SOIL SURVEY OF

Carlton 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. In line with Department of Agriculture policies, benefits of this program are available to all who need the information, regardless of race, color, national origin, sex, religion, marital status, or age.

Major fieldwork for this soil survey was completed in the period 1964–72. Soil names and descriptions were approved in 1973. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1973. 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 Carlton County Soil and Water Conservation District.

Soil maps in this survey may be copied without permission, but any enlargement of these maps could cause misunderstanding of the detail of mapping and result in erroneous interpretations. Enlarged maps do not show small areas of contrasting soils that could have been shown at a larger mapping scale.

THIS SOIL SURVEY contains information that can be applied in managing farms, woodlands, and wildlife areas; 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 Carlton County are shown on the detailed map at the back of this publication. This map consists of many sheets made from aerial photographs. Each sheet is numbered to correspond with a number on the Index to Map Sheets.

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

Finding and using information

The "Guide to mapping units" can be used to find information. This guide lists all the soils of the county in numerical order by map symbol and gives the capability classification of each. It shows the page where each soil is described and the pasture, woodland, wildlife, recreation, and community groups in which it has been placed.

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

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

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

Wildlife managers and others can find information about soils and wildlife in the section "Wildlife."

Community planners and others can read about soil properties that affect the choice of sites for nonindustrial buildings and for recreation areas in the section "Town and country planning."

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

Scientists and others can read about the soils in the section "Formation and classification of the soils."

Newcomers in the area may be especially interested in the section "General soil map," where broad patterns of soils are described. They may also be interested in the information about the county given in the section "General nature of the county."

Cover: Snowmobile trail in the nearly level to hilly Ahmeek-Omega association.

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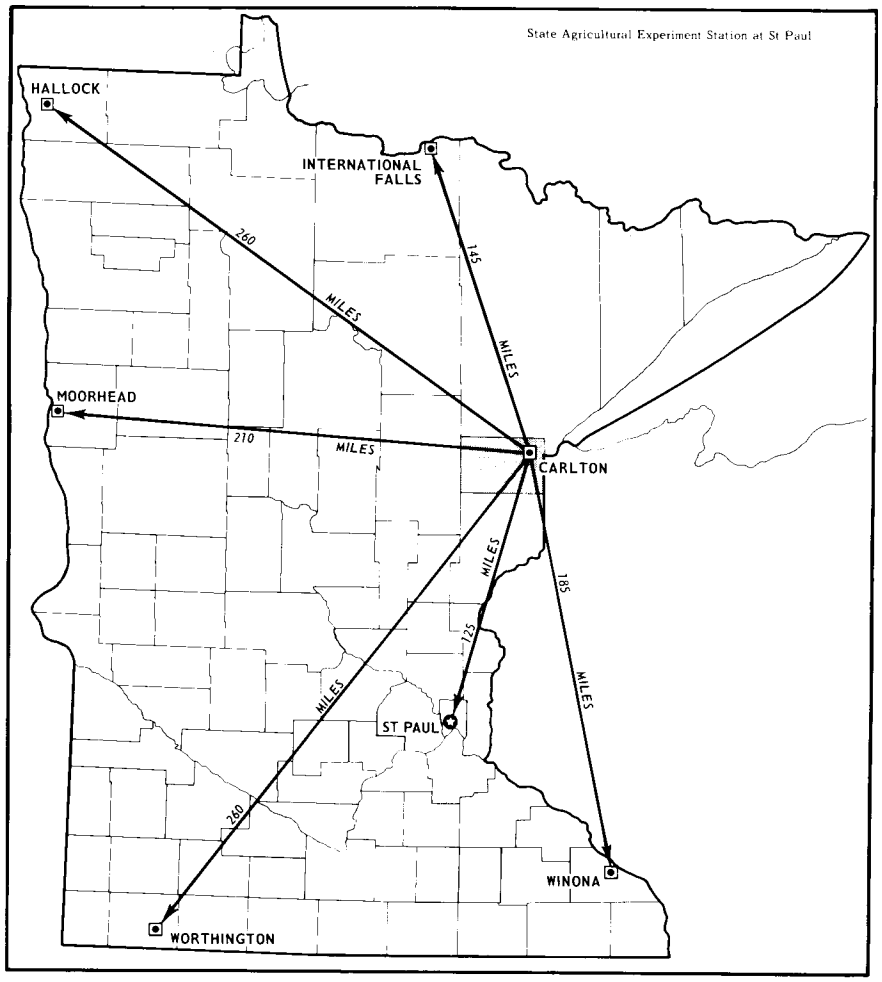

Location of Carlton County in Minnesota.

SOIL SURVEY OF CARLTON COUNTY, MINNESOTA

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

CARLTON COUNTY is in the northeastern part of Minnesota (see map on facing page). It has a land area of about 551,744 acres. Carlton, the county seat, is in the northeastern part of the county.

All of the soils in the county are acid, and most of them have a reddish brown subsoil and a substratum of glacial drift. About 48 percent of the county consists of nearly level soils. Organic soils make up about one-half of these nearly level soils, or about one-fourth of the county.

Most of the land is used for woodland, recreation, and wildlife habitat. A short, cool growing season limits the types of crops that are suited to the area. Dairying and beef production are the major farming enterprises.

How this survey was made

Soil scientists made this survey to learn what kinds of soil are in Carlton 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. Duluth and Greenwood, 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, Cloquet fine sandy loam, 0 to 2 percent slopes, is one of several phases within the Cloquet 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 Carlton 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. Ahmeek-Omega complex, 0 to 2 percent slopes, 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. If there are two or more dominant series represented in the group, the name of the group ordinarily consists of the names of the dominant soils, joined by "and." Blackhoof and Mahtowa soils, is an example.

In most areas surveyed there are places where the soil material is so shallow 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 given a subgroup name in the soil classification system. Borosaprists is an example.

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 its 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 the survey area. A soil association is a landscape that has a distinctive pattern of soils in defined proportions. It typically consists of one or more major soils and at least one minor soil, and it is named for the major soils. The soils in an association can occur in other associations, but in different patterns.

A map showing soil associations is useful to people who want to have a general idea of the soils in a survey area, who want to compare different parts of that area, or who want to locate large tracts that are suitable for a certain kind of land use. Such a map is a useful general guide for broad planning on a watershed, a wooded tract, or a wildlife area or for broad planning of recreational facilities, community developments, and such engineering works as transportation corridors. It is not a suitable map for detailed planning for management of a farm or field or for selecting the exact location of a road or building or other structure, because the soils within an association ordinarily vary in slope, depth, stoniness, drainage, and other characteristics that affect their management.

The soil associations in this survey area have been grouped into three general kinds of landscape for broad interpretive purposes. Each of the broad groups and the soil associations in each group are described in the following pages.

Deep, nearly level, acid soils

In this group are deep, nearly level, acid soils, many of which are limited by wetness. Major reclamation is necessary to provide drainage outlets in many areas. Some areas have very few roads. Five associations are in this group.

1. Duluth-Blackhoof-Mahtowa association

Nearly level, well drained to moderately well drained and poorly drained to very poorly drained soils that have a loam subsoil

This association consists of nearly level ground moraines. Local relief is about 3 feet in most of the association.

This association makes up about 1 percent of the county. It is about 50 percent Duluth soils, 25 percent Blackhoof and Mahtowa soils, and 25 percent soils of minor extent.

The Duluth soils are well drained and moderately well drained. Typically, the surface layer is very dark brown very fine sandy loam about 2 inches thick. The subsurface layer is dark brown very fine sandy loam about 1 inch thick, and it is discontinuous. The upper 9 inches of the subsoil is dark reddish brown, friable very fine sandy loam; the next 1 inch is reddish gray very fine sandy loam that tongues into the lower part of the subsoil to a depth of 18 inches; and the lower 52 inches is reddish brown, firm loam. The underlying material is dark reddish brown loam.

The Blackhoof soils are very poorly drained. Typically, black muck about 11 inches thick overlies a mineral surface layer of black, very firm silty clay loam about 4 inches thick. The subsoil is about 30 inches thick. The upper part is gray, friable loam, and the lower part is reddish brown, friable loam. The underlying material is reddish brown loam.

The Mahtowa soils are poorly drained to very poorly drained. Typically, the surface layer is black silt loam about 11 inches thick. The upper 5 inches of the subsoil is olive gray loam, the next 5 inches is grayish brown loam, and the lower 19 inches is reddish brown loam. The underlying material is reddish brown loam.

The soils of minor extent are Dusler and Beseman soils. Somewhat poorly drained and poorly drained Dusler soils are in swales and drainageways. Very poorly drained Beseman soils are in depressions and consist of muck underlain by loamy material.

Most of this association is used for woodland and recreation; a few areas, however, are used for pasture and hay. Wetness is the major limitation.

2. Greenwood-Loxley-Mooselake association

Nearly level, very poorly drained organic soils

This association consists of soils that formed in organic material. These soils are in areas that are locally called bogs. Some of the bogs are several hundred acres in size.

This association makes up about 8 percent of the county. It is about 40 percent Greenwood soils, 20 percent Loxley soils, 20 percent Mooselake soils, and 20 percent soils of minor extent (fig. 1).

Typically, the Greenwood soils have a surface layer of light gray, extremely acid sphagnum peat about 20 inches thick. The underlying material is dark reddish brown, extremely acid herbaceous mucky peat to a depth of more than 60 inches.

Typically, the Loxley soils have a surface layer of reddish brown, extremely acid peat about 6 inches thick. The underlying material is black and dark reddish brown, extremely acid herbaceous muck to a depth of 60 inches.

Typically, the Mooselake soils have a surface layer of black, strongly acid woody muck about 6 inches thick. The underlying material is dark reddish brown, medium acid woody mucky peat.

The soils of minor extent in this association include Waskish, Lobo, Beseman, and Dawson soils. The Waskish and Lobo soils are on raised bogs. Beseman and Dawson soils are commonly adjacent to uplands or to islands of mineral soils.

Most areas of this association are used for woodland and for recreation in winter. A large acreage is in the Fond Du Lac State Forest. A high water table and the lack of roads limit use. Many areas do not have suitable drainage outlets. A concentration of cold air causes frost more frequently during the growing season in these areas than on the surrounding uplands.

Areas of Waskish soils in this association have potential for the production of horticultural peat, and one bog is used commercially for this purpose. This association also has potential for wildrice, cranberries, and vegetables that tolerate light frost and have a short growing season. Forage crops also are grown, but the acreage is small.

3. Automba-Mora association

Nearly level, well drained to somewhat poorly drained soils that have a fine sandy loam subsoil

This association consists of nearly level ground

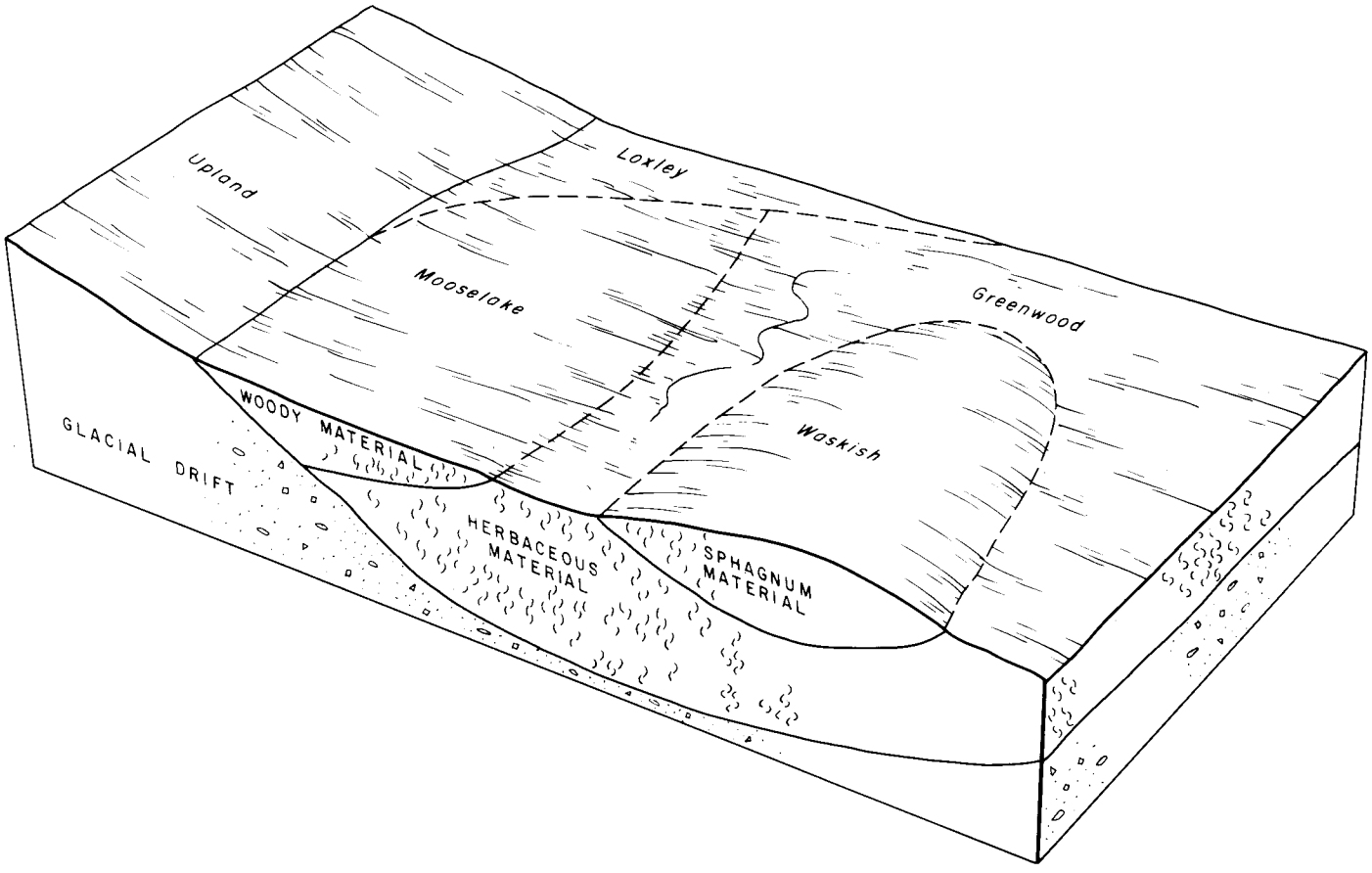


***Figure 1.*—Topography, soils, and underlying material in association 2.**

moraines. Local relief is less than 5 feet throughout most of the area.

This association makes up about 8 percent of the county. It is about 35 percent Automba soils, 20 percent Mora soils, and 45 percent soils of minor extent.

The Automba soils are dominantly nearly level and are well drained and moderately well drained. Typically, the surface layer is black fine sandy loam about 2 inches thick. The upper 22 inches of the subsoil is brown and reddish brown, very friable fine sandy loam; and the lower 22 inches is dark reddish brown, firm fine sandy loam. The underlying material is dark reddish brown fine sandy loam.

The Mora soils are nearly level and somewhat poorly drained. Typically, the surface layer is black fine sandy loam about 4 inches thick. The subsurface layer is grayish brown and yellowish brown fine sandy loam about 7 inches thick. The subsoil is reddish brown fine sandy loam about 47 inches thick. The underlying material is dark reddish brown fine sandy loam.

The soils of minor extent are Twig, Parent, and Beseman soils. These soils are in depressions and are poorly drained and very poorly drained.

Slightly more than one-half of this association is used for woodland and recreation, and the rest is used for forage crops. Dairying and raising beef cattle are common enterprises. If drainage is improved and if adequate fertilizer and lime are applied, the soils of this association have a high potential for all cultivated crops commonly grown in the county.

4. Alstad association

Nearly level, somewhat poorly drained and very poorly drained soils that have a loam and clay loam subsoil

The association consists of nearly level ground moraines. Local relief is less than 10 feet throughout most of the area.

This association makes up about 1 percent of the county. It is about 30 percent Alstad soils, 30 percent Alstad variant soils, and 40 percent soils of minor extent.

The Alstad soils are somewhat poorly drained. Typically, the surface layer is black fine sandy loam about 2 inches thick. The subsurface layer is gray fine sandy loam about 7 inches thick. The next layer is mixed gray fine sandy loam and grayish brown clay loam about 5 inches thick. The subsoil is olive gray clay loam in the upper part and reddish brown clay loam in the lower part. It is about 23 inches thick. The underlying material is reddish brown, calcareous loam.

The Alstad variant soils are in slightly concave areas and are very poorly drained. Typically, the upper 3 inches of the surface layer is dark reddish brown muck, and the lower 2 inches is black loam. The subsurface layer is dark gray loam in the upper 3 inches and gray loam in the lower 11 inches. The subsoil is about 26 inches thick. The upper part of the subsoil is reddish gray, firm clay loam; and the lower part is reddish brown loam and clay loam. The underlying material is reddish brown, calcareous loam.

The soils of minor extent are Cushing and Beseman soils. The Cushing soils are on swells and are well drained and moderately well drained. The Beseman soils are in depressions and are very poorly drained.

Most of this association is used for woodland and recreation and is too wet for most crops. Access to these areas is limited.

5. Nemadji-Newson association

Nearly level, somewhat poorly drained to very poorly drained soils that have a sand subsoil

This association consists of a nearly level lake plain. It is between areas of clayey lake sediment and the loamy or sandy uplands. Local relief is mainly 2 to 3 feet, but in a few places adjacent to drainageways the relief is 10 to 20 feet.

This association makes up about 4 percent of the county. It is about 45 percent Nemadji soils, 40 percent Newson soils, and 15 percent soils of minor extent.

The Nemadji soils are somewhat poorly drained. Typically, the surface layer is black loamy sand about 2 inches thick. The subsurface layer is reddish gray fine sand about 4 inches thick. The upper 3 inches of the subsoil is dark reddish brown fine sand, the next 6 inches is reddish brown fine sand, and the lower 24 inches is mottled yellowish red fine sand. The underlying material is reddish brown fine sand.

The Newson soils are poorly drained and very poorly drained. The surface layer is black mucky loamy sand about 5 inches thick. The underlying material is grayish brown and reddish brown sand.

Dawson muck that is in depressions is the main soil of minor extent.

Most of this association is used for woodland and recreation; a few areas, however, have been cleared and are used chiefly for pasture. Although the soils generally have a high water table except during midsummer, they are easy to till. These soils contain few or no rocks.

Deep, nearly level to steep, acid soils

In this group are deep, nearly level to steep, acid soils that range from gravelly sand to clay. Nearly all areas are used for woodland, hay, and pasture. Six associations are in this group.

6. Ahmeek-Omega association

Nearly level to hilly, somewhat excessively drained to moderately well drained soils that have a fine sandy loam or loamy sand and sand subsoil

This association consists of undulating glacial till and outwash plains. Local relief is about 20 to 40 feet in most of the association.

This association makes up about 2 percent of the county. It is about 90 percent Ahmeek and Omega soils and 10 percent soils of minor extent.

The Ahmeek soils are well drained and moderately well drained. Available water capacity is moderate. Typically, the surface layer is very dark brown loam about 2 inches thick. The subsurface layer is brown loam about 1 inch thick. The upper 13 inches of the subsoil is dark brown, very friable fine sandy loam; and the lower 44 inches is reddish brown and dark

reddish brown, firm fine sandy loam. The underlying material is reddish brown fine sandy loam.

The Omega soils are somewhat excessively drained. Available water capacity is low. Typically, about 2 inches of undecomposed and decomposed forest litter overlies a subsurface layer of reddish gray loamy sand about 1 inch thick. The subsoil is reddish brown loamy sand and sand about 21 inches thick. The underlying material is light reddish brown fine sand.

The soils of minor extent are very poorly drained Dawson and Beseman soils that are in depressions.

The part of this association that is south of Carlton mainly is used for hay and pasture and some woodland. Access to these areas is good. Woodland and recreation are major uses of this association in other parts of the county.

7. Ahmeek-Mora association

Nearly level to hilly, well drained to somewhat poorly drained soils that have a fine sandy loam subsoil

The association consists of undulating moraines marked by numerous deep swales and drumlins and cut by drainageways. Local relief is about 20 to 50 feet in most of the association.

This association makes up about 26 percent of the county. It is about 50 percent Ahmeek soils, 10 percent Mora soils, and 40 percent soils of minor extent (fig. 2).

