moderate, and fertility is medium.

Most of the acreage is used for crops, but a few areas of woodland or woodland pasture remain. If proper management practices are used, including maintenance of tilth and fertility and control of water table, these soils are well suited to most crops grown in the county.

Representative profile of Dundas silt loam, in Somerset Township, in the NW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 16, T. 106 N., R. 20 W.:

- Ap—0 to 8 inches, very dark gray (10YR 3/1) silt loam, gray (10YR 5/1) when dry; cloddy; friable; slightly acid; abrupt, smooth boundary.
- A2—8 to 12 inches, dark-gray (10YR 4/1) silt loam, gray (10YR 6/1) when dry; weak, medium, platy structure; friable; slightly acid; abrupt, wavy boundary.
- B1—12 to 16 inches, dark grayish-brown (10YR 4/2) clay loam; ped faces are dark gray (10YR 4/1); few, fine,

faint, olive (5Y 5/4) mottles; moderate, fine, subangular blocky structure; friable; about 4 percent coarse fragments; medium acid; clear, wavy boundary.

- B21t—16 to 19 inches, grayish-brown (2.5Y 5/2) clay loam; ped faces are very dark gray (10YR 3/1); many, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, fine to medium, subangular blocky structure; firm; many thick clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B22t—19 to 25 inches, olive (5Y 5/3) clay loam; ped faces are dark gray (5Y 4/1) and olive gray (5Y 4/2); many, fine, distinct, yellowish-brown (10YR 5/6) mottles; strong, coarse, subangular blocky structure parting to strong, medium, angular blocky; many thin clay films on faces of peds; about 4 percent coarse fragments; firm; strongly acid; clear, wavy boundary.
- B23t—25 to 33 inches, grayish-brown (2.5Y 5/2) clay loam; ped faces are dark grayish brown (2.5Y 4/2) and olive gray (5Y 4/2); many, medium, prominent, strong-brown (7.5YR 5/8) mottles; strong, coarse, prismatic structure; firm; many thin clay films on faces of peds; about 4 percent coarse fragments; slightly acid; clear, wavy boundary.
- B3t—33 to 37 inches, light olive-brown (2.5Y 5/4) clay loam; many, medium, prominent, strong-brown (7.5Y 5/8) mottles; massive; friable; few very dark gray (10YR 3/1) clay films along root channels; about 4 percent coarse fragments; neutral; abrupt, wavy boundary.
- C1—37 to 46 inches, olive-gray (5Y 5/2) and olive (5Y 5/3) clay loam; many, medium, prominent, strong-brown (7.5YR 5/8) mottles; massive; friable; few small lime concretions; about 4 percent coarse fragments; calcareous; mildly alkaline; clear, wavy boundary.
- C2—46 to 60 inches, grayish-brown (2.5Y 5/2) and light olive-brown (2.5Y 5/4) loam; massive; friable; about 4 percent coarse fragments; calcareous; mildly alkaline.

The Ap horizon and the A1 horizon, where present, are silt loam or loam and range from 6 to 9 inches in thickness. Structure is weak, fine, and granular or subangular blocky in the A1 horizon. Reaction in these horizons ranges from neutral to medium acid. The A2 horizon is silt loam, loam, or silty clay loam and is 2 to 8 inches thick. Reaction is slightly acid to medium acid.

The B horizon is 20 to 40 inches thick. It commonly is clay loam throughout, but the lower part of it is loam in some profiles. Clay films commonly are in the middle part of the B horizon. The most acid part is very strongly acid in some profiles.

The C horizon is clay loam or loam.

The Dundas soils are lower in content of clay and shale than the similar Shields soils. They have more sand in the upper part of the B horizon than the similar Havana soils.

Dundas silt loam (0 to 3 percent slopes) (Du).—This soil is in small shallow depressions; in 3-acre to 8-acre, winding, shallow upland draws; and on 3-acre to 15-acre flats and gentle rises. It is closely associated with the Hayden, Lester, and Le Sueur soils. Near Saco, this soil has a higher content of silt than most areas of Dundas soils.

Areas of Webster and Le Sueur soils, too small to be mapped separately, are included.

This soil is seasonally wet. The water table fluctuates seasonally between depths of 2 and 5 feet. This soil can be properly tilled only within a narrow range of moisture content. The increase in clay content and density in the lower part of the subsoil slows the movement of water out of the surface layer. Tile drainage is seldom installed in this soil, but it will effectively control the water table if the system is specifically designed for this soil. Most of this soil is used for crops, but a few areas of woodland or woodland pasture remain. (Capability unit IIIw-2)

Estherville Series

The Estherville series consists of nearly level to moderately steep, somewhat excessively drained, loamy soils that are shallow over calcareous, stratified sand and gravel. These soils formed in loamy sediments over coarser textured material. They occupy broad flats, narrow ridges, and short, steep slopes within the glacial outwash plains and stream terraces. They also occupy small hills within the rolling uplands. Slopes are simple, except in areas where Estherville soils were mapped in complexes with other soils. The native vegetation was grass and a few thin stands of oak or brush.

In a representative profile, the surface layer is black sandy loam about 8 inches thick. The subsurface layer is very dark gray, very friable sandy loam about 5 inches thick. This layer contains tongues of black and very dark grayish brown. The subsoil is dark brown and is about 10 inches thick. It is very friable sandy loam in the upper part and loose loamy coarse sand in the lower part. The underlying material is mixed grayish-brown, yellowish-brown, and light yellowish-brown, calcareous gravel with seams of sandy loam.

Permeability is moderately rapid in the upper part of the profile and rapid below a depth of about 17 inches. Runoff is slow to rapid, depending on slope. The water table is below a depth of 10 feet. The available water capacity is low. The organic-matter content is high, and fertility is low to medium.

Most of the acreage is used for crops. However, these soils are not well suited to many row crops. The low available water capacity, limited root zone, and hazard of soil blowing are major limitations that affect crop production.

Representative profile of Estherville sandy loam, 2 to 6 percent slopes, in Lemond Township, in the southeast corner of SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T. 106 N., R. 21 W.:

- A1—0 to 8 inches, black (10YR 2/1) sandy loam; weak, fine, granular structure; very friable; medium acid; clear, smooth boundary.
- A3—8 to 13 inches, very dark gray (10YR 3/1) sandy loam; few tongues of black (10YR 2/1) and very dark grayish brown (10YR 3/2); weak, fine, granular structure; very friable; medium acid; gradual, wavy boundary.
- B2—13 to 17 inches, dark-brown (10YR 3/3) sandy loam; weak, coarse, subangular blocky structure; very friable; few fine pebbles; medium acid; abrupt, wavy boundary.
- B3—17 to 23 inches, dark-brown (7.5YR 3/4) loamy coarse sand; single grain; loose; slightly acid; abrupt, smooth boundary.
- IIC—23 to 60 inches, grayish-brown (10YR 5/2), yellowish-brown (10YR 5/4), and light yellowish-brown (10YR 6/5) coarse gravel; single grain; loose; few thin seams of coarse sandy loam; calcareous; mildly alkaline.

The A1 horizon, or the Ap horizon, is sandy loam or light loam and is 6 to 10 inches thick. Its reaction is slightly acid to medium acid. The A3 horizon ranges from 3 to 6 inches in thickness. Its reaction is slightly acid or medium acid.

The B2 horizon is dark-brown, yellowish-brown, or dark yellowish-brown sandy loam or loam. It is 4 to 12 inches thick and is sticky when wet. The B3 horizon is loamy coarse sand or loamy sand. Reaction in these horizons ranges from slightly acid to medium acid.

The IIC horizon is gravel, sandy gravel, coarse sand, or stratified coarse sand and gravel. The upper few inches of this horizon is leached of lime in some profiles.

Estherville soils are shallower to the IIC horizon than the associated Wadena soils. Compared with the similar Dickinson soils, the Estherville soils have coarser sand in the A and B horizons and have coarser sand, along with gravel, in the IIC horizon. They have a thicker A1 horizon than the similar Burnsville soils. They have a finer textured B horizon than the associated Salida soils.

Estherville sandy loam, 0 to 2 percent slopes (EcA).—This soil occupies 3-acre to 200-acre tracts. The smaller tracts are commonly scattered within areas of loamy soils on uplands. The larger tracts are on the broad flats along the Straight River and its tributaries.

Included in areas mapped as this soil are small areas where slopes are greater than 2 percent and a few areas of Wadena soils. The broader areas of this Estherville soil are crossed by drainageways of a poorly developed drainage net, and many of these are occupied by Biscay and Hanska soils, or by Wadena soils where the water table is deep.

This soil is droughty. Runoff is slow. Soil blowing is a hazard, especially on the larger tracts in spring. Most of this soil is used for crops. (Capability unit III-1)

Estherville sandy loam, 2 to 6 percent slopes (EcB).—This soil occupies 3-acre to 30-acre tracts. The smaller tracts are on gentle, convex mounds and ridges within the uplands or on short side slopes below the nearly level Estherville soil. The larger tracts occur as broad, gently undulating areas adjacent to the drainage of the Straight River and its tributaries. This soil has the profile described as representative for the series.

Included in mapping are areas where slopes are less than 2 percent and greater than 6 percent. Also included are a few small areas of Wadena soils in shallow drainageways and a few areas of Salida soils on small, convex knobs at the upper part of short, sharp slopes. In a few eroded areas, material from the brownish subsoil has been mixed with the original surface layer.

This Estherville soil is droughty. Runoff is slow to medium. There are slight hazards of soil blowing and water erosion. Most of this soil is used for crops. (Capability unit IIIe-3)

Estherville sandy loam, 6 to 12 percent slopes (EcC).—This soil occupies 3-acre to 30-acre tracts. It is on short side slopes below less sloping Estherville and Wadena soils and on hills associated with loamy soils on uplands. A few areas are closely associated with Sparta soils. Slopes range from 50 to 125 feet in length.

Included in mapping are a few areas where slopes are less than 6 percent and more than 12 percent. Also included are a few small areas of Salida and Wadena soils. A few included areas are of eroded soils that have part of the brownish subsoil mixed with the original surface layer. These areas have more gravel in the surface layer than is typical.

This soil is droughty. Runoff is medium. Soil blowing and water erosion are hazards. South- and west-facing slopes have a much wider fluctuation in soil temperatures than east- and north-facing slopes. Most of this soil is used for crops. (Capability unit IVe-2)

Estherville sandy loam, 12 to 18 percent slopes (EcD).—This soil occupies 3-acre to 10-acre tracts. It is on sharp, short slopes below less sloping Estherville and Wadena

soils and on hills associated with loamy soils on uplands. Slopes range from 50 to 100 feet in length.

Included in mapping are a few areas where slopes are less than 12 percent and more than 18 percent. These areas are included because they are associated with this soil on the landscape and cover only a small acreage. Also included are a few eroded areas where the present surface layer consists mostly of material from the brownish subsoil and contains more gravel.

This soil is droughty. Runoff is rapid, and the hazard of water erosion is severe. South- and west-facing slopes have a much wider fluctuation in soil temperature than east- and north-facing slopes. This soil is poorly suited to most cultivated crops. It occurs in small areas within larger fields and commonly is farmed the same as a major soil. Permanent vegetation is generally the most satisfactory use. (Capability unit VIe-2)

Glencoe Series

The Glencoe series consists of deep, nearly level, very poorly drained soils. These soils formed in clay loam and silty clay loam alluvium over loam or clay glacial deposits. They occupy depressions and sluggish drainageways. The native vegetation was sedges and water-tolerant grasses.

In a representative profile, the surface layer is clay loam about 25 inches thick. The upper part is black, and the lower part is very dark gray and has mixings of material from the part above and the layer below. The subsoil is mottled, olive-gray and gray, friable clay loam about 13 inches thick. The underlying material is calcareous, grayish-brown and light olive-brown, friable clay loam.

Permeability is moderately slow. Runoff is slow to ponded. The water table is at a depth of 0 to 3 feet or, in drained areas, near the depth of tile. The available water capacity is high. The organic-matter content and fertility are high.

In their natural state, these soils are only moderately well suited to poorly suited to crops grown in the county. If adequately drained, they are suited to row crops and, in most areas, are used for crops.

Representative profile of Glencoe clay loam, in Meriden Township, 600 feet west and 200 feet north of the southeast corner of SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 21, T. 107 N., R. 21 W.:

- Ap—0 to 8 inches, black (N 2/0) clay loam; cloddy; friable; neutral; abrupt, smooth boundary.
- A1—8 to 17 inches, black (N 2/0) clay loam; weak, fine, subangular blocky structure; friable; neutral; clear, irregular boundary.
- A3—17 to 25 inches, very dark gray (10YR 3/1) clay loam; few tongues of black (N 2/0); weak, fine, subangular blocky structure; friable; neutral; gradual, irregular boundary.
- B1g—25 to 29 inches, gray (5Y 5/1) clay loam; few tongues of very dark gray (10YR 3/1); weak, very fine, subangular blocky structure; friable; neutral; clear, wavy boundary.
- B2g—29 to 38 inches, olive-gray (5Y 5/2) and gray (5Y 5/1) clay loam; many, fine, faint, olive (5Y 5/6) mottles; weak, fine, subangular blocky structure; friable; neutral; clear, wavy boundary.
- C—38 to 60 inches, grayish-brown (2.5Y 5/2) clay loam; many, fine, distinct, light olive-brown (2.5Y 5/4)

mottles; massive; friable; about 4 percent coarse fragments; calcareous; mildly alkaline.

The Ap and A1 horizons are clay loam or silty clay loam and range from 16 to 24 inches in combined thickness. Their reaction is commonly neutral but ranges from slightly acid to mildly alkaline. The A3 horizon is clay loam or silty clay loam and is 6 to 12 inches thick. Its reaction is neutral or mildly alkaline. The B horizon typically is clay loam or silty clay loam and ranges from 10 to 30 inches in thickness. Reaction is neutral or mildly alkaline. The C horizon is loam or clay loam.

Glencoe soils have a thicker A horizon than the associated Webster soils. They contain more sand and less silt than the similar Colo soils. Glencoe soils contain less clay and more sand than the similar Lura soils.

Glencoe clay loam (0 to 1 percent slopes) (Gc).—This soil occupies small depressions and 5-acre to 40-acre areas in long, winding, low-gradient drainageways.

Included in mapping are some places where the surface layer is calcareous. Also included are soils in small depressions near the crest of drainage divides that have a gray surface layer and a dark-colored, clayey subsoil. There is a thin organic surface layer in some undisturbed areas.

This Glencoe soil is very wet. Depth to the water table ranges from 0 to 3 feet in undrained areas. Drainage is essential to develop this soil for common crops. Most of the acreage is used for crops. (Capability unit IIIw-1)

Hanska Series

The Hanska series consists of nearly level, poorly drained, loamy soils that are moderately deep over sandy material. These soils formed in 2 to 3 feet of loam or sandy loam material over loamy sand and sand. The native vegetation was principally water-tolerant grasses.

In a representative profile, the surface layer is about 15 inches thick. The upper part is black loam, and the lower part is very dark gray and dark-gray sandy loam that has mixings from the upper part. The subsoil is very dark grayish-brown, friable sandy loam in the upper 4 inches and grayish-brown loamy sand in the lower layers. Total thickness of the subsoil is about 15 inches. Colors are increasingly mottled with depth. The underlying material is mottled, grayish-brown to olive-brown, loose sand.

Permeability is moderately rapid in the upper part of the profile and rapid below a depth of about 19 inches. Runoff is slow. The water table is at a depth of 2 to 4 feet. The available water capacity is low to moderate. The organic-matter content is high, and fertility is medium.

Most of the acreage is used for crops. Drainage is needed for dependable cropland, though in some years crop growth is limited by lack of available water in drained areas.

Representative profile of Hanska loam, 600 feet north and 300 feet west of the southeast corner of SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 5, T. 105 N., R. 20 W.:

- Ap—0 to 7 inches, black (10YR 2/1) light loam; weak, fine, granular structure; friable; neutral; abrupt, smooth boundary.
- A1—7 to 10 inches, black (10YR 2/1) loam; few tongues of very dark gray (10YR 3/1); weak, coarse, angular blocky structure parting to weak, very fine, granular; friable; neutral; gradual, irregular boundary.
- A3g—10 to 15 inches, very dark gray (10YR 3/1) and dark gray (10YR 4/1) sandy loam; few tongues of black

- (10YR 2/1) in upper part; weak, coarse, subangular blocky structure parting to weak, very fine, granular; friable; neutral; gradual, wavy boundary.
- B21—15 to 19 inches, very dark grayish-brown (2.5Y 3/2) sandy loam; weak, coarse, angular blocky structure parting to weak, very fine, granular; friable; neutral; gradual, wavy boundary.
- B22g—19 to 30 inches, grayish-brown (2.5Y 5/2) loamy sand; common, fine, distinct, light olive-brown (2.5Y 5/4) mottles; few, fine, distinct, olive-yellow (2.5Y 6/6) mottles; weak, coarse, angular blocky structure; loose; small, very dark gray (10YR 3/1) root channels; neutral; clear, wavy boundary.
- IIC1—30 to 36 inches, grayish-brown (2.5Y 5/2) sand that grades to fine sand in lower part; many, medium, distinct mottles of light olive brown (2.5Y 5/4), light yellowish brown (2.5Y 6/4), and strong brown (7.5YR 5/6); single grain: loose; neutral; clear, wavy boundary.
- IIC2—36 to 60 inches, olive-brown (2.5Y 4/4) sand; many, medium, distinct mottles of light olive brown (2.5Y 5/4), dark yellowish brown (10YR 4/4), yellowish brown (10YR 5/4), and brown (10YR 4/3); single grain; loose; few fine pebbles; neutral.

The Ap and A1 horizons have a combined thickness of 10 to 20 inches. Lighter colored streaks from the horizons below are common. Reaction is commonly neutral but ranges from slightly acid to mildly alkaline. The surface layer is limy in some places. The A3 horizon is loam or sandy loam and ranges from 4 to 8 inches in thickness. Its reaction is slightly acid or neutral.

The B horizon ranges from 10 to 20 inches in total thickness. The B21 horizon is loam or sandy loam. The B22 horizon is loam, sandy loam, or loamy sand. Reaction ranges from slightly acid to mildly alkaline in the B horizon. The B22 horizon is calcareous in some profiles.

The IIC horizon is mostly sand or fine sand, but there are layers of coarse sand and gravel in the lower part of the IIC horizon in some places. Reaction is neutral to mildly alkaline.

The Hanska soils have less clay and more sand in the A and B horizons than the associated Biscay soils. They lack free carbonates in the A horizon, but the similar Lemond soils have free carbonates in that horizon.

Hanska loam (0 to 2 percent slopes) (Hk).—This soil is in 3-acre to 5-acre swales and 5-acre to 100-acre upland tracts.

Included in mapping are small areas of Lemond soils. Some included areas have a sandy loam surface layer. A few areas that have a loamy sand subsoil also are included.

This soil is wet. Depth to the water table ranges from 2 to 4 feet in undrained areas. Runoff is slow. Drainage is needed for dependable cropland. The water table is lowered significantly in some places if a deep outlet ditch is installed nearby. Most of this soil is used for crops. (Capability unit IIw-1)

Havana Series

The Havana series consists of deep, nearly level, somewhat poorly drained soils. These soils formed in a silty mantle and the underlying friable, loamy glacial deposit. They occupy gentle rises and shallow draws in the uplands. The native vegetation was dominantly oak or brush.

In a representative profile, the surface layer is very dark gray silt loam 9 inches thick. The subsurface layer is mottled, dark grayish-brown, friable silt loam about 3 inches thick. The upper part of the subsoil is mottled grayish-brown silty clay loam about 7 inches thick. The

lower part is mottled, grayish-brown, friable clay loam and loam about 31 inches thick. The underlying material is calcareous, grayish-brown and light olive-brown, friable loam.

Permeability is moderately slow. Runoff is slow to medium. The water table fluctuates seasonally, but it is usually at a depth below 3 feet. The available water capacity is high. The organic-matter content is moderate, and fertility is medium.

Most areas of these soils are used for crops, but a few areas are in trees or woodland pasture. Under proper management, including maintenance of tilth, control of the water table, and maintenance of fertility, these soils are well suited to most crops grown in the county.

Representative profile of Havana silt loam, in Merton Township, 20 feet north and 100 feet west of first telephone pole north of field drive in SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 35, T. 108 N., R. 19 W.:

- Ap—0 to 9 inches, very dark gray (10YR 3/1) silt loam, dark gray (10YR 4/1) when dry; cloddy; friable; slightly acid; abrupt, smooth boundary.
- A2—9 to 12 inches, dark grayish-brown (2.5Y 4/2) silt loam; few, fine, distinct, light olive-brown (2.5Y 5/4) and grayish-brown (2.5Y 5/2) mottles; moderate, medium, platy structure; friable; common tubules; few dark-colored worm casts; medium acid; abrupt, smooth boundary.
- B21tg—12 to 19 inches, grayish-brown (2.5Y 5/2) silty clay loam; many, fine, faint, light olive-brown (2.5Y 5/4) mottles; moderate, fine, subangular blocky structure; friable; thin patchy clay films on faces of pedes; medium acid; clear, wavy boundary.
- IIB22tg—19 to 29 inches, grayish-brown (2.5Y 5/2) clay loam; common, fine, distinct, dark yellowish-brown (10YR 4/4) mottles; moderate, fine, subangular blocky structure; friable; thin patchy clay films on faces of pedes; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- IIB23tg—29 to 42 inches, grayish-brown (2.5Y 5/2) loam; common, medium, distinct, light olive-brown (2.5Y 5/6) mottles and few, fine, prominent, strong-brown (7.5YR 5/6) mottles; moderate, medium, prismatic structure parting to moderate, fine and medium, subangular blocky; friable; thin porous sand and silt coatings on faces of pedes; few clay films in pores; about 4 percent coarse fragments; medium acid; abrupt, wavy boundary.
- IIB3tg—42 to 50 inches, grayish-brown (2.5Y 5/2) loam; many, fine, distinct, light olive-brown (2.5Y 5/4) mottles; weak, coarse, prismatic structure; friable; thick clay films in root channels and on ped faces; about 4 percent coarse fragments; slightly acid; abrupt, wavy boundary.
- IIC1—50 to 56 inches, light olive-brown (2.5Y 5/4) and grayish-brown (2.5Y 5/2) loam; massive; friable; few clay films in root channels; few dark concretions; about 4 percent coarse fragments; mildly alkaline; gradual, wavy boundary.
- IIC2—56 to 66 inches, light olive-brown (2.5Y 5/4) and grayish-brown (2.5Y 5/2) loam; massive; friable; soft feathered lime common; few dark concretions; about 4 percent coarse fragments; calcareous; mildly alkaline.

The Ap horizon is silt loam or loam that is high in content of silt. Its reaction is neutral to slightly acid in uncultivated areas but ranges to medium acid in fields under long cultivation. The A2 horizon is silt loam or loam 2 to 8 inches thick. Its reaction is slightly acid to medium acid.

The B21tg horizon is silty clay loam or heavy silt loam, or in places it is heavy loam or clay loam, both of which are high in content of silt. Thickness of the B21tg horizon ranges from 6 to 10 inches. Faces of pedes are grayish brown and dark grayish brown in color. In some profiles faces of pedes

have bleached sand and silt grains. Mottles range from few to many. Reaction is medium acid to strongly acid.

The IIB horizon is mostly loam or clay loam, but in some profiles the upper part of the IIB horizon is coarser textured, ranging from sand or sand and gravel to sandy loam or sandy clay loam within a short lateral distance. Such horizons are less than 10 inches thick. The IIB horizon is 20 to 40 inches in total thickness. The faces of prisms in some profiles have some coatings of bleached sand and silt grains. Reaction ranges from slightly acid to strongly acid; the more acid reaction is in the upper part of the IIB horizon.

The IIC horizon is olive brown, light olive brown, or grayish brown. This horizon is generally calcareous and mildly alkaline, but the upper part of the IIC1 horizon is noncalcareous and neutral in some profiles.

The Havana soils have more silt and less sand in the upper part of the B horizon than the similar Dundas soils. Havana soils commonly are associated with Blooming, Maxcreek, and Newry soils on the landscape. Their B horizon is grayer than that of Blooming and Newry soils but is not so gray as that of Maxcreek soils.

Havana silt loam (0 to 2 percent slopes) (Hm).—This soil occupies 10-acre to 100-acre upland tracts and 3-acre to 10-acre gentle rises and shallow upland draws.

Areas of Newry and Maxcreek soils, too small to be mapped separately, are included. Small included areas in and near Rice Lake woods have a thinner, lighter colored surface layer and a higher content of clay in the upper part of the subsoil. Small areas south of Oak Glen Lake have grayer colors in the surface layer when dry than is common for Havana soils.

This soil is seasonally wet. The water table fluctuates seasonally but is usually at a depth below 3 feet. The different textural layers in the root zone slow the movement of water through the soil. In some places tile has been installed. Tile functions satisfactorily if it is specifically designed for this soil. Most of the acreage is now used for crops, but a few areas of woodland or woodland pasture remain. (Capability unit IIIw-2)

Hayden Series

The Hayden series consists of deep, gently undulating to hilly, well-drained, loamy soils that formed in loamy glacial till. These soils are on knolls, hillsides, and valley slopes in the uplands. Slopes are both concave and convex. The native vegetation was mixed hardwood forest.

In a representative profile, the surface layer is dark grayish-brown loam about 10 inches thick. The subsoil is about 34 inches thick. The upper 4 inches of the subsoil is brown, friable loam; the middle part is dark yellowish-brown or yellowish-brown, friable clay loam; and the lower 13 inches is olive-brown or light olive-brown, friable loam. The underlying material is calcareous, light olive-brown loam.

Permeability is moderate. Runoff is medium to rapid. The water table is at a depth below 10 feet. The available water capacity is high. The organic-matter content is moderate, and fertility is high.

Most of the acreage is used for crops. These soils are well suited to this use. A few areas remain in trees or woodland pasture. Control of erosion and maintenance of tilth are the main management needs. The available water capacity is slightly lower in Hayden soils having a sandy loam surface layer than it is in Hayden soils having a loam surface layer.

Representative profile of Hayden loam, 2 to 6 percent slopes, in Clinton Falls Township, 300 feet south and 300 feet west of the northeast corner of NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 22, T. 108 N., R. 20 W.:

- Ap—0 to 7 inches, dark grayish-brown (10YR 4/2) loam; weak, medium, subangular blocky structure; friable; about 2 percent coarse fragments; slightly acid; abrupt, smooth boundary.
- A2—7 to 10 inches, dark grayish-brown (10YR 4/2) loam; weak, medium, platy structure; friable; about 2 percent coarse fragments; slightly acid; abrupt, smooth boundary.
- B1t—10 to 14 inches, brown (10YR 4/3) loam; ped faces are dark grayish brown (10YR 4/2); moderate, fine and medium, subangular blocky structure; friable; common, fine, bleached sand grains on faces of peds; few thin clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B21t—14 to 19 inches, dark yellowish-brown (10YR 4/4) clay loam; ped faces are dark grayish brown (10YR 4/2); moderate, medium, subangular blocky structure; friable; many thin clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B22t—19 to 24 inches, yellowish-brown (10YR 5/4) clay loam; ped faces are dark grayish brown (10YR 4/2); moderate, medium, subangular blocky structure; friable; many thin clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B23t—24 to 31 inches, yellowish-brown (10YR 5/4) clay loam; ped faces are brown (10YR 4/3); moderate, medium, prismatic structure; friable; many thin clay films on faces of peds; about 4 percent coarse fragments; strongly acid; clear, wavy boundary.
- B24t—31 to 37 inches, olive-brown (2.5Y 4/4) loam; ped faces are brown (10YR 4/3); moderate, medium, prismatic structure; friable; few, thin, patchy clay films on faces of peds; common, medium, bleached sand grains on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B3t—37 to 44 inches, light olive-brown (2.5Y 5/4) loam; ped faces are dark grayish brown (10YR 4/2) and very dark gray (10YR 3/1); moderate, medium, prismatic structure; friable; few thin clay films on faces of peds; about 4 percent coarse fragments; slightly acid; abrupt, wavy boundary.
- C—44 to 60 inches, light olive-brown (2.5Y 5/4) loam; few, fine, prominent, strong-brown (7.5YR 5/8) mottles; few white lime segregations; massive; friable; about 4 percent coarse fragments; mildly alkaline; calcareous.

In uncultivated areas these soils have a black or very dark gray A1 horizon that is 2 to 5 inches thick. The A1 horizon, or the Ap horizon, is loam or sandy loam and is slightly acid to medium acid. The Ap horizon is grayish brown or light grayish brown in color when dry. The A2 horizon is dark grayish brown or grayish brown in color and loam or sandy loam in texture. It is 2 to 6 inches thick. Structure is weak, fine or medium, platy or subangular blocky. Reaction is slightly acid to medium acid. In cultivated fields this horizon commonly has been incorporated into the Ap horizon.

The B horizon is heavy loam or clay loam and totals 25 to 35 inches in thickness. The maximum content of clay is in the B21t and B22t horizons. The B21t and B22t horizons have moderate or strong structure.

The C horizon contains lime in the form of threads and soft masses.

The Hayden soils have a thinner A1 horizon or a lighter colored Ap horizon than the similar Lester soils.

Hayden sandy loam, 2 to 6 percent slopes, eroded (HnB2).—This soil occupies 5-acre to 20-acre areas on irregularly shaped knolls. Slopes are 80 to 150 feet long. This soil is closely associated with the Chelsea, Hayden, Lamont, and Le Sueur soils in sloping areas and with the

Glencoe and Webster soils in nearly level areas. This soil has a profile similar to that described as representative for the series, except that the surface layer and upper part of the subsoil are sandy loam.

Included in mapping are a few, narrow, wet draws that are indicated on the soil map by drainageway symbols.

This soil is moderately droughty. Runoff is medium. Soil blowing and water erosion are hazards. This soil generally is farmed in fields with other soils. (Capability unit IIe-2)

Hayden sandy loam, 6 to 12 percent slopes, eroded (HnC2).—This soil occupies 5-acre to 10-acre areas on irregularly shaped knolls. Slopes are 80 to 150 feet long. This soil is closely associated with the sloping Chelsea, Hayden, Lamont, and Le Sueur soils. The lower lying slopes are occupied by Glencoe and Webster soils. This soil has a profile similar to that described as representative for the series, except that the present surface layer consists of sandy loam and is eroded. Erosion and deep tillage have mixed the original surface layer with material from the brownish subsoil.

Included in mapping are a few uneroded areas. In a few included areas the present surface layer is mostly material from the brownish, loamy subsoil.

This soil is moderately droughty. Runoff is medium. The hazards of soil blowing and water erosion are moderate. Most of the acreage is used for crops and is farmed in fields with other soils. A few areas remain wooded. (Capability unit IIIe-2)

Hayden loam, 2 to 6 percent slopes (HoB).—This soil occupies 5-acre to 80-acre areas on irregularly shaped knolls. Slopes are 80 to 150 feet long. This soil occurs above more sloping Hayden soils and is closely associated with Dundas, Le Sueur, and Webster soils. This soil has the profile described as representative for the series. The layers are thinner where slopes are convex.

Included in mapping are a few small areas of Dundas, Le Sueur, and Webster soils. In some places these are identified on the soil map by the symbol for drainageway or depression. Small gravelly pockets are identified by gravel-spot symbols in most places.

Runoff is medium. The hazard of erosion is moderate. Good tilth is difficult to maintain without special management practices. Most of the acreage is used for crops, but a few areas remain wooded. (Capability unit IIe-2)

Hayden loam, 2 to 6 percent slopes, eroded (HoB2).—This soil occupies 5-acre to 80-acre areas on irregularly shaped knolls. Slopes are 80 to 150 feet long. This soil occurs above more sloping Hayden soils in many areas. It has a profile similar to that described as representative for the series, except that erosion, deep tillage, and tree removal have mixed the original surface layer with material from the brownish subsoil. The resulting surface layer is browner, lower in organic-matter content, and less friable than the original one. The soil layers are thinner where slopes are convex.

Included in mapping are a few areas of Dundas, Le Sueur, and Webster soils having concave slopes. Small pockets of gravel and a few uneroded areas also are included.

Runoff is medium. The hazard of erosion is moderate. Good tilth is difficult to maintain without special man-

agement. This soil is well suited to most crops grown in the county. (Capability unit IIe-2)

Hayden loam, 6 to 12 percent slopes (HoC).—This soil occupies 5-acre to 20-acre areas on irregularly shaped knolls and hillsides. Slopes are 80 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that the soil layers are thinner where slopes are convex.

Included in mapping are a few areas of Dundas, Le Sueur, and Webster soils in concave positions. Many of these are identified on the soil map by drainageway or depression symbols. Small gravelly pockets commonly are identified on the soil map by the symbol for gravel spots. A few small areas of Storden soils are included where slopes are convex.

Runoff is medium. The hazard of erosion is moderate to severe. Good tilth is difficult to maintain without special management practices. This soil is well suited to most crops grown in the county. (Capability unit IIIe-2)

Hayden loam, 6 to 12 percent slopes, eroded (HoC2).—This soil occupies 5-acre to 20-acre areas on irregularly shaped knolls and hillsides. Slopes are 80 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that erosion, deep tillage, and tree removal have mixed the original surface layer with material from the brownish subsoil. The resulting surface layer is browner, lower in organic-matter content, and less friable than the original one. The soil layers are thinnest on convex slopes.

Included in mapping are a few areas where slopes are less than 6 percent and more than 12 percent. Also included are small pockets of gravel. Small areas of Storden soils occur where slopes are convex. Also included are a few uneroded areas.

Runoff is medium. The hazard of erosion is severe. Good tilth is difficult to maintain without special management practices. Most of this soil is used for cultivated crops. (Capability unit IIIe-2)

Hayden loam, 12 to 18 percent slopes (HoD).—This soil occupies a few 5-acre to 20-acre areas on irregular knolls, but most of the acreage is in 5-acre to 20-acre areas on hillsides that commonly are crossed by shallow downslope draws and, in places, by deep ravines. Slopes are 80 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that the layers are thinner.

Included in mapping, because of limited acreage, are some areas of soils that have a sandy loam surface layer. A few included areas have slopes of less than 12 percent and more than 18 percent. The shallow downslope draws commonly are occupied by Dundas, Le Sueur, or Webster soils. Also included are small gravelly pockets. In some places the convex slopes are occupied by small spots of Storden soils.

Runoff is rapid. The hazard of erosion is severe. South- and west-facing slopes have much greater variations in soil temperature than east- and north-facing slopes. This soil is used for trees, permanent pasture, or crops. Areas used for crops generally are farmed in fields together with less sloping soils. (Capability unit IVe-1)

Hayden loam, 12 to 18 percent slopes, eroded (HoD2).—This soil occupies a few 5-acre to 20-acre areas on irregular knolls, but most of the acreage is in 5-acre to 20-

acre areas on hillsides that commonly are crossed by shallow downslope draws and a few deep ravines. Slopes are 80 to 120 feet long. This soil has a profile similar to that described as representative for this series, except that erosion, deep tillage, and tree removal have mixed the surface layer with material from the brownish subsoil. The resulting surface layer is browner, contains less organic matter, and is less friable than the original one. The layers are thinnest where slopes are convex.

Included in mapping are a few areas where slopes are less than 12 percent and more than 18 percent. Shallow downslope draws commonly are occupied by Dundas, Le Sueur, or Webster soils. Also included are small pockets of gravel. The convex slopes are occupied by small spots of Storden soils in some places.

Runoff is rapid. The hazard of erosion is severe. South- and west-facing slopes have much greater variation in soil temperature than east- and north-facing slopes. Most of the acreage is used for crops. (Capability unit IVE-1)

Hayfield Series

The Hayfield series consists of nearly level, somewhat poorly drained and moderately well drained soils that are moderately deep over sand and gravel. These soils formed in a silty mantle and in the underlying sand and gravel. They are on outwash plains and terraces. The native vegetation was dominantly oak or brush.

In a representative profile, the surface layer is very dark gray silt loam about 8 inches thick. This layer is gray when dry. The subsurface layer is dark grayish-brown silt loam about 3 inches thick. The upper part of the subsoil is brown and dark-brown, friable silt loam and silty clay loam about 10 inches thick. The lower part of the subsoil has colors that are more mixed and mottled; it ranges from friable clay loam to sandy loam and is about 17 inches thick. The underlying material is stratified loamy sand, sand, and gravel in a mixture of brownish colors.

Permeability is moderate in the upper part of the profile and rapid in the underlying material, beginning at a depth of about 38 inches. Runoff is slow to medium. The water table is at a depth of 3 to 6 feet. The available water capacity is moderate. The organic-matter content is moderate, and the fertility is medium.

Most of the acreage is used for crops, mainly corn and soybeans. These soils are well suited to these crops in most years, but crop growth is limited by lack of available water in a few years. Maintenance of tilth is the main management need.

Representative profile of Hayfield silt loam, in Aurora Township, 600 feet west and 100 feet south of the northeast corner of NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, T. 106 N., R. 19 W.:

- Ap—0 to 8 inches, very dark gray (10YR 3/1) gritty silt loam, gray (10YR 5/1) when dry; weak, medium, subangular blocky structure; friable; slightly acid; abrupt, smooth boundary.
- A2—8 to 11 inches, dark grayish-brown (10YR 4/2) gritty silt loam; weak, medium, platy structure parting to weak, fine, subangular blocky; friable; common tubular pores; medium acid; abrupt, smooth boundary.
- B1—11 to 15 inches, brown (10YR 4/3) silt loam that has a gritty feel; ped faces are dark grayish brown (10YR 4/2); weak, medium, subangular blocky structure;

friable; common tubular pores; medium acid; clear, wavy boundary.

- B21t—15 to 21 inches, dark-brown (10YR 4/3) silty clay loam; many, fine, faint, grayish-brown (10YR 5/2) mottles; weak, medium, subangular blocky structure; friable; few thin clay films on faces of peds and in root channels; medium acid; clear, wavy boundary.
- IIB22t—21 to 26 inches, dark grayish-brown (10YR 4/2) clay loam; many, fine, faint, dark-brown (10YR 3/3) and brown (10YR 4/3) mottles; weak, medium, subangular blocky structure; friable; few, thin, very dark grayish-brown clay films on faces of peds; medium acid; abrupt, wavy boundary.
- IIB3—26 to 38 inches, brown (10YR 5/3) sandy loam; many, fine, faint, dark-brown (10YR 3/3) mottles and few, medium, prominent, dark reddish-brown (5YR 3/4) mottles; weak, coarse, subangular blocky structure; very friable; few layers of sand with a few gravel particles; medium acid; abrupt, wavy boundary.
- IIIC1—38 to 50 inches, light olive-brown (2.5Y 5/4) and olive-brown (2.5Y 4/4) sand; single grain; loose; few gravel particles; medium acid; abrupt, wavy boundary.
- IIIC2—50 to 56 inches, dark-brown (7.5YR 3/2) loamy sand; single grain; loose; slightly acid; abrupt, wavy boundary.
- IIIC3—56 to 62 inches, light olive-brown (2.5Y 5/4) sand; single grain; loose; few gravel particles; mildly alkaline; calcareous.

The Ap horizon ranges in color from very dark gray to very dark grayish brown and in texture from silt loam to loam. The content of silt commonly is near 55 percent but ranges from 45 to 60 percent. Reaction is slightly acid or medium acid. The A2 horizon is gritty silt loam or loam that is high in content of silt. Its thickness ranges from 1 to 4 inches. Structure is weak or moderate, subangular blocky or thin or medium, platy. Reaction is slightly acid or medium acid.

The B1 horizon ranges from silt loam to loam that is high in content of silt. The combined thickness of the B1 and B21t horizons ranges from 8 to 14 inches. Bleached sand grains on faces of peds are a prominent feature in the B1 horizon in some areas. The IIB horizon ranges from clay loam or sandy clay loam to sandy loam in texture. Its combined thickness ranges from 10 to 20 inches. Reaction in the B horizon ranges from slightly acid to strongly acid.

The IIIC horizon consists of stratified sand and gravel in some profiles.

The Hayfield soils have browner colors in the B horizon than the associated Udolpho soils.

Hayfield silt loam (0 to 2 percent slopes) (Hs).—This soil occupies 5-acre to 100-acre tracts on outwash plains and terraces.

A few areas of Udolpho and Kato soils, too small to be mapped separately, are included.

This soil is slightly wet. Depth to the water table ranges from 3 to 6 feet. The soil is also slightly droughty if the water table is lowered. Prepared seedbeds tend to slake and settle on wetting and to crust on drying. Most of the acreage is used for crops, but a few areas of trees or woodland pasture remain. (Capability unit IIS-1)

Kato Series

The Kato series consists of nearly level, poorly drained, silty soils that are moderately deep over coarse sand and fine gravel. These soils formed in 2 to 3 feet of silty sediments and in the underlying coarser textured material. They occupy broad flats, depressions, and sluggish drainageways on outwash plains and terraces. The native vegetation was mainly water-tolerant grasses and sedges.

In a representative profile, the surface layer is about 21 inches thick. The upper part of this layer is black

silty clay loam. The lower part is very dark gray silt loam that contains tongues of dark grayish-brown material from below. The upper part of the subsoil is dark grayish-brown silt loam that has olive-gray mottles and is about 10 inches thick. The lower part of the subsoil is mottled, olive-gray loam about 4 inches thick. The underlying material is dark grayish-brown, olive, and olive-gray, stratified coarse sand and sand and gravel.

Permeability is moderate in the upper part of the profile and rapid in the underlying material, beginning at a depth of about 35 inches. Runoff is slow to ponded. The water table is at a depth of 0 to 3 feet or near tile depth if the soil is drained. The available water capacity is moderate to high. The organic-matter content and fertility are high.

Most areas of these soils are used for crops. If properly drained, Kato soils are well suited to most crops grown in the county. Control of the water table and maintenance of tilth and fertility are the main management needs.

Representative profile of Kato silty clay loam, in Blooming Prairie Township, 100 feet north and 600 feet west of the southeast corner of the NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 12, T. 105 N., R. 19 W.:

- Ap—0 to 8 inches, black (10YR 2/1) silty clay loam; cloddy; friable; slightly acid; abrupt, smooth boundary.
- A1—8 to 15 inches, black (10YR 2/1) silty clay loam; weak, fine, subangular blocky structure; friable; slightly acid; gradual, wavy boundary.
- A3—15 to 21 inches, very dark gray (10YR 3/1) heavy silt loam; few channels of dark grayish brown (2.5Y 4/2); weak, very fine, subangular blocky structure; friable; few, fine, tubular pores; slightly acid; gradual, irregular boundary.
- B21g—21 to 24 inches, dark grayish-brown (2.5Y 4/2) silt loam; few channels of very dark gray (10YR 3/1); few, fine, dark-brown (7.5YR 3/2) concretions; weak, very fine, subangular blocky structure; friable; few, fine, tubular pores; slightly acid; clear, wavy boundary.
- B22g—24 to 31 inches, dark grayish-brown (2.5Y 4/2) silt loam; few channels of very dark gray (10YR 3/1); many, fine, distinct, olive (5Y 4/3) mottles; few, fine, dark-brown (7.5YR 3/2) concretions; weak, very fine, subangular blocky structure; friable; few, fine, tubular pores; slightly acid; abrupt, wavy boundary.
- IIB3g—31 to 35 inches, olive-gray (5Y 4/2) loam; many, fine, distinct, light olive-brown (2.5Y 5/6) mottles; few channels of very dark grayish brown (10YR 3/2); common, fine, distinct, black (10YR 2/1) concretions; weak, very fine, subangular blocky structure; friable; neutral; abrupt, wavy boundary.
- IIC1—35 to 39 inches, dark grayish-brown (2.5Y 4/2) and olive-gray (5Y 5/2) sand; few streaks of black (10YR 2/1); few, prominent, yellowish-brown (10YR 5/8) vertical stains; single grain; loose; neutral; abrupt, wavy boundary.
- IIC2—39 to 50 inches, olive-gray (5Y 5/2) and olive (5Y 5/3) coarse sand; few, prominent, yellowish-brown (10YR 5/8) vertical stains; single grain; loose; few fine pebbles; neutral; abrupt, wavy boundary.
- IIC3—50 to 65 inches, olive-gray (5Y 5/2) and olive (5Y 5/3) coarse sand with some fine gravel; few, prominent, yellowish-brown (10YR 5/8) vertical stains; single grain; loose; mildly alkaline; calcareous.

The Ap and A1 horizons commonly are silty clay loam, but in places they range to silt loam. Their combined thickness ranges from 12 to 20 inches. Reaction in each of these horizons is slightly acid to neutral. The A3 horizon ranges from silty clay loam to silt loam and is 5 to 10 inches thick. Reaction is slightly acid or neutral.

The B2 horizon has a matrix color of dark grayish brown, grayish brown, or olive gray. Combined thickness of the B2 horizons ranges from 9 to 18 inches. Texture typically ranges

from silt loam to silty clay loam. The IIB3g horizon is sandy loam, sandy clay loam, loam, or clay loam and is 2 to 6 inches thick.

The IIC horizon commonly is sand, coarse sand, or gravelly coarse sand, but in some profiles it is stratified sand and gravel. One of the IIC horizons is yellowish brown or strong brown in some profiles. In some profiles the IIC horizon is calcareous throughout.

The Kato soils have more silt and less sand in the A and B horizons than the similar Biscay soils. They lack free lime in the A horizon, whereas the similar Kato, calcareous variant, soils have lime in that horizon.

Kato silty clay loam (0 to 2 percent slopes) (Kc).—This soil occupies 3-acre to 100-acre tracts on outwash plains and terraces. This soil has the profile described as representative for the series.

Included in mapping are a few small areas of Udolpho soils and the calcareous variant of the Kato series. Also included are a few areas where the surface layer is loamy rather than silty.

This soil is wet. Runoff is slow. Depth to the water table ranges from 1 to 3 feet in undrained areas. Drainage is needed for dependable cropland for the commonly grown crops. Tile drainage effectively controls the perched water table. Maintenance of tilth and fertility is a minor management need. (Capability unit IIw-1)

Kato silty clay loam, swales (0 to 1 percent slopes) (Kd).—This soil occupies small depressions in 5-acre to 30-acre, long, winding, low-gradient swales. This soil has a profile similar to that described as representative for the series, except that the surface layer is generally thicker and, in some places, is loam or clay loam. The rims of the swales and depressions are commonly occupied by calcareous bands of Kato soils or of Kato soils that have a calcareous surface layer.

This soil is wet. Depth to the water table ranges from the surface to 3 feet in undrained areas. Runoff is slow to ponded. Drainage is needed for dependable cropland for the commonly grown crops. Tile drainage effectively controls the perched water table. Maintenance of tilth and fertility is a minor management need. (Capability unit IIIw-1)

Kato Series, Calcareous Variant

The Kato series, calcareous variant, consists of nearly level, poorly drained, silty soils that are moderately deep over coarse sand and fine gravel. These soils formed in 2 to 3 feet of silty sediment and in the underlying coarser textured materials. They occupy flats, depressions, and sluggish drainageways on outwash plains and terraces. These soils occur in close association with normal Kato soils and are similar in all properties except degree of calcium carbonate concentration. Carbonates are both precipitate lime and snail shells. The native vegetation was principally water-tolerant grasses and sedges.

In a representative profile, the surface layer is silty clay loam about 20 inches thick. The upper part is black, and the lower part is very dark gray with tongues of black from the part above and of very dark grayish brown from the layer below. The upper part of the subsoil is dark grayish-brown, friable silty clay loam about 12 inches thick; the lower part is olive-gray loam about 4 inches thick. The underlying material is grayish-brown coarse sand. It has olive-gray and strong-brown mottles.

Permeability is moderate in the upper part of the profile and rapid in the underlying material, beginning at a depth of about 36 inches. Runoff is slow to ponded. The water table is at a depth of 0 to 3 feet or, where the soils are drained, near tile depth. The available water capacity is moderate to high. The organic-matter content and fertility are high.

Most of the acreage is used for crops. If properly drained, these soils are suited to most crops grown in the county. Control of the water table and special treatment for high concentrations of lime are the main management needs.

