SOIL SURVEY OF

Benton County, Minnesota

United States Department of Agriculture
Soil Conservation Service

In cooperation with

Minnesota Agricultural Experiment Station

This is a publication of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and agencies of the States, usually the Agricultural Experiment Stations. In some surveys, other Federal and local agencies also contribute. The Soil Conservation Service has leadership for the Federal part of the National Cooperative Soil Survey.

Major fieldwork for this soil survey was completed in the period 1958–69. Soil names and descriptions were approved in 1969. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1970. This survey was made cooperatively by the Soil Conservation Service and the Minnesota Agricultural Experiment Station. It is part of the technical assistance furnished to the Benton Soil and Water Conservation District.

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 Benton County are shown on the detailed map at the back of this survey. This map consists of many sheets made from aerial photographs. Each sheet is numbered to correspond with numbers shown 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, woodland suitability group, and building site group in which the soil has been placed.

Individual colored maps showing the relative suitability or limitation of soils for many specific purposes can be developed by using the soil map and the information in the text. Interpretations not included in the text can be developed by grouping the soils according to their suitability or limitations for a particular use. 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 interpretative groupings.

Foresters and others can refer to the section "Woodland," where the soils of the county are grouped according to their suitability for trees.

Game managers, sportsmen, and others can find information about soils and wildlife in the sections "Wildlife" and "Recreation."

Community planners and others can read about the soil properties that affect the choice of homesites, industrial sites, schools, and parks in the section "Town and Country Planning."

Engineers and builders can find under "Engineering Uses of the Soils" tables that give engineering descriptions of the soils in the county and that name soil features that affect engineering practices and structures.

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

Students, teachers, and others will find information about soils and their management in various parts of the text.

Newcomers in Benton 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 section "General Nature of the County."

Cover: **Contour stripcropping on soils of the Brainerd-Nokay-Prebish association.**

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SOIL SURVEY OF BENTON COUNTY, MINNESOTA

BY CHARLES K. SUTTON, SOIL CONSERVATION SERVICE

FIELDWORK BY MARTIN G. ZIEBELL, IN CHARGE, AND M. F. GRIMES, D. J. PRESTON, AND C. K. SUTTON, SOIL CONSERVATION SERVICE

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

BENTON COUNTY is in the central part of Minnesota (fig. 1). It has a total land area of 254,939 acres and a water area of about 3,621 acres. The village of Foley is the county seat. Other important villages in the county are Duelm, Oak Park, Rice, Ronneby, Sartell, Sauk Rapids, and part of St. Cloud.

The main economic enterprise in the county is farming. Growing of corn, oats, rye, soybeans, and hay, dairying, and stock raising are the main sources of income.

The population of the county is 20,721. About 6,950 persons are employed, of which 1,250 are in farming and related occupations. Roughly 1,032 farms are in the county, and the average size is 187 acres per farm.

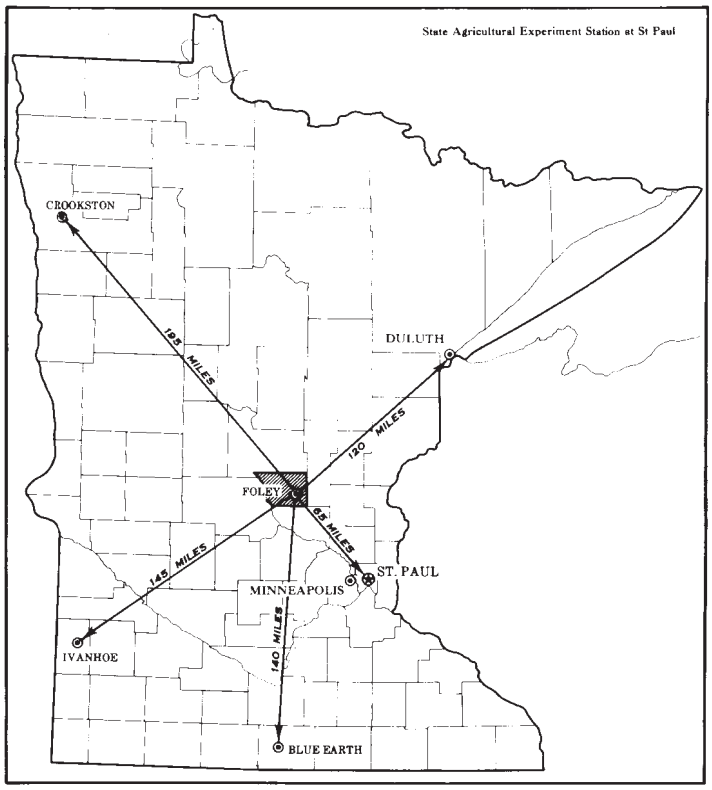

Figure 1.—Location of Benton County in Minnesota.

Benton County has dark-colored and light-colored, nearly level to steep soils that formed in glacial material. The original vegetation was medium and tall prairie grasses and mixed hardwood forest.

How This Survey Was Made

Soil scientists made this survey to learn what kinds of soil are in Benton 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 counties nearby and 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. Duelm and Sartell, 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 layer 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, Flak sandy loam, 2 to 6 percent slopes, is one of several phases within the Flak 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 at the back of this publication was prepared from 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 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 Benton County: soil complexes and undifferentiated groups.

A soil complex consists of areas of two or more soils, so intricately mixed 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. Generally, the name of a soil complex consists of the names of the dominant soils, joined by a hyphen. Chetek-Milaca complex is an example.

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. Prebish and Parent loams is an undifferentiated soil group in this county.

In most areas surveyed there are places where the soil material is so rocky, so shallow, so severely eroded, or so variable that it has not been 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. Granite rock land is a land type in this county.

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

Soil scientists observe how soils behave when used as a growing place for native and cultivated plants, and as material for structures, foundations for structures, or covering for structures. They relate this behavior to properties of the soils. For example, they observe that filter fields for onsite disposal of sewage fail on a given kind of soil, and they relate this to the slow permeability of the soil or a high water table. They see that streets, road pavements, and foundations for houses are cracked on a named kind of soil and they relate this failure to the high shrink-swell potential of the soil material. Thus, they use observation and knowledge of soil properties, together with available research data, to predict limitations or suitability of soils for present and potential uses.

After data have been collected and tested for the key, or benchmark, soils in a survey area, the soil scientists set up trial groups of soils. They test these groups by further study and by consultation with farmers, agronomists, engineers, and others. They then adjust 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 current 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 Benton County. A soil association is a landscape that has a distinctive proportional 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 soil associations in Benton County are discussed in the following pages.

1. Parent-Ronneby-Prebish association

Deep, somewhat poorly drained to very poorly drained, level and depressional loams formed in reddish-brown and brown glacial till; on uplands

This association is on ground moraines that have relief ranging from 2 to 5 feet. It is characterized by large flats and many depressions (fig. 2).

This association covers about 22 percent of the county. About 30 percent of it is Parent soils, 25 percent is Ronneby soils, 15 percent is Prebish soils, and 30 percent is minor soils.

Parent soils are on large, broad flats and in narrow areas that encircle depressions. They are level and poorly drained. Permeability is moderately slow to slow. The surface layer is black loam about 11 inches thick. The subsoil is dark grayish-brown and grayish-brown fine sandy loam in the upper part and firm, reddish-brown fine sandy loam in the lower part. The underlying material is firm, reddish-brown sandy loam.

Ronneby soils are at the base of slopes, at the heads of shallow drainageways, and on ground moraines. These soils are nearly level and somewhat poorly drained. Permeability is moderately slow. The surface

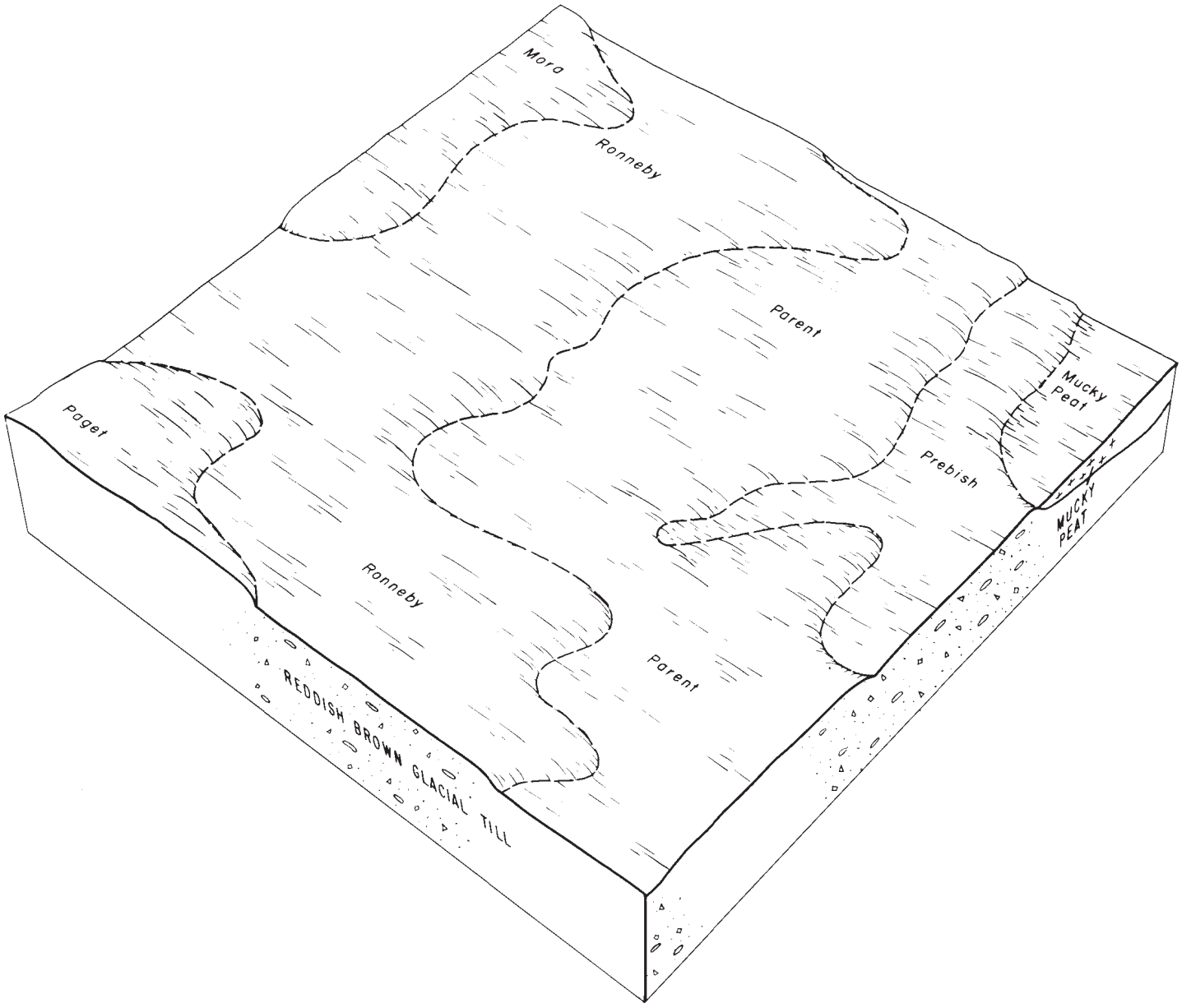

***Figure 2.*—Pattern of soils and underlying material in association 1.**

layer is black loam about 4 inches thick. The subsurface layer is dark-gray and dark grayish-brown fine sandy loam about 8 inches thick. The subsoil is mainly dark-brown fine sandy loam. It is underlain by firm, reddish-brown fine sandy loam at a depth of about 56 inches. A fragipan starts at a depth of about 22 to 36 inches.

Prebish soils are in shallow depressions and on the margins of larger depressions that occur in undulating to rolling ground moraines and between drumlins. These soils are very poorly drained. Permeability is moderately slow. The surface layer is black loam 16 inches thick. The subsoil is gray fine sandy loam. It is underlain by firm, reddish-brown sandy loam at a depth of about 46 inches.

Minor soils in this association are in the Mora, Antigo, Ogilvie, Hillet, Freer, and Paget series. Also included are some Mucky peat. The swales and low, concave areas are occupied by wet Ronneby, Parent, and Prebish soils, and Mucky peat. Areas of gently sloping, moderately well drained Mora and Paget soils are near the somewhat poorly drained Ronneby and Freer soils. Well-drained Antigo soils are near the somewhat poorly drained Ogilvie soils and the very poorly drained Hillet soils.

Corn, soybeans, small grain, and hay grow fairly well in areas of this association if adequate drainage is provided. Fertility is medium. Organic-matter content generally is high, but the Ronneby soils have moderate organic-matter content. Available water capacity is

moderate to high. The main needs of management are providing adequate drainage, maintaining tilth, and increasing fertility. Stones must be removed periodically.

2. *Mora-Ronneby-Parent association*

Deep, moderately well drained to very poorly drained, nearly level to gently sloping fine sandy loams and loams formed in reddish-brown glacial till; on uplands

This association is on ground moraines that have relief between the swells and swales ranging from 5 to 20 feet. Slopes are mostly nearly level to gently sloping. The gentle slopes range from 100 to 500 feet in length. Slopes are steeper in a few places, especially along the larger drainageways.

This soil association covers about 27 percent of the county. About 51 percent of it is Mora soils, 10 percent is Ronneby soils, 8 percent is Parent soils, and 31 percent is minor soils.

Mora soils are on elliptical swells. They are moderately well drained. Permeability is moderately slow. The surface layer is black fine sandy loam about 4 inches thick. It changes abruptly to a subsurface layer of dark grayish-brown and brown fine sandy loam about 8 inches thick. The subsoil is mainly reddish-brown fine sandy loam. It is underlain by firm, dark reddish-brown and reddish-brown sandy loam at a depth of about 48 inches. A fragipan starts at a depth of about 18 to 32 inches.

Ronneby soils are at the base of slopes, at the heads of drainageways, and on ground moraines. These soils are nearly level. They are somewhat poorly drained. Permeability is moderately slow. The surface layer is black loam about 4 inches thick. It changes to a subsurface layer of dark-gray and dark grayish-brown fine sandy loam about 8 inches thick. The subsoil is mainly dark-brown fine sandy loam. It is underlain by firm, reddish-brown fine sandy loam at a depth of about 56 inches. A thick fragipan starts at a depth of about 22 to 36 inches.

Parent soils are on large, broad flats and in narrow areas that encircle depressions. They are poorly drained. Permeability is moderately slow to slow. The surface layer is black loam about 11 inches thick. The subsoil is dark grayish-brown and grayish-brown fine sandy loam in the upper part and firm, reddish-brown fine sandy loam in the lower part. The underlying material is firm, reddish-brown sandy loam.

Minor soils in this association are in the Milaca and Chetek series. Also included are mucky peats. The swales and low, concave areas are occupied by the wet Ronneby and Parent soils and mucky peats. Areas of the sloping Milaca and Chetek soils are closely intermingled with areas of Mora soils. The Chetek soils also occur on outwash terraces.

Corn, soybeans, small grain, and hay grow fairly well on the soils of this association. Fertility and organic-matter content generally are medium to low, but the Parent soils have high organic-matter content. Available water capacity is moderate to high. The main needs of management are controlling water erosion, improving drainage, maintaining tilth, and increasing fertility. Stones must be removed periodically.

About 70 percent of this association is in cultivated crops. Some steep areas, forested areas, and undrained wet areas are used for permanent pasture and wildlife habitat. The main enterprise is dairying. The soils have a moderate potential for all cultivated crops commonly grown in the county.

3. *Brainerd-Nokay-Prebish association*

Deep, moderately well drained to very poorly drained, nearly level to gently sloping sandy loams and loams formed in brown glacial till; on uplands

This association is on ground moraines that are made up of elongated swells called drumlins (fig. 3). The drumlins are separated by swales and by flats in which there are long, shallow depressions. Relief ranges from 10 to 30 feet. The gentle slopes range from 400 to 1,000 feet in length. Slopes are steeper in a few places, especially along the larger drainageways.

This association covers about 28 percent of the county. About 30 percent of it is Brainerd soils, 15 percent is Nokay soils, 11 percent is Prebish soils, and 44 percent is minor soils.

Brainerd soils are on the drumlins. They are moderately well drained. Permeability is moderately slow. The surface layer is very dark grayish-brown sandy loam about 6 inches thick. It changes abruptly to a brown sandy loam subsurface layer that is about 8 inches thick. The subsoil is brown and dark reddish-brown sandy loam. It is underlain by firm, brown sandy loam at a depth of about 46 inches. A fragipan starts at a depth of about 18 to 30 inches.

Nokay soils are next to depressions and narrow drainageways that cut into the better drained uplands. These soils are nearly level. They are somewhat poorly drained. Permeability is moderately slow. The surface layer is black fine sandy loam about 4 inches thick. It changes to a subsurface layer of dark grayish-brown and grayish-brown fine sandy loam about 5 inches thick. The subsoil is dark grayish-brown and grayish-brown fine sandy loam in the upper part, reddish-brown fine sandy loam in the middle part, and brown sandy loam in the lower part. It is underlain by firm, brown sandy loam at a depth of about 42 inches. A fragipan starts at a depth of about 22 to 36 inches.

Prebish soils are in shallow depressions and on the margins of larger depressions that occur on undulating to rolling ground moraines and between drumlins. These soils are very poorly drained. Permeability is moderately slow. The surface layer is black loam 16 inches thick. The subsoil is gray fine sandy loam and is underlain by firm, reddish-brown sandy loam at a depth of about 46 inches.

Minor soils in this association are in the Flak, Mora, Ronneby, Chetek, Pomroy, and Langola series. Also included are some mucky peats. The swales and low, concave areas are occupied by Nokay, Ronneby, and Prebish soils and mucky peats. Areas of sloping Flak, Chetek, Pomroy, and Langola soils are intermingled with areas of Brainerd soils. The Chetek soils also occur on outwash terraces.

Corn, soybeans, small grain, and hay grow fairly well on the soils of this association. Fertility is medium. Organic-matter content generally is low to medium, but the Prebish soils have high organic-matter content. Available water capacity is moderate to high. The main

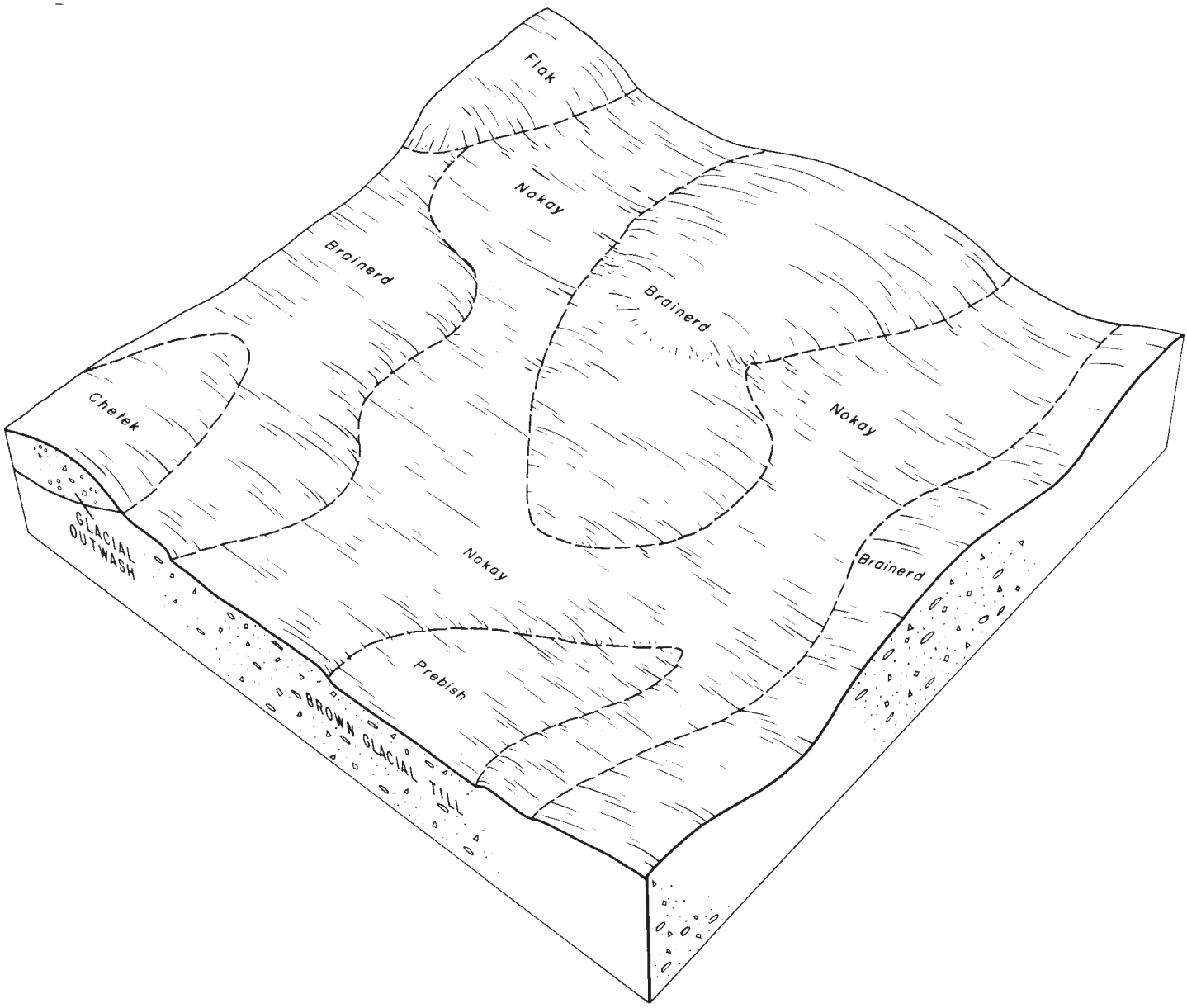

Figure 3.—**Pattern of soils and underlying material in association 3.**

needs of management are controlling water erosion, improving drainage, maintaining tilth, and increasing fertility. Stones must be removed periodically.

About 70 percent of this association is in cultivated crops. Some steep areas, forested areas, and undrained wet areas are used for permanent pasture and wildlife habitat. The main enterprise is dairying. The soils have moderate potential for all cultivated crops commonly grown in the county.

4. *Hubbard-Duelm association*

Deep, excessively drained and somewhat poorly drained, nearly level and gently sloping loamy sands; on outwash plains and terraces

This association is on nearly level and undulating glacial outwash plains and terraces adjacent to the Mississippi River and along its old glacial drainageways. Relief ranges from 5 to 10 feet. The short, gentle slopes are 100 to 200 feet in length. Slopes are steeper in a few places along the drainageways.

This soil association covers about 12 percent of the county. About 62 percent of it is Hubbard soils, 6 percent is Duelm soils, and 32 percent is minor soils.

Hubbard soils are on outwash terraces and are nearly level and gently sloping. They are excessively drained. Permeability is rapid. The surface layer is black and very dark grayish-brown loamy coarse sand about 23 inches thick. The subsoil is dark-brown to brown sand. The underlying material is brown, loose sand.

Duelm soils are in shallow depressions and narrow

areas that border deeper depressions. They are somewhat poorly drained. Permeability is rapid. The surface layer is black loamy sand about 9 inches thick. The subsoil is dark grayish-brown and brown loamy sand. It is underlain by brown sand at a depth of about 52 inches.

Minor soils in this association are in the Isanti series. Also included are Alluvial land and mucky peats. The Isanti soils and the mucky peats formed in the deep depressions. The alluvial soils formed along the Mississippi River and other streams where frequent or occasional flooding has occurred.

Corn, soybeans, small grain, and hay are suited to the soils of this association. Fertility, organic-matter content, and available water capacity are moderately low. The main needs of management are controlling wind erosion, increasing fertility, improving drainage in wet areas, and providing adequate moisture for crops.

About 65 percent of this association is in cultivated crops. The rest is used as permanent pasture, is idle, or is open oak woods. In recent years pine plantings have increased. The main enterprise is dairying. Where these soils are not irrigated, they have low potential for all cultivated crops commonly grown in the county.

5. *Hubbard-Sartell association*

Deep, excessively drained, nearly level and undulating loamy sands and fine sands; on outwash plains and terraces

This association is on nearly level and undulating glacial outwash plains and terraces that roughly parallel the Mississippi River in the Little Rock area and extend northward. Relief ranges from 10 to 20 feet. Undulating to steep dunelike areas are on the east side of Little Rock Lake (fig. 4). The slopes are 100 to 200 feet in length.

This association covers about 6 percent of the county. About 55 percent of it is Hubbard soils, 29 percent is Sartell soils, and 16 percent is minor soils.

Hubbard soils are on outwash terraces. They are excessively drained. Permeability is rapid. The surface layer is black and very dark grayish-brown loamy coarse sand about 23 inches thick. The subsoil is dark-brown to brown sand. The underlying material is brown loose sand.

Sartell soils generally are undulating and occur in dunelike areas that are undulating to steep. They are excessively drained. Permeability is rapid. The surface layer is very dark brown and very dark grayish-brown loamy fine sand about 4 inches thick. The subsoil is dark-brown and brown loose fine sand. The underlying material is brown to light yellowish-brown loose fine sand.

Minor soils in this association are in the Duelm, Isanti, Langola, and Pomroy series. Also included are mucky peats. Duelm soils occupy shallow depressions and narrow areas bordering deeper depressions. Isanti soils and the mucky peats formed in the deep depressions.

Corn, soybeans, small grain, and hay are grown on the soils of this association. Fertility, organic-matter content, and available water capacity are low. The main needs of management are controlling wind erosion, increasing fertility, and providing adequate moisture for crops.

About 60 percent of this association is cultivated, and the rest is used for wild pasture and open oak woods. In recent years, pine plantings have increased. The main enterprise is dairying. Where these soils are not irrigated, they have low potential for all cultivated crops commonly grown in the county.

6. *Sartell-Isanti-Mucky peat association*

Deep, excessively drained and very poorly drained, nearly level and undulating fine sands, loamy fine sands, and mucky peat; on outwash plains

This association is on glacial outwash plains. Relief ranges from 10 to 40 feet. The slopes range from 100 to 200 feet in length. Slopes are steeper in a few places along the drainageways.

This association covers about 5 percent of the county. About 45 percent of it is Sartell soils, 25 percent is Isanti soils, 20 percent is Mucky peat and 10 percent is minor soils.

Sartell soils are in undulating to steep dunelike areas and are excessively drained. Permeability is rapid. The surface layer is very dark brown and very dark grayish-brown fine sand about 4 inches thick. The subsoil is dark-brown and brown loose fine sand. The underlying material is brown to light yellowish-brown loose fine sand.

Isanti soils are in depressions and drainageways and are very poorly drained. Permeability is rapid. The surface layer is black mucky loamy fine sand 11 inches thick. The subsoil is dark-gray and grayish-brown fine sand. The underlying material is light brownish-gray loose fine sand.

The Mucky peat soils are in deep depressions and are very poorly drained. They consist of black or very dark brown organic material that is partly to completely decomposed. The underlying material is sand, loam, or organic material.

Minor soils in this association are in the Langola, Pomroy, Watab, and Nokasippi series. Langola and Pomroy soils are nearly level and undulating. They are well drained and moderately well drained. The Watab soils are nearly level and are somewhat poorly drained. The Nokasippi soils are in depressions and are very poorly drained.

Corn, soybeans, small grain, and hay are grown on the soils of this association. Fertility is low. Organic-matter content generally is high to very high, but the Sartell soils have a low organic-matter content. The available water capacity is moderate to low for all the soils except the mucky peat, which has high available water capacity. The main needs of management are controlling wind erosion, increasing fertility, providing adequate drainage to the wet soils, and irrigating the Sartell soils.

About 40 percent of this association is in cultivated crops. The rest is used for wild pasture, hay, or oak woods. In recent years, pine plantings have increased. The main enterprise is dairying. The soils have a low to fair potential for all cultivated crops commonly grown in the county.

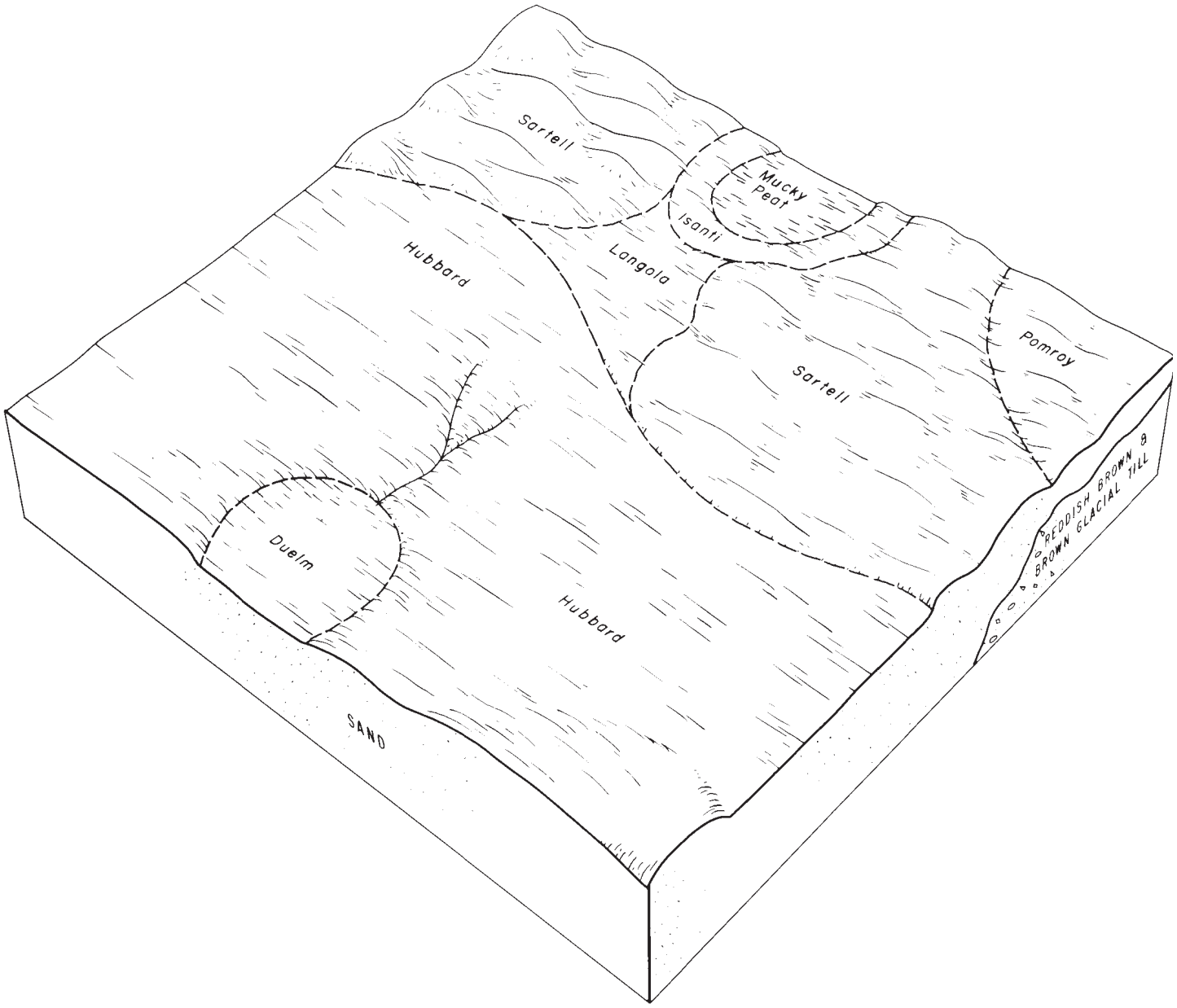

Figure 4.—**Pattern of soils and underlying material in association 5.**

Descriptions of the Soils

This section describes the soil series and mapping units in Benton County. Each soil series is described in detail, and then, briefly, each mapping unit in that series. Unless it is specifically mentioned otherwise, it is to be assumed 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 this profile. The first is brief and in terms familiar to the layman. The second is much more detailed and is for those who need to make thorough and precise studies of soils. The profile described in the series is representative for mapping units in that series. If the profile of a given mapping unit is different from the one described for the series, these differences are stated in describing the mapping unit, or they are differences that are apparent in the name of the mapping unit. Color terms are for moist soil unless otherwise stated.

As mentioned in the section "How This Survey Was Made," not all mapping units are members of a soil series. Granite rock land and Alluvial land, for example, do not belong to a soil series but, nevertheless,

are 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, woodland suitability group, and building site group in which the mapping unit has been placed. The page for the description of each capability unit, woodland suitability group, or other interpretative group can be learned by referring to the "Guide to Mapping Units" at the back of this survey.

The acreage and proportionate extent of each mapping unit are shown in table 1. Many of the terms used in describing soils can be found in the Glossary, and more detailed information about the terminology and methods of soil mapping can be obtained from the Soil Survey Manual (*7*).[1]

Adolph Series

The Adolph series consists of deep, level to depressional, very poorly drained soils in drainageways, de-

[1] Italic numbers in parentheses refer to Literature Cited, p. 116.

TABLE 1.—*Approximate acreage and proportionate extent of the soils*

Soil	Acres	Percent
Adolph silt loam	1,131	0.4
Adolph silt loam, level	957	.4
Adolph silt loam, silty subsoil variant	334	.1
Alluvial land	4,700	1.8
Antigo silt loam, 0 to 2 percent slopes	1,433	.6
Antigo silt loam, 2 to 6 percent slopes	709	.3
Blomford loamy sand	499	.2
Braham loamy fine sand, 2 to 8 percent slopes	552	.2
Brainerd sandy loam, 1 to 3 percent slopes	13,794	5.2
Brainerd sandy loam, 3 to 5 percent slopes	8,355	3.2
Brainerd stony sandy loam, 1 to 3 percent slopes	512	.2
Brainerd stony sandy loam, 3 to 5 percent slopes	328	.1
Burkhardt sandy loam, 0 to 2 percent slopes	365	.1
Burkhardt sandy loam, 2 to 6 percent slopes	187	.1
Chetek loamy sand, 2 to 6 percent slopes	1,437	.6
Chetek loamy sand, 6 to 12 percent slopes	488	.2
Chetek sandy loam, 0 to 2 percent slopes	1,076	.4
Chetek sandy loam, 2 to 6 percent slopes	2,612	1.0
Chetek sandy loam, 2 to 6 percent slopes, eroded	455	.2
Chetek sandy loam, 6 to 15 percent slopes	808	.3
Chetek-Milaca complex, 2 to 6 percent slopes	320	.1
Chetek-Milaca complex, 6 to 12 percent slopes	170	.1
Dalbo fine sandy loam, 0 to 2 percent slopes	357	.1
Dalbo silt loam, 2 to 8 percent slopes	394	.2
Dickman coarse sandy loam, 0 to 2 percent slopes	2,119	.8
Duelm loamy sand	1,971	.8
Emmert gravelly loamy sand, 6 to 25 percent slopes	439	.2
Flak sandy loam, 2 to 6 percent slopes	3,575	1.4
Flak sandy loam, 2 to 6 percent slopes, eroded	1,260	.5
Flak sandy loam, 6 to 12 percent slopes	193	.1
Flak sandy loam, 6 to 12 percent slopes, eroded	241	.1
Freer silt loam	1,763	.7
Freer stony silt loam	958	.4
Granite rock land	221	.1
Hillet silt loam	2,757	1.1
Hillet silt loam, level	2,230	.9
Hubbard loamy coarse sand, 0 to 2 percent slopes	4,008	1.5
Hubbard loamy coarse sand, 0 to 2 percent slopes, wind eroded	9,111	3.5
Hubbard loamy coarse sand, 2 to 6 percent slopes	1,218	.5
Hubbard loamy coarse sand, 2 to 6 percent slopes, eroded	4,684	1.8
Hubbard loamy fine sand, 0 to 2 percent slopes	1,160	.4
Hubbard loamy fine sand, 0 to 2 percent slopes, wind eroded	1,843	.7
Hubbard loamy fine sand, 2 to 6 percent slopes	931	.4
Hubbard loamy fine sand, 2 to 6 percent slopes, eroded	3,466	1.3
Hubbard soils, 6 to 12 percent slopes, eroded	1,008	.4
Hubbard soils, 12 to 25 percent slopes	330	.1
Isanti mucky loamy fine sand	2,969	1.1
Isanti mucky loamy fine sand, loamy subsoil variant	862	.3
Langola loamy fine sand, 0 to 2 percent slopes	840	.3
Langola loamy fine sand, 2 to 6 percent slopes, eroded	829	.3
Lino loamy fine sand	2,190	.9
Lino loamy fine sand, loamy subsoil variant	737	.3
Marsh	1,872	.7
Milaca fine sandy loam, 2 to 6 percent slopes	2,845	1.1
Milaca fine sandy loam, 2 to 6 percent slopes, eroded	1,457	.6
Milaca fine sandy loam, 6 to 12 percent slopes	568	.2
Milaca fine sandy loam, 6 to 12 percent slopes, eroded	721	.3
Milaca fine sandy loam, 12 to 25 percent slopes	222	.1
Milaca stony fine sandy loam, 2 to 6 percent slopes	1,246	.5
Milaca very fine sandy loam, 2 to 6 percent slopes	1,225	.5
Milaca stony very fine sandy loam, 2 to 6 percent slopes	533	.2
Milaca fine sandy loam, clay loam subsoil variant, 1 to 6 percent slopes	365	.1
Mora fine sandy loam, 1 to 3 percent slopes	21,151	8.1
Mora fine sandy loam, 3 to 5 percent slopes	7,051	2.7
Mora stony fine sandy loam, 1 to 3 percent slopes	7,466	2.9
Mucky peat	5,532	2.2
Mucky peat over sand	3,258	1.3
Mucky peat over loam	7,159	2.8
Nokasippi mucky loamy fine sand	1,380	.5
Nokay fine sandy loam	9,668	3.7
Nokay stony fine sandy loam	363	.1
Ogilvie silt loam	4,110	1.6
Paget silt loam, 0 to 2 percent slopes	1,030	.4
Paget silt loam, 2 to 6 percent slopes	976	.4
Paget stony silt loam, 0 to 2 percent slopes	413	.2
Paget stony silt loam, 2 to 6 percent slopes	309	.1
Parent loam	18,073	6.9
Parent stony loam	4,801	1.9
Pomroy fine sand, 2 to 6 percent slopes	1,941	.8
Pomroy fine sand, 6 to 12 percent slopes	168	.1
Pomroy loamy fine sand, 0 to 2 percent slopes	1,055	.4
Prebish loam	11,424	4.4
Prebish stony loam	4,059	1.6
Prebish and Parent loams	2,459	1.0
Ronneby loam	16,870	6.4
Ronneby stony loam	4,458	1.7
Sartell fine sand, 0 to 2 percent slopes	2,225	.9
Sartell fine sand, 2 to 6 percent slopes	6,434	2.5
Sartell fine sand, 6 to 12 percent slopes	1,198	.5
Sartell fine sand, 12 to 25 percent slopes	451	.2
Watab loamy fine sand	2,517	1.0
Water areas	3,621	1.4
Total	258,560	100.0

pressions, and level areas. These soils formed in moderately deep, silty sediment underlain by firm, loamy, reddish-brown glacial till. The native vegetation consisted mostly of grasses and sedges, some alders and willows, and a few scattered trees, such as elm and ash.

In a representative profile (fig. 5) the surface layer is black and very dark gray silt loam about 12 inches thick. The subsoil is mainly grayish-brown, friable very fine sandy loam that is about 17 inches thick and has many dark-brown mottles. The underlying material is reddish-brown, firm sandy loam.

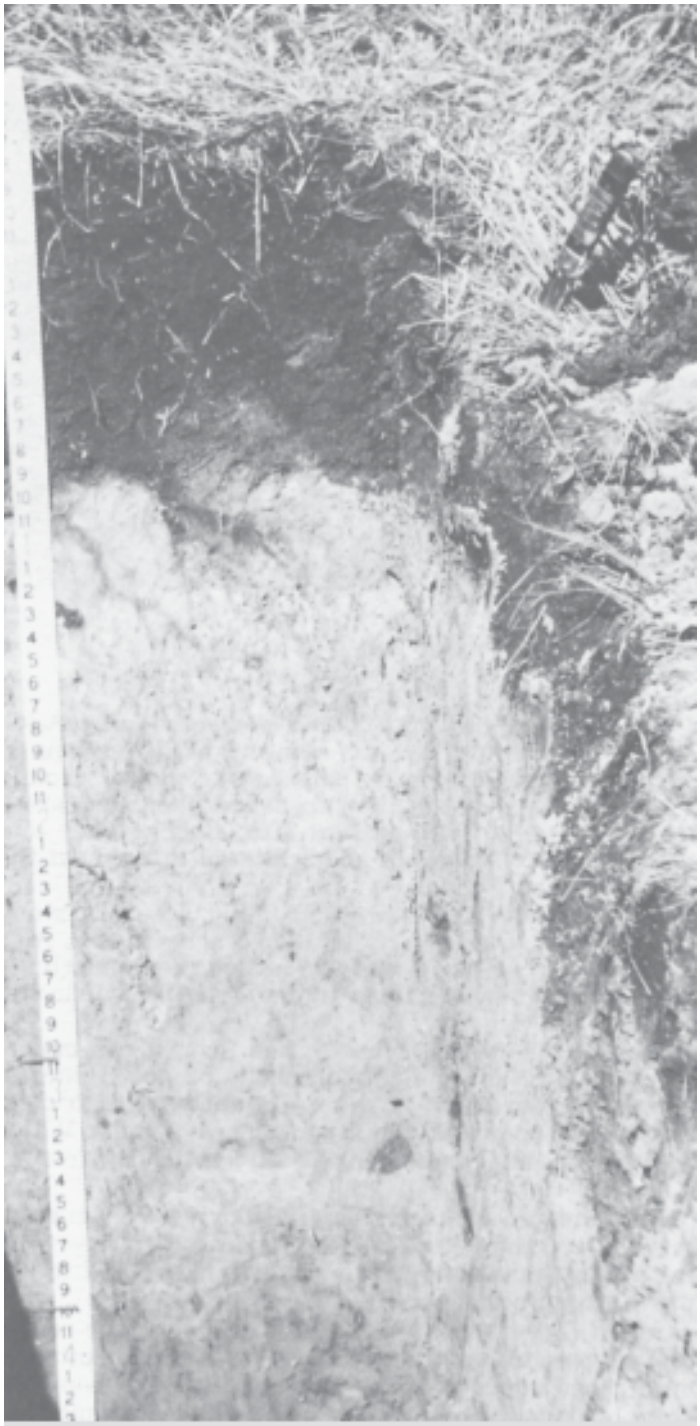

Figure 5.—**Profile of Adolph silt loam.**

Permeability is moderately slow, and available water capacity is high. Organic-matter content is high. Content of available phosphorus is medium, content of available potassium is low, and content of available nitrogen is high. A perched water table fluctuates between the surface and a depth of 3 feet. The firm till, which begins at a depth of about 32 to 44 inches, restricts the movement of water and limits the root zone.

Most areas of these soils are in pasture or are used for the production of wild hay. If drainage is adequate, the soils are suited to all of the crops commonly grown in the county.

Representative profile of Adolph silt loam in a pasture, 600 feet north and 70 feet east of the southwest corner of NW¼ sec. 1, T. 38 N., R. 28 W.:

A1—0 to 5 inches, black (10YR 2/1) silt loam; weak, medium to coarse, subangular blocky structure; friable; neutral; clear, smooth boundary.

A3—5 to 12 inches, black (10YR 2/1) to very dark gray (10YR 3/1) silt loam; weak, very fine, subangular blocky structure; friable; about 2 percent coarse fragments; neutral; clear, wavy boundary.

B1g—12 to 14 inches, dark-gray (10YR 4/1) silt loam; common, fine, distinct, dark yellowish-brown (10YR 4/4) mottles; moderate, very fine, subangular and angular blocky structure; friable; about 2 percent coarse fragments; many roots; few vesicular pores; neutral; abrupt, wavy boundary.

B2g—14 to 29 inches, grayish-brown (2.5Y 5/2) very fine sandy loam; many, moderate, distinct, dark-brown (7.5YR 4/4) and dark yellowish-brown (10YR 4/4) mottles; moderate, very fine, angular and subangular blocky structure; friable; about 2 percent coarse fragments; common roots; few vesicular pores; some, thin, dark-gray (10YR 4/1) silt coats on faces of peds; neutral; abrupt, wavy boundary.

IIC—29 to 60 inches, reddish-brown (5YR 4/3) sandy loam; many, medium, faint, reddish-brown (5YR 4/4) and distinct, yellowish-red (5YR 4/6) mottles; weak, thin, platy structure; firm; about 10 percent coarse fragments; thin, discontinuous, black coats on horizontal surfaces of peds; neutral.

The solum ranges from 26 to 50 inches in thickness. Texture of the A horizon ranges from very fine sandy loam or loam that is high in content of very fine sand to silt loam. The A1 horizon is 4 to 10 inches thick and is slightly acid to neutral. Structure ranges from weak to moderate, granular or subangular blocky. The A3 horizon is 6 to 14 inches thick. It is black or very dark gray and has mottles in some places. Structure ranges from weak to moderate, platy or subangular blocky.

The B horizon is 16 to 32 inches thick. The B1g horizon is dark gray or gray. Its texture ranges from silt loam or loam that is high in content of very fine sand to very fine sandy loam. The B2g horizon is gray or grayish brown and has distinct or prominent mottles. Texture of the B2g horizon generally is the same as that of the B1g horizon, but in some places it is sandy loam or fine sandy loam. Reaction is slightly acid or neutral in the B horizon. Depth to the first horizon that has firm consistence ranges from 18 to 24 inches.

The IIC horizon is reddish-brown or dark reddish-brown, firm sandy loam or fine sandy loam. Structure is weak to moderate, platy. Reaction is neutral to mildly alkaline.

Adolph soils are near Freer and Paget soils and are similar to Prebish soils and to Adolph soils, silty subsoil variant. They are more poorly drained than Freer and Paget soils and lack the clay films in the B horizon that are characteristic of those soils. They have more silt or very fine sand, or both, in the A and B horizons than Prebish soils. Adolph soils have a redder IIC horizon that contains more sand than Adolph soils, silty subsoil variant.

Figure 6.—Typical area of Adolph silt loam.

Adolph silt loam (0 to 1 percent slopes) (Ad).—This soil is in broad depressions and drainageways (fig. 6) of the silt-covered glacial ground moraine. Areas are elongated and range from 2 to 100 acres in size. Cobblestones and stones are on the surface and are scattered throughout the profile.

This soil has the profile described as representative for the series.

Included with this soil in mapping are areas of soils that have as much as 12 inches of peat on the surface. A few areas of soils that have more than 12 inches of peat are also included, but these areas are less than 3 acres in size. Also included are areas of soils in which the underlying material has discontinuous layers or pockets of loamy sand.

This Adolph soil is naturally wet. Because of the firm, dense underlying material at a depth of about 32 to 44 inches, downward movement of water is somewhat restricted. This causes poor trafficability after heavy rains. Early frost is a hazard.

Providing adequate drainage, removing the stones from the surface, and increasing fertility help to correct the major limitations to the use of this soil and to improve crop growth.

Most areas of this soil are in pasture and wild hay. This soil is suited to most of the crops commonly grown in the county. Among the crops grown are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IVw–1; woodland suitability group VII; building site group 9.

Adolph silt loam, level (0 to 2 percent slopes) (AdA).—This soil is in broad areas adjacent to depressions or along drainageways in the silt-covered glacial ground moraine. The irregularly shaped and elongated areas range from 3 to 80 acres in size. Cobblestones and stones are on the surface and scattered throughout the profile.

Included with this soil in mapping are very stony areas, but these areas are less than 3 acres in size. Also included are areas of soils in which the underlying material has discontinuous layers or pockets of loamy sand.

This soil is wet. Because of the firm, dense underlying material at a depth of about 32 to 44 inches, downward movement of water is somewhat restricted. This causes poor trafficability after heavy rains. Water does not become ponded on the surface. Early frost is a hazard.

Providing adequate drainage, removing the stones on the surface, and increasing the fertility help to correct the major limitations to the use of this soil and to improve crop production.

About 30 percent of this soil is cropped. The rest is used as pasture and for woodlots. This soil is suited to most crops commonly grown in the county. Among the crops grown are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIIw–1; woodland suitability group VII; building site group 9.

Adolph Variant

The Adolph variant consists of deep, level to depressional, poorly drained to very poorly drained soils in areas of a small, dissected, terracelike glacial lake basin that lies along the Elk River. These soils formed in calcareous lacustrine sediment under a canopy of sedges, alder, and a few scattered deciduous trees.

In a representative profile the surface layer is black and very dark gray silt loam and silty clay loam about 15 inches thick. The subsoil is dark-gray, friable silt loam that is about 9 inches thick and has dark yellowish-brown mottles. The underlying material is grayish-brown, friable silt loam.

Permeability is slow to moderately slow, and the available water capacity is very high.

Organic-matter content is high. The content of available phosphorus is low, the content of available potassium is medium, and the content of available nitrogen is high. A perched water table fluctuates between the surface and a depth of 3 feet.

Most areas of this soil are used for pasture or native hay. If drainage is adequate, these areas are suited to all of the crops commonly grown in the county.

Representative profile of Adolph silt loam, silty subsoil variant, that has a slope of 1 percent, in a field of wild hay 55 feet south and 500 feet west of the northeast corner of sec. 14, T. 36 N., R. 30 W.:

A1—0 to 10 inches, black (10YR 2/1) silt loam; weak, fine, subangular blocky structure; friable; high in organic-matter content; slight effervescence; mildly alkaline; clear, wavy boundary.

A3—10 to 15 inches, very dark gray (10YR 3/1) silty clay loam; common, fine, faint, dark-brown (10YR 3/3) mottles; moderate, very fine, subangular blocky structure; friable; mildly alkaline; clear, wavy boundary.

B21g—15 to 21 inches, dark-gray (10YR 4/1) silt loam; few, fine, distinct, dark yellowish-brown (10YR 4/4) mottles; moderate, fine, subangular blocky structure; friable; slight effervescence; mildly alkaline; clear, irregular boundary.

B22g—21 to 24 inches, dark-gray (10YR 4/1) and grayish-brown (10YR 5/2) silt loam; many, fine, distinct, dark yellowish-brown (10YR 4/4) mottles; moderate, very fine, angular and subangular blocky structure; friable; strong effervescence; moderately alkaline; clear, wavy boundary.

Cg—24 to 60 inches, grayish-brown (10YR 5/2) silt loam; many, medium, prominent, dark yellowish-brown (10YR 4/4) mottles; moderate, very fine, angular and subangular blocky structure; friable; common yellowish-red (5YR 4/6) and reddish-brown (5YR 4/4) stains along root channels; few lime threads; strong effervescence; moderately alkaline.

The solum ranges from 14 to 32 inches in thickness. Texture of the A horizon is silt loam, silty clay loam, or loam. The A1 horizon ranges from 4 to 12 inches in thickness. It is neutral or mildly alkaline and effervescent or noneffervescent. Structure ranges from weak platy to subangular blocky. The A3 horizon is 4 to 8 inches thick. Structure is moderate platy or subangular blocky.

The B horizon is 6 to 12 inches thick. Texture of this horizon ranges from silt loam to silty clay loam. The B horizon is neutral to moderately alkaline and has slight effervescence to strong effervescence. Structure is moderate platy or subangular blocky.

The C horizon is silt loam or silty clay loam. Reaction in this horizon is mildly alkaline to moderately alkaline. Structure is moderate platy, subangular, or angular blocky.

Adolph variant soils are near Dalbo and Adolph soils. They are grayer in the B horizon than Dalbo soils. They have a grayer, less sandy C horizon than Adolph soils.

Adolph silt loam, silty subsoil variant (0 to 2 percent slopes) (Ah).—This soil is on flats and in broad shallow depressions on a dissected glacial lake basin. Areas are irregular and elongated in shape and range from 2 to 120 acres in size, but areas 20 to 40 acres in size are most common.

Included with this soil in mapping are a few areas of soils that are somewhat better drained and have a thin, black surface layer less than 2 inches thick. Also included are a few areas of soils that have a thin layer of peat as much as 12 inches thick, and a few areas where peat is more than 12 inches thick; areas of these soils are less than 3 acres in size.

This soil is naturally wet. Water stands on it in spring and causes poor trafficability. Early frost is a hazard.

Providing adequate drainage, maintaining organic-matter content, and increasing fertility, help to correct the major limitations to the use of this soil and improve the growth of crops.

Nearly all areas of this soil are in pasture and wild hay. This soil is suited to corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIIw–1; woodland suitability group VII; building site group 9.

Alluvial Land

Alluvial land (Ao) consists of fairly extensive areas of recently deposited, stratified alluvium on flood plains along the major rivers in the county. This nearly level to gently undulating land type is subject to frequent flooding, scouring, and cutting by streams. Many areas are dissected by old stream channels. As a consequence, these areas are characterized by short, narrow ridges that give them a corrugated appearance. Slopes are 0 to 3 percent.

This land type consists of fine sandy loam to coarse sand that is generally stratified. Color and reaction vary. Alluvial land is very poorly drained to somewhat poorly drained and has a seasonally high water table. It is dry or only slightly wet between periods of flooding. It is subject to change caused by continued deposition of new material or by scouring and shifting of stream channels.

This land type is too recent for horizons to have formed, but the presence of mottling in places indicates that the processes of soil formation are operational.

Most areas of this land type are used only for unimproved pasture because of the hazard of flooding. A small acreage is wooded. Capability unit VIw–1; woodland suitability group VII; building site group 9.

Antigo Series

The Antigo series consists of nearly level to gently sloping, well-drained soils on broad glacial outwash plains and stream terraces. Slopes are gentle along the edges of the better defined drainageways. These soils formed in moderately deep, silty sediment underlain by acid sand and gravel. The native vegetation was mixed hardwoods and conifers.

In a representative profile the surface layer is very dark gray silt loam about 8 inches thick. The sub-

surface layer is brown silt loam about 3 inches thick. The subsoil is brown to dark-brown, friable silty clay loam in the upper 17 inches and firm, brown to dark-brown sandy loam in the lower 6 inches. The underlying material is loose, dark-brown sand and gravel.

Permeability is moderate in the upper part of these soils and rapid in the lower part. The available water capacity is moderate. The organic-matter content is low. The content of available phosphorus is medium, and the content of available potassium and nitrogen is low. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are in pasture or are wooded. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Antigo silt loam, 0 to 2 percent slopes, in a cultivated field, 76 feet north and 1,320 feet west of southeast corner of sec. 11, T. 36 N., R. 28 W.:

Ap—0 to 8 inches, very dark gray (10YR 3/1) silt loam; weak, very fine, subangular blocky structure; friable; medium acid; abrupt, smooth boundary.

A2—8 to 11 inches, brown to dark-brown (10YR 4/3) silt loam; weak, thick, platy structure that parts in places to weak, fine, subangular blocky; friable; thick, porous, grayish-brown (10YR 5/2) sandy and silty coatings on faces of peds; medium acid; clear, smooth boundary.

B&A—11 to 15 inches, dark-brown (10YR 3/3) silt loam; moderate, fine, subangular blocky structure; friable; nearly continuous, thick, porous, grayish-brown (10YR 5/2) sandy and silty coatings on faces of peds; medium acid; clear, smooth boundary.

B21t—15 to 19 inches, brown to dark-brown (10YR 4/3) silty clay loam; moderate, fine, subangular blocky structure; friable; thin patchy clay films and medium, patchy, grayish-brown (10YR 5/2), sandy and silty coatings on faces of peds; very strongly acid; clear, smooth boundary.

B22t—19 to 28 inches, brown to dark-brown (10YR 4/3) silty clay loam; moderate, fine and medium, subangular blocky structure; friable; medium, nearly continuous, dark-brown (7.5YR 3/2) clay films on faces of peds; very strongly acid; clear, wavy boundary.

IIB3—28 to 34 inches, brown to dark-brown (7.5YR 4/4) sandy loam; weak, coarse, subangular blocky structure; firm; nearly continuous, thin, dark reddish-brown (5YR 3/2) clay films on vertical faces of peds and patchy films on horizontal faces of peds; few vesicular pores; very strongly acid; clear, wavy boundary.

IIIC1—34 to 36 inches, dark-brown (7.5YR 3/2) gravelly and cobbly sandy loam; weak, coarse, subangular blocky structure; friable; strongly acid; clear, wavy boundary.

IIIC2—36 to 60 inches, dark-brown (7.5YR 3/2) and brown (7.5YR 4/4) stratified sand and gravel; single grained; loose; strongly acid.

The solum ranges from 24 to 36 inches in thickness. The Ap horizon is 6 to 9 inches thick and is medium acid to strongly acid. Texture of the A horizon ranges from very fine sandy loam to loam that has a high content of very fine sand or silt loam. The A2 horizon is 3 to 5 inches thick in cultivated areas. In undisturbed areas, there is a black or very dark gray A1 horizon 2 to 4 inches thick and an A2 horizon 8 to 10 inches thick.

The B horizon is 18 to 26 inches thick and ranges from silt loam to silty clay loam. Reaction is medium acid to very strongly acid.

The IIC horizon ranges from gravelly and cobbly sandy loam or loamy sand in the IIC1 horizon to stratified sand and gravel or gravelly coarse sand in the IIC2 horizon. Reaction in the IIC horizon is medium acid to very strongly acid.

The Antigo soils in this county have an A1 horizon that is thicker or an Ap horizon that is darker colored than is defined as within the range for the series, but this difference does not alter their usefulness and behavior.

Antigo soils are near Ogilvie and Hillet soils and are similar to the Chetek soils. They have a thinner, lighter colored A horizon and a B horizon that has a higher chroma than the Ogilvie and Hillet soils. They have more silt and less fine and coarse sand in the A horizon and in the upper part of the B horizon than the Chetek soils.

Antigo silt loam, 0 to 2 percent slopes (A+A).—This soil is in broad areas on a glacial outwash plain. Areas are elongated and range from 5 to 80 acres in size, but areas 10 to 20 acres in size are most common.

This soil has the profile described as representative of the series. In undisturbed areas the surface layer is thinner and darker colored than in cultivated areas.

Included with this soil in mapping are small areas of moderately well drained soils that have faint mottles in the subsoil. Areas of soils that have a surface layer of very fine sandy loam are also included.

This soil has medium fertility. Depth of the root zone ranges from 24 to 36 inches and the quantity of available water is limited, thus slight droughtiness occurs during prolonged dry periods.

About 80 percent of the acreage of this soil is used for crops. The rest is in pasture and wooded pasture. This soil is suited to all of the crops commonly grown in the county. Among the crops grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIs–1; woodland suitability group I; building site group 1.

Antigo silt loam, 2 to 6 percent slopes (A+B).—This soil is on a glacial outwash plain. Areas are elongated and generally are narrow. They range from 10 to 40 acres in size, but areas 10 to 20 acres in size are most common. Slopes are 75 to 200 feet long and are irregular and uneven.

This soil has a profile similar to the one described as representative for the series, except that sand and gravel are at a somewhat shallower depth, generally 24 to 30 inches.

Included with this soil in mapping are areas of soils that have a surface layer of loam and fine sandy loam. In some of the cultivated areas on crests of slopes where rills have formed and gravel is exposed, evidence of erosion is indicated by the lighter colored surface layer.

This soil has medium fertility. The hazard of erosion is slight. Available water capacity is limited, and crops show the effects of droughtiness during prolonged dry periods.

About 80 percent of the acreage of this soil is used for crops. The rest is used for pasture and wooded pasture. This soil is suited to all of the crops commonly grown in the county. Among the crops grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIe–2; woodland suitability group I; building site group 1.

Blomford Series

The Blomford series consists of deep, nearly level to slightly depressional, somewhat poorly drained and poorly drained soils. These soils are on the edges of small depressions or in narrow drainageways of larger, very poorly drained depressions. They formed in sandy

glacial outwash sediment overlying silty glacial lake deposits. The native vegetation was deciduous trees, primarily oak, ash, elm, and aspen.

In a representative profile the surface layer is black loamy sand about 8 inches thick. The subsurface layer is grayish-brown and very dark grayish-brown loamy sand that is about 3 inches thick and has dark yellowish-brown and brown mottles. The subsoil is about 30 inches of mottled, very dark gray, very friable loamy sand and very dark brown, friable sandy loam. The underlying material is grayish-brown, light brownish-gray, and greenish-gray, friable silt loam that is moderately alkaline.

Permeability is rapid in the upper part of these soils and moderately slow in the lower part. The available water capacity is high. Organic-matter content is moderate. The content of available phosphorus, potassium, and nitrogen is low. A perched water table fluctuates between depths of 2 and 4 feet.

Most areas of these soils are in crops. Some of the acreage is wooded or in pasture. Blomford soils are suited to all of the crops commonly grown in the county.

Representative profile of Blomford loamy sand in a cultivated field where slope is 1 percent, 1,170 feet west and 960 feet north of the southeast corner of NW¼ of sec. 2, T. 36 N., R. 30 W.:

Ap—0 to 8 inches, black (10YR 2/1) loamy sand; weak, fine, subangular blocky structure; very friable; neutral; abrupt, wavy boundary.

A2—8 to 11 inches, grayish-brown (10YR 5/2) and some very dark grayish-brown (10YR 3/2) loamy sand; common, medium, distinct, dark yellowish-brown (10YR 4/4) and brown (10YR 4/3) mottles; weak, medium, platy structure; very friable; neutral; clear, irregular boundary.

B1g—11 to 21 inches, dark-gray (10YR 4/1), very dark gray (10YR 3/1), and grayish-brown (2.5YR 5/2) loamy sand; common, medium, distinct, dark yellowish-brown (10YR 4/4) mottles; weak, medium, subangular blocky structure; very friable; neutral; clear, wavy boundary.

IIB2g—21 to 41 inches, very dark brown (10YR 2/2) sandy loam; common, fine, faint, dark-brown (10YR 4/3) mottles; weak, fine, subangular blocky structure; very friable to friable; neutral; abrupt, wavy boundary.

IICg—41 to 60 inches, grayish-brown (2.5Y 5/2), light brownish-gray (2.5Y 6/2), and greenish-gray (5G 6/1) silt loam; many, medium, prominent, dark yellowish-brown (10YR 4/4) and yellowish-brown (10YR 5/6) mottles; weak, subangular blocky structure; friable; moderately alkaline.

The solum ranges from 36 to 52 inches in thickness. The Ap horizon is 7 to 10 inches in thickness and medium acid to neutral in reaction. In uncultivated areas the A1 horizon ranges from 3 to 6 inches in thickness. The Ap and A1 horizons are black or very dark gray loamy sand or loamy fine sand in most places, but they are sandy loam or fine sandy loam in a few places. Structure ranges from weak crumb to granular or subangular blocky. The A2 horizon is 3 to 12 inches in thickness and medium to neutral in reaction. It is a grayish-brown to dark grayish-brown sand or fine sand, loamy fine sand, or loamy sand. Structure ranges from weak platy to massive or single grain.

The B1g horizon is 6 to 20 inches thick. It is dark gray, gray, grayish brown, or dark brown and has faint to distinct mottles. Its texture ranges from sand or fine sand to loamy sand or loamy fine sand. It is massive or has weakly developed structure. Depth to the IIB horizon ranges from 20 to 40 inches. The IIB2g horizon ranges from very dark brown to grayish brown or gray in color. It is sandy loam, loam, silt loam, or silty clay loam. It has weak or moderate subangular blocky structure. Reaction in the B1g and IIB2g horizons ranges from medium acid to neutral. Clay films are on faces of peds in the IIB2g horizon in some places.

The IICg horizon generally is silt loam but ranges to silty clay loam. Reaction is neutral to moderately alkaline. Structure ranges from weak to moderate and from platy to subangular blocky or massive.

The Blomford soils in this county have a IIB horizon that shows stronger evidence of illuviation or has darker colors than is defined as within the range for the series, but this difference does not alter their usefulness and behavior.

Blomford soils are near Braham soils and are similar to Lino and Watab soils. They have a lower chroma in the B horizon than Braham soils. They are similar to Lino soils, but Lino soils are sandy to a depth of more than 40 inches. Blomford soils have a grayish-brown silty IIC horizon, whereas Watab soils have a reddish-brown loamy IIC horizon.

Blomford loamy sand (0 to 2 percent slopes) (Bd).—This soil is on flats and in slight depressions along drainageways and around depressions of a sand-covered glacial lakebed. Areas are irregular in shape or elongated and range from 5 to 40 acres in size, but 10 to 20 acres in size is most common.

In undisturbed areas the surface layer is thinner than the one described in the representative profile.

Included with this soil in mapping are some small areas of soils that have slopes of 3 percent and also some very small areas of wetter soils.

This soil is naturally wet. Providing adequate drainage, maintaining organic-matter content, and increasing fertility help to correct the major limitations to the use of this soil for field crops. Wind erosion is a hazard where large fields are drained and left barren.

About 60 percent of the acreage of this soil is used for crops. The rest is used for pasture and woodlots. This soil is moderately well suited to most crops grown in the county. Among the crops grown are corn, rye, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIIw–2; woodland suitability group V; building site group 7.

Braham Series

The Braham series consists of deep, gently sloping to sloping, well-drained soils in a small local glacial lake basin between the glacial uplands and the lake deposits. These soils formed in sandy glacial outwash sediment underlain by silty glacial lake deposits. The native vegetation consisted of a canopy of deciduous trees, dominantly oaks with occasional elms and hard maples.

In a representative profile the surface layer is black and very dark brown loamy fine sand about 11 inches thick. The subsoil is about 33 inches thick. The upper 17 inches is dark grayish-brown and brown, very friable loamy fine sand and fine sand, and the lower 16 inches is brown, friable clay loam. The underlying material is pale-brown, very friable silt loam that is mildly alkaline.

Permeability is rapid in the upper part of these soils and moderate in the lower part. The available water capacity is moderate. The content of organic matter is low. The content of available phosphorous, potassium, and nitrogen is low. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some of the acreage is wooded or in permanent pasture. Braham

soils are suited to all of the crops commonly grown in the county.

Representative profile of Braham loamy fine sand, 2 to 8 percent slopes, in a pasture, 730 feet west and 1,235 feet south of the northeast corner of sec. 35, T. 37 N., R. 30 W.:

A1—0 to 3 inches, black (10YR 2/1) loamy fine sand; weak, very fine. subangular blocky structure; very friable; slightly acid; clear, wavy boundary.

A3—3 to 11 inches, very dark brown (10YR 2/2) loamy fine sand; about 10 percent is black (10YR 2/1); weak, very fine, subangular blocky structure; very friable; neutral; clear, irregular boundary.

B11—11 to 17 inches, dark grayish-brown (10YR 4/2) loamy fine sand, light gray (10YR 7/2) when dry; about 20 percent is very dark brown (10YR 2/2); weak, thick, platy structure parting to weak, fine, subangular blocky; very friable; neutral; clear, irregular boundary.