The Ahmeek soils are nearly level to hilly and are well drained and moderately well drained. Typically, the surface layer is very dark brown loam about 2 inches thick. The subsurface layer is brown loam about 1 inch thick. The upper 13 inches of the subsoil is dark brown fine sandy loam, and the lower 44 inches is reddish brown and dark reddish brown, firm fine sandy loam. The underlying material is reddish brown fine sandy loam.

The Mora soils are nearly level and somewhat poorly drained. Typically, the surface layer is black fine sandy loam about 4 inches thick. The subsurface layer is grayish brown and yellowish brown fine sandy loam about 7 inches thick. The subsoil is reddish brown fine sandy loam about 47 inches thick. The underlying material is dark reddish brown fine sandy loam.

Soils of minor extent are Twig, Parent, Greenwood, Loxley, and Mooselake soils. They are in depressions.

Most of this association is used for woodland and recreation. A large acreage is in State forests or is owned by the county. South of Cromwell, where private ownership is dominant, the acreage is used for hay and pasture. In this association, rooting depth is restricted by a dense subsoil. The soils generally contain numerous cobbles.

8. Campia-Spooner association

Nearly level to hilly, well drained, somewhat poorly drained and poorly drained soils that have a silty clay loam and silt loam subsoil

This association consists of a nearly level lake plain that is dissected by drainageways in places. Local relief ranges from less than 2 feet in the northern part of the association to more than 30 feet in the eastern and southern parts.

This association makes up about 2 percent of the county. It is about 45 percent Campia soils, 25 percent Spooner soils, and 30 percent soils of minor extent.

The Campia soils are nearly level to hilly and are well drained. Typically, the surface layer is very dark grayish brown silt loam about 7 inches thick. The subsoil is about 33 inches thick. The upper part of the subsoil is brown and yellowish brown silty clay loam, and the lower part is thin strata of light yellowish brown, yellowish brown, reddish brown, and weak red

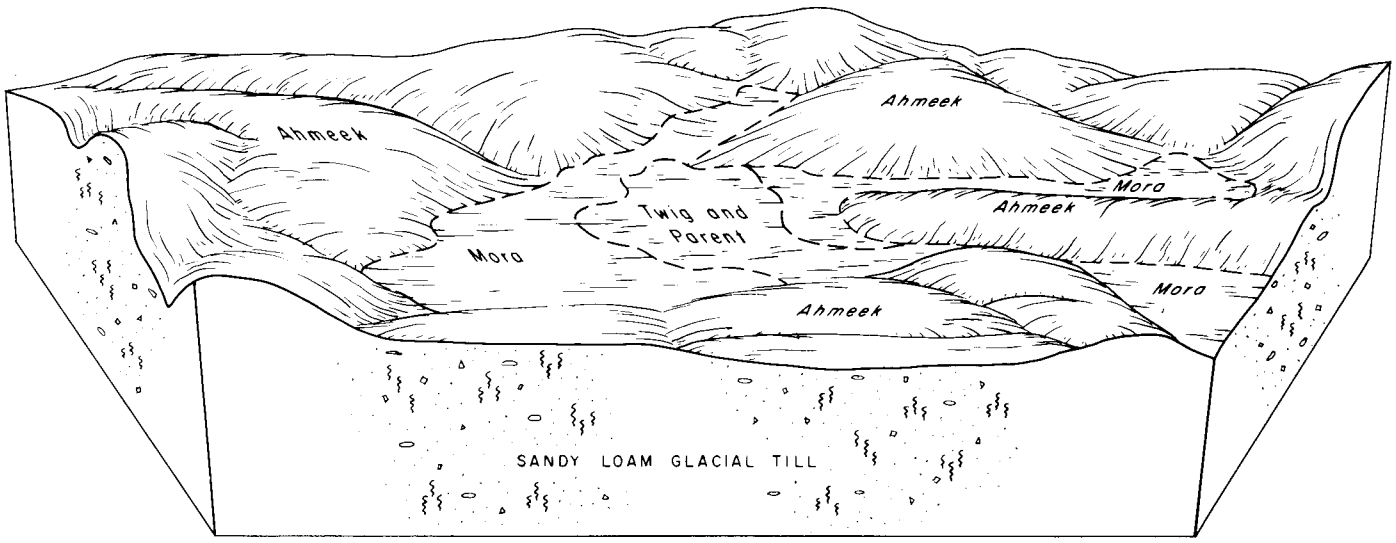


Figure 2.—**Topography, soils, and underlying material in association 7.**

silt loam. The underlying material is thin strata of light yellowish brown, yellowish brown, reddish brown, and weak red, calcareous fine sandy loam.

The Spooner soils are nearly level and are poorly drained and somewhat poorly drained. Typically, the surface layer is black silt loam about 7 inches thick. The subsurface layer is grayish brown silt loam about 3 inches thick. The upper 10 inches of the subsoil is dark grayish brown and olive gray light silty clay loam, and the lower 10 inches is pale brown and light grayish brown silt loam. The underlying material is light gray and yellowish brown, calcareous silt loam.

The soils of minor extent are chiefly Omega and Ontonagon soils.

Most of this association has been cleared and is used for hay, pasture, and cultivated crops. A small acreage is used for potatoes, sod, and horticultural crops. The soils are mainly fertile and generally are easy to till. Some areas need drainage if cultivated crops are grown.

9. Duluth-Dusler association

Nearly level to hilly, well drained to poorly drained soils that have a loam subsoil

This association consists of undulating moraines. Local relief is mainly 20 to 40 feet.

This association makes up about 15 percent of the county. It is about 65 percent Duluth soils, 10 percent Dusler soils, and 25 percent soils of minor extent (fig. 3).

The Duluth soils are nearly level to hilly and are well drained and moderately well drained. Typically, the surface layer is very dark brown very fine sandy loam about 2 inches thick. The subsurface layer is dark brown very fine sandy loam about 1 inch thick, and it is discontinuous. The upper 9 inches of the subsoil is dark reddish brown, friable very fine sandy loam; the next 1 inch is reddish gray very fine sandy loam that tongues into the lower part of the subsoil to a depth of 18 inches; and the lower 52 inches is dark reddish brown, firm loam. The underlying material is dark reddish brown loam.

The Dusler soils are nearly level and are somewhat poorly drained and poorly drained. Typically, the surface layer is very dark gray silt loam about 4 inches thick. The upper 7 inches of the subsurface layer is very dark gray silt loam, and the lower 4 inches is gray fine sandy loam that tongues into the subsoil to a depth of 22 inches. The subsoil is reddish brown, firm loam about 40 inches thick. The underlying material is reddish brown loam.

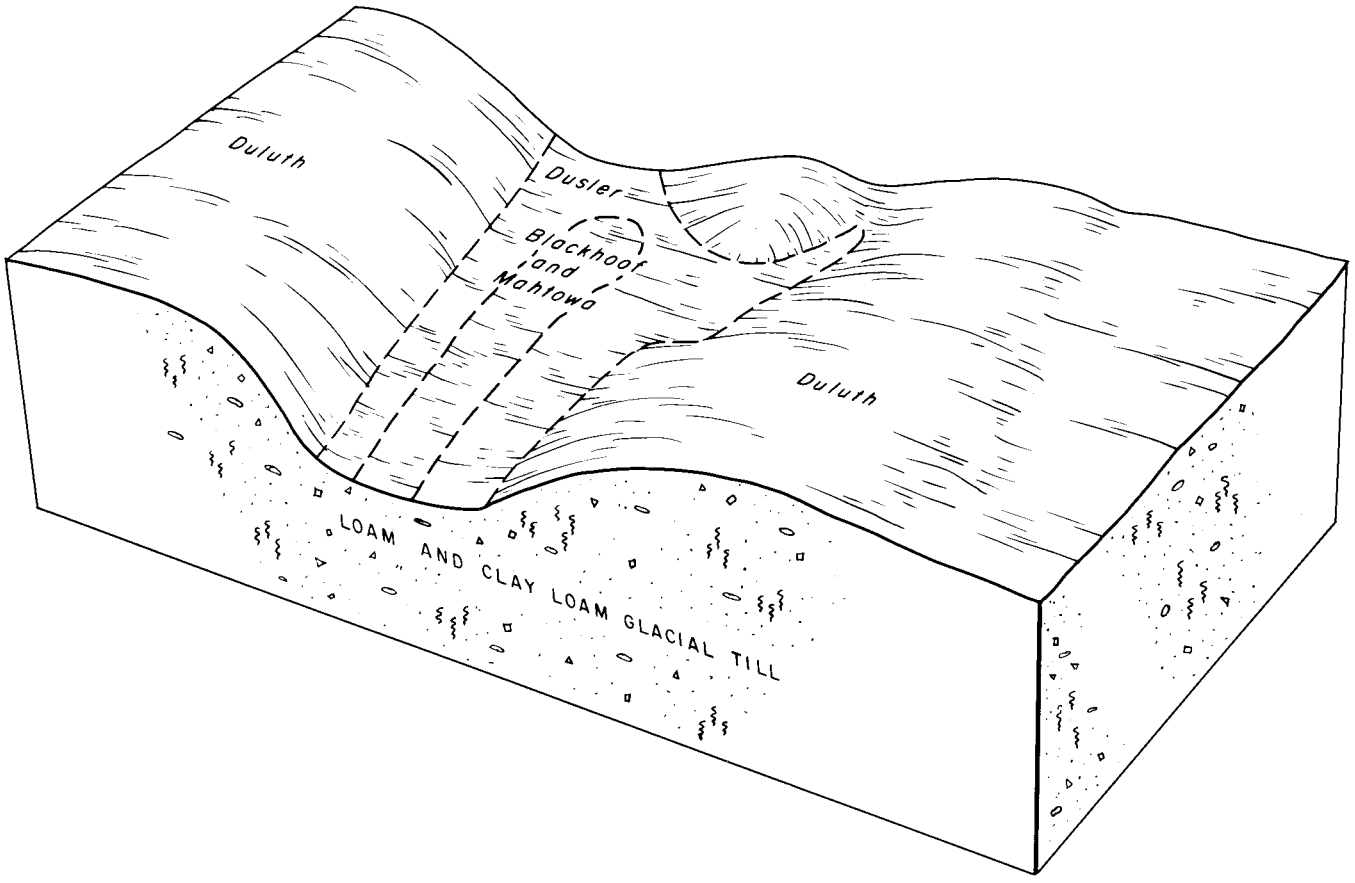


Figure 3.—**Topography, soils, and underlying material in association 9.**

Soils of minor extent are Blackhoof, Mahtowa, and Greenwood soils. These soils are in depressions.

Much of this association has been cleared, especially in Thompson Township. These cleared areas are mainly used for hay and pasture, but some are idle. The rest of the association is used for woodland and recreation. Most of the acreage is privately owned. The soils are chiefly deep loams that have a slowly permeable subsoil. They are mainly free of cobbles that interfere with cultivation.

10. Omega-Cloquet-Cromwell association

Nearly level to steep, somewhat excessively drained soils that have sand and gravelly sand underlying material

This association consists of nearly level outwash plains, eskers, kames, and kettles. Local relief ranges from about 5 feet in areas of gently sloping soils to 150 feet in areas that have eskers and kettles.

This association makes up about 20 percent of the county. It is about 30 percent Omega soils, 25 percent Cloquet soils, 10 percent Cromwell soils, and 35 percent soils of minor extent (fig. 4).

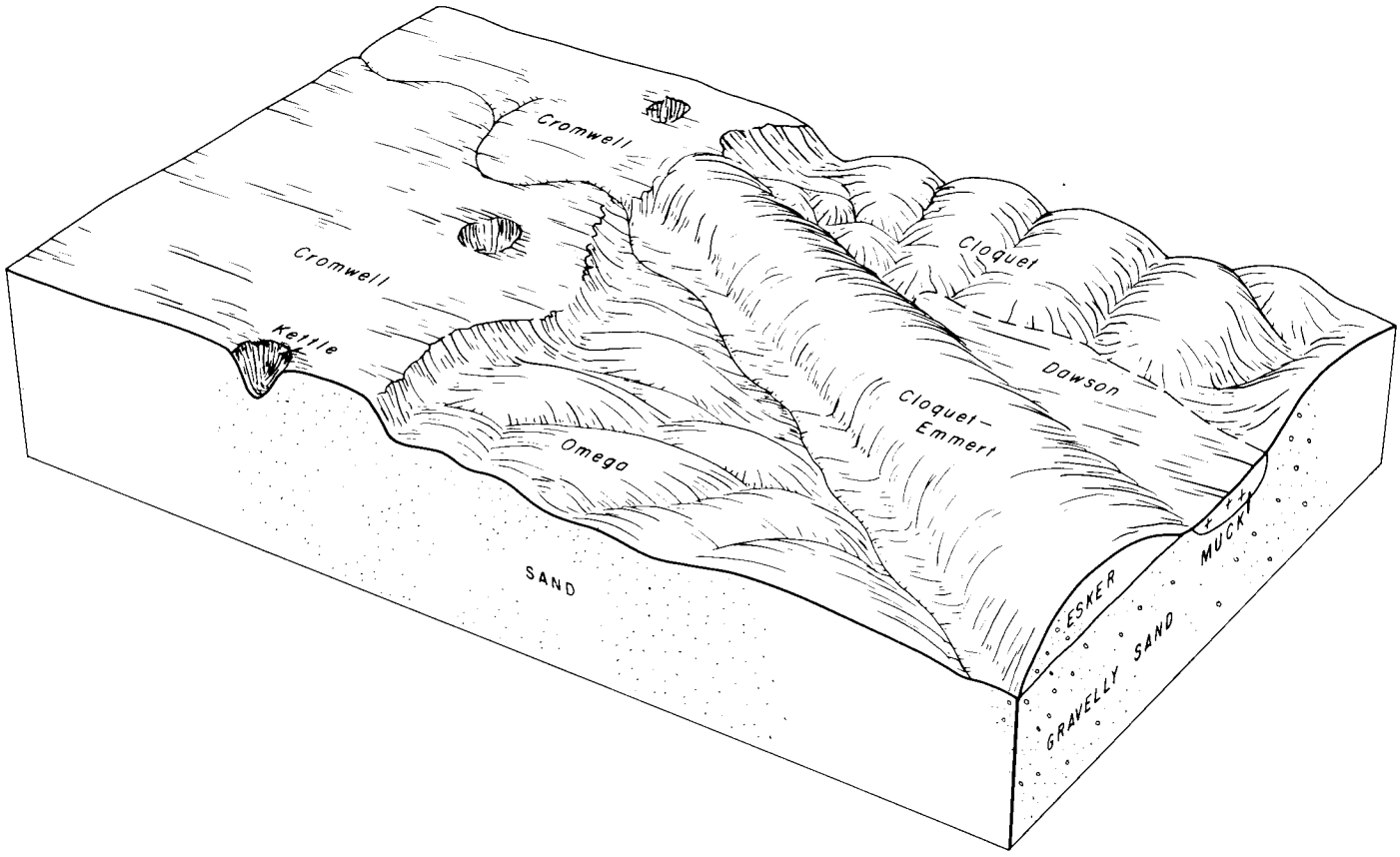
The Omega soils are nearly level to hilly. Typically, about 2 inches of undecomposed and decomposed forest litter overlies a subsurface layer of reddish gray loamy sand about 1 inch thick. The subsoil is reddish brown loamy sand and sand about 21 inches thick. The underlying material is light reddish brown fine sand.

The Cloquet soils are nearly level to steep. Typically, the surface layer is black fine sandy loam about 1 inch thick. The subsurface layer is grayish brown fine sandy loam about 3 inches thick. The upper 11 inches of the subsoil is dark brown, very friable sandy loam; and the lower 22 inches is reddish brown, loose gravelly coarse sand. The underlying material is reddish brown gravelly coarse sand.

The Cromwell soils are nearly level to gently sloping. Typically, the surface layer is black sandy loam about 2 inches thick. The subsurface layer is reddish gray sandy loam about 1 inch thick. The upper 12 inches of the subsoil is dark brown, very friable sandy loam; and the lower 25 inches is reddish brown, stratified sand and coarse sand. The underlying material is reddish brown, stratified sand and coarse sand.

Soils of minor extent are mainly Emmert soils on side slopes and Dawson and Greenwood soils in depressions.

Most of this association is used for woodland and recreation. A few cleared areas are used for hay and pasture. The soils are droughty or have low available water capacity because of the sandy texture or the shallow depth to sand and gravel. These soils can be plowed



ure 4.—**Topography, soils, and underlying material in association 10.**

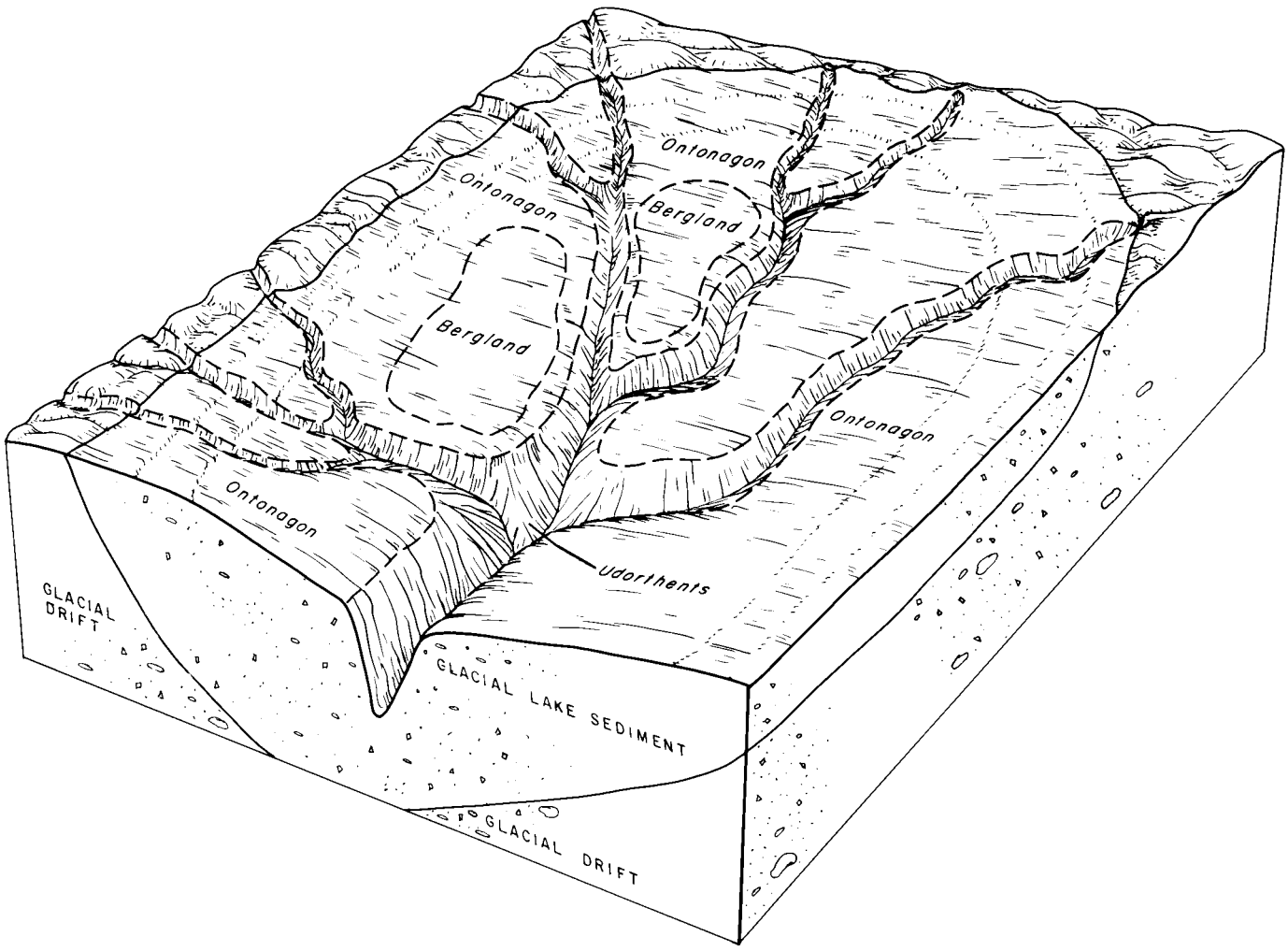


Figure 5.—**Topography, soils, and underlying material in association 11.**

in spring before many of the other finer textured soils in the county.