Representative profile of Kato silty clay loam, calcareous variant, in Blooming Prairie Township, in the NW $\frac{1}{4}$ SE $\frac{1}{4}$ of sec. 12, T. 105 N., R. 19 W.:

- Ap—0 to 8 inches, black (10YR 2/1) silty clay loam, dark gray (10YR 4/1) when dry; cloddy; friable; mildly alkaline; calcareous; abrupt, smooth boundary.
- A1—8 to 13 inches, black (10YR 2/1) silty clay loam; weak, fine, subangular blocky structure; friable; mildly alkaline; calcareous; gradual, irregular boundary.
- A3g—13 to 20 inches, very dark gray (10YR 3/1) silty clay loam; few tongues and worm channels of black (10YR 2/1) and dark grayish brown (2.5Y 4/2); weak, fine, subangular blocky structure; friable; many, fine, tubular pores; mildly alkaline; calcareous; gradual, irregular boundary.
- B21g—20 to 25 inches, dark grayish-brown (2.5Y 4/2) silty clay loam; many, fine, distinct, olive-gray (5Y 4/2) mottles; weak, fine, subangular blocky structure; friable; many, fine, tubular pores; mildly alkaline; calcareous; clear, wavy boundary.
- B22g—25 to 32 inches, dark grayish-brown (2.5Y 4/2) silty clay loam; many, fine, distinct, light olive-brown (2.5Y 5/4) mottles; weak, fine, subangular blocky structure; friable; many, fine, tubular pores; neutral; abrupt, wavy boundary.
- IIB3g—32 to 36 inches, olive-gray (5Y 4/2) loam; weak, fine, subangular blocky structure; friable; neutral; abrupt, wavy boundary.
- IIC—36 to 60 inches, grayish-brown (2.5Y 5/2) coarse sand; many, fine, faint, olive-gray (5Y 5/2) mottles and few, fine, prominent, strong-brown (7.5YR 5/8) mottles; single grain; loose; few fine pebbles; neutral.

The A horizon typically is silty clay loam, but in some areas the A1 horizon, the A3 horizon, or both, are silt loam. The total thickness of the A horizon is 16 to 24 inches. The B2 horizon is silty clay loam or silt loam. Its total thickness is 10 to 24 inches. The B2 horizon has free carbonates in all parts in some profiles. The IIB3g horizon is sandy loam, sandy clay loam, loam, or clay loam. In some profiles it lacks free carbonates, and in others it has free carbonates. It is 2 to 6 inches thick. The IIC horizon is sand, coarse sand, gravelly coarse sand, or stratified sand and gravel. It has free carbonates throughout in some profiles.

The Kato, calcareous variant, soils differ from normal Kato soils by having free carbonates in the A horizon.

Kato silty clay loam, calcareous variant (0 to 2 percent slopes) (Ke).—This soil occupies 3-acre to 10-acre tracts on rims of depressions and swales and on slight rises within areas of the normal Kato soils. This soil has the profile described as representative for the Kato series, calcareous variant.

Included in mapping are a few small areas of normal Kato soils.

This soil is wet. Depth to the water table ranges from 1 to 3 feet in undrained areas. Drainage is needed if this soil is to be dependable cropland. Tile drainage effectively controls the perched water table. This soil has a high concentration of lime carbonates. Concentrations gen-

erally are greatest on the rims of depressions and lower in the broad, nearly level tracts. Calcium carbonate equivalents are commonly between 5 and 15 percent but small included areas have some layers that exceed 20 percent. Most of the acreage is used for crops. (Capability unit IIw-2)

Kato silty clay loam, calcareous variant, depression (Kf).—This soil occupies small depressions and 5-acre to 20-acre areas in long, winding, low-gradient swales. This soil has a profile similar to that described as representative for the variant, but generally it contains lower concentrations of lime carbonates. In some areas lime carbonate consists largely of snail shells.

This soil is very wet. Depth to the water table ranges from 0 to 3 feet in undrained areas. Runoff is slow to ponded. Drainage is needed if this soil is to be dependable for crops. Surface waterways are used to prevent ponding. Tile drainage effectively controls the water table. Crops respond favorably to special fertility treatments, which are needed because of the high concentrations of lime. Most of the acreage is used for crops. (Capability unit IIIw-3)

Kilkenny Series

The Kilkenny series consists of deep, gently undulating to rolling, well-drained, loamy soils on knolls and sidehill slopes. These soils formed in shaly clay loam glacial till 3 to 10 feet thick. Slopes are both simple and complex. In most places they are 75 to 200 feet long, and the gradient ranges from 3 to 12 percent. The native vegetation was dominantly oak.

In a representative profile, the surface layer is very dark gray clay loam about 7 inches thick. The subsurface layer is very dark grayish-brown clay loam about 3 inches thick. The subsoil is olive-brown, firm and very firm clay loam 38 inches thick; the lower 4 inches is grayish brown and light olive brown. Ped faces are coated with dark grayish-brown clay films. The underlying material is calcareous, grayish-brown and light olive-brown, friable clay loam.

Permeability is moderately slow. Runoff is medium to rapid. The water table is at a depth of more than 10 feet, and the available water capacity is high. The organic-matter content is moderate, and fertility is high.

Some of the areas are in woodland, but most are cultivated. If properly managed, Kilkenny soils are suited to most crops grown in the county. Maintenance of tilth and control of erosion are the principal management needs.

Representative profile of Kilkenny clay loam, 500 feet south and 100 feet west of the northeast corner of sec. 7, T. 108 N., R. 21 W.:

- Ap—0 to 7 inches, very dark gray (10YR 3/1) clay loam; weak, fine, granular structure; friable; slightly acid; clear, smooth boundary.
- A2—7 to 10 inches, very dark grayish-brown (10YR 3/2) clay loam, light gray (10YR 6/1) when dry; very dark gray (10YR 3/1) ped faces; weak, fine and medium, subangular blocky structure; friable; slightly acid; abrupt, wavy boundary.
- B1—10 to 16 inches, olive-brown (2.5Y 4/3) clay loam; moderate, fine and medium, subangular blocky structure; friable; porous, very dark grayish-brown coatings on ped faces; many sand-size shale particles; about 2

percent coarse fragments, mostly shale; medium acid; gradual, wavy boundary.

- B21t—16 to 30 inches, olive-brown (2.5Y 4/4) clay loam; moderate, fine and medium, prismatic structure and moderate, fine and medium, subangular blocky; very firm; many, thin to thick, dark grayish-brown clay films on ped faces; many, fine, rounded shale particles; about 2 percent coarse fragments, mostly shale; strongly acid; clear, wavy boundary.
- B22t—30 to 36 inches, olive-brown (2.5Y 4/4) clay loam; moderate, fine and medium, prismatic structure and moderate, fine and medium, subangular blocky; very firm; many thin and few thick, dark-brown clay films on ped faces; many, fine, rounded, sand-size shale particles; about 2 percent coarse fragments, mostly shale; strongly acid; clear, wavy boundary.
- B31t—36 to 44 inches, olive-brown (2.5Y 4/4) clay loam; moderate, fine, angular blocky structure; firm; few, thick, dark grayish-brown clay films on ped faces; about 4 percent coarse fragments, mostly shale; medium acid; clear, wavy boundary.
- B32t—44 to 48 inches, grayish-brown (2.5Y 5/2) and light olive-brown (2.5Y 5/4) clay loam; moderate, medium, angular blocky structure; firm; few, thick, very dark grayish-brown clay films on ped faces; about 4 percent coarse fragments, mostly shale; slightly acid; abrupt, wavy boundary.
- C—48 to 60 inches, grayish-brown (2.5Y 5/2) and light olive-brown (2.5Y 5/4) clay loam; massive; a few oblique cleavage planes; friable; about 4 percent coarse fragments, mostly shale; mildly alkaline; calcareous.

The A1 or Ap horizon ranges in color from black to very dark gray and in texture from clay loam to loam. Thickness ranges from 6 to 10 inches. Structure is weak, fine, granular or weak, fine, subangular blocky in uncultivated areas and in some places is weak or moderate, fine or medium, subangular blocky where cultivated. Reaction ranges from slightly acid to medium acid in uncultivated areas and in many places is medium acid where cultivated.

The A2 horizon ranges in texture from loam to clay loam or silty clay loam and in thickness from 1 to 4 inches. Structure is weak, medium, platy in some places. This horizon is incorporated into the Ap horizon in most places. Reaction ranges from slightly acid to medium acid.

The B1 horizon ranges from clay loam to silty clay loam or loam. The B2 horizons range from clay loam to silty clay loam, silty clay, or clay. Combined thickness of the B horizons ranges from 30 to 45 inches. Interiors of peds in the B2 horizons range from olive brown to light olive brown. Reaction of the B1 horizon is slightly acid to medium acid. Reaction of the B2 horizon is strongly acid to very strongly acid. Reaction of the B3 horizon is slightly acid to medium acid.

Kilkenny soils have more clay in their B2 horizon than similar Lester soils. Kilkenny soils have browner colors in the B horizon than the associated Lerdal soils.

Kilkenny clay loam, 2 to 6 percent slopes, eroded (KkB2).—This soil occupies 5-acre to 20-acre knolls that have concave and convex relief. Slopes are 80 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that erosion, deep tillage, and tree removal have mixed the surface layer with part of the brownish subsoil. The resulting surface layer is browner and less friable than that of the profile representative for the series.

Included with this soil in mapping are a few uneroded areas where the surface layer is up to 10 inches thick. Also included are a few areas of Lerdal and Shields soils that are too small to be mapped separately. These inclusions are in shallow draws or downslope drainageways. Granite boulders are a common feature of this landscape, but most are being removed or buried.

Most of this soil is used for cultivated crops, but a few areas remain in woodland. Runoff is medium. The hazard of erosion is moderate. (Capability unit IIe-3)

Kilkenny clay loam, 6 to 12 percent slopes, eroded (KkC2).—This soil occupies 5-acre to 20-acre knolls that have concave and convex slopes, and simple sidehill slopes below less sloping Kilkenny soils. Slopes range from 80 to 150 feet in length. This soil has a profile similar to that described as representative for the series, except that erosion, deep tillage, and tree removal have mixed the surface layer with part of the brownish subsoil. The resulting surface layer is browner, lower in organic-matter content, and less friable than that of the profile representative for the series. The soil layers also are thinner.

Included with this soil in mapping are a few areas where free lime carbonates occur near a depth of 20 inches. Also included near Swan Lake are a few areas where the slope ranges from 18 to 25 percent. A few narrow swales of Marna soils and depressions of Glencoe soils are included. Also included are small areas of Dundas, Lerdal, and Shields soils that are too small to be mapped separately. These inclusions occur in narrow, shallow draws, on concave slopes, or in downslope draws. A soil that has a thickened surface layer commonly occurs at the base of slopes and is included because of its narrow width and small acreage. Granite boulders are a common feature of this landscape, but most are being removed or buried.

A few areas of this Kilkenny soil remain in woodland, but most of the acreage is used for cultivated crops. Runoff is medium to rapid. The hazard of erosion is severe. (Capability unit IIIe-2)

Lake Beaches

Lake beaches (lc) consists of dark-colored, sandy and gravelly material that occurs as beaches, sandbars, and ice ramparts around the edges of lakes and larger peat bogs. The soil material is so intermingled and so variable that it cannot be classified in a soil series.

The Lake beaches land type is wet or droughty, depending on lake levels or drainage development. Most of this mapping unit remains in its natural state, but a few areas are cultivated in places where adjacent organic soils have been artificially drained. (Capability unit VIw-1)

Lamont Series

The Lamont series consists of deep, gently sloping to moderately steep, well-drained, loamy soils that formed in sand. They occupy 5-acre to 40-acre sandhills within the loamy glacial uplands, particularly east of the Straight River. They occur in association with the Lester and Hayden soils. In places the tops of the sandhills are Lamont soils and the side slopes are Chelsea soils. Slopes are simple. The native vegetation was oak or brush.

In a representative profile, the surface layer is very dark grayish-brown sandy loam about 7 inches thick. This layer dries to grayish brown. The subsurface layer is dark grayish-brown, very friable sandy loam about 3 inches thick. The subsoil is yellowish-brown and brown, friable loam or sandy clay loam about 13 inches thick. The underlying material is yellowish-brown, light yellowish-brown, and light olive-brown, loose sand.

Permeability is moderately rapid in the upper part of the profile and rapid in the underlying material, beginning at a depth of about 23 inches. Runoff is medium to rapid. The water table is at a depth below 10 feet. The available water capacity is low to moderate. The organic-matter content is moderate, and fertility is low to medium.

Most areas of these soils are used for crops, but some areas are wooded. These soils are only moderately well suited to most crops because of their low available water capacity and fertility. The hazards of soil blowing and water erosion, in addition to the low water capacity and fertility, are major limitations for crop production.

Representative profile of Lamont sandy loam, 2 to 6 percent slopes, in Blooming Prairie Township, in the SE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ of sec. 32, T. 105 N., R. 19 W.:

- Ap—0 to 7 inches, very dark grayish-brown (10YR 3/2) sandy loam, grayish brown (10YR 5/2) when dry; weak, medium, subangular blocky structure; very friable; slightly acid; abrupt, smooth boundary.
- A2—7 to 10 inches, dark grayish-brown (10YR 4/2) sandy loam, brown (10YR 5/3) when dry; weak, thick, platy structure; very friable; medium acid; abrupt, wavy boundary.
- B2t—10 to 17 inches, yellowish-brown (10YR 5/4) loam; weak, medium, subangular blocky structure; friable; few, thin, dark-brown clay films on faces of peds and in pores; few bleached sand grains on faces of peds; medium acid; clear, wavy boundary.
- B3t—17 to 23 inches, brown (10YR 4/3) sandy clay loam; weak, coarse, subangular blocky structure; friable; few, thin, dark reddish-brown clay films on faces of peds; medium acid; clear, wavy boundary.
- IIC1—23 to 40 inches, yellowish-brown (10YR 5/4) and light yellowish-brown (10YR 6/4) sand; single grain; loose; medium acid; clear, wavy boundary.
- IIC2—40 to 60 inches, light olive-brown (2.5Y 5/4) sand; single grain; loose; slightly acid.

The Ap horizon ranges from very dark grayish brown to dark grayish brown in color; it is brown to grayish brown when dry. In undisturbed areas, these soils have a black or very dark gray A1 horizon that ranges from 3 to 6 inches in thickness. The A horizon typically is sandy loam but ranges to loam. Reaction is slightly acid to medium acid. The A2 horizon is dark grayish brown or grayish brown. Reaction is slightly acid to medium acid.

The B2t horizon ranges from sandy loam to fine sandy loam or loam. The B3t horizon ranges from sandy loam or fine sandy loam to sandy clay loam. Reaction in the B horizon is slightly acid or medium acid.

The IIC horizon is sand, fine sand, loamy sand, or loamy fine sand. Reaction is medium acid to neutral. Free lime is below a depth of 60 inches.

The Lamont soils have less clay in the B horizon than the similar Bixby and Dakota soils. They have a B horizon that is continuous vertically, whereas the similar Chelsea soils have a B horizon in the form of bands.

Lamont sandy loam, 2 to 6 percent slopes (LcB).—This soil occupies 5-acre to 40-acre tracts. It occurs on hilltops and gentle side slopes associated with the Lester, Hayden, and Chelsea soils. This soil has the profile described as representative for the series. The surface layer commonly is disturbed by rodent burrowing.

Included in mapping are a few eroded areas in which the original surface layer has been mixed with material from the browner subsoil.

This soil is droughty. Runoff is slow. Soil blowing and water erosion are hazards. Some areas are wooded, but most are used for cultivated crops. (Capability unit IIIe-3)

Lamont sandy loam, 6 to 12 percent slopes (LcC).—This soil occupies 5-acre to 20-acre tracts. It occurs on side slopes below less sloping Lamont soils. Rodent burrowings have disturbed the surface layer.

Included in mapping are a few eroded areas. In these areas the original surface layer has been mixed with material from the browner subsoil.

This soil is droughty. Runoff is medium. The hazards of soil blowing and water erosion are moderate. Most of the acreage is used for cultivated crops, but a few areas remain wooded. (Capability unit IVe-2)

Lamont sandy loam, 12 to 18 percent slopes (LcD).—This soil occupies 5-acre to 10-acre sidehill slopes below less sloping Lamont soils. Rodent burrowings have disturbed the surface layer in many places.

Included in mapping are a few scattered tracts where slopes are 18 to 24 percent. Also included are a few eroded areas in which the original surface layer has been mixed with material from the browner subsoil.

This soil is droughty. Runoff is rapid. The hazard of erosion is severe. This soil is better suited to permanent vegetation, preferably conifers, than to cultivated crops. (Capability unit VIe-2)

Lemond Series

The Lemond series consists of nearly level, poorly drained, loamy soils that are moderately deep over loamy sand or sand. These soils formed in 2 or 3 feet of loam or sandy loam material over sandy material. They occur principally on large sand flats. The native vegetation was mainly water-tolerant grasses.

In a representative profile, the surface layer is loam about 19 inches thick. The upper part of this layer is black, and the lower part is very dark gray. The upper part of the subsoil is mottled, grayish-brown, very friable sandy loam about 9 inches thick. The lower part of the subsoil is mottled, olive-gray loamy sand about 5 inches thick. The underlying material is mottled, olive-gray, loose sand.

Where these soils are drained, permeability is moderately rapid in the upper part of the profile and rapid in the underlying material, beginning at a depth of about 28 inches. Runoff is slow to ponded. The water table is at a depth of 2 to 4 feet or, in drained areas, near tile depth. The available water capacity is low to moderate. The organic-matter content is high, and fertility is medium.

Most areas of Lemond soils are used for crops. Drainage is needed for dependable cropland. In some years crop growth is limited by lack of available water in drained areas. Control of the water table and maintenance of fertility are the main management needs.

Representative profile of Lemond loams, in the southeast corner of SE $\frac{1}{4}$ NE $\frac{1}{4}$ of sec. 6, T. 105 N., R. 20 W

- Ap—0 to 9 inches, black (N 2/0) loam; cloddy; very friable; mildly alkaline; calcareous; abrupt, smooth boundary.
- A1—9 to 16 inches, black (10YR 2/1) loam; weak, fine, granular structure; very friable; mildly alkaline; calcareous; clear, wavy boundary.
- A3—16 to 19 inches, very dark gray (10YR 3/1) loam; weak, fine, subangular blocky structure; very friable; mildly alkaline; calcareous; gradual, wavy boundary.
- B2g—19 to 28 inches, grayish-brown (2.5Y 5/2) sandy loam; few, fine, faint, light olive-brown (2.5Y 5/4) mottles and few, fine, distinct, olive (5Y 5/4) mottles; weak.

fine, subangular blocky structure; very friable; mildly alkaline; calcareous; gradual, wavy boundary.

B3g—28 to 33 inches, olive-gray (5Y 5/2) loamy sand; many, medium, faint, olive (5Y 5/3) mottles; single grain; loose; neutral; abrupt, wavy boundary.

IIC1—33 to 48 inches, olive-gray (5Y 5/2) sand; many, medium, faint, olive (5Y 5/3) mottles; single grain; loose; neutral; abrupt, wavy boundary.

IIC2—48 to 60 inches, olive-gray (5Y 5/2) sand; single grain; loose; mildly alkaline; calcareous.

The Ap and A1 horizons are loam or sandy loam and have a combined thickness of 12 to 20 inches. They dry to very dark gray, the exact color depending on the concentration of lime. Structure, if present, is commonly fine granular but ranges to subangular blocky. The A3 horizon is loam or sandy loam and is 3 to 8 inches thick. Tongues and channels of the A1 horizon extend into this horizon in some areas. Structure is fine subangular blocky or granular.

The B2g horizon is loam or sandy loam. Its thickness ranges from 6 to 14 inches. The B3g horizon ranges from loam or sandy loam to loamy sand. It has weak granular to weak subangular blocky structure or is single grain. The B3g horizon is neutral to mildly alkaline in reaction but lacks free carbonates in some places. The IIC horizon typically is sand, but the range is from fine sand to coarse sand and includes thin strata containing fine gravel. The IIC horizon commonly is calcareous, but part to all of the IIC1 horizon lacks free carbonates and is neutral in some profiles.

The Lemond soils have free carbonates in the A horizon, whereas the similar Hanska soils lack free carbonates in that horizon. Lemond soils have less clay in the A and B horizons than the similar Mayer soils.

Lemond loam (0 to 2 percent slopes) (ld).—This soil occupies 3-acre to 10-acre tracts on rims of depressions and swales and on slight rises within areas of the Hanska soils. It also occurs in broad tracts 10 to 100 acres in size. The highest concentration of carbonates generally is at the surface on the rims of the depressions; the concentration is lower in the soil on the broad tracts.

Included in mapping are small areas of Hanska soils. Also included are a few areas in which the surface layer is sandy loam. A few small included areas have a subsoil of loamy sand, and in some places the underlying material is coarse and very coarse sand.

This Lemond soil is wet. Depth to the water table ranges from 2 to 4 feet in undrained areas. Drainage is needed for dependable cropland. The water table is lowered significantly in some places if a deep outlet ditch is installed. Droughtiness sometimes results from drainage. Because of the high concentration of carbonates, most crops respond favorably to special fertility treatments. A few rims and rises have calcium carbonate equivalents that exceed 20 percent. Most of the acreage is used for crops. (Capability unit IIw-2)

Lerdal Series

The Lerdal series consists of deep, gently undulating, somewhat poorly drained soils that have a clayey subsoil. These soils formed in a shaly, clayey mantle 3 to 10 feet thick. They occur in upland till plains. Slopes are simple and complex. Slopes range from 2 to 6 percent and are commonly 75 to 150 feet long. The native vegetation was dominantly oak.

In a representative profile, the surface layer is very dark gray silty clay loam about 7 inches thick. The subsoil is about 37 inches thick. The upper 16 inches of the subsoil is olive-brown, firm silty clay loam and very firm clay. The middle part is mottled, grayish-brown, very

firm clay. The lower 16 inches is grayish-brown, firm clay loam that contains light olive-brown mottles. Most surfaces of peds have a very dark grayish-brown coating of clay films. The underlying material is calcareous, grayish-brown, firm clay loam that has light olive-brown mottles.

Permeability is slow. Runoff is medium. The water table is usually below a depth of 6 feet. The available water capacity is high. The organic-matter content is moderate to high, and fertility is medium.

Most areas of these soils are used for crops. A few areas are wooded. Maintenance of tilth and control of erosion are the main management needs.

Representative profile of Lerdal silty clay loam, 2 to 6 percent slopes, in Deerfield Township, in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ of sec. 34, T. 108 N., R. 21 W.:

Ap—0 to 7 inches, very dark gray (10YR 3/1) silty clay loam; weak, medium, subangular blocky structure; friable; slightly acid; abrupt, smooth boundary.

B1—7 to 14 inches, olive-brown (2.5Y 4/3) silty clay loam; faces of peds are very dark grayish brown (2.5Y 4/2); common, medium, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, fine and medium, subangular blocky structure; firm; faces of peds are porous and gray (10YR 5/1) when dry; about 4 percent coarse fragments, mostly shale; medium acid; clear, wavy boundary.

B21t—14 to 23 inches, olive-brown (2.5Y 4/3) clay; faces of peds are very dark grayish brown (2.5Y 3/2); many, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, fine and medium, subangular blocky structure; very firm; common thick clay films on faces of peds; common sand-size shale particles; about 4 percent coarse fragments, mostly shale; strongly acid; clear, wavy boundary.

B22tg—23 to 28 inches, grayish-brown (2.5Y 5/2) clay; faces of peds are very dark grayish brown (10YR 3/2); many, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, coarse, prismatic structure; very firm; common thick clay films on faces of peds; few, grayish, porous coatings on faces of peds; common sand-size shale particles; about 4 percent coarse fragments, mostly shale; strongly acid; clear, wavy boundary.

B3tg—28 to 44 inches, grayish-brown (2.5Y 5/2) clay loam; faces of peds are very dark grayish brown (10YR 3/2); many, fine, distinct, light olive-brown (2.5Y 5/6) mottles; weak, coarse, prismatic structure; firm; few medium clay films on faces of peds and along root channels; about 4 percent coarse fragments, mostly shale; slightly acid; abrupt, wavy boundary.

C—44 to 60 inches, grayish-brown (2.5Y 5/2) clay loam; many, fine, distinct, light olive-brown (2.5Y 5/6) mottles; massive; firm; common, medium, black clay films in old root channels; about 5 percent coarse fragments, mostly shale; mildly alkaline; calcareous.

The Ap horizon is black or very dark gray and is clay loam or silty clay loam. It is 6 to 10 inches thick. Its reaction is slightly acid or medium acid. The A2 horizon is in some profiles, and it is up to 4 inches thick. It is clay loam or silty clay loam. Structure is weak, fine, granular or moderate, medium, platy. Reaction is slightly acid or medium acid. This horizon commonly is incorporated into the Ap horizon.

The B1 horizon is clay loam or silty clay loam and is 4 to 8 inches thick. Structure is moderate or strong and subangular or angular blocky. Reaction is slightly acid or medium acid. The B21t and B22tg horizons are silty clay loam, clay loam, clay, or silty clay that has a gritty feel. Mottles range from few to many and from prominent to distinct in these horizons. Consistence is firm or very firm, and reaction is very strongly acid or strongly acid.

The C horizon is loam, clay loam, or gritty silty clay loam. Consistence is friable or firm. There are a few soft masses of lime in the upper part of this horizon in some profiles.

The Lerdal soils have a higher content of clay than the similar Le Sueur soils. They have more grayish colors in the B horizon than the associated Kilkenny soils.

Lerdal silty clay loam, 2 to 6 percent slopes (LeB).—This soil occupies 5-acre to 30-acre knolls, gentle rises, and hilltops. Slopes are 75 to 150 feet long. This soil is associated with the Dundas, Glencoe, Kilkenny, Lura, Marna, and Shields soils. It has the profile described as representative for the series.

Included in the mapping are a few eroded areas. In these areas the original surface layer is mixed with material from the brownish subsoil, and the present surface layer is lower in organic-matter content and is less friable than the original one. Lime carbonates are near a depth of 20 inches in a few areas. Granite boulders are a common landscape feature, but most are being removed and buried.

This Lerdal soil is seasonally wet. Runoff is medium. The hazard of erosion is moderate. Good tilth is difficult to maintain without special management practices. A few areas are wooded, but most of this soil is used for crops. (Capability unit IIe-3)

Lerdal silty clay loam, 2 to 6 percent slopes, eroded (LeB2).—This soil occupies 5-acre to 20-acre knolls that have concave and convex slopes. In places it is on sidehill slopes. It is associated with Dundas, Glencoe, Kilkenny, Lura, Marna, and Shields soils. This soil has a profile similar to that described as representative for the series, except that it is eroded. The resulting surface layer is browner, lower in organic-matter content, and less friable than the original one. The surface layer is thinnest on the convex slopes.

Included are a few areas of Kilkenny and Shields soils that are too small to be mapped separately. In a few areas lime carbonates are near a depth of 20 inches. Granite boulders are a common feature of the landscape, but most are being removed and buried.

This soil is seasonally wet. Runoff is medium. The hazard of erosion is moderate. Good tilth is difficult to maintain without special management practices. Most of the acreage is used for crops. (Capability unit IIe-3)

Lester Series

The Lester series consists of deep, gently undulating to very steep, well-drained, loamy soils that formed in loamy glacial till. These soils are on knolls, hillsides, and valley slopes in the upland till plain. Slopes are convex and concave. The native vegetation was mixed hardwoods, principally oak.

In a representative profile, the surface layer is very dark gray loam about 7 inches thick. The subsurface layer, about 3 inches thick, is very dark grayish-brown, friable loam that dries to dark grayish brown and grayish brown. The subsoil is about 30 inches thick. The upper 3 inches of the subsoil is very dark grayish-brown to dark-brown, friable loam. The middle part is brown and dark yellowish-brown, friable and firm clay loam. The lower 16 inches is olive-brown and light olive-brown, friable loam. The underlying material is calcareous, light olive-brown, friable loam.

Permeability is moderate. Runoff is medium to rapid. The water table is below a depth of 10 feet. The available

water capacity is high. The organic-matter content is moderate to high, and fertility is high.

Most of the less sloping areas are used for crops. The steeper areas are in trees or permanent pasture. The hazard of erosion is the major limitation to use of these soils for crops, and the maintenance of tilth is a special management need.

Representative profile of Lester loam, 2 to 6 percent slopes, in Lemond Township, 200 feet south and 100 feet east of the northeast corner of SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 9, T. 106 N., R. 21 W.:

- A1—0 to 7 inches, very dark gray (10YR 3/1) loam; weak, medium, subangular blocky structure; friable; about 2 percent coarse fragments; slightly acid; abrupt, smooth boundary.
- A2—7 to 10 inches, very dark grayish-brown (10YR 3/2) loam, grayish brown (10YR 5/2) when dry; weak, fine, subangular blocky structure; friable; common bleached sand grains on faces of peds; about 2 percent coarse fragments; slightly acid; clear, wavy boundary.
- B1—10 to 13 inches, dark-brown (10YR 3/3) loam; faces of peds are very dark grayish brown (10YR 3/2); weak, fine and medium, subangular blocky structure; friable; few bleached sand grains on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B21t—13 to 19 inches, brown (10YR 4/3) clay loam; faces of peds are dark brown (10YR 3/3); moderate, medium and fine, subangular blocky structure; friable; few thin clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B22t—19 to 24 inches, dark yellowish-brown (10YR 4/4) clay loam; moderate, medium, prismatic structure parting to weak to moderate, medium to coarse, subangular blocky; firm; many, thin, dark-brown clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B31t—24 to 33 inches, olive-brown (2.5Y 4/4) loam; moderate, medium, prismatic structure parting to weak, medium, subangular blocky; friable; common, thin, dark-brown and very dark grayish-brown clay films on faces of peds and along root channels; about 4 percent coarse fragments; slightly acid; clear, wavy boundary.
- B32t—33 to 40 inches, light olive-brown (2.5Y 4/4) loam; weak, medium, subangular blocky structure; friable; few, thin, very dark grayish-brown and dark-brown clay films on faces of peds and in root channels; about 4 percent coarse fragments; slightly acid; abrupt, wavy boundary.
- C—40 to 60 inches, light olive-brown (2.5Y 5/4) loam; massive; friable; mildly alkaline; calcareous.

The Ap, or the A1, horizon is black, very dark gray, or very dark grayish brown. Its structure is weak, fine or medium, subangular blocky or weak, fine, granular. Reaction is slightly acid or medium acid. The A1 horizon is 6 to 10 inches thick and is neutral or slightly acid. The A2 horizon is very dark grayish brown to dark grayish brown. Dry color is dark grayish brown or grayish brown. Structure is weak, thin platy; weak, fine, subangular blocky; or weak, fine, granular. Reaction is slightly acid to medium acid. Thickness of the A2 horizon ranges up to 4 inches, but in some areas this horizon is incorporated into the Ap horizon.

The B1 horizon is dark brown or brown and is slightly acid or medium acid. The B2 horizon is medium acid or strongly acid, and its total thickness is 9 to 20 inches. The B3 horizon is slightly acid or neutral.

The Lester soils have a darker colored A2 and B1 horizon than the defined range of the series, but this difference does not alter their usefulness and behavior.

Lester soils have an A2 horizon rather than an A3 horizon that is in the similar Clarion soils. They have a thicker A1 horizon or a darker colored Ap horizon than the similar Hayden soils. They developed in glacial till, whereas the similar Blooming soils developed in multiple glacial materials.

Lester loam, 2 to 6 percent slopes (LIB).—This soil occupies 5-acre to 80-acre, irregularly shaped knolls. Slopes are 80 to 150 feet long. In most places this soil is above the more sloping Lester soils. It has the profile described as representative for the series. The layers are thinner on the convex slopes.

Included in mapping are a few small areas of Storden soils on the convex slopes. The concave slopes commonly include small areas of Dundas, Le Sueur, or Webster soils. Also included are small pockets of gravel.

Runoff is medium. The hazard of erosion is moderate. Good tilth is difficult to maintain without special management practices. Most of the acreage is used for crops. There are a few wooded areas. (Capability unit IIe-1)

Lester loam, 2 to 6 percent slopes, eroded (LIB2).—This soil occupies 5-acre to 80-acre, irregularly shaped knolls. Slopes are 80 to 150 feet long. In most places this soil is above the more sloping Lester soils. It has a profile similar to that described as representative for the series, except that erosion, tree removal, and deep tillage have caused a mixing of the original surface layer with part of the brownish subsoil. The resulting surface layer has browner colors, contains less organic matter, and is less friable than the original one. The layers are thinnest on the convex slopes.

Included in mapping are a few small areas of Storden soils on convex slopes. The concave slopes commonly include small areas of Dundas, Le Sueur, or Webster soils. Small pockets of gravel and a few uneroded areas also are included.

Runoff is medium. The hazard of erosion is moderate. Good tilth is difficult to maintain without special management practices. Most of the acreage is used for crops. (Capability unit IIe-1)

Lester loam, 6 to 12 percent slopes (LIC).—This soil occupies 5-acre to 20-acre, irregularly shaped knolls and hillsides. In the southwestern part of Berlin Township, it is on the smooth side slopes of somewhat circular, flat-topped hills. Slopes are 80 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that soil layers are thinner on convex slopes.

Included in mapping are a few areas where slopes are less than 6 percent and more than 12 percent. Small areas of Storden soils are included on convex slopes. The concave slopes commonly include small areas of Dundas, Le Sueur, or Webster soils. Also included are small pockets of gravel, and a few areas that are eroded and where part of the brownish subsoil has been mixed with the original surface layer.

Runoff is medium. The hazard of erosion is moderate. Fertility is difficult to maintain without special management practices. The soil is in woodland and cropland and is well suited to most crops grown in the county. (Capability unit IIIe-1)

Lester loam, 6 to 12 percent slopes, eroded (LIC2).—This soil occupies 5-acre to 20-acre, irregularly shaped knolls and hillsides where slopes are convex and concave. Slopes are 80 to 150 feet long. In the southwestern part of Berlin Township, this soil is on smooth side slopes of somewhat circular, flat-topped hills. This soil has a profile similar to that described as representative for the series, except that erosion, tree removal, and deep tillage

have caused the mixing of part of the brownish subsoil with the original surface layer. The present surface layer has browner colors, has a lower organic-matter content, and is less friable than the original one. The soil layers are thinner on convex slopes.

Included in mapping are a few areas where slopes are less than 6 percent and more than 12 percent. Small areas of Storden soils are included on convex slopes. The concave slopes commonly include Dundas, Le Sueur, and Webster soils. Also included are small pockets of gravel and a few uneroded areas.

Runoff is medium. The hazard of erosion is moderate. Good tilth is difficult to maintain without special management practices. Most of the acreage is used for crops. Contour cultivation is easily applied to slopes in the southwestern part of Berlin Township. (Capability unit IIIe-1)

Lester loam, 12 to 18 percent slopes, eroded (LID2).—This soil occupies a few 5-acre to 20-acre, irregularly shaped knolls, but most of it is on 5-acre to 20-acre hillside slopes that are crossed by many narrow draws and by a few deep ravines. In the southwestern part of Berlin Township, this soil is on smooth side slopes of somewhat circular, flat-topped tills. Slopes are 80 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that erosion has caused material from the brownish subsoil to be mixed with the original surface layer. The present surface layer is browner, lower in organic-matter content, and less friable than the original one. The soil layers are thinner on the convex slopes.

Included in mapping are a few areas where slopes are less than 12 percent and more than 18 percent. Small areas of Storden soils are included on the convex slopes. The shallow, narrow, downslope draws commonly include Dundas, Le Sueur, or Webster soils. Also included are small pockets of gravel. A soil that has a thickened surface layer is included at the base of many slopes because it is in narrow areas. Also included are some uneroded areas in woodland.

Runoff is rapid. The hazard of erosion is severe. Good tilth is difficult to maintain without special management practices. Part of the acreage of this soil is used for crops. (Capability unit IVe-1)

Lester-Estherville-Storden complex, 2 to 6 percent slopes, eroded (LmB2).—This complex occupies small, scattered tracts and consists of approximately 40 percent Lester loam, about 30 percent Estherville sandy loam, and about 30 percent Storden loam. These soils have profiles similar to those described as representative for their respective series, but because of erosion, part of the brownish subsoil has been mixed with the original surface layer.

Included in mapping are some small areas of Salida soils; these generally are identified on the soil map by gravel-spot symbols. Also included are some uneroded areas that are in woodland.

Soils of this complex are generally farmed in fields with other soils. Runoff is medium, and the hazard of erosion is moderate. The droughtiness of the Estherville soils and the high content of lime carbonates in the Storden soils require special management practices. (Capability unit IIIe-4)

Lester-Estherville-Storden complex, 6 to 18 percent slopes, eroded (LmD2).—This complex occupies small, scattered tracts and consists of approximately 40 percent Lester loam, about 30 percent Estherville sandy loam, and about 30 percent Storden loam. It occurs throughout the county but is located principally near drainage-ways and near the edge of glacial outwash. The soils in this complex have profiles similar to those described as representative for their respective series, except that they are eroded and part of the brownish subsoil has been mixed with the original surface layer. The present surface layer is browner, lower in organic-matter content, and less friable than the original one.

Included in mapping are some small areas of Salida soils that generally are identified on the soil map by gravel-spot symbols. A few uneroded areas in woodland also are included.

These soils are generally farmed in fields with other soils. Runoff is rapid, and the hazard of erosion is moderate to severe. South- and west-facing slopes have wider temperature variations than east- and north-facing slopes. Droughtiness of the Estherville soil and the high content of lime carbonates in the Storden soil require special management practices. (Capability unit VIe-1)

Lester and Hayden loams, 18 to 25 percent slopes (LnE).—These steep soils have slopes that are 80 to 300 feet long. Slopes are both convex and concave. These soils are dissected at close intervals by shallow downslope draws and in a few places by abrupt, deep, narrow ravines. This undifferentiated group consists of approximately 60 percent Lester loam and nearly 40 percent Hayden loam. These soils have profiles similar to those described as representative for their respective series, except that the layers are thinner.

A few small areas of Storden soils are included on the convex slopes. A few included areas are of Estherville soils intermingled with Storden soils, and some areas have a thin sandy loam mantle. Also included are a few eroded areas in which the present surface layer consists mostly of material from the brownish subsoil.

Most of the acreage is in woodland. A few areas are used as permanent pasture. The steep wooded slopes commonly limit use of these soils to esthetic enhancement of the environment. (Capability unit VIe-1)

Lester and Hayden loams, 25 to 35 percent slopes (LnF).—These very steep soils have slopes that are 80 to 300 feet long and are concave and convex. They are dissected by many shallow draws and, in a few places, by abrupt, deep, narrow ravines. The mapping unit consists of approximately 60 percent Lester loam and nearly 40 percent Hayden loam. These soils have profiles similar to those described as representative for their respective series, except that the layers are thinner.

Small areas of Storden soils are included in areas mapped as these soils. A few included areas are eroded, and in these the present surface layer consists mostly of material from the brownish subsoil.

These soils are in woodland and permanent pasture. Runoff is rapid, and the hazard of erosion is very severe. The steep wooded slopes commonly limit use of these soils to enhancement of the environment. (Capability unit VIIe-1)

Lester-Storden complex, 6 to 12 percent slopes, eroded (LoC2).—This complex occupies 5-acre to 30-acre, irregularly shaped knolls. About 70 percent is Lester loam, and nearly 30 percent is the lighter colored Storden loam. The Storden soil occupies the convex slopes. These soils have profiles similar to those described as representative for their respective series, but erosion has resulted in part of the brownish subsoil being mixed with the original surface layer of the Lester soil.

Included in mapping, at the base of the slopes, are small areas of a soil that has a thickened surface layer. Small spots of gravel also are included.

Most of the acreage is used for cultivated crops. Runoff is medium, and the hazard of erosion is severe. Special fertility treatments are beneficial for most crops on the calcareous Storden soil. (Capability unit IIIe-1)

Lester-Storden complex, 12 to 18 percent slopes, eroded (LoD2).—This complex occupies 5-acre to 30-acre areas on irregularly shaped knolls and hillside slopes. Slopes are 75 to 150 feet long. This unit consists of about 70 percent Lester loam and nearly 30 percent Storden loam. These soils have profiles similar to those described as representative for their respective series, except that erosion has resulted in part of the browner subsoil being mixed with material from the surface layer of the Lester soil. Also, the soil layers are thinner.

Included in mapping are a few areas where slopes are less than 12 percent and greater than 18 percent. A soil that has a thickened surface layer is at the base of the slopes in many areas. Some included tracts are a complex of Lester, Estherville, and Storden soils. Also included are a few uneroded areas that are in woodland.

Most of the acreage is used for crops. Runoff is rapid, and the hazard of erosion is severe. Special fertility treatments are beneficial for most crops on the calcareous Storden soil. (Capability unit IVe-1)

Le Sueur Series

The Le Sueur series consists of deep, nearly level to gently undulating, moderately well drained and somewhat poorly drained, loamy soils. These soils formed in friable loam or clay loam glacial till. They are on knolls and a few sidehill slopes in the upland till plain. Slopes are both simple and complex. They are 75 to 100 feet long and range from 0 to 4 percent. The native vegetation was mixed hardwoods.

In a representative profile, the surface layer is black and very dark gray clay loam about 10 inches thick. The subsoil, about 33 inches thick, is very dark grayish-brown and dark grayish-brown, friable and firm clay loam in the upper 25 inches. It has light olive-brown mottles. The lower 8 inches is olive-gray clay loam. The underlying material is strongly calcareous, friable, grayish-brown loam that contains light olive-brown mottles.

Permeability is moderate. Runoff is slow to medium. The water table is at a depth of 5 to 10 feet. The available water capacity is high. The organic-matter content and fertility are high.

Most areas of these soils are used for crops, but some remain in trees. These soils are well suited to most crops commonly grown in the county and have few limitations to use for crops.

Representative profile of Le Sueur clay loam, 0 to 2 percent slopes, in Berlin Township, 700 feet east and 300 feet north of the southwest corner of SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, T. 105 N., R. 21 W.:

- Ap—0 to 6 inches, black (10YR 2/1) clay loam; weak, fine, granular structure; friable; about 2 percent coarse fragments; slightly acid; clear, wavy boundary.
- A3—6 to 10 inches, very dark gray (10YR 3/1) clay loam; few dark-gray (10YR 4/1) tongues; moderate, fine and very fine, subangular blocky structure; friable; about 2 percent coarse fragments; slightly acid; clear, wavy boundary.
- B1t—10 to 15 inches, very dark grayish-brown (10YR 3/2) clay loam; faces of peds are very dark gray (10YR 3/1); moderate, fine and medium, subangular blocky structure; friable; few thin clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B21t—15 to 21 inches, dark grayish-brown (10YR 4/2) clay loam; faces of peds are very dark grayish brown (10YR 3/2); few, fine, distinct, light olive-brown (2.5Y 5/4) mottles; moderate, fine, angular blocky structure; friable; many thin clay films on faces of peds, in pores, and along root channels; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B22t—21 to 27 inches, dark grayish-brown (10YR 4/2) clay loam; faces of peds are very dark grayish brown (10YR 3/2); few, fine, distinct, light olive-brown (2.5Y 5/4) mottles; moderate, fine, prismatic structure parting to moderate, medium, subangular blocky; firm; many thin to thick clay films on faces of peds and in pores and root channels; about 4 percent coarse fragments; strongly acid; clear, wavy boundary.
- B23t—27 to 35 inches, dark grayish-brown (2.5Y 4/2) clay loam; faces of peds are very dark grayish brown (2.5Y 3/2); moderate, fine and medium, prismatic structure parting to moderate, medium, subangular blocky; firm; many thick clay films on faces of peds; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B3t—35 to 43 inches, olive-gray (5Y 5/2) clay loam; many, fine, distinct, olive (5Y 5/4) mottles; weak, coarse, prismatic structure; friable; many, very dark gray, clayey fillings in old root channels; about 4 percent coarse fragments; slightly acid; abrupt, wavy boundary.
- C—43 to 60 inches, grayish-brown (2.5Y 5/2) loam; many, fine, distinct, light olive-brown (2.5Y 5/4) mottles; massive; friable; about 4 percent coarse fragments; mildly alkaline; strongly calcareous.

The Ap horizon, or the A1 horizon, is black or very dark gray clay loam or loam. Its structure is weak, fine, granular or weak, fine and medium, subangular blocky. Reaction is slightly acid to medium acid. The A1 horizon is 6 to 12 inches thick. The A3 horizon is lacking in some areas, and in others it ranges up to 5 inches in thickness. Reaction is slightly acid to medium acid. The total thickness of the B horizon ranges from 26 to 40 inches. The B3 horizon ranges from loam to clay loam in texture. Depth to the C horizon ranges from 36 to 54 inches.

The Le Sueur soils have less clay in the A horizon than the similar Lerdal soils and more clay in the B horizon than the similar Nicollet soils. They have a darker colored A horizon than the similar Newry soils.

Le Sueur clay loam, 0 to 2 percent slopes (luA).—This soil occupies 5-acre to 30-acre rises within areas of Glencoe, Hayden, Lester, and Webster soils. It also occurs on hilltops above more sloping Lester soils. This soil has the profile described as representative for the series.

Included in mapping are a few areas, near the valleys of the Straight River and Maple Creek, in which the surface layer is thinner than normal. The surface layer in

these areas is grayer than normal when dry. Also included, in and near sections 13 and 24 in Somerset Township, in sections 18 and 19 in Aurora Township, and southwest of Havana station, are small areas of a soil that has a silty mantle 12 to 30 inches thick. This soil is included because of its small acreage.

This Le Sueur soil is moderately wet during wet periods. Runoff is slow. Other than seasonal wetness, there are few limitations for crops. Most of the acreage is used for crops, but some areas remain wooded. (Capability unit I-1)

Le Sueur clay loam, 2 to 4 percent slopes (luB).—This soil occupies 5-acre to 20-acre knolls and rises associated with Glencoe, Hayden, Lester, and Webster soils. A few areas are in shallow drainageways. Slopes range from 75 to 100 feet long.

Included in mapping are a few areas, near the valleys of the Straight River and Maple Creek, where the surface layer is thinner than normal and is grayer than normal when dry. Also included, in east-central Somerset Township, are small areas of a soil that has a thin silty mantle. A few concave slopes have loam rather than clay loam layers in the subsoil. Glencoe and Webster soils are included in draws and small depressions. Also included are a few small areas of Dundas soils and a few areas that are slightly eroded and have part of the subsoil mixed with the original surface layer.

This Le Sueur soil is slightly wet during wet seasons. Runoff is medium, and the hazard of erosion is slight. Most of the acreage is used for crops, and the soil is well suited to this use. (Capability unit IIe-1)

Lura Series

The Lura series consists of deep, nearly level, very poorly drained soils that have a clayey subsoil. These soils formed in clayey sediments 3 to 10 feet thick. They occupy depressions and sluggish drainageways. The native vegetation was sedges and water-tolerant grasses.

In a representative profile, the surface layer is black, firm silty clay loam and silty clay about 32 inches thick. The subsoil is gray and dark-gray, firm silty clay about 16 inches thick. It has olive, olive-gray, and light olive-brown mottles. Tongues of dark-colored material extend into the subsoil. The underlying material is mottled, dark-gray, firm silty clay.

Permeability is slow. Runoff is slow to ponded. The water table is at a depth of 0 to 3 feet or, in drained areas, near tile depth. The available water capacity is high. The organic-matter content and fertility are high.

Most areas are used for crops. In their natural state, these soils are only moderately well suited to poorly suited to most crops grown in the county. If adequately drained, they are suited to most crops grown locally. Control of the water table and maintenance of tilth and fertility are main management needs.

Representative profile of Lura silty clay loam, in Deerfield Township, 200 feet east and 30 feet north of the southwest corner of SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 22, T. 108 N., R. 21 W.:

- Ap—0 to 8 inches, black (N 2/0) silty clay loam; weak, fine, subangular blocky structure; firm; neutral; abrupt, smooth boundary.