B12—17 to 28 inches, brown (10YR 5/3) fine sand; about 10 percent is dark brown (10YR 4/3); weak, thick, platy structure parting to weak, medium, subangular blocky; very friable; few, thin, very dark brown (10YR 2/2) bands of loamy fine sand; neutral; abrupt, wavy boundary.

IIB2t—28 to 44 inches, brown (10YR 4/3) clay loam that grades with depth to silt loam; strong, fine, subangular blocky structure; friable; medium, moderately patchy, dark-brown (10YR 3/3) clay films on faces of peds; some sandy coatings on vertical faces of peds in upper part; medium acid; clear, wavy boundary.

IIC—44 to 60 inches, pale-brown (10YR 6/3) silt loam; moderate, medium, platy structure; very friable; thin, patchy, to thick, moderately patchy, very dark brown (10YR 2/2) and black (10YR 2/1) clay films on vertical faces of peds and along root channels; few lime concretions; mildly alkaline; slight effervescence.

The solum ranges from 30 to 50 inches in thickness. The A1 horizon is 2 to 6 inches thick and is medium acid or slightly acid. It is dominantly black or very dark gray loamy fine sand or loamy sand, but in places it is fine sandy loam. The Ap horizon, where present, is 6 to 8 inches thick and is black to dark brown. An A3 horizon is present in most profiles, but in some places there is an A2 horizon instead. The A3 horizon is 2 to 8 inches thick. It is very dark brown to dark grayish-brown loamy sand or loamy fine sand. Structure ranges from weak platy to weak subangular blocky.

The B horizon is 20 to 40 inches thick. Texture ranges from loamy fine sand to fine sand in the B1 horizon and is fine sandy loam, sandy clay loam, silt loam, silty clay loam, or clay loam in the IIB2t horizon. The depth to the IIB2t horizon ranges from 20 to 40 inches. Structure in the IIB2t horizon is moderate or strong, subangular blocky. Reaction is slightly acid or neutral in the B1 horizon and slightly acid or medium acid in the IIB2t horizon. A few, fine, dark-colored concretions are scattered throughout the horizon in some places. Structure ranges from moderate, platy or subangular blocky to massive.

The IIC horizon ranges from loam to silty clay loam. Reaction ranges from slightly acid to moderately alkaline. The IIC horizon is pale brown to brown.

The Braham soils in this county have a dark-colored A horizon that is thicker than is defined as within the range for the series, but this difference does not alter their usefulness and behavior.

Braham soils are near Sartell, Dalbo, and Blomford soils and are similar to Pomroy soils. They have a loamy IIB horizon that begins above a depth of 40 inches, whereas Sartell soils do not have a IIB horizon. They have more sand and less silt and clay in the A and B horizons than Dalbo soils. They have a higher chroma in their B horizon than Blomford soils. They have a finer textured and less sandy IIC horizon than Pomroy soils.

Braham loamy fine sand, 2 to 8 percent slopes (BhC).—This soil is in areas of a sand-covered glacial lakebed. Areas range from 5 to 30 acres in size, but areas 10 to 20 acres in size are most common.

Included with this soil in mapping are some small areas of Blomford soils in depressions. Also included are some areas of soils where cultivation has mixed material from the subsoil with the original surface layer.

The sandy upper layers limit the quantity of water available for plant growth. Growth therefore is limited during prolonged dry periods. Controlling erosion and increasing organic-matter content and fertility help to correct the major limitations to the use of this soil and to improve growth of crops.

About 70 percent of the acreage of this soil is used for crops. The rest is in pasture and woodlots. This soil is moderately well suited to all crops commonly grown in the county. Among the crops grown are corn, rye, soybeans, alfalfa, and red clover. Capability unit IVs–1; woodland suitability group IV; building site group 5.

Brainerd Series

The Brainerd series consists of deep, nearly level to gently sloping, moderately well drained soils on glacial ground moraines and drumlins. These soils formed in firm, loamy, brown glacial till under a canopy of mixed hardwoods and conifers. Cobblestones and stones are on the surface and throughout the soil.

In a representative profile the surface layer is very dark grayish brown sandy loam about 6 inches thick. The subsurface layer is brown, friable sandy loam that is about 8 inches thick and has faint, dark-brown and yellowish-brown mottles. The subsoil is about 32 inches thick. The upper 10 inches is brown, friable sandy loam, and the lower part is brown and dark reddish-brown, firm sandy loam. Mottles occur throughout the subsoil. The underlying material is brown, firm sandy loam that has prominent, red and brown mottles.

Permeability is moderately slow, and available water capacity is moderate. Organic-matter content is low. The content of available phosphorus is medium, and the content of available potassium and nitrogen is low. The firm fragipan, which starts at a depth of about 24 inches, restricts the movement of water and limits the root zone. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are wooded or are in pasture. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Brainerd sandy loam, 1 to 3 percent slopes, in a road cut, 15 feet east and 960 feet north of southwest corner of sec. 15, T. 37 N., R. 30 W.:

Ap—0 to 6 inches, very dark grayish-brown (10YR 3/2) sandy loam; weak, very fine, subangular blocky structure; friable; about 2 percent coarse fragments; strongly acid; abrupt, smooth boundary.

A2—6 to 14 inches, brown (10YR 5/3) sandy loam; few, fine, faint, dark-brown (10YR 4/3) and yellowish-brown (10YR 5/4) mottles and few, medium, distinct, strong-brown (7.5YR 5/8) mottles; moderate, thin and medium, platy structure; friable; about 2 percent coarse fragments; medium acid; clear, wavy boundary.

B1—14 to 24 inches, brown (10YR 5/3) sandy loam; many, fine, distinct, dark-brown (7.5YR 4/4) mottles; weak, thin, platy structure that parts to weak,

very fine, subangular blocky; friable; about 20 percent coarse fragments, very thin patchy clay films on faces of peds; medium acid; clear, wavy boundary.

Bx—24 to 46 inches, brown (7.5YR 4/4) and dark reddish-brown (5YR 3/3) sandy loam; common, medium, distinct, reddish-brown (5YR 4/4), dark reddish-brown (5YR 3/4), and yellowish-red (5YR 4/6) mottles; strong, medium, platy structure; firm; about 10 percent coarse fragments; few thin clay films on faces of peds; medium acid; diffuse, wavy boundary.

Cx—46 to 60 inches, brown (7.5YR 4/4) sandy loam; few, coarse, prominent, grayish-brown (10YR 5/2), reddish-brown (5YR 4/4), and yellowish-red (10YR 5/6) mottles; weak, fine and medium, platy structure; firm; about 10 percent coarse fragments; medium acid.

The solum ranges from 40 to 60 inches in thickness. The content of coarse fragments ranges from 2 to 20 percent in the A horizon and from 8 to 25 percent in the B and C horizons.

The Ap horizon is 6 to 9 inches thick and is very strongly acid to strongly acid. It is very dark grayish-brown or very dark gray sandy loam or fine sandy loam. In uncultivated areas the A1 horizon is 3 to 5 inches thick and is very strongly acid or strongly acid. It is black or very dark brown sandy loam or fine sandy loam. Structure ranges from weak to moderate granular, crumb, or subangular blocky. The A2 horizon is brown or dark brown and has prominent or distinct mottles. It is 5 to 10 inches thick. Structure ranges from very weak to weak, thin and medium, platy.

The B horizon is 32 to 46 inches thick. Its texture ranges from sandy loam to loamy sand in the B1 horizon and from sandy loam to loam in the Bx horizon. In some places the Bx horizon is dark brown. Reaction is strongly acid or medium acid in the B1 horizon and medium acid or slightly acid in the Bx horizon. Structure ranges from weak to strong platy and from weak to moderate, subangular blocky. Depth to the Bx horizon is 18 to 30 inches.

The Cx horizon is brown or dark brown. Reaction in this horizon is medium acid or slightly acid. Mottles are present in places, especially in the upper part. Structure ranges from weak medium to fine platy.

Brainerd soils are near Flak, Nokay, and Parent soils and are similar to Mora soils. They have mottles in the A2 horizon, which are lacking in the well-drained Flak soils. They are better drained than Nokay and Parent soils, which occur downslope, and they have brighter colors in the upper part of the B horizon than these soils. Brainerd soils have a yellower matrix color in the Bx and Cx horizons and are higher in content of medium and coarse sand than Mora soils.

Brainerd sandy loam, 1 to 3 percent slopes (BrA).—This soil occupies broad areas on the glacial drumlins that are mostly west of the Elk River. Areas are elongated and are oriented in an east-west direction. Slopes are uniform, slightly convex, and 200 to 1,000 feet long. Stones are on the surface and scattered throughout the profile.

This soil has the profile described as representative for the series. In undisturbed areas the surface layer is darker and somewhat thinner than in cultivated areas.

Included with this soil in mapping are small areas of Parent and Prebish soils in depressions. Also included are small areas of sandy soils. Also included in cultivated fields are soils in areas where rills have been left by water erosion, and soils in places where cultivation has mixed part of the subsoil into the original surface layer.

Crop growth is slightly limited by climate and the restricted root zone. Controlling erosion and increasing organic-matter content and fertility help to correct the major limitations to the use of this soil for crops.

About 80 percent of the acreage of this soil is used for crops. The rest is used as pasture or for woodlots. This soil is suited to all of the common crops. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIc–1; woodland suitability group I; building site group 4.

Brainerd sandy loam, 3 to 5 percent slopes (BrB).—This soil is in broad areas on the glacial drumlins that are mostly west of the Elk River. Areas are elongated and are oriented in an east-west direction. Slopes are uniform, slightly convex, and 200 to 800 feet long. Stones are on the surface and are scattered throughout the profile.

This soil has a profile similar to the one described as representative for the series, but it is somewhat shallower because of less soil development. Also, in some places where this soil is cultivated, the surface layer is lighter colored and somewhat coarser textured because of erosion.

Included with this soil in mapping are areas of soils that have a surface layer of fine sandy loam and a few small areas of a soil that has a thin surface layer of loamy sand. There are small areas of Parent and Prebish soils in depressions and of Nokay soils in waterways. Also included are small areas of sandy material in places. The hazard of erosion is slight, and the root zone is limited. Controlling erosion and increasing organic-matter content and fertility help to correct the major limitations to the use of this soil.

About 80 percent of the acreage of this soil is used for crops. The rest is used as pasture or for woodlots. This soil is suited to all of the common crops. Among the crops commonly grown are corn, soybeans, alfalfa, and red clover. Capability unit IIe–1; woodland suitability group I; building site group 4.

Brainerd stony sandy loam, 1 to 3 percent slopes (BsA).—This soil is on the glacial drumlins that are mostly west of the Elk River. Areas are elongated and range from 5 to 40 acres in size, but areas 10 to 20 acres in size are most common. These areas are oriented in an east-west direction. Slopes are uniform, convex, and 200 to 500 feet in length.

This soil has a profile similar to the one described as representative for the series, but it is too stony for ordinary tillage and the surface layer is thinner and darker colored. It is economically feasible to remove the stones, although they are an average of 5 to 30 feet apart and are 1 to 3 feet in diameter.

Included with this soil in mapping are small areas of Parent and Prebish soils in depressions. Also included are some areas of Nokay soils in small drainageways and some small sandy spots.

Most of the acreage of this soil is used for pasture, for wooded pasture, and as woodlots. Land clearing is required before this soil can be cropped. This soil is suited to all of the crops commonly grown in the county. Among the crops grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIc–1; woodland suitability group I; building site group 4.

Brainerd stony sandy loam, 3 to 5 percent slopes (BsB).—This soil is on the glacial drumlins that are mostly west of the Elk River. Areas are elongated and range from 5 to 40 acres in size, but areas 10 to 20 acres in size are most common. These areas are oriented

in an east-west direction. Slopes are uniform, convex, and 200 to 500 feet in length.

This soil has a profile similar to the one described as representative for the series, but it is stony and the surface layer is thinner and darker colored. It is economically feasible to remove the stones, although they average 5 to 30 feet apart and are 1 to 3 feet in diameter.

Included with this soil in mapping are small areas of Parent and Prebish soils in depressions. Also included are some areas of Nokay soils in small drainageways and some small sandy spots.

The hazard of erosion is slight. Most areas of this soil are used for pasture, for wooded pasture, and as woodlots. Land clearing is required before this soil can be used for crops. It is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIe–1; woodland suitability group I; building site group 4.

Burkhardt Series

The Burkhardt series consists of shallow, nearly level to undulating, somewhat excessively drained soils on stream terraces, valley benches, and outwash plains or on pitted moraines. These soils formed in thick sandy and gravelly deposits. The native vegetation was prairie grasses and scattered bur oak.

In a representative profile the surface layer is black and very brown sandy loam about 11 inches thick. The subsoil is 17 inches thick. The upper part is dark-brown and reddish-brown, friable sandy loam about 10 inches thick, and the lower part is reddish-brown, very friable gravelly loamy sand that has small pockets of sandy loam. The underlying material is brown, loose coarse sand that has some gravel.

Permeability is moderately rapid in the upper part of these soils and very rapid in the lower part. Available water capacity is low. Organic-matter content is moderate. The content of available phosphorus is medium, and the content of available potassium and nitrogen is low. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are wooded, and some are in pasture. If these soils are irrigated, they are suited to all of the crops commonly grown in the county.

Representative profile of Burkhardt sandy loam, 0 to 2 percent slopes, in a cultivated field, 50 feet south and 900 feet east of northwest corner of sec. 17, T. 36 N., R. 28 W.:

Ap—0 to 8 inches, black (10YR 2/1) sandy loam; weak, fine, subangular blocky structure; friable; about 1 percent gravel; medium acid; clear, smooth boundary.

A3—8 to 11 inches, black (10YR 2/1) sandy loam mixed with very dark brown (10YR 2/2), and dark-brown (7.5YR 3/2) sandy loam; weak, fine, subangular blocky structure; friable; about 1 percent gravel; medium acid; clear, wavy boundary.

B1—11 to 17 inches, dark-brown (7.5YR 3/2) sandy loam; moderate, fine, subangular blocky structure; friable; about 2 percent gravel; few vesicular pores; medium acid; clear, wavy boundary.

B2—17 to 21 inches, reddish-brown (5YR 4/4) sandy loam; moderate, fine, subangular blocky structure; friable; about 5 percent gravel; few patchy clay films on faces of peds; medium acid; clear, wavy boundary.

IIB3—21 to 28 inches, reddish-brown (5YR 4/4) and dark reddish-brown (5YR 3/4) gravelly loamy sand; weak, fine, subangular blocky structure; friable; about 15 percent gravel; few inclusions of sandy loam that has few clay films; medium acid; abrupt, wavy boundary.

IIC—28 to 60 inches, brown (7.5YR 5/4) coarse sand; single grained; loose; about 10 percent gravel; medium acid.

Depth to the horizon that has a texture of loamy sand or coarser ranges from 16 to 24 inches. The A horizon generally is sandy loam but ranges to loam. Structure ranges from weak granular to crumb or subangular blocky. The Ap horizon is 6 to 9 inches thick and is medium acid or slightly acid. It is black or very dark gray. In uncultivated areas there is an A1 horizon that ranges from 6 to 10 inches in thickness. The A3 horizon is 2 to 5 inches thick and ranges from black to very grayish brown or dark brown.

The B1 and B2 horizons range from 6 to 14 inches in thickness. They generally are sandy loam but range to loam. The IIB3 horizon is loamy sand to gravelly loamy coarse sand or gravelly loamy sand.

The IIC horizon is stratified, medium, coarse, and very coarse sand and gravel or is gravelly coarse sand or coarse sand.

The Burkhardt soils in this county have an average annual soil temperature a few degrees lower than the temperature defined as within the range for the series, but this difference does not alter their usefulness and behavior.

Burkhardt soils are near Chetek soils and are similar to Dickman soils. They have a yellower color and less gravel in the lower part of the B horizon and in the C horizon than Dickman soils. They have a thicker dark-colored A horizon than the Chetek soils.

Burkhardt sandy loam, 0 to 2 percent slopes (BuA).—This soil is on glacial outwash terraces along the St. Francis River and along old glacial drainageways in the Duelm area. Areas are narrow and elongated and range from 5 to 80 acres in size, but areas 10 to 20 acres in size are most common. This soil has the profile described as representative for the series.

Included with this soil in mapping are some areas of soils that have slopes of 3 percent. Some evidence of erosion is noticeable by the presence of pebbles on the crests of slopes. In places sand and gravel are at a depth of less than 18 inches. Also included are small areas of a moderately well drained soil.

The root zone extends only to a depth of 16 to 24 inches, and crops are damaged by drought during prolonged dry periods.

About 90 percent of the acreage of this soil is used for crops. The rest of the acreage is used for wooded pasture and woodlots. This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, rye, soybeans, alfalfa, and red clover. Capability unit IIIs–2; woodland suitability group VI; buliding site group 1.

Burkhardt sandy loam, 2 to 6 percent slopes (BuB).—This undulating soil is on glacial outwash terraces along the St. Frances River and along old glacial drainageways in the Duelm area. Areas are narrow and elongated and range from 5 to 20 acres in size.

This soil has a profile similar to the one described as representative for the series, but the surface layer is thinner and somewhat lighter in color. In places the accumulation of gravel on the surface and the mixing of part of the subsoil and the original surface layer indicate that erosion has taken place.

Included with this soil in mapping are small areas of steeper soils.

Crop growth is reduced during growing seasons that have a prolonged dry period, because the root zone is limited.

Most of the acreage of this soil is used for crops. The rest is in pasture or woodlots. This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, rye, soybeans, alfalfa, and red clover. Capability unit IIIe–2; woodland suitability group VI; building site group 1.

Chetek Series

The Chetek series consists of nearly level to sloping, somewhat excessively drained soils on glacial outwash terraces and kames, mainly along the Elk, St. Frances, and Rum rivers and Stony Brook. These soils formed in sandy loam 12 to 24 inches thick over sand and gravel. A canopy of deciduous trees, dominantly oaks and some elms, cover these soils.

In a representative profile the surface layer is very dark brown sandy loam about 7 inches thick. The subsurface layer is brown loam about 5 inches thick. The subsoil is reddish-brown, friable to firm sandy loam about 11 inches thick. The underlying material is reddish-brown to brown loose sand and gravel.

Permeability is moderately rapid in the upper part of these soils and rapid in the lower part. Available water capacity is low. Organic-matter content is low. The content of available phosphorus, potassium, and nitrogen is low. Depth to the water table is 10 feet or more.

Most nearly level areas of these soils are in crops. Areas where these soils are steeper are wooded or are in permanent pasture. These soils are poorly suited to the crops commonly grown in the county. Irrigation is needed to insure good crop growth.

Representative profile of Chetek sandy loam, 0 to 2 percent slopes, in a cultivated field, 80 feet east and 35 feet north of southwest corner of the SE¼ of sec. 9, T. 37 N., R. 28 W.:

Ap—0 to 7 inches, very dark brown (10YR 2/2) sandy loam; weak, fine, crumb structure; very friable; about 5 percent gravel; medium acid; abrupt, smooth boundary.

A2—7 to 12 inches, brown (10YR 5/3) sandy loam; weak, thin, platy structure; very friable; about 5 percent gravel; medium acid; abrupt, wavy boundary.

B2t—12 to 23 inches, reddish-brown (5YR 4/4) sandy loam; moderate, medium, subangular blocky structure; friable to firm; about 10 percent gravel; medium acid; clear, wavy boundary.

IIC1—23 to 40 inches, reddish-brown (5YR 4/4) gravelly coarse sand; single grained; loose, slightly cemented in parts; medium acid; abrupt, wavy boundary.

IIC2—40 to 72 inches, brown (7.5YR 5/4) sand; single grained; loose; medium acid.

The solum ranges from 12 to 24 inches in thickness. The Ap horizon is 5 to 8 inches thick, is slightly acid or medium acid, and is very dark brown or very dark gray. In undisturbed areas the A1 horizon is 1 to 4 inches thick and is black, very dark brown, or very dark gray. The A2 horizon ranges from 1 to 6 inches in thickness. Structure is medium or thin platy. Texture in the A horizon generally is sandy loam or loamy sand, but it is loamy fine sand and fine sandy loam in places.

The B2t horizon generally is loam or sandy loam, but in some places it is loamy sand. Reaction is strongly acid or medium acid. Structure is weak to moderate, fine or medium, subangular blocky.

The IIC horizon is variable in texture and ranges from stratified sand and coarse sand and gravel to gravelly coarse sand, coarse sand, or sand.

The Chetek soils as mapped in Benton County have a thicker A1 horizon or a darker colored Ap horizon than is defined as within the range for the series, but this difference does not alter their usefulness and behavior.

Chetek soils are near Burkhardt and Emmert soils and are similar to Antigo soils. They have a thinner dark-colored A horizon and more translocated clay in the B horizon than Burkhardt soils. They have more silt and clay and less sand in the A and B horizons than Emmert soils. They have more sand and less silt and clay in the A and B horizons than Antigo soils.

Chetek loamy sand, 2 to 6 percent slopes (CeB).—This soil is in broad areas on outwash plains, valley trains, eskers, and kame moraines that are mainly along the Elk, St. Frances, and West Branch Rum Rivers. Areas are irregular in shape or elongated and range from 3 to 20 acres in size, but areas 5 to 10 acres in size are most common. Slopes range from 200 to 500 feet in length.

This soil has a profile similar to the one described as representative for the series, but it has a coarser textured surface layer and subsoil.

Included with this soil in mapping are areas of soils that have a surface layer of gravelly loamy sand, gravelly sandy loam, and gravelly sand.

This soil is limited by the hazard of erosion, droughtiness, and low fertility. Controlling wind erosion, conserving soil moisture, and increasing fertility help to correct some of the major limitations to the use of this soil.

About 70 percent of the acreage of the soil is used for crops. The rest is in pasture or wooded pasture. Capability unit IVs–2; woodland suitability group VI; building site group 1.

Chetek loamy sand, 6 to 12 percent slopes (CeC).—This rolling soil is in small areas adjacent to drainageways, rivers, and streams on outwash plains, valley trains, and kame moraines. Most of these areas are along the Elk, the St. Frances, and West Branch Rum Rivers. Areas are narrow, elongated, and 3 to 15 acres in size. Slopes range from 100 to 400 feet in length.

This soil has a profile similar to the one described as representative for the series, but it has a coarser textured surface layer and subsoil.

Included with this soil in mapping are areas of soils that have a surface layer of gravelly loamy sand, gravelly sandy loam, and gravelly sand.

The hazard of erosion, droughtiness, and low fertility are the major limitations to the use of this soil.

Almost all of the acreage of this soil is in pasture or wooded pasture. Those areas still in crops should be converted to some type of permanent vegetation. Capability unit VIs–1; woodland suitability group VI; building site group 1.

Chetek sandy loam, 0 to 2 percent slopes (ChA).—This soil is in broad areas on outwash plains, valley trains, and kame moraines that are mainly along the Elk and St. Frances Rivers and in areas scattered throughout the county. Areas generally are parallel to rivers or old glacial drainageways. They are irregular in shape and range from 5 to 25 acres in size. Slopes

are mostly 1 to 2 percent and range from 200 to 500 feet in length.

This soil has the profile described as representative for the series. However, in areas where this soil is undisturbed the surface layer is somewhat thinner and darker colored.

Included with this soil in mapping are areas where the surface layer is fine sandy loam and loam. Also included in depressional areas are soils that have some mottling in the subsoil and soils in cultivated fields that show evidence of wind erosion.

The root zone extends to a depth of 12 to 24 inches, and crops are damaged by drought during prolonged dry periods.

Controlling wind erosion, conserving soil moisture, and increasing fertility help to correct most of the major limitations to the use of this soil.

About 50 percent of the acreage of this soil is used for crops. The rest is in pasture and woodlots. Capability unit IIIs–2; woodland suitability group VI; building site group 1.

Chetek sandy loam, 2 to 6 percent slopes (ChB).—This soil is in broad areas on outwash plains, valley trains, and kame moraines. These areas are mainly along the Elk and St. Frances Rivers, but they are scattered throughout the county. Areas are irregular in shape and range from 5 to 40 acres in size. Slopes range from 200 to 500 feet in length.

This soil has a profile similar to the one described as representative for the series, but it is somewhat shallower, and where it is on crests of slopes, the surface layer is thinner, is lighter colored, and has more gravel. In cultivated fields there are some eroded areas where plowing has brought material from the subsoil to the surface.

Included with this soil in mapping are areas of soils that have a surface layer of fine sandy loam and loam.

The root zone extends to a depth of 12 to 24 inches, and crops are damaged by drought during prolonged dry periods. This soil is subject to erosion.

Controlling wind erosion, conserving soil moisture, and increasing fertility help to correct most of the major limitations to the use of this soil.

About 50 percent of the acreage of this soil is used for crops. The rest is in pasture and woodlots. Capability unit IIIe–2; woodland suitability group VI; building site group 1.

Chetek sandy loam, 2 to 6 percent slopes, eroded (ChB2).—This soil is on outwash plains, valley trains, and kame moraines. The areas are mainly along the Elk and St. Frances Rivers, but they are scattered throughout the county. Areas are irregular in shape and range from 5 to 20 acres in size. Slopes range from 200 to 500 feet in length.

This soil has a profile similar to the one described as representative for the series, but it is shallower to the underlying sand and gravel. Where this soil is on crests of slopes, and on most of the side slopes, the subsoil is exposed after cultivation. Rills form readily after a heavy rainfall, and many soils on hilltops have a surface layer mainly of gravel.

Included with this soil in mapping are areas of soils that have a surface layer of fine sandy loam and loam.

The root zone is 8 to 18 inches thick, and crops are damaged by drought during prolonged dry periods. Wind erosion and water erosion are hazards.

Controlling wind erosion, conserving soil moisture, and increasing fertility help to correct most of the major limitations to the use of this soil.

This soil is used for all of the crops commonly grown in the county. Capability unit IIIe–2; woodland suitability group VI; building site group 1.

Chetek sandy loam, 6 to 15 percent slopes (ChC).—This sloping and hilly soil is in small areas adjacent to drainageways, rivers, and streams on outwash plains, valley trains, and kame moraines, mostly along the Elk, the St. Frances, and the West Branch Rum Rivers. Areas generally are parallel to the rivers or to old glacial drainageways. They are irregular in shape or elongated, and they range from 5 to 25 acres in size. Slopes are 50 to 150 feet long.

This soil has a profile similar to the one described as representative for the series, but it is shallower to sand and gravel. Where this soil has not been disturbed, the surface layer is thinner and darker colored than it is in cultivated areas.

Included with this soil in mapping are areas of soils that have a surface layer of fine sandy loam and loam.

The root zone ranges from 10 to 16 inches in thickness, and crops are damaged by drought during dry periods.

The hazards of wind erosion, water erosion, and drought are the major limitations to the use of this soil.

About 30 percent of the acreage of this soil is used for crops. The rest is in pasture and woodlots. Consideration should be given to the use of this soil for some type of permanent vegetation. Capability unit IVe–1; woodland suitability group VI; building site group 1.

Chetek-Milaca complex, 2 to 6 percent slopes (CmB).—The soils in this complex are on glacial drumlins and ground moraines, mainly along streams and drainageways. Areas range from 5 to 15 acres in size. Slopes are irregular and short. About 70 percent of this complex is Chetek sandy loam, and 30 percent Milaca fine sandy loam.

In some areas where these soils are cultivated, there is evidence of erosion, and brownish material from the subsoil is exposed on the convex knolls. Where cultivated, this complex dominantly has the characteristics of Chetek sandy loam.

Included with these soils in mapping are a few areas of soils that are stony enough to interfere with tillage of row crops. These stones can be removed. Also included are a few small areas of sandy and gravelly soils. In a few areas are nearly level soils. In the northeastern and eastern parts of the county, there are areas of Emmert and Paget soils.

The main limitations in cultivated areas of this complex are low available water capacity and moderate hazards of wind erosion and water erosion.

This complex is suited to all of the crops commonly grown in the county, but crop growth is reduced by prolonged dry periods. The main management needs are controlling erosion, increasing fertility, and using a cropping system that makes efficient use of available water. Both soils in capability unit IIIe–2; Chetek soil in woodland suitability group VI, and Milaca soil in woodland suitability group I; both soils in building site group 3.

Chetek-Milaca complex, 6 to 12 percent slopes (CmC).—The hilly soils in this complex are on drumlins and

ground moraines. Slopes are short and irregular. About 70 percent of this complex is Chetek sandy loam, and 30 percent is Milaca fine sandy loam.

The Chetek and Milaca soils in this complex have a profile similar to the one described as representative for their respective series, but the surface layer is somewhat thinner. In cultivated areas as much as two-thirds of the surface layer has been removed. Pockets of gravel, along with brownish material from the subsoil, are exposed on the crests of slopes. In areas where the soils of this complex have not been disturbed, boulders and cobblestones are commonplace on the surface.

Included with these soils in mapping are small areas of steeper soils.

Some of the acreage of this complex is used for the crops commonly grown in the county, but crop production generally is poor. Because of low available water capacity, a shallow root zone, and the hazard of erosion, the use of this complex should be restricted to permanent plant cover much of the time. Both soils in capability unit IVe–1; Chetek soil in woodland suitability group VI, and Milaca soils in woodland suitability group I; both soils in building site group 3.

Dalbo Series

The Dalbo series consists of deep, nearly level to gently sloping, moderately well drained soils in a small glacial lake basin that is dissected by the Elk River. These soils formed in glacial lake deposits of silt loam or silty clay loam under a canopy of mixed hardwoods.

In a representative profile the surface layer is black silt loam about 5 inches thick. The subsurface layer is dark-gray silt loam about 7 inches thick. The subsoil, about 22 inches thick, is friable silty clay loam that contains few faint mottles. It is very dark grayish-brown in the upper part and grades to brown and yellowish brown in the lower part. The underlying material is light yellowish-brown, friable silt loam.

Permeability is moderately slow, and available water capacity is very high. Organic-matter content is moderate. The content of available phosphorus is low, and the content of available potassium and nitrogen is medium. Depth to the water table is 10 feet or more.

Some areas of these soils are in crops. Other areas are in pasture or are wooded. These soils are well suited to all of the crops commonly grown in the county.

Representative profile of Dalbo silt loam in an area of Dalbo fine sandy loam, 0 to 2 percent slopes, in a pastured woodlot, 920 feet south and 1,300 feet east of the northwest corner of sec. 1, T. 36 N., R. 30 W.:

A1—0 to 5 inches, black (10YR 2/1) silt loam; moderate, very fine, subangular blocky structure; friable; medium acid; abrupt, smooth boundary.

A2—5 to 12 inches, dark-gray (10YR 4/1) silt loam; moderate, fine, subangular blocky structure; friable; common very dark gray worm casts; medium acid; clear, wavy boundary.

B1—12 to 19 inches, very dark grayish-brown (10YR 3/2) silty clay loam; dark grayish brown (10YR 4/2) crushed; few, medium, faint, dark yellowish-brown (10YR 4/4) mottles; strong, fine, angular blocky structure; friable; dark grayish-brown (10YR 4/2) and grayish-brown (10YR 5/2) coatings on faces of peds; medium acid; gradual boundary.

B2t—19 to 34 inches, brown (10YR 5/3) and yellowish brown (10YR 5/4) silty clay loam; few, medium, faint, dark yellowish-brown (10YR 4/4) mottles; strong, fine, angular blocky structure; friable; thin, moderately patchy clay films on faces of peds; few pockets of sandy loam; few small pebbles; medium acid; gradual boundary.

C1—34 to 43 inches, light yellowish-brown (10YR 6/4) silt loam; weak, coarse, angular blocky structure; friable; slight effervescence; mildly alkaline.

C2—43 to 60 inches, light yellowish-brown (10YR 6/4) silt loam; few, medium, distinct, light brownish-gray (10YR 6/2) and yellowish-brown (10YR 5/6) mottles; moderate, medium, platy structure; friable; strong effervescence; moderately alkaline.

The solum ranges from 24 to 40 inches in thickness. The A horizon generally is fine sandy loam or silt loam, but in places it is very fine sandy loam or loam. The A1 horizon is 3 to 6 inches thick, is medium acid to slightly acid, and is black or very dark brown. Structure is weak to moderate granular, crumb, or subangular blocky. The Ap horizon, where present, is very dark grayish brown to dark brown and is 6 to 9 inches thick. The A2 horizon generally is dark gray, but it is very dark gray or dark grayish brown in some places. It is 4 to 10 inches thick. Structure is weak to moderate platy or subangular blocky.

The B horizon ranges from 16 to 25 inches in thickness. It ranges from strongly acid to slightly acid and generally becomes less acid with depth. The B1 horizon is silty clay loam to clay loam. It has crushed colors of dark grayish brown or brown. The B2t horizon is silty clay loam, and silty clay, or clay loam. It has moderate or strong subangular or angular blocky or prismatic structure.

The C horizon generally is silt loam but ranges to silty clay loam and silty clay. Reaction is neutral to moderately alkaline.

Dalbo soils are near Braham soils and Adolph soils, silty subsoil variant, and they are similar to the Milaca soils, clay loam subsoil variant. They have more silt and clay and less sand in the A and B horizons than Braham soils. They have brighter colors in most of the B horizon than the more poorly drained Adolph silt loam, silty subsoil variant. They formed in glacial lake sediment, whereas Milaca soils, clay loam subsoil variant, formed in glacial till.

Dalbo fine sandy loam, 0 to 2 percent slopes (DaA).—This soil is on a dissected glacial lake basin. Areas roughly parallel the Elk River in the south-central part of the county. These areas are irregular in shape or elongated and range from 5 to 40 acres in size. Slopes range from 200 to 400 feet in length.

This soil has the profile described as representative for the series. The surface layer is fine sandy loam and silt loam, but fine sandy loam is dominant.

Included with this soil in mapping are areas of soils that have a surface layer of sandy loam, loam, silt loam, or very fine sandy loam and a subsoil that has layers of loamy sand and sandy loam 6 to 24 inches thick. Also included is a soil that has a surface layer that is somewhat darker and thicker than that of this Dalbo soil. In places there are areas of poorly drained soils in small depressions.

Climate limits crop growth slightly. Increasing fertility and maintaining organic-matter content help to correct the major limitations to the use of this soil.

This soil is one of the better soils in the county for crops. The crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIc–1; woodland suitability group I; building site group 4.

Dalbo silt loam, 2 to 8 percent slopes (DbB).—This undulating soil is on a dissected glacial lake basin. Areas range from 5 to 40 acres in size. Slopes are convex and are 200 to 500 feet long.

This soil has a profile similar to the one described as representative for the series, but it has a thinner

and lighter colored surface layer and a coarser textured subsoil.

Included with this soil in mapping are small areas of steeper soils and small areas of soils that have an exposed subsoil. Also included is a soil that has a surface layer of very dark brown sandy loam, fine sandy loam, or loam 8 to 12 inches thick. The subsoil has bands of sandy loam and loamy sand 6 to 24 inches thick.

The hazard of erosion is slight. Controlling erosion, increasing fertility, and maintaining organic-matter content help to correct the major limitations to the use of this soil.

This soil is well suited to all the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIe–1; woodland suitability group I; building site group 4.

Dickman Series

The Dickman series consists of deep, nearly level, somewhat excessively drained soils on nearly level glacial outwash plains and terraces. These soils formed in a thin layer of sandy loam underlain by noncalcareous medium and coarse sands. The native vegetation was prairie grasses and scattered bur oak and hazelnut shrubs.

In a representative profile the surface layer is black coarse sandy loam about 10 inches thick. The subsoil is about 38 inches thick. The upper part is dark-brown, very friable coarse sandy loam about 7 inches thick, and the lower part is brown, very friable to loose sand and coarse sand about 31 inches thick. The underlying material is dark yellowish-brown, loose coarse sand.

Permeability is moderately rapid in the upper part of these soils and rapid in the lower part. Available water capacity is low. Organic-matter content is moderate. The content of available phosphorus is low, and the content of available potassium and nitrogen is medium. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are in open wooded pasture. If these soils are irrigated, they are suited to all of the crops commonly grown in the county.

Representative profile of Dickman coarse sandy loam, 0 to 2 percent slopes, in an open oak woods, 60 feet north and 200 feet west of southeast corner of NE¼ of sec. 25, T. 36 N., R. 30 W.:

A1—0 to 10 inches, black (10YR 2/1) coarse sandy loam; weak, medium, crumb structure; very friable; strongly acid; clear, wavy boundary.

B1—10 to 17 inches, dark-brown (7.5YR 3/2) coarse sandy loam that grades to loamy coarse sand in the lower part; weak, fine and medium, crumb structure; very friable; medium acid; gradual, wavy boundary.

IIB2—17 to 35 inches, brown (7.5YR 4/4) sand; weak, fine and medium, crumb structure; very friable; medium acid; gradual, wavy boundary.

IIB3—35 to 48 inches, brown (7.5YR 4/4) coarse sand; single grained; loose; medium acid; gradual, wavy boundary.

IIC—48 to 60 inches, dark yellowish-brown (10YR 4/4) with some yellowish-brown (10YR 5/4) coarse sand; single grained; loose; about 15 percent gravel; medium acid.

The solum ranges from 30 to 50 inches in thickness. The depth to loamy sand or material of coarser texture ranges from 12 to 20 inches. The A1 horizon is 7 to 13 inches thick and is strongly acid to slightly acid. It is mainly black or very dark gray coarse sandy loam, but it is sandy loam in places. Structure ranges from weak granular and crumb to subangular blocky. The Ap horizon, where present, is black or very dark gray in color and is 6 to 10 inches thick.

The B horizon is 20 to 43 inches thick and is medium acid to slightly acid. The B1 horizon is dark brown or dark grayish brown. It generally is coarse sandy loam or sandy loam, but in some places the lower part of the B1 horizon is loamy coarse sand or loamy sand. The IIB2 and IIB3 horizons are brown or dark yellowish brown. The IIB2 horizon generally ranges from sand or coarse sand to loamy coarse sand or loamy sand, but it is sandy loam in a few places. The IIB3 horizon is sand or coarse sand.

The IIC horizon is coarse sand or sand. Content of gravel in the IIC horizon ranges from 0 to 20 percent. Reaction is medium acid to mildly alkaline.

Dickman soils in this county have more coarse sand and very coarse sand throughout the profile and have an average annual soil temperature that is a few degrees lower than is defined as within the range for the series. These differences do not appreciably alter the usefulness and behavior of these soils.

Dickman soils are near Duelm and Hubbard soils and are similar to Burkhardt soils. They lack motttles in the B horizon, whereas the somewhat poorly drained Duelm soils have mottles in the B horizon. They have more silt and clay in the A and B horizons than Hubbard soils. They contain less gravel and are more yellow in color in the IIC horizon than Burkhardt soils.

Dickman coarse sandy loam, 0 to 2 percent slopes (DcA).—This soil is in shallow, well-drained drainageways on a glacial outwash terrace that is 1 to 6 miles wide. Areas are parallel to the Mississippi River. These areas are elongated and range from 10 to 120 acres in size. The bordering areas at slightly higher elevations are occupied by Hubbard soils. The lower positions in the landscape are occupied by Duelm and Isanti soils.

Included with this soil in mapping are soils on low alluvial terraces that lie along the Mississippi River. These terraces have a corrugated appearance. Also included are small areas of moderately well drained soils in which mottles occur at a depth of 24 to 36 inches. There are also areas of soils underlain by bands of gravelly sand. These bands are as much as 18 inches thick and occur at various depths.

The Dickman soil in this mapping unit is somewhat excessively drained, and the major limitation to its use is the low available water capacity. It is somewhat droughty during dry spells, and there is a hazard of soil blowing in areas where it is cultivated. The main management need is the use of cropping systems that maintain organic-matter content and protect the soil from blowing. Use of field shelterbelts and wind stripcropping helps to reduce wind erosion.

Most areas of this soil are cultivated. Some areas are in native pasture and open scrub oaks. This soil is suited to most crops commonly grown in the county, and crop production is fair. If this soil is irrigated, crop production is good to excellent. Capability unit IIIs–2; woodland suitability group VI; building site group 1.

Duelm Series

The Duelm series consists of deep, nearly level to slightly depressional, somewhat poorly drained soils on glacial outwash terraces and plains. These soils formed in deep sand under prairie grasses, willows, and scattered oaks.

In a representative profile the surface layer is black loamy sand about 9 inches thick. The subsoil is about 43 inches thick. It is dark grayish-brown, dark-gray, and brown, very friable and loose loamy sand and sand that are mottled. The underlying material is brown loose sand that is mottled.

Permeability is rapid, and available water capacity is moderate. Organic-matter content is moderate. The content of available phosphorus and potassium is low, and the content of available nitrogen is medium. The water table fluctuates between the depths of 2 and 4 feet.

Most areas of these soils are in crops. Small areas are in open wooded pasture. These soils are not well suited to all of the crops commonly grown in the county. Irrigation is needed to insure good crop production.

Representative profile of level Duelm loamy sand, in a cultivated field, 1,140 feet west and 50 feet south of northeast corner of SE¼ of sec. 30, T. 36 N., R. 29 W.:

Ap—0 to 9 inches, black (10YR 2/1) loamy sand; weak, fine, subangular blocky structure; friable; very strongly acid; abrupt, smooth boundary.

B21—9 to 12 inches, dark grayish-brown (10YR 4/2) loamy sand that has some dark-gray (10YR 4/1) and gray (10YR 5/1) common, medium, distinct, dark-brown (7.5YR 4/4) and dark reddish-brown (5YR 3/4) mottles; weak, medium, platy structure; very friable; very strongly acid; clear, irregular boundary.

B22—12 to 17 inches, dark grayish-brown (10YR 4/2) loamy sand; many, medium, prominent, dark-brown (7.5YR 4/4) mottles; weak, medium, platy structure parting to weak, very fine, subangular blocky; friable; matrix color has vertical streaked effect; strongly acid; clear, irregular boundary.

B31—17 to 33 inches, dark grayish-brown (10YR 4/2) and brown (10YR 4/3) sand; many, large, prominent, dark-brown (7.5YR 4/4) and reddish-brown (5YR 4/4) mottles; massive; very friable; few dark reddish-brown (2.5YR 3/4) mottles along root channels; few dark reddish-brown (5YR 2/2) concretions in lower part; strongly acid; clear, wavy boundary.

B32—33 to 52 inches, dark grayish-brown (10YR 4/2) and brown (10YR 4/3) fine sand; many, medium, prominent, dark reddish-brown (5YR 3/3), dark-brown (7.5YR 4/4), and light brownish-gray (10YR 6/2) mottles; single grained; loose; strongly acid; clear, wavy boundary.

C—52 to 60 inches, brown (10YR 5/3) sand; many, large, prominent, dark-brown (7.5YR 4/4) mottles and few reddish-brown (5YR 4/4) and dark reddish-brown (5YR 3/4) mottles; single grained; loose; medium acid.

The solum ranges from 32 to 60 inches in thickness. The Ap horizon is 6 to 10 inches thick and is very strongly acid to medium acid. It is black, very dark-gray, or very dark grayish-brown loamy sand and, in a few places, sandy loam. Structure ranges from weak crumb to subangular blocky. In places the A3 horizon is as much as 6 inches thick and has a matrix color of dark brown, very dark grayish brown, or dark grayish brown.

The B horizon is 20 to 50 inches thick. The B2 horizon is dark grayish brown, grayish brown, or brown and commonly has distinct and prominent mottles. Texture is loamy coarse sand or loamy sand. Structure ranges from weak to subangular blocky. Texture in the B3 horizon is fine sand, sand, or coarse sand. The B horizon is medium acid to strongly acid.

The C horizon generally is sand or coarse sand, but layers of fine sand are in some places. Reaction is medium acid or strongly acid.

Some of the Duelm soils in this county have a thinner dark-colored A horizon than is defined as within the range for the series, but this difference does not alter their usefulness and behavior.

Duelm soils are near Hubbard and Dickman soils and are similar to Lino soils. They formed in material similar to the parent material of Hubbard soils, but they generally have mottles and have a lower chroma in their B and C horizons. They have less silt and clay and more sand in the A and B horizons than the better drained Dickman soils. They have a thicker dark-colored A horizon and are dominantly medium and coarser sands, whereas Lino soils have a thin dark-colored A horizon and formed in fine sand.

Duelm loamy sand (Du).—This soil is in areas around small depressions and narrow drainageways on an outwash terrace that is 1 to 6 miles wide and is parallel to the Mississippi River. Most areas are 10 to 60 acres in size. Where this soil is not cultivated, the surface layer is thinner than it is in cultivated areas.

Included with this soil in mapping are small areas of soils that have a coarse sandy loam surface layer. Also included are very poorly drained soils in small depressions.

Providing adequate drainage, increasing fertility, maintaining organic-matter content, and controlling wind erosion help to correct the major limitations to the use of this soil.

Most of the acreage of this soil is used for the crops commonly grown in the county. Among the crops commonly grown are corn, rye, and soybeans and red clover, timothy, and alsike clover mixtures. Crop production is poor to fair. If this soil is irrigated, crop production is good. Capability unit IIIw–2; woodland suitability group V; building site group 7.

Emmert Series

The Emmert series consists of shallow, nearly level to steep, excessively drained soils on glacial eskers and kames, mainly along the Stony Brook, Elk, St. Frances, and Rum Rivers. These soils formed in gravelly sandy loam or coarse loamy sand less than 12 inches thick over gravelly or cobbly sand or coarse sand under a canopy of stunted mixed hardwoods. Cobblestones and stones are on the surface and throughout the profile.

In a representative profile the surface layer is black gravelly coarse sandy loam about 1 inch thick. The subsoil is about 23 inches thick. The upper part is dark-brown, very friable gravelly loamy sand about 4 inches thick, and the lower part is dark reddish-brown, loose gravelly coarse sand about 19 inches thick. The underlying material is reddish-brown gravelly coarse sand.

Permeability is very rapid, and available water capacity is very low. Organic-matter content is very low. The content of available phosphorus, potassium, and nitrogen is low. Depth to the water table is 10 feet or more.

Most areas of these soils are wooded. Some areas are used as pasture or as sources of gravel. These soils are not suited to the crops commonly grown in the county.

Representative profile of an Emmert gravelly loamy sand that has a slope of 15 percent, in a wooded pasture on an esker, 1,500 feet west and 60 feet north of southeast corner of sec. 35, T. 37 N., R. 29 W.:

A1—0 to 1 inch, black (10YR 2/1) gravelly coarse sandy loam; moderate, fine, crumb structure; very friable; about 20 percent coarse fragments; slightly acid; abrupt, wavy boundary.

B2—1 to 5 inches, dark-brown (7.5YR 3/2) gravelly loamy sand; weak, fine, crumb structure; very friable;

about 30 percent coarse fragments; slightly acid; clear, wavy boundary.

B3—5 to 24 inches, dark reddish-brown (5YR 3/4) gravelly coarse sand; single grained; loose; about 40 percent coarse fragments; neutral; diffuse, wavy boundary.

C—24 to 72 inches, reddish-brown (5YR 4/4) gravelly coarse sand; single grained; loose; about 50 percent coarse fragments; neutral.

The solum ranges from 12 to 28 inches in thickness. The average content of coarse fragments throughout the profile ranges from 35 to 60 percent. The A1 horizon is 1 to 4 inches thick and is strongly acid to slightly acid. It is black or very dark grayish-brown coarse sandy loam, sandy loam, loamy coarse sand, or loamy sand that commonly is gravelly or cobbly. Structure ranges from weak crumb to granular. Some profiles have an A2 horizon that is less than 4 inches thick and consists of dark-gray to dark grayish-brown loamy coarse sand and loamy sand.

The B horizon is 10 to 31 inches thick. It is coarse sand, sand, and loamy coarse sandy or loamy sand that is gravelly or cobbly. Color ranges from dark brown to dark reddish brown and reddish brown. Reaction is strongly acid to neutral. Structure ranges from weak crumb or granular to single grained.

The C horizon is gravelly or cobbly sand or coarse sand and is commonly stratified. It is brown to reddish brown and ranges from neutral to strongly acid in reaction.

Emmert soils are near the Chetek soils. They have thinner A and B horizons than Chetek soils and contain less silt and clay.

Emmert gravelly loamy sand, 6 to 25 percent slopes (EmE).—This sloping and rolling to steep soil is on kames and eskers on the glacial ground moraines and drumlins throughout the county. In most places the eskers are along streams and drainageways such as the Foley esker, which is adjacent to Stony Brook for much of its length. Areas are narrow and range from 3 to 20 acres in size. Slopes are convex and short and are 50 to 200 feet in length. Cobblestones, stones, and gravel are on the surface and are scattered throughout the profile.

Included with this soil in mapping are areas of soils that have a surface layer of sandy loam, gravelly sandy loam, gravelly sand, and loamy sand.

This Emmert soil is naturally excessively drained and has very rapid permeability. Fertility is low, and the organic-matter content and available water capacity are very low.

The major limitations to the use of this soil are slope and the low available water capacity, natural fertility, and organic-matter content. The main management need is to maintain permanent vegetation.

Most areas of this soil are used for wooded pasture in which the trees are stunted red oak and bur oak. This soil is a good source of gravel and sand. It is not suited to the common farm crops. Capability unit VIIs–1; woodland suitability group VI; building site group 2.

Flak Series

The Flak series consists of deep, nearly level to sloping, well-drained soils on the upper part of the slopes or the crests of drumlins. These soils formed in firm, loamy, brown glacial till under a forest canopy of mixed hardwoods and conifers. Cobblestones and stones are on the surface and throughout the profile.

In a representative profile the surface layer is very dark brown sandy loam about 7 inches thick. The subsurface layer is brown sandy loam about 7 inches thick. The subsoil is about 22 inches thick. The upper part is brown, friable sandy loam; the middle part is dark-brown to brown, firm sandy loam that is faintly mottled; and the lower part is brown to reddish-brown, firm sandy loam that has distinct mottles. The underlying material is brown to reddish-brown, firm sandy loam.

Permeability is moderately slow. The available water capacity is moderate, and organic-matter content is low. The content of available phosphorus is medium, and the content of available potassium and nitrogen is low. The firm fragipan, which begins at a depth of about 20 inches, restricts the movement of water and limits the thickness of the root zone. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are in woodlots and pasture. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Flak sandy loam, 2 to 6 percent slopes, at the edge of a cultivated field, 675 feet south and 1,400 feet east of northwest corner of the SW¼ of sec. 16, T. 37 N., R. 30 W.:

Ap—0 to 7 inches, very dark brown (10YR 2/2) sandy loam; weak, very fine and fine, crumb structure; very friable; about 5 percent coarse fragments; medium acid; abrupt, smooth boundary.

A2—7 to 14 inches, brown (10YR 4/3) sandy loam; weak, thin, platy structure; very friable; about 10 percent coarse fragments; medium acid; clear, smooth boundary.

B1—14 to 20 inches, brown (7.5YR 5/4) sandy loam; few, medium, faint, dark-brown to brown (7.5YR 4/4) mottles; weak, medium, subangular blocky structure; friable; about 20 percent coarse fragments; medium acid; clear, wavy boundary.

Bx1—20 to 29 inches, dark-brown to brown (7.5YR 4/4) sandy loam; common, medium, faint, brown (7.5YR 5/4) and reddish brown (5YR 4/4) mottles; weak, medium, subangular blocky structure; firm; about 10 percent coarse fragments; medium acid; clear, irregular boundary.

Bx2—29 to 36 inches, brown (7.5YR 4/4) sandy loam; many, coarse, distinct, brown (7.5YR 5/4), yellowish-red (5YR 4/6), dark reddish-brown (5YR 3/4), and reddish-brown (5YR 4/4) mottles; moderate, medium, platy structure; firm to very firm, thin, patchy clay films on faces of peds; few black stains on horizontal faces of peds; about 10 percent coarse fragments; slightly acid; diffuse, smooth boundary.

Cx—36 to 60 inches, brown (7.5YR 4/4) sandy loam; many, large, prominent, brown (7.5YR 5/4), yellowish-red (5YR 4/6), dark reddish-brown (5YR 3/4), and reddish-brown (5YR 4/4) mottles; moderate, medium, platy structure; firm, few black stains on horizontal faces of peds; about 10 percent coarse fragments; slightly acid.

The solum ranges from 28 to 50 inches in thickness. The content of coarse fragments ranges from 2 to 20 percent in the A horizon and 8 to 25 percent in the B and C horizons. The Ap horizon is 6 to 9 inches thick and is strongly acid to slightly acid. It is very dark brown or very dark grayish brown and is sandy loam in most places and fine sandy loam in a few places. In uncultivated areas, the A1 horizon is black or very dark gray and is 2 to 5 inches thick. Structure ranges from weak to moderate granular or crumb. The A2 horizon is brown and is 4 to 9 inches thick. It has weak platy or subangular blocky structure.

The B horizon is 28 to 50 inches thick. It is brown or dark brown and has some reddish brown interspersed in the horizon in some profiles. Texture ranges from sandy loam and fine sandy loam in the B1 horizon, to sandy loam and heavy sandy loam in the Bx1 horizon, and to sandy loam in the Bx2 horizon. Reaction ranges from strongly acid to slightly

acid in the B1 horizon and becomes less acid with depth. Depth to the fragipan ranges from 14 to 28 inches. Mottling occurs in the lower part of the B horizon in some places. Structure ranges from weak and moderate platy to subangular blocky.

The C horizon is brown and has some reddish-brown colors interpersed in some profiles. Reaction is medium acid to slightly acid. Structure ranges from weak to moderate platy.

Flak soils are near Brainerd, Nokay, and Parent soils and are similar to Milaca soils. They lack mottles in the upper part of the B horizon, which are characteristic of the less well drained Brainerd, Nokay, and Parent soils. Also, they have a brighter colored B horizon than Nokay and Parent soils. They have browner colors in the Bx and Cx horizons than Mora soils.

Flak sandy loam, 2 to 6 percent slopes (FlB).—This soil is on the upper parts of glacial drumlins, mostly in the area west of the Elk River. Slopes are uniform. They range from 200 to 400 feet in length and mostly have north and south exposures. Areas are elongated and range from 10 to 80 acres in size, but areas 10 to 20 acres in size are most common. These areas are oriented in an east-west direction. Stones are on the surface and throughout the profile.

This soil has the profile described as representative for the series. In undisturbed areas, the surface layer is somewhat thinner and slightly darker in color.

Included with this soil in mapping are small areas of nearly level Brainerd soils and some areas of Brainerd soils in concave drainageways 25 to 50 feet wide. Also included are areas of soils that are underlain by material that is interbedded or mixed with reddish-brown glacial till material. There are also stony areas.

The hazard of erosion is slgiht. There is also a slight hazard of drought during prolonged dry spells because of the limited root zone. Controlling erosion and increasing organic-matter content and fertility help to overcome the limitations on these soils.

About 80 percent of this soil is used for crops. The rest is used for pasture and woodlots. This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, and alfalfa. Capability unit IIe–1; woodland suitability group I; building site group 3.

Flak sandy loam, 2 to 6 percent slopes, eroded (FlB2).—This soil is on the upper parts of glacial drumlins, mostly in the area west of the Elk River. Areas are elongated and range from 10 to 80 acres in size, but most areas are 10 to 20 acres. These areas are oriented in an east-west direction. Slopes are uniform, range from 200 to 400 feet in length, and mostly have north and south exposures. Stones are on the surface and throughout the soil.

This soil has a profile similar to the one described as representative for the series, but much of the surface layer has been removed by water erosion. This erosion has resulted in a lighter colored surface layer and in areas where brown subsoil material is exposed. In spring, rilling is visible on cultivated slopes and an occasional small gully forms.

Included with this soil in mapping are small areas of nearly level Brainerd soils and areas of Brainerd soils in concave drainageways that are 25 to 50 feet side. Also included are areas of soil underlain by material that is interbedded or mixed with reddish-brown glacial till material. There are also stony areas.

The hazard of erosion is moderate. There is also a hazard of drought during prolonged dry spells because of the limited root zone. Controlling erosion and increasing organic-matter content and fertility help to overcome the limitations on this soil.

Nearly all the acreage of this soil is used for crops. It is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, and alfalfa. Capability unit IIe–1; woodland suitability group I; building site group 3.

Flak sandy loam, 6 to 12 percent slopes (FlC).—This soil is on side slopes of glacial drumlins that run in an east-west direction and mostly are in the area west of the Elk River. Areas are elongated and range from 5 to 20 acres in size. Slopes are uniform. They range from 200 to 400 feet in length, and most of them have north and south exposures. Stones are on the surface and throughout the profile.

This soil has a profile similar to the one described as representative for the series, but is somewhat thinner because of less soil development. Also, in undisturbed areas the surface layer is somewhat thinner and slightly darker than it is in cultivated areas.

Included with this soil in mapping are soils that have small areas of loamy sand. Also included are small stony areas and areas of soils where some mixing and interbedding of reddish-brown till has occurred in the subsoil and underlying material.

The hazard of erosion is severe. There is also a hazard of drought during prolonged dry spells. Controlling erosion and increasing organic-matter content help to overcome the limitations on this soil.

About 75 percent of the acreage of this soil is used for crops. The rest is used for pasture or woodlots. This soil is suited to all of the crops commonly grown in the area. Among the crops commonly grown are corn, oats, soybeans, and alfalfa. Capability unit IIIe–1; woodland suitability group I; building site group 3.

Flak sandy loam, 6 to 12 percent slopes, eroded (FlC2).—This soil is on cultivated side slopes of the glacial drumlins, mostly west of the Elk River. Areas are elongated and range from 5 to 20 acres in size. These areas are oriented in an east-west direction. Slopes are uniform and range from 200 to 400 feet in length, and most of them have north and south exposures. Stones are on the surface and throughout the soil.

This soil has a profile similar to the one described as representative for the series, but it is somewhat thinner because of less soil development. In addition, much of the surface layer has been removed by erosion, and cultivation has mixed some of the material from the subsoil into the surface layer. This erosion and mixing results in a lighter colored surface layer, except in places where the brown subsoil is exposed. In spring, rills and an occasional small gully are visible in areas of cultivated soils on side slopes.

The hazard of erosion is severe. There is a hazard of drought during prolonged dry periods. Controlling erosion and increasing fertility and organic-matter content help to correct the major limitations to the use of this soil.

This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, and alfalfa. Capability unit IIIe–1; woodland suitability group I; building site group 3.

Freer Series

The Freer series consists of deep, nearly level, somewhat poorly drained soils in areas of the glacial ground moraine. These soils formed in a thin layer of silty sediment underlain by firm, loamy, reddish-brown glacial till. The native vegetation was a forest canopy of mxed hardwoods and conifers. Cobblestones and stones are on the surface and throughout the profile.

In a representative profile (fig. 7) the surface layer is very dark gray silt loam about 7 inches thick. The subsurface layer is grayish-brown silt loam that is about 5 inches thick and has dark-brown mottles. The subsoil is about 26 inches thick. The upper part is light brownish-gray and grayish-brown, very friable silt loam that is about 8 inches thick and is mottled. The lower part is grayish-brown, friable very fine sandy loam that is about 18 inches thick and has mottles. The underlying material is dark reddish-brown, firm sandy loam that has many mottles.

Permeability is moderately slow, and the available water capacity is high. Organic-matter content is moderate. The content of available phosphorus is medium, content of available potassium is low, and content of nitrogen is moderate. The firm underlying material, which starts at a depth of about 38 inches, restricts the movement of water and limits the depth to which roots can penetrate. A perched water table fluctuates between depths of 2 and 4 feet.

Some areas of these soils are in crops and pasture. The rest are wooded. If these soils are adequately drained, they are suited to all of the crops commonly grown in the county.

Representative profile of Freer silt loam in a road cut at the edge of a cultivated field, 392 feet south and 15 feet east of the northwest corner of sec. 3, T. 38 N., R. 28 W.:

Ap—0 to 7 inches, very dark gray (10YR 3/1) silt loam; moderate, fine and medium, crumb structure; very friable; about 2 percent coarse fragments; strongly acid; abrupt, smooth boundary.

A2g—7 to 12 inches, grayish-brown (10YR 5/2) silt loam; common, fine, prominent, dark-brown (10YR 4/3) and dark yellowish-brown (10YR 4/4) mottles; weak, thin, platy structure; very friable; about 2 percent coarse fragments; very strongly acid; abrupt, irregular boundary.

B&A—12 to 20 inches, light brownish-gray (10YR 6/2) and grayish-brown (10YR 5/2) silt loam; many, medium, prominent, brown (7.5YR 4/4) and yellowish-brown (10YR 5/6) mottles; weak, medium, platy structure parting to moderate, very fine, subangular blocky; very friable; many, thin, silty coatings on faces of peds; few tongues from the A2 horizon; few black concretions; about 20 percent coarse fragments; very strongly acid; clear, irregular boundary.

IIB2t—20 to 38 inches, grayish-brown (10YR 5/2) very fine sandy loam; many, medium, prominent, brown (7.5YR 4/4) mottles; weak, fine, subangular blocky and angular blocky structure parting to weak, platy; friable; about 10 percent coarse fragments; strongly acid; abrupt, wavy boundary.

IIC—38 to 60 inches, dark reddish-brown (5YR 3/4) sandy loam; many, coarse, prominent, pinkish-gray (7.5YR 6/2) and brown (7.5YR 5/4) mottles; weak, medium, platy structure; firm; few black stains on faces of peds; about 10 percent coarse fragments; medium acid.

The solum ranges from 36 to 50 inches in thickness. Content of coarse fragments ranges from 0 to 5 percent in the A horizon and from 5 to 25 percent in the B and C horizons. The A horizon ranges from very fine sandy loam to loam that is high in content of very fine sand to silt loam. The Ap horizon is 6 to 10 inches thick and very strongly acid to medium acid. It is very dark gray or very dark grayish brown. In uncultivated areas the A1 horizon is black or very dark brown and is 2 to 5 inches thick. Its structure ranges from weak to moderate granular or crumb. The A2 horizon is 4 to 12 inches thick. It is dark gray, gray, grayish brown, or brown. It has few to many mottles. Structure is weak to moderate platy.

The B horizon is 14 to 28 inches thick. It is strongly acid or medium acid and becomes less acid with depth. The B&A horizon ranges from silt loam to loam or silty clay loam. The IIB2t horizon generally ranges from very fine sandy loam to loam, silt loam, or silty clay loam. In some places,

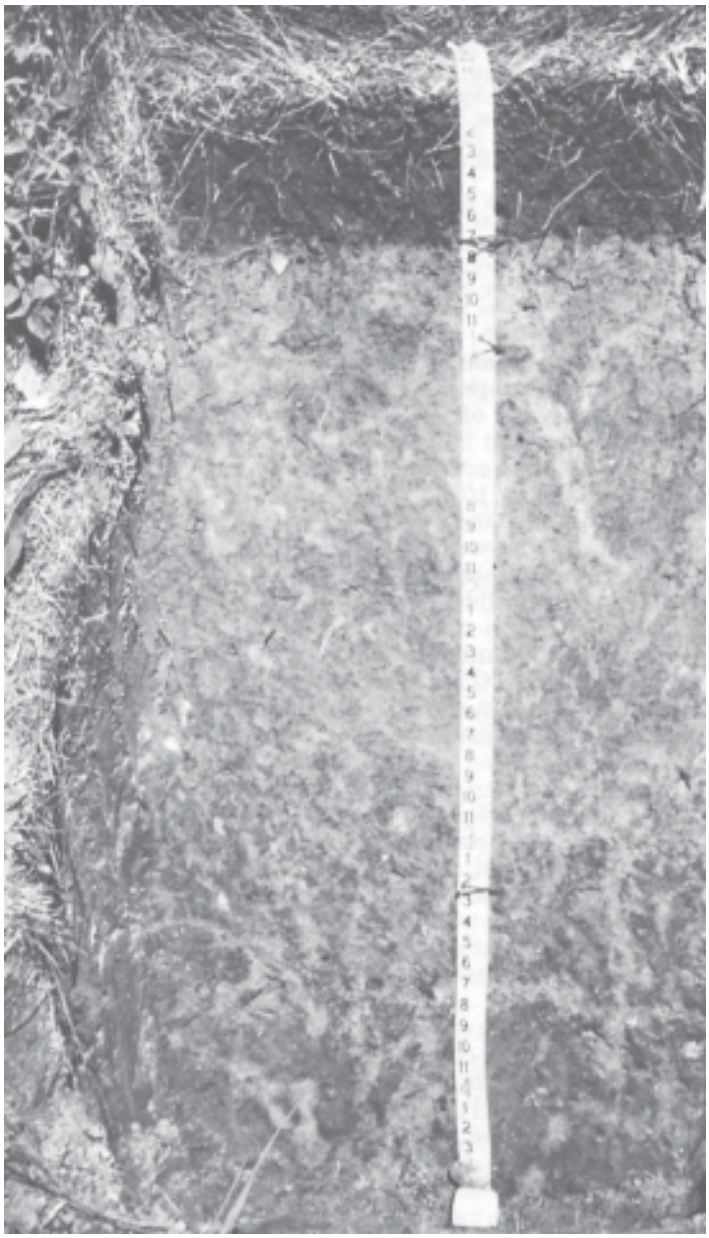

Figure 7.—**Profile of Freer silt loam showing dark-colored surface layer and tongues of subsurface material that extend into the mottled subsoil. At the bottom is underlying sandy loam glacial till.**

there is a IIB3 horizon of reddish-brown sandy loam or fine sandy loam.

The C horizon is dark reddish-brown or reddish-brown sandy loam or fine sandy loam. Reaction ranges from medium acid to neutral. Structure ranges from weak to moderate platy.

Freer soils are near Paget and Adolph soils and are similar to Ronneby soils. They have a grayer color in most of the B horizon than the better drained Paget soils. They have more illuviated clay in the B horizon than the more poorly drained Adolph soils. They have more silt and clay in the A and B horizons than the Ronneby soils.

Freer silt loam (Fr).—This nearly level soil is on silt-covered glacial ground moraines in the Rum River watershed. Some areas are broad and have small depressions of wetter soils. Other areas are narrow and elongated and surround large depressions or occupy draws that extend into the sloping uplands. Areas range from 10 to 80 acres in size, but most areas are 20 to 40 acres in size. Slopes are concave. Stones are on the surface and throughout the profile.

This soil has the profile described as representative for the series. In undisturbed areas, however, the surface layer is somewhat thinner and slightly darker in color.

Included with this soil in mapping are areas of Paget soils on small rises and areas of Adolph soils in small depressions.

This Freer soil has a perched water table that hampers fieldwork and reduces crop growth. The firm, dense underlying material restricts the downward movement of water and the growth of roots. A need of management is to provide drainage that removes excess internal water and removes run-on from higher lying soils.

About half the acreage of this soil is used for crops and pasture. The rest is in woodlots. This soil is suited to most of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIw–1; woodland suitability group III; building site group 6.

Freer stony silt loam (Fs).—This nearly level soil is on silt-covered glacial ground moraines in the Rum River watershed. Some areas are broad and have small depressions of wetter soils. Other areas are narrow and elongated and surround large depressions or occupy draws that extend into the sloping uplands. Areas range from 10 to 60 acres in size, but areas 20 to 40 acres in size are most common. Slopes are concave.