11. Ontonagon association

Nearly level to hilly, well drained and moderately well drained soils that have a clay subsoil

This association consists of a nearly level lake plain that has many deeply entrenched streams. Between the streams are nearly level ridges that generally are ½ to 1 mile wide and several miles long.

This association makes up about 12 percent of the county. It is about 50 percent Ontonagon soils and 50 percent soils of minor extent (fig. 5).

The Ontonagon soils have a surface layer of very dark gray silty clay about 3 inches thick. The subsurface layer is pinkish gray silty clay about 3 inches thick. It tongues into the subsoil to a depth of about 12 inches. The subsoil is reddish brown, very firm clay about 18 inches thick. The underlying material is reddish brown calcareous clay.

The soils of minor extent are Bergland soils and Udorthents. Bergland soils are in slight depressions and are poorly drained. Udorthents are steep and are adjacent to creeks and rivers.

Most of this association is used for woodland and recreation. A few scattered areas have been cleared and are used for forage. These soils are too clayey for most crops.

Very shallow soils

In this group are soils that are very shallow over bedrock and are too droughty for many uses. One association is in this group.

12. Borofolists association

Nearly level to undulating, very shallow, excessively drained soils and rock outcrop

This association consists chiefly of very shallow soils and bedrock outcrop. Local relief is about 5 to 10 feet. In some places, however, the rock ridges are steep and are generally oriented in an east-west direction.

This association makes up about 1 percent of the county. It is about 75 percent Borofolists and rock out-

crop and about 25 percent soils of minor extent, mainly Borosaprists.

Borofolists are nearly level to undulating. About 2 to 8 inches of organic soil material overlies graywacke bedrock.

This association is used mainly for wildlife habitat and recreation. The rooting zone is very shallow, and most plant species grow slowly.

Descriptions of the soils

This section describes the soil series and mapping units in Carlton 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. Color terms are for moist soil unless otherwise stated. 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.

As mentioned in the section "How this survey was made," not all mapping units are members of a soil series. Borofolists, for example, do not belong to a soil series, but, nevertheless, are listed in alphabetic order along with the soil series.

Preceding the name of each mapping unit is a symbol. 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 and woodland group in which the mapping unit has been placed. The page for the description of each capability unit, woodland group, or other interpretative group can be found 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

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

Soil	Acres	Percent	Soil	Acres	Percent
Ahmeek loam, 0 to 2 percent slopes	16,718	3.0	Duluth very fine sandy loam, 2 to 12 percent slopes	45,923	8.3
Ahmeek loam, 2 to 12 percent slopes	54,877	9.9	Duluth very fine sandy loam, 12 to 25 percent slopes	3,148	.6
Ahmeek loam, 12 to 25 percent slopes	4,167	.8	Duluth very fine sandy loam, 25 to 35 percent slopes	1,043	.2
Ahmeek-Omega complex, 0 to 2 percent slopes	823	.1	Dusler silt loam	10,057	1.8
Ahmeek-Omega complex, 2 to 12 percent slopes	9,980	1.8	Emmert gravelly fine sandy loam, 1 to 12 percent slopes	2,337	.4
Ahmeek-Omega complex, 12 to 25 percent slopes	1,781	.3	Emmert gravelly fine sandy loam, 12 to 25 percent slopes	1,295	.2
Allendale loamy fine sand	2,748	.5	Fluvaquents	7,204	1.3
Alstad fine sandy loam	2,578	.5	Greenwood mucky peat	9,218	1.7
Alstad Variant loam	2,201	.4	Greenwood peat	32,078	5.8
Automba fine sandy loam, 0 to 2 percent slopes	15,462	2.8	Hibbing silt loam, 0 to 2 percent slopes	429	.1
Automba fine sandy loam, 2 to 6 percent slopes	5,496	1.0	Hibbing silt loam, 2 to 12 percent slopes	432	.1
Bergland clay	4,157	.8	Lobo peat	1,622	.3
Beseman muck	21,765	3.9	Loxley muck	28,734	5.2
Blackhoof and Mahtowa soils	10,551	1.9	Merwin mucky peat	3,308	.6
Borofolists	6,492	1.2	Mooselake mucky peat	25,538	4.6
Borosaprists	2,534	.5	Mora fine sandy loam, wet	22,812	4.1
Campia silt loam, 0 to 2 percent slopes	2,737	.5	Nemadji fine sand	10,667	1.9
Campia silt loam, 2 to 12 percent slopes	2,881	.5	Newson mucky loamy sand	9,822	1.8
Campia silt loam, 12 to 25 percent slopes	1,343	.2	Omega loamy sand, 0 to 2 percent slopes	10,921	2.0
Campia-Ontonagon complex, 2 to 12 percent slopes	1,416	.3	Omega loamy sand, 2 to 12 percent slopes	17,589	3.2
Cloquet fine sandy loam, 0 to 2 percent slopes	11,288	2.0	Omega loamy sand, 12 to 25 percent slopes	3,955	.7
Cloquet fine sandy loam, 2 to 12 percent slopes	15,920	2.9	Ontonagon silty clay, 0 to 2 percent slopes	25,109	4.5
Cloquet fine sandy loam, 12 to 25 percent slopes	1,705	.3	Ontonagon silty clay, 2 to 12 percent slopes	3,624	.7
Cloquet-Emmert complex, 25 to 60 percent slopes	968	.2	Ontonagon silty clay, 12 to 25 percent slopes	2,534	.5
Cromwell sandy loam, 0 to 2 percent slopes	6,768	1.2	Spooner silt loam	2,909	.5
Cromwell sandy loam, 2 to 6 percent slopes	7,536	1.4	Twig and Parent soils	10,580	1.9
Cushing fine sandy loam	517	.1	Udorthents	15,993	2.9
Dawson muck	10,240	1.9	Warman fine sandy loam	1,421	.3
Duluth very fine sandy loam, 0 to 2 percent slopes	10,531	1.9	Warman mucky loam	3,082	.6
			Waskish peat	2,180	.4
			Total	551,744	100.0

in describing soils can be found in the Glossary at the end of this survey, and more detailed information about the terminology and methods of soil mapping can be obtained from the Soil Survey Manual (*14*).[1]

Ahmeek series

The Ahmeek series consists of nearly level to hilly, well drained and moderately well drained soils that formed in fine sandy loam till. These soils are on convex sides and tops of moraines and drumlins.

In a representative profile the surface layer is very dark brown loam about 2 inches thick. The subsurface layer is brown loam about 1 inch thick. The upper 13 inches of the subsoil is dark brown, very friable fine sandy loam, and the lower 44 inches is reddish brown and dark reddish brown, firm fine sandy loam. The underlying material is reddish brown fine sandy loam.

Permeability is moderately slow, and the available water capacity is moderate. Organic matter content is low. The availability of phosphorus and potassium is medium. The lower part of the subsoil and the underlying material are very dense. Coarse rock fragments are common on the surface and throughout the profile.

Most areas of Ahmeek soils are used for forest and pasture. The major limitation is the hazard of erosion on the steeper soils.

Representative profile of Ahmeek loam, 2 to 12 percent slopes, in a deciduous-coniferous forest, 1,050 feet west and 180 feet south of the center of sec. 34, T. 49 N., R. 20 W.:

O—½ inch to 0; mixture of decomposed and partly decomposed plant material.

A1—0 to 2 inches; very dark brown (10YR 2/2) loam; moderate fine and very fine granular structure; very friable; many roots; about 1 percent coarse fragments, mostly 4 to 20 centimeters in diameter; strongly acid; abrupt wavy boundary.

A2—2 to 3 inches; brown (7.5YR 5/2) loam; weak medium platy structure; very friable; many roots; few tubular pores; about 1 percent coarse fragments, mostly 4 to 20 millimeters in diameter; horizon is discontinuous, occupying about 20 percent of pedon; very strongly acid; abrupt smooth boundary.

B21hir—3 to 5 inches; dark brown (7.5 4/4) loam; weak very fine crumb structure and some strong fine granular structure; very friable; many roots; about 1 percent coarse fragments, mostly 4 to 20 millimeters in diameter; very strongly acid; abrupt wavy boundary.

B22hir—5 to 9 inches; dark brown (7.5YR 4/4) fine sandy loam; weak fine and very fine subangular blocky structure parting to weak very fine crumb; very friable; many roots; about 1 percent coarse fragments, mostly 4 to 20 millimeters in diameter; strongly acid; clear smooth boundary.

B23hir—9 to 16 inches; dark brown (7.5YR 4/4) fine sandy loam; moderate fine and medium subangular blocky structure parting to very fine subangular blocky; very friable; many roots; about 1 percent coarse fragments, mostly 4 to 20 millimeters in diameter; strongly acid; clear wavy boundary.

Bx1—16 to 26 inches; reddish brown (5YR 4/3) fine sandy loam; massive in some parts, some weak very coarse prismatic structure, and weak medium platy structure in other parts; firm; few roots; few tubular and vesicular pores; few thin clay films on upper faces of platy peds; few reddish gray (5YR 5/2) porous vertical streaks and coatings on faces of peds; about 8 percent coarse fragments, mostly 2 to 5 centimeters in diameter; medium acid; clear smooth boundary.

Bx2—26 to 36 inches; dark reddish brown (5YR 3/3) fine sandy loam; moderate medium platy structure parting to moderate very thin platy; firm; many thin clay films on upper faces of peds and a few lower faces; very few vesicular pores; few random vertical reddish brown (5YR 5/3) porous streaks; about 8 percent coarse fragments, mostly 2 to 5 centimeters in diameter; medium acid; diffuse smooth boundary.

Bx3—36 to 45 inches; dark reddish brown (5YR 3/3) fine sandy loam; moderate medium platy structure parting to moderate thin and very thin platy; firm; common thin clay films on upper faces of peds and a few thin clay films on lower faces; about 8 percent coarse fragments, mostly 2 to 5 centimeters in diameter; slightly acid; diffuse smooth boundary.

Bx4—45 to 60 inches; dark reddish brown (5YR 3/3) fine sandy loam; moderate thin platy structure; firm; few thin clay films on upper faces of peds; about 8 percent coarse fragments, mostly 2 to 5 centimeters in diameter; neutral; abrupt smooth boundary.

C—60 to 75 inches; reddish brown (5YR 4/3) fine sandy loam; weak medium and thick platy structure; friable; few thin strata of loamy sand and silt loam; about 10 percent coarse fragments; neutral.

The solum is 40 to 70 inches thick. Depth to the fragipan ranges from 12 to 24 inches. The content of coarse fragments ranges from about 5 to 15 percent of the profile. The A horizon is predominantly loam but ranges to fine sandy loam, very fine sandy loam, and silt loam. It is 1 inch to 6 inches thick and is strongly acid to medium acid. The B2hir horizon is dark reddish brown, reddish brown, or dark brown and is mainly loam but ranges to fine sandy loam, very fine sandy loam, and silt loam. It ranges from very strongly acid to medium acid. The Bx horizon is sandy loam or fine sandy loam. The content of clay ranges from 5 to 12 percent, and the content of silt from 25 to 38 percent. The C horizon is sandy loam or fine sandy loam.

Ahmeek soils formed in material similar to that in which Mora, Twig, and Parent soils formed, but Ahmeek soils are on convex slopes. They are better drained than Mora, Twig, and Parent soils, and they do not

[1] Italic numbers in parentheses refer to References, p. 75.

have the mottles or grayish colors that are characteristic of those soils.

21—Ahmeek loam, 0 to 2 percent slopes. This nearly level soil is on the top of drumlins and moraines. Most areas are elongated to irregular in shape and generally are less than 20 acres in size. In the largest areas that have little relief, much of this soil is moderately well drained and contains a few faint mottles in the upper part of the subsoil.

Included with this soil in mapping are small areas of Automba and Cloquet soils in a random pattern and areas of Mora soils in shallow depressions and waterways. Also included are areas of Parent and Twig soils in 1- to 3-acre depressions and areas of stony and very stony soils 1 acre to 5 acres in size, all of which are indicated by spot symbols on the soil map.

Most areas of this soil are used for aspen, paper birch, basswood, and maple. A few areas have been cleared and are used for crops commonly grown in the county. Gravel, cobbles, and stones are common throughout the profile of this soil, and they interfere with tillage unless removed. Runoff is medium. The short, cool summer limits the choice of crops. Capability unit IIc–1; woodland group 2o1.

21C—Ahmeek loam, 2 to 12 percent slopes. This undulating soil is on moraines and drumlins that have slopes 250 to 500 feet long. Most areas are elongated and irregular in shape and generally are less than 80 acres in size. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Automba and Cloquet soils in a random pattern, areas of Mora soils in waterways and along foot slopes, and a few areas of nearly level and hilly Ahmeek soils. Also included are areas of Parent and Twig soils in 1- to 3-acre depressions and areas of stony and very stony soils 1 acre to 5 acres in size, all of which are indicated by spot symbols on the soil map.

Most areas of this soil are used for aspen, paper birch, basswood, and maple. A few fields have been cleared and are used for crops commonly grown in the county. Gravel, cobbles, and stones are common throughout the profile of this soil, and they interfere with tillage. Control of erosion is necessary to good management. Capability unit IIIe–1; woodland group 2o1.

21E—Ahmeek loam, 12 to 25 percent slopes. This hilly soil is in irregularly shaped, 10- to 30-acre areas that have slopes 150 to 300 feet long. Maximum relief is about 50 feet. This soil is adjacent to areas of Ahmeek soils that have slopes of less than 12 percent.

Included with this soil in mapping are small areas of Automba and Cloquet soils. The Automba soil is in a random pattern, and the Cloquet soil is mainly on knobs or at the crest of slopes. Also included are small areas of undulating Ahmeek soils.

Nearly all areas of this soil are used for trees. Because of very rapid runoff and the severe hazard of erosion, the soil generally is not suited to cultivated crops, but it can be used for pasture and hay. Capability unit VIe–1; woodland group 2r1.

975—Ahmeek-Omega complex, 0 to 2 percent slopes. This nearly level complex is on upland slopes. It is about 20 percent Ahmeek loam, 10 percent Omega loamy sand, and 70 percent soils that commonly are underlain by sand or gravelly sand at a depth of 24 to 50 inches. Most areas of this complex in the southeastern part of the county are underlain by sand. The percentage of each soil in different areas of this complex varies considerably. The soils are in a random pattern.

Included with this complex in mapping are a few areas of Duluth and Hibbing soils and areas of undulating soils. Also included are wet areas as much as 3 acres in size that are indicated by a spot symbol on the soil map.

A few areas of this complex are used for grass and cultivated crops, but most areas are used for trees. The low available water capacity of the Omega soil in this complex limits plant growth. Capability unit IVs–1; Ahmeek soil in woodland group 2o1, Omega soil in woodland group 2s1.

975C—Ahmeek-Omega complex, 2 to 12 percent slopes. This undulating complex has convex slopes that are about 150 to 300 feet long. It is about 20 percent Ahmeek soil, 10 percent Omega soil, and 70 percent soils that are commonly underlain by sand or gravelly sand at a depth of 24 to 50 inches. Most areas of this complex in the southeastern part of the county are underlain by sand. The percentage of each soil in different areas of this complex varies considerably.

Included with this complex in mapping are small areas of Duluth and Hibbing soils. Also included are wet areas less than 3 acres in size that are indicated by a spot symbol on the soil map.

A few areas are used for grass and cultivated crops, but most areas are used for trees. The low available water capacity of the Omego soil in this complex limits plant growth. There is a hazard of erosion in areas where vegetation has been removed. Capability unit VIs–1; Ahmeek soil in woodland group 2o1, Omega soil in woodland group 2s1.

975E—Ahmeek-Omega complex, 12 to 25 percent slopes. This hilly complex has slopes that are mostly convex and are 150 to 300 feet long. It is about 20 percent Ahmeek soil, 10 percent Omega soil, and 70 percent soils that are commonly underlain by sand or gravelly sand at a depth of 24 to 50 inches. The percentage of each soil in the different areas of this complex varies considerably.

Included with this complex in mapping are small areas of Duluth and Hibbing soils. Also included are wet areas less than 3 acres in size that are indicated by a spot symbol on the soil map.

A few areas are used for grass and cultivated crops, but most areas are used for trees. The low available water capacity of the Omega soil in this complex limits plant growth. Runoff is very rapid, and the hazard of erosion is severe in areas where vegetation has been removed. Capability unit VIIs–1; Ahmeek soil in woodland group 2r1, Omega soil woodland group 2s1.

Allendale series

The Allendale series consists of nearly level, somewhat poorly drained soils that formed in sandy material overlying clayey material. These soils are on the edge of a glacial lake.

In a representative profile the surface layer is very dark gray loamy fine sand about 7 inches thick. The upper 24 inches of the subsoil is reddish brown, loose fine sand, and the lower 22 inches is reddish brown, very sticky clay. The underlying material is reddish brown clay.

Permeability is rapid in the sandy upper part of the profile and slow in the clayey lower part. The available water capacity is low to moderate. Organic matter content is low. The availability of phosphorus and potassium is low. A seasonal high water table is above the clay subsoil early in summer and late in fall.

Most areas of Allendale soils are used for forest and pasture. The major limitation is the hazard of wetness.

Representative profile of Allendale loamy fine sand, in a cultivated field planted to red pine, 750 feet east and 100 feet north of the center of sec. 14, T. 46 N., R. 17 W.:

Ap—0 to 7 inches; very dark gray (10YR 3/1) loamy fine sand; weak fine granular structure; very friable; many fine random roots; strongly acid; abrupt smooth boundary.

B21hir—7 to 17 inches; reddish brown (5YR 4/4) fine sand; common fine distinct yellowish red (10YR 4/6) mottles; single grained; loose; many fine random roots; strongly acid; gradual smooth boundary.

B22ir—17 to 31 inches; reddish brown (2.5YR 4/4) fine sand; few medium and large faint yellowish red (2.5YR 5/6) mottles and many fine distinct yellowish red (10YR 4/6) mottles; single grained; loose; common very fine vertical roots; medium acid; abrupt smooth boundary.

IIB21t—31 to 43 inches; reddish brown (2.5YR 4/4) clay; many fine distinct olive mottles (5Y 5/6) in the upper inch; strong coarse prismatic structure parting to strong very fine and fine angular blocky; very sticky; very few very fine vertical roots concentrated along surfaces of peds; many small slickensides; very few thin gray (5Y 6/1) clay films, mostly on vertical faces of peds, and many moderately thick gray (5Y 6/1) clay films in root pores; neutral; gradual smooth boundary.

IIB22t—43 to 53 inches; reddish brown (2.5YR 4/4) clay; strong coarse prismatic structure parting to strong fine angular blocky; very sticky; many small slickensides; very few thin gray (5Y 6/1) clay films, mostly on vertical faces of peds, and many moderately thick gray (5Y 6/1) clay films in root pores; mildly alkaline; abrupt smooth boundary.

IIC—53 to 60 inches; reddish brown (2.5YR 4/4) clay; few fine distinct yellowish red (5YR 5/6) mottles; strong very fine and fine angular blocky structure: very sticky; few moderately thick gray (5YR 5/1) clay films in pores; moderately alkaline.

The sandy mantle typically ranges from 20 to 36 inches in thickness. The Ap horizon ranges from very dark gray to dark gray. In uncultivated areas, the A1 horizon is very dark gray, very dark grayish brown, or black and is 2 to 4 inches thick. In places there is a gray, grayish brown, or light grayish brown A2 horizon. The B2 horizon is reddish brown, brown, or dark grayish brown and has distinct or prominent mottles. The A and B2 horizons are fine sand, sand, loamy sand, or loamy fine sand. The IIB2t horizon ranges from 10 to 28 inches in thickness. The C horizon is calcareous in most places.

The content of iron, aluminum, and organic matter in the Bhir horizon of these soils is less than that defined in the range for the series, but this difference does not alter their use or behavior.

Allendale soils are associated on the landscape with Ontonagon soils, but they have more sand and less clay in the upper part of the profile than those soils.

22—Allendale loamy fine sand (0 to 2 percent slopes). This nearly level soil commonly is in areas where the lake plain joins the uplands. Areas are irregular in shape and generally are 10 to 20 acres in size.