- A11—8 to 18 inches, black (N 2/0) silty clay; moderate, fine, subangular blocky structure; firm; neutral; gradual, wavy boundary.
- A12—18 to 32 inches, black (N 2/0) silty clay; weak, coarse, prismatic structure parting to moderate, fine, subangular blocky; firm; neutral; gradual, irregular boundary.
- B21g—32 to 40 inches, gray (5Y 5/1) silty clay; few, fine, distinct, olive (5Y 5/6) mottles; few tongues of black (N 2/0); moderate, medium, prismatic structure parting to moderate, fine, subangular blocky; firm; neutral; gradual, irregular boundary.
- B22g—40 to 48 inches, dark-gray (5Y 4/1) silty clay; many, fine, faint, olive-gray (5Y 4/2) mottles and common, fine, distinct, light olive-brown (2.5Y 5/6) mottles; few tongues of black (N 2/0); moderate, fine, subangular blocky structure; firm; neutral; gradual, wavy boundary.
- Cg—48 to 60 inches, dark-gray (5Y 4/1) silty clay; common, fine, prominent, strong-brown (7.5YR 5/8) mottles; moderate, fine, subangular blocky structure; firm; mildly alkaline.

The Ap horizon is silty clay or silty clay loam. Its reaction ranges from slightly acid to mildly alkaline. The A1 horizon has a total thickness of 16 to 24 inches. There are a few dark-brown and reddish-brown mottles in the A1 horizon in some profiles. Reaction ranges from slightly acid to mildly alkaline. Some profiles have a thin, very dark gray A3 horizon.

The B horizon is silty clay or clay. Its reaction is from neutral to mildly alkaline.

The C horizon typically is silty clay, clay, clay loam or silty clay loam. In some profiles the lower part of the C horizon is loam glacial till. The C horizon is neutral or mildly alkaline in the lower part. Lime is leached to a depth of 40 to 70 inches.

The Lura soils contain more clay and less sand than the similar Glencoe soils. They have a thicker A horizon than the associated Marna soils.

Lura silty clay loam (0 to 1 percent slopes) (ly).—This soil is in small depressions, short sideslope draws, and 5-acre to 20-acre, long, winding, low-gradient drainageways. It is associated with the Marna and Shields soils.

Included in mapping are some soils that have a surface mat of thin organic material in some undrained areas.

This Lura soil is very wet. Depth to the water table in undrained areas ranges from 0 to 3 feet. Runoff is slow to ponded. Drainage is needed for dependable cropland for commonly grown crops. The perched water table can be controlled by use of a properly designed and installed drainage system. This soil can be tilled only within a narrow range of moisture content. If worked when wet, this soil compacts easily, tilth is destroyed, aeration is reduced, and the soil becomes hard and cloddy when drying. The shrink-swell potential is high. During dry periods, cracks form that extend into the subsoil. Most of the acreage is used for crops. (Capability unit IIIw-1)

Madelia Series

The Madelia series consists of deep, nearly level, poorly drained, silty soils that formed in calcareous silty sediments. These soils occupy broad flats. The native vegetation was water-tolerant grasses.

In a representative profile, the surface layer is black silty clay loam about 16 inches thick. The upper part of the subsoil is dark grayish-brown, friable silty clay loam about 6 inches thick. The lower part of the subsoil is distinctly mottled, olive-gray, friable silty clay

loam about 12 inches thick. The underlying material is olive-gray, calcareous, friable silty clay loam and silt loam that contains seams of yellowish-brown sandy loam.

Permeability is moderate. Runoff is slow to ponded. The water table is at a depth of 1 to 4 feet. The available water capacity is high to very high. The organic-matter content and fertility are high.

Most areas of these soils are used for crops. In their natural state, these soils are only moderately well suited to most crops grown in the county. If adequately drained, they are well suited to most crops grown locally. Control of the water table and maintenance of tilth are the main management needs.

Representative profile of Madelia silty clay loam, in Owatonna Township, in the northeast corner of SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 26, T. 107 N., R. 20 W.:

- Ap—0 to 7 inches, black (N 2/0) silty clay loam; cloddy; friable; slightly acid; abrupt, smooth boundary.
- A1—7 to 16 inches, black (N 2/0) silty clay loam; moderate, very fine, subangular blocky structure; friable; slightly acid; gradual, irregular boundary.
- B1g—16 to 22 inches, dark grayish-brown (2.5Y 4/2) silty clay loam; ped faces are very dark gray (10YR 3/1); few tongues of black (10YR 2/1); moderate, very fine and fine, subangular blocky structure; friable; neutral; gradual, irregular boundary.
- B21g—22 to 28 inches, olive-gray (5Y 4/2) silty clay loam; common, fine, distinct, olive (5Y 5/4) mottles; moderate, very fine and fine, subangular blocky structure; friable; neutral; clear, wavy boundary.
- B22g—28 to 34 inches, olive-gray (5Y 5/2) silty clay loam; common, fine, distinct, olive (5Y 5/4) mottles; moderate, very fine, subangular blocky structure; friable; neutral; clear, smooth boundary.
- C1g—34 to 48 inches, olive-gray (5Y 5/2) silty clay loam; common, medium, prominent, yellowish-brown (10YR 5/8) mottles; many, fine, white lime threads; weak, thin to thick, platy structure; friable; mildly alkaline; calcareous; abrupt, smooth boundary.
- C2g—48 to 60 inches, olive-gray (5Y 5/2) silt loam and thin layers of yellowish-brown (10YR 5/8) sandy loam; massive; friable; mildly alkaline; calcareous.

The Ap and A1 horizons have a combined thickness of 14 to 20 inches. Reaction in these horizons ranges from slightly acid to mildly alkaline. In some profiles the Ap horizon contains a small amount of free carbonate. In some areas there is an A3 horizon that is very dark gray and is as much as 6 inches thick. It is silty clay loam or silt loam and neutral or mildly alkaline.

The B horizon has a matrix of dark gray, gray, olive gray, or dark grayish brown. Its texture ranges from silt loam to silty clay loam. Total thickness of the B horizon is 16 to 24 inches. A part of the B horizon in some profiles has free carbonates. The C horizon ranges from silt loam to silty clay loam in texture. There are thin, coarse-textured strata in the C horizon in some profiles.

The Madelia soils contain less clay and more silt than the similar Marna soils. They contain more silt and less sand than the similar Webster soils.

Madelia silty clay loam (0 to 2 percent slopes) (Mcl).—This soil occupies 10-acre to 200-acre, broad tracts. It occurs in association with Biscay, Canisteo, and Mayer soils.

Included in mapping are small areas of Canisteo soils that formed in thick silt. West of Havana station, a few small depressions are included that have a gray surface layer and an acid clayey subsoil. In a few included areas the surface layer is calcareous and the underlying material has thick layers and pockets of sand.

This Madelia soil is wet. Depth to the water table ranges from 1 to 4 feet in undrained areas. Runoff is slow.

Drainage is needed for dependable cropland for commonly grown crops. The perched water table can be controlled by use of a properly designed and installed drainage system. Most of the acreage is used for cultivated crops. (Capability unit IIw-1)

Marna Series

The Marna series consists of deep, nearly level, poorly drained soils that have a clayey subsoil. These soils formed in clayey sediments, 2 to 3 feet thick, and in the underlying loamy glacial deposits. They occupy broad, winding tracts that are intermingled with more sloping soils. The native vegetation was water-tolerant grasses.

In a representative profile, the surface layer is black silty clay loam and silty clay about 16 inches thick. The subsoil is olive-gray, firm silty clay, about 12 inches thick, that contains tongues of black from the surface layer. The underlying material is mottled, dark-gray, friable clay loam.

Permeability is slow. Runoff is slow to ponded. The water table is at a depth of 1 to 3 feet or, if the soils are drained, near tile depth. The available water capacity is high. The organic-matter content and fertility are high.

Most areas are used for crops. In their natural state these soils are only moderately well suited to poorly suited to most crops grown in the county. If adequately drained, they are suited to most crops grown locally. Control of the water table and maintenance of tilth and fertility are the main management needs.

Representative profile of Marna silty clay loam, in Deerfield Township, 600 feet west and 100 feet north of southeast corner of SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 22, T. 108 N., R. 21 W.:

- Ap—0 to 8 inches, black (N 2/0) silty clay loam; moderate, fine, granular structure; firm; slightly acid; clear, wavy boundary.
- A1—8 to 16 inches, black (N 2/0) silty clay; moderate, fine, subangular structure; firm; slightly acid; gradual, irregular boundary.
- B1g—16 to 20 inches, olive-gray (5Y 4/2) silty clay; faces of pedis are black (10YR 2/1); few tongues of black (N 2/0) material; moderate, fine, subangular blocky structure; firm; slightly acid; clear, irregular boundary.
- B2g—20 to 28 inches, olive-gray (5Y 4/2) silty clay; few tongues of black (N 2/0); few, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, medium, prismatic structure parting to moderate, fine, subangular blocky; firm; slightly acid; clear, wavy boundary.
- IICg—28 to 60 inches, dark-gray (5Y 4/1) clay loam; many, fine, distinct, light olive-brown (2.5Y 5/4) mottles and many, medium, prominent, strong-brown (7.5YR 5/8) mottles; moderate, fine, subangular blocky structure; friable; few white lime streaks; mildly alkaline; calcareous.

The Ap and A1 horizons are silty clay loam or silty clay. Their structure is weak or moderate and fine granular or very fine or fine subangular blocky. Their reaction is commonly slightly acid but in places is neutral. Combined thickness of these horizons is 12 to 20 inches. There is a very dark gray, silty clay A3 horizon in some profiles. It is slightly acid or neutral.

The B1 and B2 horizons typically are silty clay or clay, but the B2g horizon is heavy clay loam in some profiles. Total thickness of the B horizon ranges from 10 to 20 inches. Reaction ranges from slightly acid to mildly alkaline in the B horizon.

The IIC horizon ranges from clay loam to silty clay loam or loam. Consistence generally is friable or firm, but the horizon is massive in some profiles.

Marna soils have a thinner A horizon than the associated Lura soils. They contain more clay than the similar Madelia soils. Common landscape associates are the better drained Kilkenny, Lerdal, and Shields soils.

Marna silty clay loam (0 to 2 percent slopes) (Mc).— This soil occupies 5-acre to 80-acre tracts that are broad and intermingled with areas of Kilkenny, Lerdal, Lura, and Shields soils. In a few places, this soil is associated with the Lester and Le Sueur soils.

Included in mapping are a few areas of Lura and Shields soils. Also included are some areas, adjacent to the rims of drainageways, that have a calcareous surface layer.

This Marna soil is wet. Depth to the water table ranges from 1 to 4 feet in undrained areas. Runoff is slow. Drainage is needed for dependable cropland for commonly grown crops. A properly designed and installed drainage system effectively controls the perched water table. Most of the acreage is used for crops. (Capability unit IIw-1)

Marsh

Marsh (Mh) is in shallow lakes and ponds in shallow bays, and along the fringes of larger lakes. The water is shallow, and areas of open water are small.

Water-tolerant reeds, sedges, and brush grow in these areas. Several marshes are being preserved and developed to provide suitable wildlife habitat. A few areas have been developed for use as cropland, particularly for the growing of truck crops. In most places the soil material is peat or muck. (Capability unit VIIIw-1)

Maxcreek Series

The Maxcreek series consists of deep, nearly level, poorly drained, silty soils. These soils formed in 2 to 3 feet of silty sediments and in the underlying loamy glacial deposits. A sandy layer separates the silty material from the underlying, friable, loamy glacial drift. The largest acreage is on broad upland flats. These soils also occupy depressions and sluggish drainageways. The native vegetation was mainly water-tolerant grasses and sedges.

In a representative profile, the surface layer is black silty clay loam about 16 inches thick. The upper part of the subsoil is mottled, olive-gray, friable silty clay loam about 13 inches thick. The lower part is mottled, dark grayish-brown loam 4 inches thick. The underlying material consists of a thin layer of mottled, grayish-brown, loose sandy loam over calcareous, mottled, dark grayish-brown, friable loam.

Permeability is moderate. Runoff is slow to ponded. The water table is at a depth of 0 to 4 feet or, in drained areas, near tile depth. The available water capacity is high. The organic-matter content and fertility are high.

Most areas are used for crops. In their natural state, these soils are only moderately well suited to poorly suited to most crops grown in the county. If adequately drained, they are well suited to most crops grown locally. Control of the water table and maintenance of tilth are the main management needs.

Representative profile of Maxcreek silty clay loam, in Merton Township, 300 feet east and 100 feet north of the southwest corner of SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 1, T. 108 N., R. 19 W.:

- Ap—0 to 11 inches, black (N 2/0) silty clay loam; cloddy; friable; neutral; gradual, irregular boundary.
- A3—11 to 16 inches, black (5Y 2/2) silty clay loam; weak, fine, subangular blocky structure; friable; neutral; gradual, irregular boundary.
- B21g—16 to 21 inches, olive-gray (5Y 4/2) silty clay loam; few tongues of black (5Y 2/2); weak, fine, subangular blocky structure; friable; neutral; clear, wavy boundary.
- B22g—21 to 29 inches, olive-gray (5Y 5/2) silty clay loam; few, fine, distinct, light olive-brown (2.5Y 5/6) mottles; weak, fine, subangular blocky structure; friable; neutral; clear, wavy boundary.
- B3g—29 to 33 inches, dark grayish-brown (2.5Y 4/2) loam; common, fine, prominent, yellowish-brown (10YR 5/8) mottles; weak, fine, subangular blocky structure; friable; mildly alkaline; calcareous; abrupt, wavy boundary.
- IIC1g—33 to 39 inches, grayish-brown (2.5Y 5/2) sandy loam; many, fine, distinct, light olive-brown (2.5Y 5/4) mottles; a few seams of dark red (2.5Y 3/6); single grain; loose; mildly alkaline; calcareous; abrupt, smooth boundary.
- IIC2g—39 to 60 inches, dark grayish-brown (2.5Y 4/2) loam; many, fine, prominent, strong-brown (7.5YR 5/6) mottles; massive; about 5 percent coarse fragments; friable; mildly alkaline; calcareous.

In some profiles an A1 horizon of silty clay loam, up to 6 inches thick, underlies the Ap horizon. Reaction in the Ap horizon, or the A1 horizon, commonly is neutral but ranges from slightly acid to mildly alkaline. Combined thickness of the A1 and Ap horizons is 10 to 16 inches. The A3 horizon is 4 to 10 inches thick. Its structure is weak or moderate, subangular blocky. Its reaction is neutral to mildly alkaline. The lower boundary of this horizon is smooth in some profiles but commonly is tongued into the B horizon.

The B21g horizon is olive gray or dark gray. The B22g horizon is silty clay loam or silt loam. Mottles commonly increase in abundance with depth in the B horizon. The B3g horizon is loam, silt loam, or silty clay loam. Reaction in the B horizon typically is neutral but in places is mildly alkaline.

The IIC1g horizon ranges from sandy clay loam, sandy loam, or loamy sand to sand or sand and gravel. Thickness typically ranges from 5 to 10 inches, but this horizon is not present in some profiles. Depth to free lime ranges from 20 to 40 inches.

The Maxcreek soils contain more silt and less sand in the A and B horizons than the similar Webster soils. They lack free lime in the A horizon, whereas the similar Canisteo soils contain free lime in that horizon.

Maxcreek silty clay loam (0 to 2 percent slopes) (Mm).—This nearly level soil occupies 3-acre to 50-acre tracts. It has the profile described as representative for the series.

Areas of Canisteo, Havana, and Merton soils, too small to be mapped separately, are included. In some included areas the silty mantle is thin or is loamy and has a high content of silt.

This soil is wet. Runoff is slow. Depth to the water table ranges from 1 to 4 feet in undrained areas. Drainage is needed for dependable cropland for commonly grown crops. A properly designed and installed drainage system effectively controls the perched water table. Crops respond favorably to special additions of fertilizer in the small areas where concentrations of lime are high. Most of this soil is used for crops. (Capability unit IIw-1)

Maxcreek silty clay loam, swales (0 to 1 percent slopes) (Mn).—This soil is in small depressions and in 5-acre to 40-acre areas in long, winding, low-gradient swales. This soil has a profile similar to that described as representative for the series, except that the surface layer is somewhat thicker and the subsoil colors are grayer.

Included in mapping are a few small areas of Canisteo soils and areas of soils that have a calcareous surface layer. In a few included areas, the deeper subsoil layer is greenish gray.

This soil is very wet. Runoff is slow to ponded. Depth to the water table ranges from 0 to 3 feet in undrained areas. Drainage is needed for dependable cropland for commonly grown crops. A properly designed and installed drainage system effectively controls the water table. Surface waterways are used in places to prevent ponding. Most of the acreage is used for crops. (Capability unit IIIw-1)

Mayer Series

The Mayer series consists of nearly level, poorly drained, calcareous, loamy soils that formed in 2 to 3 feet of loamy sediment and in the underlying coarse sand and fine gravel. The native vegetation was mainly water-tolerant grasses and sedges.

In a representative profile, the surface layer is calcareous loam about 20 inches thick. The upper part of this layer is black, and the lower part is very dark gray. The subsoil is olive-gray, friable loam, very friable sandy clay loam, and very friable sandy loam about 16 inches thick. It contains olive-brown and olive mottles. The underlying material is grayish-brown, loose coarse sand that is mottled with olive gray and light olive brown.

Permeability in drained areas is moderate in the upper part of the profile and rapid in the underlying material beginning at a depth of about 36 inches. Runoff is slow to ponded. The water table is at a depth of 1 to 3 feet or is near tile depth in drained areas. The available water capacity is moderate. The organic-matter content is high and fertility is medium.

Most areas are used for crops. In their natural state, these soils are only moderately well suited to poorly suited to most crops grown in the county. If adequately drained, they are suited to most crops grown locally. Special additions of fertilizer are beneficial for most crops because of the high concentration of lime carbonates in these soils.

Representative profile of Mayer loam, in Aurora Township, 300 feet south of northwest corner of sec. 8, T. 106 N., R. 19 W.:

- Ap—0 to 9 inches, black (N 2/0) loam; cloddy; friable; mildly alkaline; calcareous; abrupt, smooth boundary.
- A1—9 to 13 inches, black (10YR 2/1) loam; weak, fine, granular structure; friable; mildly alkaline; calcareous; abrupt, wavy boundary.
- A3—13 to 20 inches, very dark gray (10YR 3/1) loam; few streaks of dark gray (10 YR 4/1); weak, fine, granular structure; friable; mildly alkaline; calcareous; gradual, wavy boundary.
- B21g—20 to 26 inches, olive-gray (5Y 5/2) loam; few fine, distinct, light olive-brown (2.5Y 5/4) mottles; weak, fine, granular structure; friable; mildly alkaline; calcareous; clear, wavy boundary.
- B22g—26 to 30 inches, olive-gray (5Y 5/2) light sandy loam; few, fine, faint, olive (5Y 5/3) mottles; weak, medium, subangular blocky structure; very friable; neutral; clear, wavy boundary.

- B3—30 to 36 inches, olive-gray (5Y 5/2) sandy loam; weak, medium and coarse, subangular blocky structure; very friable; neutral; abrupt, wavy boundary.
- IIC1—36 to 42 inches, grayish-brown (2.5Y 5/2) coarse sand; many, fine, faint, olive-gray (5Y 5/2) mottles; single grain; loose; neutral; clear, wavy boundary.
- IIC2—42 to 50 inches, grayish-brown (2.5Y 5/2) coarse sand; many, fine, distinct, light olive-brown (2.5Y 5/4) mottles; single grain; loose; few gravel particles; mildly alkaline; calcareous; abrupt, wavy boundary.
- IIC3—50 to 60 inches, grayish-brown (2.5Y 5/2) coarse sand; common, medium, distinct, light olive-brown (2.5Y 5/4) mottles and few, medium, prominent, strong-brown (7.5YR 5/8) mottles; single grain; loose; few fine gravel particles; mildly alkaline; calcareous.

The Ap and A1 horizons have a combined thickness of 10 to 20 inches. The A3 horizon is 3 to 8 inches thick. There are tongues and channels of the A1 horizon in the A3 horizon in some profiles. Structure of the A3 horizon ranges from fine granular to fine subangular blocky.

The B2 horizon is either loam or sandy clay loam. The B3 horizon is sandy loam, sandy clay loam, or loam. Combined thickness of the B horizons is 12 to 20 inches. The B2g and B3 horizons are mildly alkaline and calcareous in some profiles.

The IIC horizon is gravelly coarse sand or stratified sand and gravel in some profiles. In some profiles the IIC horizon is calcareous throughout.

The Mayer soils contain more clay in the A and B horizons than the similar Lemond soils. They contain less clay in the A and B horizons than the similar Talcot soils.

Mayer loam (0 to 2 percent slopes) (Mo).—This soil occupies 3-acre to 10-acre tracts on rims of depressions and swales and on slight rises associated with areas of the Biscay soils. It also occurs in broad tracts 10 to 100 acres in size.

Included in mapping are a few small areas of Hanska and Talcot soils. A few included areas have a sandy loam or clay loam surface layer. Small tracts near the Straight River, near the southern county line, are underlain by fine sand.

This Mayer soil is wet. Depth to the water table ranges from 1 to 3 feet in undrained areas. Runoff is slow. Drainage is needed for dependable cropland for commonly grown crops. The water table is sometimes lowered significantly if a deep outlet ditch is installed. The concentrations of lime carbonate generally is greatest at the surface on the rims of the depressions and is lower in the soil profile in the broad, nearly level tracts. Most crops respond favorably to special additions of fertilizer in areas of high concentrations of lime carbonate. Most of the acreage is used for crops. (Capability unit IIw-2)

Merton Series

The Merton series consists of deep, nearly level to gently sloping, moderately well drained soils. These soils formed in multilayered material that consists of a silty mantle over loamy glacial drift, with an intervening coarsely textured layer. Slopes are simple. These soils occur in the uplands. The native vegetation was tall prairie grasses.

In a representative profile, the surface layer is silt loam about 13 inches thick. The upper part of this layer is black, and the lower part is dark grayish brown. The upper part of the subsoil is grayish-brown and brown silt loam about 8 inches thick. The lower part of the subsoil is mottled, olive-brown, friable loam and sandy loam

about 19 inches thick. The underlying material is calcareous, light olive-brown, friable loam.

Permeability is moderate. Runoff is slow to medium. The water table is below a depth of 6 feet. The available water capacity is high. The organic-matter content and fertility are high.

Most areas are in cropland and are well suited to this use. These soils have few limitations for crop production. Control of erosion in the more sloping areas and maintenance of tilth and fertility are the main management needs.

Representative profile of Merton silt loam, 0 to 2 percent slopes, in Merton Township, 700 feet south and 100 feet east of the northwest corner of NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 2, T. 108 N., R. 19 W.:

- Ap—0 to 7 inches, black (10YR 2/1) silt loam; weak, medium, subangular blocky structure; very friable; medium acid; abrupt, smooth boundary.
- A1—7 to 10 inches, black (10YR 2/1) silt loam; weak, very fine, subangular blocky structure; very friable; slightly acid; clear, wavy boundary.
- A3—10 to 13 inches, dark grayish-brown (10YR 4/2) silt loam; faces of pedis are very dark gray (10YR 3/1); weak, fine, subangular blocky structure; very friable; slightly acid; clear, wavy boundary.
- B1—13 to 17 inches, dark grayish-brown (10YR 4/2) silt loam; weak, fine, subangular blocky structure; very friable; slightly acid; abrupt, wavy boundary.
- B21—17 to 21 inches, brown (10YR 4/3) silt loam; few, fine, faint, yellowish-brown (10YR 5/4) mottles; weak, medium, subangular blocky structure; friable; slightly acid; clear, smooth boundary.
- B22—21 to 30 inches, olive-brown (2.5Y 4/4) loam; common, fine, faint, dark grayish-brown (2.5Y 4/2) mottles; weak, medium, subangular blocky structure; friable; medium acid; abrupt, wavy boundary.
- IIB23—30 to 34 inches, olive-brown (2.5Y 4/4) sandy loam; common, fine, faint, dark grayish-brown (2.5Y 4/2) mottles and few, fine, distinct, yellowish-brown (10YR 5/4) mottles; massive; very friable; slightly acid; abrupt, wavy boundary.
- IIB3—34 to 40 inches, olive-brown (2.5Y 4/4) loam; weak, fine and medium, prismatic structure; friable; about 5 percent coarse fragments; slightly acid; abrupt, wavy boundary.
- IIC—40 to 60 inches, light olive-brown (2.5Y 5/4) loam; few, medium, distinct, yellowish-brown (10YR 5/4) mottles and few, medium, prominent, yellowish-red (5YR 5/8) mottles; massive; friable; about 5 percent coarse fragments; calcareous; mildly alkaline.

The Ap and A1 horizons are silt loam or loam that is high in content of silt. The combined thickness of these horizons is 8 to 16 inches. Reaction is slightly acid or medium acid. The A3 horizon is very dark gray, dark grayish brown, or very dark grayish brown and is 3 to 8 inches thick. Reaction is slightly acid or medium acid.

The B1 and B21 horizons have a combined thickness of 6 to 12 inches. The B22 horizon is 4 to 10 inches thick. The IIB23 horizon is variable in texture, ranging from sand, sand and gravel, or loamy sand to sandy loam or sandy clay loam. It commonly is 2 to 10 inches thick but is lacking in some profiles. Reaction is slightly acid or medium acid. The IIB3 horizon is 6 to 12 inches thick. The prismatic structural units part to subangular blocky units in some profiles. Reaction is medium acid to neutral.

The IIC horizon typically is loam, but the upper part of it is sandy clay loam in some profiles.

The Merton soils contain more silt and less sand in the A horizon and in the upper part of the B horizon than the similar Nicollet soils. Also, they formed in multiple glacial materials, whereas the Nicollet soils formed entirely in glacial till.

Merton silt loam, 0 to 2 percent slopes (MrA).—This soil occupies 3-acre to 100-acre upland tracts. It is asso-

ciated with Blooming, Maxcreek, and Moland soils. This soil has the profile described as representative for the series.

Included in mapping are a few areas, near the village of Blooming Prairie, that are underlain by sand at a depth below 10 feet.

This soil has a moderate seasonal wetness. Tile is installed in a few areas. Most of the acreage is used for crops, and the soil has few limitations for that use. (Capability unit I-1)

Merton silt loam, 2 to 4 percent slopes (MrB).—This soil occupies 3-acre to 60-acre tracts. It is associated with the Blooming and Moland soils.

Included in mapping are a few small areas of Blooming and Moland soils. Some of the narrow draws include areas of Maxcreek soils that are too small to be mapped separately. Also included are a few areas where slopes are close to 8 percent. A few convex areas are slightly eroded and have a thinner surface layer.

This soil has a slight seasonal wetness. Runoff is medium, and the hazard of erosion is slight. Most of the acreage is used for cropland and is well suited to this use. (Capability unit IIe-1)

Moland Series

The Moland series consists of deep, nearly level to gently undulating, well-drained soils. These soils formed in multilayered material that consists of a silty mantle over loamy glacial drift, with an intervening coarse-textured layer. Slopes are slightly complex. These soils occur in the uplands. The native vegetation was mainly tall prairie grasses, but a thin stand of brush covered a few slope crests.

In a representative profile, the surface layer is silt loam about 13 inches thick. The upper part of this layer is black, and the lower part is very dark grayish brown. The upper part of the subsoil is dark-brown and dark yellowish-brown, friable silt loam about 7 inches thick. A 7-inch layer of brown, very friable loam and sandy loam separates the silty layer from the lower part of the subsoil. The lower part of the subsoil is yellowish-brown, friable loam about 10 inches thick. The underlying material is mottled, light olive-brown, calcareous, friable loam.

Permeability is moderate. Runoff is slow to medium. The water table is at a depth below 10 feet. The available water capacity is high. The organic-matter content and fertility are high.

Most areas are in cropland and are well suited to this use. These soils have few limitations for crop production. Control of erosion in the more sloping areas and maintenance of high fertility are the main management needs.

Representative profile of Moland silt loam, 0 to 2 percent slopes, in Merton Township, 400 feet north and 75 feet west of the southeast corner of SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 10, T. 108 N., R. 19 W.:

- Ap—0 to 10 inches, black (10YR 2/1) silt loam; weak, medium, subangular blocky structure; friable; slightly acid; abrupt, smooth boundary.
- A3—10 to 13 inches, very dark grayish-brown (10YR 3/2) silt loam; faces of peds are very dark gray (10YR 3/1); weak, fine and medium, subangular blocky structure; friable; slightly acid; gradual, wavy boundary.
- B1—13 to 16 inches, dark-brown (10YR 3/3) silt loam; faces of peds are very dark grayish brown (10YR 3/2);

weak, fine and medium, subangular blocky structure; friable; slightly acid; clear, wavy boundary.

B21—16 to 20 inches, dark yellowish-brown (10YR 4/4) silt loam; faces of peds are dark brown (10YR 3/3); weak, medium, prismatic structure parting to weak, coarse, subangular blocky; friable; slightly acid; gradual, wavy boundary.

B22—20 to 24 inches, brown (10YR 4/3) loam; faces of peds are dark brown (10YR 3/3); weak, coarse, subangular blocky structure parting to weak, very fine, subangular blocky; friable; slightly acid; abrupt, wavy boundary.

IIB23—24 to 27 inches, brown (10YR 5/4) sandy loam; weak, medium, subangular blocky structure; very friable; neutral; abrupt, wavy boundary.

IIB3—27 to 37 inches, yellowish-brown (10YR 5/4) loam; common, fine, distinct, olive-brown (2.5Y 4/4) mottles; weak, medium and fine, prismatic structure; friable; about 4 percent coarse fragments; neutral; abrupt, wavy boundary.

IIC—37 to 60 inches, light olive-brown (2.5Y 5/4) loam; many, fine, faint, olive-brown (2.5Y 4/4) and grayish-brown (2.5Y 5/2) mottles and few, fine, distinct, yellowish-brown (10YR 5/8) mottles; weak, very fine, subangular blocky structure; friable; about 4 percent coarse fragments; mildly alkaline; calcareous.

The Ap horizon is black, very dark brown, or very dark gray. It typically is silt loam, but in some profiles it is loam that is high in content of silt. Reaction is slightly acid or medium acid. The A3 horizon is very dark grayish brown or very dark brown and is commonly 2 to 6 inches thick. Reaction is slightly acid or medium acid. This horizon is lacking in some profiles.

The B21 and B22 horizons have a combined thickness of 6 to 14 inches. The B22 horizon is lacking in some areas and is thicker in areas that lack a IIB23 horizon. The IIB23 horizon is variable in texture, ranging from sandy clay loam or sandy loam to loamy sand or sand and gravel. It commonly ranges from 2 to 10 inches thick, but it is lacking in some profiles. Reaction is neutral, slightly acid, or medium acid. The IIB3 horizon is loam or light clay loam and is 6 to 12 inches thick. Reaction is neutral to slightly acid.

The IIC horizon typically is loam, but the upper few inches of it is sandy clay loam in some profiles.

The Moland soils contain more silt and less sand in the A horizon and in the upper part of the B horizon than the similar Clarion soils. They have a thicker dark-colored A horizon than the similar Blooming soils.

Moland silt loam, 0 to 2 percent slopes (MsA).—This nearly level soil occupies broad upland areas. It has the profile described as representative for the series.

Included in mapping are a few small areas of Maxcreek and Merton soils in the shallow draws. Fine sand is commonly below a depth of 10 feet, but some areas are underlain by fine sand at a depth of 6 feet.

Most of the acreage is used for crops, and the soil has few limitations for this use. (Capability unit I-1)

Moland silt loam, 2 to 6 percent slopes (MsB).—This soil occupies 3-acre to 15-acre knolls and rises. It is associated with Maxcreek and Merton soils. Slopes are 75 to 150 feet long and, in most places, are 3 or 4 percent.

Included in mapping are a few small areas of Maxcreek soils in downslope draws. In many places the sharply convex knolls have a thicker and coarser textured sand layer at a depth of about 24 inches. A few small areas of Merton soils also are included.

Runoff is medium, and the hazard of erosion is moderate. Most of the acreage is used for crops. (Capability unit IIe-1)

Moland silt loam, 2 to 8 percent slopes, eroded (MsB2).—This soil occupies 3-acre to 20-acre upland knolls

and rises where most slopes are 4 to 6 percent. It also is on a few irregular hills where slopes are 6 to 8 percent. Because of erosion, part of the brownish subsoil has been mixed with the original surface layer. There are a few cobblestones and pebbles on the surface.

Included in mapping are a few areas on convex knolls that have a loamy mantle rather than a silty mantle. The sharply convex knolls commonly have a thicker, coarser textured sand layer near a depth of 24 inches. Also included are a few small areas of Merton soils and a few, small, slightly eroded areas.

Most of the acreage is used for crops. Runoff is medium. The hazard of erosion is moderate. (Capability unit IIe-1)

Muck

Muck soils are made up of slightly decomposed to well-decomposed organic material from reeds and sedges. These water-tolerant plants generally encroach from the edge of the shallow lakes and ponds or accumulate over seepage areas. They may fill an area to the level of the outlet channel or persist as a boggy fringe around a center of open water.

Muck is 30 percent or more organic matter. The mineral part is commonly sediments from surrounding uplands, lime precipitate from the water, and minerals from the remains of plants and animals, such as snails.

The muck layer is at least 12 inches thick in drained bogs and is 18 inches thick in undrained bogs. In Steele County the thickness commonly ranges from 12 to 50 inches, but in a few areas the muck probably is several feet thicker.

There is no detailed profile description, but the common soil layers are as follows:

The surface layer in cultivated fields is black or very dark brown muck. In undrained bogs the surface layer commonly is a 6- to 10-inch mat of plant roots and slightly decomposed vegetation. Below the surface layer is a 6- to 10-inch layer of black or very dark grayish-brown muck in which the fibers darken and are easily destroyed if rubbed. The next layer is very dark grayish-brown or brown muck that ranges between 12 and 30 inches thick. Here, the fibers darken and are easily destroyed if rubbed. The layer above the mineral soil material is commonly reddish brown or dark grayish brown and contains fibers that are more decomposed than those in the layer above it. In some areas the underlying material is dominantly clay loam, silty clay loam, loam, or sandy loam and has a thin layer of dark-colored material in the upper part. In other areas the underlying material is dominantly loamy sand or of some other sandy texture and contains a few seams of fine gravel in many places.

Muck soils in Steele County are well supplied with calcium, but their reaction generally ranges from medium acid to moderately alkaline. A few areas are strongly acid. Reaction commonly varies widely within a bog, where the edge is alkaline but the central part is acid. Layers within a muck soil range abruptly from acid to alkaline because snail shells are present in some layers. The available water capacity is very high. The water table is at a depth of 0 to 3 feet or is near tile depth in drained areas.

Muck (0 to 2 percent slopes) (Mu).—These soils occupy seeps on low mounds, 4-acre to 8-acre depressions, and several bogs more than 200 acres in size. A few moderately steep sidehill seeps in the valley of the Straight River south of Medford are included, but most of these are shown on the soil map by a seepage symbol. The layer of muck is more than 40 inches thick. It is underlain by clay loam, silty clay loam, or sandy loam, generally at a depth of 50 to 60 inches but at a greater depth in a few places. The edge of the larger bogs commonly has a narrow, discontinuous strip of sandy or gravelly underlying material.

Included in mapping are a few small sandy islands and sandbars. In small included areas, the muck is less than 40 inches deep because the surface of the underlying substratum is irregular. A few areas that have a calcareous surface layer also are included.

Much of the acreage is in crops. Some of the larger areas are used for truck crops. Some areas are in pasture. Several of the larger bogs are in their natural state. The largest areas of Muck are along the eastern branch of the Straight River. Drainage and maintenance of fertility are the main management needs. Dikes are needed in some places to control flooding. (Capability unit IIIw-4)

Muck, calcareous (0 to 2 percent slopes) (Mv).—These soils occupy 4-acre to 8-acre depressions and rims of depressions, as well as several bogs more than 200 acres in size. The muck layer commonly ranges between 12 and 60 inches in thickness, but it is thicker in a few places. In some areas these soils have mucky layers that are thinner than 12 inches and have an organic-matter content of less than 30 percent. The underlying material is loamy. The edges of the larger bogs commonly have a narrow, discontinuous strip of sandy or gravelly underlying material. In a few places a thin sandy layer separates the muck from the finer textured material. A few areas where slopes are 4 percent are included. The lime carbonate percentage ranges from 5 to 20 percent. A high percentage of the lime carbonates is remnants of snail shells.

Many of the areas are in cropland. Truck crops are grown in some of the larger areas. Some bogs are in pasture. Dikes and pumps are needed to prevent ponding in some areas. Drainage and maintenance of fertility are the main management needs. (Capability unit IIIw-4)

Muck, sandy substratum (0 to 2 percent slopes) (Mw).—These soils are in a few 4-acre to 8-acre depressions and 30-acre to 100-acre bogs on bottom lands along the Straight River in Summit Township. The muck layer ranges from 12 to 40 inches in thickness. A few areas are calcareous. The substratum is commonly loamy sand or sand.

Most of the acreage is in cropland or pasture. Drainage and maintenance of fertility are the main management needs. (Capability unit IIIw-4)

Muck, loamy substratum (0 to 2 percent slopes) (My).—These soils are in many 4-acre to 8-acre depressions and a few bogs up to 1,000 acres in size. The mucky layers generally range from 12 to 40 inches in thickness but are thicker in a few places. In small areas the mucky layers are thinner than 12 inches and have an organic-matter content of less than 30 percent. A few small areas have a calcareous surface layer. The substratum is clay loam, silty clay loam, loam, or sandy loam. The sandy loam substratum commonly becomes more sandy with depth. In places a

thin sandy layer separates the muck from the finer textured substratum.

Many of the areas are in cropland. Some of the larger areas are used for truck crops. Several of the larger bogs have never been drained sufficiently to be cultivated. Drainage and maintenance of fertility are the main management needs. (Capability unit IIIw-4)

Newry Series

The Newry series consists of deep, nearly level to very gently undulating, moderately well drained or somewhat poorly drained soils. These soils formed in a silty mantle and in the underlying, friable, loamy glacial drift. A sandy layer commonly separates the silty mantle from the loamy material. There are a few stones on the surface of the underlying material. These soils occupy upland tracts along the eastern edge of the county. The native vegetation was dominantly oak or brush.

In a representative profile, the surface layer is very dark grayish-brown silt loam 7 inches thick. The subsurface layer is dark grayish-brown and brown, friable silt loam about 3 inches thick. The upper part of the subsoil is brown, friable silt loam and loam about 10 inches thick. Mottled, olive-brown, friable sandy loam, about 4 inches thick, separates the silty mantle and the underlying loam. The lower part of the subsoil is mottled, dark grayish-brown, friable loam about 20 inches thick. The underlying material is mottled, grayish-brown, friable loam.

Permeability is moderate, but movement of water or air is slowed at the boundaries of textural change. Runoff is slow to medium. The water table is at a depth below 10 feet. The available water capacity is high. The organic-matter content is moderate, and fertility is medium.

Most areas of these soils are in cropland, but a few are in woodland or permanent pasture. Newry soils are well suited to most crops grown in the county and have few limitations for use. Maintenance of tilth and fertility is the main management need.

Representative profile of Newry silt loam, 0 to 3 percent slopes, in Blooming Prairie Township, in the southeast corner of SE $\frac{1}{4}$ sec. 3, T. 105 N., R. 19 W.:

- Ap—0 to 7 inches, very dark grayish-brown (10YR 3/2) silt loam; cloddy; friable; slightly acid; abrupt, smooth boundary.
- A2—7 to 10 inches, dark grayish-brown (10YR 4/2) and brown (10YR 4/3) silt loam; moderate, medium, platy structure; friable; many fine tubular pores; medium acid; abrupt, smooth boundary.
- B21t—10 to 15 inches, brown (10YR 4/3) silt loam; faces of peds are dark brown (10YR 3/3); moderate, fine, subangular blocky structure; friable; few thin clay films on faces of peds; many fine tubular pores; strongly acid; clear, wavy boundary.
- B22t—15 to 20 inches, brown (10YR 4/3) loam that is high in content of silt; faces of peds are dark brown (10YR 3/3); few, fine, distinct, light olive-brown (2.5Y 5/6) and grayish-brown (2.5Y 5/2) mottles; moderate, medium, subangular blocky structure; friable; few bleached sand grains on faces of peds; few thin clay films on faces of peds; strongly acid; clear, wavy boundary.
- IIB23t—20 to 24 inches, olive-brown (2.5Y 4/4) sandy loam; faces of peds are dark grayish brown (10YR 4/2); few, fine, faint, light olive-brown (2.5Y 5/6) mottles; moderate, medium, prismatic structure; friable; few bleached sand grains on faces of peds; few thin clay films on faces of peds; strongly acid; abrupt, wavy boundary.

IIB3—24 to 44 inches, dark grayish-brown (10YR 4/2) loam; common, fine, distinct, grayish-brown (2.5Y 5/2) and olive-brown (2.5Y 4/4) mottles; moderate, coarse, prismatic structure; friable; many bleached sand grains on faces of peds; about 5 percent coarse fragments; strongly acid; clear, wavy boundary.

IIC—44 to 60 inches, grayish-brown (2.5Y 5/2) loam; many, fine, distinct, light olive-brown (2.5Y 5/4) mottles and many, fine, prominent, brown (7.5YR 5/4) mottles; massive; friable; few, black, clayey fillings in old root channels; about 5 percent coarse fragments; neutral in some parts and mildly alkaline and calcareous in other parts.

The Ap horizon is silt loam or loam that is high in content of silt. It is grayish brown or dark grayish brown when dry. In undisturbed areas there is a black to very dark grayish-brown A1 horizon. Reaction is slightly acid or neutral in these areas, but it ranges to medium acid in some fields that have been under long-time cultivation. The A2 horizon is dark grayish brown or brown and is silt loam or loam that is high in content of silt. Thickness of the A2 horizon ranges from 2 to 4 inches. Structure is weak or moderate, thin or medium, platy. Reaction is slightly acid to medium acid.

The B21t horizon is silt loam or silty clay loam. The B22t horizon is silt loam, loam, or silty clay loam. Reaction in the B21t and B22t horizons is medium acid or strongly acid. The IIB23t horizon is variable in texture, ranging from sand or sand and gravel to loamy sand, sandy loam, or sandy clay loam. It commonly ranges from 2 to 10 inches in thickness but is lacking in some profiles. Reaction is medium acid or strongly acid. The IIB3 horizon is loam, sandy clay loam, or clay loam. Its thickness ranges between 15 to 30 inches. Consistence is commonly friable but ranges to slightly firm. Primary structure is moderate or strong, medium or coarse, prismatic. Some profiles have a secondary structure of weak or moderate, fine or medium, angular or subangular blocky in the IIB3 horizon. There are clay films on the faces of prisms in some profiles. Reaction is medium acid or strongly acid, but in some places it is slightly acid or neutral in the lower part.

The IIC horizon is loam, sandy clay loam, or clay loam. It commonly is calcareous and mildly alkaline, but its upper few inches is leached and is neutral in some profiles.

Newry soils have a browner B horizon than the associated Havana soils. They have a lighter colored A horizon than the similar Le Sueur soils.

Newry silt loam, 0 to 3 percent slopes (NbA).—This soil occupies 3-acre to 200-acre upland tracts.

A few areas of Blooming and Havana soils, too small to be mapped separately, are included. Small areas in and near Rice Lake State Park have a thinner, lighter colored surface layer and a higher content of clay in the upper part of the subsoil than this Newry soil. Small areas south of Oak Glen Lake have a grayer surface color when dry. In a few included areas there are sandy gravel beds below a depth of 6 feet.

This soil has a slight seasonal wetness. Runoff is slow to medium. The hazard of erosion is slight. This soil can be properly tilled only within a narrow range of moisture content. The different textural layers in the root zone slow the movement of water through the soil. Most of the acreage is used for crops, but a few areas remain in trees or woodland pasture. (Capability unit IIe-2)

Nicollet Series

The Nicollet series consists of deep, nearly level to gently undulating, moderately well drained and somewhat poorly drained, loamy soils. These soils formed in loamy glacial till. They occur on flats and low knolls in the uplands. The native vegetation was tall prairie grasses.

In a representative profile, the surface layer is clay loam about 16 inches thick. The upper part of this layer is black, and the lower part is very dark grayish brown. The subsoil is mottled, dark grayish-brown and grayish-brown, friable clay loam about 14 inches thick. The underlying material is calcareous, grayish-brown, friable loam with light olive-brown mottles.

Permeability is moderate. Runoff is slow to medium. The water table is at a depth of 4 to 10 feet. The available water capacity is high. The organic-matter content and fertility are high.

Most areas are in cropland, to which they are well suited. Nicollet soils have few limitations for crop production. Maintenance of tith and fertility and control of erosion in the more sloping areas are the main management needs.

Representative profile of Nicollet clay loam, 0 to 2 percent slopes, in Meriden Township, 300 feet north and 200 feet west of the southwest corner of SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 107 N., R. 21 W.:

- Ap—0 to 8 inches, black (10YR 2/1) clay loam, very dark gray (10YR 3/1) when rubbed; weak, medium, subangular blocky structure; friable; about 2 percent coarse fragments; medium acid; abrupt, smooth boundary.
- A1—8 to 12 inches, black (10YR 2/1) clay loam; very dark gray (10YR 3/1) when rubbed; moderate, fine, subangular blocky structure; friable; about 2 percent coarse fragments; medium acid; gradual, wavy boundary.
- A3—12 to 16 inches, very dark grayish-brown (10YR 3/2) clay loam; faces of peds are very dark gray (10YR 3/1); weak, very fine, subangular blocky structure; friable; about 4 percent coarse fragments; medium acid; clear, wavy boundary.
- B21—16 to 22 inches, dark grayish-brown (10YR 4/2) clay loam; few streaks of very dark grayish brown (10YR 3/2); moderate, fine, subangular blocky structure; friable; about 4 percent coarse fragments; slightly acid; clear, wavy boundary.
- B22—22 to 30 inches, grayish-brown (2.5Y 5/2) clay loam; few, fine, faint, light olive-brown (2.5Y 5/4) mottles; moderate, fine and medium, prismatic structure; friable; about 4 percent coarse fragments; slightly acid; abrupt, smooth boundary.
- C—30 to 60 inches, grayish-brown (2.5Y 5/2) loam; many, fine, faint, light olive-brown (2.5Y 5/4) mottles; weak, very fine, subangular blocky structure; friable; about 4 percent coarse fragments; mildly alkaline; calcareous.

The Ap and A1 horizons are black or very dark gray. Their combined thickness ranges from 8 to 16 inches. Their reaction is slightly acid or medium acid. The A3 horizon is very dark gray or very dark grayish brown and is 3 to 6 inches thick. Its reaction is slightly acid or medium acid. Tongues of this horizon extend into the B horizon in some profiles.

The B22 horizon is grayish brown or light olive brown and commonly contains mottles. It is clay loam or heavy loam. Some profiles have weak, fine and very fine, subangular blocky secondary structure. Total thickness of the B horizons ranges from 12 to 20 inches. Reaction in the B horizon is slightly acid to neutral.

The C horizon is loam or light clay loam.

The Nicollet soils contain less clay in the B horizon than the similar Le Sueur soils. They developed almost entirely in glacial till, whereas the similar Merton soils developed in multiple glacial materials.

Nicollet clay loam, 0 to 2 percent slopes (NcA).—This soil occupies 5-acre to 30-acre upland tracts. It occurs principally as slight rises within larger areas of Webster soils and as nearly level areas above more sloping Nicollet

or Clarion soils. This soil has the profile described as representative for the series.

Included in mapping are a few areas in which the surface layer is loam. Also included is a small acreage at the Owatonna Airport that was disturbed during construction.

This soil has a slight to moderate seasonal wetness. Runoff is slow. Tile has been installed in a few areas. Most of the acreage is used for cultivated crops, and the soil has few limitations for this use. (Capability unit I-1)

Nicollet clay loam, 2 to 4 percent slopes (NcB).—This soil occupies 5-acre to 20-acre knolls and rises that are associated with the Clarion and Webster soils.

Included in mapping are a few small areas of Webster soils in the downslope draws. Also included are small areas at the Owatonna Airport that were disturbed in construction.

This soil has a slight seasonal wetness. Runoff is medium, and the hazard of erosion is slight. Most of the acreage is used for crops, and the soil has few limitations for this use. (Capability unit IIe-1)

Salida Series

The Salida series consists of hilly to steep, excessively drained soils that formed in gravelly and coarse sandy sediments. These soils occupy sharply convex gravelly knolls and short steep slopes of outwash plains below the less sloping Estherville and Wadena soils. Slopes are both simple and complex. The native vegetation was a sparse growth of grass.