This soil has a profile similar to the one described as representative for the series, but it is too stony to till in its natural condition. Stones average 5 to 30 feet apart and are 1 to 3 feet in diameter, but their removal is economically feasible. This soil also has a thinner and darker colored surface layer than it does if cultivated.

Included with this soil in mapping are areas of Paget soils on small rises and areas of Adolph soils in small depressions.

This Freer soil has a perched water table that hampers fieldwork and reduces crop growth. The firm, dense underlying material limits the downward movement of water and restricts the growth of roots.

Providing adequate drainage and land clearing are essential before this soil can be cultivated.

Most areas of this soil are used for pasture. The rest is in woodlots. This soil is suited to most of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIw–1; woodland suitability group III; building site group 6.

Granite Rock Land

Granite rock land (Gr) occurs along the Mississippi River in Watab and Sauk Rapids Townships and along West Branch Rum River in Granite Ledge Township. It consists of granite formations, most of which protrude 5 to 10 feet above the surrounding landforms. In places they protrude as much as 20 to 50 feet. Some exposures are the dramatic formations called roches moutonnées (fig. 8), which resemble sheep. The glacier polished and striated the gently sloping back, or stoss, side and plucked away at the leeward side. One such exposure is in section 27, Watab Township, south from the point where the Little Rock Lake outlet enters the Mississippi River. Most of the granite outcrops are smooth and almost flush with their surroundings.

The age of the granite formations, according to Thiel (*6*), is middle Keweenawan for the pink and red granites and Algoman for the gray granites and diorites. Woyski (*13*) differentiates Thiel's post-Archeozoic granites into St. Cloud gray granodiorite, Hillman gneissoid tonalite, and Stearns magma series.

In places within the formation, a thin layer of soil-like material occurs that supports sparse vegetation, such as drought-resistant grasses, shrubs, and stunted oak trees. Capability unit VIIIs–1; woodland suitability group VII; building site group 9.

Hillet Series

The Hillet series consists of level and depressional, very poorly drained and poorly drained soils. These soils are in depressions, drainageways, and some level areas, mainly along the St. Francis River. They formed in 20 to 40 inches of silty and loamy material underlain by outwash material of gravelly coarse sand. Native vegetation was water-tolerant grasses, sedges, alders, and willows.

In a representative profile the surface layer is black silt loam and loam about 13 inches thick. The subsoil is about 17 inches thick. The upper 15 inches is dark grayish-brown and grayish-brown, friable and very friable silt loam that has prominent, dark-brown mottles. The lower part is grayish-brown, mottled, very friable fine sandy loam. The underlying material is reddish-brown, loose gravelly coarse sand.

Permeability is moderate in the upper part of these soils and rapid in the lower part. The available water capacity is moderate. The content of organic matter is high. The content of available phosphorus is medium, the content of available potassium is low, and the content of available nitrogen is high. The water table fluctuates between the surface and a depth of 3 feet.

Most areas of these soils are used for wild pasture and hay. Some cultivated areas are in hay and pasture. If adequately drained, these soils are suited to all of the crops commonly grown in the county.

Representative profile of Hillet silt loam, level, in a cultivated field, 540 feet east and 43 feet south of the

Figure 8.—Area of Granite rock land.

northwest corner of NE¼ of sec. 23, T. 36 N., R. 28 W.:

Ap—0 to 7 inches, black (10YR 2/1) silt loam that is high in content of very fine sand; weak, very fine, subangular blocky structure; friable; slightly acid; clear, wavy boundary.

A12—7 to 13 inches, black (10YR 2/1) loam that is high in content of very fine sand and silt; common, medium, distinct, dark-gray (10YR 4/1) mottles; weak, very thick, platy structure parting easily to moderate, very fine, subangular blocky; very friable; few vesicular pores; medium acid; clear, wavy boundary.

B1g—13 to 20 inches, dark grayish-brown (2.5Y 4/2) silt loam; many, fine, prominent, dark yellowish-brown (10YR 4/4) and dark-brown (7.5YR 4/4) mottles; weak, medium, platy structure parting to weak, very fine, subangular blocky; very friable; some darker colored coatings along root channels; vesicular; slightly acid; clear, wavy boundary.

B2g—20 to 28 inches, grayish-brown (2.5Y 5/2) silt loam; many, medium, prominent, dark yellowish-brown (10YR 4/4) and dark-brown (7.5YR 4/4) mottles; weak, medium, platy structure parting to weak, very fine, subangular blocky; friable; vesicular; some darker coatings along root channels; slightly acid; abrupt, wavy boundary.

IIB3g—28 to 30 inches, grayish-brown (2.5Y 5/2) fine sandy loam; many, coarse, prominent, dark-brown (7.5YR 4/4) mottles; weak, medium, subangular blocky structure; very friable; horizon is discontinuous; medium acid; abrupt, wavy boundary.

IIC—30 to 60 inches, reddish-brown (5YR 4/4) gravelly coarse sand; single grained; loose; about 40 percent fine gravel; slightly acid.

The solum ranges from 20 to 40 inches in thickness. The A1 horizon is 10 to 22 inches thick and slightly acid or medium acid. It is black or very dark gray loam, silt loam, or very fine sandy loam. Mottles are in the lower part of this horizon in most places. Structure ranges from weak to moderate granular, subangular blocky, or platy.

The B horizon is 10 to 28 inches thick. It is gray and grayish brown and has distinct or prominent mottles. Structure is weak platy or subangular blocky. Reaction ranges from medium acid to neutral. The B1 and B2 horizons are silt loam, loam, or very fine sandy loam. The B3 horizon is fine sandy loam, sandy loam, coarse sandy loam, loamy coarse sand, loamy sand, or loamy fine sand. It ranges from 0 to 5 inches in thickness.

The C horizon ranges from dark brown or brown to dark reddish brown and is loose sand or coarse sand that is as much as 50 percent gravel. Reaction is medium acid to neutral.

Hillet soils are near Antigo and Ogilvie soils, which formed in similar material, and they are similar to Adolph soils. They have a thicker dark-colored A horizon and a grayer colored B horizon than the better drained Antigo soils. They have a thicker dark-colored A horizon than Ogilvie soils. They have a sandy and gravelly IIC horizon, whereas Adolph soils have a loamy IIC horizon.

Hillet silt loam (Hm).—This nearly level soil is in depressions and drainageways that have a gradient of less than 1 percent. It is on an outwash plain in the vicinity of the hamlet of Glendorado. Areas range from 5 to 160 acres in size, but most areas are 15 to 50 acres in size.

This soil has a profile similar to the one described as representative for the series, but it is somewhat wetter.

Included with this soil in mapping are areas of soils that have a surface layer of loam and very fine sandy loam, and some soils covered by a thin layer of mucky peat less than 12 inches thick. Also included are areas of soils that are underlain by coarse material at a depth of 24 to 42 inches, and small areas of Mucky peat that are too small to map separately.

This Hillet soil has a high water table in spring. The growing season is shortened at times because of the high water table, frequent ponding, and the hazard of early frost. To prevent compaction, use of heavy machinery should be avoided when the soil is wet.

This soil is used mainly for pasture and wild hay, but if excess water is drained and the proper level of fertility is maintained, it is suited to corn, soybeans, small grain, grasses, and shallow-rooted legumes. Capability unit IVw–1; woodland suitability group VII; building site group 9.

Hillet silt loam, level (HmA).—This soil is on wet flats of a glacial outwash plain in the vicinity of the hamlet of Glendorado. Areas range from 10 to 100 acres in size, but areas 15 to 30 acres in size are most common.

This soil has the profile described as representative for the series.

Included with this soil in mapping are areas of soils that have a surface layer of very fine sandy loam and loam and some areas of soils that are covered by a thin layer of mucky peat less than 12 inches thick. Also included are areas of soils that are underlain by coarse material at a depth of 24 to 42 inches, and small areas of shallow peat too small to map separately.

This Hillet soil has a high water table in spring. The high water table and the hazard of early frost shorten the growing season in some years. To prevent compaction, traffic of heavy machines should be avoided when the soil is wet.

This soil is used mainly for pasture and wild hay, but if excess water is drained and the proper level of fertility is maintained, it is suited to corn, soybeans, oats, grasses, and shallow-rooted legumes. Capability unit IIIw–1; woodland suitability group VII; building site group 9.

Hubbard Series

The Hubbard series consists of deep, nearly level to steep, excessively drained soils on glacial outwash plains and valley trains. These soils formed in leached, calcareous sands in the Mississippi Valley under prairie grasses and scattered bur oak and hazelnut shrubs.

In a representative profile the surface layer is black and very dark grayish-brown loamy coarse sand about 23 inches thick. The subsoil is dark-brown and brown, very friable to loose sand about 21 inches thick. The underlying material is brown, loose sand.

Permeability is rapid, and available water capacity low. The content of organic matter and available phosphorus, potassium, and nitrogen is low. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are in open woods and pasture. These soils are poorly suited to all of the crops commonly grown in the county. Irrigation is needed to insure good crop production.

Representative profile of Hubbard loamy coarse sand, 0 to 2 percent slopes, in a woodlot, 457 feet north and 60 feet west of southeast corner of the NE¼ of sec. 21, T. 37 N., R. 31 W.:

A11—0 to 12 inches, black (10YR 2/1) loamy coarse sand; weak, medium, subangular blocky structure; very friable; medium acid; clear, wavy boundary.

A12—12 to 16 inches, black (10YR 2/1) loamy coarse sand; weak, medium, subangular blocky structure; very friable to loose; medium acid; clear, wavy boundary.

A3—16 to 23 inches, very dark grayish-brown (10YR 3/2) loamy sand; massive; very friable to loose; strongly acid; gradual, wavy boundary.

B2—23 to 31 inches, dark-brown (10YR 3/3) sand that grades to dark yellowish brown (10YR 3/4); single grained; very friable to loose; strongly acid; gradual, wavy boundary.

B3—31 to 44 inches, brown (10YR 4/3) sand; single grained; loose; some gravel; medium acid; diffuse boundary.

C—44 to 61 inches, brown (10YR 4/3) sand; single grained; loose; medium acid.

The solum and underlying material above a depth of 50 inches generally are free of coarse fragments, but in some places gravel-sized particles either dispersed in the matrix or as strata make up as much as 20 percent, by volume. The solum ranges from 26 to 50 inches in thickness. The A1 horizon is 9 to 18 inches thick and is medium acid or slightly acid. It is black or very dark gray loamy coarse sand, loamy sand, coarse sand, or sand. Structure ranges from weak crumb to subangular blocky. The A3 horizon is very dark brown, dark brown, or very dark grayish brown and is 3 to 14 inches thick. It has weak crumb or subangular blocky structure.

The B horizon is 16 to 38 inches thick and ranges from loamy coarse sand or loamy sand to coarse sand or sand. Reaction is strongly acid or medium acid. This horizon is dark brown and brown and has a higher value with depth. Structure ranges from massive to single grained.

The C horizon is loose coarse sand or sand. Reaction ranges from medium acid to mildly alkaline. This horizon is brown, pale brown, or light yellowish brown and is mottled below a depth of 40 inches in some places.

The Hubbard soils in Benton County have more fine sand than is defined as within the range for the series, but this difference does not alter the usefulness or behavior of the soils.

Hubbard soils are near Dickman and Duelm soils. They have more sand and less silt and clay in the A horizon and in the upper part of the B horizon than those soils. They have a higher chroma in the B horizon than Duelm soils.

Hubbard loamy coarse sand, 0 to 2 percent slopes (HoA).—This soil is on a glacial outwash terrace that is 1 to 6 miles wide and is parallel to the Mississippi River. Areas are elongated and are 160 to 400 acres in size. Narrow and shallow drainageways form a braided pattern on the surface. These drainageways are parallel to the river, and during spring thaws, the flow is in the same general direction. Some areas of this soil surround depressions and pits or iceblock holes.

This soil has the profile described as representative for the series. In cultivated areas, most of the acreage of this soil is slightly eroded, but some spots are moderately eroded.

Figure 9.—**Wind stripcropping on Hubbard soils in the Rice Prairie area.**

Included with this soil in mapping are areas of soils that have a sandy loam surface layer and occur in very narrow drainageways. Also included are some areas of soils that are underlain by bands of gravelly sand that are as much as 18 inches thick.

The major limitation to the use of this Hubbard soil is its low available water capacity. This soil is droughty during dry spells, and where cultivated, the soil is also subject to wind erosion. Cropping systems that conserve moisture and increase organic-matter content are needed on this soil. The use of field shelterbelts and wind stripcropping are practices that help to reduce wind erosion.

Most areas of this soil are cultivated. Some of the acreage in the Rice Prairie area has been planted to pine trees. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legume crops and to early maturing crops, such as winter rye. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Hubbard loamy coarse sand, 0 to 2 percent slopes, wind eroded (HoA2).—This soil is on a glacial outwash terrace 1 to 6 miles wide along the Mississippi River. Areas are elongated and are generally 160 to 400 acres in size. Some very shallow and very narrow drainageways 10 to 25 feet wide form a braided pattern on the surface. Some small areas of this soil are adjacent to depressions of semicircular iceblock holes.

This soil has a profile similar to the one described as representative for the series, but much of the original surface layer has been removed by wind erosion. Erosion is evidenced by the accumulation or drifting of soil along fence rows and field boundaries. Much of the fine textured material has been removed from the plow layer. The color of the surface layer is mainly dark brown. In places a few pebbles are on the surface.

Included with this soil in mapping are areas of soils that occur in the very narrow drainageways and have a surface layer of sandy loam. Also included are small areas of severely eroded soils that are on the crests of slight rises and have a sand surface layer. There are some areas of soils that are underlain by bands of gravelly sand as much as 18 inches thick.

The major limitation to the use of this soil is the low available water capacity, which makes the soil droughty in dry spells. A severe hazard of wind erosion is also a limitation. Cropping systems that conserve moisture and increase organic-matter content are needed. Field shelterbelts and wind stripcropping help to reduce wind erosion (fig. 9).

Most areas of this soil are cultivated. Many areas in the Rice Prairie area have been planted to pine trees. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legume crops and to early maturing crops, such as winter rye. Crop growth is

Figure 10.—**Irrigation by self-propelled, center-pivot system on Hubbard soils.**

poor, but under irrigation it is good to excellent (fig. 10). Capability unit IVs–2; woodland suitability group VI; building site group 2.

Hubbard loamy coarse sand, 2 to 6 percent slopes (HoB).—This gently sloping and undulating soil is adjacent to drainageways on a glacial outwash terrace that is 1 to 6 miles wide. Areas have numerous remnant iceblock holes that are typical of a pitted outwash plain. Slopes are short, and the depressions generally are well drained. Where the terrace is lower next to the Mississippi River, this soil has a corrugated appearance.

This soil has a profile similar to the one described as representative for the series, but because of slope, it is somewhat thinner. Most of the cultivated acreage is only slightly eroded, but on crests of slopes, moderate erosion has occurred. Erosion is evidenced by the lighter color of the surface layer on crests of slopes where the subsoil is mixed with the remaining material from the surface layer. On some crests this soil has a pebbly surface layer.

Included with this soil in mapping are areas of soils that occur in the very narrow drainageways and have a surface layer of sandy loam. Also included are soils in somewhat poorly drained or poorly drained depressions that are too small to map separately. There are some areas of soils that are underlain by bands of gravelly sand that are as much as 18 inches thick.

The major limitation to use of this soil is the low available water capacity, which makes the soil droughty in dry spells. The hazards of wind erosion and water erosion are also limitations. Cropping systems that conserve moisture and increase organic-matter content are needed. Use of field shelterbelts and wind stripcropping helps to reduce wind erosion.

Most areas of this soil are cultivated. Some of the acreage in the Rice Prairie area has been planted to pine trees. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legume crops and to early maturing crops, such as winter rye. Crop production is poor, but under irrigation it is good to excellent. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Hubbard loamy coarse sand, 2 to 6 percent slopes, eroded (HoB2).—This gently sloping and undulating soil is in areas adjacent to drainageways on a glacial outwash terrace 1 to 6 miles wide. Areas have numerous remnant iceblock holes that typify a pitted outwash plain. Slopes are 150 to 250 feet in length, and the depressions generally are well drained. Where the terrace is lower, next to the Mississippi River, this soil has a corrugated appearance.

This soil has a profile similar to the one described as representative for the series, but it is thinner because of slope and the loss of much of the original surface layer through erosion. The surface layer is

browner and has lost much of its original fines. Erosion is evidenced by the accumulation and drifting of soil along fence rows and field boundaries. Accumulations of wind-blown material have also collected in the depressions.

Included with this soil in mapping are areas of severely eroded sandy soils on crests of slopes. Also included are some areas of soils that are underlain by bands of gravelly sand that are as much as 18 inches in thickness.

The major limitation to use of this soil is the low available water capacity, which makes the soil droughty in dry spells. The hazard of wind erosion is also a limitation. Cropping systems that conserve moisture and increase organic-matter content are needed. Use of field shelterbelts and wind stripcropping helps to reduce wind erosion.

Most areas of this soil are cultivated. Some of the acreage in the Rice Prairie area has been planted to pine trees. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legumes and to early maturing crops, such as winter rye. Crop production is poor, but under irrigation it is good to excellent. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Hubbard loamy fine sand, 0 to 2 percent slopes (HrA). —This soil is on a glacial outwash terrace 1 to 4 miles wide that encircles Little Rock Lake and extends northward to the county line. Areas are irregular in shape and range from 10 to 100 acres in size.

This soil has a profile similar to the one described as representative for the series, but it has finer sand in the surface layer and subsoil and a somewhat lighter colored surface layer. Where cultivated, most of the acreage of this soil is slightly eroded, but it is moderately eroded in spots.

Included with this soil in mapping are small areas of soils that have a surface layer of loamy coarse sand and fine sand. Also included are some areas of gently sloping soils that have short slopes and that surround small depressions and pits or iceblock holes.

The major limitation to the use of this soil is the low available water capacity. The soil is droughty during dry spells, and wind erosion is a hazard if the soil is cultivated.

Cropping systems that conserve moisture and increase organic-matter content are needed. Use of field shelterbelts and wind stripcropping helps to reduce wind erosion.

Most areas of this soil are cultivated. Some of the acreage in the Little Rock Lake area has been planted to pine trees. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legume crops and to early maturing crops, such as winter rye. If this soil is irrigated, crop production is good to excellent. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Hubbard loamy fine sand, 0 to 2 percent slopes, wind eroded (HrA2).—This soil is in areas on a glacial outwash terrace 1 to 4 miles wide that encircles Little Rock Lake and extends northward to the county line. Areas are irregular in shape and range from 20 to 400 acres in size. Some small, gently sloping areas of this soil surround small depressions and pits or iceblock holes.

This soil has a profile similar to the one described as representative for the series, but it has finer sand in the surface layer and subsoil and has a somewhat lighter colored surface layer. Much of the original surface layer has been removed by wind erosion. Erosion is evidenced by the accumulation or drifting of soil material along fence rows and field boundaries. Much of the original, finer material has been removed from the plow layer. In places, dark yellowish-brown, unstable fine sand is exposed at the surface.

Included with this soil in mapping are small areas of soils that have a surface layer of loamy coarse sand and fine sand.

The major limitation to the use of this Hubbard soil is the low available water capacity. This soil is droughty during dry spells, and wind erosion is a hazard if the soil is cultivated. Cropping systems that conserve moisture and increase organic-matter content are needed. Use of field shelterbelts and wind stripcropping helps to reduce wind erosion.

Most areas of this soil are cultivated. Some of the acreage in the Little Rock Lake area has been planted to pine trees. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legumes and to early maturing crops, such as winter rye. If this soil is irrigated, crop production is good to excellent. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Hubbard loamy fine sand, 2 to 6 percent slopes (HrB). —This gently sloping and undulating soil is in areas adjacent to drainageways on a glacial terrace 1 to 4 miles wide that encircles Little Rock Lake and extends northward to the county line. Areas are irregular in shape and range from 10 to 160 acres in size. Slopes are numerous, short, and complex, and the relief is dunelike.

This soil has a profile similar to the one described as representative for the series, but it has finer sand in the surface layer and subsoil and a somewhat lighter colored surface layer. Most of the cultivated acreage of this soil is slightly eroded, but on crests of slopes it is moderately eroded. Erosion is evidenced by the lighter color of the surface layer on crests where cultivation has mixed part of the subsoil with the remaining material of the surface layer.

Included with this soil in mapping are small areas of soils that have a surface layer of loamy coarse sand and fine sand.

This Hubbard soil is excessively drained, and the major limitation to its use is the low available water capacity. It is droughty during dry spells, and where it is cultivated, wind erosion is a hazard. Cropping systems that conserve moisture and increase organic-matter content are needed. Use of field shelterbelts and wind stripcropping helps to reduce wind erosion.

Most areas of this soil are cultivated. Some of the acreage in the Little Rock Lake area has been planted to pine trees. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legumes and to early maturing crops, such as winter rye. If this soil is irrigated, crop production is good to excellent. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Hubbard loamy fine sand, 2 to 6 percent slopes, eroded (HrB2).—This gently sloping and undulating soil

is in areas adjacent to drainageways on a glacial outwash terrace 1 to 4 miles wide that encircles Little Rock Lake and extends northward to the county line. Areas are irregular in shape and range from 20 to 400 acres in size. This soil has numerous, short, complex slopes that are typical of dunelike relief.

This soil has a profile similar to the one described as representative for the series, but it has finer sand in the surface layer and subsoil and a somewhat lighter colored surface layer. Most of the cultivated acreage of this soil is moderately eroded, but on the crests of slopes in many places, it is severely eroded. Erosion is evidenced by the accumulation and drifting of soil material along fence rows and field boundaries. Accumulations of wind-blown material are in the low areas.

Included with this soil in mapping are severely eroded sandy areas on the crests of slopes. Also included are small areas of soils that have a surface layer of loamy coarse sand and fine sand.

The major limitation to the use of this soil is the low available water capacity. This soil is droughty during dry spells, and wind erosion is a hazard if the soil is cultivated. The natural fertility is low. Cropping systems that conserve moisture and increase organic-matter content are needed. Use of field shelterbelts and wind stripcropping helps to reduce wind erosion.

Most areas of this soil are cultivated. Some of the acreage in the Little Rock Lake area has been planted to pine trees. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legumes and early maturing crops, such as winter rye. If this soil is irrigated, crop production is good to excellent. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Hubbard soils, 6 to 12 percent slopes, eroded (HsC2).—These soils are on narrow outwash embankments, 100 to 500 feet wide, adjacent to drainageways and gullies. Areas are 15 to 30 acres in size. Slopes are 75 to 150 feet long.

These soils have a profile similar to the one described as representative for the series, but they are thinner because of slope. Also, much of the original surface layer has been removed by erosion. The remaining material from the surface layer is browner and includes both loamy coarse sand and loamy fine sand.

Included with these soils in mapping are a few areas of severely eroded soils on crests of slopes. These areas are now dark-brown and brown sand. Also included are some areas of soils that are underlain by bands of gravelly sand that are as much as 18 inches thick. This gravelly sand is exposed on the crests of slopes in a few areas.

The major limitations to the use of these soils are low available water capacity and severe hazards of wind erosion and water erosion.

Most of the acreage of these soils is cultivated or is in pasture. These soils are poorly suited to grain crops because they are droughty. They are better suited to permanent pasture and to trees. The main management needs are controlling erosion, increasing fertility, and controlling grazing. Capability unit VIs–1; woodland suitability group VI; building site group 2.

Hubbard soils, 12 to 25 percent slopes (HsE).—These hilly and steep soils are on narrow outwash embankments, 100 to 300 feet wide, adjacent to the Mississippi River and its tributaries in the Little Rock Lake area. Areas are 15 to 30 acres in size. Slopes are 75 to 150 feet long.

These soils have a profile similar to the one described as representative for the series, but they are thinner because of slopes. The texture of the surface layer ranges from loamy coarse sand to loamy sand, sand, or fine sand.

Included with these soils in mapping are some areas of severely eroded soils that have gravelly bands of sand exposed at the surface, some areas of soils that are subject to slippage, and a few gullies.

The major limitations to the use of these soils are low available water capacity, degree of slopes, low level of fertility, and a severe hazard of erosion. Providing permanent cover, such as trees or grasses, is the main management need. Controlling erosion and limiting the amount of grazing also are essential.

Most areas of these soils are in permanent pasture or are covered with scrub bur oak and red oak. Capability unit VIIs–1; woodland suitability group VI; building site group 2.

Isanti Series

The Isanti series consists of deep, level and depressional, very poorly drained soils in depressions and drainageways of glacial outwash plains. These soils formed in outwash sand that had been sorted by wind and water. The native vegetation was wetland grasses, sedges, and shrubs.

In a representative profile the surface layer is black, mucky loamy fine sand about 11 inches thick. The subsoil is mottled, dark-gray and grayish-brown, very friable fine sand about 17 inches thick. The underlying material is light brownish-gray, loose fine sand that has faint mottles.

Permeability is rapid, and available water capacity is low. Organic-matter content is high. The content of available nitrogen is high. The water table fluctuates between the surface and a depth of 2 feet.

Most areas of these soils are in pasture or are idle. Some areas where these soils are drained are used for crops. These soils are suited to all of the crops commonly grown in the county if they are irrigated where needed and adequate drainage is provided.

Representative profile of Isanti mucky loamy fine sand, in a cultivated field, 535 feet east and 560 feet north from southwest corner of sec. 33, T. 36 N., R. 29 W.:

Ap—0 to 11 inches, black (N 2/0) mucky loamy fine sand; weak, medium, granular structure; very friable, nonsticky; few inclusions of organic soil material; strongly acid; clear, wavy boundary.

B1g—11 to 14 inches, dark-gray (2.5Y 4/1) fine sand; few, fine, prominent, brown (7.5YR 5/4) mottles; weak, medium, subangular blocky structure; very friable; medium acid; gradual, irregular boundary.

B2g—14 to 28 inches, grayish-brown (2.5Y 5/2) fine sand; common, medium, faint, light olive-brown (2.5Y 5/4) mottles; weak, medium, subangular blocky structure that breaks to single grained; very friable; slightly acid; diffuse, irregular boundary.

C—28 to 60 inches, light brownish-gray (2.5Y 6/2) fine sand; common, medium, faint, light olive-brown (2.5Y 5/4) mottles; single grained; loose, slightly acid.

The solum ranges from 20 to 40 inches in thickness. The Ap horizon, where present, is black or very dark gray in color and 6 to 8 inches thick. Structure is weak crumb and granular to platy. The A1 horizon, where present, is 10 to 14 inches thick and medium acid or strongly acid. It ranges from mucky loamy fine sand and mucky fine sandy loam to loamy sand, loamy fine sand, fine sand, and sand. Mottles are in this horizon in some places. An organic layer as much as 6 inches thick is in some profiles.

The B horizon is dark gray, gray, dark grayish brown, and grayish brown. Texture typically is fine sand, but it is sand, loamy sand, and loamy fine sand in places. Reaction ranges from strongly acid to slightly acid.

The C horizon is gray to grayish brown or light brownish gray. It generally is fine sand, but it is sand in places.

Isanti soils are near Sartell and Lino soils and are similar to Isanti soils, loamy subsoil variant. Isanti soils have a lower chroma in the B and C horizons than Lino or Sartell soils. They have less silt and very fine sand and more fine sand in the C horizon than the Isanti soils, loamy subsoil variant.

Isanti mucky loamy fine sand (Im).—This nearly level soil is in shallow, channellike drainageways or saucer-shaped depressions on a glacial outwash plain adjacent to the Mississippi River. Areas range from 5 to 160 acres in size, but areas 10 to 20 acres in size are most common.

Included with this soil in mapping are areas of a shallow mucky peat, but the areas are too small to show separately on the soil map. Also included is a somewhat coarser textured soil that occurs near Hubbard soils.

Isanti soils are very poorly drained and have a high water table. Sometimes the soil is ponded in spring. Generally the water table subsides as the growing season progresses. If adequately drained, this soil becomes droughty during prolonged dry periods because of its rapid permeability and low available water capacity. This soil is also low in fertility and is subject to early frost.

Most areas of this soil are undrained, and aquatic grasses, sedges, and willows grow on it. Where this soil is cultivated, the commonly grown crops are corn, soybeans, and oats and red clover, timothy, and alsike clover mixtures. Capability unit IVw–2; woodland suitability group VII; building site group 8.

Isanti Variant

The Isanti variant consists of deep, level and depressional, very poorly drained soils in shallow channellike depressions and small saucer-shaped depressions. These soils formed in sorted glacial outwash sand that has layers of loamy lacustrine sediment in the underlying material. The native vegetation was wetland grasses, sedges, and shrubs.

In a representative profile the surface layer is black mucky loamy fine sand in the upper 9 inches and very dark gray loamy fine sand in the lower 9 inches. The subsoil is grayish-brown, very friable fine sand that has some mottling and is about 14 inches thick. The upper 15 inches of the underlying material is gray, very friable very fine sandy loam that is mottled. The lower 13 inches is brown and grayish-brown, loose sand that is also mottled.

Permeability is rapid in the sandy part of the profile and moderate in the medium-textured part. The available water capacity is low. The content of organic matter is high. The content of available phosphorus and potassium is low. The water table fluctuates between the surface and a depth of 3 feet.

Most areas of these soils are in pasture. Some areas in which adequate drainage has been provided are in crops. These soils are suited to all of the crops commonly grown in the county if adequate drainage is provided and if they are irrigated where needed.

Representative profile of Isanti mucky loamy fine sand, loamy subsoil variant, in a cultivated field, 339 feet north and 436 feet west from southeast corner of the NW¼ of sec. 23, T. 36 N., R. 28 W.:

A1—0 to 9 inches, black (10YR 2/1) mucky loamy fine sand; very fine, subangular blocky structure; very friable; neutral; abrupt, smooth boundary.

A3g—9 to 18 inches, very dark gray (10YR 3/1) loamy fine sand; weak, thin, platy structure; very friable; neutral; abrupt, wavy boundary.

B2g—18 to 32 inches, grayish-brown (2.5Y 5/2) fine sand; few, large, distinct, yellowish-brown (10YR 5/4) and dark yellowish-brown (10YR 4/4) mottles; single grained; loose; neutral; abrupt, wavy boundary.

IIC1g—32 to 47 inches, gray (5Y 6/1) very fine sandy loam; many, medium, prominent, strong-brown (7.5YR 5/6) and dark-brown (7.5YR 4/4) mottles; weak, very fine, angular blocky structure; very friable; nonsticky; neutral; abrupt, wavy boundary.

IIIC2—47 to 60 inches, brown (7.5YR 5/2) and grayish-brown (10YR 5/2) sand; many, large, distinct, dark-brown (7.5YR 4/4) and dark yellowish-brown (10YR 4/4) mottles; single grained; loose; few pebbles; neutral.

The solum ranges from 22 to 48 inches in thickness. The Ap horizon, where present, is black or very dark gray and is 6 to 8 inches thick. Its structure ranges from weak granular or crumb to angular blocky. The A1 horizon is 8 to 12 inches thick and is slightly acid or neutral. It is black or very dark gray mucky loamy fine sand to fine sandy loam. The A3 horizon is 4 to 12 inches thick.

The B2g horizon is grayish-brown or gray sand, fine sand, loamy fine sand, or loamy sand. Reaction is slightly acid or neutral.

The IIC1g horizon is gray, grayish brown, or brown. It is fine sandy loam or very fine sandy loam to loam or silt loam. It commonly occurs as one or more layers between coarser textured layers, and it ranges from ½ inch to 24 inches in thickness. Depth to the IIC1g horizon is from 28 to 50 inches. The IIIC horizon generally is sand or fine sand, but it also is loamy sand and loamy fine sand in some places.

Isanti variant soils are mainly near Lino variant soils and are similar to Isanti soils. They have a thicker dark-colored A horizon and are more poorly drained than Lino variant soils. They have more very fine sand and silt and less fine sand in the part of the C horizon above a depth of 50 inches than Isanti soils.

Isanti mucky loamy fine sand, loamy subsoil variant (It).—This nearly level soil is in shallow, channellike drainageways or saucer-shaped depressions, mostly in the southeastern part of the county. Areas range from 5 to 40 acres in size, but areas 10 to 20 acres in size are most common.

Depth to the underlying layers of finer textured material ranges from 24 to 48 inches. In places these layers are at a greater depth or are absent. Also included are small areas of shallow peat that are too small to map separately.

This soil has a high water table and is sometimes ponded in spring. Generally, the water table subsides as the growing season progresses. Permeability is rapid in the upper, sandy part of the soil and moderate

in the banded part. Susceptibility to early frost and droughtiness in prolonged dry periods are other limitations to plant growth.

If this soil is adequately drained, crop production is fair, but proper liming and fertilizing are needed. Corn, soybeans, and oats and red clover, timothy, and alsike clover mixtures are the commonly grown crops. Capability unit IVw–2; woodland suitability group VII; building site group 8.

Langola Series

The Langola series consists of deep, nearly level to gently sloping, well drained and moderately well drained soils on sand-covered drumlins. These soils formed in glacial outwash sand 25 to 48 inches thick over firm sandy loam glacial till. Native vegetation was an open forest canopy of oaks and an understory of prairie grasses.

In a representative profile the surface layer is black to very dark grayish-brown loamy fine sand about 14 inches thick. The subsoil is about 27 inches thick. The upper 10 inches is dark-brown, very friable loamy fine sand. The lower 17 inches is brown, very friable loamy sand that grades with depth to reddish-brown, firm sandy loam that is 10 to 15 percent coarse fragments. The underlying material is dark-brown, firm sandy loam that has faint mottles.

Permeability is moderately slow, and available water capacity is moderate. Organic-matter content is low. The content of available phosphorus, potassium, and nitrogen is low. The firm till, which begins at a depth of 25 to 48 inches, restricts the movement of water and limits the root zone. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are in open woods and pasture. These soils are suited to all of the crops commonly grown in the county. Irrigation is needed to insure good crop growth.

Representative profile of Langola loamy fine sand, 0 to 2 percent slopes, in a cultivated field, 50 feet south and 90 feet east of the northwest corner of SW¼ of sec. 18, T. 38 N., R. 30 W.:

Ap—0 to 9 inches, very dark gray (10YR 3/1) to black (10YR 2/1) loamy fine sand; weak, fine, subangular blocky structure; soft, very friable; medium acid; abrupt, smooth boundary.

A3—9 to 14 inches, very dark grayish-brown (10YR 3/2) loamy fine sand; weak, medium, subangular blocky structure; soft, very friable; slightly acid; clear, wavy boundary.

B2—14 to 24 inches, dark-brown (10YR 4/3) loamy fine sand; weak, medium, subangular blocky structure; soft, very friable; slightly acid.

B31—24 to 31 inches, brown (7.5YR 5/4) loamy sand; massive; soft, very friable; about 15 percent coarse fragments; slightly acid; clear, wavy boundary.

IIB32—31 to 41 inches, reddish-brown (5Y 4/3) sandy loam; weak, very thick, platy structure parting to moderate, medium, subangular blocky; firm; few, thin, patchy clay films on upper surfaces of platy units; about 10 percent coarse fragments; slightly acid; gradual, wavy boundary.

IIC—41 to 60 inches, dark-brown (7.5YR 4/4) sandy loam; few, fine, faint, yellowish-red (5YR 4/6) and reddish-gray (5YR 5/2) mottles; moderate, medium, platy structure; firm; about 10 percent coarse fragments; medium acid.

The solum ranges from 36 to 54 inches in thickness. The Ap horizon is 6 to 10 inches thick and is strongly acid to neutral. It is black or very dark gray and generally is loamy fine sand or loamy sand, but it ranges from heavy fine sand or heavy sand to light fine sandy loam or light sandy loam. In undisturbed areas the A1 horizon is black or very dark brown and is 6 to 10 inches thick. The A3 horizon is very dark grayish-brown to dark-brown loamy fine sand and loamy sand 4 to 6 inches thick.

The reaction of the B horizon is slightly acid or neutral. Structure ranges from weak to moderate, subangular blocky or platy, or the horizon is massive. The B2 and B31 horizons are loamy fine sand or loamy sand to fine sand or sand. Mottles are in these horizons in some places. A concentration of gravel and cobblestones is in the lower part of the B31 horizon in some places. The IIB32 horizon is reddish-brown or brown, friable or firm fine sandy loam or sandy loam. The depth to the IIB32 horizon is 25 to 48 inches.

The IIC horizon generally is dark brown or brown, but is dark reddish brown and reddish brown in places. Texture ranges from fine sandy loam to sandy loam, and reaction is slightly acid or neutral. Content of coarse fragments in the IIB32 horizon and IIC horizon is 5 to 15 percent.

Langola soils are near Hubbard, Nokasippi, and Watab soils and are similar to Pomroy soils. They formed in a sandy overburden underlain by loamy glacial till, but Hubbard soils formed in deep, sandy sediment. They formed in materials similar to the Nokasippi and Watab soils but are better drained than those soils. Langola soils have a thick dark-colored A horizon, whereas Pomroy soils have a thin dark-colored A horizon.

Langola loamy fine sand, 0 to 2 percent slopes (LaA).—This soil is on the glacial uplands. It is on slightly convex crests of sand-covered drumlins, at the base of long slopes, and in concave saddles between drumlins. Areas are irregular in shape and 10 to 80 acres in size. A few large stones are in some areas.

This soil has the profile described as representative for the series. Where this soil is cultivated, most of the acreage is slightly eroded, but in places moderate wind erosion has occurred.

Included with this soil in mapping are a few small areas of soils that have a surface layer of sandy loam. Also included are areas of soils that are less than 18 inches deep to the underlying material, and the depth varies within a short lateral distance to more than 48 inches. There are also soils that have slopes of 3 percent. These slopes are 75 to 150 feet long.

This soil is droughty during dry spells, and if cultivated, it is subject to wind erosion. Conserving moisture and increasing organic-matter content help to overcome limitations on this soil. Field shelterbelts help to reduce wind erosion.

Most areas of this soil are cultivated, and the soil is suited to corn, rye, soybeans, and alfalfa. If this soil is irrigated, crop production is good to excellent. Capability unit IIIs–1; woodland suitability group IV; building site group 5.

Langola loamy fine sand, 2 to 6 percent slopes, eroded (LaB2).—This soil is on crests and the upper slopes of drumlins on the glacial uplands. Areas range from 5 to 100 acres in size, but areas 10 to 20 acres in size are most common. Slopes are plane to convex and range from 300 to 1,000 feet in length. Some areas have a few large stones.

This soil has a profile similar to the one described as representative for the series, but much of the surface layer has been removed by wind erosion. Erosion is indicated by accumulation or drifting along fence rows and field boundaries. Much of the finer material originally in the plow layer has been removed. The surface

layer is mainly very dark grayish brown and has been mixed with material from the dark-brown subsoil. Dark-colored, sandy material has accumulated in the dips and concave areas.

Included with this soil in mapping are some areas of soils that have a sandy loam surface layer. Depth to the underlying material varies within short lateral distances, and it ranges from less than 18 inches to more than 48 inches.

The major limitation to the use of this soil is the moderate available water capacity, which makes the soil droughty during dry periods. Wind erosion is a severe hazard. Cropping systems that conserve moisture and increase organic-matter content are needed. Use of field shelterbelts and wind stripcropping helps to reduce wind erosion.

Most areas of this soil are cultivated. The soil is suited to all of the crops commonly grown in the county. If this soil is irrigated, crop production is good to excellent. Capability unit IIIs–1; woodland suitability group IV; building site group 5.

Lino Series

The Lino series consists of deep, nearly level, somewhat poorly drained soils on the edge of small depressions, in narrow drainageways that lead from larger depressions, in nearly level areas where there is a high water table, and in small islandlike areas that rise above surrounding wetter soils. These soils formed in deep fine sand deposits that are partly or entirely of eolian origin. The native vegetation was red oak, aspen, and grasses.

In a representative profile the surface layer is very dark brown loamy fine sand about 6 inches thick. The subsoil is about 28 inches thick. The upper 4 inches is dark grayish-brown, very friable loamy fine sand that is faintly mottled. The lower part is brown, loose fine sand and is mottled. The underlying material is pale-brown and light brownish-gray, loose fine sand that is distinctly mottled.

Permeability is rapid, and available water capacity is low. Organic-matter content is low. The content of available phosphorus, potassium, and nitrogen is low. The water table fluctuates between depths of 2 and 4 feet.

Some areas of these soils are in crops. Some areas are used as pasture and as woodlots. These soils are not suited to all of the crops commonly grown in the county. Adequate drainage and irrigation water are needed to insure crop growth.

Representative profile of Lino loamy fine sand in a cultivated field, 1,215 feet north and 75 feet east of southwest corner of sec. 18, T. 37 N., R. 30 W.:

Ap—0 to 6 inches, very dark brown (10YR 2/2) loamy fine sand; weak, fine, subangular blocky structure; very friable; very strongly acid; abrupt, wavy boundary.

B2—6 to 10 inches, dark grayish-brown (10YR 4/2) loamy fine sand; common, fine, faint, dark-brown (10YR 3/3) and dark yellowish-brown (10YR 4/4) mottles; massive, very friable; very strongly acid; clear, wavy boundary.

B31—10 to 24 inches, brown (10YR 4/3) fine sand; many, coarse, distinct, brown (7.5YR 4/4), yellowish-red (5YR 4/6), and dark reddish-brown (5YR 3/4) mottles; single grained; loose; very strongly acid; diffuse, wavy boundary.

B32—24 to 34 inches, brown (10YR 5/3) fine sand; many, coarse, distinct, brown (7.5YR 4/4), yellowish-red (5YR 4/6), and dark reddish-brown (5YR 3/4) mottles; single grained; loose; strongly acid; clear, wavy boundary.

C—34 to 60 inches, light brownish gray (10YR 6/2) and pale brown (10YR 6/3) fine sand; few, fine, distinct, yellowish-brown (10YR 5/6) and brownish-yellow (10YR 6/6) mottles; single grained; loose; strongly acid.

The solum ranges from 30 to 46 inches in thickness. The Ap horizon is 6 to 8 inches thick and is very strongly acid to medium acid. It is very dark brown or dark grayish-brown loamy fine sand. The A1 horizon, where present, is black or very dark gray loamy fine sand 2 to 5 inches thick.

The B horizon is 24 to 38 inches thick. The B2 horizon is dark grayish-brown or dark-brown loamy fine sand or fine sand that has faint to prominent mottles. The B3 horizon is dark-brown or brown fine sand and sand that has distinct or prominent mottles.

The C horizon is light brownish-gray or pale-brown fine sand or sand that has faint to prominent red, yellow, brown, or gray mottles.

Lino soils are near Sartell and Isanti soils and are similar to Lino variant soils, and Duelm soils. They formed in material similar to that of Sartell and Isanti soils. They have mottles in their B horizon, whereas the excessively drained Sartell soils lack mottles in that horizon. They have a thinner dark-colored A horizon than the very poorly drained Isanti soils. They have more fine sand and less very fine sand and silt in their C horizon than Lino soils, loamy subsoil variant. They have more fine sand and less medium and coarser sand throughout than Duelm soils.

Lino loamy fine sand (Ln).—This soil is mainly in nearly level areas around small depressions and in narrow drainageways that lead from larger, very poorly drained depressions on the glacial outwash plains. It also occurs in level areas, where the water table is high, and in small islandlike areas that are a few feet higher in elevation than the larger, surrounding, very poorly drained areas. Areas range from 5 to 100 acres in size, but areas 10 to 20 acres in size are most common. Slopes are 0 to 2 percent and are short.

This soil has the profile described as representative for the series.

In undisturbed areas the surface layer is somewhat thinner and slightly darker in color. In some areas where this soil is cultivated, it is slightly eroded.

Included with this soil in mapping are small areas of very poorly drained soils in depressions. Also included are some areas of soils that do not have mottles in the upper 12 to 18 inches, which is an indication of local spots of soils that are better drained than this soil.

This Lino soil has a high water table that subsides soon after the growing season begins. Where adequately drained, this soil becomes droughty during prolonged dry periods because of its rapid permeability and low available water capacity. This soil is also low in natural fertility and is subject to wind erosion if cultivated.

Most areas of this soil are used as pasture and woodlots. Where this soil is cultivated, the crops commonly grown are corn, soybeans, and rye and red clover, timothy, and alsike clover mixtures. Capability unit IIIw–2; woodland suitability group V; building site group 7.

Lino Variant

The Lino variant consists of deep, nearly level, somewhat poorly drained soils on outwash plains or in

lacustrine areas that have many depressions and shallow draws. These soils formed in laminated, deep deposits of fine sand that is partly of eolian origin. The native vegetation was a canopy of deciduous trees, dominantly oak, and scattered pines.

In a representative profile the surface layer is very dark brown loamy fine sand about 9 inches thick. The subsurface layer is dark grayish-brown loamy fine sand that has dark-brown mottles and is about 4 inches thick. The subsoil is about 29 inches thick. The upper 14 inches is grayish-brown, loose sand mottled with brown. The lower part is grayish-brown, very friable fine sandy loam that is mottled. The underlying material is light brownish-gray, mottled, very friable silt loam that grades with depth to reddish-brown, loose sand.

Permeability is rapid in the upper part of these soils and moderate in the lower part. The available water capacity is moderate. Organic-matter content is low. The content of available phosphorus, potassium, and nitrogen is low. The water table fluctuates between depths of 2 and 4 feet.

Most areas of these soils are in crops. Some areas are used as woodlots and pasture. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Lino loamy fine sand, loamy subsoil variant, that has a slope of 1 percent, in a cultivated field, 190 feet south and 200 feet east of the northwest corner of SE¼ of sec. 23, T. 36 N., R. 28 W.:

Ap—0 to 9 inches, very dark brown (10YR 2/2) loamy fine sand; massive; very friable; medium acid; abrupt, smooth boundary.

A2g—9 to 13 inches, dark grayish-brown (10YR 4/2) loamy fine sand; many, medium, distinct, dark-brown (7.5YR 4/4) mottles; massive; very friable; strongly acid; abrupt, wavy boundary.

B1—13 to 27 inches, grayish-brown (10YR 5/2) sand; many, large, prominent, dark-brown (7.5YR 4/4), strong-brown (7.5YR 5/6), and reddish brown (5YR 4/4) mottles; single grained; loose; strongly acid; abrupt, smooth boundary.

IIB2—27 to 42 inches, grayish-brown (2.5Y 5/2) fine sandy loam; many, medium, prominent, dark-brown (7.5YR 4/4) and brown (7.5YR 5/4) mottles; weak, medium, platy structure; very friable; strongly acid; abrupt, smooth boundary.

IIC1g—42 to 54 inches, light brownish-gray (2.5Y 6/2) silt loam; common, medium, prominent, yellowish-brown (10YR 5/4) and dark yellowish-brown (10YR 4/4) mottles; weak, thin, platy structure; very friable; strongly acid; abrupt, smooth boundary.

IIIC2—54 to 60 inches, reddish-brown (5YR 4/4) sand; single grained; loose; about 10 percent very fine gravel; slightly acid.

The solum ranges from 20 to 46 inches in thickness. The depth to fine sandy loam or to a finer texture in the IIB or IIC horizon ranges from 24 to 50 inches. The Ap horizon is 6 to 9 inches thick and is medium acid or slightly acid. It is very dark grayish-brown or very dark gray loamy fine sand, loamy sand, fine sand, or sand. The A1 horizon, where present, is black or very dark brown and is 2 to 5 inches thick. Structure ranges from weak granular or crumb in the A1 horizon and weak subangular blocky to massive in the Ap horizon. The A2 horizon is 4 to 8 inches thick, and its structure is massive to weak platy. It is dark grayish-brown or dark-brown loamy fine sand, fine sand, or sand.

The B1 horizon is grayish-brown or brown sand, fine sand, or loamy fine sand that has distinct or prominent mottles. Reaction is medium acid or strongly acid. The IIB2 horizon is grayish brown or pale brown and generally is fine sandy loam, but it is loamy very fine sand, loamy fine sand, very fine sandy loam, loam, or silt loam in places. Prominent brown mottles increase in size and abundance with depth. Reaction is medium acid or strongly acid in the IIB2 horizon. Structure is massive or weak platy.

The IIC1 horizon is grayish brown or light brownish gray. Its texture is similar to that of the IIB horizon, but in some places it has coarser textured layers. Reaction is medium acid or strongly acid in the IIB2 and IIC1 horizons. The combined thickness of the IIB2 and IIC1 horizons is more than 6 inches. The IIIC2 horizon is fine sand or sand that ranges from reddish brown to grayish brown.

Lino variant soils are mainly near Isanti variant soils, and are similar to Lino soils. They have a thinner dark-colored A horizon than the more poorly drained Isanti variant soils. They have more silt and very fine sand and less fine sand throughout than Lino soils.

Lino loamy fine sand, loamy subsoil variant (Lo).—This soil is in small flat areas on a local outwash plain near the hamlet of Glendorado. Areas range from 3 to 80 acres in size, but areas 5 to 10 acres in size are most common. Slopes are short and have a gradient of 0 to 2 percent.

Included with this soil in mapping are areas of moderately well drained soils on small rises. Also included are some areas of very poorly drained soils in small depressions.

This soil has a high water table that gradually subsides after the growing season begins. If adequately drained, this soil becomes droughty during prolonged dry periods because it has rapid permeability in the upper part and moderate available water capacity. It is also low in natural fertility and is subject to wind erosion if cultivated.

Most of the acreage of this soil is presently used for crops. Crops commonly grown are corn, soybeans, and rye and red clover, timothy, and alsike clover mixtures. Capability unit IIIw–2; woodland suitability group V; building site group 7.

Marsh

Marsh (Ma) consists of undrained depressions and ponds that are covered by 1 to 3 feet of water except in dry years. Cattails, reeds, sedges, and other plants that tolerate water grow in these areas. The soils under the water in these areas have not been identified. Many of these areas are impracticable to drain, because they are located near streams and lakes.

Marsh provides excellent habitat for wetland wildlife. Capability unit VIIIw–1; woodland suitability group VII; building site group 9.

Milaca Series

The Milaca series consists of deep, gently sloping to steep, well-drained soils on the upper part of slopes or crests of low ridges and knolls and on long, narrow slopes along the edge of drainageways. These soils formed in firm, loamy, reddish-brown glacial till under a forest canopy of mixed hardwoods and conifers. Cobblestones and stones are on the surface and throughout the profile (fig. 11).

In a representative profile the surface layer is black fine sandy loam about 1 inch thick. The subsurface layer is dark-gray and dark grayish-brown fine sandy loam about 9 inches thick. The subsoil is about 30 inches thick. The upper 9 inches is dark-brown, friable fine sandy loam. The lower 21 inches is reddish-brown and

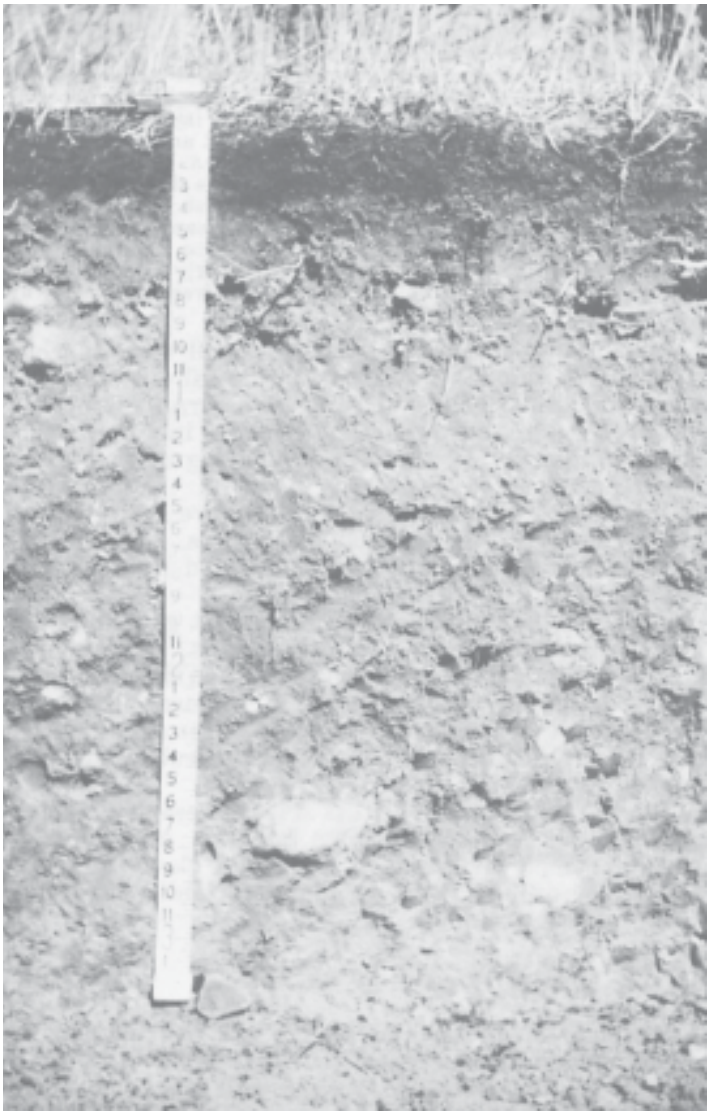

Figure 11.—**Profile of a Milaca fine sandy loam.**

dark reddish-brown, firm fine sandy loam that generally is faintly mottled in the lower part. The underlying material is reddish-brown and dark reddish-brown, firm sandy loam.

Permeability is moderately slow, and available water capacity is moderate. Organic-matter content is low. Content of available phosphorus is medium, and content of available potassium and nitrogen is low. The firm fragipan is at a depth of about 20 inches and restricts the movement of water and limits the root zone. Depth to the water table is 10 feet or more.

Most gently sloping areas of these soils are in crops. Steeper areas are used as pasture and woodlots. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Milaca fine sandy loam, 2 to 6 percent slopes, in a pastured woodlot, 530 feet east and 1,000 feet south of northwest corner of sec. 33, T. 38 N., R. 29 W.:

A1—0 to 1 inch, black (10YR 2/1) loam; weak, fine, crumb structure; very friable; about 2 percent coarse fragments; slightly acid; abrupt, smooth boundary.

A21—1 to 4 inches, dark-gray (10YR 4/1) fine sandy loam; common inclusions of dark grayish brown (10YR 4/2); weak, medium and fine, platy structure; very friable; about 2 percent coarse fragments; medium acid; clear, smooth boundary.

A22—4 to 10 inches, dark grayish-brown (10YR 4/2) fine sandy loam that grades to brown (10YR 4/3) in the lower part; weak, medium and fine, platy structure; very friable; about 10 percent coarse fragments; strongly acid; clear, smooth boundary.

B1—10 to 19 inches, dark-brown (7.5YR 4/3) fine sandy loam; weak, medium, platy structure and some weak, medium, subangular blocky structure; friable; thin porous coats on faces of peds; about 15 percent coarse fragments; strongly acid; gradual, smooth boundary.

Bx1—19 to 28 inches, reddish-brown (5YR 4/3) fine sandy loam; weak, medium, platy structure and some massive spots; firm; common fine pores; few thin clay films on upper surface of plates; about 25 percent coarse fragments; medium acid; gradual, smooth boundary.

Bx2—28 to 40 inches, dark reddish-brown (5YR 3/3) fine sandy loam; few, large, faint mottles that have dark reddish-gray (5YR 4/2) centers and reddish-brown (5YR 4/4) exteriors; moderate, fine and medium, platy structure; firm; some clay bridges between sand grains and few thin clay films in pores and adjacent to coarse fragments; about 15 percent coarse fragments; medium acid; gradual boundary.

Cx—40 to 72 inches, reddish-brown (5YR 4/3) and dark reddish-brown (5YR 3/3) sandy loam; moderate, fine and medium, platy structure; firm; about 10 percent coarse fragments; medium acid.

The solum ranges from 34 to 48 inches in thickness. The content of coarse fragments ranges from 0 to 15 percent in the A horizon and from 8 to 30 percent in the B and C horizons. In cultivated areas the Ap horizon is very dark gray and very dark grayish brown and is 6 to 8 inches thick. The A1 horizon is 1 to 4 inches thick and slightly acid to strongly acid. This horizon is mainly black or very dark gray fine sandy loam or very fine sandy loam. In places it is sandy loam, light loam, or light silt loam. Structure is weak or moderate granular or crumb. The A2 horizon is dark-gray to brown fine sandy loam, very fine sandy loam, and sandy loam 6 to 14 inches thick. Structure is weak or moderate platy.

The B horizon is 22 to 40 inches thick. The B1 horizon is dark-brown or brown, friable or firm fine sandy loam, sandy loam, or light loam. Reaction is strongly acid or medium acid. Structure is weak subangular blocky or platy. The Bx1 and Bx2 horizons are reddish-brown and dark reddish-brown, firm and very firm fine sandy loam or sandy loam. Reaction ranges from medium acid to neutral and generally is less acid with depth. Depth to the Bx1 horizon is 14 to 24 inches. Structure is weak to moderate platy.

The Cx horizon is sandy loam or fine sandy loam that is faintly to distinctly mottled in places. Reaction ranges from medium acid to neutral. Structure is weak or moderate platy.

Milaca soils are near Mora, Ronneby, Parent, and Prebish soils, and they are similar to Flak soils. Milaca soils formed in parent material similar to that of Mora, Ronneby, Parent, and Prebish soils. Milaca soils have a brighter color and lack mottles in the B horizon in most places, whereas the nearby soils have a duller color in the mottled B horizon. Milaca soils have a redder hue in the Bx and Cx horizons than Flak soils.

Milaca fine sandy loam, 2 to 6 percent slopes (McB).—This gently sloping and undulating soil is in small areas on the crests of slopes of ground moraines and some drumlins, mostly east of the Elk River. Areas are elongated and range from 2 to 25 acres in size, but

areas 5 to 15 acres in size are most common. Slopes are convex and range from 100 to 300 feet in length. Stones are on the surface and scattered throughout the profile. This soil has the profile described as representative for the series.

Included with this soil in mapping are small areas of Mora soils that are more nearly level than this Milaca soil or are in depressional areas. Also included are areas of cultivated soils that show slight evidence of water erosion.

A slight hazard of erosion and a limited root zone are the main limitations to the use of this soil.

About 60 percent of this soil is used for crops. The rest is used as pasture and woodlots. This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIe–1; woodland suitability group I; building site group 3.

Milaca fine sandy loam, 2 to 6 percent slopes, eroded (McB2).—This gently sloping and undulating soil is in small cultivated areas on the crests of slopes of ground moraines and of some drumlins that are mostly east of the Elk River. Areas are elongated and range from 2 to 20 acres in size, but areas 5 to 15 acres in size are most common. Slopes are convex and 100 to 300 feet in length. Stones are on the surface and throughout the profile.

This soil has a profile similar to the one described as representative for the series, but much of the surface layer has been removed by water erosion. The surface layer is therefore lighter in color, and the brown subsoil is exposed in places. In spring, rills and an occasional small gully form in cultivated areas.

Included with this soil in mapping are small areas of Mora soils that are more nearly level than this Milaca soil or are in depressional areas. Also included are areas of soils that have a surface layer of very fine sandy loam and silt loam.

The hazard of erosion is moderate, and the root zone is limited. Controlling erosion and increasing fertility and organic-matter content help to correct the major limitations of this soil.

About 60 percent of the acreage of this soil is used for crops. The rest is used as pasture and woodlots. This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIe–1; woodland suitability group I; building site group 3.

Milaca fine sandy loam, 6 to 12 percent slopes (McC).—This sloping and rolling soil is on side slopes of glacial ground moraines and of some drumlins, mostly east of the Elk River. It is in long, narrow areas along rivers. Areas range from 5 to 15 acres in size, but areas 5 to 10 acres in size are most common. Slopes are convex and are 100 to 300 feet long. Stones are on the surface and are scattered throughout the soil.

This soil has a profile similar to the one described as representative for the series, but the surface layer is somewhat thinner. In cultivated areas some fields show evidence of water erosion on the crest of slopes.

Included with this soil in mapping is a minor acreage of a soil that has a subsoil of clay loam. Also included are areas of soils that have a surface layer of very fine sandy loam and silt loam.

The hazard of erosion is severe, and the root zone is limited. Controlling erosion and increasing fertility and organic-matter content help to correct the major limitations of this soil.

About 50 percent of the acreage of this soil is used for crops. The rest is used as pasture and woodlots. This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIIe–1; woodland suitability group I; building site group 3.

Milaca fine sandy loam, 6 to 12 percent slopes, eroded (McC2).—This sloping and rolling soil is in cultivated areas on glacial ground moraines and on some drumlins, mostly east of the Elk River. Areas are along rivers. The areas are long and narrow and range from 5 to 15 acres in size, but areas 5 to 10 acres in size are most common. Slopes are 100 to 300 feet long. Stones are on the surface and scattered throughout the soil.

This soil has a profile similar to the one described as representative for the series, but the surface layer is thinner. Much of the thin surface layer has been removed by erosion, and cultivation has mixed some of the material from the subsoil into the plow layer. The present surface layer is therefore lighter in color, and the brown subsoil is exposed in places. In spring, rills and an occasional small gully form in cultivated fields.

Included with this soil in mapping is a minor acreage of a soil that has a subsoil of clay loam. Also included are areas of soils that have a surface layer of very fine sandy loam and silt loam.

The hazard of erosion is severe, and the root zone is limited. Controlling erosion and increasing fertility and organic-matter content help to correct the major limitations of this soil.

This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIIe–1; woodland suitability group I; building site group 3.

Milaca fine sandy loam, 12 to 25 percent slopes (McE).—This hilly and steep soil is in small areas on a glacial moraine east of the Elk River. Areas are along rivers. These areas are long and narrow and range from 3 to 10 acres in size, but areas about 5 acres in size are most common. Slopes are convex and are 100 to 300 feet long.

This soil has a profile similar to the one described as representative for the series, but it is thinner. Also, the surface layer is lighter in color and is more gravelly and cobbly. In cultivated areas this soil has been eroded, and rills and an occasional gully are present.

Included with this soil in mapping are areas of soils that have a surface layer of very fine sandy loam and silt loam.

A severe hazard of erosion and a limited root zone are major limitations to the use of this soil. Controlling erosion and increasing fertility and organic-matter content help to correct these limitations.

Most areas of this soil are in hay and in wooded or unwooded pasture. This soil is suited to the production of quality timber. Capability unit VIe–1; woodland suitability group II; building site group 3.

Milaca stony fine sandy loam, 2 to 6 percent slopes (MdB).—This gently sloping and undulating soil is in small areas on the crests of slopes of glacial ground

moraines and of some drumlins, mostly east of the Elk River. Areas are elongated and range from 3 to 25 acres in size, but most areas are 5 to 15 acres in size. Slopes are convex and range from 100 to 300 feet in length.

This soil has a profile similar to the one described as representative for the series, but it is more stony. The stoniness of this soil prevents normal tillage. It is economically feasible to remove the stones, although they average 5 to 30 feet apart and are 1 to 3 feet in diameter.

Included with this soil in mapping are small areas of Mora soils that are more nearly level than this Milaca soil or are in depressional areas.

A slight hazard of erosion and a limited root zone are the main limitations to the use of this soil.

This soil is used as wooded and unwooded pasture and as woodlots. If cleared, it is well suited to all of the crops commonly grown in the county. Capability unit IIe–1; woodland suitability group I; building site group 3.

Milaca very fine sandy loam, 2 to 6 percent slopes (MfB).—This gently sloping and undulating soil is in small areas on the crests of slopes of a glacial ground moraine in the Rum River watershed. Areas are elongated and range from 3 to 20 acres in size, but areas 5 to 15 acres in size are most common. Slopes are convex and are 100 to 300 feet long. Stones are on the surface and are scattered throughout the profile.

This soil has a profile similar to the one described as representative for the series, but the surface layer contains a higher percentage of very fine sand. In areas where this soil is more nearly level, faint mottling is present in the upper part of the subsoil.

Included with this soil in mapping are small areas of Paget soils that are more nearly level than this Milaca soil or are in depressional areas.

A slight hazard of erosion and a limited root zone are the major limitations to the use of this soil. Controlling erosion and increasing fertility and organic-matter content help to overcome the limitations.

About 80 percent of the acreage of this soil is in crops and pasture. The rest is in woodlots. This soil is well suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIe–1; woodland suitability group I; building site group 3.

Milaca stony very fine sandy loam, 2 to 6 percent slopes (MhB).—This gently sloping and undulating soil is in small areas on the crests of slopes of a glacial ground moraine in the Rum River watershed. Areas are elongated and range from 3 to 20 acres in size, but areas 5 to 15 acres in size are most common. Slopes are convex and are 100 to 300 feet long.

This soil has a profile similar to the one described as representative for the series, but the surface layer has a higher percentage of very fine sand.

Included with this soil in mapping are small areas of Paget soils that are more nearly level than this Milaca soil or are in depressional areas.

A slight hazard of erosion and a limited root zone are the major limitations to the use of this soil. The stoniness of this soil prevents normal tillage. It is economically feasible to remove the stones, although they ordinarily are 5 to 30 feet apart and 1 to 3 feet in diameter.

This soil is used as wooded or unwooded pasture and as woodlots. If cleared, it is well suited to all of the crops commonly grown in the county. Capability unit IIe–1; woodland suitability group I; building site group 3.

Milaca Variant

The Milaca variant consists of deep, nearly level to gently sloping, well-drained soils on glacial ground moraines. These soils formed in loamy and silty glacial till under a forest canopy of hardwoods.

In a representative profile the surface layer is very dark gray fine sandy loam about 6 inches thick. The subsurface layer is brown fine sandy loam about 4 inches thick. The subsoil is dark-brown and dark yellowish-brown, friable clay loam about 43 inches thick that has some cobblestones and stones in the upper part. The underlying material is yellowish-brown, faintly mottled, friable clay loam that changes with depth to reddish-brown, firm sandy loam.

Permeability is moderate and available water capacity is moderate to high. Organic-matter content is low. The content of available phosphorus and potassium is medium, but the content of available nitrogen is low. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are in wooded pasture. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Milaca fine sandy loam, clay loam subsoil variant, 1 to 6 percent slopes, in a cultivated field, 870 feet north and 35 feet west of southeast corner NE¼ sec. 32, T. 36 N., R. 30 W.:

Ap—0 to 6 inches, very dark gray (10YR 3/1) fine sandy loam; weak, fine, subangular blocky structure; friable; medium acid; abrupt, smooth boundary.

A2—6 to 10 inches, brown (10YR 4/3) fine sandy loam; weak, medium, platy structure; friable; abundant worm casts; slightly acid; clear, wavy boundary.

B21t—10 to 17 inches, dark-brown (7.5YR 4/4) clay loam; weak, fine, subangular blocky structure; friable; few clay films on faces of peds and adjacent to coarse fragments; about 15 percent coarse fragments; slightly acid; clear, wavy boundary.

B22t—17 to 25 inches, dark yellowish-brown (10YR 4/4) clay loam; moderate. fine. subangular blocky structure; friable; thin, patchy, dark yellowish-brown (10YR 3/4) clay films on faces of peds; few vesicular pores; about 5 percent coarse fragments; few small particles of shale; slightly acid; clear, wavy boundary.