Included with this soil in mapping are areas of soils that are similar to Allendale soils but that do not have mottles in the subsoil and are better drained. They commonly are on the highest part of areas where slopes are about 2 percent. Also included are areas of soils that are very fine sand above the clayey material and small areas of Nemadji and Ontonagon soils.

Nearly all areas of this soil are used for trees. A few rounded surface stones are in some areas. A high water table restricts the choice of plants and crops. Capability unit IIIw–2; woodland group 2w1.

Alstad series

The Alstad series consists of nearly level, somewhat poorly drained soils that formed in calcareous glacial till. Slopes are slightly concave. Surface runoff is slow.

In a representative profile the surface layer is black fine sandy loam about 2 inches thick. The subsurface layer is gray fine sandy loam about 7 inches thick. The next layer is mixed gray fine sandy loam and grayish brown clay loam about 5 inches thick. The subsoil is olive gray clay loam in the upper part and reddish brown clay loam in the lower part. It is about 3 inches thick. The underlying material is reddish brown, calcareous loam.

Permeability is moderately slow, and the available water capacity is high. Organic matter content is high. The availability of phosphorus and potassium is medium. A seasonal high water table is commonly above a depth of 2 feet except for parts of July and August.

Most areas of Alstad soils are used for forest and wildlife habitat. The major limitation is wetness.

Representative profile of Alstad fine sandy loam, in a deciduous forest, 607 feet south and 1,090 feet east of the northwest corner of sec. 9, T. 49 N., R. 21 W.:

O—1 inch to 0; leaves and twigs.

A1—0 to 2 inches; black (10YR 2/1) fine sandy loam; strong very fine granular and subangular blocky structure; very friable; strongly acid; abrupt wavy boundary.

A2—2 to 9 inches; gray (10YR 5/1) fine sandy loam; comon fine distinct yellowish brown

mottles; weak medium platy structure parting to moderate very fine subangular blocky; very friable; about 1 to 2 percent coarse fragments; strongly acid; clear wavy boundary.

A&B—9 to 14 inches; gray (10YR 6/1) tongues of fine sandy loam penetrating grayish brown (2.5Y 5/2) clay loam; common fine prominent strong brown mottles; strong fine and medium subangular blocky structure; friable; about 1 to 2 percent coarse fragments; strongly acid; clear wavy boundary.

B21tg—14 to 30 inches; olive gray (5YR 5/2) clay loam; strong fine and medium subangular blocky structure; firm, sticky; many thick gray (5Y 5/1) clay films on faces of peds and pores; about 1 to 2 percent coarse fragments; medium acid; abrupt wavy boundary.

B22t—30 to 37 inches; reddish brown (5YR 4/3) clay loam; moderate coarse prismatic structure parting to strong very fine subangular blocky; friable; common thick gray (10YR 5/1) clay films on vertical surfaces of peds and pores; about 1 to 2 percent coarse fragments; slightly acid; abrupt wavy boundary.

C—37 to 64 inches; reddish brown (5YR 4/3) loam; weak medium platy structure parting to moderate very fine subangular blocky; friable; strongly effervescent; light gray soft threads and seams of carbonates; few fragments of gray shale; moderately alkaline.

The thickness of the solum and the depth to carbonates range from 32 to 42 inches. The solum is 1 to 5 percent coarse fragments. The A1 horizon ranges from fine sandy loam or loam to silt loam. It is medium acid to strongly acid. The A2 horizon ranges from silt loam or loam to fine sandy loam. It is very strongly acid to strongly acid. Mottles are few to many and distinct or prominent. The B2t horizon ranges from reddish brown, olive gray, or grayish brown to brown. It ranges from heavy loam to light clay loam that is about 25 to 35 percent clay. It is medium acid to slightly acid. The C horizon ranges from reddish brown, olive gray, or grayish brown to brown. It ranges from loam to light clay loam.

The B horizon is slightly grayer in the Alstad soils in this area than is defined in the range of the series, but this difference does not alter their use or behavior.

Alstad soils formed in parent material similar to that in which Cushing soils formed, but they have concave slopes and they have slower surface runoff and are wetter than Cushing soils.

292—Alstad fine sandy loam (0 to 2 percent slopes). This nearly level soil is in areas that have relief of 1 foot to 2 feet and that range from 5 to 150 acres in size. Many small areas of this soil are surrounded by areas of Alstad variant soils.

Included with this soil in mapping are small areas of Cushing soils that have slightly convex slopes and more rapid surface runoff than the Alstad soil. Also included are areas of very poorly drained soils in 1- to 3-acre depressions, which are indicated on the soil map by a spot symbol; a few areas of soils that have a loamy sand surface layer 12 to 18 inches thick; and a few areas of soils that contain more silt, less sand, and less coarse fragments than this Alstad soil and that have a subsoil that is about 35 to 40 percent clay.

Most areas of this soil are used for aspen, elm, ash, basswood, and balsam fir. A few areas have been cleared, and they are used mainly for pasture or hay. The high water table restricts the choice of crops. Capability unit IIw–1; woodland group 2w1.

Alstad Variant

The Alstad variant consists of nearly level, very poorly drained soils that formed in calcareous glacial till. These soils are on ground moraines. Slopes are concave. Runoff is very slow.

In a representative profile the upper 3 inches of the surface layer is dark reddish brown muck, and the lower 2 inches is black loam. The upper 3 inches of the subsurface layer is dark gray loam, and the lower 11 inches is gray loam. The subsoil is about 26 inches thick. The upper part of the subsoil is reddish gray, firm clay loam, and the lower part is reddish brown loam and clay loam. The underlying material is reddish brown, calcareous loam.

Permeability is moderately slow, and the available water capacity is high. Organic matter content is high. The availability of phosphorus and potassium is medium. These soils have a high water table during most of the growing season.

Most areas of Alstad variant soils are used for forest and wildlife habitat. The major limitation is wetness.

Representative profile of Alstad Variant loam, in a sedge meadow with a few scattered black ash, 2,310 feet north and 1,320 feet west of the southeast corner of sec. 5, T. 49 N., R. 21 W.:

Oa—0 to 3 inches; dark reddish brown (5YR 2/2), broken face, sapric material, black (10YR 2/1) rubbed; about 60 percent herbaceous fibers and 40 percent woody fibers; nonsticky, very friable; many very fine and fine random roots; strongly acid; clear wavy boundary.

A1—3 to 5 inches; black (10YR 2/1) loam; moderate very fine granular structure; friable, sticky and plastic; many very fine and fine vertical roots; strongly acid; clear smooth boundary.

A21g—5 to 8 inches; dark gray (10YR 4/1) loam; few fine distinct yellowish brown mottles; massive parting to weak medium platy structure; firm, nonsticky and nonplastic; high bulk density; common very fine vertical roots; very few very fine vertical tubular pores; about 1 to 2 percent coarse fragments; very strongly acid; abrupt wavy boundary.

A22g—8 to 19 inches; gray (10YR 5/1) loam; many large distinct yellowish brown (10YR 5/6) mottles; weak coarse platy structure; friable, slightly sticky and slightly plastic; very few fine vertical roots; few pockets of sand and very fine sandy loam; about 1 to 2 percent coarse fragments; medium acid; gradual wavy boundary.

B21tg—19 to 25 inches; reddish gray (5YR 5/2) clay loam; few fine distinct yellowish brown mottles; weak coarse prismatic structure parting to weak fine and very fine subangular blocky; firm, plastic; few fine soft black accretions; few highly weathered fragments of shale; many moderately thick dark gray clay films on faces of peds; very few very fine random roots; about 1 to 2 percent coarse fragments; medium acid; clear smooth boundary.

B22t—25 to 37 inches; reddish brown (5YR 4/3) clay loam; common fine distinct yellowish brown mottles; weak coarse prismatic structure parting to weak very fine subangular blocky; friable, plastic; common thin dark gray clay films mostly on vertical surfaces of peds; about 1 to 2 percent coarse fragments; slightly acid; clear smooth boundary.

B3t—37 to 45 inches; reddish brown (5YR 4/3) loam; moderate medium platy structure; friable; very few thin dark gray clay films on surface of peds; about 1 to 2 percent coarse fragments; neutral; clear smooth boundary.

C—45 to 60 inches; reddish brown (5YR 4/4) loam; moderate medium platy structure; friable; lime in soft threads and seams; strongly effervescent; about 1 to 2 percent coarse fragments; moderately alkaline.

Thickness of the solum and the depth to carbonates range from about 36 to 46 inches. The O horizon ranges from 0 to 6 inches in thickness. The A1 horizon ranges from silt loam to loam or light silty clay loam. It is medium acid to strongly acid. The A2 horizon ranges from very dark gray to gray. Mottles are distinct or prominent, and they range from few to many. The A2 horizon ranges from light loam to silt loam. It is strongly acid to very strongly acid. The Bt horizon ranges from olive gray or reddish gray to reddish brown. Mottles in the upper part of the Bt horizon range from few to many and from faint to distinct. The Bt horizon is loam or clay loam that has a clay content of 25 to 26 percent. It is medium acid to strongly acid in the upper part and is slightly acid or neutral in the lower part. The C horizon ranges from olive to reddish brown loam to light clay loam.

Alstad variant soils formed in the same kind of parent material as Alstad and Cushing soils. They typically are wetter than those soils.

V292—Alstad Variant loam (0 to 1 percent slopes). This soil is in low lying areas that are commonly elongated or circular and range from about 5 to 150 acres in size. Surface runoff is very slow.

Included with this soil in mapping are small areas of soils that are better drained than this Alstad Variant soil. Also included are areas of soils that have a surface layer of peat or muck less than 16 inches thick.

Many areas of this soil are used for sedges, grasses, and a few willows. Other areas are wooded, consisting chiefly of black ash and alder thickets. The high water table restricts the choice of crops. Capability unit IVw–1; woodland group 4w2.

Automba series

The Automba series consists of nearly level to undulating, well drained and moderately well drained soils that formed in fine sandy loam till. These soils are on ground moraines and rolling terminal moraines.

In a representative profile the surface layer is black fine sandy loam about 2 inches thick. The upper 22 inches of the subsoil is brown and reddish brown, very friable fine sandy loam, and the lower 22 inches is dark reddish brown, firm fine sandy loam. The underlying material is dark reddish brown fine sandy loam.

Permeability is moderately slow, and the available water capacity is moderate. Organic matter content is low. The availability of phosphorus and potassium is medium. The subsoil is very dense.

Most areas of Automba soils are used for forest, pasture, and crops. The major limitation is the hazard of erosion on the undulating soils.

Representative profile of Automba fine sandy loam, 0 to 2 percent slopes, on a ground moraine under a forest dominated by aspen, 290 feet north and 907 feet west of the southeast corner of sec. 30, T. 47 N., R. 20 W.:

A1—0 to 2 inches; black (10YR 2/1) fine sandy loam; moderate fine granular structure; very friable; many roots; about 1 percent coarse fragments; strongly acid; clear wavy boundary.

B21hir—2 to 5 inches; dark brown (7.5YR 4/3) fine sandy loam; moderate fine subangular blocky structure in some parts and some fine and very fine granular structure; very friable; many roots; about 1 percent coarse fragments; strongly acid; clear smooth boundary.

B22hir—5 to 11 inches; brown (7.5YR 5/4) fine sandy loam, about 20 percent yellowish brown (10YR 5/4); few fine faint strong brown mottles; moderate fine subangular blocky structure; very friable; many roots; about 2 percent coarse fragments; very strongly acid; clear wavy boundary.

B3—11 to 24 inches; reddish brown (5YR 4/3) fine sandy loam; few fine faint yellowish red mottles; weak medium platy structure; very friable; few roots; about 10 percent coarse fragments; strongly acid in upper part, medium acid in lower part; clear wavy boundary.

B&A—24 to 27 inches; dark reddish brown (5YR 3/3) fine sandy loam, about 25 percent reddish gray (5YR 5/2) (A2) tongues about 20 millimeters in diameter at a depth of 24 inches and decrease in width as depth increases; common fine distinct yellowish red mottles in A2 horizon and few fine faint dark reddish brown mottles in B horizon; weak coarse prismatic structure parting to weak medium and coarse angular and subangular blocky; A2 horizon is firm and ruptures to friable mass under medium pressure; few roots; common very fine tubular pores lined with moderately thick clay films in B hori-

zon; many fine and very fine tubular pores in A2 horizon; about 8 percent coarse fragments; slightly acid; clear wavy boundary.

B21t—27 to 32 inches; dark reddish brown (5YR 3/3) fine sandy loam reddish brown (5YR 4/4) coatings on faces of peds; few faint fine and medium yellowish red mottles; weak coarse prismatic structure parting mostly to weak medium platy and some moderate medium subangular and angular blocky; firm; very few roots; mostly on prism faces; common thin and moderately thick clay films on faces of prisms and common thin clay films on secondary faces of peds; about 8 percent coarse fragments; slightly acid; gradual smooth boundary.

B22t—32 to 40 inches; dark reddish brown (5YR 3/3) fine sandy loam; moderate medium platy structure; firm in place but ruptures under slight pressure to a friable mass; very few roots; very few tubular pores; few moderately thick clay films on upper faces of plates and a few thin clay films on faces of lower plates, about 8 percent coarse fragments; slightly acid; gradual smooth boundary.

B3t—40 to 46 inches; dark reddish brown (5YR 3/3) fine sandy loam; moderate medium platy structure; firm in place but ruptures under slight pressure to a friable mass; very few roots; very few tubular pores; about 8 percent coarse fragments; few thin clay films on upper faces of plates; neutral; gradual smooth boundary.

C—46 to 60 inches; dark reddish brown (5YR 3/3) fine sandy loam; moderate medium platy structure; slightly firm in place but ruptures under slight pressure to a friable mass; very few tubular pores; about 8 percent coarse fragments; neutral.

The solum ranges from 36 to 52 inches in thickness. Depth to free carbonates ranges from 55 to 100 inches or more. The upper sequum ranges from 12 to 28 inches in thickness. The content of coarse fragments ranges from about 5 to 15 percent. A thin O horizon is in some places. The A1 horizon ranges from black or very dark gray to very dark brown. It is 1 inch to 4 inches thick. A discontinuous A2 horizon that has a maximum thickness of about 2 inches is in some places. The A horizon is fine sandy loam, very fine sandy loam, loam, or silt loam. It is very strongly acid to medium acid. The B horizon of the upper sequum ranges from dark reddish brown or dark brown to brown. Some pedons do not have mottles in the lower part. The B horizon is fine sandy loam, very fine sandy loam, loam, or silt loam. It is very strongly acid to medium acid. Some pedons have a reddish gray A2 horizon as much as 2 inches thick. The A2 horizon tongues into the upper part of the Bt horizon. The Bt horizon ranges from dark reddish brown to reddish brown. It is sandy loam, fine sandy loam, or loam, and it is 12 to 18 percent clay. Clay films range from thin to moderately thick and from patchy to nearly continuous. They are more common on vertical faces of peds. The Bt horizon is medium acid to slightly acid in the upper part and slightly acid to neutral in the lower part. The C horizon ranges from dark reddish brown to reddish brown. It is sandy loam or fine sandy loam, and it is 5 to 12 percent clay.

Automba soils formed in parent material similar to that in which Ahmeek soils formed. They have more clay in the Bt horizon than Ahmeek soils.

43—Automba fine sandy loam, 0 to 2 percent slopes. This nearly level soil is in irregularly shaped areas in the western part of the county. Areas range from 10 to 80 acres in size. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Mora soils that are in elongated, shallow drainageways; a few small areas of undulating soils; and 1- to 3-acre areas of wet soils in depressions, which are indicated by a spot symbol on the soil map. Also included are many areas of Duluth and Ahmeek soils that are adjacent to this Automba soil and that are in a random pattern.

Most areas of this soil are used for aspen and maple. Cleared areas are used for crops commonly grown in the county. Fertilizer and lime are generally needed for maximum yields of cultivated crops. The cool summer and short growing season limit the choice of crops. Capability unit IIc–1; woodland group 2o1.

43B—Automba fine sandy loam, 2 to 6 percent slopes. This gently undulating soil is mainly in irregularly shaped areas that are 10 to 30 acres in size. Slopes are 150 to 250 feet long.

Included with this soil in mapping are small areas of Ahmeek and Duluth soils that are in a random pattern and areas of Mora soils that generally are on foot slopes and in elongated drainageways. Also included are areas of wet soils in 1- to 3-acre depressions, which are indicated on the soil map by a spot symbol.

Most areas of this soil are used for aspen, birch, and maple. Cleared areas are used for cultivated crops commonly grown in the county. Control of erosion is needed. Capability unit IIIe–1; woodland group 2o1.

Bergland series

The Bergland series consists of nearly level, poorly drained soils that formed in reddish brown clayey material. These soils are between drainageways on glacial lake plains. Slopes are slightly concave.

In a representative profile the surface layer is black clay about 6 inches thick. The subsoil is about 19 inches thick. The upper part of the subsoil is dark reddish gray clay, and the lower part is reddish brown clay. The underlying material is reddish brown calcareous clay.

Permeability is very slow, and the available water capacity is moderate. Organic matter content is high. The availability of phosphorus and potassium is low. A seasonal high water table is at a depth of 1 foot except during parts of July and August.

Most areas of Bergland soils are used for forest and wildlife habitat. The major limitation is wetness.

Representative profile of Bergland clay, in a black ash forest, about 100 feet east and about 1,320 feet

north of the southwest corner of sec. 23, T. 47 N., R. 17 W.:

O—½ inch to 0; decomposed and undecomposed leaves and twigs.

A1—0 to 6 inches; black (N 2/0) clay, black (10YR 2/1) to very dark gray (10YR 3/1) dry; strong very fine and fine subangular blocky structure; hard, firm, very sticky and very plastic; many roots; horizon ranges from 2 to 6 inches thick within the pedon; medium acid; abrupt wavy boundary.

B21—6 to 8 inches; black (10YR 2/1) clay, very dark gray (10YR 3/1) dry; few fine faint dark grayish brown mottles; strong medium prismatic structure parting to strong fine and medium subangular blocky; very hard, very firm, very plastic and very sticky; few roots; very few very fine pores; this horizon is discontinuous, occupies about ⅓ of the pedon, and ranges from 0 to 8 inches in thickness; medium acid; clear irregular and wavy boundary.

B22g—8 to 17 inches; dark reddish gray (5YR 4/2) clay; few fine faint reddish brown mottles; strong medium prismatic structure parting to strong medium and very fine subangular blocky; very hard, very firm, very sticky and very plastic; few roots; very few very fine pores; surfaces of peds are shiny; slightly acid; clear wavy boundary.

B3—17 to 25 inches; reddish brown (2.5YR 4/4) clay; strong medium prismatic structure parting to strong medium and very fine subangular blocky; very hard, very firm, very sticky and very plastic; very few root channels lined with moderately thick black clay films; very few fine rounded soft lime masses; very few roots; very few pores; neutral; clear wavy boundary.

C1—25 to 38 inches; reddish brown (2.5YR 4/4) clay; moderate coarse prismatic structure parting to strong coarse and fine subangular blocky; very hard, very firm, very plastic; very few roots; few slickensides that are about 45 degrees from vertical and extend into the B3 and C2 horizons; strongly effervescent; common fine light reddish brown rounded soft and hard lime masses; very few thin light gray to gray films on vertical surfaces of peds; mildly alkaline; clear wavy boundary.

C2—38 to 60 inches; reddish brown (2.5YR 4/4) clay; strong coarse angular blocky structure parting to strong medium angular blocky; very hard, very firm, very plastic; very few roots that are concentrated mainly in vertical cleavage planes; strongly effervescent; common fine and medium light reddish brown rounded soft and hard lime masses; very few thin light gray to gray films on horizontal and vertical surfaces of peds; mildly alkaline; abrupt smooth boundary.

The thickness of the solum and the depth to carbonates are typically 18 to 30 inches. The upper part of the solum is slightly acid to strongly acid, and the lower part is slightly acid or neutral. Mottles are common in the lower part of the A horizon and the upper part of the B horizon. The A horizon ranges from clay to silty clay. It ranges from 2 to 8 inches in thickness. The B horizon typically ranges from reddish brown or dark reddish gray to weak red; however, in some profiles the B22g horizon is olive gray. The B horizon is firm to very firm. Faces of peds and root channels in the C horizon are commonly gray, light gray, or greenish gray. The C horizon commonly contains segregated lime in the form of threads of filaments, soft masses or concretions, or seams. Content of lime commonly ranges from about 12 to 20 percent.