In a representative profile, the surface layer is black gravelly loamy sand about 8 inches thick. The subsoil is dark yellowish-brown, very friable gravelly loamy sand about 6 inches thick. The underlying material is calcareous, grayish-brown and yellowish-brown, loose gravel that contains seams of sand.

Permeability is rapid to very rapid. Runoff is medium. The water table is below a depth of 10 feet. The available water capacity is very low. The organic-matter content is low to moderate. Fertility is low.

Many areas of these soils are in cropland and are farmed with adjoining areas of other soils. Salida soils are poorly suited to most crops grown in the county because of the very low available water capacity. Droughtiness is the main limitation to use for crops.

Representative profile of Salida gravelly loamy sand, 12 to 25 percent slopes, in Lemond Township, 600 feet west of the northeast corner of SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 10, T. 106 N., R. 21 W.:

- Ap—0 to 8 inches, black (10YR 2/1) gravelly loamy sand; weak, coarse, subangular blocky structure; very friable; neutral; abrupt, smooth boundary.
- B2—8 to 14 inches, dark yellowish-brown (10YR 4/4) gravelly loamy sand; weak, coarse, subangular blocky structure; very friable; few calcareous spots in the lower part of the horizon; mildly alkaline; clear, wavy boundary.
- C—14 to 60 inches, grayish-brown (10YR 5/2) and yellowish-brown (10YR 5/4 and 5/6) gravel; few sand seams; single grain; loose; mildly alkaline; calcareous.

The Ap horizon, or the A1 horizon in areas where an Ap horizon is lacking, is black or very dark brown in color and ranges from gravelly loamy sand or gravelly loamy coarse sand to gravelly coarse sandy loam or gravelly coarse sand.

Thickness is 6 to 10 inches. This horizon is calcareous and mildly alkaline in some places.

The B2 horizon is dark brown or dark yellowish brown and is gravelly loamy sand, gravelly loamy coarse sand, gravelly coarse sand, or gravelly sand. It is 4 to 8 inches thick. It is neutral or mildly alkaline and commonly is calcareous.

The C horizon is gravel, sandy gravel, gravelly coarse sand, or stratified sand and gravel.

Salida soils have a thinner, coarser textured B horizon than the associated Estherville soils.

Salida gravelly loamy sand, 12 to 25 percent slopes (ScE).—This soil is on convex gravelly knolls and moderately steep side slopes. It is closely associated with the Estherville and Wadena soils.

This Salida soil is very droughty. Runoff is medium. The hazard of erosion is moderate. The very low available water capacity and shallow rooting zone are the main limitations to use of this soil for most crops. This soil is better suited to permanent vegetation than to crops that require cultivation. (Capability unit VIIIs-1)

Shields Series

The Shields series consists of deep, nearly level, somewhat poorly drained and poorly drained soils of the uplands that are clayey in the subsoil. These soils formed in the upper part of a shaly, clayey mantle 3 to 10 feet thick. They occupy low knolls, nearly level tracts, and shallow draws in the uplands. The native vegetation was dominantly oak.

In a representative profile, the surface layer is very dark gray silty clay loam about 8 inches thick. The subsoil is very firm and firm, mottled, dark grayish-brown and grayish-brown silty clay about 33 inches thick. This layer is olive gray in the lower part. The underlying material is calcareous, mottled, olive, firm silty clay loam.

Permeability is slow. Runoff is slow to medium. The water table is at a depth of 1 to 5 feet. Available water capacity is high. Organic-matter content is moderate, and fertility is medium.

Most areas of Shields soils are used for crops, but a few areas are in trees or woodland pasture. These soils are moderately well suited to most crops grown in the county, but they can be satisfactorily tilled only within a narrow range of moisture content. Maintenance of tilth and fertility and control of the water table are the main management needs.

Representative profile of Shields silty clay loam, in Deerfield Township, in the northeast corner of NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 27, T. 108 N., R. 21 W., 300 feet west and 90 feet south of the first light pole west of the northwest corner of the grove:

Ap—0 to 8 inches, very dark gray (10YR 3/1) silty clay loam, dark gray (10YR 4/1) when dry; cloddy; firm; a few inclusions of an A2 horizon that is light gray (10YR 6/1) when dry; medium acid; abrupt, smooth boundary.

B1g—8 to 12 inches, dark grayish-brown (2.5Y 4/2) silty clay; faces of peds are dark gray (2.5Y 4/1); few, (2.5Y 3/2), gray (10YR 5/1) when dry; few, fine, faint, olive-brown (2.5Y 4/4) mottles; moderate, fine and very fine, subangular blocky structure; very firm; about 2 percent coarse fragments, mostly shale; common sand-size shale particles; medium acid; abrupt, smooth boundary.

B21tg—12 to 18 inches, dark grayish-brown (2.5Y 4/2) silty clay; faces of peds are very dark grayish brown fine, faint, olive-brown (2.5Y 4/4) mottles; moder-

ate, fine, subangular blocky structure; very firm; common thick clay films on faces of peds; about 2 percent coarse fragments, mostly shale; common sand-size shale particles; strongly acid; abrupt, wavy boundary.

B22tg—18 to 27 inches, grayish-brown (2.5Y 5/2) silty clay; faces of peds are mixed very dark gray (10YR 3/1), very dark brown (10YR 2/2), and dark grayish brown (2.5Y 4/2); many, fine, distinct, yellowish-brown (10YR 5/4), brown (10YR 5/3), and dark yellowish-brown (10YR 4/4) mottles; moderate, fine and medium, prismatic structure parting to weak, fine and medium, subangular blocky; very firm; common thick clay films on faces of peds; common, black (N 2/0 and 10YR 2/1), clayey fillings in root channels; few slickensides; about 4 percent coarse fragments, mostly shale; strongly acid; clear, wavy boundary.

B3g—27 to 41 inches, olive-gray (5Y 5/2) silty clay; many, fine, faint, gray (5Y 5/1) mottles and many, fine, distinct, light olive-brown (2.5Y 5/6) and olive-brown (2.5Y 4/4) mottles; weak, fine and medium, subangular blocky structure; firm; about 4 percent coarse fragments, mostly shale; common, rounded, sand-size shale particles; medium acid; abrupt, wavy boundary.

C—41 to 60 inches, olive (5Y 5/3) silty clay loam; many, fine, distinct, olive-brown (2.5Y 4/4) and light olive-brown (2.5Y 5/6) mottles; massive; firm; about 5 percent coarse fragments, mostly shale; common, small, hard lime concretions; mildly alkaline; calcareous.

The Ap horizon ranges from black to very dark gray in color and from silt loam to silty clay loam in texture. It is dark gray or gray when dry. In uncultivated areas, these soils have a black or very dark gray A1 horizon that is 4 to 8 inches thick. It is similar to the Ap horizon in texture. Reaction in the Ap and A1 horizons is medium acid to slightly acid. Some profiles have an A2 horizon up to 8 inches thick. It is dark gray, gray, or grayish brown and is silt loam or light silty clay loam. It is thickest in the shallow draws. In areas where this horizon is thin, cultivation has incorporated it into the plow layer. The A2 horizon dries to a gray or light-gray color and gives a spotty appearance to the Ap horizon if mixed with that horizon. The A2 horizon has platy structure. Reaction is slightly acid to medium acid.

The B1g and B2 horizons range from silty clay to clay in texture. These horizons contain appreciably more clay than the A horizon, and the content of clay increases abruptly from the A horizon to the upper part of the B horizon. The color of the faces of peds in the B horizon varies considerably. The darkest colors commonly are in the middle or upper part of the B horizon, but they are in the lower part of the B horizon in those profiles that have a thicker A2 horizon. Reaction in the B2 horizon ranges from medium acid to very strongly acid. The B3g horizon ranges from clay loam or silty clay loam to clay or silty clay.

The C horizon ranges from clay loam or silty clay loam to clay.

The Shields soils have more clay in the B horizon than the similar Dundas soils.

Shields silty clay loam (0 to 3 percent slopes) (Sh).—This nearly level to gently undulating soil occupies 5-acre to 80-acre upland tracts.

Areas of Lerdal and Lura soils, too small to be mapped separately, are included. In a few included areas, part of the brownish subsoil has been mixed with the original surface layer. These areas lose good tilth more easily.

This soil has seasonal wetness. The water table fluctuates seasonally between depths of 1 and 5 feet. Runoff is slow to medium. Tile is seldom installed in this soil. This soil can be satisfactorily tilled only within a narrow range of moisture content. During dry periods, cracks form in the cultivated layer. If dry and cracked, the soil absorbs water at a moderate rate. Percolation is slowed if the soil

is saturated and the cracks seal. The shrink-swell potential of the subsoil is high. The increase in clay content and density in the lower part of the subsoil slows the movement of water out of the surface layer. Most of the acreage is used for crops, but a few areas of trees or woodland pasture remain. (Capability unit IIIw-2)

Sparta Series

The Sparta series consists of deep, gently sloping to steep, excessively drained, sandy soils. These soils formed in sandy sediments in which the sand commonly is fine and medium. They occupy 5-acre to 15-acre circular sandhills. They were mapped in complexes with Dickinson soils. Slopes are simple. The native vegetation was grass and a few thin stands of oak and brush.

In a representative profile, the surface layer is loamy fine sand about 18 inches thick. The upper part of this layer is very dark brown, and the lower part is very dark grayish brown. The subsoil is dark-brown to dark yellowish-brown, loose loamy fine sand or fine sand about 18 inches thick. The underlying material is yellowish-brown, loose fine sand. A few, thin, discontinuous bands of loamy fine sand and sandy loam are present near a depth of 48 inches.

Permeability is rapid. Runoff is slow to medium, depending on slope. The water table is below a depth of 10 feet. The available water capacity is low. The organic-matter content is moderate, and fertility is low.

Some areas of these soils are farmed with other soils in the field. Most areas are kept in permanent or long-term vegetation.

Representative profile of a Sparta loamy fine sand having slopes of 2 to 6 percent, in Merton Township, 600 feet south and 50 feet east of the northwest corner of NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 20, T. 108 N., R. 19 W.:

- Ap—0 to 10 inches, very dark brown (10YR 2/2) loamy fine sand; single grain; loose; slightly acid; gradual, wavy boundary.
- A3—10 to 18 inches, very dark grayish-brown (10YR 3/2) loamy fine sand; single grain; loose; slightly acid; gradual, wavy boundary.
- B2—18 to 24 inches, dark-brown (10YR 3/3) loamy fine sand; brown (10YR 4/3) when rubbed; single grain; loose; few fine pebbles; medium acid; clear, wavy boundary.
- B3—24 to 36 inches, dark yellowish-brown (10YR 4/4) and yellowish-brown (10YR 5/4) fine sand; single grain; loose; medium acid; abrupt, wavy boundary.
- C1—36 to 48 inches, yellowish-brown (10YR 5/4) fine sand; few thin bands of loamy fine sand; single grain; loose; medium acid; abrupt, wavy boundary.
- IIC2—48 to 54 inches, yellowish-brown (10YR 5/4) sandy loam; single grain; loose; medium acid; abrupt, wavy boundary.
- IIC3—54 to 60 inches, yellowish-brown (10YR 5/4) fine sand; single grain; loose; medium acid.

The A horizon is very dark brown, very dark grayish-brown, or dark brown loamy fine sand or fine sand. Thickness of this horizon ranges from 12 to 24 inches. Its reaction is slightly acid or medium acid. The B horizon is loamy fine sand, loamy sand, fine sand, or sand and is 10 to 25 inches thick. The C horizon is mostly fine sand or sand, but there are a few, thin, discontinuous bands of sandy loam, fine sandy loam, loamy fine sand, or loamy sand below a depth of 48 inches in some profiles. Reaction ranges from medium acid to mildly alkaline, but lime generally is leached to a depth of more than 60 inches. Depth of leaching of carbonates is limited by seams of coarse sand and finer textured seams in some of the underlying material. It is also thinner on steeper slopes.

The Sparta soils have a thicker and darker colored A horizon than the similar Chelsea soils and lack the many, thin, loamy bands that occur in the B horizon of those soils.

Sparta-Dickinson complex, 2 to 6 percent slopes (SkB).—This complex occupies 3-acre to 6-acre hilltops and gentle side slopes and crests of circular sandhills. It occurs within larger areas of Clarion and Lester soils. This complex consists of about 55 percent Sparta loamy fine sand and nearly 45 percent Dickinson sandy loam. The Sparta soil has the profile described as representative for its respective series.

Included in mapping are a few eroded areas in which the present surface layer consists mostly of material from the brownish subsoil.

Soils of this complex are droughty. Runoff is low. There are hazards of soil blowing and water erosion. In addition, the upper layers of the soils commonly are disturbed by rodent burrowings. This complex is suited to permanent vegetation, preferably conifers. Some areas have been used as sand pits. (Capability unit VIs-1)

Sparta-Dickinson complex, 6 to 12 percent slopes (SkC).—This complex occupies 4-acre to 8-acre side slopes of circular sandhills. This complex consists of about 70 percent Sparta loamy fine sand and nearly 30 percent Dickinson sandy loam. These soils have profiles similar to those described as representative for their respective series.

Included in mapping are a few eroded areas. The present surface layer of these areas consists mostly of material from the brownish subsoil.

Soils of this complex are droughty. Runoff is medium. There are moderate hazards of soil blowing and water erosion. In addition, the upper layers of the soils commonly are disturbed by rodent burrowings. This complex is suited to permanent vegetation, preferably conifers. (Capability unit VIs-1)

Sparta-Dickinson complex, 12 to 25 percent slopes (SkE).—This complex occupies 4-acre to 16-acre side slopes of circular sandhills. This complex consists of about 70 percent Sparta loamy fine sand and nearly 30 percent Dickinson sandy loam. These soils have profiles similar to those described as representative for their respective series, but the upper layers commonly are disturbed by rodent burrowings.

Included in mapping are eroded areas. The present surface layer in these areas consists mostly of material from the brownish subsoil. A soil that has a thickened surface layer is included at the base of some slopes. Lime carbonates are near a depth of 24 inches in some places. A few small areas in section 19 of Blooming Prairie Township are calcareous at the surface.

Soils of this complex are droughty. Runoff is rapid, and the hazard of erosion is severe. Many of these areas have been converted to permanent vegetation, generally conifers. (Capability unit VIIs-1)

Storden Series

The Storden series consists of deep, gently undulating to moderately steep, somewhat excessively drained, loamy soils. These soils formed in calcareous, loamy glacial till. They are on knolls in the uplands, where slopes are convex. They are closely associated with, and were mapped only in complexes with Clarion soils, Lester and Esther-

ville soils, and Lester soils. The native vegetation was a sparse growth of grass or trees.

In a representative profile, the surface layer is calcareous, very dark grayish-brown loam about 7 inches thick. The underlying material is a calcareous mixture of dark grayish-brown, light brownish-gray, and light olive-brown, friable loam. Light olive brown becomes more prominent with depth.

Permeability is moderate. Infiltration commonly is slowed because of the fine lime flour in the upper part of the profile. Runoff is medium to very rapid. The water table is at a depth below 10 feet. The available water capacity is high. The organic-matter content is moderate, and fertility is medium.

Most areas of these soils are cultivated with the associated soils in the field. The hazard of erosion is severe. Special fertility programs are beneficial for most crops because of the high content of lime.

Representative profile of a Storden loam, in Lemond Township, in the northwest corner of the NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 21, T. 106 N., R. 21 W.:

- Ap—0 to 7 inches, very dark grayish-brown (10YR 3/2) loam; weak, medium, subangular blocky structure; friable; about 4 percent coarse fragments; mildly alkaline; calcareous; abrupt, smooth boundary.
- C1—7 to 19 inches, mixed dark grayish-brown (2.5Y 4/2) and light brownish-gray (2.5Y 6/2) loam; weak, fine, granular structure; friable; about 4 percent coarse fragments; moderately alkaline; calcareous; clear, wavy boundary.
- C2—19 to 60 inches, light olive-brown (2.5Y 5/4) loam; much light brownish-gray (2.5Y 6/2) feathered lime; massive; friable; about 4 percent coarse fragments; moderately alkaline; calcareous.

The Ap horizon is very dark brown or very dark grayish brown in color. The C1 horizon is light olive brown or olive brown in color in some profiles.

The Storden soils lack a B horizon, whereas the associated Clarion soils have a B horizon. Free carbonates occur in all horizons of the Storden soils, but they are leached to a depth of more than 2 feet in the Clarion soils.

Talcot Series

The Talcot series consists of nearly level, very poorly drained, loamy soils that formed in 2 to 3 feet of clay loam sediment that overlies stratified loamy sand, sand, and sand and gravel. These soils are on broad sand flats. The native vegetation was principally water-tolerant grasses and sedges.

In a representative profile, the surface layer is calcareous clay loam about 23 inches thick. The upper part of this layer is black but dries to dark gray, and the lower part is very dark gray. The subsoil is distinctly mottled, olive-gray and grayish-brown, calcareous sandy clay loam about 15 inches thick. The underlying material is mottled, olive-gray, stratified, calcareous coarse sand that contains seams of fine gravel and sandy loam.

In drained areas permeability is moderate in the upper part of the profile and rapid in the underlying material, beginning at a depth of about 38 inches. Runoff is slow to ponded. In undrained areas the water table is at a depth of 0 to 3 feet; it is near tile depth in drained areas. The available water capacity is moderate, organic-matter content is high, and fertility is medium.

Most areas of Talcot soils are used for cropland. In their natural state, these soils are only moderately well

sited to poorly suited to most crops grown in the county. If adequately drained, they are suited to most local crops. Special fertility treatments are beneficial for most crops because of the high concentration of lime carbonates.

Representative profile of Talcot clay loam, in Lemond Township, 400 feet east and 100 feet north of the southwest corner of SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 25, T. 106 N., R. 21 W.:

- A11—0 to 12 inches, black (10YR 2/1) clay loam, dark gray (10YR 4/1) when dry; weak, fine, granular structure; friable; mildly alkaline; calcareous; abrupt, wavy boundary.
- A12—12 to 20 inches, very dark gray (10YR 3/1) clay loam; weak, fine, granular structure; friable; mildly alkaline; calcareous; abrupt, irregular boundary.
- A3—20 to 23 inches, very dark gray (5Y 3/1) clay loam; few very dark grayish-brown (2.5Y 3/2) streaks; weak, very fine, subangular blocky structure; friable; mildly alkaline; calcareous; gradual, irregular boundary.
- B21g—23 to 32 inches, olive-gray (5Y 5/2) sandy clay loam; many, medium, distinct, light olive-brown (2.5Y 5/6) mottles; weak, very fine, subangular blocky structure; friable; mildly alkaline; calcareous; abrupt, wavy boundary.
- B22g—32 to 38 inches, grayish-brown (2.5Y 5/2) sandy clay loam; few, medium, distinct, light olive-brown (2.5Y 5/6) mottles; weak, fine, subangular blocky structure; friable; mildly alkaline; calcareous; abrupt, wavy boundary.
- IIC—38 to 60 inches, olive-gray (5Y 5/2) coarse sand that contains seams of fine gravel and sandy loam; many, medium, prominent, dark-brown (7.5YR 3/2) mottles; single grain; loose; mildly alkaline; calcareous.

The A1 horizons range in color from black to very dark gray and in texture from silty clay loam to clay loam. Their combined thickness ranges from 10 to 22 inches.

The A3 horizon ranges from clay loam or silty clay loam in texture and from 3 to 8 inches in thickness. Tongues from the horizons above and below are common in this horizon. Content of lime in the A horizons ranges from 5 to 15 percent.

The B horizons range in texture from clay loam or silty clay loam to sandy clay loam. Reaction is commonly mildly alkaline throughout, but in some profiles the B22g horizon is neutral and noncalcareous. The combined thickness of the B horizons ranges from 10 to 20 inches.

The IIC horizon ranges in texture from coarse sand to gravelly coarse sand to stratified sand and gravel. Thin seams of fine gravel, loamy sand, or sandy loam occur in this horizon in some places. The upper part of this horizon is noncalcareous and neutral in some profiles.

Talcot soils have more clay in the A and B horizons than Mayer soils.

Talcot clay loam (0 to 2 percent slopes) (Tc).—This nearly level soil occupies 5-acre to 100-acre tracts in rims of depressions and drainageways.

Included with this soil in mapping are a few areas of Biscay and Mayer soils that are too small to be mapped separately. Biscay soils generally occupy small depressions and drainageways.

This is a very wet soil. In undrained areas, depth to the water table ranges from 0 to 3 feet. Runoff is slow to ponded. Drainage is needed for dependable cropland for present crops; the water table may be lowered significantly if a deep outlet ditch is installed. In most places lime carbonate concentration is greatest in the upper 20 inches, and a few small rims and rises have more than 20 percent calcium carbonate. Most crops respond favorably to special fertility treatment in these high-lime soils. (Capability unit IIIw-3)

Terril Series

The Terril series consists of deep, nearly level, moderately well drained, loamy soils. These soils formed in more than 40 inches of recently deposited, loamy alluvium. They occupy first bottom lands of the Straight River and its tributaries. The native vegetation was elm, basswood, willow, and grass.

In a representative profile, the surface layer is black loam about 24 inches thick. The underlying material is very dark grayish-brown or grayish-brown, friable loam.

Permeability is moderate. Runoff is slow except at flood stage, when it is ponded. The water table is at a depth of 4 to 10 feet. The available water capacity is high. The organic-matter content and fertility are high.

The hazard of flooding is the main limitation to the use of these soils. Some areas that are only occasionally flooded are used for crops, but most are in permanent pasture. If protected from flooding, these soils are well suited to most crops grown in the county.

Representative profile of Terril loam, occasionally flooded, in Medford Township, 1,200 feet west and 800 feet north of the southeast corner of NE $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 108 N., R. 20 W.:

- Ap—0 to 8 inches, black (10YR 2/1) loam; weak, fine, granular structure; friable; neutral; abrupt, smooth boundary.
- A1—8 to 24 inches, black (10YR 2/1) loam; weak, fine, granular structure; friable; neutral; clear, wavy boundary.
- C1—24 to 48 inches, very dark grayish-brown (10YR 3/2) loam; weak, fine, granular structure; friable; neutral; abrupt, wavy boundary.
- C2—48 to 54 inches, very dark grayish-brown (10YR 3/2) loam; massive; friable; neutral; abrupt, wavy boundary.
- C3—54 to 64 inches, grayish-brown (2.5Y 5/2) and light olive-brown (2.5Y 5/4 and 5/6) loam; massive; friable; mildly alkaline; calcareous.

The A horizon is black, very dark brown, or very dark gray in color. Its texture ranges from loam to light silty clay loam. Total thickness of the A horizon ranges from 18 to 30 inches. The C3 horizon ranges from loam to sandy loam in texture.

The Terril soils in this county are outside the defined range of the Terril series because they lack a B horizon. However, this difference does not affect their use and management.

The Terril soils contain more sand and less silt and are better drained than the similar Colo soils.

Terril loam, occasionally flooded (0 to 2 percent slopes) (Te).—This soil is on the slightly higher bottom lands along the Straight River and its tributaries. A few meander channels cross these areas. This soil has the profile described as representative for the series.

Included in mapping are a few small areas that have a weakly calcareous surface layer.

Flooding generally occurs on this soil at the time of spring snowmelt and sometimes during heavy rains in June and July. Some of the areas in the upper drainages are seldom flooded. This soil is used for row crops and pasture. (Capability unit IIw-3)

Terril loam, frequently flooded (0 to 2 percent slopes) (Tf).—This soil occupies the lower lying first bottom lands and is subject to frequent overflow and streambank cutting. Meander channels are few to common.

This soil is used for pasture in most places, but crops are grown in a few local areas. (Capability unit VIw-1)

Udolpho Series

The Udolpho series consists of nearly level, somewhat poorly drained to poorly drained, silty outwash soils that are moderately deep over stratified sand and gravel. These soils formed in a silty mantle and in the underlying coarser textured material. They occupy flats and shallow draws. The native vegetation was dominantly oak or brush.

In a representative profile, the surface layer is black silt loam about 9 inches thick. The subsurface layer is mottled, dark-gray, friable silt loam about 3 inches thick. The upper part of the subsoil is dark grayish-brown and grayish-brown, friable silt loam and silty clay loam about 18 inches thick. It is mottled with strong brown and light olive brown. An olive-gray, friable loam layer, 4 inches thick, generally separates the silty mantle from the lower part of the subsoil. The lower part of the subsoil is olive-gray gravelly coarse sand, about 12 inches thick, that contains discontinuous lenses of clay loam. The underlying material is olive, loose gravelly coarse sand.

In drained areas, permeability is moderate in the upper part of the profile and rapid in the underlying material beginning at a depth of about 34 inches. Runoff is slow. The water table is at a depth of 2 to 5 feet or near tile depth in drained areas. The available water capacity is moderate. The organic-matter content is moderate, and fertility is medium.

Most areas are used for crops, but a few areas of trees or woodland pasture remain. If properly managed, these soils are well suited to most crops grown in the county. Control of the water table and maintenance of tilth and fertility are the main management needs.

Representative profile of Udolpho silt loam, in Bloomington Prairie Township, 200 feet north and 300 feet west of the southeast corner of the NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 12, T. 105 N., R. 19 W.:

- Ap—0 to 9 inches, black (10YR 2/1) gritty silt loam; cloddy; friable; slightly acid; abrupt, smooth boundary.
- A2—9 to 12 inches, dark-gray (2.5Y 4/1) gritty silt loam; few coatings on peds of very dark gray (10YR 3/1); few, fine, faint, dark grayish-brown (2.5Y 4/2) mottles and few, fine, prominent, strong-brown (7.5YR 5/8) mottles; weak, medium, platy structure; friable; many fine tubular pores; medium acid; clear, smooth boundary.
- B1g—12 to 18 inches, dark grayish-brown (2.5Y 4/2) silt loam; few, fine and medium, prominent, strong-brown (7.5YR 5/8) mottles and few, fine and medium, faint, grayish-brown (2.5Y 4/2) mottles; moderate, fine, subangular blocky structure; friable; many fine tubular pores; medium acid; clear, wavy boundary.
- B21tg—18 to 24 inches, dark grayish-brown (2.5Y 4/2) silt loam; many, fine and medium, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, fine and medium, subangular blocky structure; friable; many fine tubular pores; few thin clay films on faces of peds; strongly acid; clear, wavy boundary.
- B22tg—24 to 30 inches, grayish-brown (2.5Y 5/2) silty clay loam; many, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, weak, medium, subangular blocky structure; friable; many fine tubular pores; common thin clay films on faces of peds; strongly acid; abrupt, wavy boundary.
- B31g—30 to 34 inches, olive-gray (5Y 4/2) loam; weak, medium, subangular blocky structure; friable; medium acid; abrupt, wavy boundary.
- IIB32g—34 to 46 inches, olive-gray (5Y 5/2) gravelly coarse sand; common, thin, discontinuous lenses of clay

loam; common, medium, prominent, reddish-brown (5YR 5/4) mottles; single grain; loose; slightly acid; abrupt, smooth boundary.

- IIC1—46 to 54 inches, olive (5Y 5/4) gravelly coarse sand; single grain; loose; neutral; abrupt, smooth boundary.
IIC2—54 to 60 inches, olive (5Y 5/4) gravelly coarse sand; single grain; loose; mildly alkaline; calcareous.

The Ap horizon, or the A1 horizon in undisturbed areas, is black or very dark gray in color and is gritty silt loam or loam that is high in content of silt in texture. Reaction is neutral to slightly acid in uncultivated areas but is medium acid in some fields that have been under long-time cultivation. The A2 horizon is mottled dark gray or gray in color and is friable gritty silt loam or loam that is high in content of silt. Its thickness ranges from 1 to 4 inches. Reaction is slightly acid to medium acid.

The B21tg horizon is silt loam or silty clay loam. Combined thickness of the B1 and B2 horizons ranges from 16 to 30 inches. There are bleached sand grains on faces of peds in the B1 horizon in some profiles. The IIB32g horizon is loam, sandy clay loam, sandy loam, or gravelly coarse sand. The finer textured lenses are absent in the IIB32g horizon in some profiles.

The IIC horizon consists of stratified sand and gravel in some profiles. The depth to free carbonates ranges from 42 to 60 inches.

The Udolpho soils have grayer colors in the B horizon than the associated Hayfield soils.

Udolpho silt loam (0 to 2 percent slopes) (Ud).—This soil occupies 5-acre to 100-acre tracts on outwash plains and terraces.

Areas of Hayfield and Kato soils, too small to be mapped separately, are included.

This soil is seasonally wet. Depth to the perched water table ranges from 2 to 5 feet. Runoff is slow. In some areas the draining of associated Kato soils effectively lowers the water table in this soil. Tile drains have been installed in some areas. The prepared seedbed tends to slake and settle on wetting and to crust on drying. Most of the acreage is used for crops, but a few areas of trees or woodland pasture remain. (Capability unit IIw-1)

Wadena Series

The Wadena series consists of nearly level to sloping, well-drained, loamy soils that are moderately deep over calcareous, stratified sand and gravel. These soils formed in loamy sediment 24 to 40 inches thick over coarser textured material. They occupy broad flats and narrow ridges, and some of the moderately steep areas that have short slopes are on glacial outwash plains and stream terraces. These soils also occupy small hills within the rolling uplands. Slopes are commonly simple, but some upland hills have complex slopes. The native vegetation was grass and a few thin stands of oak or brush.

In a representative profile, the surface layer is loam about 17 inches thick. The upper part of this layer is black, and the lower part is very dark brown. The upper part of the subsoil is dark yellowish-brown and brown, friable loam about 16 inches thick. The lower part is dark-brown gravelly sandy loam about 8 inches thick. The underlying material is calcareous, dark yellowish-brown to pale-brown coarse sand and gravelly coarse sand.

Permeability is moderate in the upper part of the profile and rapid in the underlying material, beginning at a depth of about 33 inches. Runoff is slow to medium. The water table is at a depth below 10 feet. The available

water capacity is moderate. The organic-matter content is moderate to high, and fertility is medium.

Most areas are used for crops, to which these soils are moderately well suited. The moderate available water capacity and hazards of soil blowing and erosion are the main limitations that affect crop production.

Representative profile of Wadena loam, 0 to 2 percent slopes, in Owatonna Township, 600 feet south of the northeast corner of SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 17, T. 107 N., R. 20 W.:

- Ap—0 to 7 inches, black (10YR 2/1) loam, very dark brown (10YR 2/2) when rubbed; weak, fine and medium, subangular blocky structure; friable; slightly acid; clear, smooth boundary.
A1—7 to 12 inches, black (10YR 2/1) loam, very dark brown (10YR 2/2) when rubbed; weak, coarse, subangular blocky structure parting to weak, fine, subangular blocky and weak, fine, granular; friable; slightly acid; clear, wavy boundary.
A3—12 to 17 inches, very dark brown (10YR 2/2) loam; weak, medium, prismatic structure parting to weak, fine, subangular blocky; friable; slightly acid; clear, wavy boundary.
B21—17 to 21 inches, dark yellowish-brown (10YR 4/4) loam; faces of peds are very dark brown (10YR 2/2); weak, medium to coarse, prismatic structure parting to weak, fine and medium, subangular blocky; friable; medium acid; clear, wavy boundary.
B22—21 to 25 inches, brown (7.5YR 4/4) loam; faces of peds are dark brown (7.5YR 3/4); very weak, medium and coarse, prismatic structure parting to weak, fine and medium, subangular blocky; friable; few thin clay films in root channels and pores; medium acid; clear, wavy boundary.
B3—25 to 33 inches, dark-brown (7.5YR 3/4) gravelly sandy loam; very weak, coarse, subangular blocky structure; friable; medium acid; clear, wavy boundary.
IIC1—33 to 37 inches, dark yellowish-brown (10YR 4/4) gravelly coarse sand; single grain; loose; mildly alkaline; calcareous; abrupt, wavy boundary.
IIC2—37 to 40 inches, brown (10YR 5/3) coarse sand; slightly cemented when dry; single grain; loose; mildly alkaline; calcareous; abrupt, wavy boundary.
IIC3—40 to 60 inches, pale-brown (10YR 6/3) gravelly coarse sand; single grain; loose; mildly alkaline; calcareous.

The Ap and A1 horizons are black or very dark brown. Their combined thickness ranges from 8 to 14 inches. Reaction is slightly acid to medium acid. The A3 horizon is very dark brown, very dark grayish brown, or dark brown and is 3 to 6 inches thick. The B22 horizon ranges from loam to sandy clay loam in texture.

The B2 horizon ranges from 8 to 20 inches in thickness. The B3 horizon is gravelly sandy loam or gravelly loamy sand. Reaction in the B horizon is slightly acid to medium acid.

The IIC horizon is mostly gravelly coarse sand or stratified sand and gravel. In some profiles the IIC horizon contains some cobblestones, and in other profiles it has some seams of gravel.

Some areas of Wadena soils along the Maple Creek terraces and in eastern Aurora and northern Blooming Prairie Townships have a grayer colored A horizon and contain slightly more clay in the B horizon than is normal for the series.

Wadena soils have a thicker and darker colored A horizon than the similar Bixby soils. They contain less clay in the B horizon than the similar Dakota soils. They have a thicker B horizon than the similar Esterville soils. Wadena soils contain more sand and less silt in the A and B horizons than the similar Waukegan soils.

Wadena loam, 0 to 2 percent slopes (Woa).—This soil occupies 3-acre to 50-acre tracts. The smaller tracts are commonly scattered within the loamy uplands. The larger tracts are on the broad flats along the Straight River

and its tributaries. This soil has the profile described as representative for the series.

Included in mapping are small areas where slopes are greater than 2 percent. The broader areas are commonly crossed by drainageways of a poorly developed drainage net. Many of these drainageways are occupied by Biscay soils. Also included because of their small acreage, in section 1 of Lemond Township, are a few areas of soils that have grayer colors in the subsoil.

This Wadena soil is moderately droughty. Runoff is slow. There is a hazard of soil blowing on the larger tracts, especially in spring. Most of this soil is used for cultivated crops. (Capability unit IIs-1)

Wadena loam, 2 to 6 percent slopes (W_aB).—This soil occupies 2-acre to 50-acre tracts. It is on irregular hills within the loamy uplands or on steeper side slopes below the less sloping Wadena soils. Slopes range from 50 to 125 feet in length.

A few small areas of Estherville soils are included. Small inclusions of Salida soils are noted on the soil map by gravel spot symbols. A few areas are included where slopes are less than 2 percent and greater than 6 percent. Also included are a few, small, eroded areas in which material from the brownish subsoil has been mixed with material from the original surface layer.

This Wadena soil is moderately droughty. Runoff is medium. The hazards of soil blowing and erosion are moderate. Most of this soil is used for cultivated crops. (Capability unit IIe-4)

Wadena loam, 6 to 12 percent slopes, eroded (W_aC2).—This soil occupies 3-acre to 15-acre tracts. It is on short side slopes below areas of less sloping Wadena soils and on hills within areas of loamy soils on uplands. Slopes are 50 to 100 feet long. This soil has a profile similar to that described as representative for the series, except that the surface layer is dark brown because of mixing with material from the subsoil.

Included in mapping are a few areas where slopes are less than 6 percent and greater than 12 percent. A few included areas are of a soil that is more silty than normal for the series. Small areas of included Salida soils are indicated on the soil map by gravel spot symbols. Also included were a few areas that are only slightly eroded.

This Wadena soil is moderately droughty. Runoff is medium. The hazard of erosion is moderate. Most of the acreage is used for cultivated crops. (Capability unit IIIe-4)

Waukegan Series

The Waukegan series consists of nearly level to gently sloping, well-drained, silty soils that are moderately deep over sand and gravel. These soils formed in 24 to 40 inches of silty sediment over coarser textured material. They occupy broad flats and steeper side slopes of the level areas within the glacial outwash plains. Slopes are both simple and complex. The native vegetation was grass and groves of oak or brush.

In a representative profile, the surface layer is silt loam about 13 inches thick. The upper part of this layer is very dark brown, and the lower part is very dark grayish brown. The upper part of the subsoil is dark yellowish-brown, friable silt loam about 19 inches thick. The lower part is dark yellowish-brown, friable loam about 6 inches

thick. The underlying material is yellowish-brown to pale-brown, loose coarse sand and gravelly coarse sand.

Permeability is moderate in the upper part of the profile and rapid in the underlying material, beginning at a depth of about 38 inches. Runoff is slow to medium. The water table is at a depth below 6 feet. The available water capacity is moderate. The organic-matter content is high, and fertility is medium.

Most areas are used for crops, but a few small areas remain in trees. If properly managed, these soils are well suited to most crops grown in the county. Crop growth is limited by lack of available water in some years. Control of erosion in the more sloping areas is the main management need.

Representative profile of Waukegan silt loam, 0 to 2 percent slopes, in Merton Township, 400 feet west and 200 feet south of the northeast corner of NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 28, T. 108 N., R. 19 W.:

Ap—0 to 9 inches, very dark brown (10YR 2/2) silt loam, dark grayish brown (10YR 4/2) when dry; weak, medium, subangular blocky structure; friable; slightly acid; abrupt, smooth boundary.

A3—9 to 13 inches, very dark grayish-brown (10YR 3/2) silt loam; weak, fine, subangular blocky structure; friable; common tubular pores; slightly acid; clear, smooth boundary.

B21—13 to 22 inches, dark yellowish-brown (10YR 4/4) silt loam; faces of peds are brown (10YR 4/3); weak, fine and medium, subangular blocky structure; friable; common tubular pores; few bleached sand grains on faces of peds; medium acid; clear, wavy boundary.

B22—22 to 32 inches, dark yellowish-brown (10YR 4/4) silt loam; faces of peds are brown (10YR 4/3); moderate, fine, subangular blocky structure; friable; common tubular pores; medium acid; clear, wavy boundary.

B3—32 to 38 inches, dark yellowish-brown (10YR 4/4) loam; faces of peds are brown (10YR 4/3); weak, fine and medium, subangular blocky structure; friable; few bleached sand grains on vertical faces of peds; slightly acid; abrupt, smooth boundary.

IIC1—38 to 48 inches, yellowish-brown (10YR 5/6) coarse sand; single grain; loose; few fine gravel particles; slightly acid; clear, wavy boundary.

IIC2—48 to 60 inches, pale-brown (10YR 6/3) and light yellowish-brown (10YR 6/4) gravelly coarse sand; single grain; loose; mildly alkaline; calcareous.

The Ap horizon and the A1 horizon, where present, are very dark brown, very dark gray, or black. Dry colors range from very dark gray or dark grayish brown to grayish brown. The combined thickness of the Ap and A1 horizons ranges from 8 to 14 inches. Reaction is slightly acid to medium acid. The A3 horizon is very dark grayish brown or dark brown. It ranges from 2 to 6 inches in thickness. Reaction is slightly acid or medium acid.

Total thickness of the B2 horizons is 12 to 20 inches. There are a few thin clay films on faces of peds in the B22 horizon in some profiles. Reaction is slightly acid or medium acid in the B2 horizon. The B3 horizon is 4 to 10 inches thick.

The IIC horizon is coarse sand, gravelly coarse sand, or stratified sand and gravel. Depth to free carbonates is 40 to 60 inches.

Waukegan soils have a thicker and darker colored A horizon than the similar Bixby soils. They contain more silt in the A and B horizons than the similar Wadena soils. They contain less clay and more silt in the B horizon than the similar Dakota soils.

Waukegan silt loam, 0 to 2 percent slopes (W_gA).—This soil occupies 5-acre to 100-acre tracts. It is on flat tops of large, low-lying hills and in broad outwash areas. In Merton Township it is associated with Dakota, Kato,

and Sparta soils. In Aurora and Blooming Prairie Townships it is associated with Bixby, Hayfield, and Kato soils. This soil has the profile described as representative for the series.

Included in mapping are a few areas of soils that have a surface layer and subsoil of loam that is high in content of silt.

This Waukegan soil is moderately droughty. Runoff is slow. Soil blowing is a slight hazard. Most of the acreage is used for crops. (Capability unit IIs-1)

Waukegan silt loam, 2 to 6 percent slopes (WgB).—This soil occupies 5-acre to 160-acre tracts. It is on small, irregularly shaped hills and broad outwash areas.

Included in mapping are a few eroded areas in which material from the subsoil is mixed with material from the original surface layer. This browner layer is lower in content of organic matter and is less friable than the original surface layer. In the vicinity of Bixby, the surface layer dries to grayer colors and contains more sand in the subsoil than is normal for the series.

This Waukegan soil is moderately droughty. Runoff is medium. There is a hazard of erosion. Most of the acreage is used for crops. (Capability unit IIe-4)

Webster Series

The Webster series consists of deep, nearly level, poorly drained, loamy soils that formed in calcareous, loamy glacial deposits. These soils occupy broad upland flats and drainageways intermingled with more sloping soils. The native vegetation was water-tolerant grasses.

In a representative profile, the surface layer is black, friable clay loam about 20 inches thick. The subsoil is mottled, olive-gray, friable clay loam about 8 inches thick. The underlying material is calcareous, mottled, olive-gray clay loam.

Permeability in drained areas is moderate. Runoff is slow to ponded. The water table is at a depth of 1½ to 3 feet or near tile depth in drained areas. The available water capacity is high. The organic-matter content and fertility are high.

Most areas are used for crops. In their natural state, these soils are only moderately well suited to poorly suited to most crops grown in the county. If adequately drained, they are well suited to most local crops. Control of the water table and maintenance of tilth and fertility are the main management needs.

Representative profile of Webster clay loam, located in Meriden Township, 500 feet south and 900 feet west of the northeast corner of SE¼SW¼ sec. 12, T. 107 N., R. 21 W.:

- Ap—0 to 7 inches, black (N 2/0) clay loam; cloddy; friable; about 2 percent coarse fragments; neutral; abrupt, smooth boundary.
- A1—7 to 12 inches, black (N 2/0) clay loam; weak, fine, subangular blocky structure; friable; about 2 percent coarse fragments; slightly acid; clear, wavy boundary.
- A3—12 to 20 inches, black (10YR 2/1) clay loam; weak, very fine, subangular blocky structure; friable; about 4 percent coarse fragments; neutral; gradual, irregular boundary.
- B2g—20 to 28 inches, olive-gray (5Y 4/2) clay loam; few tongues of black (10YR 2/1); few, fine, distinct, light olive-brown (2.5Y 5/6) mottles; weak, fine, subangular blocky structure; friable; about 4 per-

cent coarse fragments; neutral; abrupt, smooth boundary.

Cg—28 to 60 inches, olive-gray (5Y 4/2) clay loam; common, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, fine, subangular blocky structure; friable; about 4 percent coarse fragments; mildly alkaline; calcareous.

The Ap and A1 horizons are clay loam or silty clay loam and have a combined thickness of 10 to 16 inches. Their reaction is commonly neutral but ranges from slightly acid to mildly alkaline. The A3 horizon is black or very dark gray. It is clay loam or silty clay loam and is 3 to 10 inches thick. Its reaction is neutral to mildly alkaline.

The B2g horizon is 8 to 14 inches thick. Its reaction is neutral to mildly alkaline.

The Cg horizon is clay loam or loam.

The Webster soils lack free carbonates in the A horizon, whereas the associated Canistee soils contain free carbonates in that horizon. They have a thinner A horizon than the associated Glencoe soils. They contain more sand and less silt in all horizons than the similar Madelia soils. They developed almost entirely in glacial till, whereas the Maxcreek soils developed in multiple glacial materials.

Webster clay loam (0 to 2 percent slopes) (Wt).—This soil occupies 5-acre to 500-acre tracts. It is in broad tracts broken by a few gentle rises or in broad, winding, lower lying tracts within areas of gently rolling to rolling soils of uplands.

Included in mapping are small depressions, near the crests of the drainage divides, where the soil has a grayish surface layer and a dark-colored, clayey subsoil. Some of the narrow drainageways have a thicker surface layer and a more clayey subsoil. In many places the slight rises have a calcareous surface layer. A few areas of Canistee soils on rims of depressions and drainageways are included because of their small size. A few included areas that once were covered with dense stands of timber have an incipient gray layer near a depth of 10 inches and a distinct increase in content of clay in the subsoil.

This Webster soil is wet. Runoff is slow. The water table ranges from a depth of 1½ to 3 feet in undrained areas. Drainage is needed for dependable cropland for currently grown crops. Properly designed and installed drainage systems effectively control the perched water table. Most of the acreage is used for crops. (Capability unit IIw-1)

Use and Management of the Soils

This section discusses use and management of the soils for crops and pasture and gives predicted yields per acre for the commonly grown crops. It also gives facts about suitability of the soils for wildlife, gives estimated engineering properties of the soils, and describes the suitability and limitations of the soils for various engineering uses.

Use of the Soils for Crops and Pasture

This subsection describes how the properties of the soils of Steele County affect use and management of soils for crops and pasture.

The soils in Steele County are in a very intermingled pattern in many places. A given field or pasture can be made up of both level, wet soils and naturally well-drained, sloping soils. Another field or pasture can contain droughty soils or moderately droughty soils that are

intermingled with wet soils and sloping soils that have high available water capacity. The wet soils need a drainage system to control the perched water table. The sloping soils need protection from loss of soil and water. The droughty soils respond to irrigation.

The climate usually limits field operations to the period April 15 to November 15. The opportunity for timely field operations is limited.

Field crops and pasture plants on most soils respond efficiently to additions of fertilizer. Nitrogen, phosphorus, and potassium are the principal elements added at this time. Minor elements are used on some truck crops. The need for fertilizer depends on the kind of soil, the past and present management, and the crop that is grown. Soil tests provide part of the information that is needed to choose the best kinds and amounts of fertilizer.

TILLAGE PRACTICES.—Frequent tillage or tilling when the soils are too wet or too dry damages the structure of the soils. Frequent tillage makes the surface layer powdery, so that water is not absorbed readily. If the surface layer is powdery, the amount of runoff increases, the moisture available to plants is limited, and erosion becomes more serious. Tilling when the soil does not contain the proper amount of moisture also makes the surface layer cloddy and unsuitable as a seedbed. It destroys the possible benefits to be derived from other practices that improve tilth.

The soils should be tilled only enough to prepare a good seedbed, to control the growth of weeds, and to control the volunteer growth of crops from the previous year. By applying chemicals to control weeds and by using machinery that permits minimum tillage, the amount of tillage needed can be reduced.

Plowing in fall is a common practice on the nearly level to gently undulating soils (fig. 3). If the soils are plowed in fall, freezing and thawing in winter break the clods and make tillage easier in spring. The soils can also be tilled earlier in spring than soils that have not been plowed in the previous fall. As a result, a better seedbed is generally prepared, and the possibility of obtaining a good stand of plants is increased.

The practice of plowing in fall is suited to the precipitation pattern of this county. The average monthly low-intensity precipitation between October and March ranges from about 1.5 inches to less than 1 inch. Beginning in March or April, there is a rapid increase in the amount of rainfall. This disrupts the timeliness of spring plowing and often causes the soils to be tilled when they are too wet.

The nearly level to gently undulating soils dry out slowly in spring. Fall plowing is therefore more suitable for those soils than spring plowing. Tillage other than rough plowing, however, should be avoided in fall. A rough surface holds the moisture from melting snow and reduces the hazard of erosion.

Sloping soils can be protected by using minimum tillage and rough tillage and by properly managing all crop residues. These practices help to control erosion and also provide a better seedbed for crops that are adapted to minimum tillage. The hazard of erosion increases as the slope increases. Therefore, sloping soils should be cultivated on the contour where possible. Fall plowing is suitable if such soils are terraced and if manure or some other protective mulch is used.



Figure 3.—A field of Merton and Maxcreek soils that was plowed in fall.

EROSION CONTROL.—Controlling erosion and conserving water are necessary on erodible soils to reduce losses of soil and water. Practices that help to control soil blowing and erosion include contour cultivation, terracing, strip-cropping, sodding of waterways, mulch tillage, rough tillage, and minimum tillage. Sloping soils can be protected against erosion by maintaining the content of organic matter and the level of fertility. A high content of organic matter and a high level of fertility increase the infiltration of water and enable the soil to support crops that improve soil structure.

Soil blowing is generally not a problem in this county, except in a few of the larger areas of muck. Blowing of sandy soils and of organic soils can be prevented by strip-cropping, rough tillage, maintaining a cover of plants or crop residues, wind strip-cropping, and providing wind-breaks for exposed areas.

DRAINAGE.—About 48 percent of the acreage in the county is made up of wet soils. Many farmers have installed tile, but many areas still need artificial drainage. Artificial drainage has been one of the most important

factors that have contributed to the development of farming in this county.