B23t—25 to 53 inches, yellowish-brown (10YR 5/4) clay loam that has a few streaks of light olive brown (2.5Y 5/4); few, fine, faint, dark yellowish-brown (10YR 4/4) mottles and a few streaks of grayish brown (2.5Y 5/2) in lower part; weak to moderate, subangular blocky structure; friable; sticky; about 5 percent coarse fragments, including a few shale particles; neutral; abrupt, wavy boundary.

IIC—53 to 60 inches, reddish-brown (5YR 4/4) sandy loam; weak, medium, platy structure; firm; neutral.

The solum ranges from 33 to 63 inches in thickness. The horizon is 6 to 9 inches thick and is medium acid or slightly acid. It is very dark gray or very dark brown fine sandy loam or loam. The A1 horizon, where present, is black to very dark brown fine sandy loam to loam. Structure is weak to moderate, granular or subangular blocky. The A2 horizon is dark grayish-brown to brown fine sandy loam, sandy loam,

and loam 3 to 8 inches thick. Structure is weak, platy or subangular blocky.

The B horizon is 25 to 48 inches thick. The texture ranges from friable loam and clay loam to sandy clay loam in the lower part. The color ranges from brown to dark yellowish brown or yellowish brown. Mottles are in the lower part of the horizon in some places. Reaction is strongly acid to neutral. Structure of the B horizon is weak or moderate, subangular blocky.

The C horizon is reddish-brown or brown, firm sandy loam or fine sandy loam. Structure is weak or moderate platy.

Milaca variant soils are near Dalbo soils and are similar to Milaca soils. They have more sand and less silt and clay in the A and B horizons than the Dalbo soils, which formed in lacustrine sediment of silt loam or silty clay loam. They have more clay and less sand than Milaca soils and also have a yellower hue in the A and B horizons.

Milaca fine sandy loam, clay loam subsoil variant, 1 to 6 percent slopes (MlB).—This undulating soil is in small areas on the ground moraine in southeastern Minden Township. Slopes are convex and range from 200 to 400 feet in length. Areas are elongated and commonly are irregular in shape. They range from 20 to 160 acres in size, but most areas are 10 to 30 acres in size. Some cobblestones and stones are on the surface and scattered throughout the profile.

Included with this soil in mapping are areas of soils that have a loam surface layer and a few gravel spots on the surface. Also included are areas of a somewhat poorly drained soil that is dissected by a waterway. In some cultivated areas some material from the subsoil has been mixed with the surface layer.

The hazard of erosion is slight. Controlling erosion and increasing fertility and organic-matter content help to correct the major limitations to the use of this soil.

This soil is well suited to all of the crops commonly grown in the area. Among the crops commonly grown are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIe–1; woodland suitability group II; building site group 3.

Mora Series

The Mora series consists of deep, nearly level to gently sloping, moderately well drained soils in slightly convex areas on ground moraines. These soils formed in firm, loamy, reddish-brown glacial till under a forest canopy of mixed hardwoods and conifers. Cobblestones and stones are on the surface and throughout the profile.

In a representative profile the surface layer is black loam about 4 inches thick. The subsurface layer is dark grayish-brown and brown fine sandy loam about 8 inches thick that is mottled dark brown to yellowish brown. The subsoil is about 36 inches thick. The upper 12 inches is dark-brown and reddish-brown, friable fine sandy loam that has some mottles, and the lower part is reddish-brown and dark reddish-brown, firm sandy loam and fine sandy loam that has some mottles. The underlying material is dark reddish-brown and reddish brown, firm fine sandy loam.

Permeability is moderately slow, and available water capacity is moderate. Organic-matter content is low. The content of available phosphorus is medium, and the content of available potassium and nitrogen is low. The firm fragipan, which starts at a depth of about 24 inches, restricts the movement of water and limits the root zone. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are used as pasture and woodlots. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Mora fine sandy loam, 1 to 3 percent slopes, in a pastured woodlot, 300 feet north and 40 feet east of the southwest corner of sec. 13, T. 37 N., R. 29 W.:

A1—0 to 4 inches, black (10YR 2/1) loam; moderate, medium, granular strutcure; very friable; few (10YR 5/3) worm casts; about 2 percent coarse fragments; slightly acid; abrupt, smooth boundary.

A21—4 to 7 inches, dark grayish-brown (10YR 4/2) fine sandy loam; common, fine, dark-brown (10YR 4/3) and dark yellowish-brown (10YR 4/4) mottles; weak, medium and thin, platy structure; very friable; about 2 percent coarse fragments; slightly acid; clear, smooth boundary.

A22—7 to 12 inches, brown (10YR 5/3) fine sandy loam; common, fine, faint, yellowish-brown (10YR 5/4) and dark-brown (10YR 4/3) mottles; weak, thin and medium, platy structure; friable; about 2 percent coarse fragments; slightly acid; clear, smooth boundary.

B1—12 to 17 inches, dark-brown (7.5YR 4/4) fine sandy loam; common, fine, faint, brown (7.5YR 5/4) mottles and common, fine, distinct, reddish-brown (5YR 4/3) mottles; weak, medium and fine, subangular blocky structure; friable; common, medium, porous, grayish coats on faces of peds; about 10 percent coarse fragments; slightly acid; clear, wavy boundary.

B2—17 to 24 inches, reddish brown (5YR 4/3) fine sandy loam; common, fine, distinct, reddish-gray (5YR 5/2) mottles and few, fine, faint, dark reddish-brown (5YR 3/4) mottles; weak, medium and thin, platy structure; friable; about 20 percent coarse fragments; slightly acid; gradual, wavy boundary.

Bx1—24 to 31 inches, variegated reddish-brown (5YR 4/3 and 5YR 5/3) sandy loam; common, fine, faint, yellowish-red (5YR 4/6) mottles; weak, medium and thick, platy structure; friable to firm; few, thin, patchy clay films on upper surface of plates and in some pores; about 10 percent coarse fragments; slightly acid; clear, irregular boundary.

Bx2—31 to 48 inches, variegated dark reddish-brown (5YR 3/3) and reddish-brown (5YR 4/3) fine sandy loam; few, coarse, distinct, reddish-brown (5YR 5/3) mottles; strong, thin and medium, platy structure; firm; peds fail abruptly under pressure; about 10 percent coarse fragments; slightly acid; diffuse boundary.

Cx—48 to 75 inches, variegated dark reddish-brown (5YR 3/4) and reddish-brown (5YR 4/3) fine sandy loam; moderate, thin and medium, platy structure; firm, peds fail abruptly under pressure; about 10 percent coarse fragments; neutral.

The solum ranges from 40 to 60 inches in thickness. The content of coarse fragments ranges from 0 to 15 percent in the A horizon and 8 to 25 percent in the B and C horizons. The A1 horizon is 2 to 4 inches thick and is strongly acid to slightly acid. In most places it is black or very dark gray loam or fine sandy loam, but in a few places it is sandy loam, very fine sandy loam, or silt loam. Structure is weak to moderate, crumb or granular. The Ap horizon is very dark grayish brown and is 6 to 9 inches thick. The A2 horizon is 5 to 11 inches thick and has faint, brown mottles. Structure is weak or moderate platy.

The B horizon is 24 to 54 inches thick. The texture ranges from loam or fine sandy loam in the B1 horizon to fine sandy loam or sandy loam in the B2 and B3 horizons. Reaction ranges from strongly acid to slightly acid in the B1 horizon and generally becomes less acid with depth. Structure in the B1 and the B2 horizons ranges from weak to moderate, subangular blocky. Depth to the Bx1 horizon ranges from 18 to 32 inches. Structure in the Bx horizon

ranges from weak to strong platy. Consistence in the Bx horizon is firm or very firm.

The Cx horizon is firm sandy loam or fine sandy loam. Reaction is neutral to mildly alkaline. Mottles are present in places, especially in the upper part. Structure is weak or moderate platy.

Mora soils are near Milaca, Ronneby, Parent, and Prebish soils and are similar to Brainerd and Paget soils. They have mottles of low chroma in the A2 horizon and the upper part of the B horizon, whereas Milaca soils lack mottles in these parts of their profile. They have a brighter color in the B horizon than the more poorly drained Ronneby, Parent, and Prebish soils. Mora soils have a matrix color of 5YR in hue in the B2, B3, and C horizons, whereas Brainerd soils have a matrix color of 7.5YR and a solum that has a higher content of medium and coarser sand. Mora soils formed in loamy, reddish-brown glacial till, whereas Paget soils formed in a thin, silty mantle over sandy loam, reddish-brown till.

Mora fine sandy loam, 1 to 3 percent slopes (MoA).—This nearly level to gently undulating soil is in broad areas of drumlins and ground moraines. Areas are elongated and range from 20 to 160 acres in size. These areas are oriented in an east-west direction on the drumlin field. Slopes are 150 to 800 feet long. Where this soil is cultivated, the surface layer has a grayish color that is not evident in undisturbed areas.

This soil has the profile described as representative for the series.

Included with this soil in mapping are small depressional areas of Prebish, Parent, and Ronneby soils. Also included in the eastern part of the county are areas of Mora soils that have a surface layer of silt loam.

Crop production on this soil is slightly limited by climate and by the restricted root zone. Stones are throughout the profile, but they do not prevent ordinary tillage operations. In some areas where this soil is cultivated, there is slight evidence of water erosion.

About 70 percent of the acreage is used for crops, and the rest is used as pasture and woodlots. The crops commonly grown on this soil are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIc–1; woodland suitability group I; building site group 4.

Mora fine sandy loam, 3 to 5 percent slopes (MoB).—This soil is in broad areas on drumlins and ground moraines. Areas are elongated and range from 20 to 160 acres in size. These areas are oriented in an east-west direction on the drumlin field. Slopes are 150 to 500 feet long.

This soil has a profile similar to the one described as representative for the series, but in some places it is not so deep to the firm, brittle, compact layer in the subsoil and the surface layer is somewhat lighter in color and coarser in texture. In some areas where this soil is cultivated, water erosion is evidenced by rilling and by small areas where the surface layer is somewhat lighter colored and has a greater quantity of cobblestones and gravel on the surface. Included with this soil in mapping are areas of Ronneby soils in narrow drainageways.

A slight hazard of erosion and a somewhat restricted root zone are the main limitations to the use of this soil. Controlling erosion and increasing fertility and organic-matter content help to overcome the limitations. Stones are throughout the profile, but they do not prevent ordinary tillage operations.

The crops commonly grown on this soil are corn, oats, soybeans, alfalfa, and red clover. Capability unit IIe–1; woodland suitability group I; building site group 4.

Mora stony fine sandy loam, 1 to 3 percent slopes (MrA).—This nearly level to gently undulating soil is in broad areas on glacial ground moraines and on some drumlins that are mostly east of the Elk River. Areas are elongated and range from 20 to 160 acres in size, but areas 20 to 40 acres in size are common. Slopes range from 150 to 500 feet long.

This soil has a profile similar to the one described as representative for the series, but it is more stony.

Included with this soil in mapping are small depressional areas of Prebish, Parent, and Ronneby soils.

Crop production on this soil is slightly limited by climate and by the restricted root zone. This soil is too stony for normal tillage. It is economically feasible to remove the stones, although they average 5 to 30 feet apart and are 1 to 3 feet in diameter.

This soil is used for open pasture, wooded pasture, and woodlots. Where cleared, it is well suited to all of the crops commonly grown in the county. Capability unit IIc–1; woodland suitability group I; building site group 4.

Mucky Peat

Mucky peat consists of deep, level to depressional, very poorly drained soils in drainageways, low-lying flats, wet depressions, and former ponds and on flood plains. These soils formed in accumulated plant remains that have partly decomposed under water-tolerant grasses, sedges, mosses, willows, and alders.

In a representative profile the surface layer is dark-brown, moderately decomposed, organic (*hemic*) material that is 40 percent fiber and is about 8 inches thick. The next layer is dark-brown, moderately decomposed, organic (*hemic*) material that is about 60 percent fiber and is about 48 inches thick. The underlying material is dark-brown, moderately decomposed, organic (*hemic*) material.

Permeability is moderately rapid, and available water capacity is very high. Content of organic matter is very high. The content of available phosphorus and potassium is low, and the content of available nitrogen is high. Mineral material that ranges in texture from loam to sand underlies the organic material at a depth of more than 42 inches.

These soils are wet and marshy in spring, but generally they dry out by midsummer. Almost all of the acreage is used for pasture or wild hay. Drained areas of these soils are suited to most of the crops commonly grown in the county.

Representative profile of Mucky peat in a bog, 420 feet north and 80 feet east of the southwest corner of sec. 36, T. 36 N., R. 30 W.:

Oe1—0 to 8 inches, dark-brown (7.5YR 3/2) broken face and rubbed hemic material; about 40 percent fiber, about 20 percent rubbed; massive; nonsticky; herbaceous fiber; gradual boundary.

Oe2—8 to 56 inches, dark-brown (10YR 3/3) broken face and rubbed hemic material; about 60 percent fiber, about 30 percent rubbed; massive; nonsticky; herbaceous fiber; gradual boundary.

Oe3—56 to 74 inches, dark-brown (7.5YR 3/3) broken face

hemic material, dark-brown (7.5YR 3/2) rubbed; massive; nonsticky; herbaceous fiber.

The organic material is more than 40 inches thick and generally ranges from 42 to 100 inches in thickness. Mineral material underlies the organic material. The organic material generally is moderately decomposed, but in some places it is partly to almost entirely decomposed. Fiber in this material generally is derived from herbaceous plants, but in some places part of it is derived from woody plants. The organic soil material commonly is dark brown or very dark brown, but in some places it is black, very dark grayish brown, or brown. Reaction ranges from neutral to medium acid.

Mucky peat generally is near Prebish soils and is similar to Mucky peat over sand and Mucky peat over loam. It consists of organic material, whereas Prebish soils mostly lack organic material, although some profiles have a thin surface layer of organic material less than 12 inches thick. Mucky peat has more than 42 inches of organic soil material, whereas Mucky peat over sand and Mucky peat over loam have a mineral substratum above a depth of 40 inches.

Mucky peat (Ms).—This nearly level soil is in broad depressions and drainageways on the outwash plains and glacial ground moraines in the county. Areas are elongated and range from 20 to 160 acres in size, but most areas are 40 to 60 acres in size.

Included with this soil in mapping are areas of soils that have less than 42 inches of organic material. Also included are areas of soils that have a calcareous layer at the contact line between the organic material and the mineral material.

This soil has a high water table, and drainage is essential if crops are to be grown. Early frost and fire are hazards, and so is wind erosion if this soil is cultivated.

Almost all of the acreage is used for pasture and wild hay. If adequately drained, this soil is suited to most crops commonly grown in the county, and to such vegetables as potatoes, cabbage, turnips, onions, radishes, and carrots. Among the crops commonly grown are corn for silage, oats, and red clover, timothy, and alsike clover mixtures. Cultured sod can also be grown on this soil. Capability unit IVw–3; woodland suitability group VII; building site group 9.

Mucky Peat Over Sand

Mucky peat over sand consists of deep, level to depressional, very poorly drained soils. These soils are in drainageways, on low-lying flats, in wet depressions, and in former ponds. They formed in the remains of accumulated plant material that has partly decomposed under a canopy of water-tolerant grasses, sedges, mosses, willows, and alders.

In a representative profile the surface layer is very dark-brown, highly decomposed organic (*sapric*) material about 9 inches thick that is about 5 percent fiber. The next layer is black, highly decomposed organic (*sapric*) material about 4 inches thick that is about 5 percent fiber. The next layer is dark reddish-brown, highly decomposed organic (*sapric*) material about 2 inches thick that is about 30 percent fiber. The next layer is very dark brown, highly decomposed organic (*sapric*) material about 3 inches thick that is about 5 percent fiber. Below this layer is black, friable loamy sand about 4 inches thick over a layer of very dark gray, very friable sand 10 inches thick. The underlying material is light brownish-gray, loose sand.

Permeability is moderately rapid, and the available water capacity and organic-matter content are high. The content of available phosphorus and potassium is low, and the content of nitrogen is high.

These soils are wet and marshy in spring, but they generally dry by midsummer, when nearly all of the areas are used as pasture or for wild hay. Drained areas of these soils are suited to adapted pasture plants and tame hay crops or vegetables.

Representative profile of Mucky peat over sand in a bog, 1,210 feet east and 90 feet south of the northwest corner of the SE¼ of sec. 31, T. 36 N., R. 30 W.:

Oa1—0 to 9 inches, very dark brown (7.5YR 2/2) on broken face and rubbed sapric soil material; about 5 percent fiber; weak, fine and medium, granular structure; very friable; herbaceous fiber; neutral; clear, smooth boundary.

Oa2—9 to 13 inches, black (10YR 2/1) on broken face and rubbed sapric material; about 5 percent fiber; weak, fine and medium, granular structure; very friable, nonsticky; herbaceous fiber; neutral; abrupt, smooth boundary.

Oa3—13 to 15 inches, dark reddish-brown (5YR 3/3) on broken face sapric material, dark reddish brown (5YR 2/2) rubbed; about 30 percent fiber, about 5 percent rubbed; weak, medium, platy structure; nonsticky; herbaceous fiber; neutral; abrupt boundary.

Oa4—15 to 18 inches, very dark brown (10YR 2/2) on broken face rubbed sapric material; about 5 percent fiber; massive; slightly sticky; herbaceous fiber; neutral; clear boundary.

IIA11b—18 to 22 inches, black (10YR 2/1) loamy sand; massive; friable; clear boundary.

IIA12b—22 to 32 inches, very dark gray (2.5Y 3/1) sand; massive; very friable; gradual boundary.

IIC—32 to 60 inches, light brownish-gray (2.5Y 6/2) sand; single grained; loose.

The organic material ranges from 12 to 42 inches in thickness. It is underlain by mineral that is dominantly sand but includes loamy sand and fine sand in places. The organic material typically is well decomposed, but in some places it is moderately or partly decomposed. Fiber in this material is derived mostly from herbaceous plants, but in some places part of it is derived from woody plants. The organic material typically is very dark brown or black, but in some places it is dark grayish brown, dark brown, or brown. Reaction ranges from neutral to medium acid.

Mucky peat over sand generally is near Isanti soils and is similar to Mucky peat over loam and Mucky peat. It consists of organic soil material 12 to 42 inches thick over sandy mineral material, whereas Isanti soils generally lack organic soil material, although in some places Isanti soils have a surface layer less than 12 inches thick. Mucky peat over sand has a sandy substratum, but Mucky peat over loam has a loamy substratum.

Mucky peat over sand (Mu).—This nearly level soil is in broad depressions and drainageways on outwash plains throughout the county. Areas are elongated and range from 10 to 100 acres in size, but most areas are 10 to 30 acres in size.

Included with this soil in mapping are small areas of Mucky peat that is thicker than 42 inches over sand and also a few areas of soils that have underlying material at a depth of 12 inches or less.

This soil has a high water table and must be drained before forage crops can be grown. It is subject to early frost and fire, and wind erosion is a hazard if the soil is cultivated.

Nearly all of the acreage of this soil is used as pasture and for wild hay. If adequately drained, the soil

can be used more intensively as improved pasture or for tame hay. Capability unit IVw–3; woodland suitability group VII; building site group 9.

Mucky Peat Over Loam

Mucky peat over loam consists of deep, level to depressional, very poorly drained soils in drainageways, on low-lying flats, in wet depressions, and in former ponds. These soils formed in the remains of accumulated plant material that has partially decomposed under a canopy of water-tolerant grasses, sedges, mosses, willows, and alder.

In a representative profile the surface layer is very dark grayish-brown, highly decomposed organic (*sapric*) material that is about 36 inches thick and is 20 percent fiber. The underlying material is very dark gray sandy loam that grades to dark brown in the lower part.

Permeability is moderate. Available water capacity and organic-matter content are high to very high. Content of available phosphorus and potassium is low, and content of available nitrogen is high.

These soils are wet and marshy in spring, but generally they dry out by midsummer. Nearly all areas are used as pasture or for wild hay. Drained areas of these soils are suited to most of the crops commonly grown in the county.

Representative profile of Mucky peat over loam, in a bog, about 1,300 feet north and 530 feet east of the southwest corner of SW¼ sec. 23, T. 38 N., R. 30 W.:

Oa—0 to 36 inches, very dark grayish-brown (10YR 3/2) sapric material; about 20 percent fiber; massive; slightly sticky; herbaceous fiber; clear, boundary.

IIC—36 to 60 inches, very dark gray (10YR 3/1) sandy loam that grades to dark brown (10YR 3/3) in the lower part; massive.

The organic material ranges from 12 to 42 inches in thickness. It is underlain by mineral material that has a dominant texture of loam but is fine sandy loam and sandy loam in places. The material generally is well decomposed, but in some places it is moderately or partly decomposed. Fiber in this material is mostly derived from herbaceous plants, but in some places part of it is derived from woody plants. The organic material typically is very dark grayish brown or very dark brown, but in some places it is black, dark brown, or brown.

Mucky peat over loam generally is near Prebish soils and is similar to Mucky peat over sand and Mucky peat. It consists of organic material 12 to 42 inches thick over loamy mineral material, whereas Prebish soils mostly lack organic material and in some places have a surface layer that is less than 12 inches thick. Mucky peat over loam has a loamy substratum, whereas Mucky peat over sand has a sandy substratum. It has less than 42 inches of organic material but Mucky peat has more than 42 inches.

Mucky peat over loam (Mx).—This nearly level soil is in broad depressions and drainageways in the drumlin field and on glacial ground moraines. Areas are elongated and range from 10 to 120 acres in size, but areas 20 to 40 acres in size are most common.

Included with this soil in mapping are small areas of Mucky peat and a few areas in which the organic material is 12 inches thick or less.

This soil has a high water table, and it must be drained before crops can be grown. It is subject to early frost and fire, and wind erosion is a hazard if this soil is cultivated.

Nearly all of the acreage of this soil is used as pasture and for wild hay. If adequately drained, the soil is suited to most crops grown in the county. Among the crops commonly grown are corn for silage, oats, and red clover, timothy, and alsike clover mixtures. This soil is also suited to potatoes, cabbage, turnips, onions, radishes, carrots, and other vegetables. Sod can also be grown as a crop. Capability unit IVw–3; woodland suitability group VII; building site group 9.

Nokasippi Series

The Nokasippi series consists of deep, level to depressional, very poorly drained soils in depressions of glacial outwash areas close to the glacial uplands. These soils formed in outwash sands 18 to 35 inches thick over firm, sandy loam glacial till. The native vegetation was wetland grasses, sedges, and shrubs.

In a representative profile the surface layer is black and very dark gray, mottled mucky loamy fine sand about 14 inches thick. The subsoil is about 34 inches thick. The upper 11 inches is gray, very friable fine sand that has distinct, dark-brown mottles. The lower part is dark-gray light loam that grades with depth to reddish-brown, mottled, very friable to friable sandy loam. The underlying material is reddish-brown, firm sandy loam.

Permeability is rapid in the upper part of these soils and moderately slow in the lower part. The available water capacity is moderate. The organic-matter content is high. The content of available phosphorus and potassium is low, and the content of available nitrogen is high. The firm till at a depth of 18 to 35 inches restricts the movement of water and limits the root zone. A perched water table fluctuates between the surface and a depth of 3 feet.

Most areas of these soils are in permanent pasture or are used for wild hay. If adequately drained, these areas are suited to all of the crops commonly grown in the county.

Representative profile of Nokasippi mucky loamy fine sand, in a cultivated field, 750 feet north and 70 feet east of corner of NW¼ of sec. 30, T. 37 N., R. 30 W.:

Ap—0 to 9 inches, black (10YR 2/1) mucky loamy fine sand; weak, medium, subangular blocky structure; very friable; strongly acid; abrupt, irregular boundary.

A3g—9 to 14 inches, very dark gray (10YR 3/1) loamy fine sand; few, medium, distinct, dark-brown (7.5YR 4/4) mottles; weak, medium, platy structure parting to weak, very fine, subangular blocky; very friable; strongly acid; abrupt irregular boundary.

B1g—14 to 25 inches, gray (10YR 5/1) fine sand; few, medium, distinct, dark yellowish-brown (10YR 4/4) and dark-brown (7.5YR 4/4) mottles; weak, thick, platy structure; very friable; about 5 percent coarse fragments; medium acid; abrupt, wavy boundary.

IIB2g—25 to 38 inches, dark-gray (10YR 4/1) light loam; many, large, prominent, dark-brown (7.5YR 4/4) mottles; weak, medium, platy structure; friable; few yellowish-red (5YR 4/6) coatings in old root channels; about 20 percent coarse fragments; medium acid; clear, wavy boundary.

IIB3—38 to 48 inches, reddish-brown (5YR 4/4) sandy loam; many, medium, prominent, light brownish-gray (10YR 6/2) mottles, many, medium, distinct, dark-brown (7.5YR 4/4) mottles, and few, medium, distinct, reddish-gray (5YR 5/2) mottles; weak, medium, platy structure; friable; few, vertical

streaks of dark grayish-brown (10YR 4/2) sand; common, black concretions; about 10 percent coarse fragments; neutral; gradual, irregular boundary.

IIC—48 to 60 inches, reddish-brown (5YR 4/4) sandy loam; common, medium, faint, dark reddish-brown (5YR 3/4) mottles and common, medium, prominent, grayish-brown (10YR 5/2) mottles; dark reddish brown commonly occurs around edges of grayish-brown mottles; moderate, medium, platy structure; firm; about 10 percent coarse fragments; neutral.

The solum ranges from 35 to 55 inches in thickness. The Ap horizon is 7 to 10 inches thick and is strongly acid to slightly acid. It is black or very dark gray and typically is mucky loamy fine sand, but loamy sand, sandy loam, and fine sandy loam are included in the range. The A1 horizon, where present, is black and is 6 to 10 inches thick. The A1 and Ap horizons have a weak or moderate, granular, crumb, or subangular blocky structure. The A3 horizon is very dark gray and very dark grayish-brown, mottled loamy fine sand or loamy sand that is 3 to 6 inches thick. Structure is weak or moderate, subangular blocky or platy. In some places a layer of organic material as much as 6 inches thick is on the surface.

The B1 horizon is loamy fine sand, fine sand, sand, or loamy sand, and the IIB2 and IIB3 horizons are sandy loam, light loam, or fine sandy loam. The B1 and IIB2 horizons are dark gray, gray, dark grayish brown, or grayish brown. Depth to the IIB2g horizon ranges from 18 to 35 inches. The IIB3 horizon is brown or reddish brown and has faint to prominent mottles. Reaction is medium acid to neutral in the B horizon.

The IIC horizon is brown or reddish-brown sandy loam or fine sandy loam that is faintly to prominently mottled. Reaction ranges from medium acid to neutral. Structure is weak to moderate platy.

Nokasippi soils are near Langola, Pomroy, and Watab soils. They are more poorly drained than these soils and have a grayer or duller color in the B horizon. They are similar to the Isanti soils but have more silt and clay and less sand in the lower part of the B horizon and in the C horizon.

Nokasippi mucky loamy fine sand (Nm).—This nearly level soil is in concave areas of shallow depressions or in drainageways between sand-covered glacial drumlins and ground moraines. Some areas of this soil encircle areas of Mucky peat, and others occupy saucer-shaped depressions within and along the edge of the glacial ground moraine where it borders the outwash plain in Watab and Mayhew Lake Townships. Areas range from 10 to 60 acres in size, but most areas are 10 to 20 acres in size.

Included with this soil in mapping are some areas of soils that have a surface layer of mucky sandy loam or mucky peat and a few small areas of soils that have a surface layer of mucky peat that is more than 12 inches thick. Also included are areas of soils where a few boulders or stones are on the surface.

Providing sufficient drainage to relieve wetness and increasing fertility are the major needs of this soil for crop production.

Most of the acreage of this soil is used as pasture or for hay. Under proper management, this soil is suited to all the crops commonly grown in the county. Among the crops commonly grown are corn, oats, and soybeans, and red clover, timothy, and alsike clover mixtures. Capability unit IVw–2; woodland suitability group VII; building site group 8.

Nokay Series

The Nokay series consists of deep, nearly level, somewhat poorly drained soils in areas next to depressions and narrow drainageways that intrude into the better drained uplands. These soils formed in firm, brown, loamy glacial till under a forest canopy of mixed hardwoods and conifers. Cobblestones and stones are on the surface and throughout the profile.

In a representative profile the surface layer is black fine sandy loam about 4 inches thick. The subsurface layer is dark grayish-brown and grayish-brown fine sandy loam that has distinct brown mottles and is about 5 inches thick. The subsoil is 33 inches thick. The upper 7 inches is dark grayish-brown and grayish-brown, friable fine sandy loam that has prominent brown mottles. The next 6 inches is reddish-brown, friable to firm fine sandy loam. The lower 20 inches is brown, fine sandy loam that has distinct, red and brown mottles. The underlying material is brown, firm sandy loam that is distinctly mottled in the upper part.

Permeability is moderately slow, and the available water capacity is moderate. Organic-matter content is moderate. The content of available phosphorus is medium, of available potassium is low, and of available nitrogen is medium. A perched water table fluctuates between depths of 2 and 4 feet.

The firm fragipan, which begins at a depth of about 28 inches, restricts the movement of water and limits the root zone.

Most areas of these soils are in crops. Some areas are used as pasture and woodlots. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Nokay fine sandy loam in a woodlot, 970 feet south and 70 feet west of the northeast corner of SE¼ of sec. 16, T. 37 N., R. 30 W.:

A11—0 to 2 inches, black (10YR 2/1) fine sandy loam; moderate, medium, subangular blocky structure; very friable; about 5 percent coarse fragments; strongly acid; clear, irregular boundary.

A12—2 to 4 inches, very dark gray (10YR 3/1) fine sandy loam; weak, thick, platy structure parting to moderate, coarse, subangular blocky; friable; about 5 percent coarse fragments; strongly acid; clear, smooth boundary.

A2g—4 to 9 inches, dark grayish-brown (10YR 4/2) and grayish-brown (10YR 5/2) fine sandy loam; common, medium, distinct, dark yellowish-brown (10YR 4/4) and yellowish-brown (10YR 5/6) mottles; weak, thick, platy structure parting to moderate, fine, subangular blocky; friable; about 5 percent coarse fragments; strongly acid; clear, smooth boundary.

B1g—9 to 16 inches, dark grayish-brown (10YR 4/2) and grayish-brown (10YR 5/2) fine sandy loam; many, medium, prominent, dark-brown (7.5YR 4/4) and reddish-brown (5YR 4/4) mottles; weak, thick, platy structure parting to moderate, fine, subangular blocky; friable; about 20 percent coarse fragments; strongly acid; clear, wavy boundary.

B2t—16 to 22 inches, reddish-brown (5YR 4/3) and dark reddish-brown (5YR 3/4) fine sandy loam; many, medium, prominent, reddish-brown (5YR 4/4), yellowish-red (5YR 4/6) mottles and distinct, gray (10YR 6/1) mottles; moderate, subangular structure; friable to firm; gray (10YR 5/1) coatings and common thin clay films on faces of peds; about 10 percent coarse fragments; medium acid; clear, wavy boundary.

Bx1—22 to 33 inches, brown (7.5YR 4/4) sandy loam; many coarse, distinct, yellowish-red (5YR 5/6) and reddish-brown (5YR 5/3) mottles; weak to moderate, thick, platy structure; firm; about 10 percent coarse fragments; medium acid; clear, wavy boundary.

Bx2—33 to 42 inches, brown (7.5YR 4/4) sandy loam; common, coarse, distinct, brown (7.5YR 5/2) and strong-brown (7.5YR 5/6) mottles; weak, thick, platy structure; firm; about 10 percent coarse fragments; neutral; diffuse, wavy boundary.

Cx—42 to 60 inches, brown (7.5YR 4/3) sandy loam; few, medium, prominent yellowish-red (5YR 4/6), reddish-brown (5YR 4/4), and pinkish-gray (7.5YR 6/2) mottles; weak, medium, platy structure; firm; about 10 percent coarse fragments; neutral.

The solum ranges from 38 to 54 inches in thickness. The content of coarse fragments ranges from 0 to 15 percent in the A horizon and from 8 to 25 percent in the B and C horizons. The Ap horizon, where present, is very dark gray or very dark grayish brown and is 6 to 9 inches thick. The A1 horizon is 1 to 5 inches thick and is strongly acid or very strongly acid. It is black or very dark gray fine sandy loam, sandy loam, or loam. It has a weak or moderate, granular or crumb structure. The A2 horizon ranges from dark grayish-brown and grayish-brown fine sandy loam to sandy loam. Structure is weak to moderate platy in the A2 horizon.

The B1g horizon ranges from dark grayish-brown and grayish-brown fine sandy loam to sandy loam. The B2t horizon ranges from fine sandy loam to sandy loam or loam, and its structure is weak or moderate, subangular blocky. The Bx horizon has weak or moderate platy structure. Depth to the Bx1 horizon ranges from 22 to 36 inches. Reaction ranges from medium acid to slightly acid in the B2t horizon and is slightly acid or neutral in the Bx horizon.

The C horizon is brown or dark brown. Reaction is medium acid to neutral. Structure is weak to moderate, platy.

Nokay soils are near Flak, Brainerd, and Parent soils and are similar to Ronneby soils. Nokay soils have a lower chroma and more development in the B2 horizon than the Flak and Brainerd soils. They have a thinner A1 horizon and a B horizon that has clay accumulation, whereas the Parent soils have a thick A1 horizon and lack clay accumulation in the B horizon. Nokay soils have a hue of 7.5YR in the lower part of the B horizon and in the C horizon, whereas Ronneby soils have a dominant hue of 2.5YR and 5YR in the lower part of the B horizon and in the C horizon.

Nokay fine sandy loam (No).—This nearly level soil is in narrow, concave areas on the lower parts of slopes and on the upper parts of shallow draws on the drumlins and ground moraines west of the Elk River. The draws in many places fan out and encircle depressional areas. Areas of this soil are elongated and range from 5 to 120 acres in size, but most areas are 20 to 40 acres in size. Stones are on the surface and throughout the profile.

This soil has the profile described as representative for the series.

Included with this soil in mapping are some small sandy spots. Also included are some areas of Prebish soils in wet depressions and drainageways about 50 feet wide.

The major limitations to the use of this soil are wetness and the fragipan. The main management needs are providing adequate drainage, increasing fertility, and using a cropping system that maintains good tilth and organic-matter content.

About 60 percent of the acreage of this soil is in crops. The rest is used as pasture and woodlots. This soil is well suited to most of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIw–1; woodland suitability group III; building site group 6.

Nokay stony fine sandy loam (Ns).—This nearly level soil is in narrow, concave areas on the lower parts of slopes and in the upper parts of shallow draws on the drumlins and ground moraines west of the Elk River. In many places the draws fan out and encircle depressions. Areas are elongated and range from 5 to 20 acres in size, but most areas are 10 to 15 acres in size.

This soil has a profile similar to the one described as representative for the series, but it is stony.

Included with this soil in mapping are some small sandy spots. Also included are some areas of Prebish soils in wet depressions and in drainageways about 50 feet wide.

Land clearing, providing adequate drainage, and increasing fertility help to correct the major limitations to the use of this soil and help to improve crop production. This soil is too stony for normal tillage. It is economically feasible to remove the stones, although they average 5 to 30 feet apart and are 1 to 3 feet in diameter.

Where the land is cleared and adequate drainage has been installed, this soil is well suited to most crops commonly grown in the county. This soil is used as pasture and woodlots. Capability unit IIw–1; woodland suitability group III; building site group 6.

Ogilvie Series

The Ogilvie series consists of nearly level, somewhat poorly drained soils in depressional areas on broad outwash plains, mainly along the St. Frances River. These soils formed in a medium-textured mantle of lacustrine or eolian origin that is moderately deep over leached, reddish or brownish sand and gravel. The original vegetation was a hardwood forest.

In a representative profile the surface layer is very dark gray silt loam about 8 inches thick. The subsurface layer, about 9 inches thick, is dark-gray and grayish-brown silt loam that has dark-brown mottles. The subsoil, about 15 inches thick, is grayish-brown, friable loam that has dark-brown mottles. The underlying material is brown, weakly cemented to loose coarse sand that has brown and gray mottles.

Permeability is moderate in the upper part of these soils and rapid in the lower part. The available water capacity is moderate. Organic-matter content is high. The content of available phosphorus is medium, the content of available potassium is low, and the content of available nitrogen is high. The water table fluctuates between depths of 2 and 4 feet.

Most areas of these soils are in crops. Some areas are used as pasture and woodlots. They are suited to all the crops commonly grown in the county.

Representative profile of Ogilvie silt loam, in a level area in a cultivated field, 10 feet east and 95 feet south of the center of sec. 14, T. 36 N., R. 28 W.:

Ap—0 to 8 inches, very dark gray (10YR 3/1) silt loam; weak, medium, subangular blocky structure; friable; medium acid; abrupt, smooth boundary.

A21g—8 to 11 inches, mixed dark-gray (10YR 4/1) and grayish-brown (10YR 5/2) silt loam; many, medium, distinct, very dark brown (10YR 2/2) mottles and common, medium, distinct, dark-brown (10YR 3/3) and dark yellowish-brown (10YR 4/4) mottles; moderate, medium, platy structure; friable; strongly acid; abrupt, irregular boundary.

A22g—11 to 17 inches, grayish-brown (10YR 5/2) silt loam; many, medium, distinct, dark yellowish-brown (10YR 4/4) mottles and common, medium, faint, dark grayish-brown (10YR 4/2) mottles; weak,

medium, platy structure parting to moderate, very fine, subangular blocky; friable; few, small, dark-colored concretions; strongly acid; clear, wavy boundary.

B2g—17 to 32 inches, grayish-brown (10YR 5/2) loam; many, medium, distinct, dark-brown (7.5YR 4/4) mottles; moderate, medium, subangular blocky structure; friable; medium, nearly continuous, grayish-brown silty coatings on faces of peds; few, small, dark-colored concretions; very strongly acid; abrupt, wavy boundary.

IIC—32 to 60 inches, brown (7.5YR 5/4) coarse sand; many, coarse, distinct, dark reddish-brown (5YR 3/4) and reddish-brown (5YR 5/3) mottles and few, medium, distinct, light brownish-gray (10YR 6/2) mottles; single grained; upper part is weakly cemented, lower part is loose; about 15 percent gravel; strongly acid.

The solum ranges from 20 to 40 inches in thickness. The Ap horizon is 6 to 9 inches thick and is medium acid to very strongly acid. It is black or very dark gray and typically is silt loam, but it is very fine sandy loam or loam in places. The A1 horizon, where present, is black, is 5 to 8 inches thick, and has weak to moderate, granular or crumb structure. The A2 horizon is grayish brown, dark gray, or gray and is similar in texture to the A1 horizon. It is 6 to 18 inches thick and has weak or moderate, platy structure.

The B horizon is grayish brown or gray. It typically is loam or silt loam but is fine sandy loam and sandy loam in the lower part in some places. Faint to prominent mottles are in this horizon. Reaction ranges from very strongly acid to medium acid. Structure is weak or moderate, subangular blocky or platy.

The C horizon is brown and reddish brown. It consists of coarse sand or sand and is 10 to 50 percent gravel. Reaction is strongly acid to slightly acid.

Ogilvie soils are near Antigo and Hillet soils. They have a grayer or duller colored B horizon than the well-drained Antigo soils. They have a thinner dark-colored A horizon than Hillet soils.

Ogilvie silt loam (Og).—This nearly level soil is in slightly depressional areas on a broad glacial outwash plain in the vicinity of the hamlet of Glendorado. Areas range from 10 to 80 acres in size, but most are 20 to 30 acres. In undisturbed areas the surface layer is somewhat thinner and darker colored than it is elsewhere.

Included with this soil in mapping are areas of soils that have a surface layer of very fine sandy loam and loam that has a high content of very fine sand. Also included are a few areas of Hillet soils in small depressions.

This soil is somewhat wet. Providing adequate drainage, increasing fertility, and maintaining organic-matter content help to correct major limitations to the use of this soil.

About 60 percent of the acreage of this soil is cultivated, and the rest is used as pasture and woodlots. This soil is suited to most of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIw–2; woodland suitability group III; building site group 6.

Paget Series

The Paget series consists of deep, nearly level to gently sloping, moderately well drained soils on slightly convex ground moraines. These soils formed in a moderately thin silty mantle of eolian or lacustrine origin and are underlain by firm, loamy, reddish-brown glacial till. The native vegetation was a forest canopy of mixed hardwoods and conifers. Cobblestones and stones are on the surface and throughout the profile.

In a representative profile the surface layer is black silt loam about 2 inches thick. The subsurface layer is dark grayish-brown and brown silt loam that is about 9 inches thick and is mottled with yellowish brown. The subsoil is about 43 inches thick. The upper 6 inches is brown, friable silt loam that has brown mottles. The middle part is brown, friable fine sandy loam that is about 6 inches thick and is mottled with red and brown. The lower part is dark-brown. It is mottled red and brown. The underlying material is reddish-brown, firm fine sandy loam.

Permeability is moderately slow, and available water capacity is high, organic-matter content is low. The content of available phosphorus is medium, and the content of available potassium and nitrogen is low. The firm fragipan restricts water movement and limits the root zone. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Some areas are used as pasture and woodlots. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Paget silt loam, 2 to 6 percent slopes, in a wooded pasture, 70 feet east and 750 feet south of northwest corner of sec. 10, T. 38 N., R. 28 W.:

A1—0 to 2 inches, black (10YR 2/1) silt loam; moderate, fine and medium, crumb structure; very friable; about 2 percent coarse fragments; medium acid; abrupt, smooth boundary.

A21—2 to 6 inches, dark grayish-brown (10YR 4/2) silt loam; few, fine, faint, dark yellowish-brown mottles; moderate, thin, platy structure; very friable; about 2 percent coarse fragments; slightly acid; clear, irregular boundary.

A22—6 to 11 inches, brown (10YR 5/3) silt loam; few, fine, faint, yellowish-brown (10YR 5/4) mottles; moderate, thin, platy structure; very friable; about 2 percent coarse fragments; slightly acid; clear, wavy boundary.

B&A—11 to 17 inches, brown (10YR 5/3) and dark yellowish-brown (10YR 4/4) silt loam, grayish-brown (10YR 5/2) porous coatings on faces of peds; common, medium, distinct, reddish-brown (5YR 4/4) mottles and few, fine, faint, brown (7.5YR 5/2) mottles; moderate, fine, subangular blocky structure; friable; about 15 percent coarse fragments; medium acid; clear, wavy boundary.

IIB2t—17 to 23 inches, brown (7.5YR 5/4) fine sandy loam; common, medium, faint, dark-brown (7.5YR 4/4) mottles and distinct, reddish-brown (5YR 4/4) and yellowish-red (5YR 4/6) mottles; moderate, medium, subangular blocky structure; friable; thin patchy clay films on faces of peds and few clayey fillings in pores; thin, patchy, porous coatings on faces of peds; about 10 percent coarse fragments; medium acid; clear, wavy boundary.

IIBx1—23 to 34 inches, dark-brown (7.5YR 4/4) sandy loam; many, medium, distinct, reddish-brown (5YR 4/4) and yellowish-red (5YR 4/6) mottles and few, medium, faint, brown (10YR 5/3) mottles; moderate, very thick, platy structure parting to weak, medium, subangular blocky; very firm; thin, patchy and continuous clay films on upper faces of peds; few, fine, dark-colored concretions; about 10 percent coarse fragments; slightly acid; clear, wavy boundary.

IIBx2—34 to 54 inches, reddish-brown (2.5YR 4/4) fine sandy loam; few, medium, distinct, reddish-brown (5YR 5/3) mottles that have yellowish-red (5YR 4/6) edges; moderate, thin, platy structure; firm; thin patchy clay films on upper faces of peds and in old root channels; few, fine, dark-colored con-

cretions; about 10 percent coarse fragments; slightly acid; gradual, smooth boundary.

IICx—54 to 64 inches, reddish-brown (5YR 4/3) fine sandy loam; moderate, thin, platy structure; firm; about 10 percent coarse fragments; neutral.

The solum ranges from 40 to 60 inches in thickness. Content of coarse fragments ranges from 0 to 5 percent in the A horizon and from 10 to 20 percent in the IIB and IIC horizons. The A horizon is very fine sandy loam, silt loam, or loam that has a high content of very fine sand.

The Ap horizon, where present, is very dark grayish brown and dark grayish brown and is 6 to 9 inches thick. The A1 horizon is 1 to 3 inches thick, is strongly acid to slightly acid, and ranges from black to very dark grayish brown. Structure is weak to moderate, granular or crumb. The A2 horizon is dark grayish brown, grayish brown, or brown. It is 6 to 12 inches thick and has faint, brown mottles. Structure is weak to moderate, platy.

The B&A horizon is silt loam, very fine sandy loam, or loam. It is high in content of very fine sand and is fine sandy loam or sandy loam in the lower part in some places. Reaction is medium to strongly acid. Depth to the IIB2t horizon ranges from 15 to 25 inches. The IIB2t horizon is brown or yellowish-brown fine sandy loam, very fine sandy loam, loam, or silt loam. It has faint to prominent mottles. Reaction is strongly acid to slightly acid. Depth to the Bx1 horizon ranges from 20 to 30 inches. The IIBx horizon is dark-brown or reddish-brown, firm or very firm sandy loam or fine sandy loam. Reaction is slightly acid to neutral in this horizon.

The C horizon is reddish-brown or dark reddish-brown sandy loam and fine sandy loam. Mottles are present in places, especially in the upper part of the C horizon. Reaction is slightly acid to mildly alkaline. Structure is weak to moderate, platy.

Paget soils are near Freer and Adolph soils and are similar to Mora soils. They have less clay in the Bt horizon and have a higher chroma in the upper part of the B horizon than Freer soils. They have a higher chroma in the upper part of the B horizon and a thinner dark-colored A horizon than Adolph soils. They have more silt and very fine sand and less fine sand and coarser material in the A horizon and in the upper part of the B horizon than Mora soils.

Paget silt loam, 0 to 2 percent slopes (PaA).—This soil is in broad areas on a silt-covered glacial ground moraine in the Rum River watershed. Areas are irregular in shape and range from 5 to 80 acres in size, but most are 20 to 40 acres in size. Slopes are convex and uniform. Stones are on the surface and throughout the soil.

This soil has a profile similar to the one described as representative for the series, but in cultivated areas the surface layer is dark grayish brown and is about 8 inches thick.

Included with this soil in mapping are some small areas of stony soils. Also included are some small areas of Freer soils and, in places, soils that have short slopes of 3 percent.

Crop growth on this soil is limited by climate and the restricted root zone. Trafficability is poor after heavy rains. In most places some stones need to be removed in order to practice ordinary tillage. Increasing organic-matter content and fertility helps to overcome the limitations on this soil.

About 80 percent of the acreage of this soil is in crops and pasture. The rest is used as woodlots. This soil is well suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, and alfalfa. Capability unit IIc–1; woodland suitability group I; building site group 4.

Paget silt loam, 2 to 6 percent slopes (PaB).—This soil is in broad areas on a silt-covered glacial ground moraine in the Rum River watershed. Areas are irregular in shape and range from 5 to 80 acres in size, but most are 20 to 40 acres in size. Slopes are convex and uniform, and they range from 200 to 400 feet in length. Stones are on the surface and throughout the profile.

This soil has the profile described as representative for the series. In cultivated areas the surface layer is dark grayish brown and is about 8 inches thick. In most places stones need to be removed for ordinary tillage.

Included with this soil in mapping are some areas of stony soils. Also included are some small areas of Freer soils.

The hazard of erosion is slight, and the root zone is limited. Controlling erosion and increasing organic-matter content and fertility help to overcome the limitations on this soil.

About 80 percent of the acreage of this soil is in crops and pasture. The rest is used for woodlots. This soil is well suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, soybeans, and alfalfa. Capability unit IIe–1; woodland suitability group I; building site group 4.

Paget stony silt loam, 0 to 2 percent slopes (PbA).—This soil is in broad areas on a silt-covered glacial ground moraine in the Rum River watershed. Areas are irregular in shape and range from 5 to 80 acres in size, but areas 20 to 40 acres in size are most common. Slopes are convex and uniform.

This soil has a profile similar to the one described as representative for the series, but it is more stony.

Included with this soil in mapping are some small areas of Freer soils and some areas of soils that have short slopes of 3 percent.

This soil is too stony for ordinary tillage. It is economically feasible to remove the stones, although they average 5 to 30 feet apart and are 1 to 3 feet in diameter.

This soil is well suited to most crops commonly grown in the county if it is cleared and fertility is increased. This soil is used as pasture and woodlots. Capability unit IIc–1; woodland suitability group I; building site group 4.

Paget stony silt loam, 2 to 6 percent slopes (PbB).—This soil is in broad areas on a silt-covered glacial ground moraine in the Rum River watershed. Slopes are convex and uniform, and they range from 200 to 400 feet in length. Areas are irregular in shape and range from 5 to 80 acres in size, but areas 20 to 40 acres in size are most common.

This soil has a profile similar to the one described as representative for the series, but it is more stony.

Included with this soil in mapping are some areas of Freer soils.

The hazard of erosion is slight, and the root zone is limited. This soil is too stony for ordinary tillage. It is economically feasible to remove the stones, although the stones average 5 to 30 feet apart and are 1 to 3 feet in diameter.

This soil is well suited to most crops commonly grown in the county if it is cleared and properly fertilized. This soil is used as pasture and for woodlots. Capability unit IIe–1; woodland suitability group I; building site group 4.

Parent Series

The Parent series consists of deep, level and depressional, poorly drained soils in broad areas on gently undulating ground moraines and in somewhat narrow, elongated areas between the more sloping drumlins. These soils formed in firm, loamy, reddish-brown and brown glacial till under a forest canopy of hardwoods and an understory of wetland grasses and sedges. Cobblestones and stones are on the surface and throughout the profile.

In a representative profile the surface layer is black and very dark gray, mottled loam and fine sandy loam about 11 inches thick. The subsoil is 29 inches thick. The upper 17 inches is dark grayish-brown and grayish-brown, friable fine sandy loam mottled with brown, and the lower part is reddish-brown, firm fine sandy loam mottled with red and brown. The underlying material is reddish-brown, very firm sandy loam.

Permeability is moderately slow to slow, and available water capacity is high. Organic-matter content is high. The content of available phosphorus is medium, the content of available potassium is low, and the content of available nitrogen is high. The firm till, which is at a depth of about 18 to 35 inches, restricts the movement of water and limits the root zone. A perched water table fluctuates between depths of about 1 foot and 3 feet.

Some areas of these soils are in crops. Some areas are used as pasture and woodlots. These soils are suited to all of the crops commonly grown in the county if adequate drainage is provided.

Representative profile of Parent loam, in a cultivated field, 315 feet west and 915 feet south of northeast corner of the NW¼ of sec. 16, T. 38 N., R. 29 W.:

Ap—0 to 7 inches, black (N 2/0) loam; weak, fine and medium, subangular blocky structure; friable; about 2 percent coarse fragments; neutral; abrupt, smooth boundary.

A3g—7 to 11 inches, very dark gray (10YR 3/1) fine sandy loam; few, fine, distinct, dark yellowish-brown (10YR 4/4) mottles; weak, medium, subangular blocky structure parting to weak, medium and coarse, granular; friable; about 2 percent coarse fragments; neutral; clear, wavy boundary.

B1g—11 to 15 inches, dark grayish-brown (2.5Y 4/2) and grayish-brown (2.5Y 5/2) fine sandy loam; common, fine, distinct, dark-brown (7.5YR 4/4) mottles; weak, medium and thick, platy structure parting to weak, fine and very fine, subangular blocky; friable; about 5 percent coarse fragments; neutral; gradual, wavy boundary.

B2g—15 to 28 inches, grayish-brown (2.5Y 5/2) fine sandy loam; many, fine, distinct, strong-brown (7.5YR 5/6) mottles; weak, medium, platy structure parting to weak, very fine, subangular; friable; about 5 percent coarse fragments; neutral; clear, wavy boundary.

IIB3—28 to 40 inches, reddish-brown (5YR 4/3) fine sandy loam; common, medium, faint, reddish-brown (5YR 4/4) and yellowish-red (5YR 4/6) mottles; weak, medium and thick, platy structure; firm; about 10 percent coarse fragments; neutral; clear, wavy boundary.

IIC—40 to 60 inches, reddish-brown (5YR 4/3) sandy loam; weak, medium, platy structure; very firm; about 10 percent coarse fragments; neutral.

The solum ranges from 30 to 50 inches in thickness. Depth to the first horizon that has firm consistence ranges from 18 to 35 inches. Content of coarse fragments ranges from 0 to 8 percent in the A horizon and upper part of the B horizon and from 5 to 15 percent in the lower part of the B horizon and in the IIC horizon.

The texture of the A horizon ranges from sandy loam or fine sandy loam to silt loam or loam. Reaction is slightly acid or neutral. The Ap horizon is 6 to 10 inches thick. It has weak to moderate, granular or subangular blocky structure. The A1 horizon, where present, is 6 to 10 inches thick. The A3 horizon ranges from 3 to 8 inches in thickness. In some places this horizon is not mottled.

The B and IIC horizons are sandy loam or fine sandy loam in texture. These horizons range from reddish brown to brown in color.

Parent soils generally are near Nokay, Ronneby, and Prebish soils and are similar to Adolph soils. They have a thicker dark-colored A horizon and are more poorly drained than Nokay and Ronneby soils. They have a firm IIB horizon at a shallower depth than the Prebish soils. They have more fine sand and coarser material and less silt and very fine sand than Adolph soils.

Parent loam (Pe).—This nearly level soil is in broad areas and in narrow margins that encircle depressions in areas of subdued relief on the drumlin field and the ground moraine near Foley. Areas are irregular in shape and range from 10 to 200 acres in size, but areas 40 to 80 acres in size are most common. Slopes are 200 to 1,000 feet long. Stones are present on the surface and throughout the profile. This soil has the profile described as representative for the series.

Included with this soil in mapping are small areas of soils that have a calcareous surface layer and, in places, a discontinuous layer of loamy sand in the underlying material that is beneficial to internal drainage. Also included are small areas of Prebish soils in depressions.

This soil is naturally wet. Providing adequate drainage, completing land clearing, and increasing fertility help to correct the limitations to use of this soil and to improve crop production.

About 40 percent of the acreage of this soil is in crops, 40 percent is in pasture, and the rest is used for woodlots. This soil is well suited to most crops commonly grown in the county. Among the commonly grown crops are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIIw–1; woodland suitability group III; building site group 9.

Parent stony loam (Pk).—This nearly level soil is in broad areas and in narrow margins that encircle depressions in areas of subdued relief on the drumlin field and ground moraine near Foley. Areas are irregular in shape and range from 10 to 60 acres in size, but areas 20 to 40 acres in size are most common. Slopes are 200 to 1,000 feet long.

This soil has a profile similar to the one described as representative for the series, but it is more stony.

Included with this soil in mapping are small areas of soils that have a calcareous surface layer and, in places, a discontinuous layer of loamy sand in the underlying material that is beneficial to internal drainage. Also included are small areas of Prebish soils in the depressions.

This soil is naturally wet. Land clearing, providing adequate drainage, and increasing fertility help to correct the major limitations to the use of this soil and to improve crop growth. This soil is too stony for ordinary tillage. It is economically feasible to remove the stones, although they are 5 to 30 feet apart and are 1 to 3 feet in diameter.

This soil is well suited to most of the crops commonly

grown in the county if it is cleared and adequate drainage is installed. This soil is used as pasture and for woodlots. Capability unit IIIw–1; woodland suitability group III; building site group 9.

Pomroy Series

The Pomroy series consists of deep, nearly level to sloping, well drained and moderately well drained soils on sand-covered glacial ground moraines and drumlins. These soils formed in a moderately thick, sandy mantle of eolian or lacustrine origin and are underlain by firm, loamy, brown and reddish-brown glacial till. The native vegetation was a forest canopy of hardwoods.

In a representative profile the surface layer is brown fine sand about 11 inches thick. The subsoil is about 26 inches thick. The upper 17 inches is brown, very friable fine sand that grades to dark-brown, mottled, friable loamy fine sand. The lower part is yellowish-red, mottled, firm sandy loam about 9 inches thick. The underlying material is brown, mottled, very firm sandy loam.

Permeability is rapid in the upper part of these soils and moderately slow in the lower part. Available water capacity is moderate. Organic-matter content is low. The content of available phosphorus, potassium, and nitrogen is low. The firm fragipan, which begins at a depth of about 30 inches, restricts the movement of water and limits the root zone. Depth to the water table is 10 feet or more.

Most areas of these soils are in crops. Steeper areas are used for woodlots and pasture. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Pomroy fine sand, 2 to 6 percent slopes, in a cultivated field, 230 feet south and 185 feet west of northeast corner of sec. 25, T. 37 N., R. 31 W.:

Ap—0 to 11 inches, brown (10YR 4/3) fine sand; massive; very friable; medium acid; clear, wavy boundary.

B1—11 to 24 inches, brown (10YR 5/3) fine sand; few, fine, distinct, yellowish-brown (10YR 5/6) mottles in lower part; massive; very friable; medium acid; clear, wavy boundary.

IIB2—24 to 28 inches, dark-brown (7.5YR 4/2) loamy fine sand; common, medium, distinct, light brownish-gray (10YR 6/2) mottles and few, fine, prominent, yellowish-red (5YR 4/6) mottles; massive; friable; about 30 percent coarse fragments; medium acid; clear, smooth boundary.

IIBx—28 to 37 inches, yellowish-red (5YR 4/6) sandy loam; many, fine and medium, distinct, reddish-gray (5YR 5/2) mottles; rinds 1 to 2 millimeters thick around coarse fragments; massive in some parts and weak, medium, angular blocky and platy structure in others; firm; few patchy clay films in pores; few, fine, dark-colored concretions; about 15 percent coarse fragments; medium acid; gradual, wavy boundary.

IICx—37 to 60 inches, brown (7.5YR 4/3) sandy loam; massive breaking to moderate, medium, platy structure; very firm; about 2 percent of matrix is thin, vertical, and reddish gray (5YR 5/2) and has a strong-brown (7.5YR 5/6) rind; about 15 percent coarse fragments; slightly acid.

The solum ranges from 30 to 50 inches in thickness. The Ap horizon is 7 to 12 inches thick and is strongly acid or medium acid. It is dark-brown or brown fine sand or loamy fine sand, and in places it is loamy sand and sand. The A1 horizon, where present, is very dark grayish brown or dark grayish brown and is 3 to 10 inches thick. Its texture is the same as that of the Ap horizon. Its structure is weak crumb to granular, or the horizon is massive.

The B1 and IIB2 horizons are dark brown, brown, dark yellowish brown, and yellowish brown. The B1 horizon is sand, fine sand, loamy sand, or loamy fine sand. The IIB2 horizon is loamy sand, loamy fine sand, sandy loam, or fine sandy loam. Reaction in the B horizon is medium acid or strongly acid. The IIB2 and IIC horizons range from dark brown to yellowish red. The higher value and chroma are restricted to the IIB3 horizon. Texture in these horizons is sandy loam or fine sandy loam, and consistence is firm or very firm. Depth to the IIBx horizon ranges from 20 to 42 inches. The IIC horizon is medium acid to neutral.

Pomroy soils are near Nokasippi and Watab soils and are similar to Langola soils. They have a brighter color in the B horizon and are better drained than Nokasippi and Watab soils. They have a thinner dark-colored A1 horizon or a lighter colored Ap horizon than Langola soils.

Pomroy fine sand, 2 to 6 percent slopes (PoB).—This gently sloping and undulating soil is on crests and the upper part of side slopes on sand-covered drumlins and ground moraines on the glacial uplands. Slopes are plane to convex and are 200 to 500 feet long. Areas range from 5 to 40 acres in size, but areas 10 to 15 acres in size are most common.

This soil has the profile described as representative for the series. In undisturbed areas the surface layer is somewhat thinner and slightly darker than elsewhere. Most of the cultivated acreage is only slightly eroded, but some areas are moderately eroded.

Included with this soil in mapping are some areas of soils that have a surface layer of loamy fine sand; in places the depth to the underlying material is less than 24 inches, but within a short lateral distance it ranges to more than 42 inches.

This soil is droughty in dry periods because available water capacity is only moderate. The hazard of wind erosion is severe. Practices that conserve moisture and increase organic-matter content are needed. Field shelterbelts and wind stripcropping help to reduce wind erosion.

About 50 percent of the acreage of this soil is cultivated. The rest is used as open pasture or wooded pasture. This soil is suited to corn, rye, soybeans, and alfalfa. Capability unit IIIs–1; woodland suitability group IV; building site group 5.

Pomroy fine sand, 6 to 12 percent slopes (PoC).—This sloping and rolling soil is on crests and the upper part of side slopes on sand-covered drumlins and ground moraines on the glacial uplands. Areas range from 5 to 20 acres in size, but areas 10 to 15 acres in size are most common. Slopes are convex and are 200 to 300 feet long.

This soil has a profile similar to the one described as representative for the series, but in undisturbed areas it has a somewhat thinner and slightly darker surface layer. Most of the acreage where this soil is cultivated is slightly eroded, but some moderate erosion is also indicated by a lighter color on the crests of slopes and by an occasional shallow gully.

Included with this soil in mapping are some areas of soils that have a surface layer of loamy fine sand; in places the depth to the underlying material is less than 24 inches, but it ranges to more than 42 inches within a short lateral distance.

The sandy upper layers limit the quantity of water available for plant growth; growth therefore is limited during prolonged dry periods. Controlling erosion and increasing organic-matter content and fertility help to overcome the limitations on this soil.

About 50 percent of the acreage of this soil is cultivated. The rest is used as open pasture or wooded pasture. This soil is suited to corn, rye, soybeans, and alfalfa. Capability unit IVs–1; woodland suitability group IV; building site group 5.

Pomroy loamy fine sand, 0 to 2 percent slopes (PrA).—This soil is on sand-covered drumlins and ground moraines on the glacial uplands. Areas range from 5 to 30 acres in size, but areas 10 to 20 acres in size are most common. Slopes are short and convex and are 50 to 100 feet long.

This soil has a profile similar to the one described as representative for the series, but in undisturbed areas the surface layer is loamy fine sand that is somewhat thinner and slightly darker in color. Although only slight erosion has generally occurred in the undisturbed areas, some moderate erosion is indicated in places by drifts along fence lines.

Included with this soil in mapping are some areas of somewhat poorly drained Watab soils that are mottled at a depth of 18 inches in places. Also included are areas of soils that have underlying material at a depth that ranges from less than 24 inches to more than 42 inches within a short lateral distance.

This soil is droughty during dry spells because available water capacity is only moderate. The hazard of wind erosion is severe. Practices that conserve moisture and increase organic-matter content are needed. Field shelterbelts and wind stripcropping help to reduce wind erosion.

About 50 percent of the acreage of this soil is cultivated. The rest is used as pasture or wooded pasture. This soil is suited to corn, rye, soybeans, and alfalfa. Capability unit IIIs–1; woodland suitability group IV; building site group 5.

Prebish Series

The Prebish series consists of deep, nearly level, very poorly drained soils in shallow depressions and on the margins of larger depressions that occur on undulating to rolling ground moraines and in areas between drumlins. These soils formed in firm, loamy, reddish-brown or brown glacial till. The native vegetation was wetland grasses and sedges and scattered alder and willow shrubs.

In a representative profile the surface layer is black loam and fine sandy loam about 16 inches thick that is mottled in the lower part. The subsoil is grayish-brown and gray, friable fine sandy loam 30 inches thick that is mottled with red and brown. The underlying material is reddish-brown, very firm sandy loam that has many red mottles.

Permeability is moderately slow, and available water capacity is moderate. Organic-matter content is high. The content of available phosphorus is medium, the content of available potassium is low, and the content of available nitrogen is high. The firm till, which begins at a depth of about 40 to 60 inches, restricts the movement of water and limits the root zone. A perched water table fluctuates between the surface and a depth of 3 feet.

Most areas of these soils are used for pasture or hay. A few areas are in crops. Where adequately drained, these soils are suited to all of the crops commonly grown in the county.

Representative profile of Prebish loam, in a cultivated field, 1,085 feet south and 330 feet west of northeast corner of NW¼ of sec. 16, T. 38 N., R. 29 W.:

Ap—0 to 6 inches, black (5YR 2/1) loam that has a high content of organic matter; weak, medium, crumb structure; very friable; neutral; abrupt, wavy boundary.

A12—6 to 11 inches, black (N 2/0) fine sandy loam; weak, medium and coarse, subangular blocky structure; friable; about 2 percent coarse fragments; neutral; clear, irregular boundary.

A13g—11 to 16 inches, black (2.5Y 2/1) fine sandy loam; few, fine, distinct, dark reddish-brown (5YR 3/3) mottles; weak, medium, subangular blocky structure; friable; about 2 percent coarse fragments; neutral; clear, wavy boundary.

B1g—16 to 19 inches, grayish-brown (2.5Y 5/2) to dark grayish-brown (2.5Y 4/2) fine sandy loam; few, fine, prominent, dark-red (2.5YR 3/6) mottles; weak, medium and thick, platy structure; friable; about 5 percent coarse fragments; neutral; clear, irregular boundary.

B2g—19 to 46 inches, gray (5YR 5/1) fine sandy loam; common, medium, distinct, reddish-brown (5YR 4/4) mottles; weak, medium and thick, platy structure; friable; about 5 percent coarse fragments; neutral; clear, wavy boundary.

IIC—46 to 60 inches, reddish-brown (5YR 4/3) sandy loam; many medium, faint, yellowish-red (5YR 4/6) mottles; weak, medium, platy structure; very firm; about 10 percent coarse fragments; neutral.

The solum ranges from 40 to 60 inches in thickness. The content of coarse fragments ranges from 0 to 8 percent in the surface layer and upper part of the subsoil and from 5 to 18 percent in the lower part of the subsoil and in the IIC horizon. The A1 horizon, where present, is 10 to 18 inches thick and is slightly acid to mildly alkaline. It is mostly black or very dark gray loam, but it is sandy loam, fine sandy loam, or silt loam in places. Distinct or prominent mottles are common. Structure ranges from weak to moderate crumb, granular, or subangular blocky.

The B horizon commonly is grayish-brown, dark grayish-brown, and gray, friable fine sandy loam, but in some places, it is sandy loam and loam. It has distinct to prominent, red and brown mottles. Reaction is slightly acid to mildly alkaline. Structure is weak subangular blocky or platy.

The IIC horizon is reddish-brown or dark reddish-brown, very firm or firm sandy loam or fine sandy loam. Mottles commonly are present in the upper part. Reaction is neutral to moderately alkaline. This horizon is weak to moderate platy in structure.

Prebish soils generally are near Parent and Ronneby soils and are similar to Adolph soils. They have a friable horizon that extends to a greater depth than that of Parent soils. They have a friable horizon that extends to a greater depth than that of Parent soils. They have a thicker dark-colored A horizon than the better drained Ronneby soils. They have more fine sand and coarser sand and less silt and very fine sand than Adolph soils.