Bergland soils formed in parent material similar to that in which Ontonagon soils formed. They have mottles in the upper part of the B horizon, and they are wetter than Ontonagon soils.

305—Bergland clay (0 to 1 percent slopes). This soil is in areas 3 to 320 acres in size on a glacial lake plain. Many areas are on flat ridgetops that are ¼ to 1 mile wide and that are between deeply entrenched streams, and most areas are surrounded by better drained Ontonagon soils.

Included with this soil in mapping are irregularly shaped areas of Ontonagon soils that are mainly at a slightly higher elevation than this Bergland soil. Also included are soils that have a black surface layer, a gray subsurface layer, and a black subsoil. These soils are in small depressions.

This soil is used for black spruce and black ash, but some areas are chiefly in lowland brush. A few cleared and drained areas are used for forage. Wetness limits the choice of crops and makes plowing difficult. Capability unit IIIw–1; woodland group 4w2.

Beseman series

The Beseman series consists of nearly level, very poorly drained soils that formed in organic material overlying loamy material at a depth of 16 to 51 inches. These soils are in depressions surrounded by uplands.

In a representative profile the surface layer is dark reddish brown muck about 8 inches thick. Below this is black muck about 28 inches thick. The underlying material is gray loam.

Permeability is moderately slow to moderately rapid in the organic material and moderately slow in the loamy material. The available water capacity is very high. Organic matter content is very high. The availability of phosphorus is high and of potassium is low. These soils have a high water table during most of the growing season.

Most areas of Beseman soils are used for forest and wildlife habitat. The major limitation is wetness.

Representative profile of Beseman muck, in a meadow of mostly sedges, 610 feet east and 100 feet south of the northwest corner of sec. 34, T. 49 N., R. 21 W.:

Oa1—0 to 8 inches; dark reddish brown (5YR 3/3), broken face, sapric material, dark reddish brown (5YR 3/2) rubbed; about 40 per-

cent fiber, about 10 percent rubbed; massive in some parts and weak very coarse platy structure in other parts; nonsticky; herbaceous fiber; about 15 percent mineral material; very strongly acid; abrupt smooth boundary.

Oa2—8 to 36 inches; black (10YR 2/1), broken face and rubbed, sapric material; about 5 percent fiber; trace rubbed; massive in some parts and weak coarse platy structure in other parts; nonsticky; herbaceous fiber; about 20 percent mineral material; very strongly acid; abrupt smooth boundary.

IICg—36 to 60 inches; gray (5YR 6/1) loam; massive; friable; about 5 percent coarse fragments; very strongly acid.

The thickness of organic soil material and the depth to the mineral substratum range from 16 to 51 inches. Typically, the fiber is of herbaceous origin in all parts of the organic material, but a small part is woody in some places. The organic material typically is all sapric; however, in a few profiles the surface layer or a thin underlying layer consists partly to entirely of hemic or fabric material, or of a combination of both. The sapric material ranges from black, very dark gray, dark reddish brown, or dark brown to very dark brown, and the color is the same when rubbed. The sapric material has a content of fiber that ranges from 0 to 45 percent and from 0 to 15 percent after rubbing. It is 10 to 30 percent mineral material. A thin buried soil is in the upper part of the mineral substratum in places. The mineral substratum, which typically is glacial till, is loamy.

Beseman soils formed in the same kind of parent material as Loxley soils. They are underlain by loamy material at a shallower depth than Loxley soils.

531—Beseman muck (0 to 1 percent slopes). This soil is in bogs containing mostly mucky herbaceous organic material overlying loamy material at a depth of 16 to 51 inches. In areas surrounded by nearly level uplands, this soil generally occupies entire bogs. In areas surrounded by undulating uplands, it is generally between thicker organic soils and mineral soils. Also, it commonly is in drainageways between large bogs. Areas are generally circular or irregular in shape and mainly range from 10 to more than 80 acres in size.

Included with this soil in mapping are small areas of Loxley and Dawson soils in a random pattern and many areas of soils that are similar to this Beseman soil but that have a surface layer of extremely acid sphagnum moss peat as much as 12 inches thick. Also included are areas of soils that are medium acid throughout. Some of these medium acid soils formed in moderately thick organic material derived chiefly from woody plants; others formed in moderately thick organic material derived chiefly from herbaceous plants and are adjacent to streams that are frequently flooded.

Most areas of this soil are used for sedges, grasses, lowland brush, and hardwoods. A high water table and low fertility limit the choice of crops. Capability unit IVw–2; woodland group 4w1.

Blackhoof series

The Blackhoof series consists of nearly level, very poorly drained soils that formed in a thin layer of organic material and reddish brown loam or clay loam. These soils are in depressions on nearly level to undulating moraines.

In a representative profile (fig. 6) black muck about 11 inches thick overlies a mineral surface layer of black, very thin silty clay loam about 4 inches thick. The subsoil is about 30 inches thick. The upper part is gray, friable loam, and the lower part is reddish brown, friable loam. The underlying material is reddish brown loam.

Permeability is very slow to slow, and it is restricted by a dense pan. The available water capacity is moderate. Organic matter content is very high. The availability of phosphorus and potassium is low. These soils have a high water table during most of the growing season.

Most areas of Blackhoof soils are used for forest and pasture. The major limitation is wetness.

Representative profile of Blackhoof muck, in a pasture, 1,520 feet south and 128 feet east of the northwest corner of sec. 4, T. 46 N., R. 19 W.:

Oa1—0 to 3 inches; black (5YR 2/1), broken face and rubbed, sapric material; about 5 percent fiber, trace rubbed; weak fine granular structure; soft, very friable, slightly sticky; about 30 percent mineral material; many roots;

Figure 6.—**Profile of a Blackhoof soil.**

herbaceous fiber; medium acid; clear smooth boundary.

Oa2—3 to 7 inches; black (5YR 2/1), broken face, sapric material, dark reddish brown (5YR 2/2) rubbed; about 25 percent fiber, about 10 percent rubbed; weak fine platy structure; soft, very friable, nonsticky; about 20 percent mineral material; many roots; mostly herbaceous fiber, a trace of woody fiber; medium acid; clear wavy boundary.

Oa3—7 to 11 inches; black (5YR 2/1), broken face and rubbed, sapric material; trace of fiber; weak very fine subangular blocky structure; soft, very friable, slightly sticky; about 40 percent mineral material; many roots; herbaceous fiber; medium acid; abrupt wavy boundary.

A1—11 to 15 inches; black (N 2/0) silty clay loam grading to very dark gray (10YR 3/1) in lower part; massive; very hard, very firm, sticky, very dense; very few roots; very few pores; about 1 percent coarse fragments; slightly acid; abrupt irregular boundary.

B1g—15 to 23 inches; gray (5YR 5/1) loam; common fine distinct reddish brown mottles; weak thin platy structure; very hard, friable, sticky; few roots; common very fine pores; about 1 percent coarse fragments; strong brown coatings along root channels; neutral; clear wavy boundary.

B21—23 to 26 inches; reddish brown (5YR 4/3) loam; common medium distinct strong brown (7.5YR 5/6) mottles; weak medium platy structure; very hard, friable, sticky; few fine soft strong brown iron-oxide masses; dusky red coatings along root channels; about 2 percent coarse fragments; neutral; clear smooth boundary.

B22—26 to 45 inches; reddish brown (5YR 4/3) loam; common coarse distinct strong brown (7.5YR 5/6) mottles; weak medium platy structure; very hard, friable, sticky; common fine soft strong brown iron-oxide masses; about 2 percent coarse fragments; neutral; gradual wavy boundary.

C—45 to 60 inches; reddish brown (5YR 4/3) loam; few fine distinct strong brown mottles; weak medium platy structure; very hard, friable, sticky; about 2 percent coarse fragments; slightly effervescent; mildly alkaline.

The solum is 30 to 60 inches thick. Depth to free carbonates ranges from 40 to 80 inches. Content of coarse fragments in the solum and C horizon typically ranges from 1 to 8 percent, but the upper part of the solum in some profiles does not have coarse fragments. The organic soil material is 4 to 16 inches thick. It ranges from strongly acid to slightly acid. The A horizon typically is silt loam or silty clay loam but ranges to loam or clay loam. It is firm or very firm. Bulk density is commonly 1.8 to 2.0. The A horizon is slightly acid to strongly acid. The upper part of the B horizon ranges from dark gray or reddish gray to olive gray. It is loam, silt loam, silty clay loam, or clay loam. It ranges from neutral to strongly acid. The lower part of the B horizon ranges from reddish gray to reddish brown. It is loam or light clay loam. It is neutral or slightly acid. The C horizon ranges from neutral or mildly alkaline in the upper part to mildly alkaline in the lower part.

Blackhoof soils formed in the same kind of parent material as Mahtowa soils. Blackhoof soils have a thin layer of organic soil material at the surface that Mahtowa soils do not have.

980—Blackhoof and Mahtowa soils (0 to 1 percent slopes). These soils are in low-lying, circular depressions and drainageways in areas that generally range from 3 to 10 acres in size. They are on moraines that are mainly loam to clay loam till and are commonly adjacent to Duluth and Dusler soils. Areas of this unit consist of Mahtowa silt loam or Blackhoof muck, or both.

Included with these soils in mapping are areas of soils that have a dark colored surface layer that is thicker or thinner than that described as typical of these soils. Also included are areas of soils that have a grayish subsurface layer more than 30 inches thick and small areas of Beseman soils that are generally near the center of depressions.

Most areas of these soils are used for lowland brush and hardwood. Some cleared and drained areas are used for forage and small grain. A high water table restricts the choice of crops. Capability unit IVw–1; woodland group 4w2.

Borofolists

1073—Borofolists (1 to 12 percent slopes). These soils are very shallow, nearly level to undulating, and excessively drained. A layer of organic soil material 2 to 8 inches thick overlies graywacke rock. The available water capacity is very low. Content of organic matter is very high.

Included with these soils in mapping are bedrock ridges, which make up about 10 to 20 percent of the mapped area, and areas of sandy or loamy soils about 1 foot to 2 feet thick over bedrock, which make up 5 to 10 percent of the area. Also included are a few areas of wet soils where 5 to 10 inches of muck or mucky silt loam overlies bedrock.

The dominant tree species on these soils is slow-growing aspen, but white pine, red pine, and white cedar grow in places. The shallowness of the soil and the very low available water capacity preclude cultivation. Capability unit VIIs–2; woodland group 5d1.

Borosaprists

1074—Borosaprists (0 to 1 percent slopes). These nearly level soils are in low-lying, wet areas. They receive runoff mainly from surrounding areas of nearly level to undulating Borofolists. Typically, 2 to 10 inches of muck or mucky silt loam overlies graywacke rock. The available water capacity is low. Organic matter content is very high.

Included with these soils in mapping are a few areas of soils where 16 to 40 inches of muck overlies bedrock. Also included are areas of soils where more than

90 percent of the surface is covered with stones and boulders. The underlying material in such places is chiefly sand and gravel. These areas are in former glacial drainage channels. A few adjacent, higher areas of somewhat better drained soils are also included.

Alder thickets, black ash, and black spruce grow on these soils. The high water table and very shallow rooting zone severely restrict the choice of crops. Capability unit VIIw–2; woodland group 5d1.

Campia series

The Campia series consists of nearly level to hilly, well drained soils that formed in loamy lake sediment on a glacial lake plain. Slopes are convex.

In a representative profile the surface layer is very dark grayish brown silt loam about 7 inches thick. The subsoil is about 33 inches thick. The upper part of the subsoil is brown and yellowish brown, firm and friable silty clay loam; and the lower part is thin strata of light yellowish brown, yellowish brown, reddish brown, and weak red silt loam. The underlying material is thin strata of light yellowish brown, yellowish brown, reddish brown, and weak red very fine sandy loam.

Permeability is moderate, and the available water capacity is high. Organic matter content is low. The availability of phosphorus and potassium is medium.

Most areas of Campia soils are used for cultivated crops, woodland, and pasture. These soils are among the most productive in the county. The major limitation is the hazard of erosion.

Representative profile of Campia silt loam, 0 to 2 percent slopes, in a cultivated field, about 1,200 feet west and 900 feet north of the center of sec. 28, T. 48 N., R. 16 W.:

Ap—0 to 7 inches; very dark grayish brown (10YR 3/2) silt loam; moderate fine granular and subangular blocky structure; friable; neutral; abrupt smooth boundary.

B&A—7 to 9 inches; brown (7.5YR 4/4) silty clay loam and light brownish gray (10YR 6/2) silt loam; moderate thin platy and moderate medium subangular blocky structure; friable medium acid; clear smooth boundary.

B21t—9 to 16 inches; brown (7.5YR 4/4) silty clay loam; moderate medium prismatic structure parting to moderate fine subangular blocky; firm; grayish brown (10YR 5/2) interfingers about 6 to 8 millimeters in diameter are between prisms and make up about 10 percent of horizon; common moderately thick clay films on vertical and horizontal surface of peds and along root channels; medium acid; gradual smooth boundary.

B22t—16 to 24 inches; yellowish brown (10YR 5/4) and brown (7.5YR 5/4) light silty clay loam; moderate fine subangular blocky structure; friable; common moderately thick clay films on vertical and horizontal surfaces of peds and along root channels; medium acid; gradual smooth boundary.

B3t—24 to 40 inches; discernible thin horizontal strata of light yellowish brown (10YR 6/4), yellowish brown (10YR 5/6), reddish brown (5YR 4/4), and weak red (2.5YR 5/2) silt loam; weak medium platy structure parting to weak very fine subangular blocky; friable; common moderately thick black clay films on vertical cleavage faces; slightly acid; gradual smooth boundary.

C—40 to 60 inches; very distinct 1/16- to 1/4-inch horizontal strata of light yellowish brown (10YR 6/4), yellowish brown (10YR 5/6), reddish brown (5YR 4/4), and weak red (2.5YR 5/2) very fine sandy loam; weak medium platy structure; friable; few moderately thick black clay films on vertical cleavage faces in upper part; mildly alkaline; slightly effervescent.

The solum ranges from about 30 to 45 inches in thickness. The depth to carbonates ranges from 26 to 80 inches. The Ap horizon ranges from very dark grayish brown to dark brown silt loam to very fine sandy loam. The B2t horizon typically is heavy silt loam or silty clay loam that is 18 to 35 percent clay and 50 to 75 percent silt. It is medium acid to neutral. The upper 10 inches of the Bt horizon is free of mottles, and the lower part has fine or medium, faint or distinct mottles in places. The strata in the C horizon range from very fine sand to silty clay loam. The C horizon is slightly acid to mildly alkaline.

The Campia soils in this county have a higher degree of base saturation in the B horizon than is defined in the range for the series. However, this difference does not alter their use or behavior.

Campia soils formed in parent material similar to that in which Spooner soils formed. They do not have mottles in the upper part of the B2t horizon, as Spooner soils do, and they are better drained than Spooner soils.

367—Campia silt loam, 0 to 2 percent slopes. This nearly level soil is in irregularly shaped areas on the edge of Glacial Lake Duluth. Areas range from 10 to 200 acres in size. This soil has the profile described as representative of the series.

Included with this soil in mapping are areas of soils that are predominantly very fine sand or loamy very fine sand throughout the profile. Also included are small areas of soils that have slopes of 3 to 4 percent and a few small areas of Spooner and Ontonagon soils.

Most areas of this soil are cultivated, and potential productivity is high. Fertility is medium. The cool climate and short growing season restrict the choice of crops. Capability unit IIc–1; woodland group 2o1.

367C—Campia silt loam, 2 to 12 percent slopes. This undulating soil is in irregularly shaped areas on the edge of Glacial Lake Duluth. Areas range from 5 to 200 acres in size. Slopes are commonly 150 to 300 feet long.

Included with this soil in mapping are areas of soils that are predominantly very fine sand or loamy very fine sand throughout the profile. Also included are areas of Ontonagon soils and small areas of nearly level and hilly soils.

Most areas of this soil are cleared and are well suited to all crops commonly grown in the county. Runoff is

medium. The hazard of erosion is moderate in cultivated areas, so careful management is needed. Terraces, grassed waterways, stripcropping, and crop rotations help to control erosion. Capability unit IIIe–1; woodland group 2o1.

367E—Campia silt loam, 12 to 25 percent slopes. This hilly soil is in elongated areas along natural drainageways. Areas are 10 to 80 acres in size. Slopes are 100 to 350 feet long.

Included with this soil in mapping are areas of soils that are predominantly very fine sand or loamy very fine sand throughout the profile. Also included are small areas of Ontonagon soils and small areas of undulating and steep soils.

Most areas of this soil are used for pasture or trees, and the soil is well suited to these uses. Runoff is rapid. The hazard of erosion is severe, especially on the steeper soils, so careful management is needed. Capability unit VIe–1; woodland group 2r1.

976C—Campia-Ontonagon complex, 2 to 12 percent slopes. This undulating complex has mainly convex slopes that are about 150 to 350 feet long. It is about 30 percent Campia soils, 25 percent Ontonagon soils, and 45 percent well drained soils that are chiefly very fine sand or loamy very fine sand throughout the profile. The percentage of each soil in different areas of this complex varies considerably, and the soils are in a random pattern.

Included with this complex in mapping are poorly drained soils adjacent to foot slopes and in drainageways. Also included are a few areas of nearly level soils.

A few areas of this complex are used for grass and cultivated crops, but most areas are used for trees. The Campia soil is more permeable than the Ontonagon soil. There is a hazard of erosion where vegetation has been removed. Capability unit IIIe–1; Campia soil in woodland group 2o1, Ontonagon soil in woodland group 4c1.

Cloquet series

The Cloquet series consists of nearly level to steep, somewhat excessively drained soils that formed in 1 foot to 2 feet of loamy material and the underlying stratified sand and gravel. These soils are on outwash plains, eskers, and kames. Slopes are plane and convex.

In a representative profile (fig. 7) the surface layer is black fine sandy loam about 1 inch thick. The subsurface layer is grayish brown fine sandy loam about 2 inches thick. The upper 11 inches of the subsoil is dark brown, very friable silt loam and sandy loam, and the lower 22 inches is reddish brown, loose gravelly coarse sand. The underlying material is reddish brown gravelly coarse sand.

Permeability is moderate in the loamy upper part of the profile and very rapid in the sandy lower part. The available water capacity is low. Organic matter content is low. The availability of phosphorus and potassium is low.

Most areas of Cloquet soils are used for forest. A few areas are used for pasture and crops. The major limitation is the hazard of drought.

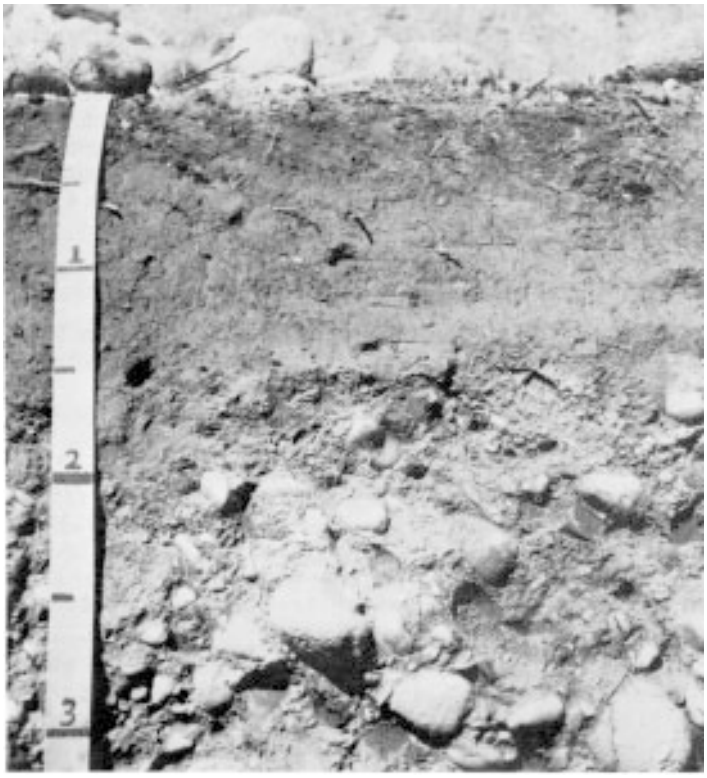


Figure 7.—**Profile of a Cloquet soil.**

Representative profile of Cloquet fine sandy loam, 12 to 25 percent slopes, on an outwash plain under a mixed deciduous and coniferous forest, 1,050 feet north and 1,370 feet east of the southwest corner of sec. 16, T. 48 N., R. 18 W.:

O—½ inch to 0; mixture of undecomposed, slightly decomposed, and decomposed plant material.