A tile drainage system will function properly in most of the soils. In local areas that are underlain by sandy or gravelly material, however, it is difficult to install tile and maintain open drains.

Root development is good in soils that are adequately drained, because the movement of air and water is not restricted. Soils that are adequately drained generally warm up earlier in spring and are less susceptible to frost heaving than poorly drained soils. Effective drainage also facilitates the use of larger farm equipment and permits more timely field operations than are possible in areas that are not drained.

Areas to be drained should be inspected by someone who knows the soils, because the depth and spacing of the tile depend on the kind of soil and the pattern of occurrence of the various soils. Open ditches are commonly used to remove excess surface water and to provide an outlet for other drainage systems (fig. 4).

LIMING.—The requirements for lime depend upon the natural acidity of the soils, the previous management, and the cropping system that is planned. Originally, the soils of the county were high in content of calcium. Now, in some of them the calcium has been leached out of the surface layer. After the calcium has been leached out, the soils need periodic applications of lime to correct acidity. The need for lime and the response to it vary considerably. The soils of this county are generally so intermingled that the soils in one part of the field may need lime and those in another part may not. Soil tests should be made to determine the requirements for lime.

Correcting the acidity in the surface layer helps to make other plant nutrients available to crops. In areas where the acidity has been corrected, there is better response to the inoculation of legumes.

Capability grouping

Capability grouping shows, in a general way, the suitability of soils for most kinds of field crops. The groups are made according to the limitations of the soils when used for field crops, the risk of damage when they are used, and the way they respond to treatment. The grouping does not take into account major and generally expensive landforming that would change slope, depth, or other characteristics of the soils; does not take into consideration possible but unlikely major reclamation projects; and does not apply to horticultural crops or to other crops that require special management.



Figure 4.—Drainage ditch in an area of Webster soils. A good stand of bromegrass controls erosion on the ditchbanks.

Those familiar with the capability classification can infer from it much about the behavior of soils when used for other purposes, but this classification is not a substitute for interpretations designed to show suitability and limitations of groups of soils for range, for forest trees, or for engineering.

In the capability system, all kinds of soils are grouped at three levels: the capability class, subclass, and unit. These are discussed in the following paragraphs.

CAPABILITY CLASSES, the broadest groups, are designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use, defined as follows:

- Class I soils have few limitations that restrict their use.
- Class II soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.
- Class III soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.
- Class IV soils have very severe limitations that reduce the choice of plants, require very careful management, or both.
- Class V soils are not likely to erode but have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife habitat. (None in Steele County.)
- Class VI soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture, range, woodland, or wildlife habitat.
- Class VII soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to pasture, range, woodland, or wildlife habitat.
- Class VIII soils and landforms have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife habitat, or water supply or to esthetic purposes.

CAPABILITY SUBCLASSES are soil groups within one class; they are designated by adding a small letter, *e*, *w*, *s*, or *c*, to the class numeral, for example, IIe. The letter *e* shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; *w* shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c*, used in only some parts of the United States but not in Steele County, shows that the chief limitation is climate that is too cold or too dry.

In class I there are no subclasses, because the soils of this class have few limitations. Class V (none in Steele County) can contain, at the most, only the subclasses indicated by *w*, *s*, and *c*, because the soils in class V are subject to little or no erosion, although they have other limitations that restrict their use largely to pasture, range, woodland, wildlife habitat, or recreation.

CAPABILITY UNITS are soil groups within the subclasses. The soils in one capability unit are enough alike to be suited to the same crops and pasture plants, to require similar management, and to have similar productivity and

other responses to management. Thus, the capability unit is a convenient grouping for making many statements about management of soils. Capability units are generally designated by adding an Arabic numeral to the subclass symbol, for example, IIe-4 or IIIe-2. Thus, in one symbol, the Roman numeral designates the capability class, or degree of limitation; the small letter indicates the subclass, or kind of limitation, as defined in the foregoing paragraph; and the Arabic numeral specifically identifies the capability unit within each subclass.

Management by capability units

In the following pages the capability units in Steele County are described and suggestions for the use and management of the soils are given. The names of soil series represented are mentioned in the description of each capability unit. This does not mean, however, that all the soils of a series are in a given capability unit. To find the capability unit of any given soil, refer to the "Guide to Mapping Units" at the back of this survey.

CAPABILITY UNIT I-1

This unit consists of deep, well-drained to somewhat poorly drained, medium-textured and moderately fine textured, nearly level soils (fig. 5). These soils are in the Le Sueur, Merton, Moland, and Nicollet series. They have few limitations that restrict their use. Erosion is not a significant problem. Available water capacity is high. Permeability is moderate. Corn, soybeans, oats, and alfalfa-brome are the main crops. Sweet corn, peas, green beans, and asparagus are other important crops.

Return of residues from high-yielding crops, limited tillage, and tillage at proper moisture content maintain good tilth and control compaction. Crops on these soils give efficient response to additions of fertilizer.

Proper fertilization and seeding to suitable grasses and legumes provide high-yielding pasture.

CAPABILITY UNIT IIe-1

This unit consists of deep, well-drained to somewhat poorly drained soils on irregular, gently undulating slopes. These soils are in the Blooming, Clarion, Lester, Le Sueur, Merton, Moland, and Nicollet series. Available water capacity is high. Permeability is moderate. The



Figure 5.—Cattle grazing on a Nicollet soil of capability unit I-1 that is intermingled with areas of Webster soil of capability unit IIw-1. Tile drains have been installed in the Webster soil.

hazard of erosion is slight and moderate. Soil blowing is an additional hazard on the Clarion sandy loam. Corn, soybeans, oats, and alfalfa-brome are the main crops.

Control of erosion, good tilth, and a high level of productivity are commonly maintained by the return of residues from high-yielding crops, limited tillage, tillage at proper moisture content, and additions of fertilizer. Contour cultivation and terracing can be applied to the larger tracts with smooth slopes. The waterways need to be properly designed and kept in grass. Response to and need for lime vary. Crop yields are lower on soils where erosion has increased the amount of material from the subsoil in the cultivated layer unless extra management is applied. Proper fertilization and seeding to suitable grasses and legumes provide high-yielding pasture.

CAPABILITY UNIT IIe-2

This unit consists of deep, well-drained to somewhat poorly drained, nearly level or gently undulating soils. These soils are in the Hayden and Newry series. The hazard of erosion is slight to moderate. Available water capacity is high. Soil blowing is an additional hazard on the Hayden sandy loam. Permeability is moderate. Except for the Hayden sandy loam, these soils have a narrow range of optimum moisture content for proper tillage. The surface layer tends to slake and settle on wetting and to crust on drying. Corn, soybeans, oats, and alfalfa-brome are the main crops.

Control of erosion, good tilth, and high fertility are maintained by the return of residue from high-yielding crops, limited tillage, tillage at proper moisture content, and additions of fertilizer. The Newry soil has slopes of 3 percent or less. Contour cultivation and terracing can be applied to selected areas of the Hayden soils.

Waterways should be properly designed and kept in grass. Applications of lime are commonly needed, and crops grown on these soils respond well to additions of nitrogen, phosphorus, and potassium. Unless extra management is applied, yields are lower on soils where erosion has increased the amount of material from the subsoil in the cultivated layer.

Good pastures are obtained by properly fertilizing the soils and seeding them to suitable grasses and legumes.

Thinly wooded areas can be improved by underplanting with red pine and by restricting grazing. White pine is better than other species of trees for underplanting in thickly wooded areas.

Trees in the few odd woodlots are mixed hard maple, red and American elm, basswood, ironwood, and oak. If these soils are left in trees, hard maple, basswood, white oak, and white ash should be encouraged.

CAPABILITY UNIT IIe-3

This unit consists of deep, well-drained and somewhat poorly drained, moderately fine textured, gently undulating soils. These soils are in the Kilkenny and Lerdal series. Available water capacity is high. Permeability is moderately slow to slow. The hazard of erosion is moderate. The soils of this unit are farmed in fields with soils of other units. They can be readily tilled only within a narrow range of moisture content. If worked when too wet, the soil generally remains cloddy for the balance of the growing season. Corn, soybeans, oats, and alfalfa-brome are the main crops.

Control of erosion, good tilth, and high fertility are maintained by the use of sod crops, the return of residue from high-yielding crops, limited tillage, tillage at proper moisture content, and additions of fertilizer. The high clay content in the upper part of the subsoil markedly increases the effects of erosion. Caution must be used in terrace construction; too nearly level a grade can cause the development of wetness in and below the channel. Spring plowing produces a cloddy seedbed.

The waterways need to be properly designed and kept in grass. Soils in this unit need to be limed.

Unless extra management is applied, crop yields are lower in areas where erosion has increased the amount of material from the subsoil in the cultivated layer. Proper fertilization and seeding to suitable grasses and legumes provide high-yielding pasture.

Only a few, small oak groves remain. Thinly wooded areas can be improved by underplanting with red pine and by restricting grazing.

CAPABILITY UNIT IIc-4

This unit consists of moderately deep, well-drained, gently undulating soils that are underlain by sand and gravel. These soils are in the Bixby, Dakota, Wadena, and Waukegan series. They have moderate available water capacity. Permeability is moderate in the upper part and rapid in the underlying material. Corn, soybeans, oats, and alfalfa-brome are the main crops. Canning peas, sweet corn, and green beans are other important crops.

Control of erosion, addition of fertilizer, and adjustment of the plant population to available water and irrigation are the main management needs. The Bixby soils have a surface layer in poorer tilth than the other soils in this unit. Crop growth is directly related to the amount and timeliness of rainfall. Cropping programs commonly are used that combine short-season crops with long-season crops to adjust to these variations in available water. Livestock can be kept to use the forage. All waterways should be properly designed and kept in grass.

If these soils are used for permanent pasture, periodic additions of nitrogen, phosphorus, and potassium sustain satisfactory growth of pasture plants. Ordinarily, neither permanent nor rotation pasture provides adequate quantities of forage for grazing in dry periods.

Soils in this unit are especially suited to growth of conifers. The few existing woodlots need protection from fire and grazing.

CAPABILITY UNIT IIw-1

This unit consists of moderately deep and deep, poorly drained, medium-textured and moderately fine textured, nearly level soils on broad flats and in wide draws. These soils are in the Biscay, Colo, Hanska, Kato, Madelia, Maxcreek, Marna, Udolpho, and Webster series. Available water capacity is low to very high. Permeability is moderate to moderately rapid in the upper part and rapid in the underlying material of the Biscay, Hanska, Kato, and Udolpho soils. Permeability is moderate to slow in the Colo, Madelia, Maxcreek, Marna, and Webster soils.

Corn and soybeans are the main crops in areas where these soils are dominant in a field. Large acreages of asparagus are grown in some areas. In places where these soils occur as smaller tracts within areas of the more

sloping soils, they are farmed similarly to the dominant sloping soils.

Control of the perched water table, maintenance of good tilth, and maintenance of a high level of productivity are the main management needs. The Colo soil is occasionally flooded. Most areas are used for crops. Soils in this unit are not dependable cropland unless properly designed waterways and outlet ditches are constructed and drain tile is installed. Open inlets or French drains are sometimes needed to prevent ponding in small depressions. Closer spacing of tiles is needed in the Marna soil than in the Webster soil because of the clayey subsoil in Marna. Wider tile spacings can be used in the Biscay, Hanska, Kato, and Udolpho soils. The coarse-textured underlying material of the Biscay, Kato, Hanska, and Udolpho soils and the coarse-textured seams in the Maxcreek soil cave and slough during ditch construction and tile installation. If these soils are adequately drained and managed, row crops can be grown year after year (fig. 6).

Return of residue from high-yielding crops, limited tillage, and tillage at proper moisture content maintain good tilth and keep compaction at a minimum. Crops grown on these soils respond well to additions of fertilizer in adequately drained areas.

CAPABILITY UNIT IIw-2

This unit consists of moderately deep and deep, poorly drained, medium-textured and moderately fine textured, nearly level, limy soils. These soils are on slight rises and rims adjacent to depressions and drainageways. They are in the Canisteo, Kato, Lemond, and Mayer series. Available water capacity is moderate to high. Permeability is moderate to moderately rapid in the upper part and rapid in the underlying material of the Kato, Lemond, and Mayer soils. Permeability is moderate in the Canisteo soils. Corn, soybeans, and asparagus are the principal crops.

Control of the perched water table, maintenance of good tilth, and special fertilization treatment related to the high concentrations of carbonates are the main management needs. Most areas are used for crops, but the soils are not dependable cropland unless properly designed waterways and outlet ditches are constructed and drain tiles are installed. Wider tile spacings can be used in the Kato, Lemond, and Mayer soils because of the coarser



Figure 6.—An inadequately drained area of Maxcreek silty clay loam in capability unit IIw-1 after a heavy rain. Ditches and tile drains would improve the suitability of this soil for crops.

textured underlying material. This material will cave and slough during construction.

The high concentration of lime carbonates requires special kinds and additions of nitrogen, phosphorus, and potassium. The need for minor elements varies with the crop grown. Pesticide and herbicide effectiveness and residual carryover differ from those on noncalcareous soils. Return of residue from high-yielding crops and limited and timely tillage help to keep compaction effects to a minimum.

CAPABILITY UNIT IIw-3

This unit consists of deep, well drained and moderately well drained, medium-textured soils that are subject to occasional flooding. These soils are on the higher first bottoms adjacent to the Straight River and its tributaries. The soils are Alluvial land, occasionally flooded, and Terril loam, occasionally flooded. Available water capacity is high in most places but is variable in Alluvial land, occasionally flooded. Permeability is moderate to moderately rapid.

Flooding is common during most spring snowmelts but only occasional during the crop season. Some areas are in permanent pasture. If cultivated, these soils are commonly planted to corn and soybeans. Droughtiness is a problem in some of the sandier areas of Alluvial land, occasionally flooded. Permanent pasture can be improved by topdressing with nitrogen, phosphorus, and potassium.

CAPABILITY UNIT II_s-1

This unit consists of moderately deep, well-drained to somewhat poorly drained, nearly level soils. These soils are underlain by sand or sand and gravel. They are members of the Bixby, Dakota, Hayfield, Wadena, and Waukegan series. Available water capacity is moderate. Permeability is moderate in the upper part and rapid in the underlying material. The hazards of soil blowing and erosion are slight. Corn and soybeans are the main crops. Canning peas, sweet corn, and green beans are other important crops.

Protecting the soil from blowing, proper fertilization, irrigation, and plant populations adjusted to available water are the main management needs. Crop growth is directly related to the amount and timeliness of rainfall. Cropping systems commonly are used that combine short-season crops and long-season crops to adjust to variations in available water. Livestock can be kept to use available forage.

Periodic additions of nitrogen, phosphorus, and potassium sustain satisfactory growth of pasture. Ordinarily, neither permanent nor rotation pasture provides adequate quantities of forage for grazing in dry periods.

Soils in this unit are well suited to conifers. Protection from fire and grazing is needed in woodlots.

CAPABILITY UNIT IIIe-1

This unit consists mostly of deep, well-drained, medium-textured, sloping and rolling Blooming, Clarion, and Lester soils, but it includes small areas of somewhat excessively drained Storden soils. The available water capacity is high. Permeability is moderate. Corn, soybeans, oats, and alfalfa-brome are the main crops.

Control of erosion, good tilth, and high productivity are maintained by the return of residue from high-yield-

ing crops, limited tillage, tillage at proper moisture content, and additions of fertilizer. Contour cultivation and terracing can be used on the larger tracts with smooth slopes. Waterways need to be properly designed and kept in grass.

Response to and the need for lime vary. Crops grown on soils of this unit respond efficiently to additions of nitrogen, phosphorus, and potassium.

Unless extra management is applied, crop growth is lower on soils where erosion has increased the amount of material from the subsoil in the cultivated layer. Many small tracts of these soils are farmed with larger areas of less sloping soils. In these small areas, extra manure or special use of crop residue is needed to reduce erosion and to maintain good tilth.

Proper fertilization and seeding to suitable grasses and legumes provide high-yielding pasture.

A few small areas are wooded, and protection from fire and grazing is needed in those areas. Thinly wooded areas can be improved by underplanting with red pine. White pine is good for underplanting in thickly wooded areas.

CAPABILITY UNIT IIIe-2

This unit consists of deep, well-drained, moderately coarse textured to moderately fine textured, rolling soils of the Hayden and Kilkenny series. Available water capacity is high. Permeability is moderately slow or moderate. For all the soils of this unit, the hazard of water erosion is moderate to severe, and soil blowing is an additional hazard on the Hayden sandy loam. Except for the Hayden sandy loam, soils in this unit can be satisfactorily tilled only within a narrow range of moisture content. The surface layer of the Hayden loams tends to slake and settle on wetting and to crust on drying. The Kilkenny soil is less permeable than the Hayden soils, and the plow layer becomes very cloddy if worked when wet. The higher clay content in the subsoil of the Kilkenny soil increases the effect of erosion. Soils of this unit occur in fields with soils of other capability units (fig. 7). Corn, oats, and alfalfa-brome are the main crops.

Control of erosion, good tilth, and high fertility are commonly maintained by the return of residues from



Figure 7.—Irregular topography in a field of Hayden and Webster soils. The Hayden soils occupy the higher areas, and the Webster soil is in the swales.

high-yielding crops, limited tillage, tillage at proper moisture content, and additions of fertilizer. Contour cultivation and terracing can be used on selected tracts. Waterways need to be properly designed and kept in grass. The soils of this unit commonly need applications of lime. Crops grown on these soils respond efficiently to additions of nitrogen, phosphorus, and potassium. Unless extra management is used, crop growth is poorer on soils where erosion has increased the amount of material from the subsoil in the cultivated layer.

Proper fertilization and seeding to suitable grasses and legumes provide high-yielding pasture.

Thinly wooded areas can be improved by underplanting with red pine, restricting grazing, and protecting from fire. The few remaining woodlots contain such mixed hardwoods as hard maple, red and American elm, basswood, ash, ironwood, and oak. If these tracts are left in trees, hard maple, red elm, basswood, white oak, and white ash should be encouraged.

CAPABILITY UNIT IIIc-3

This unit consists of shallow or deep, somewhat excessively drained or well-drained, moderately coarse textured, gently undulating soils of the Burnsville, Dickinson, Estherville, and Lamont series. Available water capacity is low to moderate. Permeability is moderate to moderately rapid in the upper part and rapid in the underlying material. The hazards of soil blowing and erosion are moderate to severe. Corn, oats, and alfalfa-brome are the main crops. Another important crop is early-season canning peas.

Control of soil blowing and erosion, proper fertilization, and adjustment of plant populations to available water capacity and irrigation are the major management needs. Crop growth is directly related to the amount and timeliness of rainfall. Cropping systems commonly are used that combine short-season crops and long-season crops to adjust to variations of available water. Livestock can be kept to use available forage. Erosion is controlled principally by residue management. Periodic topdressings of nitrogen, phosphorus, and potassium increase pasture growth during spring and fall. Ordinarily, neither permanent nor rotation pasture provides enough forage for grazing in dry seasons.

A few areas of these soils are irrigated for potatoes and sweet corn.

These soils are suitable for Scotch pine and red pine.

CAPABILITY UNIT IIIe-4

This unit consists of shallow to deep, somewhat excessively drained and well-drained, moderately coarse textured and medium-textured, gently undulating to rolling soils. They are members of the Bixby, Dakota, Lester, Estherville, Storden, and Wadena series. Available water capacity is low to high. Permeability is generally moderate or moderately rapid but is rapid in the underlying material of the Bixby, Dakota, Estherville, and Wadena soils. The erosion hazard is moderate to severe. Corn, oats, and alfalfa-brome are the main crops.

Erosion control, proper fertilization, and plant populations adjusted to the available water capacity are the main management needs. Cropping systems commonly are used that combine short-season crops with long-season crops to meet variations in available water. Livestock can

be kept to use available forage. Erosion can be controlled by having fields cultivated on the contour and by residue management. Rodent burrows are an additional limitation on these soils.

In areas where these soils are in permanent pasture or long-term meadow, periodic topdressings of nitrogen, phosphorus, and potassium increase growth of forage during spring and fall. Ordinarily, neither permanent nor rotation pasture provides adequate forage for grazing in dry seasons.

These soils are suitable for conifers.

CAPABILITY UNIT IIIw-1

This unit consists of deep and moderately deep, poorly drained and very poorly drained, medium-textured and moderately fine textured soils in low-gradient drainage ways and depressions. These soils are in the Biscay, Glencoe, Kato, Lura, and Maxcreek series. Available water capacity is moderate or high. Permeability is moderate to slow but is rapid in the underlying material of the Biscay and Kato soils. Soils of this unit are in fields with soils of other capability units. Timeliness of field operations is affected in areas where these soils are inadequately drained.

Control of the water table and maintenance of good tilth and high productivity are the main management needs. Soils of this unit are seldom used for crops unless waterways or ditches are constructed and drain tiles are installed. However, most areas have been drained and are used for crops. Open inlets or French drains are needed in places to remove ponded water in closed depressions. Closer spacing of tiles is needed in the Lura soil than in the Glencoe and Maxcreek soils. Wider spacing can be used in the Biscay and Kato soils. The coarse-textured seams in the Maxcreek soil cave and slough during ditch construction and tile installation. If the soils of this unit are adequately drained and managed, row crops can be grown year after year.

Return of residues from high-yielding crops, minimum tillage, and tillage at proper moisture content help to maintain good tilth and to keep compaction at a minimum. If adequately drained, these soils give efficient response to additions of fertilizer. Lime is not needed. Areas of excess lime occur occasionally and need specific fertilizer treatment.

Some undeveloped areas in this unit provide waterfowl habitat.

CAPABILITY UNIT IIIw-2

This unit consists of deep, poorly drained to somewhat poorly drained, medium-textured and moderately fine textured, nearly level soils of the Dundas, Havana, and Shields series. Available water capacity is high. Permeability is moderately slow or slow. Corn, soybeans, oats, and alfalfa-brome are the main crops.

Soils of this unit are slow in drying out and warming up in spring. The cultivated surface layer is weakly aggregated and loses good tilth easily. These soils respond well to additions of fertilizer, particularly nitrogen. A liming program must be considered. Proper fertilization, minimum tillage, addition of crop residues from high-yielding crops, and tillage at proper moisture content help to maintain good tilth. The prepared seedbed

tends to slake and settle on wetting and to crust on drying. This reduces aeration and slows seedling emergence. If these soils are worked when too wet, the cultivated layer becomes persistently cloddy for the balance of the crop season.

Water is slow to leave the surface layer because of the higher clay content in the subsoil. The perched water table is at a depth of 1 to 3 feet in periods of high rainfall, and near a depth of 5 feet in drier periods. Tile drainage is not generally installed in these soils at this time but is effective in controlling the water table. Surface waterways remove excess water. Closer spacing of tiles is needed on the Shields soil. An adequate outlet drain is needed for proper functioning of tile. Ponding in shallow depressions can be reduced if open intakes or French drains are installed.

Timeliness of field operations on associated soils is affected by small inclusions of soils of this unit in shallow draws and depressions.

The high shrink-swell potential of the Shields soil and the water-logging of the surface layer on all soils of this unit increase winter damage to plants having taproots.

The trees of the few wooded areas are mostly oak, ironwood, and American elm. If the soils are to be left in trees, growth of white oak should be encouraged. Odd areas can be made to provide cover for wildlife by planting evergreens, shrubs, and grasses that are tolerant of seasonal wetness and acidity.

CAPABILITY UNIT IIIw-3

This unit consists of deep and moderately deep, poorly drained and very poorly drained, moderately fine textured, limy soils in depressions and low-gradient drainageways. These soils are in the Canisteo, Kato, and Talcot series. Available water capacity is moderate to high. All of these soils have moderate permeability, but the material underlying the Kato and Talcot soils is rapidly permeable. Corn and soybeans are the main crops.

These soils are not generally used for crops unless waterways or ditches are constructed and tile drains are installed. However, most areas have been drained and are used for crops. Open inlets or French drains are needed in places to remove ponded water in small closed depressions. The loose, coarse-textured material underlying the Kato and Talcot soils caves and sloughs during construction.

The high concentration of lime carbonates requires extra additions of nitrogen, phosphorus, and potassium fertilizer. Minor-element needs vary with the crops grown. Pesticide and herbicide effectiveness and residual carryover vary from noncalcareous soils.

Return of residues from high-yielding crops and limited and timely tillage help to keep compaction at a minimum.

Some undeveloped areas of the soils in this unit provide waterfowl habitat.

CAPABILITY UNIT IIIw-4

This unit consists of Muck soils. Control of the water table and maintenance of fertility are the main management needs in areas used for crops. Crop growth and use are directly related to drainage development. Outlet ditches and provisions for removal of surface water are essential for adequate drainage of cropland (fig. 8). Con-



Figure 8.—Drainage ditch in a large area of Muck. This ditch is needed to provide an outlet for tile drains.

trol of the water table reduces oxidation and subsidence.

In large areas, installation of diversion terraces and interceptor ditches on the surrounding higher soils helps to control the surface water that would otherwise flood over the bog. A tile line near the base of the surrounding mineral soils helps to control seepage. Muck, sandy substratum, sloughs and caves during construction. Rate of subsidence varies with the depth of the Muck, intensity of cropping operations, level of the water table, and the degree of wetness of the original site. The rapid rate of early subsidence in some bogs, owing to the removal of water by outlet ditch, may be great enough that the installation of tile should be delayed for a year or two.

The soil reaction can vary widely within bogs. It is moderately alkaline near the outer edges and medium acid in the balance of the area. Reaction also varies greatly from one area to another.

All organic soils in this group are well supplied with calcium. Phosphate and potash levels ordinarily are very low. The nitrogen potential is high, but crops grown in some recently developed bogs or in bogs under longtime cultivation respond economically to additions of nitrogen. Some bogs, particularly those used for truck crops, require additions of trace elements.

Fire is a constant hazard. Once a fire becomes established, the effort and cost of extinguishing it are high. Muck soils neither absorb nor conduct heat nearly so rapidly as mineral soils. Except late in June, in July, and

early in August, the possibility of frost is a hazard. The degree of hazard varies with the air drainage of the surrounding area. Heat transfer is higher from a moist surface. Farm crops generally are limited to soybeans, silage corn, sweet corn, and, occasionally, early maturing field corn. Truck crops are potatoes, carrots, onions, red beets, and mint (fig. 9).

Soil blowing is controlled by use of windbreaks, irrigation, rough tillage, and cover crops.

Pasture growth varies widely, depending on drainage and kinds of grasses. In areas where some drainage improvement is possible and that have been seeded to desirable grasses and properly fertilized, high forage yields are obtained.

Some undeveloped areas of the soils in this unit provide excellent habitat for waterfowl, and selected areas provide winter cover for upland birds.

CAPABILITY UNIT III_s-1

This unit consists of shallow, moderately deep and deep, somewhat excessively drained and well-drained, moderately coarse textured, nearly level soils of the Dakota, Dickinson, and Estherville series. These soils are underlain by sand or sand and gravel. Available water capacity is low to moderate. Permeability is moderate or moderately rapid in the upper part and rapid in the underlying material. The hazard of soil blowing is moderate to severe. Corn, oats, and alfalfa-brome are the

main crops. Early-season canning peas and green beans are also grown, and sweet corn and potatoes are grown under irrigation in a few places.

Control of soil blowing, proper fertilization, irrigation, and adjustment of plant populations to the available water capacity are the main management needs. Cropping systems commonly are used that combine short-season crops with long-season crops to meet variations in available water. Livestock can be kept to use available forage. Soil blowing can be controlled by residue management. There is a hazard of crop damage by rodents on these soils.

In areas where these soils are in permanent pasture or long-term meadow, periodic topdressings of nitrogen, phosphorus, and potassium increase growth of forage plants during spring and fall. Ordinarily, neither permanent nor rotation pasture provides adequate forage for grazing in dry periods.

These soils are suitable for conifers.

CAPABILITY UNIT IV_e-1

This unit consists of deep, medium-textured, moderately steep and hilly soils of the Clarion, Hayden, Lester, and Storden series. All of these soils, except the Storden, are well drained. The Storden soils are somewhat excessively drained. All the soils have high available water capacity and moderate permeability. The hazard of erosion is severe.



Figure 9.—Harvesting potatoes in a large field of Muck.

Control of erosion in cultivated fields and improvement of forage for hay and pasture are the main management needs.

Loss of soil and water can be controlled in cultivated fields through the use of contouring, residue management, and limited tillage. Slopes are commonly too steep for terracing and too irregular for contouring. Additions of manure or special use of crop residues are main erosion control methods. Corn, oats, and alfalfa-brome are the main crops. Many areas are small and are farmed with larger areas of less sloping soils.

Long-term meadow or pasture needs periodic topdressings of nitrogen, phosphorus, and potassium. During the hot summer there is less growth on south- and west-facing slopes than on north- and east-facing slopes.

A few areas are wooded. These areas need protection from fire and grazing. Thinly wooded areas can be improved by underplanting with adapted species.

CAPABILITY UNIT IVc-2

This unit consists of shallow and moderately deep, well-drained and somewhat excessively drained, medium-textured and moderately coarse textured, sloping to moderately steep soils of the Bixby, Burnsville, Dakota, Estherville, and Lamont series. These soils are underlain by sand or sand and gravel. Available water capacity is moderate or low. Permeability is moderate or moderately rapid in the upper part and rapid in the underlying material. The hazards of soil blowing and erosion are severe in cultivated fields.

Control of erosion and adjustment of crops to available water capacity are the main management needs. The soils of this unit occur as small tracts associated with soils that have higher available water capacity. Corn, oats, and alfalfa are the common crops grown on the soils in this unit. Plant populations and additions of fertilizer need to be adjusted to the available water capacity of these soils. Long-term yields of grass and legumes are sustained or increased with topdressings of nitrogen, phosphorus, and potassium. Contour tillage and residue management are effective erosion control practices.

Ordinarily, neither permanent nor rotation pasture provides sufficient forage for grazing in dry periods.

The soils in this unit are suited to conifers for Christmas trees or for wildlife cover. Slope aspect is an important factor in choosing species. The rodent population is commonly high.

CAPABILITY UNIT VIc-1

This unit consists mostly of deep, well-drained, sloping to steep, medium-textured soils of the Lester and Hayden series. The available water capacity is high. Permeability is moderate. This unit also includes small areas of the shallow, somewhat excessively drained Estherville soils and the deep, somewhat excessively drained Storden soils that were mapped in a complex with the Lester series. The hazard of erosion is severe, but few areas of these soils are cultivated.

Increase in yields of hay and pasture and improvement of woodlots are the main management needs. Larger tracts are better suited to permanent vegetation, such as long-term alfalfa-brome or specially treated permanent pasture, than to cultivated crops. Woodland and wildlife plantings can be established on smaller tracts. Additions

of lime, nitrogen, phosphorus, and potassium increase growth of pasture plants. Production on south- and west-facing slopes is low during the hot summer. If these soils are cultivated, loss of soil and water can be reduced through the use of contouring, residue management, and limited tillage. Slopes are commonly too steep for terracing.

Wooded areas need protection from fire and grazing. Thinly wooded areas can be improved by underplanting with adapted species.

CAPABILITY UNIT VIc-2

This unit consists of shallow and deep, somewhat excessively drained and well-drained, moderately coarse textured, moderately steep soils of the Estherville and Lamont series. Available water capacity is low to moderate. Permeability is moderately rapid. The hazard of erosion is severe. Most areas of these soils are in permanent vegetation.

Control of erosion and maintenance of satisfactory stands of forage and other types of permanent vegetation are the main management needs. Growth is often reduced by limited or untimely rainfall, high winds, or high temperatures. Many areas of the soils in this unit occur as small tracts associated with less sloping soils or with soils that have higher available water capacity. Additions of fertilizer need to be adjusted to the available water capacity of these soils. Long-term yields of grass and legumes are sustained or increased by topdressings of nitrogen, phosphorus, and potassium. Contour tillage and residue management are practices that help to control erosion in cultivated areas.

Ordinarily, neither permanent nor rotation pasture provides sufficient forage for grazing in dry periods.

The soils in this unit are suitable for conifers for Christmas trees or wildlife cover. Slope aspect is an important factor in choosing species. The rodent population is commonly high.

CAPABILITY UNIT VIw-1

This unit consists of Alluvial land, frequently flooded, Lake beaches, and soils of the Calco, Colo, and Terril series. These areas are frequently flooded. Except for Alluvial land and Lake beaches, which are variable, the soils have high available water capacity and moderate to moderately slow permeability.

Most of the areas are in permanent vegetation. They are poorly suited to cultivated crops because of the hazard of flooding. Improved permanent pasture, wildlife, and recreation are suitable uses. Lake beaches are occasionally cultivated in areas adjacent to organic soils that have been artificially drained, but they generally become droughty if the water table is thus lowered.

CAPABILITY UNIT VIc-1

This unit consists of deep, coarse textured and moderately coarse textured, gently sloping to moderately steep soils of the Chelsea, Dickinson, and Sparta series. Available water capacity is very low to moderate. The soils have rapid to moderately rapid permeability. They commonly occur as small tracts within areas of more productive soils. The hazards of soil blowing and erosion are severe in cultivated areas.

Maintenance of permanent vegetative cover is the main management need. Woodland is commonly the best general use. These soils are suitable for Christmas trees. Early spring planting of transplant stock increases survival from droughtiness. Species should be selected according to different slope aspects. Rodents abound in these soils.

CAPABILITY UNIT VIIe-1

Only one mapping unit, Lester and Hayden loams, 25 to 35 percent slopes, is in this unit. These are deep, well-drained, medium-textured, very steep soils. Available water capacity is high. Permeability is moderate. The hazard of erosion is very severe. Management needs for these soils are mostly related to retaining the natural environment for esthetic reasons. Total acreage is small.

Most of this unit is wooded. Wooded areas should be protected and improved. Open areas can be planted to suitable conifers and native hardwoods.

CAPABILITY UNIT VIIIs-1

This unit consists of shallow and deep, somewhat excessively drained and excessively drained, moderately coarse textured and coarse textured, moderately steep to steep soils or gravel pits. These soils are in the Dickinson, Salida, and Sparta series. Available water capacity is moderate to very low. Permeability is moderately rapid to rapid. In places soils of this unit occur as small tracts within areas of more productive soils. The hazards of soil blowing and erosion are severe in cultivated areas.

Maintenance of a permanent vegetative cover is the main management need. Woodland is commonly the best general use. South- and west-facing slopes should be planted to jack pine or red pine. White pine and red pine can be planted on north- and east-facing slopes. Because of droughtiness, transplanted stock rather than seedlings should be planted early in spring.

CAPABILITY UNIT VIIIw-1

This unit consists only of Marsh. It is generally unsuited to cultivated crops and poorly suited to pasture because of high water levels.

Management needs for this unit are mostly related to wildlife adapted to a marshy environment. Marsh areas can be improved by level ditching or water level controls (fig. 10). Selected areas will provide winter cover for upland birds.



Figure 10.—An area of Marsh in Swan Lake. The water table is controlled to make this area more suitable for waterfowl.

Predicted yields

The yields shown in table 2 can be obtained if the following management is applied.

Lime needs are corrected. Special fertility treatments have been applied to the calcareous soils. Tillage operations maintain optimum tilth. Erosion is controlled on sloping soils. Pesticides and herbicides are used. Soils are adequately drained. Plant populations are adjusted to available water capacity of soils. Fertilizer is applied according to the results of soil tests.

Starter fertilizer is applied to corn at the rates of 10 to 12 pounds per acre of nitrogen, 22 to 24 pounds of phosphorus, and 40 to 46 pounds of potassium. In addition, 60 to 90 pounds per acre of potassium and 10 to 15 pounds per acre of phosphorus are plowed down or topdressed before planting, and 80 to 125 pounds per acre of nitrogen are applied before planting or are sidedressed 2 to 6 weeks after the corn is planted. As a rule, corn receives only starter nitrogen if it is planted the first year after a legume crop has been grown. A small grain seeded with a legume-grass companion mixture normally receives 18 pounds per acre of nitrogen, 32 to 34 pounds of phosphorus, and 60 to 64 pounds of potassium. The following year the legume-grass is topdressed with 8 to 10 pounds per acre of phosphorus and 16 to 18 pounds per acre of potassium. Soybeans receive small additions of phosphorus and potassium to supplement the supply remaining from previous applications. Yield predictions of alfalfa or alfalfa-brome mixtures grown for hay are based on three cuttings per season.

To convert phosphorus applications to phosphate, multiply by a factor of 2.32. To convert potassium applications to potash, multiply by a factor of 1.20.

The yield predictions were based on information obtained from the following sources: records of measured yields obtained in experiments made on specific soils, records of yields and soil management practices reported by farmers for crops on specific soils, observations of crops and interviews with farmers during the course of the survey, knowledge of soil properties that are known to affect crop growth, consultation with county agents and personnel of the Soil Conservation Service, and average yield values published in agricultural census data.

The use of improved varieties of seed, of new and improved farming practices, and of larger amounts of fertilizer makes it possible to obtain higher yields than those given in table 2. Yields vary from year to year because of disease and insect infestations and variations in climate, especially rainfall. Therefore, the predicted yields are averages that can be expected for a 5- to 10-year period and not for any 1 year.

Use of the Soils for Wildlife²

The soils of Steele County have the potential to provide excellent habitat for various species of wildlife. The soil associations have different potentials for producing various components of wildlife habitat. Table 3 rates the potential of soil associations for producing wildlife habitat. There is a distinct interrelationship between different types of plants growing on soils of the various soil asso-

² By JOHN W. BEDISH, biologist, Soil Conservation Service.

TABLE 2.—*Predicted average acre yields of principal crops*

[Dashes in columns indicate yields are too variable to estimate or crops listed are not normally grown on the soil]

Soil	Corn	Oats	Soy-beans	Alfalfa or alfalfa-brome hay	Soil	Corn	Oats	Soy-beans	Alfalfa or alfalfa-brome hay
	Bu.	Bu.	Bu.	Tons		Bu.	Bu.	Bu.	Tons
Alluvial land, occasionally flooded ¹	70	55	27	3.0	Hayden sandy loam, 2 to 6 percent slopes, eroded	80	75	32	3.0
Alluvial land, frequently flooded					Hayden sandy loam, 6 to 12 percent slopes, eroded	75	70	28	2.8
Biscay loam ¹	80	70	32	3.0	Hayden loam, 2 to 6 percent slopes	100	85	35	4.5
Biscay loam, depressional ¹	75	60	30	3.0	Hayden loam, 2 to 6 percent slopes, eroded	95	80	30	4.2
Bixby loam, 0 to 2 percent slopes	80	65	28	2.5	Hayden loam, 6 to 12 percent slopes	85	65	24	4.0
Bixby loam, 2 to 6 percent slopes	80	60	25	2.5	Hayden loam, 6 to 12 percent slopes, eroded	75	65	22	4.0
Bixby loam, 2 to 6 percent slopes, eroded	75	55	20	2.2	Hayden loam, 12 to 18 percent slopes	65	60	20	3.0
Bixby loam, 6 to 12 percent slopes, eroded	60	45	16	2.0	Hayden loam, 12 to 18 percent slopes, eroded	50	50		2.5
Bixby loam, 12 to 18 percent slopes, eroded		35		2.0	Hayfield silt loam	75	65	30	3.0
Blooming silt loam, 2 to 6 percent slopes, eroded	120	80	35	4.5	Kato silty clay loam ¹	95	65	35	4.0
Blooming silt loam, 6 to 14 percent slopes, eroded	100	75	30	4.0	Kato silty clay loam, swales ¹	80	60	30	3.5
Burnsville sandy loam, 2 to 6 percent slopes	60	50	20	2.7	Kato silty clay loam, calcareous variant ¹	85	65	25	4.0
Burnsville sandy loam, 6 to 12 percent slopes	50	45	16	2.2	Kato silty clay loam, calcareous variant, depressional ¹	75	60	25	3.5
Calco silty clay loam, very wet					Kilkenny clay loam, 2 to 6 percent slopes, eroded	90	75	34	4.5
Canisteo silty clay loam ¹	110	75	36	4.5	Kilkenny clay loam, 6 to 12 percent slopes, eroded	80	65	30	4.0
Canisteo silty clay loam, depressional ¹	95	65	30	4.0	Lake beaches				
Canisteo clay loam ¹	110	75	36	4.5	Lamont sandy loam, 2 to 6 percent slopes	60	45	16	2.0
Canisteo clay loam, depressional ¹	95	65	30	4.0	Lamont sandy loam, 6 to 12 percent slopes	40	35	12	1.5
Chelsea loamy fine sand, 2 to 18 percent slopes	30	30		1.5	Lamont sandy loam, 12 to 18 percent slopes	70	30		1.5
Clarion sandy loam, 2 to 6 percent slopes, eroded	80	75	32	3.0	Lemond loam ¹	70	60	28	3.5
Clarion loam, 2 to 6 percent slopes	120	85	40	4.5	Lerdal silty clay loam, 2 to 6 percent slopes	90	75	35	4.5
Clarion loam, 2 to 6 percent slopes, eroded	115	80	36	4.5	Lerdal silty clay loam, 2 to 6 percent slopes, eroded	85	70	30	4.5
Clarion loam, 6 to 12 percent slopes, eroded	95	65	30	4.0	Lester loam, 2 to 6 percent slopes	120	85	40	4.5
Clarion-Storden complex, 6 to 12 percent slopes, eroded	75	60	25	3.0	Lester loam, 2 to 6 percent slopes, eroded	115	80	35	4.5
Clarion-Storden complex, 12 to 18 percent slopes, eroded	60	40		2.5	Lester loam, 6 to 12 percent slopes	95	65	30	3.7
Colo silty clay loam, occasionally flooded ¹	90	60	30	3.0	Lester loam, 6 to 12 percent slopes, eroded	85	60	28	3.5
Colo silty clay loam, frequently flooded					Lester loam, 12 to 18 percent slopes, eroded	70	55	20	3.0
Dakota sandy loam, 0 to 2 percent slopes	60	55	26	3.0	Lester-Estherville-Storden complex, 2 to 6 percent slopes, eroded	80	65	25	3.5
Dakota sandy loam, 2 to 6 percent slopes	55	50	22	2.5	Lester-Estherville-Storden complex, 6 to 18 percent slopes, eroded	65	50	20	2.5
Dakota sandy loam, 6 to 14 percent slopes	50	45	15	2.0	Lester and Hayden loams, 18 to 25 percent slopes				2.0
Dakota loam, 0 to 2 percent slopes	80	65	28	3.5	Lester and Hayden loams, 25 to 35 percent slopes				
Dakota loam, 2 to 6 percent slopes	80	60	25	3.0	Lester-Storden complex, 6 to 12 percent slopes, eroded	70	60	25	3.0
Dickinson sandy loam, terrace, 0 to 2 percent slopes	70	65	24	3.0	Lester-Storden complex, 12 to 18 percent slopes, eroded	60	40		2.5
Dickinson sandy loam, terrace, 2 to 6 percent slopes	65	60	20	2.7	Le Sueur clay loam, 0 to 2 percent slopes	120	80	40	4.5
Dundas silt loam	85	65	30	3.5	Le Sueur clay loam, 2 to 4 percent slopes	120	80	40	4.5
Estherville sandy loam, 0 to 2 percent slopes	60	50	24	2.7					
Estherville sandy loam, 2 to 6 percent slopes	60	50	22	2.5					
Estherville sandy loam, 6 to 12 percent slopes	50	45	20	2.2					
Estherville sandy loam, 12 to 18 percent slopes		30		1.8					
Glencoe clay loam ¹	95	75	35	4.0					
Hanska loam ¹	75	60	28	3.0					
Havana silt loam	85	65	30	4.5					

See footnotes at end of table.

TABLE 2.—Predicted average acre yields of principal crops—Continued

Soil	Corn	Oats	Soy-beans	Alfalfa or alfalfa-brome hay	Soil	Corn	Oats	Soy-beans	Alfalfa or alfalfa-brome hay
	<i>Bu.</i>	<i>Bu.</i>	<i>Bu.</i>	<i>Tons</i>		<i>Bu.</i>	<i>Bu.</i>	<i>Bu.</i>	<i>Tons</i>
Lura silty clay loam ¹ -----	90	75	30	4. 0	Nicollet clay loam, 2 to 4 percent slopes-----	120	80	40	4. 5
Madelia silty clay loam ¹ -----	120	80	35	4. 5	Salida gravelly loamy sand, 12 to 25 percent slopes-----		30		1. 8
Marna silty clay loam ¹ -----	120	80	35	4. 5	Shields silty clay loam-----	80	60	25	2. 5
Marsh-----					Sparta-Dickinson complex, 2 to 6 percent slopes-----	40	35	15	2. 0
Maxcreek silty clay loam ¹ -----	120	80	40	4. 5	Sparta-Dickinson complex, 6 to 12 percent slopes-----				1. 0
Maxcreek silty clay loam, swales ¹ -----	85	65	30	4. 0	Sparta-Dickinson complex, 12 to 25 percent slopes-----				1. 0
Mayer loam ¹ -----	80	60	30	3. 0	Talcot clay loam ¹ -----	85	65	30	4. 0
Merton silt loam, 0 to 2 percent slopes-----	120	80	40	4. 5	Terril loam, occasionally flooded-----	80	55	33	3. 0
Merton silt loam, 2 to 4 percent slopes-----	120	80	40	4. 5	Terril loam, frequently flooded-----				
Moland silt loam, 0 to 2 percent slopes-----	120	80	40	4. 5	Udolpho silt loam ¹ -----	80	70	28	3. 5
Moland silt loam, 2 to 6 percent slopes-----	100	80	40	4. 5	Wadena loam, 0 to 2 percent slopes-----	75	55	26	3. 0
Moland silt loam, 2 to 8 percent slopes, eroded-----	90	75	30	4. 5	Wadena loam, 2 to 6 percent slopes-----	70	50	22	2. 5
Muck ² -----	70	50	28		Wadena loam, 6 to 12 percent slopes, eroded-----	55	50	20	2. 0
Muck, calcareous ² -----	65	45	22		Waukegan silt loam, 0 to 2 percent slopes-----	100	75	35	3. 5
Muck, sandy substratum ² -----	70	50	26		Waukegan silt loam, 2 to 6 percent slopes-----	95	70	30	3. 5
Muck, loamy substratum ² -----	70	50	28		Webster clay loam ¹ -----	120	75	40	4. 5
Newry silt loam, 0 to 3 percent slopes-----	95	80	35	4. 5					
Nicollet clay loam, 0 to 2 percent slopes-----	120	80	40	4. 5					

¹ Yields can be obtained where the soil has a complete drainage system.

² Corn is grown for grain on a minor acreage of this soil. Soybeans or silage corn are the principal crops. Hay grown on this soil is brome or reed canarygrass, but not alfalfa.

TABLE 3.—Potential for production of wildlife habitat by soil associations

[Ratings are based on yields of suitable vegetation required by the stated kinds of wildlife, and they assume that the habitat will be managed]

Soil association ¹	Potential for production of habitat for—				
	Pheasant	Duck, mink, and muskrat	Squirrels	Deer	Song birds
1. Webster-Clarion-Nicolett-----	High-----	Low ² -----	High-----	Low-----	High-----
2. Lester-Webster-Le Sueur-----	High-----	Low ² -----	High-----	Medium-----	High-----
3. Lerdal-Kilkenny-Shields-----	High-----	Low ² -----	High-----	Medium-----	High-----
4. Hayden-Webster-Lester-----	High-----	Low ² -----	High-----	Medium-----	High-----
5. Maxcreek-Moland-Merton-----	High-----	Low ² -----	High-----	Low-----	High-----
6. Bixby-Dakota-Biscay-Estherville-----	Medium-----	Low ² -----	Medium-----	Low-----	Medium-----

¹ See General Soil Map.

² Naturally poorly drained and very poorly drained soils have a high potential for wetland development if they are not artificially drained.

ciations and the animals associated with these plants. For example, the Webster, Clarion, and Nicollet soils of association 1 have a high potential for producing habitat elements that the ring-necked pheasant requires. Clarion and Nicollet soils are well suited to the grasses and legumes that pheasants use for nesting and escape cover. These soils can produce high-yield food plants and woody plants for winter cover. Undrained Glencoe soils in this association can produce cattails, sedges, and water-tolerant grasses that provide escape cover, nesting cover, and winter cover. If drained, Glencoe soils are well suited to corn and soybeans, which are excellent food sources for pheasant. On the other hand, the potential of Glencoe soils for producing woodland food and cover is lower than that of other soils, so the habitat potential for deer is somewhat limited.