Prebish loam (Ps).—This nearly level soil is in concave areas in shallow depressions or in drainageways between glacial drumlins, mostly west of the Elk River. Some areas encircle areas of Mucky peat, and others are in saucer-shaped depressions. Areas range from 5 to 200 acres in size, but most areas are 20 to 40 acres in size. Stones are on the surface and throughout the profile. This soil has the profile described as representative for the series.

Included with this soil in mapping are areas of soils that have a thin layer of mucky peat as much as 12 inches thick on the surface. There are also a few areas of soils that have a layer of mucky peat more than 12 inches thick on the surface, but these areas are less

than 3 acres in size. Also included in places, are soils that have a discontinuous layer of loamy sand in the underlying material that is beneficial to internal drainage.

This soil is naturally wet. Early frost is a hazard to crops. Providing adequate drainage, removing stones from the surface, and increasing fertility help to correct the major limitations to the use of this soil and to improve crop production.

Nearly all of the acreage of this soil is used for pasture and wild hay. If this soil is drained, it is suited to most of the crops commonly grown in the county. Commonly grown crops are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IVw–1; woodland suitability group VII; building site group 9.

Prebish stony loam (Pt).—This nearly level soil is in concave areas in shallow depressions or in drainageways between glacial drumlins, mostly west of the Elk River. Some areas encircle areas of Mucky peat, and others are in saucer-shaped depressions. Areas range from 5 to 40 acres in size, but most areas are 10 to 20 acres.

This soil has a profile similar to the one described as representative for the series, but it is more stony. This soil is naturally wet.

Included with this soil in mapping are areas of soils that have a thin layer of mucky peat as much as 12 inches thick on the surface and a few areas of soils that have a layer of mucky peat on the surface more than 12 inches thick, but these areas are less than 3 acres in size. Also included are areas of soils that have a discontinuous layer of loamy sand in the underlying material that is beneficial to internal drainage.

Providing adequate drainage and increasing fertility help to correct the major limitations to the use of this soil and to improve crop production. Stoniness prevents ordinary tillage of this soil. It is economically feasible to remove the stones, although they are 5 to 30 feet apart and are 1 to 3 feet in diameter.

All of the acreage of this soil is used for pasture. This soil is suited to most of the crops commonly grown in the county if stones are removed and adequate drainage is installed. Capability unit IVw–1; woodland suitability group VII; building site group 9.

Prebish and Parent loams (Pu).—This undifferentiated group is in broad, level or nearly level, depressional areas in the more subdued parts of the drumlin field and ground moraine near Foley. Areas range from 10 to 100 acres in size, but most are 20 to 40 acres. Stones are on the surface and throughout the profile. Prebish loam makes up about 60 percent of the acreage and Parent loam 40 percent. These soils have a profile similar to the one described as representative for their respective series. In undisturbed areas these soils mostly have wetness characteristics similar to those of the Parent soils.

Included with these soils in mapping are a few areas of soils that are stony. The stones interfere with tillage of row crops, but it is economically feasible to remove them. Also included are a few areas of Ronneby soils on small rises.

This soil is naturally wet. Installing an adequate drainage system, completing land clearing, and increasing fertility help to correct the major limitations and to increase crop production.

Most of the acreage of these soils is in crops, and the rest is used as pasture and for woodlots. These soils are well suited to most of the crops commonly grown in the county. Where these soils are drained, the commonly grown crops are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Both soils in capability unit IIIw–1; Prebish soils in woodland suitability group VII, and Parent soils in woodland suitability group III; both soils in building site group 9.

Ronneby Series

The Ronneby series consists of deep, nearly level, somewhat poorly drained soils in slightly concave areas at the base of slopes, at the heads of shallow drainageways, and on ground moraines. These soils formed in firm, loamy, reddish-brown glacial till under a forest canopy of mixed hardwoods and conifers. Stones and cobblestones are on the surface and throughout the profile.

In a representative profile the surface layer is black loam about 4 inches thick. The subsurface layer is dark-gray and very dark gray fine sandy loam that becomes dark grayish brown with depth and has dark-brown mottles. The subsoil is about 44 inches thick. The upper 21 inches is grayish-brown and dark-brown, friable loam and fine sandy loam that has brown mottles. The lower part is dark reddish-brown, firm fine sandy loam that has reddish-brown and dark-brown mottles. The underlying material is reddish-brown, very firm fine sandy loam.

Permeability is moderately slow, and available water capacity is moderate. Organic-matter content is medium. The content of available phosphorus and nitrogen is medium, and the content of available potassium is low. A firm fragipan, which begins at a depth of about 28 inches, restricts the movement of water and limits the root zone. A perched water table fluctuates between depths of 2 and 4 feet.

Most areas of these soils are in crops. Some areas are used as pasture or for woodlots. These soils are suited to all of the crops commonly grown in the county.

Representative profile of Ronneby loam in a wooded pasture where slopes are 1 percent, 1,210 feet south and 180 feet east of northwest corner of sec. 6, T. 36 N., R. 28 W.:

A1—0 to 4 inches, black (10YR 2/1) loam; moderate, fine and very fine, granular structure; very friable; about 2 percent coarse fragments; medium acid; clear, smooth boundary.

A21g—4 to 7 inches, mixed, dark-gray (10YR 4/1) and very dark gray (10YR 3/1) fine sandy loam; common, fine, distinct, dark yellowish-brown (10YR 4/4) mottles; moderate, medium and thin, platy structure; very friable; about 2 percent coarse fragments; slightly acid; clear, smooth boundary.

A22g—7 to 12 inches, dark grayish-brown (10YR 4/2) fine sandy loam; common, fine, distinct, dark-brown (10YR 4/3) and dark yellowish-brown (10YR 4/4) mottles; upper faces of plates have dark gray (10YR 4/1) stains and a few dark-brown (7.5YR 4/4) mottles; moderate, medium, platy structure; friable; about 5 percent coarse fragments; medium acid; clear, smooth boundary.

B1g—12 to 17 inches, grayish-brown (10YR 5/2) and

brown (10YR 5/3) loam; many, fine, distinct, dark-brown (7.5YR 4/4) mottles; weak, fine, subangular blocky structure; friable; about 20 percent coarse fragments; medium, porous, grayish coatings on faces of peds; medium acid; clear, smooth boundary.

B21g—17 to 25 inches, dark brown (7.5YR 4/2) fine sandy loam; many, fine, faint, brown (7.5YR 4/4) mottles; weak, medium and thick, platy structure; friable; about 10 percent coarse fragments; few, porous, grayish coatings on vertical cleavage faces; medium acid; gradual, wavy boundary.

B22tg—25 to 33 inches, dark-brown (7.5YR 4/2) and brown (7.5YR 4/4) fine sandy loam; many, fine, faint, brown (7.5YR 5/2) and strong-brown (7.5YR 5/6) mottles; moderate, medium and thick, platy structure; friable; about 10 percent coarse fragments; moderately thick clay films in old root channels; medium acid; clear, wavy boundary.

Bx1—33 to 45 inches, dark reddish-gray (5YR 4/2) and reddish-brown (5YR 4/3) fine sandy loam; common, fine, distinct, reddish-brown (5YR 4/4) and dark-brown (7.5YR 4/4) mottles; weak, medium, platy structure; firm; about 10 percent coarse fragments; thin dark reddish-brown (5YR 3/2) films on surface of plates and around pebble pockets; neutral; gradual, wavy boundary.

Bx2—45 to 56 inches, dark reddish-brown (5YR 3/3) and dark-brown (7.5YR 3/3) fine sandy loam, few, coarse, faint, dark reddish-brown (2.5YR 3/4) and reddish-brown (2.5YR 4/4) mottles; weak, medium, platy structure; firm; about 10 percent coarse fragments; neutral; clear, wavy boundary.

Cx—56 to 61 inches, reddish-brown (5YR 4/4) fine sandy loam; weak, thin and medium, platy structure; very firm; about 10 percent coarse fragments; moderately alkaline.

The solum ranges from 40 to 60 inches in thickness. The content of coarse fragments ranges from 0 to 15 percent in the A horizon and from 8 to 25 percent in the B and C horizons. The Ap horizon, where present, is very dark grayish brown or very dark brown and is 6 to 9 inches thick. The A1 horizon is 2 to 6 inches thick and is strongly acid to slightly acid. It is black or very dark gray and typically is loam, but it is fine sandy loam, sandy loam, very fine sandy loam, and silt loam in a few places. Structure is moderate to strong, granular or crumb. The A2 horizon is very dark gray and dark gray in the upper part and gray or grayish brown in the lower part. Its texture typically is fine sandy loam, but it is sandy loam and very fine sandy loam in places. Structure is weak to moderate, platy.

The B horizon is 27 to 54 inches thick. The texture ranges from loam or fine sandy loam to sandy loam in the B1 and B2 horizons and from fine sandy loam to sandy loam in the Bx horizon. Color is grayish brown or brown in the B1 horizon and grades with depth to dark grayish brown or dark brown in the B2 horizon and dark reddish gray, dark brown, and dark reddish brown in the Bx horizon. Depth to the Bx1 horizon ranges from 22 to 36 inches. Reaction ranges from strongly acid to slightly acid in the B1 and B2 horizons and from slightly acid to neutral in the Bx horizon.

The Cx horizon is firm or very firm reddish-brown or dark reddish brown sandy loam and fine sandy loam. Reaction is neutral to mildly alkaline. Structure is weak to moderate platy.

Ronneby soils commonly are near Milaca, Mora, and Parent soils and are similar to Nokay soils. They have a lower chroma in the B horizon than the better drained Milaca and Mora soils. They have a thinner dark-colored A horizon than the more poorly drained Parent soils. They have a redder color in the Bx and Cx horizons than Nokay soils.

Ronneby loam (Rn).—This soil is in areas on the ground moraine and on some drumlins east of the Elk River. The areas are mostly narrow and concave and are at the bottom of gentle slopes and in the upper parts of shallow draws that fan out to encircle depressions. Areas are elongated and range from 10 to 160 acres in size, but most are 20 to 40 acres. Slopes are 1 to 2 percent and 200 to 500 feet long. Stones are on the surface and throughout the profile. This soil has the profile described as representative for the series.

Included with this soil in mapping are areas of soils that have a surface layer of sandy loam, fine sandy loam, and silt loam and soils at the eastern edge of the county that have a thin mantle of silt loam. Also included in the Elk River area are soils that have underlying layers that are banded or mixed with brown glacial till. There are some areas of Parent and Prebish soils in the small, wet depressions.

This soil is somewhat wet. Providing adequate drainage and increasing fertility help to increase crop production.

About 60 percent of the acreage of this soil is in crops. The rest is used as pasture and for woodlots. This soil is well suited to most of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, and soybeans and red clover, timothy, and alsike clover mixture. Capability unit IIw–1; woodland suitability group III; building site group 6.

Ronneby stony loam (Ro).—This soil is in areas on the ground moraine and on some drumlins east of the Elk River. The areas are mostly narrow and concave and are at the bottom of gentle slopes and in the upper parts of shallow draws that fan out to encircle depressions. Areas are elongated and range from 5 to 40 acres in size, but most areas are 10 to 20 acres. Slopes are 1 to 2 percent and 200 to 500 feet long.

This soil has a profile similar to the one described as representative for the series, but it is more stony.

Included with this soil in mapping are some areas of Parent and Prebish soils in small, wet depressions.

This soil is somewhat wet. It is too stony for ordinary tillage. It is economically feasible to remove the stones, although they are 5 to 30 feet apart and are 1 to 3 feet in diameter.

This soil is used for pasture and woodlots. It is well suited to all of the crops commonly grown in the county if it is cleared and drainage systems are installed. Capability unit IIw–1; woodland suitability group III; building site group 6.

Sartell Series

The Sartell series consists of deep, nearly level to steep, excessively drained soils in undulating to rolling, dune-shaped areas on outwash plains. These soils formed in deeply leached, gravel-free fine sands that are mostly eolian in origin. The native vegetation was a forest canopy of northern red oak and bur oak.

In a representative profile the surface layer is very dark brown and very dark grayish-brown loamy fine sand about 4 inches thick. The subsoil is dark-brown and brown, loose fine sand about 29 inches thick. The underlying material is brown to light yellowish-brown, loose fine sand.

Permeability is rapid, and the available water capacity is low. The organic-matter content is low. The content of available phosphorus, potassium, and nitrogen is low. Depth to the water table is 10 feet or more.

Some areas of these soils are in crops, but most areas

are used as pasture and for woodlots. These soils are not suited to all of the crops commonly grown in the county. Irrigation is needed to insure good crop production.

Representative profile of Sartell fine sand, 2 to 6 percent slopes, 1,410 feet north and 80 feet west of southeast corner of SW¼ of sec. 11, T. 37 N., R. 31 W.:

A1—0 to 4 inches, very dark brown (10YR 2/2) and very dark grayish-brown (10YR 3/2) fine sand; weak, fine, crumb structure; very friable strongly acid; clear, smooth boundary.
B1—4 to 22 inches, dark-brown (10YR 3/3) fine sand; single grained; loose; strongly acid; diffuse, wavy boundary.
B2—22 to 33 inches, brown (10YR 4/3) fine sand; single grained; loose; strongly acid; diffuse, wavy boundary.
C1—33 to 48 inches, brown (10YR 5/3) fine sand; single grained; loose; strongly acid; diffuse, wavy boundary.
C2—48 to 60 inches, yellowish-brown (10YR 5/4) fine sand; single grained; loose; medium acid; diffuse, wavy boundary.
C3—60 to 72 inches, light yellowish-brown (10YR 6/4) fine sand; single grained; loose; medium acid.

The solum ranges from 24 to 40 inches in thickness. The A1 horizon is 2 to 6 inches thick and is medium acid or strongly acid. It is very dark brown or very dark grayish-brown loamy fine sand or fine sand. Structure is weak crumb or weak subangular blocky. The Ap horizon, where present, is dark grayish brown or dark brown and is 6 to 10 inches thick.

The B horizon ranges from dark brown or brown to dark yellowish brown or yellowish brown. It typically is fine sand but ranges to sand that has a high content of fine sand. Reaction is medium acid or strongly acid.

The C horizon is fine sand or sand in a few places. Reaction is medium acid or strongly acid.

Sartell soils are near Lino and Isanti soils and are similar to Hubbard soils. Sartell soils have a higher chroma in the A and B horizons than the more poorly drained Lino and Isanti soils. They have a higher content of fine sand and less medium and coarser sand in the A and B horizons and a thinner dark-colored A horizon than Hubbard soils.

Sartell fine sand, 0 to 2 percent slopes (SaA).—This soil is mainly in areas along the eastern edge of an outwash plain that parallels the Mississippi River. It also is in a narrow area in the southern part of the county. Areas are irregular in shape and range from 5 to 80 acres in size, but most areas are 10 to 20 acres in size.

This soil has a profile similar to the one described as representative for the series, but in places it has a surface layer of loamy fine sand.

Included with this soil in mapping are areas of soils that are faintly mottled at a depth of 36 inches or more. Also included are a few areas of soils that have short slopes of 3 percent and a few areas of Lino and Isanti soils in very small slight depressions.

This soil is droughty during dry spells. If the soil is cultivated, wind erosion is a hazard. Controlling wind erosion, conserving soil moisture, and increasing fertility help to correct the major limitations to the use of this soil.

About 30 percent of the acreage of this soil is cultivated, and the rest is in wooded or unwooded pasture or is used for woodlots. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legumes and to early maturing crops, such as winter rye, than to most other crops. If this soil is irrigated, crop production is good to excellent. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Sartell fine sand, 2 to 6 percent slopes (SaB).—This gently sloping and undulating soil is mainly in areas along the eastern edge of an outwash plain that parallels the Mississippi River. It also occurs in a narrow area in the southern part of the county. Areas are irregular and dune-shaped and range from 5 to 160 acres in size, but most areas are 10 to 20 acres in size. Slopes are short, and generally they are complex. They range from 100 to 300 feet in length.

This soil has the profile described as representative for the series. Most of the acreage of this soil has been subjected to little erosion, but moderate wind erosion has occurred on the crests of slopes in cultivated areas. Erosion is indicated by a lighter colored surface layer and by drifts along fence lines.

Included with this soil in mapping are a few areas of Lino and Isanti soils in very small slight depressions.

This soil is droughty during dry spells, and where cultivated, it is subject to wind erosion. Controlling wind erosion, conserving soil moisture, and increasing fertility help to correct the major limitations to the use of this soil.

About 30 percent of the acreage of this soil is cultivated. The rest is in wooded pasture and unwooded pasture or is used for woodlots. This soil is poorly suited to late-maturing crops. It is better suited to deep-rooted legumes and to early maturing crops, such as winter rye, than to most other crops. If this soil is irrigated, crop production is good to excellent. Capability unit IVs–2; woodland suitability group VI; building site group 2.

Sartell fine sand, 6 to 12 percent slopes (SaC).—This sloping and rolling soil is on narrow outwash embankments adjacent to drainageways and major water courses that are wide and long. Areas are 5 to 30 acres in size. Slopes are 100 to 300 feet in length.

This soil has a profile similar to the one described as representative for the series, but it is thinner. Most areas of this soil have been subjected to little or no erosion, but a few cultivated areas have been subject to moderate or severe erosion. These areas have a lighter colored surface layer, loose consistence, and, in places, have a dune-shaped hill crest.

Included with this soil in mapping are areas of soils that have a surface layer of loamy fine sand.

The major limitations to the use of this soil are very low available water capacity and the severe hazards of wind erosion and water erosion. The soil also has low fertility and organic-matter content.

Nearly all of the acreage of this soil is used as wooded pasture and unwooded pasture or for woodlots. This soil is poorly suited to grain crops because it is droughty. It is better suited to use as permanent pasture and to trees. Among the main management needs are control of erosion, increase of fertility, and control of grazing. Capability unit VIs–1; woodland suitability group VI; building site group 2.

Sartell fine sand, 12 to 25 percent slopes (SaE).—This hilly and steep soil is on narrow outwash embankments adjacent to drainageways and major watercourses. Areas are 10 to 40 acres in size. Slopes are 75 to 150 feet in length.

This soil has a profile similar to the one described for the series, but it is thinner because of its greater slope. Most areas of this soil have been subject to little or no erosion.

Included with this soil in mapping are a few areas of moderately or severely eroded soils that are characterized by an occasional gully and a few partially healed dunes. Also included are areas of soils that have a surface layer of loamy fine sand.

The major limitations to the use of this soil are very low available water capacity, slope, low fertility, and a severe hazard of erosion. Providing such permanent cover as trees or grasses is the main management requirement. Controlling erosion and limiting the amount of grazing are necessary to protect this soil.

Almost all of this soil is in permanent pasture or is in bur oak and red oak trees. Capability unit VIIs–1; woodland suitability group VI; building site group 2.

Watab Series

The Watab series consists of deep, nearly level, somewhat poorly drained soils in areas adjacent to drainageways, in depressions, and on foot slopes on ground moraines and drumlin fields. These soils formed in a moderately thick, well-sorted mantle of eolian or lacustrine sand underlain by firm, loamy glacial till. The native vegetation was a forest canopy of hardwoods.

In a representative profile the surface layer is black loamy fine sand about 9 inches thick. The subsurface layer is dark grayish-brown loamy fine sand that is about 6 inches thick and has dark yellowish-brown mottles. The subsoil is about 35 inches thick. The upper 18 inches is brown, friable and very friable sandy loam that has red and brown mottles. The lower part is reddish-brown, mottled, firm sandy loam. The underlying material is reddish-brown and brown, firm sandy loam.

Permeability is rapid in the upper part of these soils and moderately slow in the lower part. Available water capacity is moderate. Organic-matter content is medium. The content of available phosphorus and potassium is low, and the content of available nitrogen is medium. A firm fragipan, which begins at a depth of about 33 inches, restricts the movement of water and limits the root zone. A perched water table fluctuates between depths of 2 and 4 feet.

Some areas of these soils are in crops or pasture. Some areas are used for woodlots. If these soils are adequately drained, they are suited to all of the crops commonly grown in the county.

Representative profile of Watab loamy fine sand in an area where slope is 1 percent, in a cultivated field, 930 feet north and 70 feet east of southwest corner of the NW¼ of sec. 30, T. 37 N., R. 30 W.:

Ap—0 to 9 inches, black (10YR 2/1) loamy fine sand; common, medium, distinct, dark-brown (10YR 3/3) mottles; weak, medium, granular structure; very friable; strongly acid; abrupt, smooth boundary.

A2—9 to 15 inches, dark grayish-brown (10YR 4/2) loamy fine sand; common, medium, distinct, dark yellowish-brown (10YR 4/4) mottles; weak, thick, platy structure parting to weak, fine, subangular blocky; very friable; strongly acid; clear, irregular boundary.

B1—15 to 23 inches, brown (10YR 4/3) fine sandy loam; many, medium, distinct, dark-brown (7.5YR 4/3) mottles; weak, medium, subangular blocky structure; very friable; about 20 percent coarse fragments in the lower part; thick, nearly continuous, brown (10YR 5/3), sandy coatings on some vertical faces of peds in upper part; strongly acid; clear, wavy boundary.

IIB2—23 to 33 inches, brown (7.5YR 4/4) fine sandy loam; many, medium, distinct, reddish-brown (5YR 4/4) and yellowish-red (5YR 4/6) mottles; weak, thick, platy structure parting to weak, fine, subangular blocky; friable; about 15 percent coarse fragments; thick, brown (7.5YR 5/4), nearly continuous, sandy coatings on some vertical faces of peds; medium acid; clear, wavy boundary.

IIBx—33 to 50 inches, reddish-brown (5YR 4/3) sandy loam; many, medium, faint, dark reddish-brown (5YR 3/4) and reddish-brown (5YR 5/3) mottles and many, medium, distinct, brown (7.5YR 5/2) mottles; moderate, medium, platy structure; firm; about 15 percent coarse fragments; thin, patchy, silty and clayey films on upper faces of peds; slightly acid; diffuse, wavy boundary.

IICx—50 to 60 inches, reddish-brown (5YR 4/3) sandy loam; moderate, medium, platy structure; firm; about 15 percent coarse fragments; neutral.

The solum ranges from 36 to 56 inches in thickness. Content of coarse fragments ranges from 0 to 5 percent in the A horizon and the upper part of the B horizon to 8 to 20 percent in the lower part of the B horizon and in the IICx horizon. The Ap horizon is 7 to 10 inches thick and is medium acid or strongly acid. It is black, very dark gray, or very dark grayish brown and typically is loamy fine sand, but it is loamy sand, fine sandy loam, or sandy loam in a few places. The A1 horizon, where present, is black or very dark gray and is 3 to 8 inches thick. Its texture is similar to that of the Ap horizon, and its structure is weak to moderate granular or crumb. The A2 horizon is dark grayish-brown or brown loamy fine sand, loamy sand, fine sand, or sand 3 to 10 inches thick. It has weak platy or subangular blocky structure.

The B horizon is 20 to 46 inches thick. The B1 horizon ranges from loamy fine sand or loamy sand to fine sandy loam and sandy loam. It is brown or yellowish brown and has faint to distinct mottles. Reaction is strongly acid to slightly acid. Structure is weak subangular blocky, or the horizon is massive. Texture in the IIB and IICx horizons is fine sandy loam or sandy loam. The color is brown or reddish brown, and the IIB horizon has distinct to prominent mottles. Reaction ranges from medium acid to neutral. These horizons have a weak or moderate platy structure.

Watab soils are near Pomroy, Langola, and Nokasippi soils and are similar to Blomford soils. They have mottles in the A horizon and the upper part of the B horizon, and the better drained Pomroy and Langola soils do not. They have a thinner dark-colored A horizon than the more poorly drained Nokasippi soils. They have more sand and less silt and clay in the IIB and IIC horizons than Blomford soils.

Watab loamy fine sand (Wa).—This nearly level soil is in areas at the foot of sand-covered glacial drumlins and ground moraines. The areas encircle depressions or are adjacent to drainageways that are occupied by Nokasippi soils. These areas are in Watab and Mayhew Lake Townships. Areas are dominantly elongated and range from 5 to 100 acres in size.

Included with this soil in mapping are areas of soils that have a surface layer of loamy sand or sandy loam in places and some areas of soils near the Langola soils in Langola Township that have a thicker surface layer. Also included are areas of soils that have firm, loamy till below a depth of 42 inches, some areas of soils that have a few stones, small areas of Nokasippi soils in depressions, and Pomroy soils on small rises.

This soil is somewhat wet. Providing adequate drainage to relieve wetness in spring, increasing fertility,

and maintaining organic-matter content are the management needs of this soil.

About 50 percent of the acreage of this soil is in crops and pasture. The rest is used for woodlots. This soil is suited to all of the crops commonly grown in the county. Among the crops commonly grown are corn, oats, and soybeans and red clover, timothy, and alsike clover mixtures. Capability unit IIIw–2; woodland suitability group V; building site group 7.

Use and Management of the Soils

This section gives interpretations of the soils for use in the production of crops, predicts yields, and describes the management required for such yields. It also describes the use and management of the soils for woodland, wildlife, and recreation and the suitability of the soils for use in engineering and for town and country planning.

Use of the Soils for Crops

This subsection discusses the capability classification of soils that is used by the Soil Conservation Service and describes the capability units in which the soils are placed. It also gives predictions of the yields to be expected when the different soils are used for crops and for pasture.

Most of the farmland in the county is used for the production of corn, oats, rye, soybeans, and alfalfa. The crops are sold or are fed to livestock.

Some of the cultivated soils are subject to erosion if they are not protected. The use of erosion control practices, the incorporation of plant residue, and the use of cropping systems that include an occasional sod crop help to control erosion. Drainage is needed for intensive farming of the level or depressional soils. Ditches are needed to remove surface water and to provide an outlet for laterals and the tile drainage system.

Crops on all the soils in the county respond to applications of fertilizer. The soils are especially low in content of available potassium and nitrogen. The need for fertilizer depends on the kind of soil, the past and present management, and the crop that is grown. Soil tests provide some of the information that is needed to choose the proper mixture and amount of fertilizer. Lime is necessary on almost all of the upland soils in the county, and alfalfa does not grow well without it.

Capability grouping

Capability grouping shows, in a general way, the suitability of soils for most kinds of field crops. The soils are grouped according to their limitations when used for field crops, the risk of damage when they are so 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 rice, cranberries, horticultural crops, or other crops requiring special management.

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, the 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. (None in Benton County.)

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. (None in Benton County.)

Class VI soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wildlife.

Class VII soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to pasture or range, woodland, or wildlife.

Class VIII soils and landforms have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife, water supply, or 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, 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 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, though they have other limitations that restrict their use largely to pasture, range, woodland, wildlife, 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–2 or IVe–1. 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 Benton 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, but this does not mean that all the soils of a series are in a given capability unit. To find the capability classification of any given soil, refer to the "Guide to Mapping Units" at the back of this survey.

CAPABILITY UNIT IIe–1

This unit consists of deep, well drained and moderately well drained, gently sloping soils of the Brainerd, Dalbo, Flak, Milaca, Mora, and Paget series and the Milaca variant. These soils have a surface layer of fine sandy loam, sandy loam, very fine sandy loam, or silt loam. The subsoil is sandy loam, fine sandy loam, and, in places, loam. The available water capacity generally is moderate to high, but the Dalbo soil has very high available water capacity. Fertility is medium. Permeability is moderately slow; consequently, some water runs off the soils in cultivated areas during periods of heavy rainfall and some erosion occurs. The soils generally are low to moderate in organic-matter content.

The soils of this unit generally are easy to till; however, stones and cobblestones interfere with tillage in some areas and must be removed periodically. Except for the Dalbo soil, a fragipan in these soils restricts the movement of water and tends to perch the water in the upper part of the soil. Proper timing of fieldwork is therefore necessary. The fragipan also restricts downward growth of roots. Water erosion is a slight hazard on these soils.

These soils are well suited to corn, soybeans, small grain, and alfalfa and other hay crops. Some areas have not been opened to cultivation, but doing so is economically feasible.

Erosion control, maintenance of tilth, and proper use of fertilizer are the most important management requirements. Returning plant residue to the soil and applying manure help to maintain tilth and increase fertility. Leaving a trashy, rough surface on the soil when tilling in fall helps to reduce erosion. Use of graded parallel terraces and grassed waterways or tile outlets is an effective measure for controlling water erosion. Contour stripcropping so that hay or a close-growing crop is grown in every other strip is also very effective in controlling erosion. Cropping systems that include green-manure crops and legume-grass crops help to preserve structure and increase organic-matter content. No-till planting helps to reduce compaction and cost of field operations while maintaining normal yields.

CAPABILITY UNIT IIe–2

This unit consists only of well-drained Antigo silt loam, 2 to 6 percent slopes. This soil has a surface layer of silt loam and a subsoil of silty clay loam that becomes sandy loam with depth. It is moderately deep over loose sand and gravel. Available water capacity is moderate, and natural fertility is medium. Permeability is moderate in the upper part of the soil and rapid in the lower part. Organic-matter content is low.

This soil is easy to till, and tilth is easy to maintain. It is somewhat droughty at times, because the substratum is sandy and gravelly. Erosion is a slight hazard.

This soil is well suited to corn, soybeans, small grain, and alfalfa and other hay and pasture crops.

Erosion control, maintenance of tilth, and proper use of fertilizer are the most important management requirements. Spring tillage is effective in reducing wind erosion and water erosion. Reducing the size of open fields and practicing minimum tillage also reduce wind erosion. Contour farming and cross-slope tillage help to conserve moisture and reduce erosion. Returning plant residue and applying manure help to maintain tilth and increase fertility. Cropping systems that include legumes and grasses are helpful in preserving structure, maintaining tilth, and providing organic matter. No-till planting helps to reduce compaction, erosion, and the cost of field operations while maintaining normal yields.

CAPABILITY UNIT IIw–1

This unit consists of deep, nearly level, somewhat poorly drained soils of the Freer, Nokay, and Ronneby series. These soils have a surface layer of loam, silt loam, and fine sandy loam and a subsoil of loam, very fine sandy loam, silt loam, and sandy loam. Available water capacity is moderate to high, and fertility is medium. Permeability is moderately slow; consequently, some water stands on these soils for short periods after heavy rains. Organic-matter content generally is moderate.

The soils of this unit commonly are easy to till; however, stones and cobblestones interfere with tillage in some areas and must be removed periodically. Drainage is needed before these soils can be farmed intensively. These soils have a fragipan or a layer of firm till that restricts the movement of water and tends to perch the water in the upper part of the soil. It also restricts downward growth of plant roots. The limitation caused by wetness can be reduced by diverting runoff from higher lying soils to waterways and outlet ditches. Conditions for tillage are more favorable in fall than in spring because the soils are somewhat wet in spring and become cloddy if tilled when too moist. Fall-tilled soils generally have better tilth, and they warm up earlier in spring. The earlier warmup permits earlier seedbed preparation in spring.

These soils are well suited to corn, soybeans, and small grain, and to alfalfa and other hay crops. Alfalfa

requires good internal drainage. Some areas have not been opened to cultivation, but doing so is economically feasible.

Adequate drainage, proper use of fertilizer, and maintenance of tilth are the most important management requirements. Grassed waterways and shallow field ditches correct most wetness conditions. All crop residue should be returned to the soil to maintain tilth. Cropping systems that include an occasional deep-rooted legume are helpful in preserving structure, maintaining tilth, and providing organic matter.

CAPABILITY UNIT IIw–2

This unit consists only of somewhat poorly drained Ogilvie silt loam. This soil has a surface layer of silt loam or very fine sandy loam and a subsoil of loam, sandy loam, or fine sandy loam. It is moderately deep over sand and gravel. Available water capacity is moderate, and fertility is medium. Permeability is moderate in the upper part of the soil and rapid in the lower part. Organic-matter content is high.

This soil warms up slowly in spring and is easy to till. Drainage is needed before it can be farmed intensively. A substantial increase in the production of all the commonly grown crops can be expected after the soil is drained. Conditions for tillage are more favorable in fall than in spring, because the soil is somewhat wet in spring and becomes cloddy if tilled when too moist. Fall tillage generally results in better tilth, allows the soil to warm up earlier in spring, and permits more rapid seedbed preparation.

This soil is well suited to corn, soybeans, small grain, and alfalfa and other hay crops. Alfalfa requires good internal drainage.

Adequate drainage, proper use of fertilizer, and maintenance of tilth are the most important management requirements. Grassed waterways and broad, shallow field ditches correct most wetness conditions. All crop residue should be returned to the soil to maintain tilth. Cropping systems that include an occasional deep-rooted legume are helpful in preserving structure, maintaining tilth, and providing organic matter.

CAPABILITY UNIT IIs–1

This unit consists only of well-drained Antigo silt loam, 0 to 2 percent slopes. This soil has a surface layer of silt loam or very fine sandy loam and a subsoil of silt loam that becomes silty clay loam and sandy loam with depth. It is moderately deep to loose sand and gravel. Available water capacity is moderate, and fertility is medium. Permeability is moderate in the upper part of the soil and rapid in the lower part. Organic-matter content is low.

This soil is easy to till, and tilth is easy to maintain. It is somewhat droughty at times, because the substratum is sandy and gravelly. Wind erosion is a slight hazard where large cultivated fields are exposed.

This soil is well suited to corn, soybeans, small grain, and alfalfa and other hay and pasture crops.

Erosion control, maintenance of tilth, and proper use of fertilizer are the most important management requirements. Spring tillage is effective in reducing wind erosion. Reducing the size of open fields and practicing minimum tillage also help to reduce wind erosion. Returning plant residue and applying manure help to maintain tilth and increase fertility. Cropping systems that include legumes and grasses are helpful in preserving structure, maintaining tilth, and providing organic-matter. No-till planting helps to reduce compaction, erosion, and cost of field operations while maintaining normal yields.

CAPABILITY UNIT IIc–1

This unit consists of deep, moderately well drained, nearly level soils of the Brainerd, Dalbo, Mora, and Paget series. These soils have a surface layer of sandy loam, fine sandy loam, very fine sandy loam, or silt loam. The subsoil is sandy loam, fine sandy loam, loam, silt loam, clay loam, or silty clay loam. Available water capacity generally is moderate or high, but in the Dalbo soil it is very high. Fertility is medium. Permeability is moderately slow, and water stands in puddles and delays fieldwork.

The soils generally are low to moderate in organic-matter content.

A short growing season is the only major limitation to use of these soils for crops. The soils generally are easy to till, but stones and cobblestones interfere with tillage in some areas and must be removed periodically. Except in the Dalbo soil, a fragipan restricts the movement of water and tends to perch the water in the upper part of the soil. Proper timing of fieldwork is therefore necessary. The fragipan also restricts the downward growth of roots.

These soils are well suited to corn, soybeans, small grain, and alfalfa and other hay crops. Some areas have not been opened to cultivation, but doing so is economically feasible.

Maintenance of tilth and proper use of fertilizer are the most important management requirements. Returning plant residue and applying manure help to maintain tilth and increase fertility. Leaving a trashy, rough surface and tilling in fall help to reduce wind erosion. Use of cropping systems that include green-manure crops and legume-grass crops helps to preserve structure and to increase organic-matter content. No-till planting helps to reduce compaction, erosion, and cost of field operations while maintaining normal yields.

CAPABILITY UNIT IIIe–1

This unit consists of deep, sloping and rolling, well-drained soils of the Flak and Milaca series. These soils have a surface layer of fine sandy loam, sandy loam, or very fine sandy loam. The subsoil generally is sandy loam and fine sandy loam, but in places it is loam. Available water capacity is moderate, and natural fertility is medium. Permeability is moderately slow; consequently, water runs off the soils in cultivated areas during periods of rain and causes some erosion. These soils are low in organic-matter content.

The soils of this unit generally are easy to till; however, stones and cobblestones interfere with tillage in some areas and must be removed periodically. A fragipan in these soils restricts the movement of water and tends to perch the water in the upper part of the soil; therefore, proper timing of fieldwork is necessary. The fragipan also restricts downward growth of roots. Water erosion is a moderate hazard on these soils.

These soils are suited to corn, small grain, alfalfa and other hay crops, and other crops commonly grown

in the county. They are poorly suited to soybeans, because soybeans loosen the surface layer and thus increase the hazard of erosion. Some areas have not been opened to cultivation, but doing so is economically feasible.

Erosion control, maintenance of tilth, and proper use of fertilizer are the most important management requirements. Returning plant residue to the soil and applying manure help to maintain tilth and increase fertility. Delaying tillage until spring helps to reduce erosion. Use of graded push-up terraces and grassed waterways or tile outlets is effective in controlling water erosion. In areas where slopes are more than 6 percent, however, use of contour stripcropping is more suitable for erosion control. Where slopes are too irregular for these practices, contour farming can be practiced or cropping systems that have fewer row crops can be used. Cropping systems that include a green-manure crop and legume-grass crops help to preserve structure and increase organic matter. No-till planting helps to reduce compaction, erosion, and cost of field operations while maintaining normal yields.

CAPABILITY UNIT IIIe–2

This unit consists primarily of gently sloping, somewhat excessively drained soils of the Burkhardt and Chetek series. Some areas of a Milaca soil are included in a complex with a Chetek soil. The soils in this unit have a surface layer of sandy loam. The subsoil is sandy loam and loam that is shallow to sand and gravel. The Milaca soil has a sandy loam substratum. Available water capacity generally is low, but it is moderate in the Milaca soil. Natural fertility is low. Permeability generally is moderately rapid in the upper part of the soil and very rapid in the lower part, but permeability of the Milaca soil is moderately slow. Natural fertility is low. The soils in this unit have low organic-matter content.

The soils of this unit warm up early in spring and commonly are easy to till, but stones and cobblestones interfere with tillage in some areas of the Chetek and Milaca soils and it is necessary to remove them periodically. The hazards of drought and erosion are moderate. Where eroded, the soils have lost one-third to two-thirds of their original surface layer.

These soils are suited to corn, soybeans, and small grain, and to alfalfa and other hay crops.

Erosion control, conservation of moisture, and proper use of fertilizer are the most important management requirements. Tillage should be delayed until seeding time in spring to provide winter cover. Minimum tillage is advisable. Returning crop residue and applying manure to the soil help to reduce erosion, maintain tilth, conserve moisture, and increase fertility. Field shelterbelts, wind strips, and minimum tillage are suitable practices for controlling wind erosion. Sprinkler irrigation has gradually increased in use. The sandy and loamy soils respond well to the additional moisture, and crop production is substantially increased. No-till planting helps to reduce compaction, erosion, and cost of field operations while maintaining normal yields.

CAPABILITY UNIT IIIw–1

This unit consists mainly of deep, level and depressional, poorly drained and very poorly drained soils of the Adolph variant and the Adolph, Hillet, Parent, and Prebish series. The Hillet soil is only moderately deep over sand and gravel. The soils in this unit have a surface layer of silt loam and loam and a subsoil of silt loam, very fine sandy loam, and fine sandy loam. The available water capacity is moderate to high. Fertility is medium. Permeability mainly is moderately slow and slow, and the organic-matter content is high. The Hillet soil has moderate permeability in the upper part and rapid permeability in the lower part. Water stands on these soils after heavy rains and causes damage to crops.

The soils of this unit warm up slowly in spring and generally are easy to till. Except for the Adolph variant soils and the Hillet soils, stones and cobblestones interfere with tillage in some areas and must be removed periodically. Adequate drainage is needed before these soils can be farmed intensively. Adolph variant soils and Hillet soils have a layer of firm till that restricts the movement of water and tends to perch the water in the upper part of the soil. The limitation caused by wetness is reduced by diverting the runoff from higher lying soils to waterways and outlet ditches. Conditions for tillage are more favorable in fall than in spring, because the soil is wet in spring and becomes cloddy if tilled when too moist. Fall tillage allows rapid seedbed preparation the next cropping season. Frost is a hazard late in the growing season, and occasionally crops are damaged.

These soils are well suited to corn, soybeans, small grain, and hay and pasture crops that tolerate wetness. Alfalfa stands are likely to be short lived. Early maturing varieties of corn should be planted because of the frost hazard. Most of the areas have not been opened to cultivation, but to do so is economically feasible.

Adequate drainage, proper use of fertilizer, and maintenance of tilth are the most important management requirements. Outlet ditches that have laterals and tile drainage systems or bedding provide adequate drainage (fig. 12). Returning all crop residue to the soil and applying manure help to maintain tilth and improve fertility. Cropping systems that include water-tolerant legumes and grasses are helpful in preserving structure, maintaining tilth, and providing organic matter.

CAPABILITY UNIT IIIw–2

This unit consists of deep, nearly level, somewhat poorly drained soils of the Blomford, Duelm, Lino, and Watab series and the Lino variant. These soils have a surface layer of loamy sand or loamy fine sand and a subsoil of loamy sand, fine sand, and sand that grades with depth to sandy loam or silt loam. Available water capacity generally is low to moderate, but it is high on the Blomford soils. Fertility is low. Permeability generally is rapid in the upper parts of these soils and moderate to moderately slow in the lower part, but in the Duelm and Lino soils permeability is rapid throughout. Generally, the organic-matter content is low to moderate.

The soils of this unit warm up slowly in spring but are easy to till. Excessive wetness and low fertility are the main limitations to the use of these soils. If these soils are drained, droughtiness becomes a concern dur-

Figure 12.—Bedding on wet Parent and Prebish soils.

ing prolonged dry periods and wind erosion becomes a hazard.

These soils are suited to corn, small grain, and adapted hay crops. Alfalfa stands are likely to be short lived.

Adequate drainage, proper use of fertilizer, and the control of wind erosion are the main management requirements. Use of shallow field ditches and grassed waterways corrects most wetness conditions. Tillage should be delayed until spring to provide winter cover. Minimum tillage is advisable. Returning crop residue to the soil and applying manure help to maintain tilth, conserve moisture, and improve fertility.

CAPABILITY UNIT IIIs–1

This unit consists of deep, nearly level and gently sloping, well drained to moderately well drained soils of the Langola and Pomroy series. These soils have a surface layer of loamy fine sand and fine sand. The subsoil is loamy fine sand and fine sand that grades to sandy loam with depth. Available water capacity is moderate, and natural fertility is low. Permeability is rapid in the upper part of these soils and moderately slow in the lower part. Organic-matter content is low.

The soils of this unit warm up early in spring and are easy to till. The hazards of drought and erosion are moderate. Where eroded, the soils have lost one-third to two-thirds of the original surface layer.

These soils are suited to corn, small grain, and alfalfa and other hay crops.

The control of erosion, conservation of moisture, and proper use of fertilizer are the most important management requirements. Tillage should be delayed until seeding time in spring to provide winter cover and to trap snow for added soil moisture. Minimum tillage is advisable. Returning crop residue to the soil and applying manure help to reduce erosion, maintain tilth, conserve moisture, and increase fertility. Use of field shelterbelts, winter cover crops, wind strips, and minimum tillage are suitable practices for controlling wind erosion. Sprinkler irrigation has gradually increased in use, and the sandy soils respond well to the additional moisture. No-till planting helps to reduce erosion and cost of field operations while maintaining normal yields.

CAPABILITY UNIT IIIs–2

This unit consists of nearly level, somewhat excessively drained soils of the Burkhardt, Chetek, and Dickman series. These soils have a surface layer of sandy loam or coarse sandy loam. The subsoil is sandy loam and, in some places, loam that is shallow to sand and gravel. The Dickman soil has a substratum of sand. Available water capacity and fertility are low. Permeability is mainly moderately rapid in the upper part of the soil and very rapid in the lower part, but the Dick-

man soil has rapid permeability. These soils are low to moderate in organic-matter content.

The soils of this unit warm up early in spring and generally are easy to till. Stones and cobblestones interfere somewhat with tillage on the Chetek soils. The hazards of drought and erosion are moderate. Where eroded, these soils have lost one-third to two-thirds of the original surface layer.

These soils are suited to corn, soybeans, small grain, and alfalfa and other hay crops.

Control of erosion, maintenance of tilth, and proper use of fertilizer are the most important management requirements. Tillage should be delayed until seeding time in spring to provide winter cover. Minimum tillage is advisable. Returning crop residue to the soil and applying manure help to reduce erosion, maintain tilth, conserve moisture, and increase fertility. Field shelterbelts, wind strips, winter cover crops, and minimum tillage are suitable practices for controlling wind erosion. Sprinkler irrigation has gradually increased in use, and the sandy and loamy soils have responded well to additional moisture. No-till planting helps to reduce compaction, erosion, and cost of field operations while maintaining normal yields.

CAPABILITY UNIT IVe–1

This unit consists of sloping and rolling, somewhat excessively drained and well-drained soils of the Chetek and Milaca series. These soils have a surface layer of sandy loam. The subsoil is sandy loam and loam. The Chetek soils are shallow to sand and gravel. The Milaca soils are deep to sandy loam. Available water capacity is low to moderate, and fertility is low. Permeability of the Chetek soils is moderately rapid in the upper part and very rapid in the lower part. Permeability of the Milaca soils is moderately slow. The soils in this unit are low in organic-matter content.

The soils of this unit warm up early in spring and are easy to till. Stones and cobblestones interfere with tillage in some areas and must be removed periodically. The hazards of drought and erosion are severe. Where eroded, the soils have lost one-third to two-thirds of the original surface layer and rills are evident.

The soils in this unit are poorly suited to corn, soybeans, small grain, and alfalfa and other hay crops because they are droughty and erodible. Because of the hazard of erosion, these soils are better suited to winter grain and to crops that mature early in the growing season, or they should be left in permanent vegetation except for an occasional row crop.

Control of erosion, conservation of moisture, and proper use of fertilizer are the most important management requirements. Tillage should be delayed until seeding time in spring to provide winter cover and to reduce water erosion. Minimum tillage is advisable. Returning crop residue to the soil and applying manure help to reduce erosion, maintain tilth, conserve moisture, and increase fertility. Contour strips or contour tillage together with meadow crops are effective practices for controlling water erosion. Terraces generally are impractical to use on the Chetek soils, because of the shallowness to sand and gravel and the steepness of slope. Sprinkler irrigation has gradually increased in use, and the sandy and loamy soils respond well to the additional moisture.

CAPABILITY UNIT IVw–1

This unit consists mainly of deep, depressional, very poorly drained soils of the Adolph, Hillet, and Prebish series. The Hillet soil is only moderately deep over sand and gravel. These soils have a surface layer of silt loam and loam and a subsoil of silt loam, very fine sandy loam, fine sandy loam, and sandy loam. Available water capacity is moderate to high, and natural fertility is medium. Permeability is mostly moderately slow, but the Hillet soil has moderate permeability in the upper part and rapid permeability in the lower part. The content of organic matter is high. Water stands on the soils of this unit after a heavy rainfall and damages crops.

The soils of this unit warm up very slowly in spring. They generally are easy to till. Except for the Hillet soil, however, cobblestones and stones interfere with tillage in some areas and must be removed periodically. Except for the Hillet soil, the firm till in these soils restricts the downward movement of water and tends to perch the water table in the upper part of the soils. The limitation caused by wetness can be partly corrected by diverting the runoff from higher lying soils to waterways and outlet ditches. Conditions for tillage are more favorable in fall than in spring, because the soils are wet in spring and become cloddy if tilled when too moist. Fall tillage allows rapid preparation of seedbeds in spring. Frost is a hazard late in the growing season, and occasionally crops are affected.

These soils are well suited to corn, soybeans, and small grain, and to adapted hay and pasture crops. Alfalfa stands are likely to be short lived. Early maturing varieties of corn should be planted because of the frost hazard. Most areas of this unit have not been opened to cultivation, but doing so is economically feasible. Adequate drainage is needed, however, before these soils can be farmed intensively.

Adequate drainage, proper use of fertilizer, and maintenance of tilth are the most important management requirements. Outlet ditches with laterals and tile drainage systems or bedding help to provide adequate drainage. Returning all crop residue to the soil and applying manure help to maintain tilth and increase fertility. A cropping system that includes legumes and grasses that tolerate wetness is helpful in preserving structure, maintaining tilth, and providing organic matter.

CAPABILITY UNIT IVw–2

This unit consists of deep, depressional, very poorly drained soils of the Isanti and Nokasippi series and the Isanti variant. These soils have a surface layer of mucky loamy fine sand and a subsoil of fine sand. The Nokasippi soils have a substratum of sandy loam. Available water capacity is low to moderate, and fertility is low. Permeability is rapid in the upper part of the soils and moderate to moderately slow in the lower part. The organic-matter content is high.

The soils of this unit warm up slowly in spring and are easy to till. Excessive wetness and a low level of fertility are the main limitations to the use of these soils. If these soils are drained, droughtiness is a concern during prolonged dry periods and wind erosion is a hazard.

These soils are suited to corn, small grain, and adapted hay crops. Alfalfa stands are short lived.

Adequate drainage, proper use of fertilizer, and control of wind erosion are the main management requirements. Outlet ditches that have laterals correct most wetness conditions. Tillage should be delayed until spring to provide for winter cover. Minimum tillage is advisable. Returning crop residue to the soil and applying manure help to maintain tilth, conserve moisture, and improve fertility.

CAPABILITY UNIT IVw–3

This unit consists of deep and shallow, level and depressional, very poorly drained Mucky peat, Mucky peat over loam, and Mucky peat over sand. Mucky peat is more than 42 inches thick and is moderately decomposed. It is underlain by unclassified material. Mucky peat over loam is 12 to 42 inches thick over loam mineral material, and Mucky peat over sand is 12 to 42 inches thick over sand. Available water capacity is high, and natural fertility is low. Permeability is moderately rapid, and organic-matter content is very high.

The soils of this unit are easy to till, and tilth is easy to maintain. Wetness is a severe limitation. Frost is a hazard late in the growing season, and occasonally crops are affected. When these soils become dry, there is a hazard of fire.

If properly drained, these soils are suited to corn for silage, small grain, and adapted hay crops. They are well suited to potatoes, onions, carrots, turnips, cabbage, radishes, and other vegetable crops. They are also well suited to cultured sod for landscaping uses. Most of the areas have not been opened to cultivation, because there are insufficient drainage outlets. Undrained areas of these soils are used for pasture and meadow.

Drainage and proper use of fertilizer are the main management requirements. Open ditches can be used as outlets. Water-level controls are needed to prevent the soils from becoming too dry. Good air circulation is needed to prevent early frost damage. Winter rye is an effective cover crop for the control of wind erosion.

CAPABILITY UNIT IVs–1

This unit consists of deep, gently sloping and rolling, well drained and moderately well drained soils of the Braham and Pomroy series. These soils have a surface layer of loamy fine sand and fine sand and a subsoil of loamy fine sand and fine sand that grades with depth to sandy loam or clay loam. Available water capacity is moderate, and natural fertility is low. Permeability is rapid in the upper part of these soils and moderate to moderately slow in the lower part. The organic-matter content is low.

The soils of this unit warm up early in spring and are easy to till. The hazards of drought and erosion are severe. Where eroded, the soils have lost one-third to two-thirds of the surface layer and rills are present.

These soils are poorly suited to corn, small grain, and alfafa and other hay crops because they are droughty. Unless supplemental moisture is provided, these soils are better suited to winter grain and to other crops that mature early in the growing season. Soybeans loosen the surface layer and increase the hazard of erosion.

Control of erosion, conservation of moisture, and proper use of fertilizer are the main management requirements. Tillage should be done in spring to provide winter cover. The cropping system should provide year-round cover and minimum tillage. Returning crop residue to the soil and applying manure help to maintain tilth, conserve moisture, increase fertility, and control erosion. Contour stripcropping also helps to control water erosion. Use of sprinkler irrigation has gradually increased. The sandy soils respond well to additional moisture. Recently, no-till planting has been used with qualified success.

CAPABILITY UNIT IVs–2

This unit consists of deep, nearly level and gently sloping, excessively drained soils of the Chetek, Hubbard, and Sartell series. These soils have a surface layer of loamy sand, loamy coarse sand, loamy fine sand, or fine sand. The subsoil is loamy sand, coarse sand, and fine sand, and the substratum is mainly coarse sand and fine sand. The Chetek soil has a substratum of sand and gravel. Available water capacity and natural fertility are low. Permeability is rapid. The organic-matter content is low.

The soils of this unit are the first soils to warm up in spring and are easy to till. Wind erosion and drought are serious hazards in cultivated areas. Where these soils are eroded, one-third to two-thirds of the surface layer has been removed and rills are present.

These soils are poorly suited to corn, soybeans, rye, and alfalfa because they are droughty. Unless supplemental moisture can be provided, these soils are better suited to winter grain and to other crops that mature early in the growing season. Soybeans loosen the surface layer and increase the hazard of erosion.

Erosion control, conservation of moisture, and proper use of fertilizer are the main management requirements. Tillage should not be done until spring to provide winter cover. The cropping system should provide year-round cover and a minimum of tillage. Returning crop residue to the soil and applying manure help to maintain tilth, conserve moisture, increase fertility, and reduce erosion. Use of field shelterbelts and wind strips is effective in controlling wind erosion. Recently, no-till planting has been used with qualified success. Use of sprinkler irrigation has gradually increased. The sandy soils respond well to the additional moisture, and crop production increases.

CAPABILITY UNIT VIe–1

This unit consists only of Milaca fine sandy loam, 12 to 25 percent slopes. This is a deep, well-drained, hilly and steep soil on uplands. The subsoil and substratum are fine sandy loam or sandy loam. Available water capacity is moderate, natural fertility is medium, and permeability is moderately slow.

Stones and cobblestones are on the surface and throughout the surface layer and subsoil. A fragipan restricts the movement of water and limits the root zone. This soil is droughty because of rapid runoff from steep slopes. The hazard of erosion is severe.

This soil is suited to permanent pasture, woods, and wildlife habitat. Nearly all of the acreage is in permanent pasture or is wooded. Areas now in crops should be put into permanent vegetation.

Good management is needed to maintain quality sod for permanent pasture and hay.

CAPABILITY UNIT VIw–1

This unit consists only of Alluvial land. This land type consists of very poorly drained to somewhat poorly drained soil material on low bottom lands along streams. It is frequently flooded. The material varies widely in texture and generally is stratified. Many areas are dissected by old stream channels and consequently have short, narrow ridges and appear to be corrugated. In many places Alluvial land has a shallow cap of mucky peat. Flooding is a severe limitation.

The soils of this unit are not suited to row crops. Drainage is not advisable, because there is a constant hazard of flooding. Control of flooding is impractical in most areas.

If cleared and skillfully managed, the better drained areas are well suited to pasture. These areas should be renovated and reseeded as necessary, particularly if the sod has been covered with infertile sediment. If tilled, the soils should be reseeded as soon as possible to water-tolerant grasses and legumes. The poorly drained areas are difficult to renovate, because they are wet throughout the year. These areas can be seeded to reed canarygrass or to some other species that tolerates both flooding and poor drainage. Reed canarygrass should be seeded on frozen ground either late in fall or early in spring. Pasture should not be grazed early in spring or after flooding, because the animals trample the turf.

Streambank stabilization is needed at sharp turns to keep streams from cutting into the improved areas.

CAPABILITY UNIT VIs–1

This unit consists of deep, sloping and rolling, excessively drained soils of the Chetek, Hubbard, and Sartell series. These soils have a surface layer of loamy sand, loamy coarse sand, loamy fine sand, or fine sand. The subsoil and, generally, the substratum are sand, coarse sand, or fine sand, but the Chetek soil has a substratum of sand and gravel. Available water capacity and fertility are low. Permeability is rapid. The organic-matter content is low.

The soils in this group are the first soils to warm up in spring and are easy to till. If tillage is needed, it is desirable to till as little as possible and only in spring, just before planting time. This practice provides maximum protection from erosion and conserves badly needed moisture. The cropping system should provide year-round cover.

These soils are not suited to row crops or small grain, because they are erodible and droughty. Erosion and drought are serious hazards. In eroded areas, one-third to two-thirds of the original surface layer has been removed. Areas now in crops should be put into permanent vegetation. Under careful management these soils are suited to hay and pasture. A mixture of alfalfa and bromegrass is preferred to the native bluegrass on these soils, because this mixture produces a larger quantity of higher quality forage and continues to produce throughout the growing season. Raising alfalfa requires adequate timing.

Small gullies and waterways should be shaped and seeded to grass so that they can be used as drainageways.

CAPABILITY UNIT VIIs–1

This unit consists of deep, sloping to steep, excessively drained soils of the Emmert, Hubbard, and Sartell series. These soils have a surface layer of gravelly loamy sand, loamy coarse sand, loamy sand, and fine sand. The subsoil and substratum are gravelly coarse sand, coarse sand, and fine sand. Available water capacity is low to very low, and natural fertility is low. Permeability is rapid and very rapid. All of these soils are very droughty. The organic-matter content is low, and the hazard of erosion is severe. Most areas of these soils are uneroded or only slightly eroded, but some areas have lost between one-third and two-thirds of the original surface layer.

These soils are not suited to crops. They are poorly suited to pasture, because a good plant cover is difficult to maintain. If they are used for pasture, caution should be taken to prevent overgrazing. Areas of these soils now used for crops should be seeded to permanent vegetation. Gullies in areas of these soils should be shaped and seeded to grass so that they can be used as drainageways.

CAPABILITY UNIT VIIIw–1

This capability unit consists of Marsh. This land type is in areas along the edge of Little Rock Lake, streams, shallow basins, and ponds. The vegetation consists of cattails, rushes, sedges, willows, and other water-tolerant plants. The water level fluctuates, and it is determined by the weather. Some areas are dry during years of below-normal rainfall. During prolonged dry periods, plants in areas on the edge of Marsh can be cut for wild hay or bedding.

This land type is too wet to be used for crops, woodlots, or pasture. It provides ideal habitat for waterfowl, muskrat, mink, and other game. Marsh can be improved for wildlife use by controlling the water level and by protecting areas along its edges from grazing and fire.

CAPABILITY UNIT VIIIs–1

This capability unit consists of Granite rock land. This land type occurs mainly in Granite Ledge, Sauk Rapids, and Watab Townships. Most of it is barren granite, and much of it is covered by lichens. Where thin deposits of soil material are present, drought-resistant grasses and stunted bur oak grow. This vegetation is not in sufficient quantity to provide any appreciable amount of grazing. Granite rock land is suited mainly to use for recreation and for the natural protection of wildlife.

Predicted yields

In table 2 the long-term average acre yields for the principal crops grown in Benton County are predicted for two levels of management. These predictions are based on records and observations of representatives of the Soil Conservation Service, the Extension Service, and the University of Minnesota. They are also based on interviews with farmers.

Yields are not given for crops that are not considered suitable for a particular soil. The major crops can be

TABLE 2.—*Estimated average acre yields of principal*

[Figures in columns A indicate yields under average management; figures in columns B indicate yields under high-level

Soil	Corn for grain		Corn for silage		Oats	
	A	B	A	B	A	B
	Bu	*Bu*	*Tons*	*Tons*	*Bu*	*Bu*
Adolph silt loam		75		15		60
Adolph silt loam, level	55	80	11	16	40	65
Adolph silt loam, silty subsoil variant	55	80	11	16	40	65
Alluvial land						
Antigo silt loam, 0 to 2 percent slopes	40	60	8	12	40	55
Antigo silt loam, 2 to 6 percent slopes	35	55	7	11	40	50
Blomford loamy sand	30	55	6	11	25	40
Braham loamy fine sand, 2 to 8 percent slopes	35	55	6	11	30	40
Brainerd sandy loam, 1 to 3 percent slopes	50	75	10	15	50	65
Brainerd sandy loam, 3 to 5 percent slopes	50	70	10	14	50	60
Brainerd stony sandy loam, 1 to 3 percent slopes						
Brainerd stony sandy loam, 3 to 5 percent slopes						
Burkhardt sandy loam, 0 to 2 percent slopes	30	50	6	10	30	40
Burkhardt sandy loam, 2 to 6 percent slopes	30	50	6	10	30	40
Chetek loamy sand, 2 to 6 percent slopes	25	30	5	6	25	35
Chetek loamy sand, 6 to 12 percent slopes	20	30	4	6	20	30
Chetek sandy loam, 0 to 2 percent slopes	30	50	6	10	30	40
Chetek sandy loam, 2 to 6 percent slopes	30	50	6	10	30	40
Chetek sandy loam, 2 to 6 percent slopes, eroded	25	40	5	8	30	40
Chetek sandy loam, 6 to 15 percent slopes	20	30	4	6	25	35
Chetek-Milaca complex, 2 to 6 percent slopes	30	50	6	10	35	45
Chetek-Milaca complex, 6 to 12 percent slopes	30	45	6	9	30	40
Dalbo fine sandy loam, 0 to 2 percent slopes	55	80	11	16	50	65
Dalbo silt loam, 2 to 8 percent slopes	55	80	11	16	50	65
Dickman coarse sandy loam, 0 to 2 percent slopes	30	50	6	10	30	40
Duelm loamy sand	30	50	6	10	30	40
Emmert gravelly loamy sand, 6 to 25 percent slopes						
Flak sandy loam, 2 to 6 percent slopes	50	70	10	14	50	60
Flak sandy loam, 2 to 6 percent slopes, eroded	40	55	8	11	40	50
Flak sandy loam, 6 to 12 percent slopes	40	55	8	11	40	50
Flak sandy loam, 6 to 12 percent slopes, eroded	30	50	6	10	30	50
Freer silt loam	55	80	11	16	45	65
Freer stony silt loam						
Granite rock land						
Hillet silt loam		65		13		55
Hillet silt loam, level	50	75	10	15	40	55
Hubbard loamy coarse sand, 0 to 2 percent slopes	25	35	5	7	25	35
Hubbard loamy coarse sand, 0 to 2 percent slopes, wind eroded	20	30	4	6	20	30
Hubbard loamy coarse sand, 2 to 6 percent slopes	20	30	4	6	20	30
Hubbard loamy coarse sand, 2 to 6 percent slopes, eroded	20	30	4	6	15	25
Hubbard loamy fine sand, 0 to 2 percent slopes	30	40	6	8	25	35
Hubbard loamy fine sand, 0 to 2 percent slopes, wind eroded	25	35	5	7	20	30
Hubbard loamy fine sand, 2 to 6 percent slopes	25	35	5	7	20	30
Hubbard loamy fine sand, 2 to 6 percent slopes, eroded	25	35	5	7	20	30
Hubbard soils, 6 to 12 percent slopes, eroded						
Hubbard soils, 12 to 25 percent slopes						
Isanti mucky loamy fine sand	20	40	4	8	25	40
Isanti mucky loamy fine sand, loamy subsoil variant	20	40	4	8	25	40
Langola loamy fine sand, 0 to 2 percent slopes	35	55	7	11	30	40
Langola loamy fine sand, 2 to 6 percent slopes, eroded	30	50	6	10	25	35
Lino loamy fine sand	30	50	6	10	30	40
Lino loamy fine sand, loamy subsoil variant	30	50	6	10	30	40
Marsh						
Milaca fine sandy loam, 2 to 6 percent slopes	50	70	10	14	45	65
Milaca fine sandy loam, 2 to 6 percent slopes, eroded	40	55	8	11	40	60
Milaca fine sandy loam, 6 to 12 percent slopes	40	55	8	11	40	60
Milaca fine sandy loam, 6 to 12 percent slopes, eroded	30	50	6	10	35	55
Milaca fine sandy loam, 12 to 25 percent slopes						
Milaca stony fine sandy loam, 2 to 6 percent slopes						
Milaca very fine sandy loam, 2 to 6 percent slopes	50	70	10	14	50	75
Milaca stony very fine sandy loam, 2 to 6 percent slopes						
Milaca fine sandy loam, clay loam subsoil variant, 1 to 6 percent slopes	55	80	11	16	50	70
Mora fine sandy loam, 1 to 3 percent slopes	55	80	11	16	50	70
Mora fine sandy loam, 3 to 5 percent slopes	50	75	10	15	45	65
Mora stony fine sandy loam, 1 to 3 percent slopes						
Mucky peat			6	12	30	50

crops under two levels of management

management. Absence of a yield figure indicates that the crop is not suited or is not commonly grown on the soil specified]

Rye		Soybeans		Hay [1]		Permanent pasture		Rotation pasture	
A	B	A	B	A	B	A	B	A	B
Bu	*Bu*	*Bu*	*Bu*	*Tons*	*Tons*	*AUD* [2]	*AUD* [2]	*AUD* [2]	*AUD* [2]
			25		2.5	40	100	50	100
		20	30	1.5	3.0	60	160	75	150
		20	30	1.5	3.0	60	160	75	150
		20	25	2.0	3.0	45	90	105	135
		18	23	1.8	2.5	40	80	100	125
		15	20	1.0	2.5	50	90	50	125
17	25	15	18	2.0	3.0	35	65	100	150
		20	25	3.0	4.5	65	150	150	180
		17	25	3.0	4.5	60	120	150	180
						60	150		
						60	120		
		17	20	2.0	3.0	60	125	100	150
		15	18	2.0	3.0	40	100	90	140
15	25	8	12	1.5	2.0	35	75	35	75
15	25			1.0	1.5	25	65	25	65
		12	18	2.0	3.0	60	125	100	150
		12	15	2.0	3.0	40	100	90	140
		12	15	1.5	2.5	35	75	55	110
		10	13	1.2	2.2	30	60	55	110
		14	18	2.0	3.0	60	125	100	150
		12	16	1.5	2.5	50	100	100	140
		20	30	3.5	5.0	90	180	150	180
		20	30	3.5	5.0	85	160	150	180
18	35	10	14	1.7	2.0	60	125	100	150
18	35	10	16	1.7	2.0	45	100	80	130
						25	40	80	130
		17	25	2.5	4.0	60	120	150	180
		15	22	2.0	3.0	50	110	150	180
		15	20	2.0	3.0	50	110	150	180
		12	18	1.5	2.5	45	100	130	155
		17	25	2.5	4.5	70	160	150	180
						60	120		
			25		2.5	50	120	50	100
		20	30	1.5	3.0	60	130	80	160
15	30	8	12	1.5	2.5	30	60	60	110
15	30	8	12	1.3	2.3	30	60	50	100
15	30	8	12	1.3	2.3	30	60	50	100
12	27	6	10	1.0	2.0	25	50	40	90
15	30	10	15	1.5	2.5	35	70	75	120
15	30	10	15	1.3	2.3	35	70	65	110
15	30	10	15	1.3	2.3	35	70	65	110
15	30	8	12	1.3	2.3	35	70	65	110
				1.0	2.0	25	50	40	90
						25	50		
15	30	10	18	1.0	2.0	40	100	50	130
15	30	10	18	1.0	2.0	40	100	50	130
15	30	15	20	1.8	2.8	35	70	100	150
12	27	12	15	1.5	2.5	35	70	90	140
18	35	10	16	1.7	2.0	45	100	80	130
18	35	10	18	1.7	2.0	45	100	80	130
						10	10		
		17	25	2.5	4.0	60	120	150	180
		15	25	2.0	3.0	50	110	150	180
		13	20	2.0	3.0	50	110	150	180
		13	20	1.5	2.5	45	100	130	155
				1.2	2.0	40	90	120	140
						55	110		
		17	25	2.5	4.0	60	120	150	180
						60	150		
		20	25	3.0	4.5	80	170	150	180
		20	25	3.0	4.5	80	170	150	180
		17	25	3.0	4.5	60	120	140	170
						60	120		
			25			60	120	50	

TABLE 2.—*Estimated average acre yields of principal*

Soil	Corn for grain		Corn for silage		Oats	
	A	B	A	B	A	B
	Bu	*Bu*	*Tons*	*Tons*	*Bu*	*Bu*
Mucky peat over sand			5	10	30	50
Mucky peat over loam			6	12	30	50
Nokasippi mucky loamy fine sand		60		12		45
Nokay fine sandy loam	55	80	11	16	50	65
Nokay stony fine sandy loam						
Ogilvie silt loam	55	80	11	16	40	70
Paget silt loam, 0 to 2 percent slopes	55	80	11	16	50	65
Paget silt loam, 2 to 6 percent slopes	50	75	10	15	50	60
Paget stony silt loam, 0 to 2 percent slopes						
Paget stony silt loam, 2 to 6 percent slopes						
Parent loam	55	80	11	16	40	55
Parent stony loam						
Pomroy fine sand, 2 to 6 percent slopes	30	50	6	10	25	35
Pomroy fine sand, 6 to 12 percent slopes	30	50	6	10	20	30
Pomroy loamy fine sand, 0 to 2 percent slopes	35	55	7	11	30	40
Prebish loam		75		15		50
Prebish stony loam						
Prebish and Parent loams	50	80	10	16	40	55
Ronneby loam	55	80	11	16	45	65
Ronneby stony loam						
Sartell fine sand, 0 to 2 percent slopes	25	40	5	8		
Sartell fine sand, 2 to 6 percent slopes	25	35	5	7		
Sartell fine sand, 6 to 12 percent slopes						
Sartell fine sand, 12 to 25 percent slopes						
Watab loamy fine sand	30	55	6	11	25	40

[1] Estimates for most of the soils are for alfalfa or alfalfa-bromegrass mixtures. However, Adolph, Blomford, Duelm, Freer, Hillet, Isanti, Lino, Nokay, Ogilvie, Prebish, Ronneby, and Watab soils and Alluvial land and Mucky peat are not suited to alfalfa-bromegrass mixtures. For these soils the estimates given are for red clover-alsike clover-timothy mixtures. Yield is 10 to 25 percent less for red clover-alsike clover-timothy mixtures than for alfalfa or alfalfa-bromegrass mixtures.

grown on such soils, but because the soils are droughty, steep, severely eroded, poorly drained, or susceptible to flooding, the crops are not likely to be successful. The yields in columns B reflect the limitation of soils on which adequate drainage makes a considerable difference in their suitability for crops.