A1—0 to 1 inch; black (N 2/0) fine sandy loam; weak very fine and fine granular structure; very friable; many roots; few fine charcoal fragments; about 3 percent gravel, mostly 2 to 10 centimeters in diameter; medium acid; abrupt wavy boundary.

A2—1 to 3 inches; grayish brown (10YR 5/2) fine sandy loam; moderate fine granular structure and some moderate very fine subangular blocky structure; very friable; many roots; about 3 percent gravel, mostly 2 to 10 centimeters in diameter; strongly acid; abrupt wavy boundary.

B21hir—3 to 8 inches; dark brown (7.5YR 4/4) silt loam; moderate very fine subangular blocky structure; very friable; many roots; about 5 percent gravel, mostly 2 to 10 centimeters in diameter; very strongly acid; gradual smooth boundary.

B22hir—8 to 14 inches; dark brown (7.5YR 4/4) sandy loam; moderate fine subangular blocky structure; very friable; many roots; about 10 percent gravel, mostly 2 to 10 centimeters in diameter; about 10 percent of lower and

thicker part of horizon is brown (10YR 5/3), maximum thickness of 1 inch; strongly acid; abrupt smooth boundary.

IIB23t—14 to 17 inches; reddish brown (5YR 4/3) gravelly loamy coarse sand; some parts are massive and others have weak medium subangular blocky structure; friable; few roots; about 20 percent gravel, mostly 2 to 5 centimeters in diameter; few thin clay films on faces of peds; strongly acid; clear smooth boundary.

IIB3—17 to 36 inches; reddish brown (5YR 4/4) gravelly coarse sand; single grained; loose; few roots; about 40 percent gravel; most of medium textured and coarser textured sand grains are stained; strongly acid; abrupt smooth boundary.

IIC—36 to 60 inches; reddish brown (5YR 5/4) gravelly coarse sand; single grained; loose; very few roots; about 50 percent gravel ranging from 2 to 15 millimeters in diameter; lenses are 4 to 7 inches thick and about 75 percent gravel; slightly acid.

The solum ranges from 20 to 40 inches in thickness. The loamy upper part of the soil ranges from 12 to 24 inches in thickness. Content of coarse fragments, mostly gravel, ranges from 0 to 15 percent in the loamy upper part and from 15 to 60 percent in the sandy lower part. As much as 10 percent of the sandy lower part is fragments more than 3 inches thick. In unlimed areas, the solum ranges from medium acid to very strongly acid. The A1 horizon ranges from black or very dark gray to very dark brown. It ranges from ½ inch to 4 inches in thickness. The A2 horizon, where present, ranges from fine sandy loam or very fine sandy loam to sandy loam. A thin discontinuous A2 horizon underlies the Bhir horizon in some places. It is more common where the loamy material is near the maximum range in thickness. The Bhir horizon is sandy loam or fine sandy loam high in content of silt and very fine sand or silt loam. Clay content ranges from 4 to 10 percent. The IIB horizon is loamy sand, loamy coarse sand, sand, or coarse sand, and typically it is more than 15 percent gravel. The IIC horizon typically is gravelly coarse sand or sandy gravel, but in some pedons it is stratified sand and gravel. It is medium acid or slightly acid.

Cloquet soils formed in parent material similar to that in which Cromwell soils formed. They have more gravel in the C horizon than Cromwell soils.

355—Cloquet fine sandy loam, 0 to 2 percent slopes. This nearly level soil is in irregularly shaped areas on outwash plains and river terraces. Areas range from 3 to 20 acres in size. This soil is adjacent to wet Warman soils and undulating to steep Cloquet and Emmert soils.

Included with this soil in mapping are small areas of wet soils, chiefly Warman soils, which are in circular and elongated depressions; they are indicated on the soil map by a spot symbol. Also included are areas of Cromwell, Emmert, and Omega soils in a random pattern; a few areas of undulating soils; areas of soils where the surface layer contains more cobbles than that described as typical of this Cloquet soil, and areas of soils where the underlying material has fewer coarse fragments than this soil and is mainly coarse and very coarse sand.

Most areas of this soil have a forest cover of aspen, red pine, jack pine, and birch. Some cleared areas are used for forage and grain. This soil is easily worked and warms early in spring. The available water capacity is low, and crop production is reduced in periods of low rainfall. Capability unit IIIs–1; woodland group 2s1.

355C—Cloquet fine sandy loam, 2 to 12 percent slopes. This undulating soil is in irregularly shaped areas on river terraces and on outwash plains that have knob-and-basin topography. Areas are 20 to 100 acres in size and are 10 to 30 feet above surrounding areas. Slopes are 100 to 300 feet long. This soil is commonly adjacent to wet Warman soils and nearly level and hilly Cloquet and Emmert soils.

Included with this soil in mapping are small areas of wet soils, chiefly Warman soils, which are in circular and elongated depressions; they are indicated on the map by a spot symbol. Also included are a few small areas of Emmert soils on the crest of convex slopes, small areas of Cromwell soils in a random pattern, a few areas of nearly level and hilly soils, and areas of Cloquet soils in the northwestern part of the county that mainly have brown underlying material.

Most areas of this soil are used for aspen, red pine, jack pine, and birch. A few cleared areas are used for forage and grain. This soil warms quickly in spring and is tillable soon after rain. Crop production, however, is generally limited because of the low available water capacity. In cultivated areas, the soil has a moderate hazard of erosion. Capability unit IVe–2; woodland group 2s1.

355E—Cloquet fine sandy loam, 12 to 25 percent slopes. This hilly soil is on outwash plains that have knob-and-basin topography. Areas are irregularly shaped and elongated, and are 10 to 30 acres in size, and are 20 to 80 feet higher than surrounding areas. Slopes are 100 to 300 feet long. This soil is commonly adjacent to wet Warman soils and less sloping Cloquet and Emmert soils. This soil has the profile described as representative of the series.

Included with this soil in mapping are areas of Emmert and Omega soils. The Emmert soil is on knobs and crests of convex slopes, and the Omega soil is in a random pattern. Also included are small areas of undulating soils and areas of soils where strata of well sorted sand are in the underlying material.

Most areas of this soil are used for aspen, red pine, jack pine, and birch. This soil is severely limited for crops by steep slopes, low available water capacity, and hazard of erosion. Capability unit VIIe–1; woodland group 2s1.

977G—Cloquet-Emmert complex, 25 to 60 percent slopes. This steep complex is chiefly on eskers that have narrow ridges and steep sides, but a few areas are on pitted outwash plains that have strong relief. The complex is 40 percent Cloquet fine sandy loam, 35 percent Emmert gravelly fine sandy loam, and 25 percent Omega soils and other soils of minor extent. The Emmert soil has a profile similar to the one described

as representative of the Emmert series, but the surface layer contains more sand. Slopes are 200 to 400 feet long.

All areas of this complex are forested. Because of the steep slopes, very rapid runoff, and hazard of erosion, the soils in this complex are better suited to woodland than to most other uses. Capability unit VIIs–1; woodland group 4s1.

Cromwell series

The Cromwell series consists of nearly level and gently sloping, somewhat excessively drained soils that formed in sandy loam and the underlying sand. These soils are on outwash plains.

In a representative profile the surface layer is black sandy loam about 2 inches thick. The subsurface layer is reddish gray sandy loam about 1 inch thick. The upper 12 inches of the subsoil is dark brown, very friable sandy loam, and the lower 25 inches is reddish brown, stratified sand and coarse sand. The underlying material is reddish brown, stratified sand and coarse sand.

Permeability is moderate in the loamy upper part of the profile and rapid in the sandy lower part. The available water capacity is low. Organic matter content is low. The availability of phosphorus and potassium is low.

Most areas of Cromwell soils are used for forest and for forage after clearing. The major limitation is the hazard of drought.

Representative profile of Cromwell sandy loam, 0 to 2 percent slopes, on an outwash plain in a forest of trembling aspen and paper birch, 600 feet south and 100 feet east of the northwest corner of SW¼ sec. 24, T. 48 N., R. 19 W.:

A1—0 to 2 inches; black (10YR 2/1) sandy loam; moderate very fine and fine granular structure; very friable; many roots, about 1 percent fine gravel; medium acid; abrupt wavy boundary.

A2—2 to 3 inches; reddish gray (5YR 5/2) sandy loam; weak very fine and fine subangular blocky structure; very friable; many roots; about 1 percent fine gravel; horizon is discontinuous and makes up about 15 percent of pedon; strongly acid; abrupt wavy boundary.

B21—3 to 8 inches; dark brown (7.5YR 4/4) sandy loam; weak medium and coarse subangular blocky structure; very friable; many roots; about 1 percent fine gravel; strongly acid; gradual smooth boundary.

B22—8 to 15 inches; dark brown (7.5YR 4/4) sandy loam; weak medium and course subangular blocky structure parting to weak fine subangular blocky; very friable; common roots; about 1 percent fine gravel; very strongly acid; abrupt wavy boundary.

IIB23—15 to 22 inches; reddish brown (5YR 4/4) coarse sand; massive; very friable; few roots; about 10 percent gravel, mostly 2 to 5 millimeters in diameter; most sand grains are stained; strongly acid; abrupt smooth boundary.

IIB31—22 to 31 inches; reddish brown (5YR 4/4) sand; about 50 percent breaks into weakly coherent masses, 50 percent breaks to single grained; loose; very few roots; very thin stains on about 50 percent of sand grains; few wavy bands of dark reddish brown (5YR 3/4), about 1 millimeter to 2 millimeters thick; strongly acid; gradual smooth boundary.

IIB32—31 to 40 inches; reddish brown (5YR 4/4) coarse sand; single grained; loose; very few roots; about 10 percent thin lenses of very coarse sand and some very fine gravel; very thin stains on about 50 percent of sand grains; strongly acid; abrupt smooth boundary.

IIC1—40 to 48 inches; reddish brown (5YR 5/3) coarse sand; single grained; loose; very few roots; about 10 percent gravel, mostly 2 to 10 millimeters in diameter; medium acid; abrupt smooth boundary.

IIC2—48 to 69 inches; reddish brown (5YR 5/3) sand; few coarse distinct dark reddish brown (5YR 3/3) mottles; single grained; loose; very few roots; about 20 percent weakly coherent masses that break readily to single grain; about 2 percent gravel; medium acid.

The solum ranges from 32 to 50 inches in thickness. The loamy upper material overlying the sandy lower material ranges from 12 to 24 inches in thickness. The solum is very strongly acid to medium acid, but the more acid material is only in the upper part of the solum. Some pedons have an O horizon that is as much as 2 inches thick. The A1 horizon ranges from black to very dark gray. The A2 horizon ranges from reddish gray to grayish brown. The A horizon is sandy loam or fine sandy loam and is friable or very friable. The loamy upper part of the B horizon is sandy loam or fine sandy loam. In places the lower 2 inches of the loamy part of the B horizon has clay bridges between sand grains or between thin patchy clay films on faces of peds, or both; however, such a horizon is discontinuous within the limits of the pedon. The IIB horizon typically is sand or coarse sand, but the upper part is loamy sand in places. The IIC horizon ranges from reddish brown to brown. This horizon typically is sand, but it ranges to coarse sand in places. The IIC horizon is medium acid to slightly acid.

Cromwell soils formed in material similar to that in which Cloquet soils formed. They have less gravel and more sand in the C horizon than Cloquet soils.

268—Cromwell sandy loam, 0 to 2 percent slopes. This nearly level soil is in irregularly shaped areas on outwash plains. Areas are 10 to 30 acres in size. This soil is adjacent to areas of wet Newson and Nemadji soils and to areas of Omega and Cromwell soils that have slopes of more than 2 percent. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Nemadji, Newson, Omega, and Cloquet soils. The Nemadji soils are in shallow, elongated drainageways, and the Newson soils are in circular depressions. Areas are less than 3 acres in size and are indicated on the

soil map by a special symbol. The Omega soils are on slight rises that have convex slopes, and the Cloquet soils are in a random pattern. Also included are a few areas of soils that have short undulating slopes.

Most areas of this soil are used for aspen, birch, jack pine, and red pine. A few cleared areas are used for forage, and a small acreage is used for small grain. This soil warms quickly in spring and is tillable soon after rain. Crop production is generally limited by the low available water capacity. Capability unit IIIs–1; woodland group 2s1.

268B—Cromwell sandy loam, 2 to 6 percent slopes. This gently undulating soil is in irregularly shaped areas on pitted outwash plains. Areas are 10 to 50 acres in size. Slopes are generally 150 to 250 feet long, but some are 50 to 150 feet long.

Included with this soil in mapping are small areas of Omega, Cloquet, Nemadji, and Newson soils. The Omega soils generally have convex slopes. The Cloquet soils are in a random pattern. The Nemadji soils are in shallow, elongated drainageways. The Newson soils are in circular depressions. Areas of Nemadji and Newson soils are less than 3 acres in size and are indicated on the soil map by a special symbol. Also included are a few areas of nearly level and hilly soils.

Most areas of this soil are used for aspen, birch, jack pine, and red pine. A few cleared areas are used for forage, and a small acreage is used for small grain. Crop production is generally limited by the low available water capacity. This soil has a hazard of erosion where vegetation has been removed. Capability unit IIIe–2; woodland group 2s1.

Cushing series

The Cushing series consists of nearly level, well drained and moderately well drained soils that formed in calcareous loam till. These soils are on ground moraines. Slopes are slightly convex.

In a representative profile the surface layer is black fine sandy loam about 2 inches thick. The subsurface layer is grayish brown fine sandy loam about 6 inches thick. It tongues into the subsoil to a depth of 16 inches. The subsoil is brown, friable and firm loam and clay loam about 28 inches thick. The underlying material is brown loam.

Permeability is moderately slow, and the available water capacity is high. Organic matter content is low. The availability of phosphorus and potassium is medium.

Most areas of Cushing soils are used for forest, and a few acres are used for hay and pasture.

Representative profile of Cushing fine sandy loam, on a ground moraine that has a deciduous forest, 612 feet east and 20 feet north of the southwest corner of sec. 4, T. 49 N., R. 21 W.:

A1—0 to 2 inches; black (10YR 2/1) fine sandy loam; strong very fine granular and subangular blocky structure; soft, very friable; strongly acid; abrupt wavy boundary.

A2—2 to 8 inches; grayish brown (10YR 5/2) fine sandy loam; common fine and medium faint dark yellowish brown (10YR 4/4) and brown (10YR 5/3) mottles; moderate thin platy structure; soft, very friable; about 2 percent coarse fragments; strongly acid; abrupt wavy boundary.

A&B—8 to 16 inches; gray (10YR 6/1) tongues of fine sandy loam that penetrate grayish brown (10YR 5/2) to brown (10YR 5/3) heavy loam; few fine distinct strong brown mottles; strong medium subangular blocky structure; friable; fine sandy loam makes up about 60 to 80 percent of the upper part of the horizon and 40 to 50 percent of the lower part; about 3 percent coarse fragments; strongly acid; gradual smooth boundary.

B21t—16 to 26 inches; brown (10YR 5/3) clay loam; dark brown to brown (10YR 4/3) coatings on peds and dark brown to brown (7.5 YR 4/4) in about 25 percent of pedon; common medium faint yellowish brown (10YR 5/6) mottles; strong medium and coarse subangular blocky structure; firm, plastic; many thick dark gray clay films on vertical faces of peds and in pores; many moderately thick gray clay films on horizontal faces of peds; about 4 percent coarse fragments; medium acid; gradual smooth boundary.

B22t—26 to 31 inches; brown (10YR 5/3) clay loam, dark brown to brown (7.5YR 4/4) in 25 percent of pedon; moderate fine and medium subangular blocky structure; friable, slightly plastic; many thick dark gray clay films on vertical faces of peds and pores; few moderately thick clay films on horizontal faces of peds; about 4 percent coarse fragments; slightly acid; clear smooth boundary.

B3t—31 to 36 inches; brown (10YR 5/3) loam; dark brown to brown (7.5YR 4/4) in about 25 percent of pedon; weak medium and thick platy structure parting to moderate very fine subangular blocky; friable, slightly plastic; common thick dark gray clay films on vertical faces of peds and in pores; few thin clay films on horizontal faces of peds; slightly acid; gradual smooth boundary.

C1ca—36 to 40 inches; brown (10YR 5/3) loam; weak medium and thick platy structure parting to moderate very fine subangular blocky; friable, slightly plastic; few moderately thick clay films on vertical faces of peds, common soft masses of lime, 5 to 10 millimeters in diameter; strongly effervescent; threads and seams; about 4 percent coarse fragments; mildly alkaline; gradual smooth boundary.

C2—40 to 50 inches; brown (10YR 5/3) and dark brown to brown (7.5YR 4/4) loam; moderate medium platy structure; friable, slightly plastic; limy masses; strongly effervescent; about 5 percent coarse fragments; mildly alkaline; gradual smooth boundary.

C3—50 to 68 inches; dark brown to brown (7.5 YR 4/4) loam; moderate medium platy structure; friable, slightly plastic; very few segregated limy masses; slightly effervescent;

about 5 percent coarse fragments; mildly alkaline.

The thickness of the solum ranges from about 32 to 42 inches, and it generally coincides with the depth to carbonates. The A horizon ranges from black or very dark gray to very dark brown. It is 1 inch to 4 inches thick. The A horizon ranges from loam or silt loam to fine sandy loam. It is medium acid to strongly acid. The A2 horizon ranges from gray, grayish brown, or dark gray to reddish gray. It is 4 to 12 inches thick. The A2 horizon ranges from silt loam or loam to fine sandy loam. It is very strongly acid or strongly acid. The A2 horizon tongues into the B2t horizon. The B2t horizon is dark brown to brown. It ranges from heavy loam to light clay loam, and it is about 25 to 35 percent clay. It is medium acid to slightly acid. The C horizon is dark brown to brown. It ranges from loam to light clay loam.

Cushing soils formed in the same kind of parent material as Alstad soils. They have convex slopes. They are better drained than Alstad soils and have fewer mottles or none in the A2 and B horizons.

204—Cushing fine sandy loam (0 to 2 percent slopes). This nearly level soil is on slightly convex swells or islands surrounded by nearly level, low lying areas of wet soils. Areas range from 10 to 40 acres in size and are irregular in shape.

Included with this soil in mapping are small areas of Alstad variant soils in depressions, which are indicated on the soil map by a spot symbol; patchy areas of soils that are loamy sand to a depth of about 24 to 36 inches; and a few areas of soils where the subsoil is about 35 to 40 percent clay and that contain more silt and less sand and coarse fragments than this Cushing soil. Also included are areas of soils that formed in strata of reddish brown till. These areas are in a random pattern.

This soil is used chiefly for aspen, maple, and birch. A few acres have been cleared and are used for forage. The cool climate and short growing season restrict the choice of crops. Capability unit IIc–1; woodland group 2o1.

Dawson series

The Dawson series consists of nearly level, very poorly drained soils that formed in organic soil material overlying sandy material at a depth of 16 to 51 inches. These soils are in depressions surrounded by uplands.

In a representative profile the surface layer is very dark grayish brown peat about 3 inches thick. The next layer is very dark brown and dark reddish brown muck about 24 inches thick. Below this is about 3 inches of black muck. The underlying material is reddish gray loose sand.

Permeability is moderately slow to moderately rapid, and the available water capacity is moderate to very high. Organic matter content is very high. The availability of phosphorus is high and of potassium is low. These soils have a high water table during most of the growing season.

Most areas of Dawson soils are used for forest and wildlife habitat. The major limitation is wetness.

Representative profile of Dawson muck in a depression on an outwash plain in a forest of black spruce and tamarack, 1,320 feet south and 300 feet east of the northwest corner of sec. 36, T. 49 N., R. 18 W.:

Oi—0 to 3 inches; very dark grayish brown (10YR 3/2), pressed and rubbed, fibric material; about 80 percent fiber, 50 percent rubbed; massive; nonsticky; many 1- to 2-millimeter by 5- to 6-centimeter light gray (10YR 7/2) fibers, rest smaller and darker; about 80 percent sphagnum fibers, rest herbaceous; many very fine to medium roots; extremely acid; abrupt smooth boundary.