In areas where pheasants are plentiful, the largest populations are on the Webster, Clarion, and Nicollet soils of association 1. The acreage used for row crops, especially soybeans, is constantly increasing, and that used for small grains is decreasing. This changing land-use pattern affects the future level of wildlife populations.

A small population of deer persists in the wooded areas of the county. Deer mainly inhabit areas of Hayden, Webster, and Lester soils of association 4.

Seeding ditchbanks and the borders of fields provides cover for many kinds of wildlife. Farmstead windbreaks provide nesting cover for squirrel and mourning dove and serve as winter cover for pheasant.

Facilities for fishing and boating are available on Beaver Lake (fig. 11). A State park is being developed in the woodland adjacent to Rice Lake. Permanent waterfowl habitat exists in the area of Oak Glen Lake and Swan Lake. Game farms and hunting preserves offer additional habitat.

Engineering Uses of the Soils³

Some soil properties are of special interest to engineers because they affect the construction and maintenance of roads, airports, pipelines, building foundations, facilities for water storage, erosion control structures, drainage systems, and sewage disposal systems. Among the properties most important to engineers are permeability, shear strength, compaction characteristics, drainage, shrink-swell potential, particle size, plasticity, and reaction. Depth to the water table, depth to bedrock, and topography also are important.

The soil survey of Steele County can be used by engineers to—

1. Make soil and land use studies that will aid in selecting and developing industrial, business, residential, and recreational sites.
2. Make estimates of runoff and erosion for use in designing drainage systems and planning dams and other structures for conservation of soil and water.
3. Make preliminary evaluations of soil and ground conditions that will aid in selecting highway, airport, pipeline, and cable locations and in plan-



Figure 11.—A part of Beaver Lake used for boating and fishing. Lester and Le Sueur soils occupy the area in the background.

ning detailed investigations at the selected locations.

4. Locate probable sources of gravel and other construction materials.
5. Correlate performance of engineering structures with soil mapping units to develop information for overall planning that will be useful in designing and maintaining certain engineering practices and structures.
6. Determine the suitability of soil mapping units for cross-country movement of vehicles and construction equipment.
7. Supplement the information obtained from other published maps and reports that can be used readily by engineers.
8. Make a general estimate of the hazards or useful properties of various soils for highway and earth construction when definite laboratory data are not available.

With the soil map for identification of soil areas, the engineering interpretations reported here can be useful for many purposes. It should be emphasized, however, that these interpretations may not eliminate the need for sampling and testing at the site of specific engineering works involving heavy loads and where excavations are deeper than the depth of layers here reported. Even in these situations the soil map is useful for planning more detailed field investigations and for suggesting the kinds of problems that may be expected.

Some of the terms used by the soil scientist may not be familiar to the engineer, and some words have special meanings in soil science. Most of these terms are defined in the Glossary at the back of this survey.

To make the best use of the map and the text, the engineer should understand the classification system used by soil scientists. He should also have a knowledge of the properties of the soil material and the condition of the soil in place.

Much of the information in this section is in tables. Table 4 gives soil properties significant to engineering, table 5 provides engineering interpretations of these properties, and table 6 gives engineering test data obtained when samples of these soils were tested.

Engineering classification systems

The two systems most commonly used in classifying samples of soil pedons for engineering are the AASHO

³ RICHARD D. WENBERG, assistant State conservation engineer, Soil Conservation Service, helped prepare this section.

system (1, 7) adopted by the American Association of State Highway Officials and the Unified system (7, 14) used by the Soil Conservation Service, U.S. Department of Defense, and other agencies.

The AASHO system is used to classify soils according to properties that affect use in highway construction. In this system a soil is placed in one of seven basic groups, ranging from A-1 through A-7, on the basis of grain-size distribution, liquid limit, and plasticity index. In group A-1 are gravelly soils of high bearing strength, or the best soils for subgrade (foundation). At the other extreme are clay soils that have low bearing strength when wet. The best soils for subgrade are, therefore, classified as A-1, the next best A-2, and so on to class A-7, the poorest soils for subgrade. Where laboratory data are available to justify a further breakdown, the A-1, A-2, and A-7 groups are divided as follows: A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, and A-7-6. If soil material is near a classification boundary it is given a symbol showing both classes; for example, A-2 or A-4. Within each group, the relative engineering value of a soil material can be indicated by a group index number. Group indexes range from 0 for the best material to 20 for the poorest. The AASHO classification for tested soils, with index numbers in parentheses, is shown in table 6; the estimated classifications for all soils mapped in the county are given in table 4.

In the Unified system soils are classified according to particle size distribution, plasticity, liquid limit, and organic-matter content. Soils are grouped in 15 classes. There are eight classes of coarse-grained soils, identified as GW, GP, GM, GC, SW, SP, SM, and SC; six classes of fine-grained soils, identified as ML, CL, OL, MH, CH, and OH; and one class of highly organic soils, identified as Pt. Soils on the borderline between two classes are designated by symbols for both classes; for example, CH or MH.

Estimated engineering properties

Table 4 provides estimates of soil properties significant to engineering. The estimates are based on field classification and descriptions, physical and chemical tests of selected representative samples, test data from comparable soils in adjacent areas, and detailed experience in working with the individual kind of soil in the survey area.

The USDA texture is determined by the relative proportions of sand, silt, and clay in soil material that is less than 2.0 millimeters in diameter.

Permeability relates to movement of water downward through undisturbed and uncompacted soil. It does not include lateral seepage. Permeability estimates are based on structure and porosity of the soil. Plowpans, surface crusts, and other properties resulting from use of the soils are not considered.

Available water capacity is the capacity of soil to store water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil.

Reaction is the degree of acidity or alkalinity of a soil, expressed as pH value. The pH value, and relative terms used to describe soil reaction, are explained in the Glossary.

Shrink-swell potential is an indication of the volume change to be expected of the soil material with changes in moisture content. Shrinking and swelling of soils cause much damage to building foundations, roads, and other structures. A high shrink-swell potential indicates hazards to the maintenance of structures built in, on, or by use of such materials.

Most soils of this county are deep enough over bedrock that bedrock generally does not adversely affect the use of the soils for engineering.

Engineering interpretations

Table 5 contains interpretations of properties that affect suitability of the soils as material for construction of highways, farm facilities, and sewage disposal systems. Detrimental or undesirable features are emphasized, but important desirable features may also be listed. The ratings and other interpretations in this table are based on estimates of soil properties shown in table 4; on available test data, including those in table 6; and on field experience. The information applies only to soil depths indicated in table 4, but it is reasonably reliable to a depth of about 5 or 6 feet.

Topsoil is soil material used as a topdressing for bare surfaces, lawns, parks, and gardens. It is applied to improve soil conditions for establishing or maintaining desirable vegetation.

Sand and gravel ratings are based on the probability that delineated areas of the soil contain deposits of sand or gravel. They provide guidance about where to look for them. The ratings do not indicate quality or size of the deposits.

Road fill is the material used as an embankment to support the subbase and base course or surface course. The ratings indicate performance of soil material moved from borrow areas for these purposes.

Pond reservoir areas are affected mainly by loss of water through seepage, and the soil features are those that influence such seepage.

Soil features listed for embankments, dikes, and levees are those of both the subsoil and the substratum that are important to the use of soils for constructing embankments, dikes, and levees.

Septic tank absorption fields are affected mainly by permeability, location of water table, and susceptibility to flooding. The degree of limitation and principal reasons for moderate or severe limitations are given.

Engineering test data

Table 6 contains the results of engineering tests performed by the Minnesota Department of Highways on several important soils in Steele County. The table shows the specific location where samples were taken, the depth to which sampling was done, and the results of tests to determine particle-size distribution and other properties significant to soil engineering.

Maximum dry density is the maximum unit dry weight of the soil when it has been compacted with optimum moisture by the prescribed method of compaction. The moisture content which gives the highest dry unit weight is called the optimum moisture content for the specific method of compaction.

TABLE 4.—*Estimated soil properties*

[The land types Lake beaches (La) and Marsh (Mh) are omitted from this table because their properties are variable and require onsite
For this reason the reader should carefully follow the instructions for referring

Soil series and map symbols	Depth to perched water table	Depth from surface	Classification	
			USDA texture	Unified
Alluvial land: Ad, Af.....	Feet (1)	Inches (1)	(1).....	(1)
Biscay: Bc, Bd.....	2 0-3	0-12 12-32 32-60	Loam..... Loam and sandy clay loam..... Sand and gravel.....	ML SC SP or GP
Bixby: B1A, B1B, B1B2, B1C2, B1D2.....	10+	0-7 7-25 25-47 47-65	Loam..... Clay loam, silty clay loam, or sandy clay loam..... Loamy sand..... Sand and gravel.....	ML or SC CL SM SM, GW, or SP
Blooming: BoB2, BoC2.....	10+	0-15 15-19 19-25 25-48 48-60	Silt loam..... Loam..... Sandy clay loam..... Loam..... Loam.....	ML to CL CL SM or SC CL CL
Burnsville: BuB, BuC.....	10+	0-7 7-13 13-20 20-24 24-60	Sandy loam..... Loam..... Gravelly sandy loam..... Sandy loam..... Sand and gravel.....	SM SM or SC, or ML or CL SC or SM SM or SC SP or GW
Calco: Ca.....	2 1-3	0-36 36-60	Silty clay loam..... Silty clay loam.....	OH or CH CL
Canisteo: Cc, Cd.....	2 0-3	0-20 20-30 30-34 34-38 38-60	Silty clay loam..... Silty clay loam..... Loam..... Sand..... Loam.....	MH or OH CL CL SM CL
Ce, Cf.....	2 0-3	0-20 20-31 31-60	Clay loam..... Clay loam..... Clay loam.....	OH CL CL
Chelsea: ChD.....	10+	0-8 8-46 46-72	Loamy fine sand..... Sand and loamy sand..... Sand.....	SM SM SP or SM
*Clarion: Ck B2.....	10+	0-16 16-30 30-42	Sandy loam..... Loam..... Loam.....	SM or SC CL CL
C1B, C1B2, C1C2, CsC2, CsD2..... For Storden part of CsC2 and CsD2, see Storden series.	10+	0-11 11-36 36-60	Loam..... Loam..... Loam.....	ML ML or CL CL
Colo: Ct, Cu.....	1-4	0-27 27-37 37-60	Silty clay loam..... Clay loam..... Loam.....	CH or CL CH or CL CL

significant in engineering

examination. An asterisk in the first column indicates that at least one mapping unit in this series is made up of two or more kinds of soil. to other series in the first column of this table. The sign > means greater than]

Classification— Continued	Percentage passing sieve—				Permeability	Available water capacity	Reaction	Shrink-swell potential
	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)				
(1)	(1)	(1)	(1)	(1)	<i>Inches per hour</i> (1)	<i>Inches per inch of soil</i> (1)	<i>pH value</i> 6. 6-7. 3	Low to moderate.
A-4	95-100	95-100	85-95	55-70	0. 6-2. 0	0. 18-0. 20	6. 1-7. 8	Low to moderate.
A-2	95-100	85-90	70-85	25-35	0. 6-2. 0	0. 16-0. 18	6. 6-7. 8	Low.
A-1	35-90	10-50	5-35	0-5	>6. 0	0. 02-0. 06	6. 6-7. 8	Very low.
A-4	90-100	90-100	85-95	40-55	0. 6-2. 0	0. 18-0. 20	5. 6-7. 3	Low.
A-4 or A-6	90-100	85-90	70-85	60-80	0. 6-2. 0	0. 16-0. 18	5. 1-6. 0	Moderate.
A-2	90-100	80-90	50-75	10-30	>6. 0	0. 08-0. 10	6. 1-6. 5	Low.
A-1 or A-2	45-60	10-50	5-35	0-15	>6. 0	0. 02-0. 06	7. 4-7. 8	Very low.
A-4 or A-6	95-100	95-100	85-95	65-75	0. 6-2. 0	0. 20-0. 22	5. 6-6. 5	Moderate.
A-6	95-100	85-95	80-90	50-75	0. 6-2. 0	0. 16-0. 18	5. 6-6. 5	Moderate.
A-2 or A-4	80-90	50-75	30-60	20-45	0. 6-2. 0	0. 15-0. 17	5. 6-6. 5	Moderate.
A-6	95-100	95-100	80-95	50-75	0. 6-2. 0	0. 17-0. 19	5. 6-6. 5	Moderate.
A-6	90-100	85-95	80-90	50-75	0. 6-2. 0	0. 17-0. 19	7. 4-7. 8	Moderate.
A-2	85-100	75-100	60-70	20-35	2. 0-6. 3	0. 13-0. 15	5. 6-6. 5	Low.
A-4 or A-6	95-100	95-100	80-95	35-65	0. 6-2. 0	0. 17-0. 19	5. 1-6. 0	Low to moderate.
A-2 or A-1	50-85	30-65	20-50	10-30	2. 0-6. 0	0. 05-0. 08	5. 1-6. 0	Low.
A-2	85-100	75-100	60-70	20-35	2. 0-6. 0	0. 11-0. 13	5. 1-6. 0	Low.
A-1	30-60	25-40	5-35	0-15	>6. 0	0. 02-0. 06	5. 1-7. 8	Low.
A-7	100	100	95-100	80-95	0. 2-0. 6	0. 21-0. 23	7. 4-7. 8	High.
A-7	90-100	85-95	85-90	80-90	0. 2-0. 6	0. 18-0. 20	6. 6-7. 8	Moderate.
A-7	100	100	95-100	80-95	0. 6-2. 0	0. 21-0. 23	7. 4-7. 8	Moderate to high.
A-6	95-100	95-100	90-100	80-95	0. 6-2. 0	0. 18-0. 20	6. 6-8. 4	Moderate.
A-4	95-100	95-100	85-95	50-80	0. 6-2. 0	0. 17-0. 19	6. 6-8. 4	Moderate.
A-2	95-100	95-100	50-70	5-15	>6. 0	0. 05-0. 07	7. 4-7. 8	Low.
A-6	95-100	95-100	80-95	50-80	0. 6-2. 0	0. 17-0. 19	7. 4-7. 8	Moderate to high.
A-7	100	100	90-95	55-85	0. 6-2. 0	0. 17-0. 19	7. 4-7. 8	Moderate to high.
A-7 or A-6	100	100	90-95	55-85	0. 6-2. 0	0. 15-0. 19	6. 6-7. 8	Moderate to high.
A-6	95-100	95-100	80-90	55-85	0. 6-2. 0	0. 14-0. 16	7. 4-7. 8	Moderate.
A-2 or A-4	100	95-100	65-80	10-50	>6. 0	0. 10-0. 12	5. 6-6. 5	Very low.
A-2 or A-4	100	95-100	50-75	5-50	>6. 0	0. 06-0. 10	5. 6-6. 0	Very low.
A-2 or A-3	100	95-100	50-70	5-15	>6. 0	0. 05-0. 07	6. 1-7. 8	Very low.
A-2 or A-4	95-100	95-100	60-70	25-45	2. 0-6. 0	0. 13-0. 15	5. 6-6. 5	Low.
A-4	95-100	95-100	80-95	50-80	0. 6-2. 0	0. 16-0. 19	5. 6-7. 8	Moderate.
A-6	95-100	90-95	85-95	50-80	0. 6-2. 0	0. 16-0. 19	7. 4-7. 8	Moderate.
A-4 or A-6	95-100	95-100	80-95	50-85	0. 6-2. 0	0. 20-0. 22	5. 6-6. 5	Moderate.
A-7 or A-6	95-100	95-100	85-95	50-85	0. 6-2. 0	0. 16-0. 19	5. 6-7. 3	Moderate.
A-6	95-100	90-95	80-95	50-85	0. 6-2. 0	0. 16-0. 19	7. 4-7. 8	Moderate.
A-7	100	100	95-100	80-100	0. 2-2. 0	0. 21-0. 23	6. 6-7. 8	High.
A-7	100	100	85-95	55-85	0. 2-0. 6	0. 15-0. 19	6. 6-7. 8	High.
A-6	95-100	85-95	75-85	50-80	0. 6-2. 0	0. 17-0. 19	6. 6-7. 8	Moderate.

TABLE 4.—Estimated soil properties

Soil series and map symbols	Depth to perched water table	Depth from surface	Classification	
			USDA texture	Unified
	<i>Feet</i>	<i>Inches</i>		
Dakota: DaA, DaB, DaC.....	10+	0-10 10-28 28-60	Sandy loam..... Loam and sandy clay loam..... Sand.....	SM SM or SC SP or SM
DkA, DkB.....	10+	0-13 13-29 29-36 36-60	Loam..... Loam and sandy clay loam..... Loamy sand..... Fine sand and coarse sand.....	ML SC to ML or CL SM SP or SM
Dickinson: DtA, DtB.....	10+	0-15 15-22 22-48 48-72	Sandy loam..... Sandy loam..... Loamy sand..... Sand.....	SM SM SM SP or SM
Dundas: Du.....	2-5	0-12 12-37 37-60	Silt loam..... Clay loam..... Clay loam.....	MH or ML MH or CH ML or CL
Estherville: EaA, EaB, EaC, EaD.....	10+	0-13 13-17 17-23 23-60	Sandy loam..... Sandy loam..... Coarse loamy sand..... Sand and gravel.....	SM SC or SM SM GP, SP or SM
Glencoe: Gc.....	2-3	0-25 25-38 38-60	Clay loam..... Clay loam..... Clay loam.....	MH or ML MH or CH CL or CH
Hanska: Hk.....	2-4	0-15 15-30 30-60	Loam or sandy loam..... Sandy loam or loamy sand..... Sand.....	SM or ML SM SP or SM
Havana: Hm.....	3+	0-12 12-19 24-39 39-60	Silt loam..... Silty clay loam..... Clay loam and loam..... Loam.....	ML to CL CL CL CL
Hayden: HnB2, HnC2.....	10+	0-14 14-42 42-60	Sandy loam..... Loam or clay loam..... Loam.....	SM ML or CL CL
HoB, HoB2, HoC, HoC2, HoD, HoD2.....	10+	0-10 10-44 44-60	Loam..... Loam and clay loam..... Loam.....	ML or CL CL CL or ML
Hayfield: Hs.....	3-6	0-11 11-21 21-26 26-38 38-70	Silt loam..... Silt loam or silty clay loam..... Clay loam..... Sandy loam..... Sand or sand and gravel.....	ML ML CL SM SP or GP

See footnotes at end of table.

significant in engineering—Continued

Classification— Continued	Percentage passing sieve—				Permeability	Available water capacity	Reaction	Shrink-swell potential
	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)				
					<i>Inches per hour</i>	<i>Inches per inch of soil</i>	<i>pH value</i>	
A-2 or A-4	90-100	90-100	60-70	25-45	2.0-6.0	0.13-0.15	5.6-6.5	Low.
A-2 or A-4	95-100	95-100	60-80	25-50	0.6-2.0	0.16-0.18	5.6-6.5	Low.
A-2 or A-3	80-90	80-90	50-70	0-35	>6.0	0.05-0.07	6.1-7.8	Very low.
A-6	95-100	95-100	85-95	50-80	0.6-2.0	0.20-0.22	5.6-7.5	Low.
A-2 to A-6	95-100	95-100	75-90	20-80	0.6-2.0	0.16-0.19	5.6-6.5	Low to moderate.
A-2	95-100	95-100	50-75	10-35	>6.0	0.08-0.10	5.6-6.5	Very low.
A-2 or A-3	80-90	60-90	40-60	0-15	>6.0	0.05-0.07	6.1-7.8	Very low.
A-2	95-100	95-100	60-70	20-35	2.0-6.0	0.13-0.15	5.6-6.5	Low.
A-2	95-100	95-100	60-70	20-35	2.0-6.0	0.12-0.14	5.6-6.5	Low.
A-2	95-100	95-100	50-70	10-35	>6.0	0.08-0.10	5.6-6.5	Very low.
A-2 or A-3	95-100	95-100	50-70	0-35	>6.0	0.05-0.07	5.6-7.3	Very low.
A-4	100	100	90-100	85-100	0.6-2.0	0.22-0.24	5.6-6.8	Moderate.
A-7	100	95-100	90-100	75-85	0.2-0.6	0.15-0.19	4.7-7.3	High.
A-6 or A-4	95-100	95-100	90-100	70-80	0.6-2.0	0.14-0.16	7.4-7.8	Moderate.
A-2, A-4, A-6, or A-7	95-100	95-100	60-80	20-50	2.0-6.0	0.13-0.15	5.6-6.5	Low.
A-1, A-2, or A-4	60-95	50-80	35-60	10-45	2.0-6.0	0.12-0.14	5.6-6.5	Low.
A-1 or A-2	60-95	50-80	35-55	10-20	>6.0	0.07-0.10	6.1-6.5	Very low.
A-1 A-2, or A-3	40-95	35-90	15-60	0-15	>6.0	0.03-0.07	7.4-7.8	Very low.
A-7	100	95-100	90-100	60-85	0.6-2.0	0.17-0.19	6.1-7.8	Moderate to high.
A-7	100	95-100	90-100	60-85	0.2-0.6	0.15-0.19	6.6-7.8	Moderate to high.
A-6 or A-7	100	95-100	80-100	55-80	0.6-2.0	0.14-0.16	7.4-7.8	Moderate.
A-2 or A-4	95-100	95-100	65-90	25-65	2.0-6.0	0.15-0.20	6.1-7.8	Low.
A-2 or A-4	95-100	95-100	50-75	15-50	2.0-6.0	0.09-0.12	6.1-7.8	Low.
A-2 or A-3	85-100	80-100	50-70	5-10	>6.0	0.05-0.07	6.6-7.8	Very low.
A-4	100	100	90-100	70-90	0.6-2.0	0.22-0.24	5.6-7.3	Moderate.
A-6	100	100	90-100	70-94	0.2-2.0	0.18-0.21	5.1-6.5	Moderate.
A-6	95-100	95-100	80-95	60-80	0.2-0.6	0.17-0.19	5.1-6.5	Moderate.
A-4 or A-6	95-100	90-95	80-90	50-85	0.6-2.0	0.17-0.19	7.4-7.8	Moderate to low.
A-2 or A-4	95-100	95-100	60-70	25-45	2.0-6.0	0.13-0.15	5.6-6.5	Low.
A-4 or A-6	95-100	95-100	80-90	50-80	0.6-2.0	0.15-0.19	5.1-6.5	Moderate.
A-4 or A-6	95-100	95-100	80-90	50-80	0.6-2.0	0.17-0.19	7.4-7.8	Low to moderate.
A-4	95-100	95-100	80-90	50-80	0.6-2.0	0.20-0.22	5.6-6.5	Moderate.
A-7	95-100	95-100	85-95	50-85	0.6-2.0	0.15-0.19	5.6-6.5	Moderate.
A-6 or A-4	95-100	95-100	80-90	50-85	0.6-2.0	0.17-0.19	7.4-7.8	Low to moderate.
A-4	100	100	90-100	80-90	0.6-2.0	0.22-0.24	5.6-6.5	Low to moderate.
A-4	100	100	90-100	80-90	0.6-2.0	0.18-0.22	5.1-6.5	Low to moderate.
A-6	90-100	90-100	85-95	50-65	0.6-2.0	0.15-0.19	5.1-6.5	Low to moderate.
A-2 or A-4	90-100	90-100	60-70	30-40	2.0-6.0	0.12-0.14	5.6-6.5	Low.
A-1 or A-2	45-95	40-85	20-50	0-5	>6.0	0.02-0.07	5.6-7.8	Very low.

TABLE 4.—*Estimated soil properties*

Soil series and map symbols	Depth to perched water table	Depth from surface	Classification	
			USDA texture	Unified
Kato: Kc, Kd.....	² 0-3+	^{Inches} 0-15 15-35 35-65	Silty clay loam..... Silt loam or loam..... Sand or sand and gravel.....	OL ML or CL GP, SP, SM, or SC
Kato, calcareous variant: Ke, Kf.....	² 0-3+	0-20 20-36 36-60	Silty clay loam..... Silty clay loam or loam..... Coarse sand and gravel.....	MH or OH CL GP, SM, or SP
Kilkenny: KkB2, KkC2.....	10+	0-10 10-48 48-60	Clay loam..... Clay loam or heavy clay loam..... Clay loam.....	OH or ML MH or CH MH, ML, or CL
Lamont: LcB, LcC, LcD.....	10+	0-10 10-23 23-60	Sandy loam..... Loam or sandy clay loam..... Sand.....	SM SC, ML, or CL SP or SM
Lemond: Ld.....	² 2-4	0-19 19-28 28-33 33-60	Loam..... Sandy loam..... Loamy sand..... Sand.....	SM or ML SM SM SP or SM
Lerdal: LeB, LeB2.....	6+	0-7 7-44 44-60	Silty clay loam..... Clay loam, silty clay loam, or clay. Clay loam.....	ML MH or CH ML, CL, or SC
*Lester: LIB, LIB2, LIC, LIC2, LID2, LmB2, LmD2, LnE, LnF, LoC2, LoD2. For properties of the Estherville part of mapping units LmB2 and LmD2, see Estherville series in this table; for properties of Storden part of mapping units LmB2, LmD2, LoC2, and LoD2, see Storden series; for properties of the Hayden part of mapping units LnE and LnF, see Hayden series.	10+	0-10 10-40 40-60	Loam..... Clay loam and loam..... Loam.....	ML CL CL or ML
Le Sueur: LuA, LuB.....	5-10	0-10 10-43 43-60	Clay loam..... Clay loam..... Loam.....	OL or CL CL or ML CL
Lura: Ly.....	² 0-3	0-32 32-48 48-60	Silty clay loam and silty clay..... Silty clay..... Silty clay.....	CH or MH CH CH
Madelia: Ma.....	1-4	0-22 22-48 48-60	Silty clay loam..... Silty clay loam..... Silt loam.....	MH, ML, or OL ML or CL ML
Marna: Mc.....	² 1-3	0-16 16-28 28-60	Silty clay loam or silty clay..... Silty clay..... Clay loam.....	MH or ML MH or CH ML or CL

See footnotes at end of table.

significant in engineering—Continued

Classification— Continued	Percentage passing sieve—				Permeability	Available water capacity	Reaction	Shrink-swell potential
	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)				
A-7	100	95-100	90-100	75-90	<i>Inches per hour</i> 0.6-2.0	<i>Inches per inch of soil</i> 0.21-0.23	<i>pH value</i> 6.1-7.3	Moderate.
A-7	95-100	85-100	70-100	50-85	0.6-2.0	0.18-0.21	6.1-7.3	Moderate.
A-1, A-2, or A-3	40-97	40-91	30-70	0-15	>6.0	0.02-0.07	6.6-7.8	Very low.
A-7	100	100	95-100	85-95	0.6-2.0	0.21-0.23	7.4-7.8	Moderate.
A-7 or A-6	100	100	90-100	75-95	0.6-2.0	0.18-0.20	6.6-7.8	Moderate.
A-1, A-2, or A-3	40-90	40-80	20-55	0-15	>6.0	0.02-0.07	6.6-7.8	Very low.
A-7	95-100	95-100	90-100	55-80	0.6-2.0	0.17-0.19	5.6-6.5	High.
A-7	95-100	90-100	85-95	55-80	0.2-0.6	0.15-0.19	4.5-6.5	High.
A-7	95-100	90-95	80-95	55-80	0.6-2.0	0.14-0.16	7.4-7.8	Moderate to high.
A-2	95-100	95-100	60-70	30-35	2.0-6.0	0.13-0.15	5.6-6.5	Low.
A-2 to A-6	95-100	95-100	80-95	30-80	2.0-6.0	0.16-0.19	5.6-6.5	Low.
A-3 or A-2	95-100	95-100	50-70	0-15	>6.0	0.05-0.07	5.6-7.3	Very low.
A-2 or A-4	95-100	95-100	80-90	25-65	2.0-6.0	0.20-0.22	7.4-7.8	Low.
A-2 or A-4	95-100	95-100	60-70	25-50	2.0-6.0	0.12-0.14	6.6-7.8	Low.
A-2	95-100	90-100	45-70	10-30	>6.0	0.09-0.11	6.6-7.8	Very low.
A-1, A-2, or A-3	85-100	80-100	30-60	5-10	>6.0	0.05-0.07	6.6-7.8	Very low.
A-7 or A-6	95-100	95-100	90-100	55-80	0.6-2.0	0.21-0.23	5.6-6.5	Moderate to high.
A-7	95-100	90-100	80-95	55-80	0.06-0.2	0.12-0.18	4.5-6.5	High.
A-7 or A-6	90-100	85-100	70-90	35-70	0.6-2.0	0.14-0.16	7.4-7.8	Moderate.
A-7, A-4, or A-6	100	95-100	85-95	50-70	0.6-2.0	0.20-0.22	5.6-7.8	Low to moderate.
A-6	95-100	90-100	80-95	50-75	0.6-2.0	0.15-0.19	5.1-6.5	Moderate.
A-6 or A-4	95-100	90-100	80-95	50-75	0.6-2.0	0.17-0.19	7.4-7.8	Low to moderate.
A-7	100	95-100	90-100	70-80	0.6-2.0	0.17-0.19	5.6-6.5	Moderate.
A-7 or A-6	95-100	95-100	90-100	60-80	0.6-2.0	0.15-0.19	5.1-6.5	Moderate to high.
A-6 or A-4	95-100	95-100	80-95	50-80	0.6-2.0	0.17-0.19	7.4-7.8	Low to moderate.
A-7	100	100	95-100	90-95	0.2-0.6	0.12-0.16	6.1-7.8	High.
A-7	100	100	95-100	90-94	0.06-0.2	0.11-0.14	6.6-7.8	High.
A-7	100	100	95-100	80-95	0.2-2.0	0.10-0.12	6.6-7.8	High to moderate.
A-7	100	100	95-100	85-95	0.6-2.0	0.21-0.23	6.1-7.8	Moderate.
A-7	100	100	95-100	85-95	0.6-2.0	0.18-0.20	6.6-7.8	Moderate.
A-7	100	100	95-100	85-95	0.6-2.0	0.20-0.22	6.6-7.8	Moderate.
A-7	100	100	95-100	80-95	0.2-0.6	0.16-0.20	6.1-7.3	Moderate to high.
A-7	100	100	95-100	80-95	0.06-0.2	0.12-0.14	6.1-7.8	High.
A-6 or A-7	100	95-100	90-100	60-80	0.2-2.0	0.14-0.16	7.4-7.8	Moderate to high.

TABLE 4.—Estimated soil properties

Soil series and map symbols	Depth to perched water table	Depth from surface	Classification	
			USDA texture	Unified
Maxcreek: Mm, Mn	Feet 2 0-4	Inches 0-16	Silty clay loam	ML or OL
		16-33	Silty clay loam and loam	CL
		33-39	Sandy loam	SM or SC
		39-60	Loam	SM or CL
Mayer: Mo	2 1-3	0-20	Loam	SM or ML
		20-36	Loam, sandy clay loam, loam, or sandy loam.	SC
		36-60	Sand or sand and gravel	SP or GP
Merton: MrA, MrB	6+	0-13	Silt loam	ML
		13-30	Silt loam and loam	ML to CL
		30-34	Sandy loam	SM
		34-60	Loam	CL
Moland: MsA, MsB, MsB2	10+	0-16	Silt loam	ML
		16-24	Silt loam and loam	ML to CL
		24-27	Sandy loam	SM
		27-37	Loam	CL
		37-60	Loam	CL
Muck: Mu, Mv, Mw, My	2 0-3	(¹)	(¹)	Pt
Newry: NbA	10+	0-10	Silt loam	ML
		10-20	Silt loam or loam	ML or CL
		20-24	Sandy loam	SM
		24-44	Loam	CL
		44-60	Loam	CL
Nicollet: NcA, NcB	4-10	0-16	Clay loam	ML
		16-30	Clay loam	ML or CL
		30-60	Clay loam	CL
Salida: SaE	10+	0-14	Gravelly loamy sand	SM or GM
		14-60	Sand and gravel	SP or GP
Shields: Sh	1-5	0-8	Silty clay loam	OH or OL
		8-41	Silty clay	MH or CH
		41-60	Silty clay loam	MH to CH or CL
*Sparta: SkB, SkC, SkE For properties of Dickinson part of these mapping units, see Dickinson series.	10+	0-18	Loamy fine sand	SM
		18-24	Loamy fine sand	SM
		24-48	Fine sand	SM
		48-54	Sandy loam	SM
		54-60	Loamy sand	SM
Storden Mapped only in complexes with Clarion and Lester soils.	10+	0-7	Loam	ML
		7-19	Loam	CL
		19-60	Loam	ML or CL
Talcot: Ta	2 0-3	0-23	Clay loam	ML or CL
		23-38	Sandy clay loam	CL
		38-60	Coarse sand	SM or SP
Terril: Te, Tf	4-10	0-64	Loam	CL

See footnotes at end of table.

significant in engineering—Continued

Classification— Continued	Percentage passing sieve—				Permeability	Available water capacity	Reaction	Shrink-swell potential
	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)				
A-7	100	100	95-100	85-95	<i>Inches per hour</i> 0.6-2.0	<i>Inches per inch of soil</i> 0.21-0.23	<i>pH value</i> 6.5-7.8	Moderate to high.
A-6	95-100	95-100	85-100	50-90	0.6-2.0	0.17-0.20	6.6-7.8	Moderate to high.
A-2, A-4, or A-6	85-95	95-100	60-70	30-40	2.0-6.0	0.12-0.14	7.4-7.8	Low.
A-4 or A-6	95-100	95-100	80-90	45-80	0.6-2.0	0.17-0.19	7.4-7.8	Moderate.
A-4	95-100	95-100	80-90	45-70	0.6-2.0	0.20-0.22	7.4-7.8	Low to moderate.
A-2 or A-4	95-100	85-90	60-85	25-45	0.6-2.0	0.13-0.16	6.6-7.8	Low.
A-2 or A-1	35-90	10-50	5-35	2-5	>6.0	0.02-0.07	6.6-7.8	Very low.
A-7	95-100	95-100	95-100	80-90	0.6-2.0	0.22-0.24	5.6-6.5	Low.
A-7 or A-6	95-100	95-100	85-100	70-90	0.6-2.0	0.17-0.21	5.6-6.5	Moderate to low.
A-2 or A-4	90-100	85-95	60-70	30-50	2.0-6.0	0.12-0.14	5.6-6.5	Low.
A-4 or A-6	95-100	95-100	80-90	55-80	0.6-2.0	0.17-0.19	6.6-7.8	Low.
A-7	95-100	95-100	95-100	75-90	0.6-2.0	0.22-0.24	5.6-6.5	Low.
A-6	95-100	95-100	85-100	70-90	0.6-2.0	0.18-0.21	5.6-6.5	Low to moderate.
A-2 or A-4	95-100	95-100	60-70	30-50	2.0-6.0	0.12-0.14	5.6-6.5	Low.
A-6	95-100	95-100	85-95	55-80	0.6-2.0	0.17-0.19	6.1-7.3	Low to moderate.
A-6	95-100	95-100	80-90	50-65	0.6-2.0	0.17-0.19	7.4-7.8	Low.
A-8	(1)	(1)	(1)	(1)	(1)	0.25	(1)	(1).
A-7	100	100	95-100	80-90	0.6-2.0	0.22-0.24	5.6-7.3	Low.
A-6	100	100	90-100	70-90	0.6-2.0	0.18-0.21	5.1-6.0	Moderate to low.
A-2 or A-4	65-100	65-100	40-75	20-50	2.0-6.0	0.12-0.14	5.1-6.0	Low.
A-6	95-100	95-100	85-95	50-80	0.6-2.0	0.17-0.19	5.6-6.5	Moderate to low.
A-6	95-100	95-100	85-95	50-80	0.6-2.0	0.17-0.19	6.6-7.8	Moderate to low.
A-4 or A-6	95-100	95-100	90-100	55-85	0.6-2.0	0.17-0.19	5.6-6.5	Low.
A-7 or A-6	95-100	95-100	90-100	55-85	0.6-2.0	0.15-0.19	5.6-7.3	Moderate.
A-6	85-95	85-95	80-95	55-85	0.6-2.0	0.14-0.16	7.4-7.8	Moderate.
A-2	65-90	70-85	30-60	20-30	>6.0	0.08-0.10	6.6-7.8	Low.
A-1 or A-3	45-90	40-80	10-60	0-5	>6.0	0.03-0.07	6.6-7.8	Low.
A-5 or A-4	100	100	90-100	70-90	0.2-0.6	0.21-0.23	5.6-7.3	Moderate to high.
A-7	100	95-100	90-100	60-90	0.06-0.2	0.12-0.16	4.5-6.0	High.
A-7 or A-6	95-100	95-100	90-100	50-85	0.2-2.0	0.18-0.20	7.4-7.8	Moderate to high.
A-2 or A-4	95-100	95-100	70-85	20-45	>6.0	0.10-0.12	5.6-6.5	Low.
A-2	95-100	95-100	70-85	20-35	>6.0	0.09-0.11	5.6-6.0	Low.
A-2	95-100	95-100	65-80	10-35	>6.0	0.05-0.07	5.6-6.0	Low.
A-2 or A-4	95-100	95-100	60-70	30-45	2.0-6.0	0.11-0.13	5.6-7.3	Low.
A-2	95-100	95-100	50-75	15-30	>6.0	0.08-0.10	5.6-7.8	Very low.
A-4	95-100	95-100	80-95	50-60	0.6-2.0	0.17-0.20	7.4-8.4	Low.
A-4	95-100	85-95	80-90	50-60	0.6-2.0	0.17-0.19	7.4-8.4	Low.
A-6	95-100	85-95	80-90	50-60	0.6-2.0	0.17-0.19	7.4-8.4	Low.
A-7	95-100	95-100	95-100	55-85	0.6-2.0	0.17-0.19	7.4-7.8	Moderate to high.
A-6	95-100	85-90	80-90	50-85	0.6-2.0	0.16-0.18	6.6-7.8	Moderate to high.
A-1, A-2, or A-3	85-100	75-90	30-65	5-20	>6.0	0.02-0.07	6.6-7.8	Low.
A-4 to A-6	100	95-100	85-95	50-80	0.6-2.0	0.18-0.21	6.1-7.8	Low.

TABLE 4.—*Estimated soil properties*

Soil series and map symbols	Depth to perched water table	Depth from surface	Classification	
			USDA texture	Unified
Udolpho: Ud.....	^{Feet} ² 2-5	^{Inches} 0-9	Silt loam.....	ML
		9-12	Silt loam.....	ML
		12-30	Silt loam or silty clay loam.....	ML or CL
		30-34	Loam.....	CL
		34-60	Sand and gravel.....	SP or GP
Wadena: WaA, WaB, WaC2.....	10+	0-17	Loam.....	ML or CL
		17-25	Loam.....	SC or CL
		25-33	Gravelly sandy loam.....	SM
		33-60	Sand and gravel.....	GW, SP, or SM
Waukegan: WgA, WgB.....	6+	0-13	Silt loam.....	ML
		13-32	Silt loam.....	ML to CL
		32-38	Loam.....	CL
		38-60	Sand and gravel.....	SP or SM
Webster: Wt.....	² 1½-3	0-20	Clay loam.....	OL or CL
		20-28	Clay loam.....	CL
		28-60	Clay loam.....	CL

¹ Properties too variable to be estimated.

² In areas where soil has been drained, water table is near tile depth from surface.

TABLE 5.—*Engineering interpretations*

[The land type Marsh (Mh) is omitted from this table because onsite evaluation is required. An asterisk in the first column indicates that instructions for referring to other series shown

Soil series and map symbols	Suitability as source of—				Soil features affecting—
	Topsoil ¹	Sand	Gravel	Road fill ²	Pond reservoir areas
Alluvial land: Ad, Af.	Poor to good: check each site.	Not suitable.....	Not suitable.....	Poor to fair: variable; check each site.	Hazards of flooding and piping.
Biscay: Bc, Bd.....	Poor: poor drainage.	Good: mixed medium and coarse sand and fine gravel; shale common; high water table.	Good in some areas; gravel too fine in some places; in some places better gravel occurs at a depth of more than 6 feet; high water table.	Poor: poor drainage; high susceptibility to frost action.	Piping hazard; best suited to dugout ponds because of high water table.

See footnotes at end of table.

significant in engineering—Continued

Classification— Continued	Percentage passing sieve—				Permeability	Available water capacity	Reaction	Shrink-swell potential
	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)				
A-4	100	95-100	95-100	75-95	<i>Inches per hour</i> 0.6-2.0	<i>Inches per inch of soil</i> 0.22-0.24	<i>pH value</i> 5.6-7.3	Low to moderate.
A-4	95-100	95-100	95-100	75-95	0.6-2.0	0.20-0.22	5.6-6.5	Low to moderate.
A-6	95-100	95-100	95-100	75-95	0.6-2.0	0.18-0.22	5.1-6.0	Low to moderate.
A-6	95-100	95-100	85-95	50-80	0.6-2.0	0.17-0.19	5.6-6.5	Low to moderate.
A-1 or A-2	40-60	35-50	10-35	0-5	>6.0	0.02-0.07	6.1-7.8	Very low.
A-4	95-100	95-100	85-95	50-80	0.6-2.0	0.20-0.22	5.6-6.5	Low.
A-2 or A-4	95-100	95-100	60-90	20-80	0.6-2.0	0.17-0.19	5.6-6.5	Low.
A-2 or A-1	50-85	30-65	20-50	10-30	2.0-6.0	0.10-0.12	5.6-6.5	Very low.
A-1 or A-2	45-100	40-90	20-50	0-15	>6.0	0.02-0.07	7.4-7.8	Very low.
A-4	100	100	90-100	80-90	0.6-2.0	0.22-0.24	5.6-6.5	Low.
A-4	100	100	90-100	80-90	0.6-2.0	0.20-0.22	5.6-6.5	Low to moderate.
A-6	95-100	95-100	85-95	60-80	0.6-2.0	0.17-0.19	6.1-6.5	Low.
A-1 or A-2	50-100	45-90	20-50	5-15	>6.0	0.02-0.07	6.1-7.8	Very low.
A-7	95-100	95-100	90-100	55-90	0.6-2.0	0.17-0.20	6.1-7.8	Moderate to high.
A-7	95-100	90-100	90-100	55-85	0.6-2.0	0.15-0.19	6.6-7.8	High.
A-4 or A-6	95-100	95-100	90-100	55-85	0.6-2.0	0.15-0.17	7.4-7.8	Moderate.

of soil properties

at least one mapping unit in this series is made up of two or more kinds of soil. For this reason the reader should carefully follow the in- in the first column of this table]

Soil features affecting—Continued					Degree and kind of limitation for septic tank absorption fields
Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways	
Variable, but generally fair stability; hazard of piping.	Outlets difficult to obtain; surface needs drainage; frequently flooded.	Variable; subject to flooding.	Not applicable-----	Flooding causes scouring and deposition of debris.	Severe: flooding.
Fair to good stability and compaction characteristics; substratum has very slight compressibility and high permeability when compacted.	High water table; moderate permeability in solum; rapid permeability in substratum; sloughing and caving hazards during construction.	High water table; moderate available water capacity.	Not applicable-----	High water table; drainage.	Severe: high water table.

TABLE 5.—Engineering interpretations

Soil series and map symbols	Suitability as source of—				Soil features affecting—
	Topsoil ¹	Sand	Gravel	Road fill ²	Pond reservoir areas
Bixby: B1A, B1B, B1B2, B1C2, B1D2.	Fair: surface layer less than 16 inches thick.	Good: mixed medium and coarse sand and fine gravel; shale common.	Good in select areas; gravel too fine in some areas.	Good: most factors favorable; subsoil should be mixed with underlying material.	Permeability rapid in underlying material; deep gravel pits may reach water table.
Blooming: BoB2, BoC2.	Fair: surface layer less than 16 inches thick.	Not suitable-----	Not suitable-----	Fair: moderate shrink-swell potential and susceptibility to frost action.	Moderate permeability; slow seepage rate; occasional sand and gravel seams in substratum; slopes seldom suitable for farm ponds.
Burnsville: BuB, BuC.	Poor: shallow soils.	Good: mixed medium and coarse sand and fine gravel; shale common.	Good in select areas; gravel too fine in some areas.	Good: all factors favorable.	Underlying material permeable; deep gravel pits may reach water table.
Calco: Ca-----	Poor: difficult to excavate and handle because of high water table; high in content of free lime carbonates.	Not suitable-----	Not suitable-----	Poor: very poor drainage; moderate to high shrink-swell potential.	Suitable for dug-out ponds because of high water table; subject to flooding.
Canisteo: Cc, Cd, Ce, Cf.	Poor: difficult to excavate and handle because of high water table; high in content of free lime carbonates.	Not suitable-----	Not suitable-----	Poor: poor drainage; high susceptibility to frost action.	High water table; best suited to dug-out ponds.
Chelsea: ChD-----	Poor: too sandy--	Good to poor: poorly graded medium sand.	Not suitable-----	Good: most factors favorable.	Rapid permeability--
*Clarion: CkB2, C1B, C1B2, C1C2, CsC2, CsD2. For Storden part of CsC2 and CsD2, see Storden series.	Good: fertile. Fair where eroded.	Not suitable-----	Not suitable-----	Fair: moderate shrink-swell potential and susceptibility to frost action.	Moderate permeability; slow seepage rate; semipervious when compacted; slopes seldom suitable for farm ponds.

See footnotes at end of table.

of soil properties—Continued

Soil features affecting—Continued					Degree and kind of limitation for septic tank absorption fields
Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways	
Fair to good stability and compaction characteristics; high permeability when compacted.	Not needed.....	Moderately deep soil; moderate available water capacity.	Most features favorable; some inclusions are shallow to sand and gravel.	Erodible; coarse substratum unstable; droughtiness may slow sod establishment.	Slight: rapid permeability below depth of 3 feet; hazard of pollution. Moderate on slopes stronger than 8 percent.
Fair stability and compaction characteristics; low permeability when compacted; upper 15 inches high in content of silt.	Not needed.....	Features generally favorable.	Most features favorable; slopes are irregular in many places; tracts commonly occur as part of a field with nearly level soils.	Features generally favorable.	Slight. Moderate on slopes stronger than 8 percent.
Fair to good stability; fair to good compaction characteristics; fair to poor resistance to piping; high permeability where compacted.	Not needed.....	Low available water capacity; shallow rooting zone; moderate to rapid intake.	Shallow to sand and gravel; irregular slopes.	Erodible; coarse substratum unstable; droughty soils; difficult to establish sod.	Slight: rapid permeability at depth of 2 feet; hazard of pollution.
Poor stability; high in content of organic matter; poor compaction characteristics; high compressibility.	Outlets difficult to obtain; subject to flooding; moderately slow permeability.	High water table; subject to flooding.	Not applicable.....	High water table; drainage needed before construction; subject to flooding.	Severe: high water table; flooding.
Fair to good stability; fair to good compaction characteristics; low permeability where compacted; surface layer high in content of organic matter; in some places surface layer high in content of silt.	High water table; moderate permeability; surface ditches may be needed in addition to tile drainage.	High water table....	Not applicable.....	High water table; drainage needed before construction.	Severe: high water table.
Fair to poor stability; fair compaction characteristics; moderate permeability where compacted; subject to piping.	Not needed; excessively drained.	Very low to low available water capacity; rapid intake rate; soil generally is in small tracts.	Sandy material; very erodible; vegetation difficult to establish.	Unstable; sod difficult to establish because of droughtiness and low fertility.	Slight: subsoil bands may cause seepage on hillsides.
Fair to good stability and compaction characteristics; low permeability where compacted.	Not needed; well drained.	Features generally favorable.	Most features favorable; slopes are irregular in many places.	Features generally favorable.	Slight: moderate permeability. Moderate on slopes stronger than 8 percent.