Areas of permanent pasture that are under average management consist principally of native grasses such as junegrass, quackgrass, redtop, reed canarygrass, and white clover. Under improved management, in which permanent pasture is renovated at intervals, a mixture of suitable grasses and legumes is the principal cover. It is assumed that rotation pasture consists of a mixture of suitable legumes and grasses.

The yield figures represent an average to be expected over a period of 10 years. They take into account abnormal seasons of crop production but not past management on a particular farm. Considered in making the estimates were the prevailing climate, characteristics of the soils, and the influence of different kinds of management on the soils. The figures are used chiefly in judging the increases that can be expected from improved management and from draining the soils.

In columns A are yields to be expected under average management. Average management is defined as follows:

For cultivated crops—

1. Surface and internal drainage are improved, but not enough to provide optimum growing conditions where natural drainage is restricted.
2. Moderate amounts of lime and fertilizer are applied, but a more adequate program of soil testing is needed.
3. Most crop residue is returned to the soil. If low-residue crops are grown, organic matter is supplied by growing cover crops and applying manure or other organic material.
4. Seedbed preparation is either inadequate or excessive, and the soil may be worked when either too wet or too dry.
5. Weeds and insects are not adequately controlled.
6. Crop variety, seed quality, and plant population are not considered for a specified soil or location.
7. Control of erosion is inadequate.

For hay and pasture grasses—

1. Drainage is improved, but not enough to provide optimum growing conditions where natural drainage is restricted.
2. Moderate amounts of lime and fertilizer are applied, but a better program of soil testing is needed.
3. Reseeding is generally delayed until after the legumes have disappeared from the forage stand and the grasses show serious nitrogen deficiency.

crops under two levels of management—Continued

Rye		Soybeans		Hay [1]		Permanent pasture		Rotation pasture	
A	B	A	B	A	B	A	B	A	B
Bu	*Bu*	*Bu*	*Bu*	*Tons*	*Tons*	*AUD* [2]	*AUD* [2]	*AUD* [2]	*AUD* [2]
			20			50	100	50	100
			25			60	120	50	100
			20		2.5	40	100	50	100
		17	25	2.5	4.0	70	160	140	170
						60	120		
		20	30	2.5	4.0	90	150	120	160
		20	25	3.0	4.5	80	170	150	180
		17	25	3.0	4.5	70	160	150	180
						70	160		
						60	150		
		20	25	2.0	4.5	60	160	80	160
						60	160		
15	22	12	15	2.0	3.0	35	65	100	150
12	18			1.5	2.5	30	60	80	130
17	25	15	20	2.0	3.0	35	65	100	150
			25		2.5	40	100	50	100
						40	100		
		10	22	2.0	4.0	50	110	65	130
		17	25	2.5	4.5	70	160	150	180
						60	120		
		12	15	1.5	2.5	35	70	75	120
		12	15	1.3	2.3	35	70	65	110
				1.0	2.0	30	60	50	100
						25	50		
		15	20	1.0	2.5	50	90	50	125

[2] An animal-unit-day, AUD, is a term used to express animal units (one cow or steer, one horse, five hogs, or seven sheep or goats) that can graze 1 acre for 1 day without damaging the pasture. An estimate of 125 AUD indicates that 1 acre will provide adequate grazing for one animal unit for 125 days.

4. Grass-legume stands are of medium quality, crop variety and seed quality or quantity are not considered, and seedbed preparation may be inadequate.
5. Field operations are usually timely.
6. The entire pasture is grazed, and it may be overgrazed late in summer and in fall.
7. Runoff and erosion on steep slopes are not controlled.

Yields given in columns B are those to be expected under high-level management. High-level management is defined as follows:

For cultivated crops—

1. Surface and subsurface drainage provide optimum growing conditions where natural drainage is restricted.
2. Lime, phosphate, potash, nitrogen, and other amendments are applied according to crop needs as indicated by soil tests.
3. All crop residue is returned to the soil. If low-residue crops are grown, organic matter is supplied by growing cover crops and by applying manure or other organic material.
4. Seedbed preparation is limited to that needed for crop production. Tillage is avoided when the soils are wet, and spring tillage is delayed until planting time. If plowed in fall, fields are left rough in winter. Green-manure crops are plowed under no earlier than October 1 of the seeding year.
5. Weeds and insects are adequately controlled.
6. Crop variety, seed quality, and plant population are considered for a specified soil and location.
7. Erosion is kept within tolerable limits.
8. Field operations are usually timely.

For hay and pasture grasses—

1. Surface and subsurface drainage provide optimum growing conditions.
2. Lime and fertilizer are applied at seeding time according to crop needs as indicated by soil tests, and also are applied as topdressing as needed.
3. Stands are reseeded and reestablished regularly.
4. Grass-legume stands are of high quality, and crop variety is considered for a specified soil and location.
5. Haymaking operations are timely.
6. Grazing is deferred and is rotated as needed.

Woodland [2]

Much of Benton County was covered with hardwood forests at the time of settlement. The only open areas

[2] JOHN HULTGREN, woodland conservationist, Soil Conservation Service, assisted in the preparation of this section.

were marshes and parts of terraces and flood plains in the Mississippi River Valley. Figure 13 shows the distribution of the original vegetation in the county.

According to a recent survey of the forest resources of Benton County, 35,000 acres is woodlands (*10*). This amount is 13 percent of the total land area in the county. Of the total forested acreage, 27,300 acres is commercial. The commercial forest land consists of northern hardwoods, which occupy 11,000 acres and include such species as basswood, elm, hard maple, white oak, and red oak; oak, which occupies 8,000 acres and includes mostly red oak and bur oak; aspen-birch, which occupies 5,000 acres and includes largetooth and trembling aspen and paper birch; and nonstocked woodland, which occupies 3,000 acres and is made up of areas where less than 10 percent of the forest trees is stocked.

Wood production has not been great in this county for many years. Adequate growing stock has not been maintained, the better quality trees have been cut, and desirable species have been overcut. Fires are common, and 75 percent of the woodlands are grazed, which results in open, parklike stands.

Woodland suitability groups

More effective management of woodland can be planned if the soils are grouped according to those characteristics that affect the growth of trees and the management of the stand. The soils of Benton County have been placed in seven woodland groups. Each group of soils is suited to trees that require about the same management and have about the same potential productivity.

The factors considered in placing each soil in a woodland group include potential productivity, which is expressed as site index; species preferred for planting; and soil-related hazards and limitations to be considered in management.

Productivity ratings are expressed as poor, fair, good, and excellent. These ratings are based on the site index. Site index is the average height in feet that the dominant trees of a given species, growing on a specified soil, will reach at the age of 50 years. For basswood, maple, oak, jack pine, red pine, white pine, and white spruce, a rating of *poor* indicates a site index of less than 50; *fair* indicates a site index of 50 to 55; *good* indicates a site index of 55 to 60; and *excellent* indicates a site index of 60 or more. For aspen, a rating of *poor* indicates a site index of 65 or less; *fair* indicates a site index of 65 to 70; *good* indicates a site index of 70 to 75; and *excellent* indicates a site index of 75 or more.

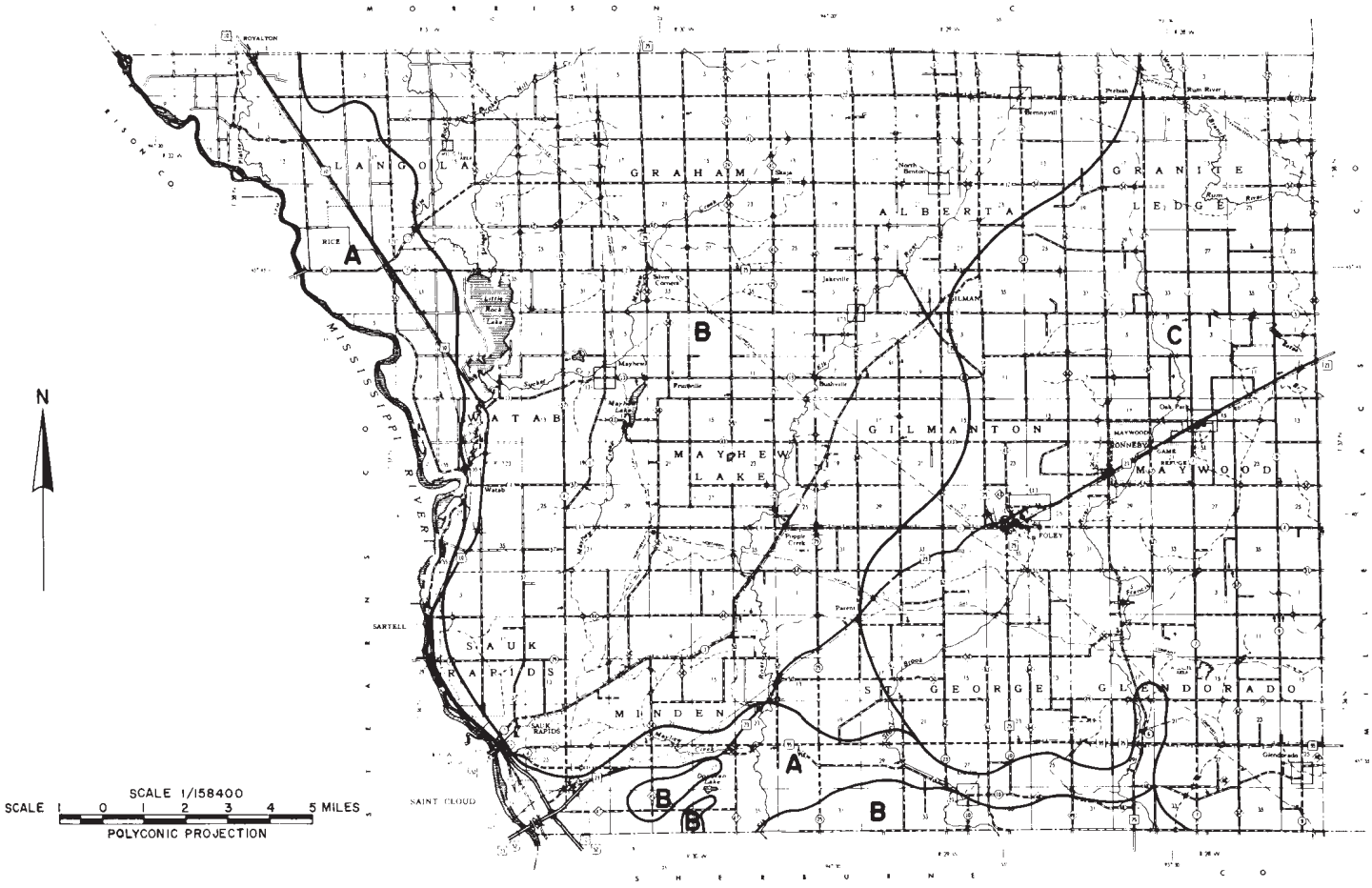

***Figure 13.*—Three types of original vegetation in Benton County: (A) true prairie; (B) oak and oak openings; and (C) northern hardwood.**

Seedling mortality refers to the expected loss of naturally occurring or planted seedlings as a result of unfavorable soil characteristics. Seedling mortality is *slight* if the expected loss is less than 25 percent. It is *moderate* if the expected loss is between 25 and 50 percent, and it is *severe* if the expected loss is more than 50 percent.

Plant competition refers to invasion by, or competitive growth of, undesirable species such as grass, shrubs, or undesirable tree species. Plant competition is *slight* if invaders do not prevent adequate regeneration and early growth and do not interfere with the development of planted seedlings. It is *moderate* if invaders delay but do not prevent the establishment of normal, fully stocked stands. Competition is *severe* if invaders prevent adequate regeneration or if intensive site preparation and maintenance are needed.

The equipment limitation is *slight* if there are no restrictions on type of equipment or on time of year that the equipment can be used. The limitation is *moderate* if use of the equipment is restricted by seasonal wetness that lasts no more than 3 months or if the use of equipment damages tree roots to some extent. The limitation is *severe* if the use of equipment is restricted by wetness that lasts more than 3 months or if the use of equipment causes severe damage to tree roots.

The hazard of erosion is the degree of potential loss of soil by wind or water. The hazard is *slight* if erosion is no problem. It is *moderate* if measures are needed to prevent unnecessary loss of soil. It is *severe* if special equipment and special methods of operation are needed to minimize loss and deterioration of the soil.

Windthrow hazard is the danger of trees being blown over by the wind. It is *slight* if roots extend to a considerable depth, so that individual trees are stable during high winds. It is *moderate* if development of tree roots is somewhat shallow, especially during periods of excessive wetness. It is *severe* if root development is severely restricted, which generally occurs during long periods of wetness.

Each of the seven woodland suitability groups in Benton County is described on the pages that follow. The names of soil series represented are mentioned in the description of each group. However, not all mapping units of a given series will necessarily be found in the same woodland suitability group. To find the woodland suitability group for any given mapping unit, refer to the "Guide to Mapping Units."

WOODLAND SUITABILITY GROUP 1

This group consists of soils of the Antigo, Brainerd, Dalbo, Flak, Milaca, Mora, and Paget series and of the Milaca variant. These soils are moderately deep to deep, medium-textured to moderately coarse textured, and well drained to moderately well drained. Fertility is moderate or high. Organic-matter content is medium to low. Available water capacity generally is moderate to high, but in the Dalbo soils it is very high. Permeability is moderate and moderately slow. Slopes range from 0 to 12 percent.

The productivity of these soils is among the highest in the county. Most of the acreage is cleared, but wooded pastures and woodlots are scattered throughout the county. The highest concentration of these areas is in the northeastern part of the county.

These soils produce timber of good quality. They are excellent for aspen, basswood, white oak, and red oak and good to excellent for hard maple, elm, green ash, red pine, jack pine, white pine, and white spruce. Aspen, red oak, elm, red pine, white pine, and white spruce are the most easily established species.

Common species are elm, white oak, hard maple, basswood, and red oak, and the trees are of fair to good quality. Hard maple is highly competitive because it is very tolerant of shade. It should not normally be favored unless the woodland is managed for maple sugar production. All of the hardwoods can be managed for pulp, lumber, and veneer.

Seedling mortality is slight. Adequate hardwood regeneration in a natural stand can be expected.

Plant competition is severe. Furrowing, scalping, spraying, or other site preparation and woodland weeding commonly are needed to insure success of a conifer plantation or to maintain desirable hardwood species in a natural stand.

The equipment limitation is slight. These soils can be worked at any time during the year, except just after a heavy rain and after snowmelt in spring.

The hazards of erosion and windthrow are slight.

Red pine, white spruce, and white pine should be preferred for replanting. Red pine and white spruce are the most suitable species. They are windfirm, moderately fast growing, relatively free from defects, and less subject to damage by insects and disease. Red pine can be managed for posts, poles, and other small wood products when it is between the ages of 20 and 40 years, and for larger products when it is between the ages of 55 and 80 years. White pine is moderately susceptible to white pine blister rust. It can be harvested for large wood products when it is between the ages of 55 and 80 years. Only Scotch pine should be planted for Christmas trees.

WOODLAND SUITABILITY GROUP 11

This group consists of deep, medium-textured to moderately coarse textured, well-drained soils of the Milaca series. Fertility and available water capacity are moderate. Permeability is moderately slow. Runoff is rapid. Slopes range from 12 to 25 percent.

Wooded pastures and small woodlots are typical on the soils of this group. Only a minor acreage is in crops.

These soils produce timber of fair to good quality and mainly support mixed stands of northern hardwoods. Aspen, red oak, green ash, elm, basswood, and hard maple are the principal species. Trees on the warmer south-facing and west-facing slopes are fair to good producers of timber. Trees on north-facing and east-facing slopes are good to excellent for wood production. Existing stands in fair to good condition can be managed for the continuous production of hardwoods. If a stand has been damaged by overgrazing or severe cutting, or has for some other reason deteriorated, replacing the hardwoods with conifers should be considered. Red pine is the preferred species for all aspects. White spruce and white pine are suitable on north-facing slopes.

Seedling mortality is moderate on south-facing slopes and slight on north-facing slopes. Plant competition is moderate or severe. Site preparation for regeneration of trees is needed.

The equipment limitation is moderate or severe, depending on slope. Stones are a concern in places.

The hazard of erosion is moderate. A cover of vegetation should be maintained on these soils, and site preparation should be confined to areas where trees are to be planted.

The hazard of windthrow is slight.

WOODLAND SUITABILITY GROUP III

This group consists of soils of the Freer, Nokay, Ogilvie, Parent, and Ronneby series. These soils are moderately deep to deep, medium-textured to moderately coarse textured, and somewhat poorly drained to poorly drained. Fertility is moderate. Organic-matter content is medium and high. Available water capacity is moderate and high, and runoff is slow. Permeability is moderate to moderately slow. Slopes range from 0 to 2 percent. Parent soils are somewhat wetter under natural drainage.

About half of the acreage of these soils is used for wooded pasture and woodlots. Productivity is good for hardwoods and conifers. Soft maple, ash, aspen, and elm are the common species.

Seedling mortality is moderate in depressional areas that are sometimes flooded. Plant competition is moderate or severe. The equipment limitation is moderate. High moisture content in these soils in spring makes it difficult to use machinery with any degree of regularity.

The soils in this group are not subject to erosion. The hazard of windthrow is moderate or severe where root development is shallow.

White pine, white spruce, red pine, or native cottonwood are suitable species for replanting.

WOODLAND SUITABILITY GROUP IV

This group consists of deep, coarse-textured, well drained and moderately well drained soils of the Braham, Pomroy, and Langola series. Fertility and organic-matter content are low. Available water capacity is moderate. Permeability is moderately rapid to rapid in the upper part of these soils and moderate to moderately slow in the lower part. Slopes range from 0 to 12 percent.

Most areas of these soils are used for grain crops, but the Pomroy soil is used mainly for wooded pasture and woodlots.

Productivity is fair to good for native hardwoods. Present species in order of abundance are red oak and bur oak. They generally have poor form and are of poor quality. Productivity is good for native pines. If the soils are to be managed as woodland, it is advisable to plant red pine, white pine, and white spruce. Red pine can be harvested for posts, poles, and pulp at the age of 20 to 40 years. All species can be harvested for larger wood products at the age of 50 to 80 years. Scotch pine should be planted for Christmas tree production only.

Seedling mortality is slight or moderate. Plant competition is moderate. Scalping of the sod to remove competing vegetation is essential before planting. Overtopping of the pine by native deciduous trees and shrubs must be controlled.

The equipment limitation and the hazards of erosion and windthrow are slight.

WOODLAND SUITABILITY GROUP V

This group consists of soils of the Blomford, Duelm, Lino, and Watab series and of the Lino variant. These soils are deep, moderately coarse textured to coarse textured, and somewhat poorly drained. Fertility is low, and available water capacity mostly is low to moderate. The Blomford soil has high available water capacity. Organic-matter content is medium and low. Permeability generally is rapid, but the Blomford and Watab soils and the Lino soil, loamy subsoil variant, have moderate or moderately slow permeability in the lower part. Because these soils have a high water table during brief periods during the growing season, they are not so droughty as their permeability rate suggests. Slopes range from 0 to 2 percent.

Productivity is excellent for aspen, red pine, and white pine, and fair to good for other hardwoods. Present species in order of abundance are aspen and oak.

Seedling mortality is moderate. For planted cottonwoods and other poplars, seedling mortality is slight. Red pine, white pine, white spruce, and cottonwood should be planted. Plant competition from dogwood, alder, sumac, and other native brush is likely to be moderate or severe.

The equipment limitation is moderate because of wetness in spring and following heavy rains. The hazard of erosion is slight. The hazard of windthrow is moderate or severe.

WOODLAND SUITABILITY GROUP VI

This group consists of shallow to deep, moderately coarse textured to coarse textured, somewhat excessively drained to excessively drained soils of the Burkhardt, Chetek, Dickman, Emmert, Hubbard, and Sartell series. Fertility is low to moderate, and available water capacity is low. Organic-matter content ranges from medium to very low. Permeability is moderately rapid to very rapid. Slopes range from 0 to 25 percent.

Soils that have slopes of more than 12 percent are used for wooded pastures, woodlots, and wildlife habitat. Productivity of the soils in this group is low to fair for hardwoods on south-facing slopes. The trees have poor form and are of poor quality. Productivity is fair to good for hardwoods on north-facing slopes. Productivity is fair to good for pine. If areas of these soils are managed as woodland, it is advisable to replace the oak trees with red pine or jack pine, but preferably red pine. Though jack pine grows well, it is of a poorer quality than red pine and is a favored host to some insect pests. It is advisable to harvest either species for pulp and small wood products when it is between the ages of 20 and 50 years. Red pine can be harvested for larger products at the age of about 50 to 80 years. Principal species in order of abundance are bur oak, red oak, aspen, and birch.

Seedling mortality is slight or moderate on the cool north-facing and east-facing slopes. It is moderate or severe on south-facing and west-facing slopes. Plant competition is slight, but steep slopes should be scalped and planted by hand. The equipment limitation is moderate or severe on steep slopes.

The hazard of both wind erosion and water erosion is moderate or severe where slopes are 12 to 25 percent and slight on lesser slopes.

WOODLAND SUITABILITY GROUP VII

This group consists mainly of soils of the Adolph, Hillet, Isanti, Nokasippi, and Prebish series; the Adolph variant; the Isanti variant; Alluvial land; Mucky peat; Granite rock land; and Marsh. The soils occur in small depressions, old river channels, marshes, and extensive peat bogs. The seasonal water table is very high. Undrained areas and areas not protected against flooding are covered with water for long periods.

Where areas of these soils and land types are wooded, the principal tree species in order of abundance are black ash and American elm and a smaller number of cottonwoods, red maple, butternut, wild cherry, willow, and alder. Most of these species are on alluvial land along the Mississippi River and on the islands in its channel. In places stunted bur oak is on Granite rock land. Willow and alder grow along the edges of the rest of the wet soils.

Windbreaks

Field windbreaks are of major importance in this county, because many of the soils are highly susceptible to wind erosion if they are cultivated. Windbreaks do not give complete protection to the soils, but they help to create an even distribution of snow in winter and to alleviate the effects of hot, dry winds in summer.

For most of the cultivated soils, pine, mainly red pine, is the most suitable and effective species for field windbreaks. Deciduous trees and shrubs are not well suited to the sandy soils of this county. Siberian elm, Norway poplar, robusta poplar, purple-osier willow, lilac, honeysuckle, and other similar species can be used, particularly on the better soils.

Farmstead and feedlot windbreaks are planted extensively in Benton County (fig. 14). Farmstead windbreaks are for protection, control of the location of snow deposition, esthetics, and wildlife food and cover.

Suitability of the soils for trees and shrubs

Trees and shrubs for wildlife and ornamental plantings and those for farmstead and field windbreaks vary in their ability to survive and grow on different kinds of soil. Table 3 provides information on the performance of trees and shrub species by woodland suitability groups.

The performance ratings given are *preferred*—rec-

***Figure 14.*—Farmstead shelterbelt on Mora soils.**

TABLE 3.—*Performance ratings for selected species of trees and shrubs by woodland suitability groups*

[Performance ratings are 1, preferred; 2, acceptable; and 3, not suited. Group VII is very severely limited and is not suited to commercial production of timber]

Species	Group I	Group II		Group III	Group IV	Group V	Group VI
		North- and east-facing slopes	South- and west-facing slopes				
	CONIFERS						
Cedar, eastern red	2	2	1	2	1	1	1
Cedar, northern white	1	1	2	----------	2	1	3
Pine, red	1	1	1	----------	1	2	1
Pine, white	2	2	2	----------	1	1	2
Pine, jack	2	2	1	----------	1	1	1
Spruce, Colorado	1	1	1	----------	1	1	2
Spruce, Norway and white	1	1	2	----------	1	1	2
	DECIDUOUS TREES						
Ash, green	1	1	1	----------	1	1	1
Basswood	1	1	3	----------	1	1	3
Birch, paper	1	1	2	----------	1	1	2
Catalpa, northern	1	2	3	----------	2	2	3
Elm, American	1	1	3	----------	1	1	2
Elm, Siberian	2	2	1	----------	1	1	1
Hackberry	2	2	3	----------	2	2	2
Maple, sugar	1	2	3	----------	1	1	3
Maple, soft	1	1	2	1	2	1	3
Poplar	1	1	2	1	1	1	2
Walnut, black	1	2	3	1	3	2	3
Willow, weeping	1	1	3	1	2	1	3
	SMALL TREES AND SHRUBS						
Buffaloberry	1	1	1	1	1	1	1
Caragana	1	1	1	1	1	1	1
Chokecherry	1	1	3	1	2	1	3
Crabapple	1	1	1	2	1	1	1
Cranberry, highbush	1	2	3	1	2	2	3
Dogwood, red-osier	1	1	3	1	2	1	3
Honeysuckle	1	1	2	1	2	1	2
Lilac	2	1	1	1	2	1	1
Ninebark	1	1	3	1	2	1	3
Plum, American	1	1	1	1	1	1	1
Russian-olive	2	2	1	1	1	2	2
Willow, purple-osier	1	1	2	1	1	1	3

ommended for use on soils in woodland suitability groups as indicated; *acceptable*—acceptable species, but only as a second choice to preferred species; and *not suited*—not suitable for use.

The performance ratings are based on soil characteristics that affect the growth and survival of listed trees and shrubs. Texture, drainage, depth, soil reaction, stoniness, steepness, and direction of slope are important soil characteristics. Each woodland suitability group consists of soils that have similar characteristics and have similar suitability for trees and shrubs.

Wildlife[3]

Benton County generally ranks low in wildlife resources compared to other parts of Minnesota. Dairy farming dominates land use, and therefore the potential for large wildlife populations is limited. The type and distribution of cover, and the fact that the survey area is on the edge of the native ranges of many kinds of wildlife, explain why there is a wide variety of wildlife in the area, but the population of each kind is small. Habitat for many kinds of wildlife is limited because of the overlapping ranges and the lack of management.

The wetter soils provide good habitat for wetland wildlife species in spring. In years of normal precipitation, however, these areas lose their surface water through natural drainage caused by the undulating relief.

Game species include white-tailed deer, ring-necked pheasant, ruffed grouse, Hungarian partridge, raccoon, mink, muskrat, and gray squirrel. Examples of water-

[3] JOHN BEDISH, biologist, Soil Conservation Service, assisted in the preparation of this section.

fowl species are mallard, blue-winged teal, wood duck, and ring-necked duck (fig. 15). Several species of nongame birds and songbirds are also present.

A small population of deer continues to inhabit the wooded areas of the county, mainly those in the Mora-Ronneby-Parent association. This association has a high potential to produce habitat elements required by white-tailed deer. Mora soils have the potential to produce good-quality woody cover and the browse plants needed by this species. Ronneby soils can produce high yields of both browse and herbaceous forage and cover if managed for that purpose. Prebish soils, in their natural condition, produce a mixture of willow, alder, and cattail, which are used by deer for escape and cover. The interrelationship between these various factors affects the well-being of the deer.

The level of population of the groups of wildlife species in Benton County is medium for upland game, which includes pheasant and raccoon; low to medium for waterfowl and furbearers, which include mallard, wood duck, teal, muskrat, and mink; low to medium for small game, which includes rabbit and squirrels; low for big game, which includes white-tailed deer; and medium for songbirds, which include warblers, thrashers, and vireos.

Table 4 gives the potential of each soil association in Benton County to produce habitat for the various kinds of wildlife.

It should be recognized that these ratings are based on the close interrelationship between plants and animals, and therefore the ratings provide only a general evaluation of the capability of each soil association to produce the kinds of plants needed by different animals. This information does not show whether or not a certain kind of wildlife is present in a certain location. It only indicates the potential of each soil association to produce plants used by that kind of wildlife. If the proper vegetation is present, and all other influencing factors such as climate, natural range of the species concerned, and competition are favorable, animals from the group in question could be present.

Recreation

Benton County, because of its location in relation to large population centers such as St. Paul-Minneapolis, Duluth, and St. Cloud, has opportunities to attract visitors for various forms of outdoor recreation. Facilities for boating, water sports, and fishing are available on Little Rock Lake and the Mississippi River. Mayhew

Figure 15.—**Livestock watering pit on Prebish soils provides habitat for young wild ducks.**

TABLE 4.—*Potential of the soil associations to produce wildlife habitat for specified kinds of wildlife*

Soil association	Upland game	Waterfowl and furbearers	Small game	Big game	Songbirds
1. Parent-Ronneby-Prebish	Low [1]	Medium to high	Medium	Medium	Medium.
2. Mora-Ronneby-Parent	Medium	Low [2]	Medium to high	Medium to high	Medium to high.
3. Brainerd-Nokay-Prebish	Medium	Low [2]	Medium to high	Medium to high	Medium to high.
4. Hubbard-Duelm	Low to medium	Low [2]	Low	Low	Medium.
5. Hubbard-Sartell	Low	Low	Low	Low	Low.
6. Sartell-Isanti-Mucky peat	Low [1]	High	Medium	Medium	Medium.

[1] Ratings made on the basis of wet soils that are in their natural condition.

[2] Undrained areas of poorly drained and very poorly drained soils have a high potential for wetland development.

Lake provides good fishing with a minimum of competition from other water uses. A county park is being developed on the north end of Little Rock Lake. Several tracts of land have been purchased by the State Department of Natural Resources for wetland development. Fox hunting provides entertainment for dog enthusiasts. Snowmobiling has become a favorite winter sport.

This section of the survey contains information about the soils of Benton County in relation to their suitability for recreational uses. This information does not consider the feasibility of various recreational enterprises from other standpoints, such as economic or social. Table 5 can serve as a general guide for selecting recreational sites and as a guide in the design of recreational developments. Evaluations are based only on soil features, and they serve merely as information preliminary to further onsite investigation.

One of the prime considerations in evaluating soils for recreational uses is the ability of the soils to support vegetation. Droughty soils have moderate to severe limitations for recreational use. Frequent watering is often required to maintain vegetation that can sustain heavy foot traffic.

Wet soils have moderate to severe limitations for recreational uses. If artificially drained, these soils can be used for most recreational developments.

Soil permeability affects how rapidly soils dry out after rains. Slowly permeable soils generally have low bearing capacity when wet.

Surface texture is very important to recreation. A loose, sandy surface layer has low bearing capacity and is subject to wind erosion. A surface layer that is high in content of clay has low bearing capacity and is slippery when wet. Soils that are high in content of clay tend to dry out slowly after rains.

Frequency of flooding varies in the degree in which it limits recreational uses. Limitations depend on the frequency and duration of overflow during the period of heaviest use.

All soils are treated as having suitable size and uniformity. However, in many landscapes the size, shape, or pattern of some soils with other soils may be such as to change the limitation greatly. These relationships should be considered before making a final decision.

The degrees of limitation are expressed as none to slight, moderate, severe, and very severe. The limitation is *none to slight* if the soil is suitable for the specified use. The limitation is *moderate* if the soil can be used but needs to be well managed. The limitation is *severe* if use is questionable. The limitation is *very severe* if use is extremely limited or unsound.

Proper management, planning, or engineering practices can overcome severe limitations. As an example, the use of fertilizer can overcome low fertility, a reason for a severe limitation for using a soil for golf courses. However, reasons such as sandy texture, susceptibility to soil blowing, or slopes of more than 6 percent would remain. As another example, a drainage system can overcome poor natural drainage, a reason for a severe limitation for playgrounds, but permeability and soil texture may still limit the soil for that use.

Playgrounds, athletic fields, and intensive play areas are subject to intensive foot traffic. Areas selected for this use generally require a nearly level surface, good drainage, and a consistence that insures a firm surface. The most desirable soils are also free of rock outcrops and coarse fragments. Wetness, flooding, permeability, slope, surface texture, depth to hard bedrock, and stoniness or rockiness were the specific items evaluated.

Picnic areas, parks, and extensive play areas are subject to a moderate amount of foot traffic, and it is feasible to use sites that are somewhat less desirable than those required for intensive play areas. Specific items evaluated were the same as those evaluated for intensive play areas.

Bridle paths, nature trails, and hiking trails are nonintensive uses that involve the random movement of people. It is assumed that these areas are to be used as they occur in nature and that little soil is excavated or moved. Specific items evaluated were wetness, flooding, slope, surface texture, and surface stoniness or rockiness.

Golf courses, fairways, and lawns are those parts of the playing course exclusive of roughs, traps, and greens. Fairways and lawns require soils that have good trafficability, a minimum of coarse fragments or stones, and slopes that are not too steep. Specific items evaluated were slope, depth to water table, surface texture, surface stoniness or rockiness, flooding, and inherent fertility.

Cottages, service buildings, and utility buildings are seasonal and year-round structures. Specific items evaluated were wetness, flooding, slope, rockiness or stoni-

TABLE 5.—*Interpretations for recreational development*

Soil and map symbols	Degree of limitation and soil features affecting—					
	Playgrounds, athletic fields, and intensive play areas	Picnic areas, parks, and extensive play areas	Bridle paths, nature trails, and hiking trails	Golf courses, fairways, and lawns	Cottages, service buildings, and utility buildings	Tent and trailer sites
Adolph: Ad, AdA.	Severe: very poor natural drainage; often ponded.	Severe: very poor natural drainage; often ponded.	Severe: very poor natural drainage; often ponded.	Severe: water table at a depth of 0 to 3 feet; often ponded.	Severe: very poor natural drainage; often ponded.	Severe: very poor natural drainage; often ponded.
Adolph variant: Ah.	Severe: high water table; moderately slow and slow permeability; slippery if wet.	Severe: poor and very poor natural drainage; sometimes ponded.	Severe: poor and very poor natural drainage; sometimes ponded.	Severe: water table at a depth of 0 to 3 feet; sometimes ponded.	Severe: poor and very poor natural drainage; sometimes ponded.	Severe: poor and very poor natural drainage; sometimes ponded.
Alluvial land: Ao.	Very severe: frequent flooding.	Very severe: frequent flooding.	Very severe: frequent flooding.	Very severe: frequent flooding.	Very severe: frequent flooding.	Very severe: frequent flooding.
Antigo:						
AtA	None to slight	None to slight	None to slight	Moderate: medium fertility.	None to slight	None to slight.
AtB	Moderate: slope.	None to slight	None to slight	Moderate: medium fertility.	None to slight	None to slight.
Blomford: Bd	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing.	Severe: low fertility.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing.
Braham: BhC	Moderate: loose, sandy soil; subject to blowing; slope; hard to maintain turf.	Moderate: loose, sandy soil; subject to blowing.	Moderate: loose, sandy soil; subject to blowing.	Severe: low fertility.	None to slight	Moderate: loose, sandy soil; subject to blowing.
Brainerd:						
BrA, BrB	Moderate: moderately slow permeability; slope; stony.	None to slight	None to slight	Moderate: medium fertility; stony.	None to slight	None to slight.
BsA, BsB	Moderate: moderately slow permeability; slope; very stony.	None to slight	Moderate: very stony.	Severe: very stony.	Moderate: very stony.	Moderate: very stony.
Burkhardt:						
BuA	None to slight	None to slight	None to slight	Moderate: medium fertility.	None to slight	None to slight.
BuB	Moderate: sloping.	None to slight	None to slight	Moderate: medium fertility.	None to slight	None to slight.
Chetek:						
CeB	Moderate: sandy surface layer.	Moderate: sandy surface layer.	Moderate: sandy surface layer.	Severe: low fertility.	None to slight	Moderate: sandy surface layer.
CeC	Severe: slope	Moderate: sandy surface layer.	Moderate: sandy surface layer.	Severe: low fertility.	Moderate: slope.	Moderate: slope; sandy surface layer.
ChA	None to slight	None to slight	None to slight	None to slight	None to slight	None to slight.
ChB, ChB2	Moderate: slope.	None to slight	None to slight	None to slight	None to slight	None to slight.
ChC	Severe: slope	Moderate: slope.	None to slight	Moderate: slope.	Moderate: slope.	Moderate: slope.

TABLE 5.—*Interpretations for recreational development*—Continued

Soil and map symbols	Degree of limitation and soil features affecting—					
	Playgrounds, athletic fields, and intensive play areas	Picnic areas, parks, and extensive play areas	Bridle paths, nature trails, and hiking trails	Golf courses, fairways, and lawns	Cottages, service buildings, and utility buildings	Tent and trailer sites
Chetek—Cont'd.						
CmB	Moderate: stony; slope.	None to slight	None to slight	Moderate: stony	None to slight	None to slight.
CmC	Severe: slope	Moderate: slope	None to slight	Moderate: slope; stony.	Moderate: slope	Moderate: slope.
Dalbo:						
DaA	Moderate: moderately slow permeability.	None to slight	None to slight	None to slight	None to slight	Moderate: moderately slow permeability.
DbB	Severe: slope	None to slight	None to slight	None to slight	Moderate: slope	Moderate: moderately slow permeability.
Dickman: DcA	None to slight	None to slight	None to slight	None to slight	None to slight	None to slight.
Duelm: Du	Moderate: somewhat poor natural drainage; sandy surface layer.	Moderate: somewhat poor natural drainage; sandy surface layer.	Moderate: somewhat poor natural drainage.	Severe: low fertility.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage; sandy surface layer.
Emmert: EmE	Severe: slope; sandy surface layer; stony.	Severe: slope; sandy surface layer.	Moderate: slope; sandy surface layer.	Severe: slope; low fertility.	Severe: slope	Severe: slope.
Flak:						
FlB, FlB2	Moderate: moderately slow permeability; slope; stony.	None to slight	None to slight	Moderate: stony; medium fertility.	None to slight	Moderate: moderately slow permeability.
FlC, FlC2	Severe: slope	Moderate: slope	None to slight	Moderate: slope; stones; low fertility.	Moderate: slope	Moderate: moderately slow permeability; slope.
Freer: Fr, Fs	Moderate: somewhat poor natural drainage; moderately slow permeability; stony.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage.	Severe: stony	Moderate: somewhat poor natural drainage; stony.	Moderate: somewhat poor natural drainage; moderately slow permeability.
Granite rock land: Gr.	Very severe: hard bedrock at the surface.	Very severe: hard bedrock at the surface.	Very severe: hard bedrock at the surface.	Very severe: hard bedrock at the surface.	Very severe: hard bedrock at the surface.	Very severe: hard bedrock at the surface.
Hillet: Hm, HmA.	Severe: very poor natural drainage; sometimes ponded; slippery if wet.	Severe: very poor natural drainage; sometimes ponded; slippery if wet.	Severe: very poor natural drainage; sometimes ponded; slippery if wet.	Severe: water table at a depth of 0 to 3 feet; sometimes ponded.	Severe: very poor natural drainage; sometimes ponded.	Severe: very poor natural drainage; sometimes ponded; slippery if wet.
Hubbard:						
HoA	Moderate: sandy surface layer; hard to maintain turf; some hazard of dust.	Moderate: sandy surface layer; hard to maintain turf.	Moderate: sandy surface layer; hard to maintain turf; some hazard of dust.	Severe: low fertility.	None to slight	Moderate: sandy surface layer; hard to maintain turf.

TABLE 5.—*Interpretations for recreational development*—Continued

Soil and map symbols	Degree of limitation and soil features affecting—					
	Playgrounds, athletic fields, and intensive play areas	Picnic areas, parks, and extensive play areas	Bridle paths, nature trails, and hiking trails	Golf courses, fairways, and lawns	Cottages, service buildings, and utility buildings	Tent and trailer sites
Hubbard—Continued						
HoA2, HoB, HoB2.	Moderate: sandy surface layer; hard to maintain turf; some hazard of dust; slope.	Moderate: sandy surface layer; hard to maintain turf.	Moderate: sandy surface layer; hard to maintain turf; some hazard of dust.	Severe: low fertility.	None to slight	Moderate: sandy surface layer; hard to maintain turf.
HrA, HrA2, HrB, HrB2.	Moderate: loose, sandy soil; subject to blowing; hard to maintain turf.	Moderate: loose, sandy soil; subject to blowing; hard to maintain turf.	Moderate: loose, sandy soil; subject to blowing; hard to maintain turf.	Severe: low fertility.	None to slight	Moderate: loose, sandy soil; subject to blowing.
HsC2	Severe: slope	Moderate: coarse, loose, sandy soil; subject to blowing and washing; hard to maintain turf.	Moderate: coarse, loose, sandy soil; subject to blowing and washing; hard to maintain turf.	Severe: low fertility.	Moderate: slope; coarse, loose, sandy soils.	Moderate: coarse, loose, sandy soil; subject to blowing and washing; hard to maintain turf.
HsE	Severe: steep slope.	Severe: steep slope.	Moderate: steep slope; coarse, loose, sandy soil; subject to blowing and washing; hard to maintain turf.	Severe: steep slope; low fertility.	Severe: steep slope; coarse, loose, sandy soil.	Severe: steep slope.
Isanti: Im	Severe: very poor natural drainage; sometimes ponded.	Severe: very poor natural drainage; sometimes ponded.	Severe: very poor natural drainage; sometimes ponded.	Severe: water table at a depth of 0 to 2 feet; sometimes ponded; low fertility.	Severe: very poor natural drainage; sometimes ponded.	Severe: very poor natural drainage; sometimes ponded.
Isanti variant: It.	Severe: very poor natural drainage; sometimes ponded.	Severe: very poor natural drainage; sometimes ponded.	Severe: very poor natural drainage; sometimes ponded.	Severe: water table at a depth of 0 to 2 feet; sometimes ponded; low fertility.	Severe: very poor natural drainage; sometimes ponded.	Severe: very poor natural drainage; sometimes ponded.
Langola:						
LaA	Moderate: moderately slow permeability; loose, sandy surface layer; subject to blowing; hard to maintain turf.	Moderate: loose, sandy surface layer; subject to blowing; hard to maintain turf.	Moderate: loose, sandy surface layer; subject to blowing; hard to maintain turf.	Severe: low fertility.	None to slight	Moderate: loose, sandy surface layer; subject to blowing; hard to maintain turf.
LaB2	Moderate: moderately slow permeability; loose, sandy surface layer; subject to blowing; hard to maintain turf; slope.	Moderate: loose, sandy surface layer; subject to blowing; hard to maintain turf.	Moderate: loose, sandy surface layer; subject to blowing; hard to maintain turf.	Severe: low fertility.	None to slight	Moderate: loose, sandy surface layer; subject to blowing; hard to maintain turf.

TABLE 5.—*Interpretations for recreational development*—Continued

Soil and map symbols	Degree of limitation and soil features affecting—					
	Playgrounds, athletic fields, and intensive play areas	Picnic areas, parks, and extensive play areas	Bridle paths, nature trails, and hiking trails	Golf courses, fairways, and lawns	Cottages, service buildings, and utility buildings	Tent and trailer sites
Lino: Ln	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing if drained; hard to maintain turf.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing if drained.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing if drained.	Severe: low fertility; loose, sandy soil; subject to blowing if drained; hard to maintain turf.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing if drained.
Lino variant: Lo.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing if drained; hard to maintain turf.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing if drained.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing if drained.	Severe: low fertility; loose, sandy soil; subject to blowing if drained; hard to maintain turf.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage; loose, sandy soil; subject to blowing if drained.
Marsh: Ma	Very severe: ponded; water table at the surface.	Very severe: ponded; water table at the surface.	Very severe: ponded; water table at the surface.	Very severe; ponded; water table at the surface.	Very severe: ponded; water table at the surface.	Very severe: ponded; water table at the surface.
Milaca:						
McB, McB2	Moderate: moderately slow permeability; slope; stony.	None to slight	None to slight	Moderate: medium fertility; stony.	None to slight	Moderate: moderately slow permeability.
McC, McC2	Severe: slope	Moderate: slope	None to slight	Moderate: slope; stony; medium fertility.	Moderate: slope	Moderate: moderately slow permeability; slope.
McE	Severe: steep slope.	Severe: steep slope.	Moderate: steep slope.	Severe: steep slope.	Severe: steep slope.	Severe: steep slope.
MdB, MhB	Moderate: moderately slow permeability; slope; very stony.	None to slight	Moderate: very stony.	Severe: very stony.	Moderate: very stony.	Moderate: moderately slow permeability; very stony.
MfB	Moderate: moderately slow permeability; slope; stony.	None to slight	None to slight	Moderate: stony; medium fertility.	None to slight	Moderate: moderately slow permeability.
Milaca variant: MlB.	Moderate: slope	None to slight	None to slight	None to slight	None to slight	None to slight.
Mora:						
MoA, MoB	Moderate: moderately slow permeability; slope; stony.	None to slight	None to slight	Moderate: stony; medium fertility.	None to slight	Moderate: moderately slow permeability.
MrA	Moderate: moderately slow permeability; slope; very stony.	None to slight	Moderate: very stony.	Severe: very stony.	Moderate: very stony.	Moderate: moderately slow permeability.

TABLE 5.—*Interpretations for recreational development*—Continued

Soil and map symbols	Degree of limitation and soil features affecting—					
	Playgrounds, athletic fields, and intensive play areas	Picnic areas, parks, and extensive play areas	Bridle paths, nature trails, and hiking trails	Golf courses, fairways, and lawns	Cottages, service buildings, and utility buildings	Tent and trailer sites
Mucky peat: Ms.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: water table at a depth of 0 to 3 feet; frequent flooding or ponding.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.
Mucky peat over sand: Mu.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: water table at a depth of 0 to 3 feet; frequent flooding or ponding.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.
Mucky peat over loam: Mx.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe: water table at a depth of 0 to 3 feet; frequent flooding or ponding.	Very severe: very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.	Very severe; very poor natural drainage; frequent flooding or ponding; water table at a depth of 0 to 3 feet.
Nokasippi: Nm	Severe: very poor natural drainage; frequent ponding.	Severe: very poor natural drainage; frequent ponding.	Severe: very poor natural drainage; frequent ponding.	Severe: water table at a depth of 0 to 3 feet; frequent ponding; low fertility.	Severe: very poor natural drainage; water table at a depth of 0 to 3 feet; frequent ponding.	Severe: very poor natural drainage; water table at a depth of 0 to 3 feet; frequent ponding.
Nokay: No	Moderate: somewhat poor natural drainage; moderately slow permeability; stony.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage.	Moderate: water table at a depth of 2 to 4 feet; stony; medium fertility.	Moderate: somewhat poor natural drainage; water table at a depth of 2 to 4 feet.	Moderate: somewhat poor natural drainage; water table at a depth of 2 to 4 feet; moderately slow permeability.
Ns	Moderate: somewhat poor natural drainage; very stony.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage; very stony.	Severe: very stony.	Moderate: somewhat poor natural drainage; water table at a depth of 2 to 4 feet.	Moderate: somewhat poor natural drainage; water table at a depth of 2 to 4 feet; moderately slow permeability; very stony.
Ogilvie: Og	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage.	Moderate: water table at a depth of 2 to 4 feet; medium fertility.	Moderate: somewhat poor natural drainage; water table at a depth of 2 to 4 feet.	Moderate: somewhat poor natural drainage; water table at a depth of 2 to 4 feet.
Paget: PaA, PaB	Moderate: moderately slow permeability; stony.	None to slight	None to slight	Moderate: stony; medium fertility.	None to slight	Moderate: moderately slow permeability.

TABLE 5.—*Interpretations for recreational development*—Continued

Soil and map symbols	Degree of limitation and soil features affecting—					
	Playgrounds, athletic fields, and intensive play areas	Picnic areas, parks, and extensive play areas	Bridle paths, nature trails, and hiking trails	Golf courses, fairways, and lawns	Cottages, service buildings, and utility buildings	Tent and trailer sites
Paget—Cont'd.						
PbA, PbB	Moderate: moderately slow permeability; slope; very stony.	None to slight	Moderate: very stony.	Severe: very stony; medium fertility.	Moderate: very stony.	Moderate: moderately slow permeability; very stony.
Parent:						
Pe	Severe: poor natural drainage; sometimes briefly ponded; slippery and sticky if wet.	Severe: poor natural drainage; sometimes briefly ponded.	Severe: poor natural drainage; sometimes briefly ponded.	Severe: water table at a depth of 1 to 3 feet.	Severe: poor natural drainage; water table at a depth of 1 to 3 feet; sometimes briefly ponded.	Severe: poor natural drainage; water table at a depth of 1 to 3 feet; sometimes briefly ponded.
Pk	Severe: poor natural drainage; sometimes briefly ponded; slippery and sticky if wet.	Severe: poor natural drainage; sometimes briefly ponded.	Severe: poor natural drainage; sometimes briefly ponded.	Severe: water table at a depth of 1 to 3 feet; many stones.	Severe: poor natural drainage; water table at a depth of 1 to 3 feet; sometimes briefly ponded.	Severe: poor natural drainage; water table at a depth of 1 to 3 feet; sometimes briefly ponded.
Pomroy:						
PoB	Severe: loose, sandy surface layer; subject to severe blowing; hard to maintain turf.	Severe: loose, sandy surface layer; subject to severe blowing; hard to maintain turf.	Severe: loose, sandy surface layer; subject to severe blowing.	Severe: loose, sandy surface layer; subject to severe blowing; low fertility; hard to maintain turf.	None to slight	Severe: loose, sandy surface layer; subject to severe blowing; hard to maintain turf.
PoC	Severe: loose, sandy surface layer; subject to severe blowing; hard to maintain turf; slope.	Severe: loose, sandy surface layer; subject to severe blowing; hard to maintain turf.	Severe: loose, sandy surface layer; subject to severe blowing.	Severe: loose, sandy surface layer; subject to severe blowing; slope; low fertility; hard to maintain turf.	Moderate: slope	Severe: loose, sandy surface layer; subject to severe blowing; hard to maintain turf.
PrA	Moderate: loose, sandy surface layer; subject to blowing; hard to maintain turf; moderately slow permeability.	Moderate: loose, sandy surface layer; subject to blowing; hard to maintain turf.	Moderate: loose, sandy surface layer; subject to blowing.	Severe: low fertility.	None to slight	Moderate: moderately slow permeability; loose, sandy surface layer; subject to blowing.
Prebish:						
Ps	Severe: very poor natural drainage; frequent ponding.	Severe: very poor natural drainage; frequent ponding.	Severe: very poor natural drainage; frequent ponding.	Severe: water table at a depth of 0 to 3 feet; frequent ponding.	Severe: very poor natural drainage; frequent ponding.	Severe: very poor natural drainage; frequent ponding.
Pt	Severe: very poor natural drainage; frequent ponding.	Severe: very poor natural drainage; frequent ponding.	Severe: very poor natural drainage; frequent ponding.	Severe: water table at a depth of 0 to 3 feet; frequent ponding; many stones.	Severe: very poor natural drainage; frequent ponding.	Severe: very poor natural drainage; frequent ponding.

TABLE 5.—*Interpretations for recreational development*—Continued

Soil and map symbols	Degree of limitation and soil features affecting—					
	Playgrounds, athletic fields, and intensive play areas	Picnic areas, parks, and extensive play areas	Bridle paths, nature trails, and hiking trails	Golf courses, fairways, and lawns	Cottages, service buildings, and utility buildings	Tent and trailer sites
Prebish—Cont'd.						
Pu	Severe: poor and very poor natural drainage; sometimes briefly ponded.	Severe: poor and very poor natural drainage; sometimes briefly ponded.	Severe: poor and very poor natural drainage; sometimes briefly ponded.	Severe: water table at a depth of 0 to 3 feet; sometimes briefly ponded.	Severe: poor and very poor natural drainage; sometimes briefly ponded.	Severe: poor and very poor natural drainage; sometimes briefly and frequently ponded.
Ronneby:						
Rn	Moderate: somewhat poor natural drainage; moderately slow permeability; stony.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage.	Moderate: water table at a depth of 2 to 4 feet; stones; medium fertility.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage; moderately slow permeability.
Ro	Moderate: somewhat poor natural drainage; moderately slow permeability; very stony.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage; very stony.	Severe: very stony.	Moderate: somewhat poor natural drainage; very stony.	Moderate: somewhat poor natural drainage; moderately slow permeability; very stony.
Sartell:						
SaA, SaB	Severe: loose, sandy soil; subject to severe blowing; hard to maintain turf.	Severe: loose, sandy soil; subject to severe blowing; hard to maintain turf.	Severe: loose, sandy soil; subject to severe blowing.	Severe: loose, sandy soil; subject to severe blowing; low fertility.	None to slight	Severe: loose, sandy soil; subject to severe blowing; poor trafficability.
SaC	Severe: loose, sandy soil; subject to severe blowing; hard to maintain turf; slope.	Severe: loose, sandy soil; subject to severe blowing; hard to maintain turf.	Severe: loose, sandy soil; subject to severe blowing.	Severe: loose, sandy soil; subject to severe blowing; low fertility.	Moderate: sloping.	Severe: loose, sandy soil; subject to severe blowing; poor trafficability.
SaE	Severe: loose, sandy soil; subject to severe blowing; hard to maintain turf; steep slope.	Severe: loose, sandy soil; subject to severe blowing; hard to maintain turf; steep slope.	Severe: loose, sandy soil; subject to severe blowing; steep slope.	Severe: loose, sandy soil; subject to severe blowing; low fertility; steep slope.	Severe: steep slope.	Severe: loose, sandy soil; subject to severe blowing; poor trafficability; steep slope.
Watab: Wa	Moderate: somewhat poor natural drainage; moderately slow permeability; sandy surface layer; subject to blowing.	Moderate: somewhat poor natural drainage; sandy surface layer; subject to blowing.	Moderate: somewhat poor natural drainage; sandy surface layer; subject to blowing.	Severe: low fertility.	Moderate: somewhat poor natural drainage.	Moderate: somewhat poor natural drainage; moderately slow permeability; sandy surface layer; subject to blowing.

ness, and depth to bedrock. Such engineering factors as frost heave, shrink-swell potential, and waste disposal were not considered in this table.

Tent and trailer sites are used frequently during the season and require little site preparation. Specific items were wetness, flooding, permeability, slope, surface texture, amount of coarse fragments, and percentage of stones or rocks.

Engineering Uses of the Soils [4]

This section provides information of special interest to engineers, contractors, farmers, and others who use soil as structural material or as foundation material upon which structures are built. Information contained

[4] HAROLD C. OLSON, agricultural engineer, helped to prepare this section.

in this section is valuable to planning commissions, town and country planners, town and city managers, sanitarians, land developers, architects, and realtors who are concerned with soils and their limitations in land use planning and development.

In this section are those properties of the soils that affect construction and maintenance of roads and airports, pipelines, building foundations, water storage facilities, erosion control structures, drainage systems. sewage disposal systems, and sanitary landfill sites. Among the soil properties most important in engineering are permeability, shear strength, density, shrink-swell potential, available water capacity, grain-size distribution, plasticity, and reaction.

Information concerning these and related soil properties is given in the tables in this section. The estimates and interpretations of soil properties in these tables can be used in—

1. Selecting potential residential, industrial, commercial, and recreational areas. Among those factors which may be problems in selecting locations are depth to bedrock, seasonal high water table, flooding frequency, and permeability of the soil.
2. Selecting potential locations for roads, highways, airports, pipelines, and underground cables. Among those factors that may be problems in selecting locations are depth to bedrock, depth to water table, soil permeability, flooding frequency, and susceptibility to sliding.
3. Locating probable sources of sand, gravel, or fill suitable for use as construction material. Among those factors which may be problems in selecting locations are depth to water table, presence of stones and boulders, thickness of deposits, shrink-swell potential, susceptibility to frost action, and moisture content.
4. Planning and designing agricultural drainage systems, farm ponds, irrigation systems, diversion terraces, and other structures for controlling water and conserving soil. Among those factors that may be important are permeability and seepage rate, depth to water table, slope, available water capacity, depth to layers, such as fragipan, claypan, bedrock, and sand, that influence the rate of water movement, and flooding or stream overflow.

The engineering interpretations given here do not eliminate the need for sampling and testing at the site of specific engineering works involving heavy loads and where the excavations are to a depth greater than the one evaluated in this survey. Even in these situations, however, the soil map is useful in planning detailed field investigations and for indicating the kinds of problems that may be expected.

Some terms used by soil scientists may be unfamiliar to engineers, and some words have different meanings in soil science than they have in engineering. Among the terms that have special meaning in soil science are sand, clay, loam, surface soil, subsoil, and horizon. These and other terms are defined in the Glossary at the back of this survey.

Probably the most noticeable soil feature that affects the use of the glacial till soils in Benton County is the amount of stones on the surface and throughout the soil. In most of these soils, it is common to find a concentration of these stones and cobblestones at a contact line between the surface layer and subsoil.

Another feature that is not so noticeable, but probably has greater importance, is the fragipan that is in most of the till soils on uplands. Flak, Brainerd, Nokay, Milaca, Mora, Ronneby, and Paget soils have a fragipan. All of the "brown" and "red" glacial till soils have dense, compact parent material and a high bulk density, which influence the permeability and percolation rates. In areas of these soils, onsite sewage disposal systems commonly are inadequately designed and generally fail to function properly. The temporarily perched water above the pan causes lateral movement of water and seepage into many basements.

Granite bedrock protrudes through the surface of soils located in Watab, Sauk Rapids, and Granite Ledge Townships and can create serious difficulties and unexpected expense in construction. In some areas on the outwash plains, the underlying glacial till interferes with construction by permitting lateral seepage.

Engineering classification systems

The two systems commonly used in classifying samples of soil for engineering are the AASHTO system, adopted by the American Association of State Highway and Transportation Officials (*1*), and the Unified system, used by the SCS engineers, Department of Defense, and others (*11*). Both systems are used in this section and are briefly explained in the following paragraphs (*4*).

The AASHTO system is used to classify soils according to those properties that affect use in highway construction. In this system a soil is placed in one of seven basic groups. These range from A–1 through A–7 on the basis of grain-size distribution, liquid limit, and plasticity index. Also, in this survey, the symbol A–8 is used to designate organic soils. In group A–1 are gravelly soils of high bearing strength, or the best soils for subgrade (foundation), and at the other extreme, A–7, are clay soils that have low 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, and A–7–5, 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 soil material can be indicated by a group index number. Group indexes range from 0 for the best material to 20 or more for the poorest. The AASHTO classification for tested soils, with index numbers in parentheses, is shown in table 6; the estimated classification for all soils mapped in the survey area is given in table 7.

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, SP–SM.

Engineering test data

Table 6 contains the results of engineering tests performed by the Minnesota Department of Highways in cooperation with the U.S. Department of Commerce, Bureau of Public Roads, on several important soils in Benton 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 in engineering.

Moisture-density or compaction data are important in earthwork. If a soil material is compacted at a successively higher moisture content, assuming that the compactive effort remains constant, the density of the compacted material increases until the *optimum moisture content* is reached. After that, density decreases with an increase in moisture content. The highest dry density obtained in the compactive test is termed *maximum dry density*. As a rule, maximum strength of earthwork is obtained if the soil is compacted to the maximum dry density.

Mechanical analyses show the percentages, by weight, of soil particles that would pass sieves of specified sizes. Sand and other coarser materials do not pass through the No. 200 sieve. Fractions of particles smaller than openings in the No. 200 sieve were determined by the hydrometer method.

Liquid limit and plasticity index indicate the effect of water on the consistency of soil material. As the moisture content of a clayey soil is increased from a dry state, the material changes from a solid to a plastic state. If the moisure content is further increased, the material changes from a plastic to a liquid state. The plastic limit is the moisture content, in percentage of dry weight, at which the material changes from solid to plastic. The liquid limit is the moisture content, in percentage of dry weight, 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.

Estimated soil properties significant to engineering

Table 7 provides estimates of soil properties important to engineering. The estimates are based on field classifications 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 kinds of soil in the survey area. The data are listed by layers that have properties significant to engineering.

Except for a few areas of Granite rock land and nearby soils, bedrock is at a depth of 50 to 150 feet or more in this county and is not significant to engineering.

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. Sand, silt, clay, and some of the other terms used in the USDA textural classification are defined in the Glossary.

Permeability, as used in table 7, relates only to the movement of water downward through undisturbed and uncompacted soil. It does not include lateral seepage. The estimates are based on structure and porosity of soils on which permeability tests have been run. Plowpans, surface crusts, and other properties resulting from use of the soils are not considered.

Available water capacity is the capacity of soils 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. Generally it is expressed as inches of water per inch of soil.

Reaction is the degree of acidity or alkalinity of a soil, expressed as pH. 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 constructed in, on, or of such materials.

Engineering interpretations of the soils

Table 8 contains selected information useful to engineers and others who plan to use soil material in construction of highways, farm facilities, buildings, and sewage disposal systems. Detrimental or undesirable features are emphasized, but very important desirable features also may be listed. The ratings and other interpretations in this table are based on the estimated engineering properties of the soils given in table 7. The interpretations are based both on test data shown in table 6 and on available data on similar soils in other localities, as well as on field experience. Although the information strictly applies only to the depth indicated in table 7, it is reasonably reliable to a depth of about 5 or 6 feet.

Topsoil is material usable for spreading over barren surfaces, lawns, and gardens so as to improve soil conditions for establishing or maintaining adapted vegetation. The soils are rated good, fair, and poor as a source of topsoil. Main items considered in the rating are texture, thickness of the surface layer, coarse fragments, slope, and wetness.

Mixed sand and gravel ratings are based on the probability that delineated areas of the soil contain deposits of sand or gravel, or both. The table provides guidance for the use of available sand and gravel. The ratings do not indicate quality or size of the deposits.

Road fill (subgrade) is the material used as an embankment to support the subbase and base course or surface course. Suitability ratings for road fill material are based on the performance of the soil material when excavated and used as borrow for highway subgrade. In general, a sandy material containing adequate binder is the best. It is least affected by adverse weather conditions and can be worked during a greater number of months of the year. The poorest materials for subgrade are plastic clays or organic material. A soil rated as fair in one area may be rated as good in another area because of climatic differences.

For local roads and streets, natural soil drainage, depth to water table, susceptibility to frost heave, bearing capacity, slope, texture, erodibility, shear strength,

TABLE 6.—*Engineering*

[Tests performed by the Minnesota Department of Highways in cooperation with the standard procedures of the American Association of State

Soil name and location	Parent material	Minnesota report number	Depth	Moisture-density [1]	
				Maximum dry density	Optimum moisture
			Inches	*Pounds per cubic foot*	*Percent*
Adolph silt loam:					
600 feet N. and 70 feet E. of SW. corner of NW¼ sec. 1, T. 38 N., R. 28 W. (Modal)	Silt over reddish-brown sandy loam till.	SS–6594	0–5	96	22
		SS–6595	14–29	106	18
		SS–6596	29–54	132	7
Chetek sandy loam:					
80 feet E. and 35 feet N. of the SW. corner of SE¼ sec. 9, T. 37 N., R. 28 W. (Modal)	Brown and reddish-brown sand and gravel.	SS–6590	0–9	113	13
		SS–6590A	12–23	117	12
		SS–6591	23–40	125	9
Duelm loamy sand:					
1,140 feet W. and 50 feet S. of NE. corner of SE¼ sec. 30, T. 36 N., R. 29 W. (Modal)	Glacial outwash, medium and fine sand.	SS–6587	0–9	118	11
		SS–6588	12–33	121	10
		SS–6589	52–60	107	14
1,100 feet W. and 120 feet N. of the SE. corner of sec. 14, T. 38 N., R. 31 W. (Wetter than modal.)	Glacial outwash, medium and fine sand.	SS–6584	0–7	110	15
		SS–6585	21–33	110	13
		SS–6586	40–57	103	12
Milaca fine sandy loam:					
1,000 feet S. and 530 feet E. of the NW. corner of sec. 33, T. 38 N., R. 29 W. (Modal)	Reddish-brown glacial till.	SS–6575	1–10	106	15
		SS–6576	28–40	133	8
		SS–6577	55–72	134	7
Mora fine sandy loam:					
300 feet N. and 40 feet E. of the SW. corner of sec. 13, T. 37 N., R. 29 W. (Modal)	Reddish-brown glacial till.	SS–6572	4–12	121	10
		SS–6573	24–31	123	10
		SS–6574	48–75	131	8
Parent loam:					
350 feet S. and 160 feet W. of the NE. corner of SE¼ sec. 15, T. 36 N., R. 29 W. (Modal)	Brown or reddish-brown sandy loam till.	SS–100	0–11	91	24
		SS–101	17–24	130	8
		SS–101A	24–40	133	7
Ronneby loam:					
1,210 feet S. and 180 feet E. of the NW. corner of sec. 6, T. 36 N., R. 28 W. (Modal)	Reddish-brown glacial till.	SS–6581	4–12	118	11
		SS–6582	25–33	125	10
		SS–6583	61–72	134	7

[1] Based on AASHTO Designation T 99–57, Method C(*1*).