Oa1—3 to 8 inches; very dark brown (10YR 2/2), pressed and rubbed, sapric material; about 10 percent fibers, 1 percent rubbed; weak medium granular structure; slightly sticky; many very fine to medium roots; fibers primarily herbaceous; black (10YR 2/1) after exposure to air; extremely acid; gradual smooth boundary.

Oa2—8 to 27 inches; dark reddish brown (5YR 2/2), pressed and rubbed, sapric material; about 5 percent fibers, about 1 percent rubbed; massive parting to weak medium platy structure; slightly sticky; very few medium to very fine roots; decreasing in abundance with depth; fibers primarily herbaceous; black (10YR 2/1) after exposure to air; many 1 to 2 millimeter horizontal bands of black (N 2/0) material; extremely acid; abrupt smooth boundary.

Oa3—27 to 30 inches; black (N 2/0), pressed and rubbed, sapric material; less than 1 percent fibers unrubbed and rubbed; massive; slightly sticky, firmer than Oa2 horizon; very few roots; extremely acid; numerous sand involutions; abrupt irregular boundary.

IIC—30 to 60 inches; reddish gray (5YR 5/2) sand; single grained; loose, nonsticky; very strongly acid.

The thickness of the organic material and the depth to the mineral substratum range from 16 to 51 inches. Typically, the fiber is of herbaceous origin in all parts of the organic soil material. The average pH of the organic material is 5.5 or less. The value or chroma, or both, of the organic material generally decreases 1 to 2 units when the material is exposed to air. The organic material typically is all sapric; however, in a few places the surface layer or a thin underlying layer consists partly or entirely of hemic or fibric material or a combination of both. The sapric material ranges from black, very dark gray, dark reddish brown, and dark brown to very dark brown. It has a content of fiber that ranges from 0 to 45 percent and 0 to 5 percent after rubbing. It is 10 to 30 percent mineral material. A thin buried soil is in the upper part of the mineral substratum in some profiles. The mineral substratum, which is typically outwash, is sandy.

Dawson soils formed in the same kind of organic material as Beseman soils. Dawson soils are underlain by sandy material, whereas Beseman soils are underlain by loamy material.

536—Dawson muck (0 to 1 percent slopes). This soil is in bogs of organic material that is underlain by sand at a depth of 16 to 51 inches. Areas are in elongated drainageways, in nearly circular depressions, and at the outer edges of bogs that are thicker. Most areas range from about 5 to 100 acres in size.

Included with this soil in mapping are areas of Loxley soils that commonly are in a random pattern in the bogs and a few areas of soils that have 6 to 12 inches of extremely acid, peaty sphagnum moss in the surface layer. Also included are areas of soils in bogs near sandy uplands or mineral islands. These soils have a thinner organic surface layer than this soil, and they extend into the bog for a distance of 50 to 150 feet in places. Islands of mineral soils less than 3 acres in size are included in mapping and are indicated on the soil map by a spot symbol.

Most areas of this soil are used for sedges, grasses, lowland brush, and forest. A few areas are drained and used chiefly for forage crops. This soil has medium fertility and a high water table that limits the choice of crops. Capability unit IVw–2; woodland group 4w1.

Duluth series

The Duluth series consists of nearly level to steep, well drained and moderately well drained soils that formed in loam or clay loam till. These soils are nearly level to hilly and are on moraines.

In a representative profile (fig. 8) the surface layer is very dark brown very fine sandy loam about 2 inches thick. The subsurface layer is dark brown very fine sandy loam about 1 inch thick. This layer is discontinuous. The upper 9 inches of the subsoil is dark reddish brown, friable very fine sandy loam. The next layer is reddish gray very fine sandy loam about 1 inch thick. It tongues into the lower part of the subsoil to a depth of 18 inches. The lower 52 inches of the subsoil is reddish brown, firm loam. The underlying material is dark reddish brown loam.

Figure 8.—**Profile of a Duluth soil.**

Permeability is slow, and the available water capacity is high. Organic matter content is low. The availability of phosphorus and potassium is low.

Most areas of Duluth soils are used for forest. A small acreage is used for pasture, and a few areas are used for cultivated crops.

Representative profile of Duluth very fine sandy loam, 0 to 2 percent slopes, on a rolling terminal moraine in a deciduous forest, 660 feet south and 150 feet east of the northwest corner of sec. 34, T. 47 N., R. 18 W.:

O—½ inch to 0; mixture of undecomposed and decomposed plant material.

A1—0 to 2 inches; very dark brown (10YR 2/2) very fine sandy loam; moderate fine granular structure and some moderate fine subangular blocky structure; very friable; many roots; about 5 percent coarse fragments; strongly acid; clear smooth boundary.

A2—2 to 3 inches; dark brown (7.5YR 4/2) very fine sandy loam; moderate fine and very fine subangular blocky structure; very friable; many roots; discontinuous horizon makes up about 20 percent of profile; about 5 percent coarse fragments; strongly acid; abrupt broken boundary.

B2hir—3 to 12 inches; dark reddish brown (5YR 3/4) very fine sandy loam; moderate very fine subangular blocky structure; very friable; many roots; about 5 percent coarse fragments; strongly acid; abrupt smooth boundary.

A′2—12 to 13 inches; reddish gray (5YR 4/2) very fine sandy loam; massive parting to weak fine platy structure; firm, ruptures abruptly under medium pressure; common very fine vesicular pores that have thin clay films; few roots; about 1 percent coarse fragments; strongly acid; abrupt smooth boundary.

B&A—13 to 18 inches; about 25 to 50 percent reddish gray (5YR 4/2) very fine sandy loam tongues that grade to interfingers to vertical color coats as depth increases, and dark reddish brown (5YR 3/3) loam; strong coarse and medium prismatic structure parting to moderate medium and coarse subangular blocky; firm; many roots on faces of prisms and very few roots elsewhere; few very fine pores; common moderately thick and thin clay films on faces of prisms, especially in the lower part; few thin clay films on faces of blocky peds; about 1 percent coarse fragments; strongly acid; gradual smooth boundary.

B′21t—18 to 29 inches; dark reddish brown (5YR 3/3) loam; moderate medium and coarse

prismatic structure parting to moderate medium and coarse subangular and angular blocky; firm; few roots on faces of prisms; common thin and moderately thick dark reddish brown (5YR 3/2) clay films on faces of blocky peds; common medium dark reddish gray (5YR 4/2) porous coatings on faces of prisms; about 1 percent coarse fragments; medium acid; gradual smooth boundary.

B'22t—29 to 36 inches; dark reddish brown (5YR 3/4) loam; moderate medium and coarse prismatic structure parting to moderate medium angular and subangular blocky; firm; few roots on faces of prisms; common thin dark reddish brown (5YR 3/3) clay films and very few thin dark reddish gray (5YR 4/2) porous coatings on faces of prisms; about 1 percent coarse fragments; slightly acid; gradual smooth boundary.

B'3t—36 to 64 inches; dark reddish brown (5YR 3/4) loam; weak coarse and medium prismatic structure parting to weak medium and coarse angular blocky, coarse prismatic structure mainly in upper part; firm; very few roots on faces of prisms; very few inped tubular pores; few thin clay films on vertical faces of peds and very few thin clay films on secondary faces of peds; about 1 percent coarse fragments; neutral; diffuse smooth boundary.

C—64 to 72 inches; dark reddish brown (5YR 3/4) loam; weak medium platy structure; friable; about 2 percent coarse fragments; neutral.

The solum ranges from 46 to 70 inches in thickness. The upper part of the sequum ranges from 10 to 24 inches in thickness. The depth to free carbonates ranges from 42 to 80 inches. The upper part of the sequum ranges from very fine sandy loam or fine sandy loam to loam or silt loam and is 5 to 15 percent clay. Reaction is strongly acid to very strongly acid. The A1 horizon ranges from black and very dark brown to very dark gray, and it is 1 inch to 3 inches thick. The B2hir horizon ranges from reddish brown to brown, and it is 8 to 20 inches thick. The A'2 horizon ranges from dark reddish gray to pinkish gray, and it is 1 inch to 3 inches thick. The B2 and B3 horizons range from dark reddish brown to reddish brown, and they are 30 to 55 inches thick. These horizons are loam or clay loam. The content of clay ranges from 18 to 35 percent, but it is typically 18 to 30 percent. The B2t horizon is medium acid or slightly acid. Clay films range from few to many and from thin to thick in the B2t horizon. The B3t horizon is neutral. The C horizon ranges from dark reddish brown to reddish brown loam or clay loam, and it is neutral or mildly alkaline.

Duluth soils are associated on the landscape with Dusler, Blackhoof, and Mahtowa soils, and they formed in the same kind of parent material as those soils. Duluth soils are better drained than Dusler, Blackhoof, and Mahtowa soils, and they have fewer mottles or none in the upper part of the B horizon. Duluth soils are better drained than Dusler, Blackhoof, and Mahtowa soils.

504—Duluth very fine sandy loam, 0 to 2 percent slopes. This nearly level soil is mainly in areas that are irregular in shape and 10 to 20 acres in size. Local relief is 2 to 4 feet. In the larger areas that have little relief, much of this soil is moderately well drained and contains a few faint mottles. This soil has the profile described as representative for this series.

Included with this soil in mapping are small areas of Dusler, Mahtowa, and Blackhoof soils and small areas of Cushing soils in the northwestern part of the county. The Dusler soils are on slightly concave foot slopes and in drainageways. The Mahtowa and Blackhoof soils are chiefly in the deeper depressions, and those areas are indicated on the soil map by spot symbols if they are 1 acre to 3 acres in size. Also included in a few places are areas of soils that are loamy sand or sand in the upper 1 foot or 2 feet. These areas are in a random pattern.

Most areas of this soil are used for aspen, birch, basswood, and maple. A few fields have been cleared and are used for crops commonly grown in the county. The short, cool summer limits the choice of crops. Capability unit IIc–1; woodland group 2o1.

504C—Duluth very fine sandy loam, 2 to 12 percent slopes. This undulating soil is in irregularly shaped areas that are 10 to 60 acres in size. Slopes are complex and simple and are 150 to 300 feet long.

Included with this soil in mapping are small areas of Dusler, Mahtowa, and Blackhoof soils. The Dusler soils are in shallow drainageways, and the Mahtowa and Blackhoof soils are in nearly circular depressions. These soils are wet and are indicated on the soil map by a spot symbol. Also included are a few areas of soils that are loamy sand or sand in the upper 1 or 2 feet, a few areas of soils in the northwestern part of the county that have a brown subsoil, a few areas of soils where the subsoil is 35 to 40 percent clay, and small areas of nearly level and hilly soils.

Most areas of this soil are used for aspen, birch, basswood, and maple. A few fields have been cleared and are used for crops commonly grown in the county. Control of erosion, through the use of terraces, grassed waterways, contour stripcropping, and crop rotations, is needed. Capability unit IIIe–1; woodland group 2o1.

504E—Duluth very fine sandy loam, 12 to 25 percent slopes. This hilly soil is in areas adjacent to less sloping Duluth soils. Areas are irregularly shaped and elongated and are 10 to 60 acres in size. Slopes are 200 to 400 feet long.

Included with this soil in mapping are small areas of Hibbing and Ahmeek soils in a random pattern. Also included are a few areas of soils that have slopes of less than 12 percent or more than 25 percent.

Nearly all areas of this soil are used for trees. A few fields have been cleared and are used for pasture. Rapid runoff and a severe hazard of erosion if vegetation has been removed are the chief management concerns. Capability unit VIe–1; woodland group 2r1.

504G—Duluth very fine sandy loam, 25 to 35 percent slopes. This steep soil is commonly in areas adjacent to less sloping Duluth soils. Slopes mainly range from 200 to 400 feet in length, but along some rivers they

are longer. Most areas range from 5 to 20 acres in size.

Included with this soil in mapping are areas of steep Ahmeek soils that are commonly adjacent to undulating Ahmeek soils.

This soil is used for trees. Runoff is very rapid, and the hazard of erosion is very severe. Because of steep slopes, the soil is not suited to cultivated crops. Capability unit VIIe–2; woodland group 2r1.

Dusler series

The Dusler series consists of nearly level, somewhat poorly drained and poorly drained soils that formed in loam or clay loam till. These soils are on moraines. Slopes are concave.

In a representative profile (fig. 9) the surface layer is very dark gray silt loam about 4 inches thick. The upper 7 inches of the subsurface layer is very dark gray silt loam, and the lower 4 inches is gray fine sandy loam that tongues into the subsoil to a depth of 22 inches. The subsoil is reddish brown, firm loam about 40 inches thick. The underlying material is reddish brown loam.

Permeability is slow, and the available water capacity is high. Organic matter content is high. The availability of phosphorus and potassium is low. A high water table occurs during the growing season except for parts of the summer.

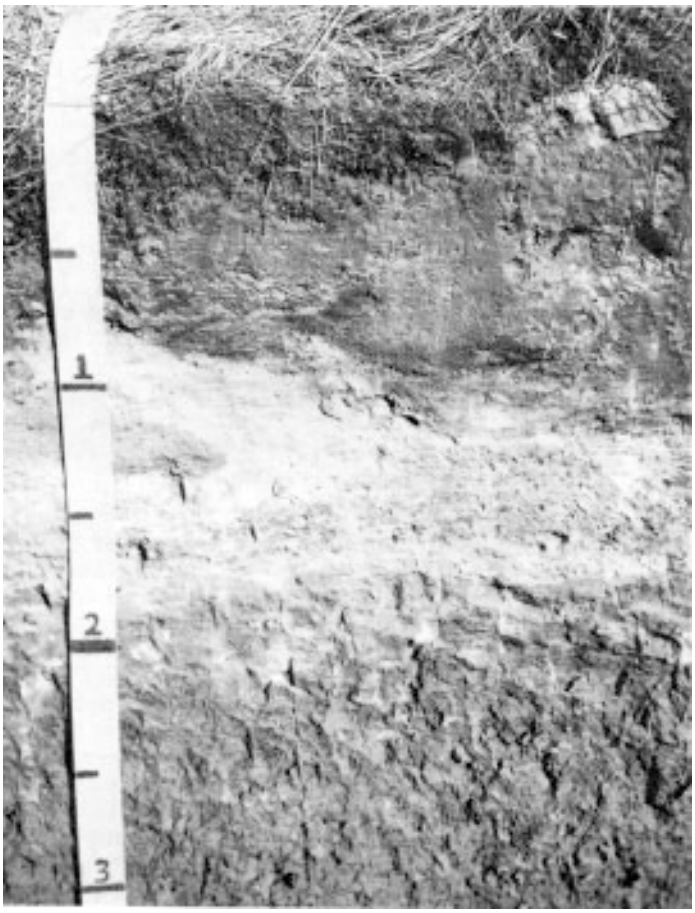


Figure 9.—Profile of a Dusler soil.

Most areas of Dusler soils are used for forest. A small acreage is used for pasture and cultivated crops. The major limitation is wetness.

Representative profile of Dusler silt loam on a concave slope in a broad drainageway in a glacial moraine in a pasture, 1,200 feet south and 300 feet east of the northwest corner of NE¼ sec 5, T. 46 N., R. 19 W.:

A1—0 to 4 inches; very dark gray (10YR 3/1) silt loam, dark gray (10YR 4/1) dry; strong fine granular structure and strong very fine subangular blocky structure; friable, slightly sticky; many fine and very fine roots; about 2 percent coarse fragments; strongly acid; clear wavy boundary.

A21—4 to 11 inches; very dark gray (10YR 3/1) silt loam, light brownish gray (10YR 6/2) dry; moderate thin platy structure; very friable, slightly sticky; many fine and very fine roots; many very fine continuous vertical pores; few fine iron and manganese oxide concretions; about 2 percent coarse fragments; clear wavy boundary.

A22g—11 to 15 inches; gray (10YR 6/1) fine sandy loam, white (10YR 8/2) dry; common fine prominent strong brown mottles; weak thin and medium platy structure; very friable, nonsticky; common fine and very fine roots; many very fine continuous vertical pores; few fine iron and manganese oxide concretions; about 2 percent coarse fragments; strongly acid; clear wavy boundary.

A&B—15 to 22 inches; reddish gray (5YR 2/2) sandy loam tongues and reddish brown (5YR 4/3) loam; common fine distinct yellowish red mottles; moderate thick platy structure; slightly hard, brittle, firm; very few roots; few vesicular pores; about 2 percent coarse fragments; strongly acid; clear wavy boundary.

B21t—22 to 37 inches; reddish brown (5YR 4/3) loam; common fine distinct yellowish red mottles; moderate coarse prismatic structure parting to strong medium subangular blocky; hard, firm, sticky; few moderately thick dark gray clay films on faces of prisms and in root channels; common thin dark reddish brown clay films on horizontal and vertical faces of blocky peds; about 2 percent coarse fragments; medium acid; diffuse smooth boundary.

B22t—37 to 47 inches; reddish brown (5YR 4/3) loam; weak coarse prismatic structure parting to moderate fine and medium subangular blocky; hard, friable, sticky; moderately thick dark gray clay films in root channels and few thin dark reddish brown clay films chiefly on vertical faces of peds; about 2 percent coarse fragments; slightly acid; diffuse smooth boundary.

B3t—47 to 55 inches; reddish brown (5YR 4/3) loam; moderate fine and medium subangular

blocky structure; hard, friable, sticky; moderately thick dark gray clay films in root channels; very few thin dark reddish clay films chiefly on vertical faces of peds; about 2 percent coarse fragments; slightly acid; diffuse smooth boundary.

C—55 to 60 inches; reddish brown (5YR 4/3) loam; weak medium platy structure; friable; about 2 percent coarse fragments; neutral.

The solum ranges from 36 to 60 inches in thickness. Depth to free carbonates ranges from 42 to 80 inches. The A1 horizon is black to very dark gray. It is 4 to 11 inches thick. It ranges from very fine sandy loam or loam to silt loam. The A1 horizon is strongly acid to medium acid. The A2 horizon ranges from very dark gray, dark gray, gray, dark grayish brown, or reddish gray to pinkish gray. Distinct or prominent mottles are in some places. The A2 horizon ranges from sandy loam or fine sandy loam to very fine sandy loam or silt loam. It is very strongly acid to strongly acid. The A2 horizon extends in tongues into the B2 horizon. The B horizon is reddish brown and has distinct or prominent mottles mainly in the upper part. It is loam or clay loam. The content of clay ranges from 18 to 35 percent, but it is typically 18 to 30 percent. Clay films in the upper part of the B horizon are thin to thick and common to many. They grade to few and thin in the lower part. The B horizon is medium acid to strongly acid in the upper part and slightly acid to neutral in the lower part. The C horizon is loam or clay loam, and it is neutral or mildly alkaline.

Dusler soils are associated on the landscape with Duluth, Blackhoof, and Mahtowa soils and they formed in the same kind of parent material as those soils. Dusler soils have more mottles in the A2 horizon and upper part of the B horizon than the better drained Duluth soils. Dusler soils are better drained and have more rapid surface runoff than the wetter Blackhoof and Mahtowa soils.

502—Dusler silt loam (0 to 2 percent slopes). This nearly level soil is in drainageways and in slightly concave areas on moraines where runoff is slow. Most areas are 3 to 10 acres in size and irregular in shape.

Included with this soil in mapping are small areas of Duluth, Mahtowa, and Blackhoof soils. The Mahtowa and Blackhoof soils are in circular depressions, and the Duluth soils are on slight rises. Also included are small areas of soils that have a darker, more clayey subsoil than this Dusler soil.

Most areas of this soil are used for maple, basswood, and elm. Cleared and drained areas are used for crops. Capability unit IIIw–1; woodland group 2w1.

Emmert series

The Emmert series consists of nearly level to steep, excessively drained soils that formed in gravelly fine sandy loam and gravelly sand. These soils are on outwash plains and fans that have knob-and-basin topography.

In a representative profile the surface layer is black gravelly fine sandy loam about 2 inches thick. The upper 7 inches of the subsoil is dark brown and dark yellowish brown, very friable gravelly fine sandy loam, and the lower 4 inches is reddish brown gravelly coarse sand. The underlying material is reddish brown gravelly coarse sand.

Permeability is very rapid, and the available water capacity is very low. Organic matter content is low. The availability of phosphorus and potassium is low.