TABLE 5.—*Engineering interpretations*

Soil series and map symbols	Suitability as source of—				Soil features affecting—
	Topsoil ¹	Sand	Gravel	Road fill ²	Pond reservoir areas
Colo: Ct, Cu-----	Poor: often too wet for proper handling.	Not suitable-----	Not suitable-----	Poor: poor drainage; high in content of organic matter; moderate to high shrink-swell potential.	Subject to flooding; suitable for dug-out ponds because of high water table.
Dakota: DaA, DaB, DaC, DkA DkB.	Fair to good: loam preferred to sandy loam.	Good to poor: poorly graded sand.	Not suitable in upper 6 feet; good gravel source below depth of 6 feet in selected areas.	Good: most factors favorable.	Rapid permeability in underlying material.
Dickinson: DtA, DtB.	Fair: moderately coarse textured.	Good to poor: poorly graded sand.	Not suitable-----	Good: most factors favorable.	Rapid permeability in underlying material; piping hazard.
Dundas: Du-----	Fair: surface layer less than 16 inches thick.	Not suitable-----	Not suitable-----	Poor: poor drainage; high susceptibility to frost action.	Seasonal high water table; moderately slow permeability; possible site for dug-out ponds.
Estherville: EaA, EaB, EaC, EaD.	Poor: shallow soils.	Good source of sand, but mixed with gravel.	Good source of gravel, but mixed with sand; wash for concrete.	Good: all factors favorable.	Rapid permeability; deeper gravel pits commonly have permanent water table.
Glencoe: Gc-----	Poor: very poor drainage.	Not suitable-----	Not suitable-----	Poor: very poor drainage; high in content of organic matter; high susceptibility to frost action.	High water table; suitable for dug-out ponds.
Hanska: Hk-----	Poor: poor drainage.	Good to poor: poorly graded sands; high water table.	Not suitable-----	Poor: poor drainage; high susceptibility to frost action.	High water table; suitable for dug-out ponds; substratum will cave and slough.

See footnotes at end of table.

of soil properties—Continued

Soil features affecting—Continued					Degree and kind of limitation for septic tank absorption fields
Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways	
Fair to poor stability and compaction characteristics; high in content of organic matter; high compressibility.	High water table; outlets difficult to obtain; subject to flooding.	High water table; subject to flooding.	Not applicable-----	High water table; drainage needed before construction; flooding.	Severe: high water table and flooding.
Fair stability; high permeability when compacted; fair to poor resistance to piping.	Not needed; well drained.	Moderate to low available water capacity; medium to rapid intake; moderate permeability in upper part.	Shallow to sand and gravel in some included soils; slopes are short or irregular.	Erodible; substratum unstable; droughty soil; sod slow to establish.	Slight: possible hazard of pollution.
Fair stability; fair to good compaction characteristics; slope protection required; slight to very slight compressibility; hazard of piping.	Not needed; somewhat excessively drained.	Moderate to low available water capacity; rapid intake.	Rapid permeability in substratum; slopes short or irregular; generally not needed.	Erodible; substratum unstable; sod difficult to establish.	Slight: possible hazard of pollution.
Fair to poor stability and compaction characteristics; good to fair resistance to piping.	Seasonal high water table; slow permeability.	Moderately slow permeability of subsoil requires special application rates; seasonal high water table.	Not applicable-----	Areas that need drainage should be tiled before construction starts.	Severe: moderately slow permeability; water table fluctuates seasonally at depths between 2 and 5 feet.
Fair stability; fair to good compaction characteristics; high permeability when compacted; fair resistance to piping.	Not needed; somewhat excessively drained.	Shallow soils; low available water capacity; rapid intake rate.	Shallow to sand and gravel; slopes are short or irregular.	Shallow soils; substratum unstable; sod difficult to establish.	Slight: rapid permeability in substratum; hazard of pollution. Moderate on slopes stronger than 8 percent.
Poor stability and compaction characteristics; high to medium compressibility.	High water table; moderately slow permeability; outlets difficult to obtain in some areas.	High water table; subject to ponding.	Not applicable-----	High water table; generally not needed.	Severe: local flooding; high water table.
Fair stability and compaction characteristics; moderate to high permeability when compacted; poor resistance to piping.	High water table; moderately rapid permeability in upper part and rapid in substratum; substratum is unstable; caves and sloughs during construction.	High water table; low to moderate available water capacity when drained.	Not applicable-----	High water table; erodible; drainage needed before construction.	Severe: high water table.

TABLE 5.—*Engineering interpretations*

Soil series and map symbols	Suitability as source of—				Soil features affecting—
	Topsoil ¹	Sand	Gravel	Road fill ²	Pond reservoir areas
Havana: Hm-----	Fair: surface layer less than 16 inches thick.	Not suitable-----	Not suitable-----	Poor: fair to somewhat poor drainage; moderate shrink-swell potential; high susceptibility to frost action.	Moderately slow permeability; slow seepage rate; occasional sand and gravel seams in substratum; seasonal high water table; possible site for dug-out ponds.
Hayden: HnB2, HnC2, HoB, HoB2, HoC, HoC2, HoD, HoD2.	Fair: surface layer less than 16 inches thick.	Not suitable-----	Not suitable-----	Fair: moderate shrink-swell potential and susceptibility to frost action.	Moderate permeability; slow seepage rate.
Hayfield: Hs-----	Fair: surface layer less than 16 inches thick.	Good: mixed medium and coarse sand and fine gravel; shale common; seasonal water table at depths from 3 to 6 feet.	Good in select areas, commonly below depths of 6 feet; gravel is fine in many areas; shale common.	Fair: somewhat poor drainage; moderate shrink-swell potential in upper 24 to 36 inches; low in substratum.	Permeability rapid in underlying material; possible site for dug-out ponds in select areas; substratum will cave and slough.
Kato: Kc, Kd-----	Poor: poor drainage.	Good: mixed medium and coarse sand and fine gravel; shale common; high water table.	Good in select areas, commonly at a depth below 6 feet; gravel is fine in many areas.	Poor: poor drainage; high susceptibility to frost action.	Moderate permeability; slow seepage rate; high water table; site for dug-out ponds.
Kato, calcareous variant: Ke, Kf.	Poor: poor drainage.	Good: mixed medium and coarse sand and fine gravel; shale common; high water table.	Good in select areas, commonly at a depth below 6 feet; gravel is fine in many areas.	Poor: poor drainage; high susceptibility to frost action.	Moderate permeability; slow seepage rate; high water table; site for dug-out ponds.
Kilkenny: KkB2, KkC2.	Fair: moderately fine texture.	Not suitable-----	Not suitable-----	Poor: moderate to high shrink-swell potential; high susceptibility to frost action.	Moderately slow permeability; slow seepage rate; slopes seldom suitable for farm ponds.
Lake beaches: La---	Poor: too sandy--	Good to poor: high water table.	Fair to poor: high high water table.	Fair to poor: high water table; material quite variable.	High water table; site for dug-out ponds.

See footnotes at end of table.

of soil properties—Continued

Soil features affecting—Continued					Degree and kind of limitation for septic tank absorption fields
Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways	
Fair to good stability and compaction characteristics below depth of 19 inches; low permeability where compacted; good resistance to piping; upper 19 inches are high in content of silt.	Seasonal high water table; moderately slow permeability.	Seasonal high water table.	Not applicable-----	Seasonal high water table; areas that need drainage should be tilled before construction starts.	Severe: moderately slow permeability; seasonal high water table.
Fair stability; fair compaction characteristics; low to moderate permeability where compacted; good to fair resistance to piping.	Not needed; well drained.	Most factors favorable; some slopes too steep or irregular.	Most features favorable; slopes are commonly irregular; tracts commonly occur as part of a field with nearly level soils.	Erodible; design to maintain low velocity.	Slight: moderate permeability.
Fair to poor stability and compaction characteristics in upper 24 to 36 inches; substratum has fair stability and high permeability when compacted.	Not needed; drainage characteristics sometimes improved by draining the surrounding wet soils.	Moderate available water capacity; seasonal wetness can be a problem.	Not applicable-----	Erodible; coarse substratum unstable.	Moderate: seasonal water table at depths between 3 to 6 feet; rapid permeability in substratum; possible hazard of pollution.
Poor stability and compaction characteristics in upper 24 to 36 inches and fair to good in substratum; rapid permeability when compacted.	High water table; moderate permeability in upper part and rapid in substratum; substratum unstable; will cave and slough during construction.	High water table----	Not applicable-----	High water table; erodible; drain before construction.	Severe: high water table.
Poor stability and compaction characteristics in upper 24 to 36 inches and fair to good in substratum; rapid permeability when compacted.	High water table; moderate permeability in upper part and rapid in substratum; substratum unstable; will cave and slough during construction.	High water table----	Not applicable-----	High water table; erodible; drain before construction.	Severe: high water table.
Fair to poor stability; poor to fair compaction characteristics; high compressibility when compacted.	Not needed; well drained.	Most factors favorable; moderately slow permeability in subsoil.	Moderately slow permeability; too nearly level a grade may cause wetness; slopes are commonly irregular.	Clay loam subsoil will slow sod establishment.	Severe: moderately slow permeability.
Variable materials; features generally unfavorable.	High water table; outlets not available in most areas.	Variable texture; unproductive soil material.	Not applicable-----	Poor soil material for establishing sod.	Severe: high water table.

TABLE 5.—*Engineering interpretations*

Soil series and map symbols	Suitability as source of—				Soil features affecting—
	Topsoil ¹	Sand	Gravel	Road fill ²	Pond reservoir areas
Lamont: LcB, LcC, LcD.	Fair: surface layer less than 16 inches thick.	Good to poor-----	Not suitable-----	Good: most factors favorable.	Permeability rapid in underlying material.
Lemond: Ld-----	Poor: poor drainage.	Good to poor: poorly graded sands; high water table.	Not suitable; select areas may have gravel below depths of 6 feet; high water table.	Poor: poor drainage.	High water table; suitable for dug-out ponds; strata will cave and slough.
Lerdal: LeB, LeB2--	Fair: moderately fine textured.	Not suitable-----	Not suitable-----	Poor: moderately high shrink-swell potential; high susceptibility to frost action.	Slow permeability; slow seepage rate; slopes seldom suitable.
*Lester: LIB, LIB2, LIC, LIC2, LID2, LmB2, LmD2, LnE, LnF, LoC2, LoD2. For Estherville part of LmB2 and LmD2, see Estherville series; for Storden part of LmB2, LmD2, LoC2, and LoD2, see Storden series; for Hayden part of LnE and LnF, see Hayden series.	Fair: surface layer less than 16 inches thick.	Not suitable-----	Not suitable-----	Fair: low to moderate shrink-swell potential; moderate susceptibility to frost action.	Moderate permeability; slow seepage rate.
Le Sueur: LuA, LuB.	Fair: moderately fine textured.	Not suitable-----	Not suitable-----	Fair: moderate shrink-swell potential; susceptibility to frost action; moderately well to somewhat poorly drained.	Moderate permeability; slow seepage rate; possible site for dug-out ponds in select areas.
Lura: Ly-----	Poor: poor drainage.	Not suitable-----	Not suitable-----	Poor: very poor drainage; high shrink-swell potential.	Slow permeability; slow seepage rate; high water table; site for dug-out ponds.

See footnotes at end of table.

of soil properties—Continued

Soil features affecting—Continued					Degree and kind of limitation for septic tank absorption fields
Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways	
Fair stability; fair to good compaction characteristics; rapid to moderate permeability when compacted; hazard of piping.	Not needed; well drained.	Low to moderate available water capacity; soil generally occurs in fields with other soils.	Permeability rapid in substratum; vegetation difficult because of low fertility and available water capacity.	Erodible; substratum unstable; droughtiness slows sod establishment.	Slight: sidehill seepage a hazard on steeper slopes.
Fair stability and fair to good compaction characteristics; moderate to rapid permeability when compacted.	High water table; moderately rapid permeability in upper part and rapid in substratum; substratum unstable; caves and sloughs during construction.	High water table; low to moderate available water capacity when drained.	Not applicable-----	High water table; erodible; substratum unstable; drained before construction.	Severe: high water table.
Poor to fair stability; fair to poor compaction characteristics; medium to high compressibility; low permeability where compacted.	Generally not needed; somewhat poorly drained; slow permeability.	Slow intake rate; slow permeability.	Slow permeability; too nearly level a grade may cause wetness; disturbed soil slow to return to normal production.	Disturbed, clayey subsoil; slow to return to normal production.	Severe: slow permeability.
Fair stability and compaction characteristics; low to moderate permeability; good to fair resistance to piping.	Not needed; well drained.	Most factors favorable; some slopes too steep or irregular.	Most factors favorable; some slopes too steep or irregular.	Features generally favorable.	Moderate on slopes of 8 to 15 percent; moderate permeability. Severe on slopes stronger than 15 percent.
Fair to good stability and compaction characteristics; medium compressibility.	Not needed; nearly level areas will benefit from drainage of adjacent wet soils.	Features generally favorable.	Most factors favorable; slopes commonly irregular; tracts occur as part of a field with nearly level soils.	Features generally favorable.	Moderate: water table may be too high on nearly level slopes; moderate permeability.
Fair to poor stability and compaction characteristics; high compressibility; low permeability where compacted.	High water table; slow permeability; surface ditches may be needed with tile drainage.	High water table; subject to ponding; slow permeability.	Not applicable-----	High water table; drainage needed before construction.	Severe: slow permeability; local flooding; high water table.

TABLE 5.—Engineering interpretations

Soil series and map symbols	Suitability as source of—				Soil features affecting—
	Topsoil ¹	Sand	Gravel	Road fill ²	Pond reservoir areas
Madelia: Ma-----	Poor: poor drainage.	Not suitable-----	Not suitable-----	Poor: poor drainage; high susceptibility to frost action.	Moderate permeability; slow seepage rate; substratum has sand seams; few areas have sand near depth of 6 feet; high water table; possible site for dug-out pond.
Marna: Mc-----	Poor: poor drainage.	Not suitable-----	Not suitable-----	Poor: poor drainage; moderate to high shrink-swell potential; susceptibility to frost action.	Slow permeability; slow seepage rate; high water table; possible site for dug-out ponds.
Maxcreek: Mm, Mn--	Poor: poor drainage.	Not suitable-----	Not suitable-----	Poor: poor drainage; high susceptibility to frost action.	High water table; moderate permeability; slow seepage rate; occasional sand and gravel seams in subsoil.
Mayer: Mo-----	Poor: poor drainage.	Good: mixed medium and coarse sand and fine gravel; shale common; high water table.	Good in select areas; gravel too fine in some areas; better gravel commonly below depth of 6 feet; high water table.	Poor: poor drainage; high susceptibility to frost action.	High water table; otherwise substratum too porous to hold water; hazard of piping.
Merton: MrA, MrB.	Good: fertile----	Not suitable-----	Not suitable-----	Fair: moderate shrink-swell potential; moderate susceptibility to frost action.	Moderate permeability; slow seepage rate; occasional sand and gravel seams in subsoil; slopes seldom suitable for farm ponds.
Moland: MsA, MsB, MsB2.	Good: fertile----	Not suitable-----	Not suitable-----	Fair: low to moderate shrink-swell potential; moderate susceptibility to frost action.	Moderate permeability; slow seepage rate; occasional sand and gravel seams in subsoil; slopes seldom suitable for farm ponds.
Muck: Mu, Mv, Mw, My.	Poor: very poor drainage; oxidizes readily; erodible.	Not suitable-----	Not suitable-----	Not suitable-----	High water table; suitable for dug-out ponds.

See footnotes at end of table.

of soil properties—Continued

Soil features affecting—Continued					Degree and kind of limitation for septic tank absorption fields
Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways	
Poor to fair stability and compaction characteristics; moderate permeability when compacted; hazard of piping.	High water table; moderate permeability.	High water table----	Not applicable-----	High water table; drainage needed before construction.	Severe: high water table.
Fair to poor stability and compaction characteristics; low permeability where compacted.	High water table; slow permeability.	High water table; slow permeability.	Not applicable-----	High water table; drainage needed before construction; clayey subsoil.	Severe: slow permeability; high water table.
Fair stability and compaction characteristics below depth of 16 inches; low permeability where compacted; upper 16 inches high in content of silt.	High water table; moderate permeability.	High water table----	Not applicable-----	High water table; drain before construction.	Severe: high water table.
Fair to poor stability; fair to good compaction characteristics; hazard of piping.	High water table; moderate permeability in upper part and rapid in substratum; substratum caves and sloughs during construction.	High water table; moderate available water capacity.	Not applicable-----	High water table; drain before construction; sod difficult to establish where substratum is exposed.	Severe: high water table.
Fair stability and compaction characteristics below a depth of 13 inches; low permeability where compacted; upper 13 inches high in content of silt.	Not needed; a few nearly level areas will benefit from tile drainage.	Features generally favorable.	Features generally favorable.	Features generally favorable.	Slight.
Fair stability and compaction characteristics below a depth of 16 inches; low permeability where compacted; upper 16 inches high in content of silt.	Not needed; well drained.	Features generally favorable.	Features generally favorable.	Features generally favorable.	Slight.
Highly organic; very poor stability and compaction characteristics; unsuitable for embankments.	High water table; poor stability; subsidence when drained.	High water table----	Not applicable-----	Not applicable-----	Severe: highly organic; high water table.

TABLE 5.—*Engineering interpretations*

Soil series and map symbols	Suitability as source of—				Soil features affecting—
	Topsoil ¹	Sand	Gravel	Road fill ²	Pond reservoir areas
Newry: NbA-----	Fair to good-----	Not suitable: overlies some deep sand and gravel beds in a few areas.	Not suitable: overlies some deep sand and gravel beds in a few areas.	Fair: low to moderate shrink-swell potential moderate; susceptibility to frost action; moderately well to somewhat poorly drained.	Moderate permeability; slow seepage rate; occasional sand and gravel seams in subsoil; slopes seldom suitable for farm ponds.
Nicollet: NcA, NcB.	Fair: moderately fine textured.	Not suitable-----	Not suitable-----	Fair: moderate shrink-swell potential and susceptibility to frost action; moderately well drained to somewhat poorly drained.	Moderate permeability; slow seepage rate; slopes seldom suitable for farm ponds.
Salida: SaE-----	Poor: shallow and sandy.	Good: stratified sand and gravel.	Good: stratified sand and gravel.	Good: all factors favorable.	Rapid permeability--
Shields: Sh-----	Fair: fair to poor workability.	Not suitable-----	Not suitable-----	Poor: somewhat poor to poor drainage; moderate shrink-swell potential; high susceptibility to frost action.	Slow permeability; slow seepage rate.
*Sparta: SkB, SkC, SkE. For Dickinson part of these units, see Dickinson series.	Poor: too sandy--	Poor: poorly graded silty sands.	Not suitable-----	Good: all factors favorable.	Rapid permeability.
Storden----- Mapped only in complexes with Clarion and Lester soils.	Fair: high in lime carbonates.	Not suitable-----	Not suitable-----	Fair: moderate susceptibility to frost action.	Moderate permeability; slow seepage rate; slopes seldom suitable for farm ponds.
Talcot: Ta-----	Poor: high water table; high in carbonates.	Good: mixed medium and coarse sand and fine gravel; shale common; high water table.	Poor: some fine gravel in sand; better gravel is commonly below depth of 6 feet; high water table.	Poor: very poor drainage; high susceptibility to frost action.	High water table; suitable for dug-out ponds; substratum will cave and slough.

See footnotes at end of table.

of soil properties—Continued

Soil features affecting—Continued					Degree and kind of limitation for septic tank absorption fields
Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways	
Fair stability and compaction characteristics below depth of 20 inches; low permeability where compacted; upper 20 inches high in content of silt.	Not needed; moderately well to somewhat poorly drained.	Features generally favorable.	Features generally favorable.	Features generally favorable.	Slight.
Fair to good stability and compaction characteristics; low where compacted.	Not generally tiled; nearly level slopes are tiled occasionally.	Features generally favorable.	Features generally favorable.	Features generally favorable.	Slight: level areas may have moderate limitations because of water table.
Fair stability; fair to good compaction characteristics; fair to poor resistance to piping.	Not needed; excessively drained.	Very low available water capacity and natural fertility; rapid intake rate.	Shallow, droughty soils.	Droughty; sod difficult to establish; substratum unstable.	Moderate to severe: slopes; rapid permeability; possible pollution hazard.
Fair to poor stability; poor compaction characteristics; high compressibility; low permeability where compacted.	Seasonal high water table; slow permeability needed in special areas; needs special design.	Seasonal high water table; slow permeability.	Not applicable-----	Disturbed clayey subsoil slow to return to normal production.	Severe: slow permeability.
Fair stability; fair to good compaction characteristics; moderate permeability when compacted; poor resistance to piping.	Not needed; excessively drained.	Low available water capacity and fertility; rapid intake rate; soils occur only in small tracts.	Rapid permeability; low fertility and available water capacity.	Erodible; substratum unstable; droughtiness and low fertility; slow sod establishment.	Slight: possible side hill seepage on sloping soils. Moderate on slopes of 8 to 15 percent. Severe on slopes stronger than 15 percent.
Fair to good stability and compaction characteristics; low permeability where compacted.	Not needed; somewhat excessively drained.	Moderate intake rate; irregular convex slopes.	Features favorable; irregular slopes.	Not applicable-----	Moderate to severe: slopes.
Fair stability; fair to good compaction characteristics; low permeability where compacted.	High water table; moderate permeability in upper part and rapid in substratum; substratum will cave and slough during construction.	High water table; moderate available water capacity.	Not applicable-----	High water table; drain before construction.	Severe: high water table.

TABLE 5.—*Engineering interpretations*

Soil series and map symbols	Suitability as source of—				Soil features affecting—
	Topsoil ¹	Sand	Gravel	Road fill ²	Pond reservoir areas
Terril: Te, Tf-----	Good: fertile-----	Not suitable-----	Not suitable-----	Fair: low to moderate shrink-swell potential; moderate to high susceptibility to frost action.	Subject to flooding; possible water table at depth of 4 to 10 feet.
Udolpho: Ud-----	Fair-----	Good: mixed medium and coarse sand and gravel; shale common; high water table.	Suitable in select areas; gravel is fine in many areas; high water table.	Fair to poor: somewhat poor to poor drainage; low to moderate shrink-swell potential; high susceptibility to frost action.	Water table is at depth of 2 to 5 feet; possible site for dug-out pond; substratum will cave and slough.
Wadena: WaA, WaB, WaC2.	Good-----	Good: contains gravel.	Good: some areas sandy.	Good: most factors favorable.	Permeability rapid in underlying material.
Waukegan: WgA, WgB.	Good-----	Good: poorly graded sand.	Fair in select areas: gravel generally fine and mixed with sand.	Fair to good: most factors favorable; moderate susceptibility to frost action.	Permeability rapid in underlying material.
Webster: Wt-----	Poor: poor drainage.	Not suitable-----	Not suitable-----	Poor in upper 24 inches; high in organic-matter content; fair to good below depth of 24 inches; high water table; moderate shrink-swell potential; moderate susceptibility to frost action.	High water table; slow seepage rate; suitable for dug-out ponds.

¹ Soils having slopes of 8 to 15 percent should be rated fair as a source of topsoil, and those over 15 percent, poor.

of soil properties—Continued

Soil features affecting—Continued					Degree and kind of limitation for septic tank absorption fields
Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways	
Fair stability; fair to good compaction characteristics; low permeability where compacted; good resistance to piping.	Generally not needed; moderately well drained.	Subject to flooding--	Not applicable-----	Erodible; subject to flooding.	Severe: subject to flooding.
Fair to poor stability and compaction characteristics; substratum highly permeable when compacted.	High water table; moderate permeability in upper part and rapid in substratum; substratum will cave and slough during construction.	High water table; moderate available water capacity.	Not applicable-----	High water table; erodible; drain before construction.	Severe: high water table.
Fair to poor stability and compaction characteristics in upper 2 to 3 feet; fair to poor in substratum; hazard of piping.	Not needed; well drained.	Moderate available water capacity; medium intake rate.	Sand and gravel within depth of 24 to 36 inches; some inclusions are gravelly to the surface; slopes are short.	Erodible; slow to vegetate because of droughtiness; substratum unstable.	Slight: rapid permeability in substratum; possible hazard of pollution.
Fair to poor stability and compaction characteristics; hazard of piping.	Not needed; well drained.	Moderate available water capacity; medium intake rate.	Sand and gravel within 24 to 36 inches; slopes are short.	Erodible; substratum unstable.	Slight: rapid permeability in substratum; possible hazard of pollution.
Fair to good stability and compaction characteristics; low permeability where compacted; good resistance to piping.	High water table; moderate permeability.	High water table----	Not applicable-----	High water table; drain before construction.	Severe: high water table.

² Soils having slopes of 15 to 25 percent should be rated fair as a source of material for road fill, and those over 25 percent, poor.

TABLE 6.—*Engineering*

[Tests were performed by the Minnesota Department of Highways, in accordance with

Soil name and location	Parent material	Minnesota report No.	Depth from surface	Moisture-density data ¹	
				Maximum dry density	Optimum moisture
Estherville sandy loam: SE. corner of SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 9, T. 108 N., R. 20 W. (Modal).	Moderately coarse textured sediment over sand and gravel (glacial outwash).	1837	<i>Inches</i> 0-8	<i>Pounds per cubic foot</i> 95	<i>Percent</i> 23
		1838	13-17	130	10
		1839	23-48	129	10
Kato silty clay loam: NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 12, T. 105 N., R. 19 W. (Modal) --	Moderately fine textured sediment over sand and gravel (outwash plain).	1846	0-8	91	26
		1847	21-31	106	18
		1848	39-58	114	14
NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, T. 105 N., R. 19 W. (Finer textured).	Moderately fine textured sediment over sand and gravel (outwash plain).	1849	0-8	93	24
		1850	19-27	109	18
		1851	37-38	126	10
NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, T. 106 N., R. 19 W. (Coarser textured).	Moderately fine textured sediment over sand and gravel (outwash plain).	1852	0-9	89	28
		1853	15-20	113	15
		1854	28-40	113	16
Kilkenny clay loam: NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 9, T. 108 N., R. 21 W. (Modal) --	Glacial till (ground moraine).	1828	0-4	69	44
		1829	18-40	83	31
		1830	54-62	84	31
NE. corner of NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 8, T. 108 N., R. 21 W. (Friable C horizon).	Glacial till (ground moraine).	1831	0-6	76	35
		1832	24-38	85	29
		1833	48-60	95	24
Lerdal silty clay loam: NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 34, T. 108 N., R. 21 W. (Modal) --	Glacial till.	1819	0-7	92	26
		1820	14-28	90	26
		1821	44-50	114	15
NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 16, T. 108 N., R. 21 W. (Friable C horizon).	Glacial till.	1822	0-9	93	24
		1823	15-31	90	27
		1824	42-48	99	21
N. side of NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 9, T. 108 N., R. 21 W. (Finer textured).	Glacial till.	1825	0-7	91	26
		1826	7-24	93	25
		1827	40-48	100	22
Lester loam: NW. corner of SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 9, T. 106 N., R. 21 W. (Modal).	Glacial till.	1810	0-7	91	25
		1811	13-24	108	18
		1812	36-44	112	16
SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T. 106 N., R. 21 W. (Modified till).	Glacial till.	1813	0-7	99	20
		1814	10-22	107	17
		1815	33-45	110	15
SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 11, T. 108 N., R. 20 W. (Marginal to Clarion).	Glacial till.	1816	0-7	101	20
		1817	12-26	112	14
		1818	30-48	112	16
Salida gravelly loamy sand: SE. corner of SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 10, T. 106 N., R. 21 W.	Sand and gravel (glacial outwash).	1843	0-8	116	14
		1844	8-14	124	11
		1845	14-36	132	10

See footnotes at end of table.

test data

standard procedures of the American Association of State Highway Officials (AASHO)]

Mechanical analysis ²									Liquid limit	Plasticity index	Classification	
Percentage passing sieve—				Percentage smaller than—				AASHO			Unified ³	
% inch	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	0.05 mm.	0.02 mm.	0.005 mm.					0.002 mm.
75	100	99	75	44	42	27	7	4	Percent 46	12	A-7-5(3)	SM
78	66	60	36	14					24	3	A-1-b(0)	SM
	62	46	18	4					(⁴)	(⁴)	A-1-a(0)	SP
	100	99	93	84	77	61	32	23	49	17	A-7-5(13)	OL
	100	99	96	84	79	59	33	28	46	21	A-7-6(13)	ML-CL
99	97	91	65	10					(⁴)	(⁴)	A-2-4(0)	SP-SM
	100	99	93	86	82	64	37	31	51	19	A-7-5(14)	OH
	98	96	88	73	68	49	31	26	44	28	A-7-6(14)	CL
97	89	72	33	13					30	11	A-2-6(0)	SC
	100	99	93	79	72	60	33	23	54	19	A-7-5(15)	OH
	94	85	70	51	49	39	22	18	40	19	A-6(6)	CL
99	97	91	67	9					(⁴)	(⁴)	A-3(0)	SP
	99	98	91	72	70	54	28	15	66	15	A-7-5(13)	OH
	99	96	88	73	69	64	51	42	66	29	A-7-5(19)	MH
100	98	94	89	75	70	63	49	39	68	33	A-7-5(20)	MH
	96	100	95	81	76	53	23	13	59	18	A-7-5-15)	OH
99	98	90	83	68	63	57	43	32	65	32	A-7-5(18)	MH-CH
99	98	95	87	68	62	53	33	24	47	21	A-7-6(11)	ML-CL
	98	96	89	72	64	56	36	25	47	14	A-7-5(10)	ML
	98	91	80	57	53	50	40	32	62	30	A-7-5(8)	MH-CH
95	92	85	70	36	30	23	14	10	30	11	A-6(0)	SC
	99	97	91	72	65	52	29	18	40	11	A-6(7)	ML
	98	95	88	68	62	54	39	33	55	23	A-7-5(15)	MH
98	97	93	82	60	51	43	28	21	43	18	A-7-6(9)	ML-CL
	99	96	89	69	63	54	39	29	50	16	A-7-5(11)	ML
	98	94	89	68	62	54	39	33	57	26	A-7-5(16)	MH-CH
98	96	92	85	65	58	51	33	26	46	20	A-7-6(11)	ML-CL
	99	97	88	58	54	35	12	6	43	11	A-7-5(5)	ML
	98	94	85	56	52	39	29	23	40	18	A-6(7)	CL
100	95	91	82	55	51	36	20	15	29	9	A-4(4)	CL
	98	96	86	56	49	32	17	13	36	9	A-4(4)	ML
	99	98	89	58	50	39	25	21	34	12	A-6(5)	ML-CL
100	97	91	81	55	53	38	22	14	34	14	A-6(6)	CL
	99	97	86	54	47	37	17	11	37	10	A-4(4)	ML
	97	94	81	38	37	27	20	15	31	11	A-6(1)	SC
100	96	92	81	50	43	34	21	16	33	13	A-6(4)	SC
	85	77	49	22	20	13	4	3	34	6	A-2-4(0)	SM
88	80	70	41	12					25	2	A-1-b(0)	SP-SM
74	59	41	13	3					(⁴)	(⁴)	A-1-a(0)	SP

TABLE 6.—*Engineering*

Soil name and location	Parent material	Minnesota report No.	Depth from surface	Moisture-density data ¹	
				Maximum dry density	Optimum moisture
			<i>Inches</i>	<i>Pounds per cubic foot</i>	<i>Percent</i>
Shields silty clay loam: SW. corner of NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 22, T. 108 N., R. 21 W. (Modal).	Glacial till.	1855	0-8	80	34
		1856	12-27	85	30
		1857	41-54	89	29
NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 28, T. 108 N., R. 21 W. (Friable C horizon).	Glacial till.	1861	0-9	97	21
		1862	13-30	97	22
		1863	38-44	105	17
SE. corner of NE $\frac{1}{4}$ sec. 27, T. 108 N., R. 21 W. (Silt loam surface layer).	Glacial till.	1858	0-7	86	28
		1859	22-34	82	35
		1860	48-54	90	28

¹ Based on AASHO Designation T 99-57, Method C (I).

² Mechanical analyses according to the AASHO Designation T 88-57 (I). Results by this procedure frequently may differ somewhat from results obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHO procedure, the fine material is analyzed by the hydrometer method, and the various grain-size fractions are calculated on the basis of all the material, including that coarser than 2 millimeters in diameter. In the SCS soil survey procedure, the fine material is analyzed by the pipette method, and the

Mechanical analyses show the percentage, by weight, of soil particles that would pass through sieves of specified sizes. Sand and other coarser materials do not pass through the No. 200 sieve. Silt and clay pass through the No. 200 sieve. Percentage fractions smaller than openings in the No. 200 sieve were determined by the hydrometer method, rather than by the pipette method that most soil scientists use in determining the clay in soil samples.

Liquid limit and plasticity index indicate the effect of water on the strength and consistence of soil material. As the moisture content of a clayey soil is increased from a dry state, the material changes from a semisolid to a plastic state. If the moisture content is further increased, the material changes from a plastic to a liquid state. The plastic limit is the moisture content at which the material passes from semisolid to plastic. The liquid limit is the moisture content at which the material changes from plastic to liquid. The plasticity index is the numerical difference between the liquid limit and the plastic limit. It indicates the range of moisture content within which a soil material is plastic.

Formation and Classification of the Soils

This section tells how the factors of soil formation have affected the development of soils in Steele County and describes processes of soil formation. It also explains the system of soil classification currently used and places each soil series in some of the categories of that system.

Formation of the Soils

Soil results when the forces of weathering and soil development act on the materials that have been depos-

ited or accumulated by geologic agencies. The characteristics of the soil in any particular place are determined by (1) the physical and mineralogical composition of the parent material, (2) the climate under which the soil material has accumulated and has existed since accumulation, (3) the plant and animal life on and in the soil, (4) the relief, or lay of the land, and the drainage that results from it, and (5) the length of time the forces of development have acted on the material. These five factors of soil formation are interdependent, and each modifies the effects of the others.

In modern civilization, man has introduced additional influences that play a part in causing soils to be as they are. He has removed the natural vegetation on some of the soils and has used methods of farming that have accelerated erosion, changed the drainage, and changed the relief or the effects of relief. Man has modified the natural differences between soils. He has increased the supply of plant nutrients in some soils by the use of fertilizer and has depleted the supply of plant nutrients in some areas by removing crops without replacing the plant nutrients.

Parent material

Steele County is covered by drift of the Cary and Mankato substages of the Wisconsin glaciation. These glacial substages occupied the area between 8,000 and 14,000 years ago. The drift is composed of relatively recent material derived through reworking of older glacial deposits.

Moderately fine textured and fine textured glacial drift, high in content of shale, covers the central part of Deerfield Township. This material occurs as a 3-foot to 10-foot mantle on the medium-textured glacial drift. Kilkenny Lerdal, Shields, and Marna soils formed in this material.

test data—Continued

Mechanical analysis ²									Liquid limit	Plasticity index	Classification		
Percentage passing sieve—				Percentage smaller than—				AASHO			Unified ³		
$\frac{3}{8}$ inch	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	0.05 mm.	0.02 mm.	0.005 mm.	0.002 mm.					
									<i>Percent</i>				
-----	100	100	96	85	83	63	29	16	48	8	A-5(10)	OL	
-----	100	99	96	86	83	74	59	49	73	36	A-7-5(20)	MH	
-----	100	99	95	83	79	69	50	38	60	30	A-7-5(20)	MH-CH	
100	99	99	93	72	65	50	24	17	33	5	A-4(7)	ML	
100	99	98	90	61	55	46	36	29	43	19	A-7-6(10)	CL	
96	91	86	76	47	41	32	22	16	38	16	A-6(4)	SC	
-----	100	99	96	86	82	69	46	33	51	16	A-7-5(13)	OH	
-----	100	99	96	86	83	75	61	48	70	33	A-7-5(20)	MH	
100	99	97	92	82	79	70	50	36	59	28	A-7-5(19)	MH-CH	

material coarser than 2 millimeters in diameter is excluded from calculations of grain-size fractions. The mechanical analysis data used in this table are not suitable for use in naming textural classes for soils.

² SCS and BPR have agreed to consider that all soils having plasticity indexes within two points of A-line are to be given a borderline classification. Examples of borderline classifications obtained by this use are ML-CL and MH-CH.

⁴ Nonplastic.

The soils in parts of Havana and Owatonna Townships have been strongly influenced by moderately fine textured lakelaid sediments. Madelia soils are common in this area.

The valley trains and glacial outwash areas were formed by the fast-flowing glacial melt water. Soils that occur in these areas commonly have a sandy and gravelly substratum and sandy to silty upper layers. Biscay, Estherville, Kato, Hanska, Wadena, Waukegan, and Salida soils are dominant in these areas.

The eastern edge of the Cary drift is covered by a thin mantle of silt. Blooming, Havana, Moland, and Merton soils formed in this material.

Throughout most of the county, the glacial drift is calcareous and loamy. Clarion, Lester, Hayden, and Webster soils formed in this material.

Climate

Steele County has a cool, sub-humid, continental type of climate, with wide variations in temperature from summer to winter. During winter, soil-forming processes are largely dormant. Generally, the soils are frozen to a depth of 2 to 3 feet for 4 to 5 months of the year. The depth to which frost penetrates depends mostly on the quantity of snowfall late in fall or early in winter.

The climate is essentially uniform for the county; however, differences in vegetation, soil materials, and relief can cause variations in the microclimate. Soils in the prairie regions are exposed to greater variations in temperature than those in the forest region. Fine-textured soils, such as the Marna and Lura, warm up more slowly than moderately coarse textured soils, such as the Estherville and Dickinson, because they contain more moisture. Dark-colored soils, such as the Clarion and Nicollet, absorb more heat from the sunlight than light-colored Hayden soils. Soils on south- and west-facing slopes receive more sunlight than soils on north- and east-facing

slopes; therefore, they tend to be drier and warmer. The interaction of all these factors affects the development of soils. For additional information about the climate of Steele County, see the subsection "Climate" near the back of this survey.

Plants and animals

Before settlement of the county, the native vegetation was most important in the complex of living organisms that affect soil development. The activities of animals were of minor importance, except for earthworm activity, which performs a function in the transformation and translocation of organic materials.

Two types of vegetation, forest and prairie, have strongly influenced the soil development in Steele County (fig. 12). The county is located along the northern margin of an extensive zone of ecological tension between prairie and forest regions. This margin advanced and retreated throughout the centuries as shifts in the climate pattern affected temperature, relative humidity, wind velocity, and precipitation patterns.

A peninsula of the big woods extended into Steele County along the valley of the Straight River. Hayden soils are common in that area. Enclaves of tall prairie grasses persisted throughout the county. Clarion, Nicollet, Moland, and Merton soils are associated with these areas. Oak openings occupied the balance of the county. Lester, Le Sueur, and Blooming soils are associated with this area.

Pioneer settlers and many early scholars believed that the prairies in this climate were the product of fire. This, no doubt, was a modifying factor along the edges of the prairie. Primarily where a given type of vegetation is favored by the climate, however, that type of vegetation is dominant (4).

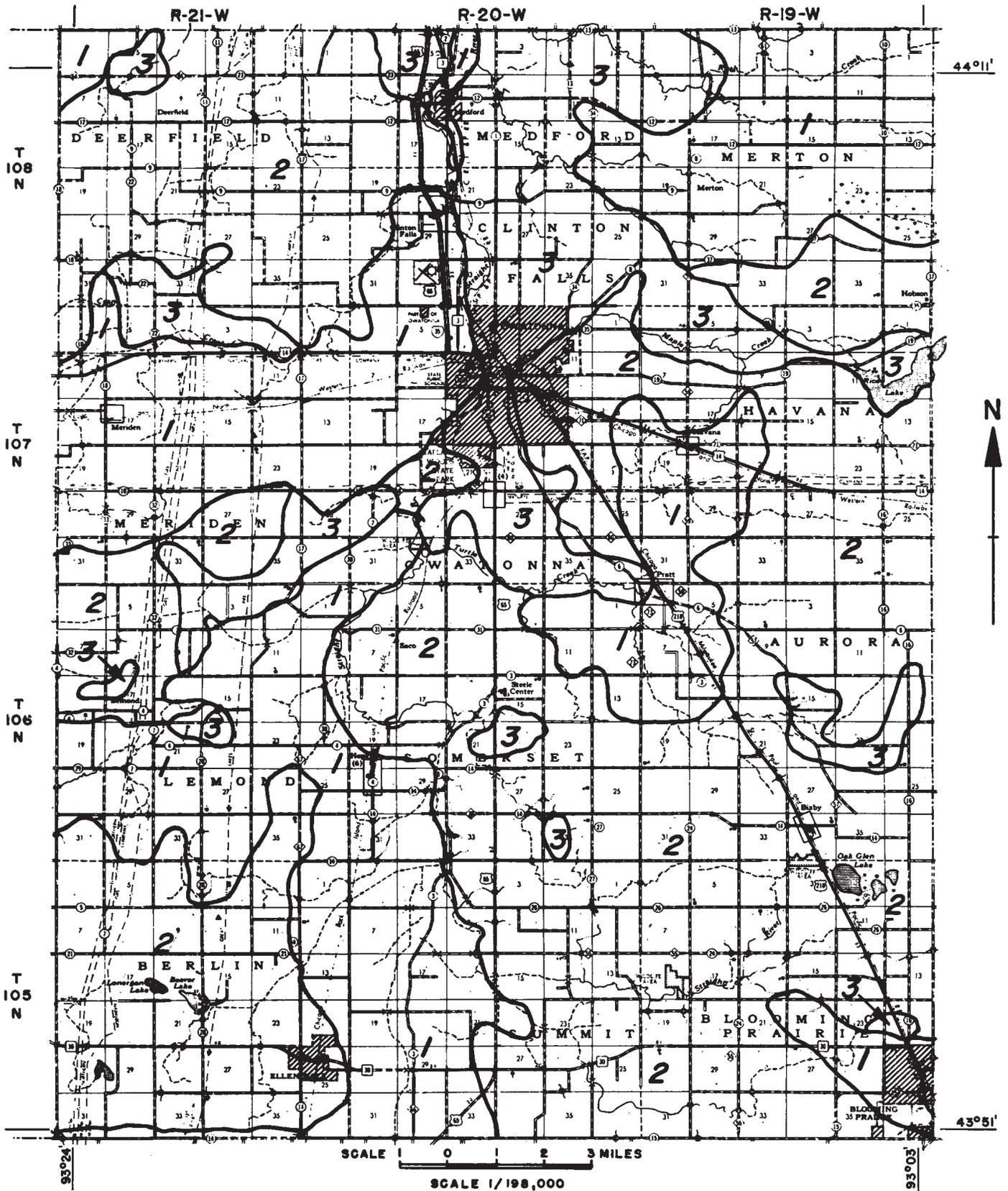


Figure 12.—Vegetation before the time of settlement in the area that is now Steele County. 1. Dominantly tall grass prairie; a few small groves of oak and aspen, and a few hazel thickets. 2. Dominantly groves of oak, elm, and aspen on the well-drained soils and tall prairie grasses and sedges on the wet soils; a few areas of solid-canopy woods near lakes and streams. 3. Solid-canopy deciduous trees, such as oak, elm, basswood, ash, and aspen.

Relief

The relief of Steele County is the product of a backwasting continental glacier that deposited glacial drift of such thickness that the underlying rock strata have little effect on the configuration of the surface relief. The relief of the county ranges from nearly level on the lake plains and ground moraines to rolling in the complex pattern of end moraines. A few large lakes and numerous small depressions have formed in the scattered ice block depressions. The main drainage channels were developed during the retreat of the glacier and occur as broad valleys within the landscape. Secondary drainage was very immature and needed extensive artificial development.

The morainic topography is of two distinct types. One is a complex of short, uneven slopes with many small, indistinct drainage patterns. The other type of topography is a series of flat-topped drumlins having smooth side slopes. This topography occurs in southwestern Berlin Township.

Time

Geologically, soils of the county are young. They were first exposed to soil-forming processes between 8,000 and 14,000 years ago. However, presuming most of the material was reworked drift of preceding glaciers, the weathering of minerals was somewhat advanced at the time of deposition as evidenced by the dominance of montmorillonite clays (2). Soils may have a well-developed profile, a poorly developed profile, or a profile somewhat in between, depending upon the intensity of the weathering factors and the resistance of the soil material to weathering. Lester and similar soils have been exposed to greater intensities of influence of the five factors of soil formation than have many other soils, and they have moderately distinct layers or horizons. The Webster soils have less pronounced lower horizons than Clarion soils because they occupy relief where a fluctuating water table modifies the normal effect of time. Storden soils have a very shallow profile because of a combination of high content of carbonates and steep slopes. Recent alluvial deposits adjacent to the major drainageways have no profile development.

Processes of Soil Formation

Theories of soil genesis reflect the state of knowledge in the soil science of their day. This state of knowledge includes the extent to which soil properties are recognized and understood. Soils are natural bodies formed on the land surface. In only a few places are individual bodies of soils set apart from their neighbors by sharp boundaries. Changes in the combined influence of soil-forming factors generally are manifest in a gradual shifting of properties as one soil body grades into another.

Soil genesis (8) can be viewed as consisting of two steps, (a) the accumulation of parent materials and (b) the development of distinctive properties in the profile. The development of soil properties is due to the interaction of processes of additions, removals, transfers, and transformations of organic matter, silicate clays, silica, soluble salts, iron, aluminum oxides, and carbonates. The terms podzolization, calcification, gleization, and lateriza-

tion stress the dominant processes in the development of soil properties.

In Steele County the five factors of soil formation interact in such a way that four processes are dominant—podzolization, calcification, gleization, and solonization.

Podzolization is the dominant soil-forming process in areas that have high humidity and forest vegetation.

Podzolization is expressed in the formation of the Hayden, Lester, and Le Sueur soils. The partial removal of organic matter and of iron and aluminum oxides, with the resultant concentration of silica, results in a graying in surface color and a reduction of thickness in the A horizon. In the Hayden soils the removal has advanced to where the silica has become concentrated to develop a clearly expressed A₂ horizon. In the Lester soils the A₂ horizon is not clearly expressed. The silicate clays and organic matter removed from the surface layer accumulate in the B horizon as films along channels or on the faces of the structural aggregates. This clay-organic accumulation, together with some weathering of silicate minerals in places, develops a distinct increase in the clay content of the subsoil.

The increase in carbonates in the lower part of the B horizon induces a precipitation of the organic materials. This results in prominent organic coatings on the surface of the structural aggregates just above the calcareous till. In Steele County the intensity of the podzolization process is aided by variations in the amount of carbonates in the parent materials. This is expressed in the stronger horizonation and thicker solum of the Kilkenny soils. Except for areas adjacent to drainageways and lakes, long-term variations in the climatic regime have restricted the normal influence of timber on the soils of Steele County.

Calcification is a process normally restricted to regions of the temperate zone where rainfall is 25 inches or less and where the dominant vegetation is grass or brush. In this process carbonates are transferred in the profile but not entirely removed. Because of the low rainfall, not enough water percolates through the profile to remove entirely the calcium carbonate that existed in the parent material.

In the calcification process, calcium and magnesium carbonates accumulate at some point in the profile that approximates the depth to which surface waters most frequently percolate. A secondary result of the process is the somewhat granular condition of the soil material. The granulation results from the action of the carbonates on the clay colloids in the soil material. Also, because the colloids are thus influenced, there is little downward movement of colloids in the profile. The calcification process therefore involves accumulation of carbonates in the soil and the absorption of calcium and magnesium ions by clay colloids.

Vegetation contributes in the formation of soils influenced by calcification. Grasses and other plants that require relatively large amounts of bases, particularly calcium, bring these bases to the surface through their roots. When the plants decay, the calcium is restored to the surface soil. In this way the loss through leaching is partially offset. Soils formed through the process of calcification therefore seldom have a strongly acid surface layer.

The large accumulation of decayed grasses on the surface and in the surface layer to a depth of 8 to 16 inches

results in the accumulation of organic matter, nitrogen, phosphorus, and sulphur.

In Steele County, the Clarion, Nicollet, Moland, and Merton soils were influenced by the process of calcification. However, they formed under a higher rainfall than is characteristic for lime-accumulation soils. Because of the higher rainfall average, downward percolation of water in soils under good grass cover may be such that there is no zone in which calcium carbonate has accumulated. Yet these soils possess a high degree of base saturation.

Gleization is a process that forms a light olive-gray or gray-colored horizon immediately below the dark-colored surface. In Steele County this occurs in areas where a perched water table occurred at or slightly below the surface. The gleization process is evident in the Webster, Marna, and associated wet soils of Steele County.

Some soils in Steele County developed in relief where fluctuation of the water table caused percolation to be offset by evaporation. This results in free carbonates being diffused throughout the profile. This condition is a result of solonization. Canisteo, Lemond, and Mayer soils are examples of soils having this condition.