[2] Mechanical analysis according to AASHTO Designation T 88–57 (*1*). Results by this procedure may differ somewhat from results obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHTO 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 material coarser than 2 millimeters in diameter is excluded from calculations of grain-size fractions. The mechanical analysis used in this table is not suitable for naming textural classes for soils.

compressibility, and the amount of stones are considered.

Artificial drainage of the wet soils is needed for optimum production of crops. Outlets for agricultural drainage have not been developed to any great extent; consequently, many of the wet soils are undeveloped in the county. Factors considered are texture, permeability, depth to water table, stoniness, depth to unfavorable material, and frequency of flooding or ponding.

Some irrigation is used in the county with good results. A large quantity of good quality water is needed for this use. A study of underground water supplies is in process in Sherburne County that will provide information that can be of use in this survey area. Factors considered for sprinkler irrigation are available water capacity, water intake rate, depth to unfavorable material, permeability, flooding, drainage class, and slope.

Terraces are the most practical measure for water management and erosion control on slopes of less than

test data

U.S. Department of Commerce, Bureau of Public Roads (BPR), in accordance with Highway and Transportation Officials (AASHTO) (*1*)]

Mechanical analysis [2]										Liquid limit	Plasticity index	Classification	
Percentage passing sieve—						Percentage smaller than—							
1 in.	⅜ in.	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.07 mm.)	0.05 mm.	0.02 mm.	0.005 mm.	0.002 mm.			AASHTO [3]	Unified [4]
										Percent			
99	98	72	70	69	63	57	38	18	13	38	4	A–4(6)	ML
		100	99	98	94	84	51	25	21	33	9	A–4(8)	CL–ML
97	94	91	87	75	39	31	19	9	5	(5)	(5)	A–2(1)	SM
		100	99	90	48	40	24	9	5	(5)	(5)	A–4(3)	SM
			100	77	28	24	18	11	6	(5)	(5)	A–2–4(0)	SM
95	85	79	75	57	6	5	4	1	1	(5)	(5)	A–3(0)	SP–SM
			100	77	23	22	17	8	7	(5)	(5)	A–2–4(0)	SM
	99	98	97	68	16	14	12	8	4	(5)	(5)	A–2–4(0)	SM
			100	84	4	1	1	1	1	(5)	(5)	A–3(0)	SP
				97	21	18	12	6	4	(5)	(5)	A–2–4(0)	SM
	100	97	97	96	12	10	7	5	3	(5)	(5)	A–2–4(0)	SP–SM
				92	4	3	3	2	1	(5)	(5)	A–1–b(0)	SP
100	98	98	97	86	45	41	26	8	5	(5)	(5)	A–4(2)	SM
92	85	71	67	55	27	23	15	7	5	16	2	A–2–4(0)	SM
95	87	83	79	64	30	24	16	9	7	15	1	A–2–4(0)	SM
98	96	93	91	81	47	40	25	10	7	17	1	A–4(2)	SM
100	97	90	87	77	39	32	22	10	6	19	3	A–4(1)	SM
98	92	89	85	74	35	27	15	7	4	(5)	(5)	A–2–4(0)	SM
100	97	94	93	86	52	46	32	15	10	38	0	A–4(3)	OL
100	96	88	84	73	38	30	22	9	6	15	1	A–4(1)	SM
99	95	91	86	73	33	27	16	8	4	(5)	(5)	A–2–4(0)	SM
		100	99	91	50	44	29	13	8	(5)	(5)	A–4(3)	SM
98	96	92	88	76	37	30	22	10	9	20	3	A–4(0)	SM
98	94	91	88	76	39	31	20	13	8	14	2	A–4(1)	SM

[3] Based on AASHTO Designation M 145–49 (*1*).

[4] 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 SM-SC and CL–ML.

[5] Nonplastic.

12 percent. Systems of parallel terraces can be laid out in many sloping areas of Brainerd, Flak, Milaca, Mora, and Paget soils. Terrace channels should have grade on them because these soils have moderately slow permeability. Stones are a concern and require removal. Diversion terraces are built mainly on soils that have slopes of more than 8 percent.

Grassed waterways are needed to conduct water safely off the sloping hillsides to nearby drainageways, streams, and depressions. Sod is difficult to maintain in these waterways when herbicides are being used in crop production. In some terrace systems the grassed waterways have been replaced by tile outlet systems.

Ratings for dwellings with basements are based chiefly on soil characteristics affecting foundations, but slope, susceptibility to flooding, seasonal wetness, depth to bedrock, and other conditions are also considered.

Septic tank absorption fields are affected mainly by permeability, location of water table, susceptibility to flooding, slope, and depth of unfavorable material. The

TABLE 7.—*Estimates of soil properties*

[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. The instructions for referring to other series that appear in the

Soil series and map symbols	Depth to water table	Depth from surface	USDA texture	Classification	
				Unified	AASHTO
	Feet	*Inches*			
Adolph: Ad, AdA	0–3	0–14	Silt loam	ML	A–4
		14–29	Very fine sandy loam	ML	A–4
		29–60	Sandy loam	SM	A–2 or A–4
Adolph variant: Ah	[1] 0–3	0–15	Silt loam and silty clay loam	ML	A–4
		15–24	Silt loam	ML	A–4
		24–60	Silt loam	ML	A–4
Alluvial land: Ao. Water table at a depth of 0 to 3 feet. No other valid estimates can be made.					
Antigo: AtA, AtB	10	0–15	Silt loam	ML	A–4
		15–28	Silty clay loam	CL	A–7
		28–36	Sandy loam	SM	A–2
		36–60	Sand and gravel	SP, GP	A–1
Blomford: Bd	[1] 2–4	0–21	Loamy sand	SM	A–2
		21–41	Sandy loam	SM	A–4
		41–60	Silt loam	ML	A–4
Braham: BhC	>10	0–17	Loamy fine sand	SM	A–2
		17–28	Fine sand	SP–SM	A–2
		28–60	Silt loam	ML	A–4
Brainerd: BrA, BrB, BsA, BsB	>10	0–14	Sandy loam	SM	A–2
		14–24	Sandy loam	SM	A–2
		24–60	Sandy loam (fragipan)	SM	A–2
Burkhardt: BuA, BuB	>10	0–11	Sandy loam	SM	A–2
		11–21	Sandy loam	SM	A–2
		21–60	Coarse sand	SP–SM	A–1
*Chetek: CeB, CeC	>10	0–12	Loamy sand	SM	A–2
		6–18	Loamy sand	SM	A–2
		18–60	Sand and gravel	SW	A–1
ChA, ChB, ChB2, ChC, CmB, CmC. For Milaca part of CmB and CmC, see Milaca series.	>10	0–12	Sandy loam	SM	A–4
		12–23	Sandy loam	SM or SC	A–2 or A–4
		23–72	Sand and gravelly coarse sand	SP or SM	A–1 or A–3
Dalbo: DaA, DbB	>10	0–12	Silt loam	ML	A–4
		12–34	Silty clay loam	CL	A–6
		34–50	Silt loam	ML	A–4
Dickman: DcA	>10	0–17	Coarse sandy loam	SM	A–2
		17–35	Sand	SM	A–2
		35–60	Coarse sand	SP–SM	A–2
Duelm: Du	2–4	0–17	Loamy sand	SM	A–2
		17–60	Sand	SP or SM	A–3 or A–1
Emmert: EmE	>10	0–5	Gravelly loamy sand	SW–SM	A–1
		5–72	Gravelly coarse sand	SW–SM	A–1
Flak: FlB, FlB2, FlC, FlC2	>10	0–14	Sandy loam	SM	A–2
		14–20	Sandy loam	SM	A–2
		20–60	Sandy loam (fragipan)	SM	A–2
Freer: Fr, Fs	[1] 2–4	0–20	Silt loam	ML	A–4
		20–38	Very fine sandy loam	ML	A–4
		38–60	Sandy loam	SM	A–2 or A–4

significant in engineering

soils in such mapping units may have different properties and limitations, and for this reason it is necessary to follow carefully the first column of this table. The symbol > means more than]

Percentage passing sieve—				Permeability	Available water capacity	Reaction	Shrink-swell potential
No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	*Inches per hour*	*Inches per inch of soil*	*pH*	
70–80	70–80	65–75	60–70	0.63–2.0	0.22–0.24	6.1–6.8	Moderate.
95–100	95–100	95–100	85–95	0.63–2.0	0.17–0.19	6.6–7.3	Moderate.
85–95	85–95	70–80	30–45	0.20–0.63	0.11–0.13	6.6–7.3	Low.
100	100	90–100	70–90	0.63–2.0	0.22–0.24	6.6–7.3	Moderate.
100	100	90–100	70–90	0.63–2.0	0.20–0.22	7.3–7.8	Moderate to high.
100	100	90–100	70–90	0.06–0.63	0.20–0.22	7.3–7.8	Moderate.
100	100	90–100	70–90	0.63–2.0	0.22–0.24	5.6–6.0	Moderate.
100	95–100	95–100	85–95	0.63–2.0	0.18–0.20	4.5–6.0	Moderate.
80–90	90–100	60–70	25–35	2.0–6.3	0.12–0.14	5.1–5.6	Low.
50–60	40–50	20–30	0–5	>6.3	0.02–0.04	5.1–5.6	Low.
100	100	50–75	10–20	>6.3	0.10–0.12	5.6–6.0	Low.
100	100	65–80	35–50	>6.3	0.06–0.08	5.6–6.0	Low.
100	100	90–100	70–90	0.20–0.63	0.20–0.22	7.4–7.8	Moderate.
100	100	70–85	10–15	>6.3	0.10–0.12	5.6–6.0	Low.
100	100	85–95	5–15	>6.3	0.06–0.08	5.6–6.0	Low.
95–100	95–100	90–100	70–90	0.20–0.63	0.20–0.22	7.4–7.8	Moderate.
95–100	85–95	60–70	25–35	2.0–6.3	0.13–0.15	5.1–6.0	Low.
80–90	80–90	60–70	25–35	0.63–2.0	0.12–0.14	5.1–6.0	Low.
80–90	80–90	60–70	25–35	0.20–0.63	[2] 0.08–0.10	5.6–6.0	Low.
90–100	90–100	60–70	25–35	2.0–6.3	0.13–0.15	5.5–6.0	Low.
90–100	90–100	60–70	25–35	2.0–6.3	0.12–0.14	5.5–6.0	Low.
70–90	50–70	20–40	5–10	>6.3	0.02–0.04	5.5–6.0	Low.
90–95	80–90	50–75	10–20	>6.3	0.10–0.12	5.5–6.0	Low.
85–90	80–85	50–75	10–20	2.0–6.3	0.09–0.11	5.5–6.0	Low.
70–80	50–60	20–40	0–5	>6.3	0.02–0.04	5.5–6.0	Low.
90–100	90–100	85–95	35–50	2.0–6.3	0.13–0.15	5.5–6.0	Low.
85–100	80–100	70–80	25–50	2.0–6.3	0.17–0.19	5.5–6.0	Low.
75–85	70–80	50–60	5–10	>6.3	0.02–0.04	5.5–6.0	Low.
100	100	90–100	70–90	0.63–2.0	0.22–0.24	6.1–7.3	Moderate.
100	100	95–100	85–95	0.2–0.63	0.18–0.20	6.1–7.3	Moderate.
100	100	90–100	70–90	0.63–2.0	0.20–0.22	7.4–7.8	Moderate.
100	100	60–70	25–35	2.0–6.3	0.13–0.15	5.6–6.5	Low.
100	95–100	50–75	10–20	>6.3	0.06–0.08	5.6–6.5	Low.
85–100	85–100	50–70	5–10	>6.3	0.02–0.04	5.6–6.5	Low.
100	95–100	70–85	15–25	>6.3	0.10–0.12	6.6–7.3	Low.
100	95–100	50–85	5–20	>6.3	0.05–0.07	6.6–7.3	Low.
80–90	75–85	45–70	5–15	>6.3	0.10–0.12	5.6–6.0	Low.
50–60	50–60	40–60	5–10	>6.3	0.02–0.04	5.6–6.0	Low.
90–100	85–95	60–70	25–35	0.63–2.0	0.13–0.15	5.1–5.5	Low.
85–95	80–90	60–70	25–35	0.63–2.0	0.12–0.14	5.6–6.0	Low.
80–90	75–85	60–70	25–35	0.20–0.63	[2] 0.08–0.10	5.6–6.0	Low.
95–100	95–100	85–95	70–90	0.63–2.0	0.22–0.24	5.1–5.6	Moderate.
80–90	75–85	60–75	50–60	0.63–2.0	0.17–0.19	5.1–5.6	Moderate.
70–80	65–75	50–60	35–45	0.20–0.63	0.11–0.13	5.6–6.0	Low.

TABLE 7.—*Estimates of soil properties*

Soil series and map symbols	Depth to water table	Depth from surface	USDA texture	Classification	
				Unified	AASHTO
	Feet	*Inches*			
Granite rock land: Gr. Variable: no valid estimates can be made.					
Hillet: Hm, HmA	0–3	0–13	Loam	ML	A–4
		13–30	Silt loam	ML	A–4
		30–60	Gravelly coarse sand	SW–SM	A–1
Hubbard:					
HoA, HoA2, HoB, HoB2	>10	0–23	Loamy coarse sand	SM	A–2
		23–61	Sand	SP–SM	A–3
HrA, HrA2, HrB, HrB2, HsC2, HsE	10	0–11	Loamy fine sand	SM	A–2
		11–50	Fine sand	SP–SM	A–3 or A–2
Isanti: Im	0–2	0–11	Mucky loamy fine sand	SM	A–2
		11–60	Fine sand	SP–SM	A–2
Isanti variant: It	0–3	0–18	Mucky loamy fine sand	SM	A–2
		18–32	Fine sand	SP–SM	A–2
		32–47	Very fine sandy loam	ML	A–4
		47–60	Sand	SP–SM	A–1
Langola: LaA, LaB2	>10	0–24	Loamy fine sand	SM	A–2 or A–4
		24–31	Loamy sand	SP–SM	A–2
		31–60	Sandy loam	SM	A–2
Lino: Ln	2–4	0–10	Loamy fine sand	SM	A–2
		10–60	Fine sand	SP–SM	A–2
Lino variant: Lo	2–4	0–13	Loamy fine sand	SM	A–2
		13–27	Sand	SP–SM	A–2
		27–54	Fine sandy loam and silt loam	ML	A–4
		54–60	Sand	SP–SM	A–2
Marsh: Ma. Water table is at the surface; no other valid estimates can be made.					
Milaca:					
McB, McB2, McC, McC2, McE, MdB	10	0–10	Fine sandy loam	SM	A–4
		10–19	Fine sandy loam	SM	A–4
		19–40	Fine sandy loam (fragipan)	SM	A–2 or A–4
		40–72	Sandy loam (fragipan)	SM	A–2 or A–4
MfB, MhB	10	0–10	Very fine sandy loam	ML, SM	A–4
		10–19	Fine sandy loam	SM	A–4
		19–40	Fine sandy loam (fragipan)	SM	A–4
		40–72	Sandy loam (fragipan)	SM	A–4
Milaca variant: MlB	10	0–10	Fine sandy loam	SM, ML	A–4
		10–53	Clay loam	CL	A–4
		53–60	Sandy loam	SM	A–2 or A–4
Mora: MoA, MoB, MrA	10	0–12	Fine sandy loam	SM	A–4
		12–24	Fine sandy loam	SM	A–4
		24–75	Fine sandy loam (fragipan)	SM	A–2 or A–4
Mucky peat: Ms, Mu, Mx	0–3	(3)	Mucky peat	Pt	A–8
Nokasippi: Nm	0–3	0–9	Mucky loamy fine sand	SM	A–2
		9–25	Fine sand	SM	A–2
		25–38	Loam	ML	A–4
		38–60	Sandy loam	SM	A–2

significant in engineering—Continued

Percentage passing sieve—				Permeability	Available water capacity	Reaction	Shrink-swell potential
No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)				
				Inches per hour	*Inches per inch of soil*	*pH*	
100	100	85–95	65–85	0.63–2.0	0.20–0.22	5.6–6.0	Moderate.
100	100	85–95	65–85	0.63–2.0	0.20–0.22	6.1–6.5	Moderate.
70–80	70–80	40–60	5–10	>6.3	0.02–0.04	6.1–6.5	Low.
100	95–100	50–60	10–20	>6.3	0.10–0.12	5.6–6.0	Low.
100	95–100	50–70	5–10	>6.3	0.05–0.07	5.6–6.0	Low.
100	100	70–85	10–20	>6.3	0.10–0.12	5.1–6.0	Low.
100	100	65–80	5–15	>6.3	0.06–0.08	5.1–6.0	Low.
100	100	70–85	15–30	>6.3	0.10–0.12	5.1–6.0	Low.
100	100	65–80	5–15	>6.3	0.05–0.07	5.1–6.0	Low.
100	100	70–85	15–30	>6.3	0.10–0.12	6.1–6.8	Low.
100	100	65–80	5–15	>6.3	0.07–0.09	6.1–6.8	Low.
100	100	85–95	50–65	>6.3	0.17–0.19	6.1–6.8	Moderate.
100	100	50–70	5–10	>6.3	0.05–0.07	6.6–7.3	Low.
100	100	70–85	30–45	>6.3	0.10–0.12	6.1–6.5	Low.
100	100	65–80	20–35	>6.3	0.07–0.09	6.1–6.5	Low.
85–95	65–75	50–60	25–35	0.20–0.63	0.08–0.10	5.6–6.0	Low.
100	100	70–85	15–30	>6.3	0.10–0.12	5.1–5.5	Low.
100	100	65–80	5–15	>6.3	0.06–0.08	5.5–6.0	Low.
100	100	70–85	10–20	>6.3	0.10–0.12	5.6–6.0	Low.
100	95–100	50–70	5–10	>6.3	0.06–0.08	5.1–5.6	Low.
100	100	85–95	50–65	0.2–0.63	0.17–0.19	5.1–5.6	Moderate.
100	100	50–70	5–10	>6.3	0.05–0.07	6.1–6.5	Low.
90–100	90–100	80–90	40–50	0.63–2.0	0.16–0.18	5.6–6.0	Low.
90–100	80–90	60–70	40–50	0.63–2.0	0.15–0.17	5.6–6.0	Low.
70–80	65–75	50–60	25–45	0.20–0.63	[2] 0.08–0.10	5.6–6.0	Low.
80–90	75–85	60–70	25–45	0.20–0.63	0.08–0.10	5.6–6.0	Low.
95–100	95–100	85–95	45–60	0.63–2.0	0.20–0.22	5.6–6.0	Low to moderate.
80–90	75–85	60–70	35–50	0.20–0.63	0.15–0.17	5.6–6.0	Low.
70–80	65–75	50–60	35–50	0.20–0.63	[2] 0.08–0.10	5.6–6.0	Low.
70–80	65–75	50–60	35–45	0.20–0.63	0.08–0.10	5.6–6.0	Low.
95–100	85–95	70–85	40–55	0.63–2.0	0.15–0.17	5.6–6.0	Low.
100	90–100	90–100	70–80	0.63–2.0	0.14–0.19	6.1–7.3	Moderate.
80–90	75–85	60–70	30–45	0.63–2.0	0.11–0.13	6.1–7.3	Low.
90–100	90–100	80–90	40–50	0.63–2.0	0.16–0.18	6.1–6.5	Low to moderate.
90–95	80–90	70–80	35–50	0.20–0.63	0.15–0.17	6.1–6.5	Low.
85–95	80–90	70–80	30–45	0.20–0.63	[2] 0.08–0.10	6.1–6.5	Low.
([3])	([3])	([3])	([3])	([3])	0.25–0.45	([3])	([3])
100	100	70–85	15–30	>6.3	0.10–0.12	5.1–5.6	Low.
100	100	65–80	5–15	>6.3	0.06–0.08	5.6–6.0	Low.
95–100	90–100	90–95	50–60	0.63–2.0	0.17–0.19	5.6–6.0	Moderate.
80–90	65–75	50–60	25–35	0.20–0.63	0.11–0.13	6.6–7.3	Low.

TABLE 7.—*Estimates of soil properties*

Soil series and map symbols	Depth to water table	Depth from surface	USDA texture	Classification	
				Unified	AASHTO
	Feet	*Inches*			
Nokay: No, Ns	2–4	0–9	Fine sandy loam	SM	A–4
		9–22	Fine sandy loam	SM	A–4
		22–60	Sandy loam (fragipan)	SM	A–2
Ogilvie: Og	2–4	0–17	Silt loam	ML	A–4
		17–32	Loam	ML	A–4
		32–60	Coarse sand	SP–SM	A–1
Paget: PaA, PaB, PbA, PbB	10	0–17	Silt loam	ML	A–4
		17–23	Fine sandy loam	SM	A–4
		23–64	Fine sandy loam (fragipan)	SM	A–4
Parent: Pe, Pk	[1] 1–3	0–7	Loam	ML, CL, OL	A–4, A–2
		7–40	Fine sandy loam	SM	A–4
		40–60	Sandy loam	SM	A–2
Pomroy: PoB, PoC, PrA	10	0–11	Fine sand	SP–SM	A–2
		11–28	Fine sand	SM	A–2
		28–60	Sandy loam (fragipan)	SM	A–2
*Prebish: Ps, Pt, Pu	0–3	0–6	Loam	ML, CL	A–4
For Parent part of Pu, see Parent series.		6–46	Fine sandy loam	SM	A–4
		46–60	Sandy loam	SM	A–2
Ronneby: Rn, Ro	[1] 2–4	0–7	Loam	ML, CL	A–4
		7–33	Fine sandy loam	SM	A–2 or A–4
		33–61	Fine sandy loam (fragipan)	SM	A–2 or A–4
Sartell: SaA, SaB, SaC, SaE	10	0–4	Fine sand	SP–SM	A–2
		4–72	Fine sand	SP	A–2
Watab: Wa	[1] 2–4	0–15	Loamy fine sand	SM	A–2 or A–4
		15–33	Fine sandy loam	SM	A–2 or A–4
		33–60	Sandy loam (fragipan)	SM	A–2

[1] This soil has a perched water table. A perched water table is one where percolating soil water encounters a soil material that is not so pervious as the material above. The true water table in these soils may be many feet deeper.

degree of limitation and the principal reasons for assigning moderate or severe limitations are given.

Sewage lagoons are influenced chiefly by soil features such as permeability, location of water table, slope, content of coarse fragments, organic-matter content, and reservoir site material.

Sanitary landfill is a method of disposing of solid wastes on or in the soil by spreading the waste in thin layers, compacting it to the smallest practical volume, and covering it with soil each day in a manner that provides maximum protection of the environment.

Town and Country Planning

The suburbs of St. Cloud and Sauk Rapids are steadily expanding into areas in the western part of Benton County that were formerly used for farming. As the population increases in these areas, so does the demand for homes, shopping centers, schools, churches, parks, golf courses, and other community developments. The suitability or the limitations of the soils must be considered before selecting a site for a residence, a highway, or an industrial facility. The best sites generally are nearly level to gently sloping, deep, well-drained soils that are relatively free of stones and boulders. The main factors considered are depth to water table, bearing strength, volume change (shrink-swell potential), frost heave, and flooding. Only the underlying material is evaluated in an undisturbed condition to determine its ability to support foundations for buildings of 3 stories or less.

The limitations of the soils for use as septic tank absorption fields are important because most of the suburban developments are in areas beyond existing sewerage lines. Each site should be examined closely to determine the capacity of the soil to absorb and filter effluent from septic tanks (*9*). Some soils absorb effluent rapidly; others absorb it very slowly. Soils that have a slow rate of absorption require a larger absorption field than those that have a rapid rate. Most septic tank failures occur because the soils are poorly drained or are dense, compact, or fine textured. In wet weather and for long periods afterwards, such soils are saturated and do not absorb effluent from septic tanks. Other causes

significant in engineering—Continued

Percentage passing sieve—				Permeability	Available water capacity	Reaction	Shrink-swell potential
No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)				
				Inches per hour	*Inches per inch of soil*	*pH*	
95–100	85–95	65–75	40–50	0.63–2.0	0.16–0.18	5.1–5.6	Low.
90–95	80–90	65–75	40–50	0.63–2.0	0.15–0.17	5.6–6.0	Low.
80–90	80–90	60–70	25–35	0.20–0.63	[2] 0.08–0.10	5.6–6.0	Low.
100	100	90–100	70–80	0.63–2.0	0.22–0.24	5.1–5.6	Moderate.
100	100	85–95	60–75	0.63–2.0	0.17–0.19	5.1–5.6	Moderate.
100	100	50–70	5–10	>6.3	0.02–0.04	5.1–5.6	Low.
95–100	95–100	80–95	70–90	0.63–2.0	0.22–0.24	5.6–6.0	Moderate.
85–95	80–90	70–85	35–50	0.63–2.0	0.17–0.19	6.1–6.5	Low.
70–80	65–75	70–85	35–50	0.20–0.63	[3] 0.08–0.10	6.1–7.3	Low.
90–100	90–100	80–95	50–65	0.63–2.0	0.20–0.22	6.6–7.3	Moderate.
85–95	80–90	70–85	30–50	0.63–2.0	0.15–0.17	6.6–7.3	Low.
85–95	80–90	60–75	25–35	0.06–0.63	0.11–0.13	6.6–7.3	Low.
100	100	65–80	5–15	>6.3	0.07–0.09	5.6–6.0	Low.
100	100	75–85	10–20	>6.3	[3] 0.06–0.08	5.6–6.0	Low.
70–80	65–75	50–60	25–35	0.20–0.63	0.08–0.10	5.6–6.5	Low.
95–100	95–100	80–90	50–65	0.63–2.0	0.20–0.22	6.6–7.3	Moderate.
80–90	75–85	60–70	35–50	0.20–0.63	0.15–0.17	6.6–7.3	Low.
70–80	65–75	50–60	25–35	0.20–0.63	0.11–0.13	6.6–7.3	Low.
90–100	90–100	85–95	50–65	0.63–2.0	0.20–0.22	5.6–6.0	Moderate.
90–95	80–90	70–80	35–50	0.63–2.0	0.15–0.17	5.6–6.0	Low.
85–95	80–90	70–80	35–45	0.20–0.63	[3] 0.08–0.10	5.6–6.5	Low.
100	100	75–85	5–10	>6.3	0.10–0.12	5.1–5.6	Low.
100	100	75–85	0–5	>6.3	0.05–0.08	5.1–6.0	Low.
100	100	75–85	30–45	>6.3	0.10–0.12	5.1–5.5	Low.
90–95	65–75	60–75	35–50	0.63–2.0	0.15–0.17	5.1–6.0	Low.
70–80	65–75	50–60	25–35	0.20–0.63	[3] 0.08–0.10	6.1–6.5	Low.

[2] The available water capacity for fragipan and underlying layers is reduced because roots are restricted and not all water is available to them.

[3] Variable.

of failure are slopes of more than 12 percent, a seasonal high water table, flooding, shallowness to bedrock, or a dense, compact, or cemented substratum. A percolation test, which measures the rate of water moving through the soil, indicates the degree of limitation and also provides the information needed to calculate the size of the absorption field.

In general, absorption fields require soils in which the water table remains at least 4 feet below the absorption-field tile lines in all seasons and soils that are not subject to flooding. The percolation rate should be less than 60 minutes per inch. Slower rates may cause effluent to rise to the surface and overflow, causing conditions that may be dangerous to public health. A high percolation rate may permit contamination of ground water. Absorption field problems are common in the county because of inadequate design of absorption systems, poor installation, and soils that predominantly have moderately slow permeability. In other places, in sandy soils, effluent travels long distances and has contaminated wells, lakes, and streams (*12*).

The soils of Benton County are generally not well suited to absorption fields, because many of the soils are poorly drained, have a seasonal high water table, are sandy and gravelly, or have a slow percolation rate. Strong consideration should be given to installing public sewer systems in areas of intensive development. Table 8 assigns a limitation rating and summarizes the interpretations of Benton County soils for septic tank absorption fields.

A sanitary landfill is a waste disposal area that is operated in such a way that odor, smoke, rodents, insect pests, blowing paper, and water pollution are avoided. Soil is used as a covering and sanitizing material. The solid waste is placed in contact with the soil either in a trench or on an area where some of the soil has been removed. It is compacted, and each day's deposit is covered with 6 inches of soil. Several alternate layers of waste and soil can be built up. The final cover of the completed landfill must be at least 2 feet of soil. Material placed in a sanitary landfill starts decomposing almost at once, and it produces gases, liquids, and heat as products of biochemical decomposition. The composition of these by-products of sanitary landfill depends on

TABLE 8.—*Engineering*

[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. The instructions for referring to other series

Soil series and map symbols	Suitability as source of—			Soil features affecting—	
	Topsoil	Mixed sand and gravel	Road fill	Local roads and streets	Agricultural drainage
Adolph: Ad, AdA	Poor: very poorly drained. Good where drained.	Not suitable	Good for subbase: low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	High organic-matter content in surface layer: perched water table; often ponded; needs artificial drainage; moderate susceptibility to frost action; stony.	Low, wet areas; moderately slow permeability; perched water table at a depth of 0 to 3 feet; often ponded; firm underlying till many feet thick; no well-developed drainage outlets.
Adolph variant: Ah	Poor: very poorly drained and poorly drained. Good where drained.	Not suitable	Poor for subbase: low to moderate shrink-swell potential, shear strength, and bearing capacity; poor stability.	Very poorly drained and poorly drained; high organic-matter content in surface layer; perched water table; often ponded; needs artificial drainage; high susceptibility to frost action.	Low, wet areas; slow to moderately slow permeability; perched water table at a depth of 0 to 3 feet; often ponded; poor stability in ditchbanks.
Alluvial land: Ao	Variable: onsite inspection needed.	Not suitable	Poor to fair for subbase: onsite inspection needed.	Subject to flooding; moderate susceptibility to frost action.	Low, wet areas adjacent to rivers and streams; high water table at a depth of 0 to 3 feet; subject to flooding.
Antigo: AtA, AtB	Fair: sand and gravel below a depth of about 20 inches.	Good: good source of coarse sand and fine gravel at a depth of 2 to 3 feet.	Good for subbase: high shear strength and bearing capacity; low shrink-swell potential and compressibility; good workability.	Well drained; coarse underlying material provides good subbase; good stability, free of slippage; low susceptibility to frost action.	Well drained [2]
Blomford: Bd	Poor: loamy surface layer; wet below a depth of 2 to 4 feet at times.	Poor for fine and medium sand: well sorted; limited quantity. Not suitable for cement.	Poor for subbase: low to moderate shrink-swell potential, shear strength, and bearing capacity; poor stability.	Poorly drained; needs artificial drainage; underlying material highly susceptible to frost action.	Low, level areas; moderately slow permeability; perched water table at a depth of 2 to 4 feet; poor stability in ditchbanks.

interpretations

soils in such mapping units may have different properties and limitations, and for this reason it is necessary to follow carefully the that appear in the first column of this table]

Soil features affecting—Continued			Degree and kind of limitation for—			
Irrigation (sprinkler)	Terraces and diversions	Waterways	Dwellings with basements	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]
Needs drainage [2]	Nearly level; slight hazard of erosion.[2]	Needs tile or open-ditch drainage.[2]	Severe: perched water table; seasonally ponded; septic tank absorption fields fail; foundations settle; lawns, trees, and shrubs drown.	Severe: water table at a depth of 0 to 3 feet; moderately slow permeability; percolation rate slower than 100 minutes per inch.	Severe: surface runoff should be diverted from the lagoon; surface layer high in organic-matter content; high water table.	Severe: high water table; moderately slow percolation.
Needs drainage [2]	Nearly level; slight hazard of erosion.[2]	High water table; needs drainage before waterway is built and vegetation is planted.	Severe: very poorly drained and poorly drained; seasonally ponded; septic tank absorption fields fail; foundations settle.	Severe: water table at a depth of 0 to 3 feet; moderately slow permeability; percolation rate slower than 100 minutes per inch.	Severe: basin floor almost impervious if scarified and compacted with soil material classified as GC, SC, or SM.	Severe: very poorly drained and poorly drained; high water table; moderately slow percolation.
Needs protection from flooding in areas.[2]	Nearly level [2]	High water table; occasional to frequent flooding; needs drainage before waterway is built and vegetation is planted.	Severe: occasional to frequent flooding.	Severe: subject to flooding; percolation variable.	Severe: subject to flooding; high permeability.	Severe: somewhat poorly drained; high water table; occasionally to frequently flooded.
Moderate available water capacity; moderate permeability in upper part and rapid in lower part; well drained; slope of 0 to 6 percent.	Gravelly substratum at a depth of 2 to 3 feet is droughty and highly erodible if exposed; fair slope pattern.	Gravelly substratum at a depth of 2 to 3 feet is droughty and erodible if exposed; low fertility in substratum.	Slight [3]	Slight: hazard of contamination to nearby water supplies; percolation rate is 30 to 100 minutes per inch in upper part and 10 minutes per inch or faster in lower part.	Severe: rapid permeability in underlying material.	Severe: risk of free flow to ground water.
Needs drainage; high available water capacity; rapid water intake; rapid permeability in upper part and moderately slow in lower part; somewhat poorly drained; slope of 0 to 2 percent.	Sandy soil; slope.[2]	Sandy soil; seasonal high water table; droughty and erodible; low fertility; vegetation difficult to establish.	Severe: somewhat poorly drained; perched water table at a depth of 2 to 4 feet; septic tank absorption fields fail occasionally.	Severe: somewhat poorly drained; perched water table that fluctuates between depths of 2 and 4 feet; percolation rate is 30 to 100 minutes per inch in lower part.	Severe: rapid permeability to a depth of 2 to 3 feet; low resistance to piping.	Severe: somewhat poorly drained; less than 10 feet to seasonal water table; loamy sand surface layer.

TABLE 8.—*Engineering*

Soil series and map symbols	Suitability as source of—			Soil features affecting—	
	Topsoil	Mixed sand and gravel	Road fill	Local roads and streets	Agricultural drainage
Braham: BhC	Poor to a depth of 20 to 30 inches; fair below a depth of 30 inches: slope of 8 percent in places.	Poor source of fine and medium sand: well sorted; limited quantity. Not suitable for cement.	Poor for subbase: low to moderate shrink-swell potential, shear strength, and bearing capacity; poor stability.	Well drained; good stability in upper 2 to 3 feet when confined; moderate susceptibility to frost action; highly erodible if exposed on embankments.	Well drained [2]
Brainerd: BrA, BrB, BsA, BsB.	Fair to a depth of 24 inches; poor below a depth of 24 inches: some stones.	Not suitable	Good for subbase: low shrink-swell potential; medium shear strength, compressibility, and bearing capacity; fair stability.	Moderately well drained; more drainage needed to stabilize roadbed; moderate susceptibility to frost action; stones.	Moderately well drained.[2]
Burkhardt: BuA, BuB	Fair to a depth of about 20 inches; unsuitable below a depth of 20 inches.	Good for well-graded sand and gravel at a depth of 16 to 21 inches.	Good for subbase: low shrink-swell potential and compressibility; high shear strength and bearing capacity; moderately rapid permeability; good workability; reasonable stability.	Somewhat excessively drained; coarse underlying material provides good subbase; good stability; free of slippage; low susceptibility to frost action.	Somewhat excessively drained.[2]
*Chetek: CeB, CeC	Poor in sandy surface layer; unsuitable below the surface layer: slope of 12 percent in places.	Good for well-graded to poorly graded coarse sand and gravel.	Good for subbase: variable in quality and compressibility.	Somewhat excessively drained; underlying material good for subbase; low susceptibility to frost action.	Somewhat excessively drained.[2]
ChA, ChB, ChB2, ChC, CmB, CmC. For Milaca part of CmB and CmC, see Milaca series.	Fair to a depth of about 20 inches; unsuitable below a depth of 20 inches: some stones; slope of 15 percent in places.	Good for well-graded to poorly graded sand and gravel.	Good for subbase: surface layer compacts for base; easily erodible shoulders.	Somewhat excessively drained; underlying material is good for subbase; stable; low susceptibility to frost action.	Somewhat excessively drained.[2]

interpretations—Continued

Soil features affecting—Continued			Degree and kind of limitation for—			
Irrigation (sprinkler)	Terraces and diversions	Waterways	Dwellings with basements	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]
Moderate available water capacity; rapid intake rate; rapid permeability in upper part and moderately slow in lower part; well drained; slope of 2 to 8 percent.	Sandy soil; highly erodible; low in fertility and in organic-matter content; droughty; vegetation difficult to establish.	Sandy soil; highly erodible; low in fertility; droughty; vegetation difficult to establish.	Slight where slope is less than 6 percent. Moderate where slope is more than 6 percent.	Moderate: moderately slow permeability in underlying material; percolation rate is 30 to 100 minutes per inch in lower part in most places.	Severe: rapid permeability in upper 2 to 3 feet; low resistance to piping.	Moderate: moderately slow percolation rate; slope.
Moderate available water capacity; moderately slow permeability; moderately well drained; slope of 1 to 5 percent.	Moderately well drained; moderately erodible; stones and boulders; good slope pattern.	Moderately erodible; stones and boulders limit construction; low in fertility in substratum.	Moderate: stones in places.	Severe: moderately slow permeability; percolation rate is slower than 100 minutes per inch.	Moderate: basin floor material is almost impervious when scarified and compacted.	Moderate: moderately well drained; moderately slow percolation rate.
Low available water capacity; rapid water intake; shallow to sand and gravel; moderately rapid permeability in upper part and rapid in underlying material.	Shallow to sand and gravel; terrace channels are droughty and erodible; poor to fair slope pattern; low in fertility.	Shallow to sand and gravel; vegetation difficult to establish where exposed; droughty; low in fertility.	Slight: no limiting factors.	Slight: no limiting factors, but a hazard of contamination to nearby water supplies; percolation rate is 10 minutes per inch or faster in lower part.	Severe: rapid permeability in underlying material.	Severe: rapid percolation rate; sandy and gravelly texture in lower part; risk of free flow to ground water.
Low available water capacity; very rapid water intake; very shallow to sand and gravel; moderately rapid permeability; excessively drained; slope of 2 to 12 percent.	Very shallow to gravel and sand; vegetation very difficult to establish.[2]	Very shallow to sand and gravel; vegetation difficult to establish where exposed; very droughty; low in fertility.	Generally slight. Moderate where slope is more than 6 percent: some difficulty with lawns, trees, and shrubs because of droughtiness.	Generally slight: no limiting factors, but a hazard of contamination to nearby water supplies. Moderate where slope is 6 to 12 percent: percolation rate of 10 minutes per inch or faster in lower part.	Severe: rapid permeability in underlying material; some slopes are more than 7 percent.	Severe: rapid percolation rate; sandy and gravelly in lower part; risk of free flow to ground water.
Low available water capacity; rapid water intake; shallow to sand and gravel; moderately rapid permeability in the upper part and rapid in the lower part; somewhat excessively drained; slope of 0 to 15 percent.	Shallow to sand and gravel; terrace channels are droughty and erodible; poor slope pattern; low in fertility.	Shallow to sand and gravel; vegetation difficult to establish where exposed; droughty; low in fertility.	Generally slight. Moderate where slope is more than 6 percent: some difficulty with lawns, trees, and shrubs because of droughtiness.	Generally slight: no limiting factors but a hazard of contamination to nearby water supplies. Moderate where slope is 6 to 12 percent: percolation rate of 10 minutes per inch or faster in lower part.	Severe: rapid permeability in underlying material; some slopes are more than 7 percent.	Severe: rapid percolation rate; sandy and gravelly in lower part; risk of free flow to ground water.

TABLE 8.—*Engineering*

Soil series and map symbols	Suitability as source of—			Soil features affecting—	
	Topsoil	Mixed sand and gravel	Road fill	Local roads and streets	Agricultural drainage
Dalbo: DaA, DbB	Good to a depth of about 10 to 16 inches; fair below a depth of 16 inches.	Not suitable	Poor for subbase: moderate shrink-swell potential, shear strength, and bearing capacity; poor stability.	Well drained and moderately well drained; poor subbase; poor stability; severe susceptibility to frost action.	Moderately well drained and well drained.[2]
Dickman: DcA	Fair to a depth of about 8 to 14 inches; unsuitable below a depth of 14 inches.	Good for medium and coarse sand: poorly graded; wash for concrete.	Good for subbase: medium shear strength; good compressibility.	Somewhat excessively drained; underlying material good for subbase; stable; moderate susceptibility to frost action.	Somewhat excessively drained.[2]
Duelm: Du	Poor: loamy sand surface layer that grades to loose sand; commonly wet at a depth of 2 to 4 feet.	Fair for medium and coarse sand; poor for gravel: fine in size; needs washing for use in concrete.	Good for subbase: good bearing capacity and shear strength; low shrink-swell potential; high water table.	Poorly drained; artificial drainage needed; high water table; underlying material good for subbase; low susceptibility to frost action; highly erodible.	Low, level areas; permeability is rapid; slow internal drainage because high water table is at a depth of 2 to 4 feet; unstable ditchbanks.
Emmert: EmE	Poor: thin sandy and gravelly surface layer; unsuitable below the surface layer; slope is as much as 25 percent.	Good for gravel	Good for road subbase: good bearing capacity; low shrink-swell potential.	Excessively drained; good for subbase material; good stability; free of slippage; low susceptibility to frost action.	Excessively drained.[2]
Flak: FlB, FlB2, FlC, FlC2	Fair to a depth of about 20 inches; poor below a depth of 20 inches.	Not suitable	Good for subbase: fair workability; reasonable stability.	Well drained; moderate susceptibility to frost action; stones; embankments subject to moderate erosion.	Well drained[2]
Freer: Fr, Fs	Good to a depth of 30 inches; fair below a depth of 30 inches: some stones.	Not suitable	Fair for subbase: medium to high consolidation; medium to low bearing capacity, shear strength, and compressibility.	Somewhat poorly drained; artificial drainage needed; perched water table; moderate susceptibility to frost action; stones.	Low, level areas; moderately slow permeability; perched water table at a depth of 2 to 4 feet; firm underlying till material many feet thick.

interpretations—Continued

Soil features affecting—Continued			Degree and kind of limitation for—			
Irrigation (sprinkler)	Terraces and diversions	Waterways	Dwellings with basements	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]
Very high available water capacity; medium water intake; moderately slow permeability; moderately well drained; slope of 0 to 8 percent.[2]	Moderately slow permeability; slight grade to terrace channels is essential.	Subsoil difficult to vegetate in places during a period of prolonged wetness.	Moderate: moderate limitation for foundations.	Severe: moderately slow permeability; percolation rate slower than 100 minutes per inch.	Moderate: basin floor material becomes nearly impervious if scarified and compacted with soils classified as GC, SC, or SM; some slopes are more than 2 percent.	Moderate: well drained and moderately well drained; moderately slow percolation rate; some slopes are more than 6 percent.
Low available water capacity; rapid water intake; rapid permeability; somewhat excessively drained; slope of 0 to 2 percent.	Not needed; nearly level.	Shallow, coarse sand; vegetation difficult to establish where exposed; droughty; low in fertility.	Slight: some problem with trees, shrubs, and lawns because of droughtiness.[3]	Slight: hazard of contamination to nearby water supplies; percolation rate of 10 minutes per inch or faster in lower part.[3]	Severe: rapid permeability; underlying material; poor resistance to piping.	Severe: rapid percolation in lower part; sandy texture in lower part; risk of free flow to ground water.
Not needed unless drained; moderate available water capacity; rapid water intake; rapid permeability; somewhat poorly drained; slope of 0 to 2 percent.	Nearly level[2] ---	Seasonal high water table; low in fertility; droughty during most of growing season.	Severe: somewhat poorly drained; seasonal high water table at a depth of 2 to 4 feet; severe limitation for foundations.	Severe: somewhat poorly drained; hazard of contamination to nearby water supplies; percolation rate of 10 minutes per inch or faster.	Severe: rapid permeability; poor resistance to piping.	Severe: somewhat poorly drained; water table at a depth of less than 10 feet; rapid percolation rate; loamy sand and sand texture; risk of free flow to ground water.
Very low available water capacity; rapid water intake; very rapid permeability; excessively drained; slope of 6 to 25 percent.	Very shallow to gravel; erodible where exposed; vegetation very difficult to establish.	Very shallow to gravel; very droughty; very low in fertility; some steep slopes; vegetation very hard to establish.	Moderate if slope is 6 to 12 percent; severe if slope is more than 12 percent: very droughty for lawns, trees, and shrubs.	Slight: hazard of contamination to nearby water supplies; percolation rate of 10 minutes per inch or faster.[3]	Severe: very rapid permeability; all slopes are more than 7 percent.	Severe: excessively drained; rapid percolation; sand and gravel texture; slope; risk of free flow to ground water.
Moderate available water capacity; rapid water intake; moderately slow permeability; well drained; slope of 2 to 12 percent.	Most soil features favorable; good slope pattern; stones and boulders are a hazard; some cuts and fills needed for good alinement.	Substratum has low fertility; stones and boulders; some steep slopes.	Slight if slope is 0 to 6 percent; moderate if slope is more than 6 percent.	Severe: moderately slow permeability; percolation rate slower than 100 minutes per inch; slope of more than 6 percent.	Moderate where slope is less than 7 percent: basin floor material is almost impervious if scarified and compacted. Severe if slope is more than 7 percent.	Moderate: moderately slow percolation rate; slope of more than 6 to 12 percent.
Drainage needed.[2]	Nearly level; slight hazard of erosion.[2]	High water table; drainage aids in construction and in vegetation.	Severe: somewhat poorly drained; severe limitation for foundations.	Severe: somewhat poorly drained; perched water table that fluctuates between depths of 2 and 4 feet; percolation rate is slower than 100 minutes per inch.	Moderate: basin floor material is almost impervious if scarified and compacted.	Severe: somewhat poorly drained; water table at a depth of less than 10 feet.

TABLE 8.—*Engineering*

Soil series and map symbols	Suitability as source of—			Soil features affecting—	
	Topsoil	Mixed sand and gravel	Road fill	Local roads and streets	Agricultural drainage
Granite rock land: Gr. No interpretations: material not suited to most uses.					
Hillet: Hm, HmA	Poor: poorly drained and very poorly drained. Good to a depth of 24 to 30 inches if drained.	Suitable for gravel below a depth of 2½ to 3 feet: difficult to excavate because of high water table.	Good for subbase: high bearing capacity and shear strength; low compressibility.	Very poorly drained and poorly drained; surface layer is high in organic-matter content; high water table, seasonally ponded; artificial drainage needed; low susceptibility to frost action.	Low, level and depressional areas; moderate permeability in upper 2 to 3 feet, rapid below; high water table at a depth of 0 to 3 feet; seasonally ponded; outlets not well developed.
Hubbard: HoA, HoA2, HoB, HoB2, HrA, HrA2, HrB, HrB2, HsC2, HsE.	Poor in sandy surface layer; unsuitable below surface layer.	Good for sand: well sorted.	Good for subbase: low shrink-swell potential and low compressibility; medium to high bearing capacity, shear strength, and permeability; very erodible.	Excessively drained; underlying material good as subbase; low susceptibility to frost action; highly erodible embankments; loose sand hinders hauling operations.	Excessively drained.[2]
Isanti: Im	Poor in loamy sand surface layer: loose sand below; very poorly drained.	Good for fine and medium sand: difficult to excavate because of high water table.	Suitable for subbase: low shrink-swell potential; medium to high bearing capacity; very erodible.	Very poorly drained; high water table; artificial drainage needed; low to moderate susceptibility to frost action; highly erodible embankments.	Low, wet areas; permeability is rapid; high water table at a depth of 0 to 2 feet; seasonally ponded; unstable ditchbanks.
Isanti variant: It	Poor in loamy sand surface layer: loose sand below that has layers of loamy material; very poorly drained.	Fair to poor for sand; not suitable for gravel: difficult to excavate because of high water table; limited quantity.	Good for subbase: medium to high consolidation; variable in physical properties.	Very poorly drained; high water table; artificial drainage needed; moderate susceptibility to frost action; highly erodible embankments.	Low, wet areas; permeability is moderate; high water table at a depth of 0 to 3 feet; seasonally ponded; unstable ditchbanks.
Langola: LaA, LaB2	Poor in sandy surface layer; fair to poor below a depth of 20 to 30 inches.	Fair for medium and fine sand to a depth of 18 to 30 inches.	Good for subbase: low shrink-swell potential; medium to high shear strength and bearing capacity.	Well drained to moderately well drained; fair stability in upper 2 to 3 feet; moderate susceptibility to frost action; stones below a depth of 2 to 3 feet.	Well drained to moderately well drained.

interpretations—Continued

Soil features affecting—Continued			Degree and kind of limitation for—			
Irrigation (sprinkler)	Terraces and diversions	Waterways	Dwellings with basements	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]
Drainage needed.[2]	Nearly level; slight hazard of erosion.[2]	Open-ditch drainage needed.[2]	Severe: very poorly drained and poorly drained; high water table at a depth of 0 to 3 feet; seasonally ponded.	Severe: water table at a depth of 0 to 3 feet; very poorly drained; percolation rate faster than 10 minutes per inch in lower part.	Severe: rapid permeability in underlying material.	Severe: very poorly drained and poorly drained; water table at a depth of less than 10 feet; risk of free flow to ground water.
Low available water capacity; very rapid water intake; rapid permeability; excessively drained; slope of 0 to 25 percent.	Sandy; highly erodible; low in fertility; poor workability; vegetation difficult to establish.	Sandy; highly erodible; droughty; slope ranges from 0 to 25 percent; poor workability; vegetation difficult to establish.	Slight if slope is 0 to 6 percent; moderate if slope is 6 to 12 percent; and severe if slope is more than 12 percent: droughty.	Slight if slope is 0 to 6 percent; moderate if slope is 6 to 12 percent; and severe if slope is more than 12 percent: hazard of downslope flow and lateral seepage; percolation rate of 10 minutes per inch or faster.	Severe: rapid permeability; slope of more than 7 percent in places; poor resistance to piping.	Severe: excessively drained; rapid percolation; sandy texture; slope of more than 12 percent; risk of free flow to ground water.
Not needed unless drained; low available water capacity; rapid water intake; rapid permeability; very poorly drained; slope of 0 to 1 percent.	Nearly level; slight hazard of erosion.[2]	Open-ditch drainage needed.[2]	Severe: very poorly drained; high water table at a depth of 0 to 2 feet; seasonally ponded.	Severe: water table at a depth of 0 to 2 feet; very poorly drained; percolation rate faster than 10 minutes per inch.	Severe: rapid permeability; poor resistance to piping.	Severe: very poorly drained; water table at a depth of less than 10 feet; rapid percolation rate; risk of free flow to ground water.
Not needed unless drained; moderate available water capacity; rapid water intake; moderate permeability; very poorly drained; slope of 0 to 1 percent.	Nearly level; slight hazard of erosion.[2]	Open-ditch drainage needed.	Severe: very poorly drained; high water table at a depth of 0 to 3 feet; seasonally ponded.	Severe: water table at a depth of 0 to 3 feet; very poorly drained; percolation rate ranges from 10 minutes per inch to 100 minutes per inch.	Severe: moderate permeability; poor resistance to piping.	Severe: very poorly drained; water table at a depth of less than 10 feet; moderately slow percolation rate; risk of free flow to ground water.
Moderate available water capacity; rapid water intake; rapid permeability in upper part and moderately slow permeability in lower part; well drained to moderately well drained; slopes of 0 to 6 percent.	Sandy soil; highly erodible; low in fertility; vegetation difficult to establish.	Sandy soil; highly erodible; low in fertility; droughty; vegetation difficult to establish.	Slight	Severe: moderately slow permeability in lower part; percolation rate slower than 100 minutes per inch.	Severe: rapid permeability in upper 2 to 3 feet; low resistance to piping.	Moderate: well drained to moderately well drained; moderately slow percolation rate in lower part; loamy sand in upper part.

TABLE 8.—*Engineering*

Soil series and map symbols	Suitability as source of—			Soil features affecting—	
	Topsoil	Mixed sand and gravel	Road fill	Local roads and streets	Agricultural drainage
Lino: Ln	Poor in loamy sand surface layer: loose sand below; commonly wet at a depth of 2 to 4 feet.	Good for fine and medium sand: some difficulty of excavation because of high water table.	Good for subbase and base fill: high shear strength; poor to medium compressibility.	Somewhat poorly drained; high water table; artificial drainage needed; low susceptibility to frost action where properly drained.	Low, level areas; permeability is rapid; slow internal drainage because high water table is at a depth of 2 to 4 feet; unstable ditchbanks.
Lino variant: Lo	Poor in the sandy surface layer and subsoil: commonly wet at a depth of 2 to 4 feet.	Fair for fine sand to a depth of 24 inches: some difficulty of excavation because of high water table; some bands of finer textured material beneath.	Good for subbase: medium to high consolidation; variable in physical properties.	Somewhat poorly drained; high water table; artificial drainage needed; low susceptibility to frost action where properly drained.	Low, sandy areas; permeability is moderate because of the layers of finer textured material in substratum; high water table at a depth of 2 to 4 feet; unstable ditchbanks.
Marsh: Ma. No interpretations: material variable.					
Milaca: McB, McB2, McC, McC2, McE, MdB, MfB, MhB.	Fair to good to a depth of 20 inches; poor below a depth of 20 inches: some stones; some steep soils.	Not suitable	Good for subbase: low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Well drained; surface drainage needed to maintain stability; moderate susceptibility to frost action; stones.	Well drained [3]
Milaca variant: MlB	Good to a depth of 10 inches; fair to poor below a depth of 10 inches: some stones.	Not suitable	Poor for subbase: moderate shrink-swell potential; low to medium bearing capacity and shear strength.	Well drained; moderate to high volume change; fair to good workability; stable embankments; moderate to high susceptibility to frost action.	Well drained [3]
Mora: MoA, MoB, MrA	Good to a depth of 24 inches; fair to poor below a depth of 24 inches: some stones.	Not suitable	Good for subbase: low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Moderately well drained; drainage needed to stabilize roadbed; moderate susceptibility to frost action; stones.	Moderately well drained.[3]

interpretations—Continued

Soil features affecting—Continued			Degree and kind of limitation for—			
Irrigation (sprinkler)	Terraces and diversions	Waterways	Dwellings with basements	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]
Not needed unless drained; low available water capacity; rapid water intake; rapid permeability; somewhat poorly drained; slopes of 0 to 2 percent.	Sandy soil; generally not needed because of topographic position.	Sandy soil; high water table; droughty and erodible; low in fertility; vegetation difficult to establish.	Severe: somewhat poorly drained; seasonal high water table at a depth of 2 to 4 feet; severe limitations for foundations.	Severe: somewhat poorly drained; hazard of contamination of nearby water supplies; percolation rate is 10 minutes per inch or faster.	Severe: rapid permeability; poor resistance to piping.	Severe: somewhat poorly drained; high water table at a depth of less than 10 feet; rapid percolation rate; sandy texture; risk of free flow to ground water.
Not needed unless drained; moderate available water capacity; rapid water intake; moderate permeability; somewhat poorly drained; slopes of 0 to 2 percent.	Sandy soil; generally not needed because of topographic position.	Sandy soil; high water table; droughty and erodible; low in fertility; vegetation difficult to establish.	Severe: somewhat poorly drained; high water table at a depth of 2 to 4 feet; severe limitations for foundations.	Severe: somewhat poorly drained; hazard of contamination of nearby water supplies; percolation rate ranges from 10 minutes per inch to 100 minutes per inch.	Moderate: moderate permeability; slopes of 0 to 2 percent; low in organic-matter content.	Severe: somewhat poorly drained; high water table at a depth of less than 10 feet; some risk of free flow to ground water.
Moderate available water capacity; rapid water intake; moderately slow permeability; well drained; slopes of 2 to 25 percent.	Well drained; moderately erodible; stones and boulders; good slope pattern.	Moderately erodible; stones and boulders limit construction; low fertility in substratum.	Moderate where stones are a limitation in places. Severe where slopes are more than 12 percent.	Severe: moderately slow permeability; hazard of downslope flow and lateral seepage where slopes are more than 12 percent; percolation rate slower than 100 minutes per inch.	Moderate: basin floor material is nearly impervious if scarified and compacted. Severe if slope is more than 7 percent.	Moderate: moderately slow percolation rate; slopes of 6 to 12 percent.
Moderate to high available water capacity; rapid water intake; moderate permeability; well drained; slopes of 1 to 6 percent.	Well drained; moderately erodible; good slope pattern.	Moderately erodible; some stones and boulders.	Moderate: moderate limitation for foundations.	Moderate: moderate permeability; percolation rate of 30 to 100 minutes per inch.	Moderate: basin floor material is nearly impervious if scarified and compacted.	Slight.
Moderate available water capacity; rapid water intake; moderately slow permeability; moderately well drained; slopes of 1 to 5 percent.	Moderately well drained; moderately erodible; good slope pattern.	Moderately erodible; stones and boulders limit construction; low fertility in substratum.	Moderate: stones are a limitation in places.	Severe: moderately slow permeability; percolation rate slower than 100 minutes per inch.	Moderate: basin floor material is nearly impervious if scarified and compacted.	Moderate: moderately well drained; moderately slow percolation rate.

TABLE 8.—*Engineering*

Soil series and map symbols	Suitability as source of—			Soil features affecting—	
	Topsoil	Mixed sand and gravel	Road fill	Local roads and streets	Agricultural drainage
Mucky peat: Ms, Mu, Mx.	Poor: very poorly drained; very high content of organic matter. Fair to good if drained and mixed with mineral materials.	Not suitable	Not suitable: all mucky peat must be removed from construction zone.	Very poorly drained; high water table; sometimes ponded; avoid using these areas for highways; if used for highway location, remove all organic material to depth of underlying mineral material; artificial drainage necessary.	Low, wet, depressional areas; moderate permeability to moderately rapid permeability; high water table; unstable ditchbanks; no well-developed drainage outlets.
Nokasippi: Nm	Poor: loamy sand in upper 24 inches; very poorly drained.	Poor for fine and medium sand to a depth of 18 to 30 inches: difficult to excavate because of high water table; limited quantity.	Good for subbase: low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Very poorly drained; perched water table; artificial drainage needed; moderate susceptibility to frost action; stones below a depth of 2 to 3 feet.	Low, wet, depressional areas; moderately slow permeability in underlying firm till; perched water table; seasonally ponded.
Nokay: No, Ns	Good to a depth of 20 inches; fair to poor below a depth of 20 inches: some stones; often wet at a depth of 2 to 4 feet.	Not suitable	Good for subbase: low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Somewhat poorly drained; perched water table; artificial drainage necessary; moderate susceptibility to frost action; stones.	Low, level areas; moderately slow permeability; compact layer in subsoil impedes water movement; perched water table at a depth of 2 to 4 feet; firm underlying till many feet thick.
Ogilvie: Og	Good to a depth of 30 inches; unsuitable below a depth of 30 inches: often wet at a depth of 2 to 4 feet.	Good for coarse sand and fine gravel at a depth of 2 to 3 feet: difficult to excavate because of high water table.	Good for subbase: low shrink-swell potential; high shear strength; low compressibility.	Somewhat poorly drained; high water table; artificial drainage necessary; low susceptibility to frost action if drained; good workability.	Low, level areas; moderate permeability in upper 2 to 3 feet, rapid in underlying material; high water table at a depth of 3 to 5 feet.

interpretations—Continued

Soil features affecting—Continued			Degree and kind of limitation for—			
Irrigation (sprinkler)	Terraces and diversions	Waterways	Dwellings with basements	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]
Drainage needed.[2]	Not needed; nearly level; slight hazard of erosion.	Open-ditch drainage needed.[2]	Severe: very poorly drained; high water table at a depth of 0 to 3 feet; unstable.	Severe: high water table at a depth of 0 to 3 feet; very poorly drained; moderate permeability and moderately rapid permeability; percolation rate of 10 to 100 minutes per inch.	Severe: highly organic material that is 1 foot to many feet thick; porous; high water table.	Severe: very poorly drained; water table at a depth of less than 10 feet; organic soil texture; risk of free flow to ground water.
Not needed unless drained; moderate available water capacity; rapid permeability in upper part and moderately slow in lower part; very poorly drained; slopes of 0 to 1 percent.	Nearly level; slight hazard of erosion.[2]	Open-ditch drainage needed.[2]	Severe: very poorly drained; perched water table at a depth of 0 to 3 feet; seasonally ponded.	Severe: high water table at a depth of 0 to 3 feet; very poorly drained; moderately slow permeability in lower part; percolation rate of 100 minutes per inch or slower in the lower part.	Severe: rapid permeability in upper 2 to 3 feet; low resistance to piping; high water table.	Severe: very poorly drained; water table at a depth of less than 10 feet; loamy sand and sand in upper part.
Not generally needed; moderate available water capacity; rapid water intake; moderately slow permeability; somewhat poorly drained; slopes of 0 to 2 percent.	Not generally needed; slight hazard of erosion.	High water table; drainage aids in construction and in establishment of vegetation.	Severe: severe limitation for foundations; some difficulty with stones in places.	Severe: somewhat poorly drained; perched water table that fluctuates between depths of 2 and 4 feet; moderately slow permeability; percolation rate slower than 100 minutes per inch.	Moderate: basin floor material is nearly impervious if scarified and compacted.	Severe: somewhat poorly drained; water table at a depth of less than 10 feet.
Not generally needed unless drained; moderate available water capacity; medium water intake; moderate permeability in upper part and rapid permeability in lower part; somewhat poorly drained; slope of 0 to 2 percent.	Nearly level; slight hazard of erosion.[2]	High water table; drainage aids in construction and in establishment of vegetation.	Severe: severe limitation for foundations.	Severe: somewhat poorly drained; water table at a depth of 2 to 4 feet; hazard of contamination of nearby water supplies; percolation rate is 30 to 100 minutes per inch in the upper part and 10 minutes per inch or faster in the lower part.	Severe: rapid permeability in underlying material.	Severe: somewhat poorly drained; water table at a depth of less than 10 feet; rapid percolation in lower part; risk of free flow to ground water.

TABLE 8.—*Engineering*

Soil series and map symbols	Suitability as source of—			Soil features affecting—	
	Topsoil	Mixed sand and gravel	Road fill	Local roads and streets	Agricultural drainage
Paget: PaA, PaB, PbA, PbB.	Good to a depth of 18 inches; fair to poor below a depth of 18 inches: some stones.	Not suitable	Good for subbase: low shrink-swell potential; medium shear strength and compressibility.	Moderately well drained; more drainage needed to stabilize roadbed; moderate susceptibility to frost action; stones.	Moderately well drained.[2]
Parent: Pe, Pk	Poor: poorly drained; some stones. Good if drained.	Not suitable	Good for subbase: medium to low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Poorly drained; perched water table; artificial drainage necessary; moderate susceptibility to frost action if drained; stones.	Low, wet, level areas; moderately slow permeability; perched water table at a depth of 1 to 3 feet; firm underlying till material many feet thick; no well-developed drainage outlets.
Pomroy: PoB, PoC, PrA	Poor: sandy surface layer; some sloping soils.	Poor for fine sand: well sorted; limited quantity. Not suitable for cement.	Good for subbase: low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Well drained to moderately well drained; stability good in upper 2 to 3 feet when confined; moderate susceptibility to frost action; highly erodible where exposed on embankments.	Well drained to moderately well drained.[2]
*Prebish: Ps, Pt, Pu For Parent part of Pu, see Parent series.	Poor: very poor drainage. Good if drained.	Not suitable	Good for subbase: moderate to low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Very poorly drained; high organic-matter content in surface layer; perched water table; often ponded; artificial drainage needed; moderate susceptibility to frost action; stones.	Low, wet, level and depressional areas; moderately slow permeability; perched water table at a depth of 0 to 3 feet; firm underlying till many feet thick; no well-developed drainage outlets.
Ronneby: Rn, Ro	Good to a depth of 24 inches; poor below a depth of 24 inches: some stones; commonly wet at a depth of 2 to 4 feet.	Not suitable	Good for subbase: moderate to low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Somewhat poorly drained; perched water table; artificial drainage needed; moderate susceptibility to frost action; stones.	Low, level areas; moderately slow permeability; compact layer in subsoil impedes water movement; perched water table at a depth of 2 to 4 feet; firm underlying till material many feet thick.

interpretations—Continued

Soil features affecting—Continued			Degree and kind of limitation for—			
Irrigation (sprinkler)	Terraces and diversions	Waterways	Dwellings with basements	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]
High available water capacity; medium water intake; moderately slow permeability; moderately well drained; slopes of 0 to 6 percent.	Moderately well drained; moderately erodible; stones and boulders.	Moderately erodible; stones and boulders limit construction; low fertility in substratum.	Moderate: some stones a hazard in places. Severe limitation for septic tank absorption fields.	Severe: moderately slow permeability; percolation rate is slower than 100 minutes per inch.	Moderate: basin floor material is nearly impervious if scarified and compacted.	Moderate: moderately well drained; percolation rate is moderately slow.
Drainage required.[2]	Nearly level; slight hazard of erosion.[2]	Bedding, tile, or open-ditch drainage needed.	Severe: poorly drained; perched water table at a depth of 1 to 3 feet; stones a hazard in places.	Severe: water table at a depth of 1 to 3 feet; moderately slow to slow permeability; percolation rate slower than 100 minutes per inch.	Moderate: basin floor material is nearly impervious if scarified and compacted; high organic-matter content in surface layer.	Severe: poorly drained; water table at a depth of less than 10 feet; moderately slow percolation.
Moderate available water capacity; rapid water intake; rapid permeability in upper part and moderately slow permeability in lower part; well drained and moderately well drained; slope of 0 to 12 percent.	Sandy soil; highly erodible; low in fertility and organic-matter content; droughty; vegetation difficult to establish.	Sandy soil; highly erodible; low in fertility; droughty; vegetation difficult to establish.	Slight where slopes are less than 6 percent. Moderate where slopes are more than 6 percent.	Severe: moderately slow permeability in lower part; percolation rate in lower part is slower than 100 minutes per inch.	Severe: rapid permeability in the upper 2 to 3 feet; poor resistance to piping; some slopes are more than 7 percent.	Moderate: well drained and moderately well drained; moderately slow percolation in lower part; loamy sand and sand in upper part.
Drainage required.[2]	Nearly level; slight hazard of erosion.[2]	Open-ditch or tile drainage needed.	Severe: very poorly drained; perched water table at a depth of 0 to 3 feet; stones in places.	Severe: water table at a depth of 0 to 3 feet; moderately slow permeability; percolation rate is slower than 100 minutes per inch.	Moderate: basin floor material is nearly impervious if scarified and compacted; high water table.	Severe: very poorly drained; water table at a depth of less than 10 feet.
Generally not needed; moderate available water capacity; medium water intake; moderate permeability; somewhat poorly drained; slope of 0 to 2 percent.	Nearly level; slight hazard of erosion.[2]	High water table; drainage aids in construction and in establishing vegetation.	Severe: severe limitation for foundations; stones in places.	Severe: somewhat poorly drained; perched water table that fluctuates between depths of 2 and 4 feet; moderately slow permeability; percolation rate slower than 100 minutes per inch.	Moderate: basin floor material is nearly impervious if scarified and compacted.	Severe: somewhat poorly drained; water table at a depth of less than 10 feet.

TABLE 8.—*Engineering*

Soil series and map symbols	Suitability as source of—			Soil features affecting—	
	Topsoil	Mixed sand and gravel	Road fill	Local roads and streets	Agricultural drainage
Sartell: SaA, SaB, SaC, SaE.	Poor: sandy soil	Good for fine sand: well sorted.	Good for subbase: low shrink-swell potential and compressibility; medium to high shear strength, bearing capacity, and permeability; reasonable stability; very erodible.	Excessively drained; low susceptibility to frost action; embankments highly erodible; loose sand hinders hauling.	Excessively drained.[2]
Watab: Wa	Poor: sandy surface layer and subsoil; commonly wet at a depth of 2 to 4 feet.	Poor for fine and medium sand to a depth of 18 to 30 inches: difficult to excavate because of high water table; limited quantity.	Good for subbase: low shrink-swell potential; medium shear strength, compressibility, and bearing capacity.	Somewhat poorly drained; perched water table; artificial drainage needed; moderate susceptibility to frost action; stones below a depth of 2 to 3 feet.	Low, level areas; rapid permeability in surface layer, moderately slow permeability in underlying material; perched water table at a depth of 2 to 4 feet; firm till many feet thick.

[1] Onsite deep studies of the underlying strata, water table, and hazards of aquifer pollution and drainage into ground water should be made for landfill deeper than 5 or 6 feet.

the ingredients of the fill and on moisture and air supplies in the fill. Placement of the waste below the water table results in putrefactive anaerobic decomposition and a high proportion of unstable compounds (*3, 12*).

Limitations for sanitary landfills are based on soil properties that affect the soil's ability to filter leachate and to serve as refuse cover. Leachate is the liquid product from the decomposition of organic refuse. The main soil properties to be considered are permeability, internal drainage, depth of the soil to coarse material, and shrink-swell potential. Slope and flood hazard are also considered.

The distance to streams and lakes was not considered in evaluating the use of soils for sanitary landfills. This factor requires consideration also. The best location for a sanitary landfill is one that is above flood level, is far removed from lakes, wells, or drainage channels, and has a substantial depth of relatively impervious material above the water table. Undesirable locations for sanitary landfills are river flood plains, areas that drain into lakes and streams, areas where the water table is high, and areas that are near water supplies.

Building site groups

The soils of Benton County have been placed in nine building site groups on the basis of similarities in their use for residential, commercial, and industrial construction that includes public sewers, septic tank absorption fields, and sanitary landfills. The soils were examined to a depth of 5 feet. Economic factors such as the distance to roads and streets were not considered.

The limitations of the soils in a group are expressed as slight, moderate, and severe. The limitation is slight if it is easy to overcome. The limitation is moderate if it can be overcome through good management and careful design. It is severe if it is difficult to overcome. Special designs or major reclamation work commonly are needed to overcome a severe limitation, and cost generally is high.

The interpretations of the soils in the groups can be useful in selecting suitable locations for residences, stores, factories, schools, and similar facilities. It should be emphasized that these interpretations do not eliminate the need for detailed onsite investigations. Also,

interpretations—Continued

Soil features affecting—Continued			Degree and kind of limitation for—			
Irrigation (sprinkler)	Terraces and diversions	Waterways	Dwellings with basements	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]
Low available water capacity; rapid water intake; rapid permeability; excessively drained; slope of 0 to 25 percent.	Sandy soil; highly erodible; low fertility and organic-matter content; droughty; vegetation difficult to establish.	Sandy soil; highly erodible; some steep slopes; low in fertility; droughty; vegetation difficult to establish.	Slight where slopes are less than 6 percent; moderate where slopes are more than 6 percent; and severe where slopes are more than 12 percent: very droughty for trees, lawns, and shrubs.	Slight where slopes are less than 6 percent: no limiting factors, but a hazard of contamination to nearby water supplies. Moderate where slopes are 6 to 12 percent; severe where slopes are more than 12 percent: percolation rate is 10 minutes per inch or faster.	Severe: rapid permeability; low resistance to piping; some slopes of more than 7 percent.	Severe: excessively drained; rapid percolation rate; sandy soil; slopes of more than 12 percent; risk of free flow to ground water.
Generally not needed unless drained; moderate available water capacity; rapid water intake; rapid permeability in upper part and moderately slow permeability in lower part.	Nearly level; slight hazard of erosion.[2]	Sandy soil; seasonal high water table; droughty and erodible if drained; low in fertility.	Severe: somewhat poorly drained; perched water table at a depth of 2 to 4 feet; severe limitation for foundations.	Severe: somewhat poorly drained; perched water table that fluctuates between depths of 2 and 4 feet; moderately slow permeability in lower part; percolation rate in lower part is slower than 100 minutes per inch.	Severe: rapid permeability in upper 2 to 3 feet; low resistance to piping.	Severe: somewhat poorly drained; high water table at a depth of less than 10 feet.

[2] Practice not applicable or not generally needed.

[3] All or most features generally favorable.

engineers and others should not apply specific values to the estimates given for bearing values of the soils.

Descriptions of the building site groups follow. The names of soil series represented are mentioned in the description of each group, but this does not mean that all the soils of a given series are in the group. To find the group in which a particular soil has been placed, refer to the "Guide to Mapping Units."

BUILDING SITE GROUP 1

Soils of the Antigo, Burkhardt, Chetek, and Dickman series are in this group. These soils are well drained to somewhat excessively drained. Permeability is moderate to moderately rapid in the upper part of the soils and rapid in the lower part. The soils are underlain by sand or sand and gravel at a depth of 1 to 3 feet. The water table is below a depth of 10 feet.

Where these soils have slopes of 0 to 6 percent, they have slight limitations for roads and streets, large residential developments, shopping centers, and industrial parks, and excavation and building costs are generally low. Where they have slopes of 6 to 12 percent, limitations are moderate and construction costs are higher.

These soils have good bearing capacity for low buildings. They have only low to moderate volume change as a result of changes in soil moisture in the upper 1 to 3 feet. The hazard of frost heave generally is slight, but the Antigo soils are subject to a moderate hazard of frost heave. Wetness is not a limitation on the soils in this group.

These soils have slight limitations for absorbing effluent from septic tanks. The percolation rate generally is 10 to 30 minutes per inch of soil. This high percolation rate means that the hazard of polluting wells, lakes, and streams is increased in areas of high population density.

These soils have severe limitations for sanitary landfills, because they are shallow to sand or sand and gravel. Leachate produced by decomposing refuse can easily travel long distances and contaminate the water table and nearby lakes and streams. Pollution can be prevented by lining the beds of sand and gravel with 3 to 4 feet of impervious fill to prevent movement of the leachate through the coarse material below.

Lawns, trees, and shrubs are relatively easy to establish and maintain, but they are damaged slightly by drought.

BUILDING SITE GROUP 2

Soils of the Emmert, Hubbard, and Sartell series are in this group. These excessively drained soils mainly are sandy throughout, but the Emmert soils are sand and gravel throughout. Permeability is rapid. The water table is below a depth of 10 feet in all of the soils in the group.

Where these soils have slopes of 0 to 6 percent, they have slight limitations for commercial and residential developments that use public sewers. Foundations are relatively easy to excavate, and construction costs for roads and streets are relatively low. Where these soils have slopes of 6 to 12 percent, limitations are moderate because of the increased grading and construction costs. Where these soils have slopes of more than 12 percent, limitations are severe, and the cost of building streets and developing the sites generally is higher. Costly retaining walls and terraces are needed in many places if these soils are to be used as desirable homesites.

These soils have good bearing capacity for foundations. They have a low volume change with change in soil moisture and have low susceptibility to frost heave.

The soils of this group have slight limitations for absorbing septic tank effluent. They have a percolation rate of 3 to 10 minutes per inch, but the high percolation rate increases the hazard of polluting wells, lakes, and streams in areas of high population density. Where slopes are more than 12 percent, downslope seepage of effluent is a severe hazard and filter fields are difficult to lay out.

These soils have severe limitations for sanitary landfills, because they are porous and readily transmit leachate to the regional underground water table. Leachate that is produced by decomposing refuse can easily travel long distances and contaminate wells, lakes, and streams. Pollution can be prevented by lining the sand and gravel beds with 3 or 4 feet of impervious fill to prevent movement of the leachate through the coarse material below.

Vegetation is difficult to establish and maintain on these soils. Frequent watering and fertilizing are necessary to maintain a vigorous lawn. It is desirable to topdress these soils with 12 to 18 inches of loamy soil that will hold moisture.

Emmert soils generally are good sources of gravel and sand for construction purposes. Consideration should be given to developing this valuable resource before developing the soils for other uses.

BUILDING SITE GROUP 3

Soils of the Chetek-Milaca complexes; the Flak and Milaca series; and the Milaca variant are in this group. These are deep, well-drained soils that generally have moderately slow permeability. The Chetek soils are somewhat excessively drained and have moderately rapid permeability in the upper part and rapid permeability in the lower part. The soils in this group have a water table at a depth below 10 feet the year round. Slopes range from 2 to 25 percent.

Where slopes are 2 to 12 percent, these soils have moderate limitations for urban and commercial developments that use public sewers. Where slopes are more than 12 percent, limitations are severe, and grading and leveling costs for homesites and streets are high. Where the steeper soils are extensive, areas generally are better suited to estate-type developments that have large lots than they are to smaller building sites.

These soils have good bearing capacity and fair shear strength. All of the soils in this group have low to moderate volume change as a result of changes in soil moisture. Good footings are needed for foundations. Roads, parking lots, and driveways and other bituminous or concrete structures need careful design to prevent their breakup from volume change or frost heave. Stones add to the difficulty of construction on the soils of this group.

When foundations are backfilled on these soils, air pockets generally form in the fill and it settles unevenly. It is a good practice to compact the fill or to allow it to settle before establishing lawns. Soaking the fill material with water during backfill operations hastens the settling.

During unusually wet years seepage occurs where slopes are more than 2 percent. It is good practice, therefore, to place a tile line around the foundation footings to intercept water that might seep into the basement. The tile line requires an outlet other than the home disposal system.

These soils generally have a severe limitation for absorbing septic tank effluent from private homes where slopes are 2 to 12 percent. The limitation is moderate for the Milaca variant soil and slight for the Chetek soils. Percolation design rates are near 120 minutes per inch for the Milaca soils. To keep failure of absorption fields to a minimum, added absorption area in specially designed systems is needed to compensate for the slow percolation rate. It is preferred to place the absorption field in undisturbed natural soils. Graded and filled areas of these soils generally absorb effluent slowly and are undesirable sites for absorption fields.

Alternative methods for disposing of sewage effluent on these soils might be to construct absorption fields in specified loamy fill or to use sand filters.

The Milaca variant soils have a percolation design rate of about 60 minutes per inch of soil, and Chetek soils have a rate of 20 minutes or less, so the members of this group can use conventional installations.

The soils in this group are suited to sewage lagoons, which are the preferred method of sewage disposal for commercial enterprises such as motels, restaurants, resorts, and service stations.

These soils have moderate limitations for sanitary landfills because the percolation rate is moderately slow and slopes are more than 6 percent. The Milaca variant soil is sticky and plastic and is somewhat difficult to use for refuse cover. Care is needed to cover refuse properly to prevent the attraction of insects, the harboring of rodents, and the escaping of noxious gases.

It is easy to establish trees, shrubs, and sod on these soils.

BUILDING SITE GROUP 4

Soils of the Brainerd, Dalbo, Mora and Paget series are in this group. These are deep, loamy and silty, moderately well drained soils that have convex slopes of 0

to 8 percent. The water table is below a depth of 10 feet the year round. Permeability is moderately slow.

These soils have slight limitations to use as residential and commercial development sites where public sewers are used. If they are used for building sites, it is important to install drain tile around the basement footings to prevent internal seepage from entering the basement. The tile line requires an adequate outlet other than the home disposal system.

These soils generally have good bearing capacity for foundations, but the Dalbo soils have poor bearing capacity. Dalbo soils require wider footings to prevent settling. All the soils in this group except Dalbo soils have moderate susceptibility to frost action and low to moderate volume change with changes in soil moisture. Dalbo soils have severe susceptibility to frost heave. Streets, roads, and sidewalks tend to heave unless they are carefully designed and have a thick sand subbase.

Where foundations are backfilled on these soils, air pockets generally form in the fill and the fill settles unevenly. Fill should be tamped or compacted. Soaking the fill with water during backfilling hastens the settling. Refills should slope away from the building before sodding or seeding.

These soils have severe limitations for absorbing septic tank effluent. Percolation design rates are near 120 minutes per inch of soil. To keep failure of absorption fields to a minimum, added absorption area in specially designed systems is needed to compensate for the slow percolation rate. It is preferred to place the absorption field in undisturbed natural soils. Graded and filled areas of these soils generally absorb effluent slowly and are undesirable sites for absorption fields.

Another method of disposing of sewage effluent on these soils is to construct absorption fields in specified loamy fill or to use sand filters.

The soils in this group are suited to sewage lagoons, which are the preferred method of sewage disposal for commercial enterprises, such as motels, restaurants, resorts, and service stations.

These soils have moderate limitations for sanitary landfills because of the moderately slow percolation rate, the drainage condition, and the presence of some areas of soils that have slopes of more than 6 percent. Dalbo soils are sticky and plastic and are somewhat difficult to use for refuse cover. Care is needed to cover refuse properly to prevent the attraction of insects, the harboring of rodents, and the escaping of noxious gases.

Sod, shrubs, and trees are easy to establish on these soils.

BUILDING SITE GROUP 5

Soils of the Braham, Langola, and Pomroy series are in this group. These well drained and moderately well drained soils consist of 18 to 40 inches of sandy material over silt loam and sandy loam. The water table is below a depth of 10 feet throughout the season on all of the soils in the group. Slope ranges from 0 to 12 percent.

These soils have slight limitations for residential and commercial development. Where slopes are 6 to 12 percent, limitations are moderate and the cost of construction is greater. If these soils are used for building sites, it is important to install drain tile around the basement footings to prevent seepage from entering the basement. An adequate outlet other than the home disposal system is needed for the tile line.

These soils have slight to severe limitations for septic tank absorption fields, depending on the thickness of the sandy upper part of the soils. Suggested percolation design rates for absorption fields constructed in the sandy material is 60 minutes per inch of soil. This rate is adjusted to the slower acceptance of effluent by the underlying material. Where absorption fields are constructed in the loamy material, the suggested rates are near 120 minutes per inch of soil. To keep failure of absorption fields to a minimum, added absorption areas in specially designed systems are needed to compensate for the slow percolation rate. It is preferred to place the absorption field in undisturbed natural soils. Graded and filled areas of these soils generally absorb effluent slowly and are undesirable sites for absorption fields. Where slopes are more than 6 percent, lateral seepage is likely to occur at the contact line between the sandy and loamy materials. Placing absorption fields on the contour and in the loamy material reduces the hazard of side-slope seepage where these soils are sloping.

These soils have moderate limitations for sanitary landfills. The underlying material has moderately slow permeability, which results in poor soil workability and trafficability. The cost of operation is greater where slopes are more than 6 percent. The sandy upper part of these soils is poor cover for refuse, because it is too porous to form a good seal over the refuse layers.

Lawns are difficult to establish and maintain on these soils. The soils should be topdressed with 12 to 18 inches of loamy material that holds moisture. Lawns need to be fertilized and watered often during the dry summer months to maintain a vigorous sod. Trees and shrubs that are resistant to drought are desirable on these soils.

BUILDING SITE GROUP 6

Soils of the Freer, Ogilvie, Nokay, and Ronneby series are in this group. These soils generally are deep, are somewhat poorly drained, and have moderately slow permeability, but the Ogilvie soils are moderately deep and have moderate permeability in the upper part and rapid permeability in the lower part. All of these soils have a high water table, which fluctuates somewhat during the year and is at a depth of 2 to 4 feet. Slopes are 0 to 2 percent.

Because of wetness these soils have severe limitations for residential and commercial developments that use public sewer systems. Wet basements occur on these soils unless the water table is lowered or the foundation is placed above the highest level of the water table.

The soils in this group have a high hazard of frost heave unless the water table is lowered. Streets, driveways, and concrete slabs are subject to heaving and cracking unless they are carefully designed. The underlying materials of these soils have good bearing capacity for low buildings of less than three stories. The soils in this group have moderate volume change with changes in soil moisture.

These soils have severe limitations for absorption fields because of the high water table and the hazard of polluting nearby wells, streams and lakes. Performance of absorption fields is severely reduced during wet pe-

riods unless the water table is controlled by regional drainage. Percolation rates are near 120 minutes per inch of soil for all of these soils except the Ogilvie soils, which have a rate of 30 to 60 minutes per inch in the silty upper part and less than 10 minutes per inch in the lower part. Where septic tank absorption fields must be constructed on soils in this group, placing the absorption fields in a 4- to 6-foot bed of specified loamy material above the highest water line reduces the pollution hazard and helps to overcome the limitation caused by wetness.

The soils in this group have severe limitations for sanitary landfills because of the high water table. Also, the Ogilvie soils have porous underlying material. Leachate from landfills can move long distances in the sand and gravel and contaminate nearby wells, lakes, and streams.

Sod, trees, and shrubs are easy to establish on these soils.

BUILDING SITE GROUP 7

Soils of the Blomford, Duelm, Lino, and Watab series and the Lino variant are in this group. These soils are deep, nearly level, and somewhat poorly drained. Permeability is mainly rapid. The underlying material in Blomford and Watab soils and in Lino soils, loamy subsoil variant, have moderate and moderately slow permeability. Blomford soils have a sandy upper part that is 18 to 36 inches thick over silty glacial lake-laid sediment, and Watab soils have a sandy upper part that is 18 to 40 inches thick over firm, loamy glacial till. Lino soils, loamy subsoil variant, are fine sands that have loamy lacustrine layers in the subsoil and substratum. The soils in this group have a high water table that ranges from 2 to 4 feet in depth.

These soils have severe limitations for residential and commercial developments. When they are used as building sites, artificial drainage is needed to control the water table, or the foundation has to be built on fill to raise it above the highest level of the water table. Questionable wet sites should have drain tile placed around the footings, and the tile should be connected to an adequate outlet. This will keep the basement dry during wet periods and will prevent the basement floor from cracking.

When foundations on these soils are backfilled, care should be taken to use the underlying loamy or silty material to prevent lateral seepage. Air pockets generally form when backfilling, but compacting and soaking the fill reduces this undesirable effect.

The hazard of frost heave is high in these soils. Streets, sidewalks, driveways, and parking ramps are subject to heaving and cracking unless they are carefully designed. The bearing capacity and shear strength is medium to high on these soils, and the volume change with a change in soil moisture is low.

These soils have severe limitations for residential developments that use septic tank absorption fields, because the water table is high and there is a hazard of polluting nearby wells, streams, and lakes. The performance of absorption fields is severely reduced during wet periods unless the water table is controlled by regional drainage. Blomford and Watab soils have percolation rates that are generally less than 10 minutes per inch of soil in the upper sandy part and near 120 minutes per inch in the underlying material. Lino soils, loamy subsoil variant, have variable percolation rates, but the rate generally is less than 30 minutes per inch. Lino and Duelm soils have percolation rates of less than 10 minutes per inch. When septic tank absorption fields must be constructed on soils in this group, placing the absorption fields in a bed of specified loamy material 4 to 6 feet thick above the highest water line reduces the hazard of pollution and helps to overcome the limitation caused by wetness.

Because of wetness, these soils have severe limitations for sanitary landfills. Placement of refuse below the water table results in anaerobic decomposition that produces undesirable odors and compounds that are hazardous to health.

When these soils are drained they are droughty, and lawns are difficult to establish and maintain. These sandy soils should be topdressed with 12 to 18 inches of loamy material that holds moisture. Lawns need to be fertilized and watered often during the dry summer months to maintain a vigorous sod. Trees and shrubs that are resistant to drought are desirable on these soils.

BUILDING SITE GROUP 8

Soils of the Isanti and Nokasippi series and the Isanti variant are in this group. These soils are deep, are very poorly drained, and have rapid permeability, except for the underlying material, which has moderate and moderately slow permeability. Isanti soils are sandy throughout, and Isanti soils, loamy subsoil variant, are sandy in the upper part and have loamy lacustrine layers in the subsoil and substratum. The upper part of the Nokasippi soil is 18 to 35 inches of fine sand, and the underlying material is firm, loamy glacial till. The soils in this group have a high water table that ranges from ponded to a depth of 3 feet.

The soils in this group have severe limitations for community development, because they are wet (fig. 16). Where these soils are used for building sites, regional drainage is required. Also, the foundations should have drain tile installed around the footings and connected to an adequate outlet to keep the basement dry during wet periods.

These soils have severe limitations for septic tank filter fields because of the very high water table. Effluent can easily contaminate the water table and the nearby lakes and streams.

These soils have severe limitations for sanitary landfills because of the hazard of polluting the ground water. Placement of refuse below the water table results in anaerobic decomposition that produces undesirable odors and compounds that are hazardous to health.

Sod, trees, and shrubs can be grown on these soils after adequate drainage has been installed. Lawns need to be fertilized and watered often during the dry summer to maintain a vigorous sod.

Many areas of these soils are suited to wildlife habitat. Some areas are suited to parks and recreational areas, such as playgrounds, picnic areas, and campsites.

BUILDING SITE GROUP 9

In this group are soils of the Adolph, Hillet, Parent, and Prebish series; the Adolph variant; and Alluvial land, Granite rock land, Marsh, Mucky peat, Mucky

Figure 16.—Area of Isanti soils that are severely limited for community development because of wetness.

peat over loam, and Mucky peat over sand. Except for Granite rock land, the soils in this group are poorly drained and very poorly drained; are loamy, silty, or organic; and are subject to ponding much of the time. The water table is at or near the surface much of the year.

These soils have severe limitations for community development because they are subject to flooding and wetness. These soils are highly susceptible to frost heave. Granite rock land is not subject to the limitations mentioned above, but it does present other difficulties for building structures (fig. 17).

Before commercial or residential developments are undertaken on the soils in this group, regional drainage is necessary to lower the water table to such a depth that it will not hinder construction and maintenance. Special design and care are needed to prevent malfunctions.

The mucky peat soils are unstable, and where drained they begin to subside and continue to do so for many years. When building a structure on organic soils, it is best to completely remove the organic material and replace it with mineral soil material that has the desired properties.

These soils have severe limitations for septic tank absorption fields because of the very high water table. Effluent contaminates the water table and the nearby lakes and streams.

Limitations for sanitary landfill are severe because of flooding and the hazard of contaminating the water table. Flooding occurs several times each year on alluvial soils, and refuse and leachate would pollute the nearby river or streams.

Alluvial land, Granite rock land, and Marsh are better suited to less intensive purposes, such as parks, wildlife sanctuaries, outdoor classrooms, camping, and recreation areas, than to most other uses.

Formation and Classification of the Soils

This section consists of two main parts. The first part relates the five factors of soil formation to the soils in Benton County, with particular emphasis on the parent materials and vegetation. The second part deals with the classification of the soils.

Factors of Soil Formation

Soil is produced by soil-forming processes acting on material deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by the physical and mineralogical composition of the parent materials; the climate under which the soil material accumulated and has existed since ac-

Figure 17.—**Home built on severely limited site. Basements, wells, and septic tank disposal systems are difficult to construct and maintain near Granite rock land.**

cumulation; the plant and animal life on and in the soil; the relief, or lay of the land; and the length of time the processes of soil formation have acted on the soil material.

Climate and vegetation are active factors of soil formation. They act on the parent material and slowly change it into a natural body that consists of genetically related layers, called horizons. The effects of climate and vegetation are conditioned by relief. The parent material also affects the kind of soil that can be formed and, in extreme cases, determines it almost entirely. Finally, time is needed for the parent material to change into a soil. It may be much or little, but some time is always required for formation of soil horizons. In most soils a long time is required for the formation of distinct horizons.

The factors of soil formation are so closely interrelated in their effect on the soil that few generalizations can be made regarding the effect of any one unless conditions are specified for the other four. Some of the processes of soil formation are unknown.

Parent material

The soils of Benton County formed in different kinds of parent material. The major kinds are glacial till, lacustrine sediment, glacial outwash, alluvium, and organic material. All of these materials except the organic deposits are of glacial origin. The glacial till exposed in the county is from the Wisconsin Glaciation (*14*). This was the last major glacial stage that took place during geologic time and occurred during the Pleistocene epoch.

Soils formed in glacial drift developed from three kinds of drift of slightly different age and markedly different composition. The Superior lobe entered the area from the northeast. The till of this drift is reddish brown, generally coarse textured, and noncalcareous. It is commonly referred to as red till. Pebbles of basalt, gabbro, felsite, and red sandstone are common. The Superior lobe retreated from the area about 13,500 years ago. The Milaca, Mora, and Ronneby soils, which occur around Foley, developed in till deposited by the Superior lobe.

At about the same time as the wastage of the Superior lobe in the county, the Rainy lobe entered the county from the east. It spread radially to the northwest and southwest and deposited brown sandy till and shaped the Pierz drumlin field. The drumlins contain compact and unstratified drift materials. A number of eskers, long, narrow ridges of fluvioglacial drift deposited by a stream in an ice-walled valley, formed. The soils that formed in materials deposited by this lobe include those of the Brainerd, Flak, and Nokay series.

The third and least important intrusion was by the

Grantsburg sublobe, a protrusion of the Des Moines lobe, which took place sometime later. This ice entered the county from the south and travelled north and east along the southern edge of the county. It left a few small areas of light olive-brown, medium-textured, calcareous drift that contains pebbles of limestone and shale. The till deposited by the Des Moines lobe is commonly referred to as gray till or friable till. Milaca soils, clay loam subsoil variant, formed in till deposited by the Grantsburg sublobe. During the retreat of the Grantsburg sublobe about 12,500 years ago, the ice stagnated to the east and Lake Grantsburg formed. It was from these sediments that the Dalbo soils and Adolph soils, silty subsoil variant, formed. The Braham and Blomford soils formed in the eolian sands deposited on top of some of the Lake Grantsburg sediments.

As the Grantsburg sublobe retreated westward, the Mississippi River was diverted eastward and the melt water produced an outwash apron along the southern edge of the county. The Sartell, Lino, and Isanti soils formed in these fine sands.

The retreat of the Grantsburg sublobe westward uncovered the Mississippi River valley. Melt water from the wasting Wadena and Rainy lobes filled the valley in Benton County with coarse alluvium. This alluvium underlies two broad terraces that are parallel to the Mississippi River. The sand is coarse textured in areas near the river and becomes finer textured with increasing distance from the river. It is poorly stratified and generally is deeply leached. The soils of this area are in the Hubbard, Dickman, and Duelm series.

As the glaciers retreated from the area, large blocks of ice were left on the till and outwash plains. When these blocks melted, lakes such as Mayhew and Little Rock formed. Some of the shallower depressions formed by these ice blocks became marshes, and organic soils developed in areas the water once occupied.

Loess deposition, in the form of a discontinuous cap, is common in the northeast corner of the county. The area is inextensive, and the silt is thought to be from local drainageways. Paget and Freer soils formed in this material.

Recent alluvium, the texture of which ranges from loam to sand, has been deposited on the floor plains of the major streams in the county.

Climate

The climate has had pronounced effects on soil development in Benton County. During winter the soil is frozen and soil-forming processes are retarded. The alternate thawing and freezing, especially in spring, play a part in the development of soil structure. The rainfall of the area has affected the translocation of clay and lime. Climate is responsible to a large degree for the forests. Grass vegetation is quite prevalent, but only because of a soil-related condition such as poor drainage. Details about the climate are given in the section "General Nature of the County."

Plant and animal life

The native vegetation was primarily mixed hardwood forests in the eastern part of Benton County, oak woods in the central part, and prairie grasses in the western part (see fig. 13, p. 66). The mixed hardwood forests consisted of white oak, green ash, hard maple, American elm, and basswood trees, and the floor cover was wood anemone, trillium, jack-in-the-pulpit, blue cohosh, black nightshade, and others.

Soils that formed under the influence of forest vegetation have a thin, dark-colored surface layer in contrast to the thick, dark-colored surface layer of soils that formed under grass. Decomposition of forest litter facilitates the movement of plant nutrients and clay-sized particles downward to the subsoil, where they accumulate. This accumulation makes the soils less permeable. Examples of soils that formed under forest vegetation are Milaca, Flak, Brainerd, Mora, Paget, Dalbo, Chetek, and Sartell soils.

The largest area of soils that formed under grass is on the outwash plain along the Mississippi River. Minor areas are scattered throughout the county. Some of the common grasses were big bluestem, little bluestem, Canada wildrye, prairie cordgrass, indiangrass, blue grama, and side-oats grama. Many kinds of flowers flourished on the native prairies, including species of aster, phlox, goldenrod, fireweed, indian paintbrush, milkweed, lilies, wild rose, mint, sunflower and many others. On the wet soils and in marshes, sedges and cattails provided dense, luxuriant vegetation.

Soils that form under grass develop a surface layer that has high content of organic matter. Most uneroded, gently sloping soils have a dark surface layer that is more than 12 inches thick. The steeper soils have a thinner surface layer as a result of greater runoff, sparse vegetation, and natural erosion. Many of the original prairie areas have had some encroachment by hardy, drought-resistant species such as bur oak. American elm and green ash are now on some of the wet soils.

Man has had a great influence on the soils. Land clearing and farming have affected most of the soil-forming processes. Accelerated erosion of the surface layer has occurred on some of the sloping soils. Some of the lower lying soils have gained deposits of eroded material. The structure in the surface layer of many soils has been weakened or destroyed. The color of the surface layer of most of the soils has become lighter as a result of mixing with material from the subsoil and a reduction in the content of organic matter. Leaching of many soils has been slowed as a result of increased runoff and reduced infiltration.

Relief

The relief in Benton County ranges from nearly level to very steep, but it is dominantly nearly level to gently sloping. Relief is the most important factor in the development of differences in soils that have similar parent material. Soils that have fairly mature, distinct horizons formed in gently sloping areas that have good drainage. Steep soils have little horizon development, mostly because runoff is excessive and geological erosion removes the surface layer about as fast at it forms. Runoff also reduces the amount of water that leaches the soil. Consequently, steep soils are droughty. They have thin, indistinct horizons that support a poor stand of plants.

Topographic position is a partial key to the kind of soil and the soil drainage class at any place in the landscape. For example, the location of Flak, Brainerd, Nokay, Parent, and Prebish soils, which make up the

Flak drainage sequence, can be predicted in a general way. Each of these soils is on a particular part of the landscape. The well-drained, sloping Flak soils are on sides and crests of hills; the moderately well drained, nearly level and gently sloping Brainerd soils are in areas below the Flak soils; the somewhat poorly drained, nearly level Nokay soils are in areas at the foot of slopes below the Brainerd soils; the nearly level Parent soils are on wet flats and in drainageways; and the Prebish soils are in closed depressions and very wet drainageways.

The glacial ground moraines have dominantly undulating relief, but the drumlin field has slopes that are dominantly uniform. Soils on the ground moraines are equally affected by problems of erosion and drainage. The outwash plains have dominantly undulating relief, but the hazard of erosion is greater.

Time

The time required for soil development depends, to a large extent, on the other factors of soil formation. Wherever relief and drainage favorable for the development of profiles exist in Benton County, relatively mature soils that have well-defined horizons have formed. Immature soils have little or no horizonation. Steep soils have immature or thin profiles because the soil-forming processes have not been effective. Alluvial soils along the streams and rivers are immature or weakly developed because fresh deposits are added to the alluvium almost annually, and distinct, mature horizons do not have time to form.

In a geological sense, all the soil materials in the county are very young. Except for the organic soils and the soils on alluvial plains, soil-forming processes have been active for about 8,000 to 13,500 years.

Classification of the Soils

Soils are classified so that we can more easily remember their significant characteristics. Classification enables us to assemble knowledge about the soils, to see their relationship to one another and to the whole environment, and to develop principles that help us understand their behavior and their response to manipulation. First through classification, and then through use of soil maps, we can apply our knowledge of soils to specific fields and other tracts of land.

Thus, in classification, soils are placed in narrow categories that are used in detailed soil surveys so that knowledge about the soils can be organized and used in managing farms, fields, and woodland; in developing rural areas; in engineering work; and in many other ways. Soils are placed in broad classes to facilitate study and comparison in large areas, such as countries and continents.

The classification system was adopted for general use by the National Cooperative Soil Survey in 1965. It is under continual study. Therefore, readers interested in developments of the system should search the latest literature available (*5, 8*). In table 9 the soil series of Benton County are placed in some categories of the system.

The current system of classification has six categories. Beginning with the broadest, these categories are order, suborder, great group, subgroup, family, and series. In this system the criteria used as a basis for classification are soil properties that are observable and measurable. The properties are chosen, however, so that the soils of similar genesis, or mode of origin, are grouped together. 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 grouping of soils. The two exceptions to this are the Entisols and Histosols, which occur in many different kinds of climate. Five soil orders are in Benton County: Entisols, Inceptisols, Histosols, Mollisols, and Alfisols.

Entisols are light-colored soils that do not have natural genetic horizons or that have only weakly expressed beginnings of such horizons. These soils do not have characteristics that reflect soil mixing caused by shrinking and swelling.

Inceptisols are mineral soils of humid regions. They have lost bases but lack diagnostic horizons of clay accumulation. They generally lack a thick, dark-colored surface layer and commonly have a fragipan.

Histosols, unlike the other orders, dominantly developed in organic material known as peat or muck. They generally are saturated with water for prolonged periods or are artificially drained, and they are 20 to 35 percent or more organic matter.

Mollisols formed under grass and have a thick, dark-colored surface horizon that contains colloids dominated by bivalent cations. The soil material in Mollisols 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 is divided 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 divided into great groups on 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 have accumulated or those that contain a pan that interferes with the growth of roots or movement of water. The features used are the self-mulching properties of clays, 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 9, because it is the last word in the name of the subgroup.

SUBGROUP: Great groups are divided into subgroups, one representing the central (typic) segment of the group, and others, called intergrades, that have properties of the group and also one or more properties of another great group, suborder, or order. Subgroups may also be made in those instances where soil properties intergrade outside the range of any other great

TABLE 9.—*Classification of soil series*

Series	Family	Subgroup	Order
Adolph	Coarse-loamy, mixed, noncalcareous, frigid	Typic Haplaquolls	Mollisols.
Adolph variant	Fine-silty, mixed, noncalcareous, frigid	Typic Haplaquolls	Mollisols.
Antigo [1]	Fine-silty over sandy or sandy-skeletal, mixed, frigid	Typic Glossoboralfs	Alfisols.
Blomford [2]	Sandy over loamy, mixed, noncalcareous, frigid	Mollic Haplaquents	Entisols.
Braham [1]	Sandy over loamy, mixed, frigid	Arenic Eutrochrepts	Inceptisols.
Brainerd [3]	Coarse-loamy, mixed, frigid	Aquic Fragiochrepts	Inceptisols.
Burkhardt [4]	Sandy, mixed, mesic	Typic Hapludolls	Mollisols.
Chetek [1]	Coarse-loamy, mixed	Hapludic Glossoboralfs	Alfisols.
Dalbo	Fine, mixed	Aquic Eutroboralfs	Alfisols.
Dickman	Sandy, mixed, mesic	Typic Hapludolls	Mollisols.
Duelm	Sandy, mixed	Aquic Haploborolls	Mollisols.
Emmert	Sandy-skeletal, mixed, noncalcareous, frigid	Typic Udorthents	Entisols.
Flak [3]	Coarse-loamy, mixed, frigid	Typic Fragiochrepts	Inceptisols.
Freer	Fine-loamy, mixed, frigid	Aeric Ochraqualfs	Alfisols.
Hillet	Coarse-silty over sandy or sandy-skeletal, mixed, frigid	Typic Haplaquolls	Mollisols.
Hubbard	Sandy, mixed	Udorthentic Haploborolls	Mollisols.
Isanti	Sandy, mixed, noncalcareous, frigid	Typic Haplaquolls	Mollisols.
Isanti variant	Sandy, mixed, noncalcareous, frigid	Typic Haplaquolls	Mollisols.
Langola [3]	Sandy, mixed	Udorthentic Haploborolls	Mollisols.
Lino	Mixed, frigid	Aquic Udipsamments	Entisols.
Lino variant	Sandy, mixed, nonacid, frigid	Aeric Haplaquents	Entisols.
Milaca [3]	Coarse-loamy, mixed, frigid	Typic Fragiochrepts	Inceptisols.
Milaca variant	Fine-loamy, mixed, frigid	Mollic Eutroboralfs	Alfisols.
Mora [3]	Coarse-loamy, mixed	Aquic Fragiboralfs	Alfisols.
Mucky peat	Euic, frigid	Typic Borohemists and Sapric Borohemists.	Histosols.
Mucky peat over sand	Sandy, mixed, euic, frigid	Terric Borosaprists	Histosols.
Mucky peat over loam	Loamy, mixed, euic, frigid	Terric Borosaprists	Histosols.
Nokasippi	Coarse-loamy, mixed, noncalcareous, frigid	Typic Haplaquolls	Mollisols.
Nokay [3]	Coarse-loamy, mixed, frigid	Aeric Fragiaqualfs	Alfisols.
Ogilvie	Fine-loamy over sandy or sandy-skeletal, mixed, nonacid, frigid	Mollic Haplaquepts	Inceptisols.
Paget [3]	Coarse-loamy, mixed	Aquic Fragiboralfs	Alfisols.
Parent	Coarse-loamy, mixed, noncalcareous, frigid	Typic Haplaquolls	Mollisols.
Pomroy [3]	Sandy, mixed, frigid	Typic Fragiochrepts	Inceptisols.
Prebish	Coarse-loamy, mixed, noncalcareous, frigid	Typic Haplaquolls	Mollisols.
Ronneby [3]	Coarse-loamy, mixed, frigid	Aeric Fragiaqualfs	Alfisols.
Sartell [5]	Mixed, frigid	Typic Udipsamments	Entisols.
Watab [4]	Coarse-loamy, mixed, frigid	Aquic Fragiochrepts	Inceptisols.

[1] This soil is a taxadjunct to the series because its surface layer either is thicker and darker in color or is darker in color than is typical for the series.

[2] This soil is a taxadjunct to the series because it has stronger illuviation in the IIB horizon than is typical for the series.

[3] Classification is affected by the presence or absence of a fragipan.

[4] This soil is a taxadjunct to the series because its average annual soil temperature is less than 47°F.

[5] The Sartell series was called Zimmerman series in the Survey of Sherburne County.

group, suborder, or order. The names of subgroups are derived by placing one or more adjectives before the great group name.

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 was prepared mainly for those not familiar with Benton County. History; physiography, drainage, and relief; climate; farming; transportation and markets; and industry are discussed.

History

At one time Benton County was the home of the Ojibwa and Sioux Indians. It was one of the first nine counties established by the Minnesota Territorial legislature in 1849. It originally included all of Benton and Sherburne Counties and parts of Anoka, Isanti, Mille Lacs, Aitkin, Crow Wing, and Morrison Counties. Gradual reduction of the size of the county began in 1856, and by 1860 it was reduced to its present size.

The county was named after Thomas H. Benton, a U.S. Senator from Missouri. Senator Benton was a popular figure in those days because of his favorable stand toward the Homestead Act. Actual settling of the county began in 1844, when Phillip Beaupre, a French-Canadian, settled along the Mississippi River north of what is now Sauk Rapids. Jeremiah Russell settled in Sauk Rapids in 1847 and David Gilman at Watab in 1848.

Physiography, Drainage, and Relief

Much of Benton County lies in the southern part of the Pierz drumlin field. This glacial ground moraine is characterized by long, gentle, uniform slopes.

TABLE 10.—*Temperature and precipitation*

[All data from Weather Bureau Airport Station, St. Cloud, Minn.]

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	21	0	39	−24	0.8	0.2	1.3	28	6
February	25	3	42	−18	.7	.2	1.6	26	8
March	37	17	53	− 8	1.2	.4	2.1	22	8
April	54	32	75	19	2.0	.5	3.6	2	2
May	67	43	83	31	3.1	1.0	5.7	[1]	0
June	77	53	91	42	3.9	2.0	8.5	0	0
July	83	58	96	48	3.1	1.3	5.8	0	0
August	81	56	93	46	2.9	.8	7.0	0	0
September	71	47	89	33	3.0	.8	5.0	0	0
October	59	35	75	22	1.6	.3	3.5	[1]	0
November	38	20	56	0	1.4	.2	2.3	8	3
December	25	6	40	−15	.7	.1	1.7	17	5
Year	53	31	[2] 97	[3] −26	24.4	21.0	32.3	103	7

[1] Less than one-half day.
[2] Average annual highest temperature.
[3] Average annual lowest temperature.

Along the southern edge of the county, the Anoka sand plain shares the landscape with islands of glacial till that protrude through the sandy deposits. The Mississippi River valley train occupies the western edge of the county. It is mainly nearly level and has a few ice-block depressions and bogs. For the most part its elevation is lower than that of the Anoka sand plain.

The county is drained by the tributaries of the Mississippi River on the western edge, by the Elk River and its tributaries in the central part, and by the St. Francis and West Branch Rum Rivers in the eastern part.

The highest elevations in the county are in the northeastern corner in Granite Ledge Township. The highest elevation is in section 5 and is about 1,270 feet above sea level. The elevation at the village of Gilman is about 1,190 feet; at Foley about 1,140 feet; at Rice about 1,063 feet; at St. Cloud about 1,041 feet; and at Duelm about 1,030 feet. The lowest elevation, about 1,000 feet, is an area near where the Elk River leaves the county to enter Sherburne County to the south. Streams and rivers in the county generally flow southwesterly and eventually into the Mississippi River. One exception is the West Branch Rum River in the northeastern parts, which flows southeastwardly and joins the Rum River in Mille Lacs County.

TABLE 11.—*Probability of low*

[All data from Weather Bureau

Probability	Dates for given probability and temperature		
	16° F	20° F	24° F
Spring:			
1 year in 10 later than	April 12	April 25	May 1
2 years in 10 later than	April 7	April 18	April 26
5 years in 10 later than	March 28	April 6	April 15
Fall:			
1 year in 10 earlier than	October 29	October 19	October 2
2 years in 10 earlier than	November 2	October 23	October 8
5 years in 10 earlier than	November 11	November 1	October 19

Climate [5]

The climate of Benton County is continental, which is typical of areas located in the center of the great land mass of North America. This means that winters are cold, summers are warm, and precipitation is at its maximum during the warm season. The interaction between cold air from the north and warm, moist air from the south causes marked daily changes in both temperature and precipitation.

The average temperature for December, January, and February is 13.3° F. Although each winter has several days in the −20° to −30° range, these temperatures generally occur when winds are light and humidity is low. The first measurable snowfall occurs late in October in one year in three, and the last in spring is generally late in April and infrequently early in May.

Although winters are cold, the other seasons are pleasant. The average temperature for June, July, and August is 68.2°. Extremely hot weather is not common and readings of 100° or higher occur in only 1 year in 10.

Precipitation is well distributed during the growing season. About 60 percent, or 17.4 inches, falls during the period May through September. Precipitation of 0.01 inch or more can be expected on about 100 days per year. Rainfall intensities of 1.10 inches per hour can be expected about once in 2 years. Some years have inadequate amounts of precipitation and some years have excessive amounts. Table 10 gives the levels of precipitation expected to occur 1 year in 10 for each month. The heaviest rains occur during thunderstorms, which average 38 annually. Some thunderstorms are accompanied by hail and damaging winds. Tornadoes are not common, and only four were reported in the county from 1916 through 1967.

Benton County has a wide range of temperature during the year. The freeze-free period is long enough that crops such as corn, soybeans, small grain, and vegetables generally have time to reach maturity. The probabilities of certain temperatures (*2*) occurring in spring and in fall are shown in table 11.

Using observed temperatures and crop phenology as basic data, minimum temperatures during stated periods were computed for St. Cloud and are applicable to Benton County. These data are given in table 12.

Dry spells, although not frequent, do occur. The driest May–September period from 1905 through 1967 occurred in 1922, when only 9.27 inches of precipitation fell. Drought takes place whenever the supply of water to crops either in the form of rainfall or from soil moisture becomes inadequate. Each day in which inadequate moisture is in the root zone is defined as a drought day.

Average windspeed ranges from 6.4 miles per hour in August to 9.8 miles per hour in April. The prevailing winds are southerly in summer and northerly in winter. Relative humidity at noon ranges from 50 percent in May to 73 percent in December. During a typical year, 96 clear days, 108 partly cloudy days, and 161 cloudy days can be expected. Heavy fog is not frequent; 20 days can be expected during the year.

Farming

Potatoes, wheat, oats, barley, and wild hay that was cut from the prairie were the principal crops produced by the first settlers. Trends in the kinds of crops grown gradually changed, and Benton County become mainly a dairy farm area. The largest acreage is used for hay crops, corn for grain and feed is next, and then oats, soybeans, and rye.

According to the Minnesota Agricultural Statistics, in 1968 there were 37,600 acres in hay, including 16,300 acres in alfalfa and alfalfa mixtures; 34,600 acres in corn; 23,500 acres in oats; 5,100 acres in soybeans; and 1,200 acres in rye.

The number of dairy cows has gradually decreased, and the number of farms that have dairy cows also has decreased, but the farms that have stayed in dairying have increased the size of their herds and raised the level of production per animal unit. Hogs have declined somewhat in number, and horses are used for hobby and recreational purposes rather than for work.

According to the Minnesota Agricultural Statistics, in 1969 there were 43,800 cattle and calves, including 15,300 milk cows; 17,400 hogs and pigs; and 700 sheep and lambs. Milk production totaled 139 million pounds.

[5] By DONALD A. HAINES, climatologist for Minnesota, National Weather Service, U.S. Department of Commerce.

temperatures in spring and in fall

Airport Station, St. Cloud, Minn.]

Dates for given probability and temperature—Continued				
28° F	32° F	36° F	40° F	50° F
May 9	May 20	June 1	June 15	----------
May 4	May 16	May 27	June 9	----------
April 24	May 7	May 19	May 29	June 20
September 25	September 12	September 4	August 25	----------
October 1	September 17	September 9	August 30	----------
October 11	September 27	September 19	September 10	July 24

TABLE 12.—*Minimum temperatures during stated periods*

Average month and day period begins	Duration of period in days	Number of days with minimum stated temperatures
April 7	40	8 days or less have 16° F or lower.
May 17	30	Less than 6 days have 32° F or lower.
June 16	76	Less than 8 days have 40° F or lower.
August 31	13	More than 2 days have 40° F or lower.
September 13	51	More than 5 days have 32° F or lower.
November 3	155	More than 31 days have 16° F or lower.

Farms in the county have been steadily decreasing in number but increasing in size. Also, the number of people living on farms has decreased, but there has been an increase in the number of rural nonfarm residents. The number of farms in 1968 was 1,032.

Only about 25 percent of the population in Benton County is employed in farming, and many farmers supplement their income by working off the farm.

Transportation and Markets

The Burlington Northern Railroad provides freight service to all major business centers in the county. U.S. Highway No. 10 and State Routes 23, 25, and 95 are the main routes to markets. Much of the county road system is blacktopped, and all farms are served by improved, all-weather roads.

Trading centers and elevators are conveniently located in the county. Livestock can be trucked to stockyards and packing plants in St. Cloud or South St. Paul. Most of the milk is marketed as whole milk and is picked up daily by truck.

All areas of the county are serviced by electricity, telephone facilities, police and fire protection, and daily mail service. Consolidated schools are located throughout the county, and churches of most denominations are in the villages and towns.

Industry

The main industrial and commercial enterprises in Benton County are manufacturing paper; quarrying and processing granite into monuments, markers, and building stone; making window sashes, doors, and crating materials; processing poultry; producing optical lenses; making butter, cheese, and ice cream; baking bread; and retailing and servicing farm machinery.

Literature Cited

(1) American Association of State Highway [and Transportation] Officials. 1961. Standard specifications for highway materials and methods of sampling and testing. Ed. 8, 2 v., illus.
(2) Baker, Donald G., and Strub, Joseph H., Jr. 1963. Probability of occurrence in the spring and fall of selected low temperatures. Pt. 1 in Climate of Minnesota, Univ. of Minn. Agr. Expt. Sta. Tech. Bul. 243, 40 pp., illus.
(3) Loughry, F. G. 1968. The soil factor in sanitary land fill. Penn. Dept. of Health. 8 pp.
(4) Portland Cement Association. 1962. PCA soil primer. 52 pp., illus.
(5) Simonson, Roy W. 1962. Soil classification in the United States. Sci. 137: 1027–1034.
(6) Thiel, George A. 1947. Geology and underground waters of northeastern Minnesota. Minn. Geol. Survey Bul. 32, 247 pp., illus.
(7) United States Department of Agriculture. 1951. Soil survey manual. Handbook 18, 503 pp., illus. [Supplement issued in 1962]
(8) ———. 1960. Soil classification, a comprehensive system, 7th approximation, 265 pp., illus. [Supplements issued in March 1967 and September 1968]
(9) ———. 1971. Soils and septic tanks. Agr. Info. Bul. No. 349, 12 pp., illus.
(10) ———. 1964. Forest type areas by counties, Minnesota, 1962. Lakes States Forest Expt. Sta. Research Note LS–55.
(11) United States Department of Defense. 1968. Unified soil classification system for roads, airfields, embankments, and foundations. MIL–STD–619B, 30 pp., illus.
(12) United States Department of Health, Education, and Welfare. 1967. Manual of septic tank practice. Pub. Health Serv. Pub. 526, 92 pp., illus.
(13) Woyski, M. S. 1949. Intrusives of central Minnesota. Geol. Soc. of Amer. Bul., 60: 999–1016.
(14) Wright, H. E., Jr. 1956. Glacial geology, eastern Minnesota. Geol. Soc. of Amer. Guidebook for Field Trips, Minneapolis Meeting., 3 v., No. 3.

Glossary

Alkali soil. Generally, a highly alkaline soil. Specifically, an alkali soil has so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that the growth of most crop plants is low from this cause.

Alluvium. Soil material, such as sand, silt, or clay, that has been deposited on land by streams.

Anaerobic bacteria. Bacteria that live in the absence of oxygen.

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.

Canopy. The covering of green leaves and branches formed by the crowns of individual trees in a forest.

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.

Clod. A soil aggregate, caused by plowing or digging, that breaks up from repeated wetting and drying.

Concretions. Grains, pellets, or nodules of various sizes, shapes, and colors consisting of concentrations of compounds, or of soil grains cemented together. The composition of some concretions is unlike that of the surrounding soil. Calcium carbonate and iron oxide are examples of material commonly found in concretions.

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" when rolled between thumb and forefinger.

Sticky.—When wet, adheres to other material, and tends to stretch somewhat and 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.

Contour farming. Plowing, cultivating, planting, and harvesting in rows that are at right angles to the natural direction of the slope or that are parallel to terrace grade.

Deciduous (botany). Refers to plants that lose their leaves at maturity, or at certain seasons. Contrasts with evergreen.

Drainage class (natural). Refers to the conditions of frequency and duration of periods of saturation or partial saturation that existed during the development of the soil, as opposed to altered drainage, which is commonly the result of artificial drainage or irrigation but may be caused by the sudden deepening of channels or the blocking of drainage outlets. Seven different classes of natural soil drainage are recognized.

Excessively drained soils are commonly very porous and rapidly permeable and have a low water-holding capacity.

Somewhat excessively drained soils are also very permeable and are free from mottling throughout their profile.

Well-drained soils are nearly free from mottling and are commonly of intermediate texture.

Moderately well drained soils commonly have a slowly permeable layer in or immediately beneath the solum. They have uniform color in the A and upper B horizons and have mottling in the lower B and the C horizons.

Somewhat poorly drained soils are wet for significant periods but not all the time, and some soils commonly have mottling at a depth below 6 to 16 inches.

Poorly drained soils are wet for long periods and are light gray and generally mottled from the surface downward, although mottling may be absent or nearly so in some soils.

Very poorly drained soils are wet nearly all the time. They have a dark-gray or black surface layer and are gray or light gray, with or without mottling, in the deeper parts of the profile.

Drumlin (geology). A streamlined hill or ridge of glacial deposits with a long axis that is parallel to the direction of flow of a former glacier.

Eolian soil material. Earthy parent material accumulated through wind action; commonly refers to sandy material in dunes or to loess in blankets on the surface.

Erosion. The wearing away of the land surface by wind (sandblast), running water, and other geological agents.

Esker (geology). A narrow, winding ridge or mound of stratified gravelly and sandy drift that was deposited by a subglacial stream.

Fertility, soil. The quality of a soil that enables it to provide compounds, in adequate amounts and in proper balance, for the growth of specified plants, when other growth factors such as light, moisture, temperature, and the physical condition of the soil are favorable.

Fragipan. A loamy, brittle, subsurface horizon that is very low in organic-matter content and clay but is rich in silt or very fine sand. The layer is seemingly cemented. When dry, it is hard or very hard and has a high bulk density in comparison with the horizon or horizons above it. When moist, the fragipan tends to rupture suddenly if pressure is applied, rather than to deform slowly. The layer is generally mottled, is slowly or very slowly permeable to water, and has few or many bleached fracture planes that form polygons. Fragipans are a few inches to several feet thick; they generally occur below the B horizon, 15 to 40 inches below the surface.

Glacial lake (geology). A lake whose basin was formed by glaciation, either drift-depressions or ice-scoured rock depressions or glaciated valleys. Also used for a water body held up by the damming action of a glacier.

Glacial till (geology). Unassorted, nonstratified glacial drift consisting of clay, silt, sand, and boulders transported and deposited by glacial ice.

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 residue.

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 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 in which the overlying horizons formed. If the material is known to be different from that in the solum, a Roman numeral precedes the letter C.

R layer.—Consolidated rock beneath the soil. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

Kame (geology). An irregular, short ridge or hill of stratified glacial drift.

Lacustrine deposit (geology). Material deposited from lake water and exposed by lowering of the water level or elevation of the land.

Loam. The textural class of soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand.

Mottling, soil. 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.

No-till planting (agronomy). The practice whereby a new crop is planted in last year's stubble or stalks without seedbed preparation. Usually fertilizer and a herbicide are applied on the same trip through the field.

Organic soil. A general term applied to a soil or 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.

Ped. An individual natural soil aggregate, such as a crumb, a prism, or a block, in contrast to a clod.

Perched water table. A body of water that has been retarded in its downward movement by an impermeable or nearly impermeable layer to such an extent that it forms an upper zone of saturation overlying, but separated from, a lower zone.

Permeability. The quality that enables the soil to transmit water or air. Terms used to describe permeability are as follows: *very slow, slow, moderately slow, moderate, moderately rapid, rapid,* and *very rapid.*

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; an alkaline soil is one that is alkaline in reaction. In words, the degrees of acidity or alkalinity are expressed thus:

	pH		pH
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	9.1 and higher
Slightly acid	6.1 to 6.5		
Neutral	6.6 to 7.3		

Rill. A steep-sided channel resulting from accelerated erosion. A rill normally is a few inches in depth and width and is not large enough to be an obstacle to farm machinery.

Roches moutonnées. Rounded hummocks of rocklike whales' backs, smoothed and striated by glacial action. Also called sheepbacks and rock sheep.

Sand. Individual rock or mineral fragments in a soil 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.

Side-slope seepage. The lateral movement of internal soil water that surfaces some distance down the slope of a hillside.

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.

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.

Stoss (geology). Facing the direction from which a glacier moves. Contrasts with *lee*.

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 either *single grain* (each grain by itself, as in dune sand) or *massive* (the particles adhering together without any regular cleavage, as in many claypans and hardpans).

Surface layer. The uppermost part of the soil, ordinarily moved in tillage, or its equivalent in uncultivated soils; roughly, the A horizon.

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 proportion 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."

Valley train (geology). The material deposited by the stream in the valley below a glacier.

Vesicular. Having small pores in the soil mass.

Water table. The highest part of the soil or underlying rock material that is wholly saturated with water. In some places an upper, or perched, water table may be separated from a lower one by a dry zone.

GUIDE TO MAPPING UNITS

For a full description of a mapping unit, read both the description of the mapping unit and that of the soil series to which the mapping unit belongs. In referring to a capability unit, read the introduction to the section it is in for general information about its management. For a discussion of windbreaks refer to page 69. Other information is given in tables as follows:

Acreage and extent, table 1, page 8.
Predicted yields, table 2, page 62.
Interpretations for recreational development, table 5, page 73.
Engineering uses of the soils, tables 6, 7, and 8, pages 82 through 105.

Map symbol	Mapping unit	Described on page	Capability unit		Woodland suitability group		Building site group	
			Symbol	Page	Number	Page	Number	Page
Ad	Adolph silt loam	10	IVw-1	59	VII	69	9	108
AdA	Adolph silt loam, level	10	IIIw-1	57	VII	69	9	108
Ah	Adolph silt loam, silty subsoil variant	11	IIIw-1	57	VII	69	9	108
Ao	Alluvial land	11	VIw-1	61	VII	69	9	108
AtA	Antigo silt loam, 0 to 2 percent slopes	12	IIs-1	56	I	67	1	105
AtB	Antigo silt loam, 2 to 6 percent slopes	12	IIe-2	55	I	67	1	105
Bd	Blomford loamy sand	13	IIIw-2	57	V	68	7	108
BhC	Braham loamy fine sand, 2 to 8 percent slopes	14	IVs-1	60	IV	68	5	107
BrA	Brainerd sandy loam, 1 to 3 percent slopes	15	IIc-1	56	I	67	4	106
BrB	Brainerd sandy loam, 3 to 5 percent slopes	15	IIe-1	55	I	67	4	106
BsA	Brainerd stony sandy loam, 1 to 3 percent slopes	15	IIc-1	56	I	67	4	106
BsB	Brainerd stony sandy loam, 3 to 5 percent slopes	15	IIe-1	55	I	67	4	106
BuA	Burkhardt sandy loam, 0 to 2 percent slopes	16	IIIs-2	58	VI	68	1	105
BuB	Burkhardt sandy loam, 2 to 6 percent slopes	16	IIIe-2	57	VI	68	1	105
CeB	Chetek loamy sand, 2 to 6 percent slopes	17	IVs-2	60	VI	68	1	105
CeC	Chetek loamy sand, 6 to 12 percent slopes	17	VIs-1	61	VI	68	1	105
ChA	Chetek sandy loam, 0 to 2 percent slopes	17	IIIs-2	58	VI	68	1	105
ChB	Chetek sandy loam, 2 to 6 percent slopes	18	IIIe-2	57	VI	68	1	105
ChB2	Chetek sandy loam, 2 to 6 percent slopes, eroded	18	IIIe-2	57	VI	68	1	105
ChC	Chetek sandy loam, 6 to 15 percent slopes	18	IVe-1	59	VI	68	1	105
CmB	Chetek-Milaca complex, 2 to 6 percent slopes	18	IIIe-2	57	---	--	3	106
	Chetek sandy loam	--	-------	--	VI	68	---	---
	Milaca fine sandy loam	--	-------	--	I	67	---	---
CmC	Chetek-Milaca complex, 6 to 12 percent slopes	18	IVe-1	59	---	--	3	106
	Chetek sandy loam	--	-------	--	VI	68	---	---
	Milaca fine sandy loam	--	-------	--	I	67	---	---
DaA	Dalbo fine sandy loam, 0 to 2 percent slopes	19	IIc-1	56	I	67	4	106
DbB	Dalbo silt loam, 2 to 8 percent slopes	19	IIe-1	55	I	67	4	106
DcA	Dickman coarse sandy loam, 0 to 2 percent slopes	20	IIIs-2	58	VI	68	1	105
Du	Duelm loamy sand	21	IIIw-2	57	V	68	7	108
EmE	Emmert gravelly loamy sand, 6 to 25 percent slopes	22	VIIs-1	61	VI	68	2	106
FlB	Flak sandy loam, 2 to 6 percent slopes	23	IIe-1	55	I	67	3	106
Fl B2	Flak sandy loam, 2 to 6 percent slopes, eroded	23	IIe-1	55	I	67	3	106
FlC	Flak sandy loam, 6 to 12 percent slopes	23	IIIe-1	56	I	67	3	106
Fl C2	Flak sandy loam, 6 to 12 percent slopes, eroded	23	IIIe-1	56	I	67	3	106
Fr	Freer silt loam	25	IIw-1	55	III	68	6	107
Fs	Freer stony silt loam	25	IIw-1	55	III	68	6	107
Gr	Granite rock land	25	VIIIs-1	61	VII	69	9	108
Hm	Hillet silt loam	27	IVw-1	59	VII	69	9	108
HmA	Hillet silt loam, level	27	IIIw-1	57	VII	69	9	108
HoA	Hubbard loamy coarse sand, 0 to 2 percent slopes	27	IVs-2	60	VI	68	2	106
HoA2	Hubbard loamy coarse sand, 0 to 2 percent slopes, wind eroded	28	IVs-2	60	VI	68	2	106
HoB	Hubbard loamy coarse sand, 2 to 6 percent slopes	29	IVs-2	60	VI	68	2	106
HoB2	Hubbard loamy coarse sand, 2 to 6 percent slopes, eroded	29	IVs-2	60	VI	68	2	106
HrA	Hubbard loamy fine sand, 0 to 2 percent slopes	30	IVs-2	60	VI	68	2	106
HrA2	Hubbard loamy fine sand, 0 to 2 percent slopes, wind eroded	30	IVs-2	60	VI	68	2	106

Map symbol	Mapping unit	Described on page	Capability unit		Woodland suitability group		Building site group	
			Symbol	Page	Number	Page	Number	Page
HrB	Hubbard loamy fine sand, 2 to 6 percent slopes	30	IVs-2	60	VI	68	2	106
HrB2	Hubbard loamy fine sand, 2 to 6 percent slopes, eroded	30	IVs-2	60	VI	68	2	106
HsC2	Hubbard soils, 6 to 12 percent slopes, eroded	31	VIs-1	61	VI	68	2	106
HsE	Hubbard soils, 12 to 25 percent slopes	31	VIIs-1	61	VI	68	2	106
Im	Isanti mucky loamy fine sand	32	IVw-2	59	VII	69	8	108
It	Isanti mucky loamy fine sand, loamy subsoil variant	32	IVw-2	59	VII	69	8	108
LaA	Langola loamy fine sand, 0 to 2 percent slopes	33	IIIs-1	58	IV	68	5	107
LaB2	Langola loamy fine sand, 2 to 6 percent slopes, eroded	33	IIIs-1	58	IV	68	5	107
Ln	Lino loamy fine sand	34	IIIw-2	57	V	68	7	108
Lo	Lino loamy fine sand, loamy subsoil variant	35	IIIw-2	57	V	68	7	108
Ma	Marsh	35	VIIIw-1	61	VII	69	9	108
McB	Milaca fine sandy loam, 2 to 6 percent slopes	36	IIe-1	55	I	67	3	106
McB2	Milaca fine sandy loam, 2 to 6 percent slopes, eroded	37	IIe-1	55	I	67	3	106
McC	Milaca fine sandy loam, 6 to 12 percent slopes	37	IIIe-1	56	I	67	3	106
McC2	Milaca fine sandy loam, 6 to 12 percent slopes, eroded	37	IIIe-1	56	I	67	3	106
McE	Milaca fine sandy loam, 12 to 25 percent slopes	37	VIe-1	60	II	67	3	106
MdB	Milaca stony fine sandy loam, 2 to 6 percent slopes	37	IIe-1	55	I	67	3	106
MfB	Milaca very fine sandy loam, 2 to 6 percent slopes	38	IIe-1	55	I	67	3	106
MhB	Milaca stony very fine sandy loam, 2 to 6 percent slopes	38	IIe-1	55	I	67	3	106
MlB	Milaca fine sandy loam, clay loam subsoil variant, 1 to 6 percent slopes	39	IIe-1	55	II	67	3	106
MoA	Mora fine sandy loam, 1 to 3 percent slopes	40	IIc-1	56	I	67	4	106
MoB	Mora fine sandy loam, 3 to 5 percent slopes	40	IIe-1	55	I	67	4	106
MrA	Mora stony fine sandy loam, 1 to 3 percent slopes	40	IIc-1	56	I	67	4	106
Ms	Mucky peat	41	IVw-3	60	VII	69	9	108
Mu	Mucky peat over sand	41	IVw-3	60	VII	69	9	108
Mx	Mucky peat over loam	42	IVw-3	60	VII	69	9	108
Nm	Nokasippi mucky loamy fine sand	43	IVw-2	59	VII	69	8	108
No	Nokay fine sandy loam	44	IIw-1	55	III	68	6	107
Ns	Nokay stony fine sandy loam	44	IIw-1	55	III	68	6	107
Og	Ogilvie silt loam	45	IIw-2	56	III	68	6	107
PaA	Paget silt loam, 0 to 2 percent slopes	46	IIc-1	56	I	67	4	106
PaB	Paget silt loam, 2 to 6 percent slopes	46	IIe-1	55	I	67	4	106
PbA	Paget stony silt loam, 0 to 2 percent slopes	46	IIc-1	56	I	67	4	106
PbB	Paget stony silt loam, 2 to 6 percent slopes	46	IIe-1	55	I	67	4	106
Pe	Parent loam	47	IIIw-1	57	III	68	9	108
Pk	Parent stony loam	47	IIIw-1	57	III	68	9	108
PoB	Pomroy fine sand, 2 to 6 percent slopes	48	IIIs-1	58	IV	68	5	107
PoC	Pomroy fine sand, 6 to 12 percent slopes	48	IVs-1	60	IV	68	5	107
PrA	Pomroy loamy fine sand, 0 to 2 percent slopes	49	IIIs-1	58	IV	68	5	107
Ps	Prebish loam	49	IVw-1	59	VII	69	9	108
Pt	Prebish stony loam	50	IVw-1	59	VII	69	9	108
Pu	Prebish and Parent loams	50	IIIw-1	57	---	--	9	108
	Prebish loam	--	-------	--	VII	69	---	---
	Parent loam	--	-------	--	III	68	---	---
Rn	Ronneby loam	51	IIw-1	55	III	68	6	107
Ro	Ronneby stony loam	51	IIw-1	55	III	68	6	107
SaA	Sartell fine sand, 0 to 2 percent slopes	52	IVs-2	60	VI	68	2	106
SaB	Sartell fine sand, 2 to 6 percent slopes	52	IVs-2	60	VI	68	2	106
SaC	Sartell fine sand, 6 to 12 percent slopes	52	VIs-1	61	VI	68	2	106
SaE	Sartell fine sand, 12 to 25 percent slopes	52	VIIs-1	61	VI	68	2	106
Wa	Watab loamy fine sand	53	IIIw-2	57	V	68	7	108

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