Small, shallow depressions exhibit prominent A2 horizon development and a pronounced textural development in the B horizon. This condition generally is associated with a site location where a low water table allowed the removal of organic matter and silicate clays from the A1 horizon, the concentration of silica in the A2 horizon, and the accumulation of silicate clays and organic matter in the B horizon. Owing to their limited acreage, these depressions have been included with areas of Glencoe, Madelia, and Webster soils.

Some soils developed in sites where abundant water encourages luxuriant growth of reeds, sedges, and mosses. The organic matter from these plants decays slowly under these very poorly drained conditions. The plant remains accumulate faster than they decay, and so a body of organic matter known as peat accumulates. If drainage is improved, the peat decays and is oxidized, thus forming muck.

Classification of the Soils

Classification consists of an orderly grouping of soils according to a system designed to make it easier to remember soil characteristics and interrelationships. Classification is useful in organizing and applying the results of experience and research. Soils are placed in narrow classes for discussion in detailed soil surveys and for application of knowledge within farms and fields. The many thousands of narrow classes are then grouped into progressively fewer and broader classes in successively higher categories, so that information can be applied to large geographic areas.

Two systems of classifying soils have been used in the United States in recent years. The older system was adopted in 1938 (3) and revised later (11). The system currently used by the National Cooperative Soil Survey was developed in the early sixties and was adopted in 1965 (13). It is under continual study. Therefore, readers interested in developments of the current system should research the latest literature available (9).

The current system of classification has six categories. Beginning with the most inclusive, these categories are the order, the suborder, the great group, the subgroup, the family, and the series. The criteria for classification are soil properties that are observable or measurable, but the properties are selected so that soils of similar genesis, or mode of origin, are grouped together. The placement of some soil series in the current system of classification, particularly in families, may change as more precise information becomes available. Table 7 shows the classification of each soil series of Steele County by family, subgroup, and order, according to the current system. Most of the classes of the current system are briefly defined in the following paragraphs.

ORDER.—Ten soil orders are recognized. They are Entisols, Vertisols, Inceptisols, Aridisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, and Histosols. The properties used to differentiate these soil orders are those that tend to give broad climatic groupings of soils. The two exceptions to this are the Entisols and Histosols, which occur in many different kinds of climate. Table 7 shows that the four soil orders in Steele County are Entisols, Histosols, Mollisols, and Alfisols.

Entisols are light-colored soils that do not have natural genetic horizons or that have only very weakly expressed beginnings of such horizons. These soils do not have traits that reflect soil mixing caused by shrinking and swelling.

Histosols have developed in organic materials. Their name is derived from the Greek word *Histos*, for tissue. In Steele County this order includes Muck soils.

Mollisols have formed under grass and have a thick, dark-colored surface horizon that contains colloids dominated by bivalent cations. The soil material in these soils has not been mixed by shrinking and swelling.

Alfisols are mineral soils that contain horizons of clay accumulation. Unlike the Mollisols, they lack a thick, dark-colored surface layer that contains colloids dominated by bivalent cations, but the base status of the lower horizons is not extremely low.

SUBORDER.—Each order has been subdivided into suborders, primarily on the basis of the characteristics that seemed to produce classes that have the greatest genetic similarity. The suborders narrow the broad climatic range permitted in the orders. The soil properties used to separate suborders are mainly those that reflect either the presence or absence of waterlogging or soil differences resulting from the climate or vegetation.

GREAT GROUP.—Suborders are separated into great groups on the basis of uniformity in the kinds and sequence of major soil horizons and features. The horizons used to make separations are those in which clay, iron, or humus has accumulated or those that contain a pan that interferes with the growth of roots or the movement of water. The features used are the self-mulching properties of clay, soil temperature, major differences in chemical composition (mainly calcium, magnesium, sodium, and potassium), and the like. The great group is not shown separately in table 7, because it is the last word in the name of the subgroup.

SUBGROUP.—Great groups are subdivided into subgroups, one representing the central (typic) segment of the group, and the other representing segments called intergrades, which have properties of the group and also have one or more properties of another great group, sub-

TABLE 7.—Soils classified according to the current system of classification

Soil series	Family	Subgroup	Order
Biscay	Fine-loamy over sandy or sandy-skeletal, mixed, noncalcareous, mesic.	Typic Haplaquolls	Mollisols.
Bixby	Fine-loamy over sandy or sandy-skeletal, mixed, mesic.	Typic Hapludalfs	Alfisols.
Blooming	Fine-loamy, mixed, mesic	Mollic Hapludalfs	Alfisols.
Burnsville	Coarse-loamy, mixed, mesic	Typic Hapludalfs	Alfisols.
Calco	Fine-silty, mixed, calcareous, mesic	Cumulic Haplaquolls	Mollisols.
Canisteo	Fine-loamy, mixed, calcareous, mesic	Typic Haplaquolls	Mollisols.
Chelsea	Sandy, mixed, mesic	Alfic Udipsamments	Entisols.
Clarion ¹	Fine-loamy, mixed, mesic	Typic Hapludolls	Mollisols.
Colo	Fine-silty, mixed, noncalcareous, mesic	Cumulic Haplaquolls	Mollisols.
Dakota	Fine-loamy over sandy or sandy-skeletal, mixed, mesic.	Typic Argiudolls	Mollisols.
Dickinson	Coarse-loamy, mixed, mesic	Typic Hapludolls	Mollisols.
Dundas	Fine-loamy, mixed, mesic	Udolic Ochraqualfs	Alfisols.
Estherville	Coarse-loamy over sandy or sandy-skeletal, mixed, mesic.	Typic Hapludolls	Mollisols.
Glencoe	Fine-loamy, mixed, noncalcareous, mesic	Cumulic Haplaquolls	Mollisols.
Hanska	Coarse-loamy, mixed, noncalcareous, mesic	Typic Haplaquolls	Mollisols.
Havana	Fine-loamy, mixed, mesic	Mollic Ochraqualfs	Alfisols.
Hayden	Fine-loamy, mixed, mesic	Typic Hapludalfs	Alfisols.
Hayfield	Fine-loamy over sandy or sandy-skeletal, mixed, mesic.	Aquollic Hapludalfs	Alfisols.
Kato	Fine-silty over sandy or sandy-skeletal, mixed, noncalcareous, mesic.	Typic Haplaquolls	Mollisols.
Kilkenny	Fine, montmorillonitic, mesic	Mollic Hapludalfs	Alfisols.
Lamont	Coarse-loamy, mixed, mesic	Typic Hapludalfs	Alfisols.
Lemond	Coarse-loamy, mixed, calcareous, mesic	Typic Haplaquolls	Mollisols.
Lerdal	Fine, montmorillonitic, mesic	Udolic Ochraqualfs	Alfisols.
Lester ²	Fine-loamy, mixed, mesic	Mollic Hapludalfs	Alfisols.
Le Sueur	Fine-loamy, mixed, mesic	Aquic Argiudolls	Mollisols.
Lura	Fine, montmorillonitic, noncalcareous, mesic	Cumulic Haplaquolls	Mollisols.
Madelia	Fine-silty, mixed, noncalcareous, mesic	Typic Haplaquolls	Mollisols.
Marna	Fine, montmorillonitic, noncalcareous, mesic	Typic Haplaquolls	Mollisols.
Maxcreek	Fine-silty, mixed, noncalcareous, mesic	Typic Haplaquolls	Mollisols.
Mayer	Fine-loamy over sandy or sandy-skeletal, mixed, calcareous, mesic.	Typic Haplaquolls	Mollisols.
Merton	Fine-loamy, mixed, mesic	Aquic Hapludolls	Mollisols.
Moland	Fine-loamy, mixed, mesic	Typic Hapludolls	Mollisols.
Muck	Undesignated	Undesignated	Histosols.
Newry	Fine-loamy, mixed, mesic	Aquollic Hapludalfs	Alfisols.
Nicollet	Fine-loamy, mixed, mesic	Aquic Hapludolls	Mollisols.
Salida	Sandy-skeletal, mixed, mesic	Entic Hapludolls	Mollisols.
Shields	Fine, montmorillonitic, mesic	Mollic Albaqualfs	Alfisols.
Sparta	Sandy, mixed, mesic	Entic Hapludolls	Mollisols.
Storden	Fine-loamy, mixed, mesic	Entic Hapludolls	Mollisols.
Talcot	Fine-loamy over sandy or sandy-skeletal, mixed, calcareous, mesic.	Typic Haplaquolls	Mollisols.
Terril ³	Fine-loamy, mixed, mesic	Cumulic Hapludolls	Mollisols.
Udolpho	Fine-loamy over sandy or sandy-skeletal, mixed, mesic.	Mollic Ochraqualfs	Alfisols.
Wadena	Fine-loamy over sandy or sandy-skeletal, mixed, mesic.	Typic Hapludolls	Mollisols.
Waukegan	Fine-silty over sandy or sandy-skeletal, mixed, mesic.	Typic Hapludolls	Mollisols.
Webster	Fine-loamy, mixed, noncalcareous, mesic	Typic Haplaquolls	Mollisols.

¹ The Clarion sandy loam soils are taxadjuncts to the Clarion series because their A horizon is coarser textured than the defined range of the series.

² The Lester soils in this county are taxadjuncts to the Lester series because they have a darker colored A2 and B1 horizons than the defined range of the series.

³ The Terril soils are taxadjuncts to the Terril series because they lack a B horizon, which is required in the defined range of the series.

order, or order. Subgroups may also be made in those instances where soil properties intergrade outside of the range of any other great group, suborder, or order. The names of subgroups are derived by placing one or more adjectives before the name of the great group.

FAMILY.—Families are separated within a subgroup primarily on the basis of properties important to the growth of plants or behavior of soils when used for engineering. Among the properties considered are texture, mineralogy, reaction, soil temperature, permeability, thickness of horizons, and consistence.

General Nature of the County

This section describes the physiography, relief, drainage, and water supplies of the county. It also discusses the climate, settlement, development, and farming of the county.

Physiography, Relief, and Drainage

Steele County is traversed by two end moraine systems, trending in a north-south direction. They were formed on the eastern margin of the Des Moines lobe of the late Wisconsin ice sheet. Except for the rolling morainic belts, the surface is essentially gently undulating and elevations are between 1,100 and 1,200 feet. The ground moraine between the end moraines is drained by the Straight River and its tributaries. The morainal system east of the river is the narrower of the two, ranging from half a mile to 5 miles in width. It is characterized by groups of irregular hills and basins and a few prominent, somewhat circular, flat-topped sandy kames. The eastern margin of this morainic system has a thin silt and loamy mantle similar to the mantled Iowan area to the east. The Western moraine, which is somewhat lower and wider, occurs along the southwestern edge of the county and extends into Waseca county to the west. The relief in the far southwestern part of the county has distinctive flat-topped hills with smooth side slopes. This area is part of a more extensive area in adjoining Freeborn and Waseca Counties. Both morainic systems have been dissected by glacial valley trains and outwash plains that carried melt water to the Zumbro and Cedar River systems (10). The major streams in the county flow in these valley trains and outwash plains.

The Straight River and its tributaries make up the largest watershed in the county. The valley of the Straight River is broad and flat where it courses through the outwash plains and is narrow and entrenched where it cuts through the intervening moraines. The southwestern part of the county drains into the Le Sueur River system. The northwestern corner of the county drains into the Cannon River. The eastern edge of the county drains into the Zumbro River system. The southeastern corner drains into the Cedar River system.

Water Supplies

Water supplies in Steele County are directly related to the thickness of the mantle of glacial drift and to the kind of rock formations that underlie the soils.

The paleozoic rocks that underlie the soils of Steele County are mainly of Cambrian and Ordovician age. The rock formations directly beneath the glacial drift mantle are limestone and shale (fig. 13). The northern margin of Devonian (Cedar Valley) limestones that cover most of Freeborn and Mower Counties extend a short distance into the southern part of Steele County. These rocks all dip southwestward toward the trough of the Albert Lea-Austin basin. In the northern part of the county, the top of the Jordan sandstone is about 600 feet above sea level, but in the southwestern corner the same stratigraphic horizon is at an elevation of 300 feet. Since these rocks continue upslope northeastward toward Red Wing, where the Jordan sandstone is 900 feet above sea level, the water in them is under high artesian pressure in the area of Steele County.

ST. CROIXIAN SERIES.—The whole series of upper Cambrian sandstone, shale, and dolomite occurs under the entire area of Steele County (fig. 14). Of these formations, the Jordan and the Dresbach are the best water producers. None of the Cambrian rocks crop out at the surface in this county.

SHAKOPEE-ONEOTA GROUP.—This group of massive dolomites, with thin Root Valley sandstone between them, reaches a total thickness of nearly 275 feet in Steele County. Few wells terminate in these rocks. St. Peter sandstone is about 110 feet thick and lies 200 to 300 feet below the surface. At Owatonna its upper surface is penetrated at a depth of about 220 feet. It generally contains abundant water and yields strong supplies.

The Platteville, Galena, and Maquoketa limestone and shale underlie the entire county and have an aggregate thickness of about 200 feet. The Maquoketa and Galena formations are the only known rock outcrops in the county. They are quarried along the Straight River about 1 mile southeast of Clinton Falls, where 27 feet of the basal part of the Maquoketa and 3 feet of the upper part of the Galena may be seen in the quarry walls. The upper part of the limestone members of these formations produces water in areas where these members occur directly under the drift.

CEDAR VALLEY FORMATION.—A shaly limestone with beds of fine-grained white sandstone occurs directly under the drift in the area south of Ellendale and Blooming Prairie. The sandstone beds yield water abundantly.

DAKOTA FORMATION.—In the region of Owatonna and northwestward into Deerfield Township, a number of wells have penetrated a bluish-black clay that is underlain by gravel and sand and thin layers of lignite. The sand and gravel under the clay generally contain considerable water.

Glacial drift mantles the surface in all parts of the county. It varies in depth from a few feet just north of Owatonna in the valley of the Straight River to 50 to 100 feet along the margins of the valley, 100 to 150 feet in the uplands of the central part of the county, and 100 to 200 feet in the morainic areas of the eastern and western parts of the county. Glacial drift reaches a thickness of 340 feet at the village of Meriden. Thin deposits of alluvial sand and silt are found in the valleys. Parts of Deerfield Township are mantled by fine-textured drift high in content of shale.

Many wells produce from sand and gravel beds in the glacial drift. In the central area of the county between the

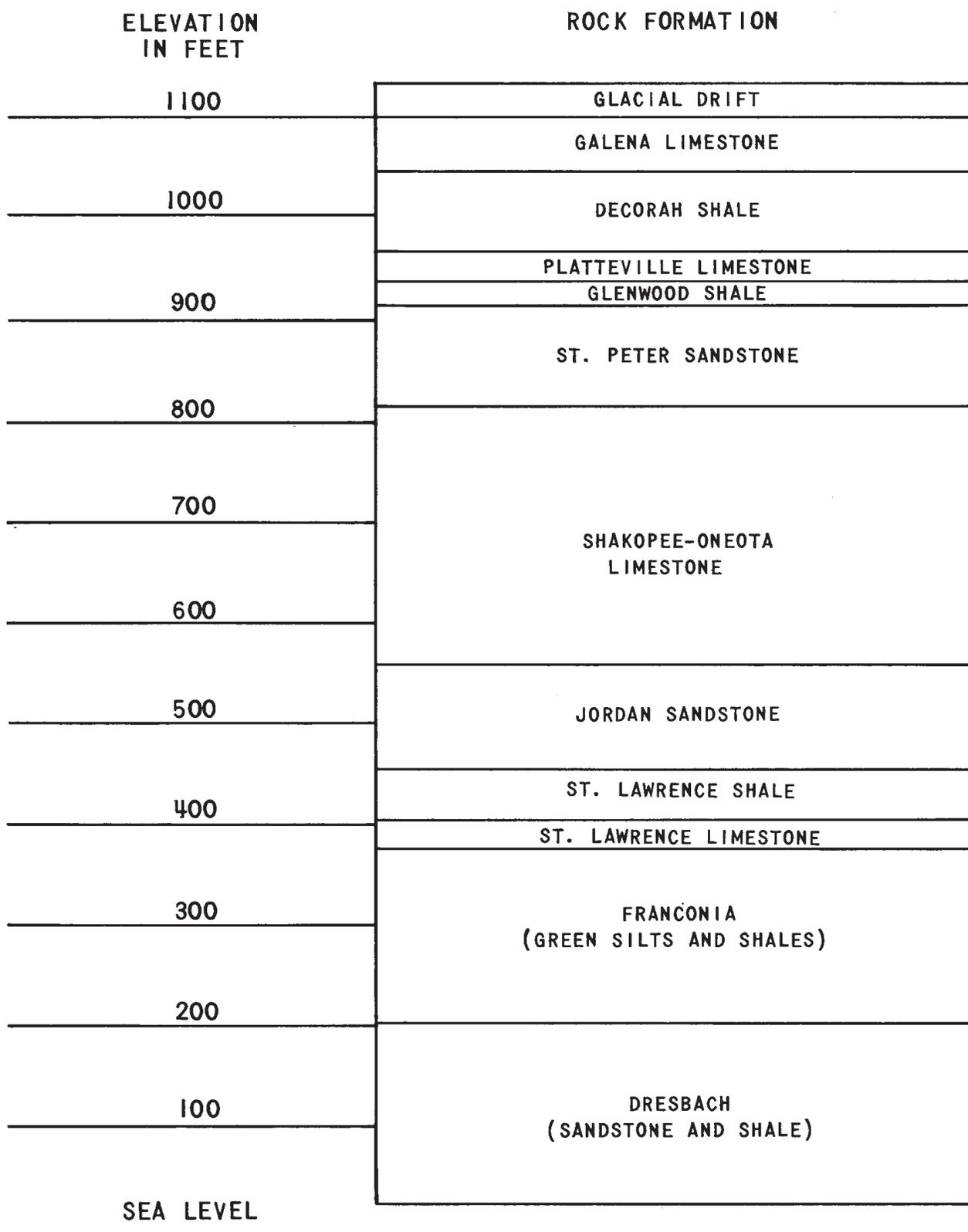


Figure 13.—Geologic section at Owatonna in Steele County, Minn.

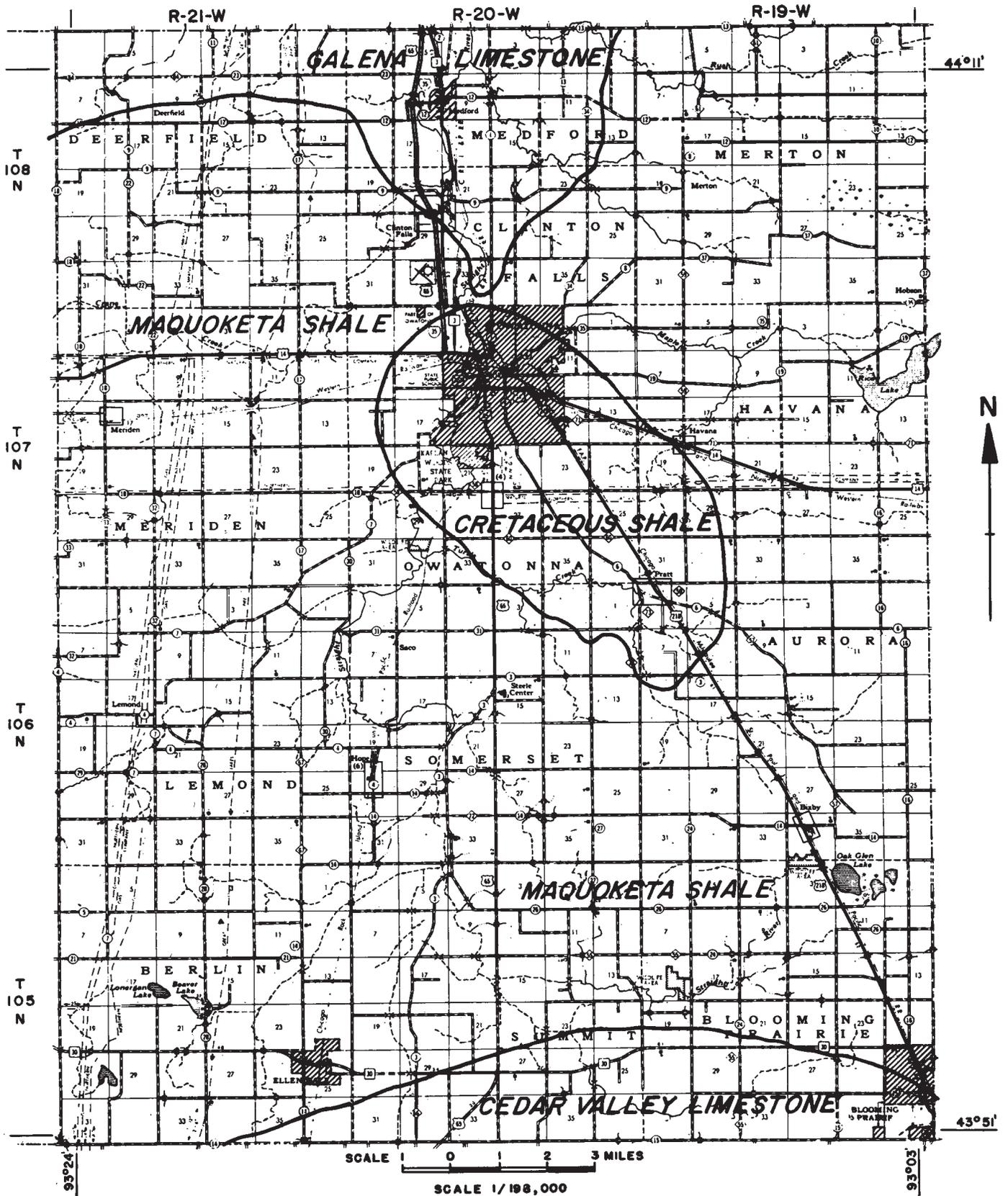


Figure 14.—Subsurface rock formations in Steele County.

two morainic belts, the hydrostatic head is sufficient to cause the wells to flow, but flowing wells are commonest in the valleys of the Straight River and its major tributaries. In the morainic belts of the eastern and western parts of the county, most of the farm wells draw their water from the sand and gravel beds in the glacial drift. In the intermorainic areas, many farm wells are drilled into the bedrock formations. Southeast of Owatonna, the wells end in limestone at a depth of about 150 to 160 feet. The drift in that area is about 130 feet thick. The water in the wells remains at a static level about 100 feet below the surface.

Climate⁴

Steele County is in the interior of the great land mass of North America. Summers are warm and pleasant. The average temperature for the months of June, July, and August is 70.8° F. Temperatures of 100° or higher have occurred only 27 times in the last 30 years and only 3 times in the last 20 years.

The temperature in winter is in sharp contrast to that in summer. In winter the land cools rapidly, and there is less effective solar heating because the days are short and the sun is low on the horizon. Northerly winds from Canada bring additional frigid air. As this air contains little moisture, it brings only a small amount of precipitation. This cold air causes the temperature to drop to zero or below about 33 days each year. A reading of -20° occurs at least once in most winters. One of the coldest periods

⁴ By JOSEPH H. STRUB, JR., climatologist for Minnesota, National Weather Service, U.S. Department of Commerce.

on record was that of December 1916 through February 1917, when the mean (average) temperature was 5.4° for a period of 3 months. The lowest temperature on record occurred in January 1924, when the temperature dropped to -37°. Table 8 gives facts about the temperature and precipitation in the county, based on records obtained at Waseca, Minn. (6).

The latest date on record when the temperature dropped to 32° in spring is June 3, and the earliest date in fall is September 10. Table 9 shows probabilities that are representative for the entire county of the last freezing temperature in spring and the first in fall. By use of this table, one can determine, for example, that 5 years in 10 there will be 227 days when the temperatures does not drop as low as 16°, 188 days when it does not drop as low as 32°, 100 days when it does not drop as low as 40°, and 28 days when it does not drop as low as 50°.

Table 10 gives the probabilities of receiving specified amounts of precipitation during the 3-week periods indicated. More than 70 percent of the annual precipitation falls during the period from April through September. Precipitation of 0.01 inch or more can be expected on an average of 95 days per year. Five of these days will have 1 inch or more of precipitation. Rainfall of an intensity of 1.10 inch per hour can be expected about once in 2 years. The greatest amount of precipitation that has fallen during any 1 month was 11.89 inches in August 1924. The heaviest rainfall occurs as a result of thunderstorms, and an average of 40 of these storms occur annually. Some thunderstorms are accompanied by hail and by damaging winds. Approximately eight hailstorms or storms with damaging winds occur each year. Tornadoes are

TABLE 8.—Temperature and precipitation for Steele County, Minnesota

[Based on records kept at Southern Experiment Station, Waseca, Minnesota]

Month	Temperature				Precipitation				
	Average daily maximum	Average daily minimum	Two years in 10 will have at least 4 days with—		Average total	One year in 10 will have—		Days with snow cover of 1.0 inch or more	Average depth of snow on days with snow cover
			Maximum temperature equal to or higher than—	Minimum temperature equal to or lower than—		Less than—	More than—		
	°F	°F	°F	°F	Inches	Inches	Inches	Number	Inches
January	24	5	40	-19	0.9	0.3	1.6	22	5
February	28	9	45	-12	1.0	.2	1.8	20	5
March	39	21	62	0	1.8	.7	3.0	13	4
April	58	35	78	21	2.3	.9	3.7	1	1
May	71	47	87	32	3.6	1.5	5.6	(¹)	0
June	80	57	92	44	4.7	1.8	7.2	0	0
July	85	61	95	50	3.4	1.2	7.0	0	0
August	83	59	93	48	3.5	1.3	5.1	0	0
September	74	50	90	35	2.9	.7	5.9	(¹)	0
October	62	39	80	25	1.6	.4	3.0	(¹)	0
November	42	24	64	4	1.6	.4	2.7	7	2
December	29	12	46	-12	.9	.3	1.7	17	3
Year	56	35	² 106	³ -35	28.2	22.0	33.7	80	4

¹ Less than 0.5 day

² Average annual maximum.

³ Average annual minimum.

TABLE 9.—*Probabilities of critical temperatures in spring and fall*
 [Based on records kept at the Southern Experiment Station, Waseca, Minnesota]

Probability	Dates for given probability and temperature							
	16° F. or lower	20° F. or lower	24° F. or lower	28° F. or lower	32° F. or lower	36° F. or lower	40° F. or lower	50° F. or lower
Spring:								
1 year in 10 later than.....	Apr. 10	Apr. 18	May 2	May 14	May 27	June 3	June 13	
2 years in 10 later than.....	Apr. 5	Apr. 12	Apr. 26	May 9	May 21	May 29	June 8	
5 years in 10 later than.....	Mar. 26	Apr. 2	Apr. 17	Apr. 28	May 10	May 19	May 30	June 22
Fall:								
1 year in 10 earlier than.....	Oct. 23	Oct. 14	Oct. 7	Sept. 23	Sept. 19	Sept. 2	Aug. 18	
2 years in 10 earlier than.....	Oct. 28	Oct. 20	Oct. 12	Sept. 29	Sept. 25	Sept. 7	Aug. 25	
5 years in 10 earlier than.....	Nov. 8	Nov. 1	Oct. 22	Oct. 10	Sept. 27	Sept. 17	Sept. 7	July 20

rare; only two tornadoes were reported in this county during the period from 1916 to 1961.

The first measurable snowfall generally occurs in November, and the last measurable snowfall comes early in April about 1 year in 2. Annual snowfall has ranged from 10.8 inches in 1930 to 88.2 inches in 1951. Snowfall is most important because it helps build up the reserves of moisture in the subsoil.

Long-term records of humidity, the amount of cloudiness, and wind direction are not available. Records at the Rochester weather station, however, are considered representative for the county. The records at Rochester indicate that in summer the average humidity at noon is between 52 and 55 percent, and that in winter the average humidity at noon is between 72 and 79 percent. The prevailing wind direction is northwesterly from November to April and southeasterly during the other months.

During a typical year there are 78 days that are clear, 135 days that are partly cloudy, and 152 days that are cloudy.

Farming in this county is influenced by shifts from the modal climatic pattern. In some years, for example, warm air from the south encroaches for brief periods in winter and causes what are locally called January or February thaws. During these short periods, the snow cover melts and there are wide extremes between daytime and nighttime temperatures. Legumes, fruit trees, and other kinds of trees are sometimes injured.

Alternate freezing and thawing during the so-called spring breakup may damage legumes on fine-textured soils that have not been drained. Occasionally, a "late spring" affects the timeliness of field operations.

The pronounced increase in precipitation during May and June is characterized by rains of high intensity. Then, erosion is likely to be especially severe on exposed

TABLE 10.—*Probabilities of precipitation in stated quantity by 3-week periods*

[Based on records kept at Waseca, Minn.]

Date	Probability by amount of precipitation							
	0 or trace ¹	0.20 inch	0.40 inch	0.60 inch	0.80 inch	1.00 inch	1.40 inches	2.00 inches
March 1 to March 21.....	Percent 0	Percent 87	Percent 73	Percent 59	Percent 48	Percent 39	Percent 25	Percent 12
March 22 to April 11.....	0	96	89	80	70	61	44	26
April 12 to May 2.....	3	97	95	90	84	77	62	40
May 3 to May 23.....	0	100	98	95	90	84	70	48
May 24 to June 13.....	0	100	99	98	95	92	85	71
June 14 to July 4.....	0	100	99	98	95	92	84	69
July 5 to July 25.....	0	98	93	88	81	74	61	43
July 26 to August 15.....	0	94	88	81	75	70	60	47
August 16 to September 5.....	0	99	97	93	87	81	67	48
September 6 to September 26.....	0	99	97	93	88	82	70	53
September 27 to October 17.....	3	86	73	62	53	44	31	18
October 18 to November 7.....	5	83	70	58	48	39	26	14
November 8 to November 28.....	5	84	71	59	49	40	27	14
November 29 to December 19.....	3	78	54	36	23	14	5	1
December 20 to January 9.....	3	78	59	44	33	24	13	5
January 10 to January 30.....	5	81	57	36	22	12	4	1
January 31 to February 27.....	3	85	65	47	32	21	9	2

¹ A trace of precipitation is an amount too small to measure.

soils where moisture is at or near field capacity. The crop cover and the generally lower supply of moisture in July and August reduce the damage done by intense rains during that period. Occasionally, a prolonged rainy period in June delays spraying or the cultivation of corn and soybeans. It may also delay the harvesting of the first crop of hay.

In some seasons high temperatures and erratic rainfall during July and early in August reduce the bushel weight of small grains and adversely affect the pollination of corn. Sometimes persistent light rains in October and early in November hamper the harvesting of corn and soybeans. Frost occasionally occurs in the lower lying areas late in May, in August, and early in September. Infrequently—once in 20 years or more—climatic patterns that are typical of those in the Great Plains (5) drift into the county, and, as a result, periods of drought stress occur (4).

Although adverse weather sometimes affects farming in this county, a crop failure has never occurred. The usual weather pattern is one especially adapted to the high production of corn, small grains, soybeans, and hay.

Social and Industrial Development

The area that is now Steele County was opened to legal settlement when the Sioux Indians transferred a large area of land west of the Mississippi by the Treaty of Traverse de Sioux in 1851. Steele County was settled in 1854 and organized in 1855. The majority of the early settlers came from the eastern areas of the United States and from Canada. Nationality of these settlers was influenced by the historic emigrations of Irish, Bohemians, Germans, and Scandinavians from Europe about the same time as the organization of Steele County. The main trading centers are Owatonna, the county seat, population 13,400; Blooming Prairie, 1,778; Ellendale, 500; Medford, 560; Hope; and Meriden.

The first railroad transportation was provided in 1871. The county is now served by three railroads and by bus lines. Adequate airport facilities for all light aircraft and for heavy aircraft that gross less than 20,000 pounds are located at Owatonna.

Convenient marketing facilities are available for farm products either within the county or at nearby larger centers. Owatonna, Blooming Prairie, Ellendale, Medford, and Meriden provide outlets for milk. Packing plants at South St. Paul, Albert Lea, and Austin provide markets for livestock products. Owatonna, Blooming Prairie, Ellendale, Hope, Medford, and Meriden have grain elevators. Plants for processing soybeans are located at nearby Mankato and Savage, and plants for processing corn, peas, pumpkins, and asparagus are located at Owatonna.

Farming

Early farming in Steele County was largely of a subsistence type. Wheat, oats, and an occasional field of barley and corn were the main crops. Wheat and oats were the principal source of cash. Livestock numbers were few. As more land was opened to cultivation, as machinery improved, as the labor supply increased, and as transportation improved, farming moved out of the subsistence type

to a cash-grain type of farming with wheat the main crop.

By 1880 the trend to diversification began. Wheat lost its economic advantage to feed grains, meat, and dairy products and began a decline in importance in Steele County. The diversification era was built around the dairy herd. Dairy animals made the most profitable utilization of the forage available on soils in need of drainage. Dairying continues to be a significant farm enterprise, but a trend has developed away from many small dairy farms to fewer and larger dairy farms. Confined feeding is rapidly becoming a major management practice. The trend away from small dairy farms has marked a shift from diversification to specialization in one or two enterprises. Hogs were of minor importance in early farming, but, with increases in the acreage and quality of corn, hogs became a prominent source of farm income.

Poultry flocks received little management until about 1930, when they became a significant source of farm income. In the 1950's economic pressure caused poultry raising to become more specialized. Only a few small flocks of sheep are kept in the county.

The raising of beef cattle was a minor enterprise in early farming. Beef herds have been limited in number. The number of feeder cattle has been significant during times of favorable prices, but they have not been so large a source of income as the dairy and hog enterprises. Increased corn production and a reduction in the number of dairy farms have created a trend to increased number of feeder cattle operations. Corn acreage was small in early farming. The majority of the early varieties were not suited to the climate of Steele County. The improvement of varieties and market facilities for corn and soybeans has been the main influence in recent shifts from diversification to specialization. Soybean acreage has increased rapidly since 1945 and is now second to corn in dollar value of cash grain. The increased soybean acreage caused a decline in small-grain and meadow acreage.

Oats were grown for livestock feed and for market in the early years. Now this crop is used primarily as a specialized feed for livestock and as a companion crop for legumes.

Early farming made use of the native prairie grasses as a source of hay. In the 1880's red clover and timothy began to be important tame hay crops. Alfalfa and sweet-clover did not achieve any great prominence until 1920, when methods for successfully growing them became better understood.

Drainage development has been one of the most significant influences on farming in Steele County. At the time of settlement, approximately 48 percent of the total acreage in the county needed artificial drainage. Improvement of drainage outlets began in the early 1880's. Interest in tile drainage developed about 1910. Tractor power, which replaced horses, and the increased size of machinery produced an accelerated interest in complete drainage during the 1940's and 50's. A few of the outlets are in need of further development, but drainage projects are now principally concerned with continued improvement of established systems and the reclaiming of odd areas. Most of the drained acreage has been shifted from pasture use to corn and soybeans.

Canning factories in Owatonna and Waseca have influenced a moderate acreage to be planted to sweet corn,

green beans, peas, asparagus, and pumpkins. Truck crops are grown on some of the larger areas of organic soils.

According to the Minnesota agricultural statistics, in 1969 there were 65,100 acres of corn, 47,600 acres of soybeans, 28,000 acres of oats, 1,900 acres of spring wheat, and 23,500 acres of all hay crops. There were 41,300 cattle and calves, 18,400 milk cows, 105,400 hogs and pigs, and 199,000 chickens in the county. There were small acreages of other crops and some other livestock.

Literature Cited

- (1) AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS.
1961. STANDARD SPECIFICATIONS FOR HIGHWAY MATERIALS AND METHODS OF SAMPLING AND TESTING. Ed. 8, 2 v., illus. Washington, D.C.
- (2) ARNEMAN, HAROLD F., KHAN, AZZIZ D., and McMILLER, P. R.
1958. PHYSICAL, CHEMICAL, AND MINERALOGICAL PROPERTIES OF RELATED MINNESOTA PRAIRIE SOILS. Univ. of Minn. Agr. Expt. Sta. Tech. Bul. 227, 47 pp., illus.
- (3) BALDWIN, MARK, KELLOGG, CHARLES E., and THORP, JAMES.
1938. SOIL CLASSIFICATION. U.S. Dept. Agr. Yearbook, 1938, 979-1001, illus.
- (4) BLAKE, G. R., ALLRED, E. R., VAN BAVEL, C. H. M., and WHISLER, F. D.
1960. AGRICULTURAL DROUGHT AND EXCESSES IN MINNESOTA. Univ. of Minn. Agr. Expt. Sta. Tech. Bul. 235, 36 pp., illus.
- (5) BORCHERT, JOHN R.
1950. THE CLIMATE OF THE CENTRAL NORTH AMERICAN GRASSLAND. Ann. of the Assoc. of Amer. Geog. 40(1), 39 pp., illus.
- (6) IOWA STATE UNIVERSITY.
1959. FIRST REPORT TO THE NORTH CENTRAL REGIONAL TECHNICAL COMMITTEE ON WEATHER INFORMATION FOR AGRICULTURE. 277 pp. Ames, Iowa.
- (7) PORTLAND CEMENT ASSOCIATION.
1956. PCA SOIL PRIMER. 86 pp., illus. Chicago.
- (8) SIMONSON, ROY W.
1959. OUTLINE OF A GENERALIZED THEORY OF SOIL GENESIS. Soil Sci. Soc. Amer. Proc. 23(2): 152-156, illus.
- (9) ———
1962. SOIL CLASSIFICATION IN THE UNITED STATES. Sci. 137: 1027-1037.
- (10) THIEL, GEORGE A.
1956. GEOLOGY AND UNDERGROUND WATERS OF SOUTHERN MINNESOTA. Minn. Geol. Surv. Bul. 31, 506 pp., illus.
- (11) THORP, JAMES, and SMITH, GUY D.
1949. HIGHER CATEGORIES OF SOIL CLASSIFICATION: ORDER, SUBORDER, AND GREAT SOIL GROUPS. Soil Sci. 67: 117-126.
- (12) UNITED STATES DEPARTMENT OF AGRICULTURE.
1951. SOIL SURVEY MANUAL. U.S. Dept. Agr. Handbook 18, 503 pp., illus. [Supplement issued in May 1962]
- (13) ———
1960. SOIL CLASSIFICATION, A COMPREHENSIVE SYSTEM. 7TH APPROXIMATION. 265 pp., illus. [Supplements issued in March 1967 and in September 1968]
- (14) UNITED STATES DEPARTMENT OF DEFENSE.
1968. UNIFIED SOIL CLASSIFICATION SYSTEM FOR ROADS, AIRFIELDS, EMBANKMENTS, AND FOUNDATIONS. MIL-STD-619B, 30 pp., illus.

Glossary

Aggregate, soil. Many fine particles held in a single mass or cluster. Natural soil aggregates, such as crumbs, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.

Alluvium. Soil material, such as sand, silt, or clay, that has been deposited on land by streams.

Available water capacity (also termed available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil.

Back-wasting glacier. An ice sheet in which the principal melting or wasting occurs along the leading edge.

Calcareous soil. A soil that contains enough calcium carbonate (often with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid.

Calcification. The soil-forming process that keeps enough calcium in the surface layer to saturate the soil colloids with exchangeable calcium to the extent that the colloids are rendered almost immobile and almost neutral in reaction.

Clay. As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt. See also Texture, soil.

Concave slope. An inwardly rounded slope.

Consistence, soil. The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms commonly used to describe consistence are—

Loose.—Noncoherent when dry or moist; does not hold together in a mass.

Friable.—When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

Firm.—When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.—When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" if rolled between thumb and forefinger.

Sticky.—When wet, adheres to other material and tends to stretch somewhat and to pull apart, rather than to pull free from other material.

Hard.—When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Soft.—When dry, breaks into powder or individual grains under very slight pressure.

Cemented.—Hard and brittle; little affected by moistening.

Convex slope. An arched, or outwardly rounded, slope.

Crust. The hard, brittle layer that forms on many soils when dry.

Drumloid (geology). More or less oval hills or ridges composed of glacial till, approaching the true drumlin in shape but less regular and less symmetrically arranged.

Erosion. The wearing away of the land surface by wind, running water, and other geological agents.

First bottom. The normal flood plain of a stream, subject to frequent or occasional flooding.

French drain. A section of a tile trench, above the tile, that is fitted with stone, gravel, or crushed rock, or a combination of these materials.

Glacial drift (geology). Rock material transported by glacial ice and then deposited; also includes the assorted and unassorted materials deposited by streams flowing from glaciers.

Glacial outwash (geology). Cross-bedded gravel, sand, and silt deposited by melt water as it flowed from glacial ice.

Glacial till (geology). Unassorted, nonstratified glacial drift that consists of clay, silt, sand, and boulders transported and deposited by glacial ice.

Gleization. The reduction, translocation, and segregation of soil compounds, notably of iron, usually in the lower horizons, as a result of waterlogging with poor aeration and drainage; expressed in the soil by mottled colors dominated by gray. The soil-forming processes leading to the development of a gley soil.

Gravelly soil material. From 15 to 50 percent of material, by volume, consists of rounded or angular rock fragments that are not prominently flattened and are up to 3 inches in diameter.

Horizon, soil. A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. These are the major horizons:

O horizon.—The layer of organic matter on the surface of a mineral soil. This layer consists of decaying plant residues.

A horizon.—The mineral horizon at the surface or just below an O horizon. This horizon is the one in which living organisms are most active, and therefore it is marked by the

accumulation of humus. The horizon may have lost one or more of soluble salts, clay, and sesquioxides (iron and aluminum oxides).

B horizon.—The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or some combination of these; (2) by prismatic or blocky structure; (3) by redder or stronger colors than the A horizon; or (4) by some combination of these. Combined A and B horizons are usually called the solum, or true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

C horizon.—The weathered rock material immediately beneath the solum. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a Roman numeral precedes the letter C.

Humus. The well-decomposed, more or less stable part of the organic matter in mineral soils.

Kame (geology). An irregular, short ridge or hill of stratified glacial drift.

Lacustrine deposit (geology). Material deposited in lake water and exposed by lowering of the water level or elevation of the land.

Lake, glacial. A lake developed by the ponding of water within or in front of a glacial ice sheet.

Lake plain. A nearly level or undulating surface covered by sediment deposited by the waters of a glacial lake.

Leaching. The removal of soluble materials from soils or other material by percolating water.

Mineral soil. Soil composed mainly of inorganic (mineral) material and low in content of organic material. Its bulk density is greater than that of an organic soil.

Montmorillonite. A fine, platy, aluminosilicate clay mineral that expands and contracts with the absorption and loss of water. It has a high cation-exchange capacity and is plastic and sticky when moist.

Moraine (geology). An accumulation of earth, stones, and other debris deposited by a glacier. Types are terminal, lateral, medial, and ground.

Mottled. Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage. Descriptive terms are as follows: Abundance—*few*, *common*, and *many*; size—*fine*, *medium*, and *coarse*; and contrast—*faint*, *distinct*, and *prominent*. The size measurements are these: *fine*, less than 5 millimeters (about 0.2 inch) in diameter along the greatest dimension; *medium*, ranging from 5 millimeters to 15 millimeters (about 0.2 to 0.6 inch; in diameter along the greatest dimension; and *coarse*, more than 15 millimeters (about 0.6 inch) in diameter along the greatest dimension.

Muck. An organic soil that consists of fairly well decomposed organic material that is relatively high in mineral content, finely divided, and dark in color.

Munsell notation. A system for designating color by degrees of the three simple variables—hue, value, and chroma. For example, a notation of 10YR 6/4 is a color with a hue of 10YR, a value of 6, and a chroma of 4.

Organic soil. A general term applied to a soil or to a soil horizon that consists primarily of organic matter, such as peat soils, muck soils, and peaty soil layers. In chemistry, organic refers to the compounds of carbon.

Parent material. The disintegrated and partly weathered rock from which soil has formed.

Peat. Unconsolidated soil material, largely undecomposed organic matter, that has accumulated where there has been excess moisture.

Podzolization. The process by which a soil is depleted of bases, becomes more acid, and develops a leached surface layer.

Productivity (of soil). The present capability of a soil for producing a specified plant or sequence of plants under a specified system of management. It is measured in terms of output, or harvest, in relation to input of production for the specific kind of soil under a specified system of management.

Profile, soil. A vertical section of the soil through all its horizons and extending into the parent material.

Reaction, soil. The degree of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is precisely

neutral in reaction because it is neither acid nor alkaline. An acid, or "sour," soil is one that gives an acid reaction. In words, the degrees of acidity or alkalinity are expressed thus:

<i>pH</i>		<i>pH</i>	
Extremely acid---	Below 4.5	Mildly alkaline-----	7.4 to 7.8
Very strongly acid--	4.5 to 5.0	Moderately alkaline--	7.9 to 8.4
Strongly acid-----	5.1 to 5.5	Strongly alkaline-----	8.5 to 9.0
Medium acid-----	5.6 to 6.0	Very strongly alkaline	
Slightly acid-----	6.1 to 6.5	line -----	9.1 and higher
Neutral-----	6.6 to 7.3		

Relief. The elevations or inequalities of a land surface, considered collectively.

Sand. Individual rock or mineral fragments in soils that range in diameter from 0.05 to 2.0 millimeters. Most sand grains consist of quartz, but they may be of any mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay. See also Texture, soil.

Silt. Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay. See also Texture, soil.

Soil. A natural, three-dimensional body on the earth's surface that supports plants and that has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

Solum. The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soil includes the A and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the underlying material. The living roots and other plant and animal life characteristic of the soil are largely confined to the solum.

Stratified. Composed of, or arranged in, strata, or layers, such as stratified alluvium. The term is confined to geological material. Layers in soils that result from the processes of soil formation are called horizons; those inherited from the parent material are called strata.

Structure, soil. The arrangement of primary soil particles into compound particles or clusters that are separated from adjoining aggregates and have properties unlike those of an equal mass of unaggregated primary soil particles. The principal forms of soil structure are—*platy* (laminated), *prismatic* (vertical axis of aggregates longer than horizontal), *columnar* (prisms with rounded tops), *blocky* (angular or subangular), and *granular*. *Structureless* soils are (1) *single grain* (each grain by itself, as in dune sand) or (2) *massive* (the particles adhering together without any regular cleavage, as in many claypans and hardpans).

Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.

Substratum. Technically, the part of the soil below the solum.

Surface soil. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, about 5 to 8 inches in thickness. The plowed layer.

Terrace. An embankment, or ridge, constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surplus runoff so that it may soak into the soil or flow slowly to a prepared outlet without harm. Terraces in fields are generally built so they can be farmed. Terraces intended mainly for drainage have a deep channel that is maintained in permanent sod.

Terrace (geological). An old alluvial plain, ordinarily flat or undulating, bordering a river, lake, or the sea. Stream terraces are frequently called second bottoms, as contrasted to flood plains, and are seldom subject to overflow. Marine terraces were deposited by the sea and are generally wide.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportions of fine particles, are *sand*, *loamy sand*, *sandy loam*, *loam*, *silt loam*, *silt*, *sandy clay loam*, *clay loam*, *silty clay loam*, *sandy clay*, *silty clay*, and *clay*. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

Till plain. A nearly level or undulating land surface covered by glacial till.

Tilth, soil. The condition of the soil in relation to the growth of plants, especially soil structure. Good tilth refers to the friable state and is associated with high noncapillary porosity and stable, granular structure. A soil in poor tilth is nonfriable, hard, nonaggregated, and difficult to till.

Topsoil. A presumed fertile soil or soil material, or one that responds to fertilization, ordinarily rich in organic matter, used to topdress roadbanks, lawns, and gardens.

Transported soil material. The parent material of a soil that has been moved from its place of origin and redeposited during the weathering process or during some part of the weathering process.

Variant, soil. A soil having properties sufficiently different from those of other known soils to suggest establishing a new soil series, but a soil of such limited known area that creation of a new series is not believed to be justified.

Accessibility Statement

This document is not accessible by screen-reader software. The Natural Resources Conservation Service (NRCS) is committed to making its information accessible to all of its customers and employees. If you are experiencing accessibility issues and need assistance, please contact our Helpdesk by phone at 1-800-457-3642 or by e-mail at ServiceDesk-FTC@ftc.usda.gov. For assistance with publications that include maps, graphs, or similar forms of information, you may also wish to contact our State or local office. You can locate the correct office and phone number at <http://offices.sc.egov.usda.gov/locator/app>.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