Most areas of Emmert soils are used for forest. The major limitation is the hazard of drought.

Representative profile of Emmert gravelly fine sandy loam, 1 to 12 percent slopes, in an area of jack pine about 1,495 feet east and 50 feet north of the southwest corner of sec. 31, T. 46 N., R. 19 W.:

O1—½ inch to 0; mostly undecomposed leaf litter, twigs, and small branches; abrupt smooth boundary.

A1—0 to 2 inches; black (5YR 2/1) gravelly fine sandy loam; weak fine and very fine granular structure; very friable; many very fine and coarse random roots; about 15 percent by volume coarse fragments; medium acid; abrupt wavy boundary.

B21—2 to 5 inches; dark brown (10YR 3/3) gravelly fine sandy loam; weak medium subangular blocky structure parting to moderate very fine subangular blocky; many fine and coarse random roots; very friable; about 15 percent coarse fragments; medium acid; clear smooth boundary.

B22—5 to 9 inches; dark yellowish brown (10YR 3/4) gravelly sandy loam; weak medium subangular blocky structure parting to moderate very fine subangular blocky; very friable; common very fine random roots; about 15 percent coarse fragments; medium acid; abrupt smooth boundary.

IIB3—9 to 13 inches; reddish brown (5YR 4/4) gravelly coarse sand; single grained; loose; sand grains stained; about 60 percent coarse fragments; slightly acid; gradual smooth boundary.

IIC—13 to 60 inches; reddish brown (5YR 5/4) gravelly coarse sand; single grained; loose; sand grains unstained; about 40 percent coarse fragments; neutral.

The solum ranges from 12 to 28 inches in thickness. There are no free carbonates above a depth of 10 feet or more. The A1 horizon ranges from black and very dark gray to very dark brown. It is 1 inch to 3 inches thick. A grayish A2 horizon less than 4 inches thick is in some places. The A horizon ranges from fine sandy loam, coarse sandy loam, sandy loam, or loamy coarse sand to loamy sand. It is slightly acid to strongly acid. The B horizon ranges from dark brown, brown, or dark yellowish brown to reddish brown. It is coarse sand, sand, loamy coarse sand, loamy sand, or sandy loam, and it has enough coarse fragments to be gravelly or cobbly. The B horizon is slightly acid to strongly acid. The C horizon ranges from reddish brown, yellowish red, dark reddish brown, or brown to dark brown. It is gravelly or cobbly sand or gravelly or cobbly coarse sand, and stratification is common. It ranges from neutral to strongly acid.

Emmert soils are associated on the landscape with Cloquet soils. They also formed in the same kind of parent material. They have more coarse fragments and a thinner solum than Cloquet soils.

12C—Emmert gravelly fine sandy loam, 1 to 12 percent slopes. This nearly level to undulating soil is on outwash plains and river terraces. Areas are irregularly shaped and 10 to 50 acres in size. Slopes range from 50 to 200 feet long, and they are about 10 to 30 feet above the surrounding area. This soil is commonly adjacent to Cloquet and Warman soils. It has the profile described as representative of the series.

Included with this soil in mapping are small areas of Omega and Cloquet soils that are generally in a random pattern.

Most areas of this soil are used for oak, red pine, and jack pine. A few areas are used for pasture. Crop yields are generally limited by the very low available water capacity. Capability unit IVs-1; woodland group 4s1.

12E—Emmert gravelly fine sandy loam, 12 to 25 percent slopes. This hilly soil is on outwash fans and plains that have knob-and-basin topography. Areas are irregularly shaped and elongated and are 10 to 30 acres in size. Slopes are 50 to 200 feet long, and they are about 80 feet above the surrounding areas. This soil is adjacent to Warman and Cloquet soils. It has a profile similar to the one described as representative of the series, but it generally has more sand in the surface layer and upper part of the subsoil.

Included with this soil in mapping are small areas of Cloquet and Omega soils. The Cloquet soils are chiefly on foot slopes, and the Omega soils are in a random pattern. A few areas of undulating soils are also included.

Most areas of this soil are used for oak, red pine, and jack pine. Because of the steep slopes and very low available water capacity, the soil is not suited to cultivated crops. Capability unit VIIs-1; woodland group 4s1.

Fluvaquents

1005—Fluvaquents (0 to 1 percent slopes). These nearly level soils are adjacent to rivers and creeks. They are wet and frequently flooded during the spring thaw and following heavy rain in the upper parts of watersheds. In most places, they consist of loamy alluvial material that commonly has thin layers of sandy and clayey material. In some places a thin layer of muck or mucky peat is at the surface, and in other places layers of muck or mucky peat are between the layers of mineral material.

Included with these soils in mapping are a few areas of soils, chiefly along the Kettle and Split Rock Rivers, that are better drained than these soils and are not frequently flooded.

These soils are mainly covered by alder thickets and other shrubs. The soils are flooded too frequently for most crops in the county, and they are better used as a floodway and for wildlife habitat. Capability unit VIw–1; woodland group 4w2.

Greenwood series

The Greenwood series consists of nearly level, very poorly drained soils that formed in organic material. These soils are in depressions in outwash plains and moraines.

In a representative profile the surface layer is light gray, extremely acid sphagnum peat about 20 inches thick. The underlying material is dark reddish brown, extremely acid herbaceous mucky peat to a depth of more than 60 inches.

Permeability is moderate to moderately rapid, and the available water capacity is very high. Organic matter content is very high. The availability of potassium is low. These soils have a high water table during most of the growing season.

Most areas of Greenwood soils are in native vegetation. The major limitation is wetness.

Representative profile of Greenwood peat, in a black spruce bog, about 1,000 feet west and 500 feet south of the northeast corner of sec. 8, T. 49 N., R. 20 W.:

Oi—0 to 20 inches; light gray (10YR 7/2), on broken face and rubbed, fibric material; about 95 percent fiber, about 70 percent fiber rubbed; massive; nonplastic and nonsticky; about 90 percent of fibers are sphagnum mosses that are chiefly 1 millimeter to 2 millimeters in diameter; dark reddish brown after exposure to air; extremely acid; abrupt wavy boundary.

Oe1—20 to 40 inches; dark reddish brown (5YR 2/2), on broken face and rubbed, hemic material; about 60 percent fiber, about 35 percent fiber rubbed; massive parting to weak thick platy structure; nonplastic and nonsticky; about 90 percent of fibers are herbaceous and are 1 millimeter to 2 millimeters in size, 10 percent woody fibers; black after exposure to air; extremely acid; gradual smooth boundary.

Oe2—40 to 70 inches; dark reddish brown (5YR 2/2), broken face and rubbed, hemic material; about 60 percent fibers, about 35 percent fibers rubbed; massive parting to weak thick platy structure; nonplastic and nonsticky; about 95 percent of fibers are herbaceous and are 1 millimeter to 2 millimeters in size, 5 percent woody fibers; black after exposure to air; extremely acid.

The organic soil material is more than 51 inches thick. It is extremely acid to very strongly acid throughout. Typically, the fiber is of herbaceous origin in all parts of the organic soil material except in the surface layer. The fiber in the surface layer is commonly derived from sphagnum moss, and the organic material is fibric. In some places the surface tier is mainly of herbaceous origin, and in these places the organic material is mainly hemic or sapric. The surface tier ranges from light gray to black. The underlying tiers range from dark reddish brown and dark brown to brown and are predominantly hemic material; however, thin layers of sapric or fibric material are in some profiles.

Greenwood soils formed in organic material of the same origin as that of Loxley soils. They are predominantly hemic material, whereas Loxley soils are predominantly sapric material throughout.

530—Greenwood mucky peat (0 to 1 percent slopes). This soil is in bogs surrounded by loamy and sandy soils on uplands. Areas range from 20 to 200 acres in size and are elongated to irregular in shape. This soil has a profile similar to the one described as representative of the series, but it does not have an extremely acid surface layer of chiefly sphagnum moss. The surface layer ranges from mucky to peaty material and has predominantly herbaceous fibers. In general, the sedge bogs have a surface layer dominated by peaty material and the brushy bogs have a surface layer dominated by mucky material.

Included with this soil in mapping are areas of Beseman, Dawson, and Loxley soils. These soils commonly are adjacent to the edges of the bog or are near islands of mineral soils. Areas of these mineral soils less than 3 acres in size are indicated on the soil map by spot symbols.

Most areas of this soil have plant growth dominated by lowland shrubs and hardwoods or by reeds and sedges. The soil is low in fertility and has a high water table that limits the choice of crops. Capability unit IVw–2; woodland group 4w1.

549—Greenwood peat (0 to 1 percent slopes). This deep soil is in bogs that have a mainly peaty herbaceous surface layer. Loamy and sandy soils on uplands surround the bogs. Most areas are circular or elongated, but some are irregular in shape. Areas range from about 40 to more than 800 acres in size. This soil has the profile described as representative of the series. The surface layer is extremely acid sphagnum material and ranges from about 6 to 20 inches in thickness. It generally is hummocky, and moss and shrub ridges range to about 24 inches above depressions in some areas.

Included with this soil in mapping are areas of soils that have a higher content of fibers than is typical of this soil. Also included are a few small areas of Lobo soils. These areas commonly occupy the interior parts of bogs. Areas of Beseman, Dawson, and Loxley soils are included near the edges of bogs and near islands of mineral soils.

Some areas of this soil are used for woodland and are covered with slow-growing black spruce and a few tamarack. Other areas are nearly treeless and have a cover of sphagnum moss and heath. Very few areas are drained and used for cultivated crops. This soil has low fertility and a high water table that limits the choice of plants. Capability unit IVw–2; woodland group 4w1.

Hibbing series

The Hibbing series consists of nearly level to undulating, well drained and moderately well drained soils that formed in reddish brown clayey till. These soils are on moraines.

In a representative profile (fig. 10) the surface layer is very dark grayish brown silt loam about 2 inches thick. The subsurface layer is reddish gray silt loam about 4 inches thick. It interfingers into the subsoil to a depth of 10 inches. The subsoil is reddish brown, firm clay about 64 inches thick. The underlying material is reddish brown clay.

Figure 10.—**Profile of a Hibbing soil.**

Permeability is slow, and the available water capacity is high. Organic matter content is low. The availability of phosphorus is high and of potassium is low.

Most areas of Hibbing soils are used for hardwood forest, and cleared areas are used for forage. The major limitation is the hazard of erosion on steep soils.

Representative profile of Hibbing silt loam, 0 to 2 percent slopes. on a rolling moraine, in a deciduous forest of maple, basewood, and birch, 525 feet north and 1,320 feet east of the southwest corner of sec. 36, T. 46 N., R. 20 W.:

O—½ inch to 0; mixture of undecomposed and decomposed plant material; abrupt smooth boundary.

A1—0 to 2 inches; very dark grayish brown (10YR 3/2) silt loam; weak fine subangular blocky structure; soft, very friable, slightly sticky; many fine roots; medium acid; clear wavy boundary.

A2—2 to 6 inches; reddish gray (5YR 5/2) silt loam; weak thin platy structure; soft, very friable, slightly sticky; few fine roots; strongly acid; clear wavy boundary.

A&B—6 to 10 inches; reddish gray (5YR 5/2) silt loam that interfingers into reddish brown (2.5YR 4/4) clay; moderate medium prismatic structure parting to moderate fine and medium subangular blocky; very hard, firm; few fine roots; strongly acid; abrupt wavy boundary.

B21t—10 to 20 inches; reddish brown (2.5YR 4/4) clay; strong medium prismatic structure parting to strong fine and medium subangular blocky; very hard, very firm, very plastic; very few fine roots; continuous moderately thick clay films on horizontal and vertical faces of peds; strongly acid; diffuse smooth boundary.

B22t—20 to 42 inches; reddish brown (2.5YR 4/4) clay; strong medium prismatic structure parting to strong fine and medium subangular blocky; very hard, very firm, plastic; continuous moderately thick clay films on horizontal and vertical faces of peds; very few fine roots; slightly acid; diffuse smooth boundary.

B31t—42 to 54 inches; reddish brown (2.5YR 4/4) clay; moderate coarse prismatic structure parting to strong fine, medium, and very fine subangular blocky; very hard, very firm, plastic; very few fine roots; many thin clay films on horizontal and vertical faces of peds; neutral; diffuse smooth boundary.

B32—54 to 70 inches; reddish brown (2.5YR 4/4) clay; weak coarse prismatic structure parting to strong fine medium and very fine subangular blocky; very hard, very firm, plastic; neutral; clear smooth boundary.

C—70 to 75 inches; reddish brown (2.5YR 4/4) clay; moderate thin platy structure; very hard, very firm, plastic; few fine threads of calcium carbonate; strongly effervescent; mildly alkaline.

The solum ranges from 40 to 70 inches in thickness. The depth to free carbonates ranges from 50 to 70 inches. The A1 horizon ranges from black or very dark gray to very dark brown. It is 0 to 3 inches thick. The A2 horizon ranges from reddish gray and grayish brown to dark grayish brown. It is 2 to 12 inches thick. It ranges from loam or very fine sandy loam to silt loam. The A horizon is very strongly acid to medium acid. The A2 horizon interfingers into the Bt horizon. In places, an A&B or B&A horizon is as much as 4 inches thick. This horizon is very strongly acid to medium acid. The content of clay in the B2t horizon typically ranges from 40 to 55 percent, but in some places it ranges from 35 to 60 percent. Clay films in the B2t horizon are patchy to continuous and thin to thick. In places, a B3 horizon is as much as 8 inches thick. The upper part of the B horizon is slightly acid to strongly acid, and the lower part is neutral to mildly alkaline. The reddish brown C horizon typically is clay, but it ranges to clay loam and silty clay loam or silty clay. It is mildly alkaline or moderately alkaline. Content of free carbonates is less than 15 percent.

Hibbing soils formed in the same color parent material as Duluth soils. They have more clay in the B horizon than Duluth soils.

254—Hibbing silt loam, 0 to 2 percent slopes. This nearly level soil is on the top of moraines. It is adjacent to Hibbing and Duluth soils that have slopes of more than 2 percent. Areas are irregularly shaped and 10 to 30 acres in size. This soil has the profile described as representative of the series.

Included with this soil in mapping are small, wet circular areas of Mahtowa and Blackhoof soils, which are indicated on the soil map by spot symbols. Also included are small areas of undulating soils.

Most areas of this soil are used for aspen, birch, and maple. Cleared areas are used for forage and grain crops. The cool climate and short growing season limits the choice of crops. Capability unit IIc–1; woodland group 2o1.

254C—Hibbing silt loam, 2 to 12 percent slopes. This undulating soil is in areas of 10 to 30 acres. Slopes generally are 150 to 300 feet long. This soil is somewhat better drained than Hibbing silt loam, 0 to 2 percent slopes.

Included with this soil in mapping are small wet areas of Mahtowa and Blackhoof soils, which are indicated on the soil map by spot symbols. Also included are small areas of Duluth and Dusler soils and small areas of nearly level and hilly soils.

Most areas of this soil are used for aspen, birch, and maple. Cleared areas are used for forage and grain crops. This soil has a hazard of erosion because of rapid runoff where the vegetation has been removed. Capability unit IIIe–1; woodland group 2o1.

Lobo series

The Lobo series consists of nearly level, very poorly drained soils that formed in organic material. These soils are in depressions on outwash plains and moraines.

In a representative profile the surface layer is dark reddish brown peat about 18 inches thick. Below this is reddish brown peat about 24 inches thick. The underlying material is very dark reddish brown mucky peat to a depth of more than 60 inches.

Permeability is moderate to moderately rapid, and the available water capacity is high. Organic matter content is very high. The availability of phosphorus and potassium is low. These soils have a high water table during most of the growing season.

Most areas of Lobo soils are used for forest. The major limitation is wetness.

Representative profile of Lobo peat on a raised bog of black spruce, heath, and sphagnum moss, 2,100 feet east and 1,250 feet south of the northwest corner of sec. 27, T. 48 N., R. 19 W.:

Oi1—0 to 8 inches; dark reddish brown (5YR 3/3), broken face and rubbed, fibric material, pinkish gray (5YR 7/2) pressed; about 95 percent fiber, same rubbed; massive; nonsticky; fibers are mainly sphagnum moss,

about 5 percent woody fragments; extremely acid; abrupt smooth boundary.

Oi2—8 to 18 inches; reddish brown (5YR 5/4), broken face and rubbed, fibric material; light reddish brown (5YR 6/4) pressed; about 95 percent fiber, same rubbed; massive; nonsticky; fibers are mainly sphagnum moss, less than 5 percent woody fragments; extremely acid; gradual smooth boundary.

Oi3—18 to 27 inches; reddish brown (5YR 4/4), broken face and rubbed, fibric material, reddish brown (5YR 5/4) pressed; about 80 percent fiber, about 60 percent rubbed; massive; nonsticky; fibers are mainly sphagnum moss, about 20 percent herbaceous, less than 5 percent woody fibers; extremely acid; abrupt smooth boundary.

Oa—27 to 31 inches; black (5YR 2/1), broken face, rubbed, and pressed, sapric material; about 30 percent fiber, about 8 percent rubbed; massive; nonsticky; fibers are mixtures of herbaceous and sphagnum; extremely acid; abrupt smooth boundary.

Oi4—31 to 42 inches; reddish brown (5YR 4/4), broken face and rubbed, fibric material, reddish brown (5YR 5/4) pressed; about 80 percent fibers, about 60 percent rubbed; massive; nonsticky; fibers are mainly sphagnum moss, about 20 percent herbaceous, less than 5 percent woody fibers; extremely acid; gradual smooth boundary.

Oe—42 to 120 inches; very dark reddish brown (5YR 2/2), broken face, rubbed, and pressed, hemic material; about 45 percent fiber, about 15 percent rubbed; massive; nonsticky; fibers are mainly herbaceous, less than 5 percent woody fibers; extremely acid.

The organic material ranges from 8 to 20 feet in thickness. The upper 35 to 53 inches is mainly fibric material that is derived mostly from sphagnum moss. Below this the soil is mostly hemic material that is of herbaceous origin. In some places, thin layers of sapric or hemic material less than 5 inches thick are in the upper 35 to 53 inches. The fibric material ranges from pinkish gray to dark reddish brown, and the lighter colors are mainly in the upper part. The content of fiber typically is more than 90 percent, but it ranges to as low as 70 percent in a few places. Content of fiber after rubbing typically exceeds 80 percent, but it is as little as 40 percent in a few places. The hemic material ranges from black to dark reddish brown. In this material, the content of fiber ranges from 35 to 65 percent and from 20 to 45 percent after rubbing. The upper 1 to 2 feet of the hemic layer commonly is stratified with alternating layers dominated by sphagnum moss and by herbaceous plants.

Lobo soils formed in the same kind of parent material as Waskish soils. They have a thinner layer of fibric material than Waskish soils.

537—Lobo peat (0 to 1 percent slopes). This extremely acid soil is in parts of bogs that have sphagnum moss over herbaceous material. The soil commonly is on the higher parts of the bog, and typically the natural drainage is away from the soil. Areas commonly are elongated to nearly circular, and they generally range from 200 to 300 acres in size. They are chiefly in large bogs. Some areas are near the center of the bogs, and others are near the edges.

Included with this soil in mapping are areas of Waskish and Greenwood soils. The Waskish soils are typically at a higher elevation than this soil. The Greenwood soils are commonly near the outer edges of this soil.

Areas of this soil are covered by dense or scattered stands of slow-growing black spruce, a few tamarack, and sphagnum moss and heath. The high water table and low fertility restrict the choice of plants. Capability unit VIIw–1; woodland group 4w1.

Loxley series

The Loxley series consists of nearly level, very poorly drained soils that formed in organic material. These soils are in lowlands or depressions in undulating outwash and moraines.

In a representative profile the surface layer is reddish brown, extremely acid peat about 6 inches thick. The underlying material is dark reddish brown and black, extremely acid herbaceous muck to a depth of more than 60 inches.

Permeability is moderately slow to moderately rapid, and the available water capacity is very high. Organic matter content is very high. The availability of phosphorus and potassium is low. These soils have a high water table during most of the growing season.

Most areas of Loxley soils have potential for frost-resistant vegetable crops if the soils are drained. The major limitation is wetness.

Representative profile of Loxley muck, on a nearly treeless bog of sphagnum moss and heath, 350 feet west and 2,376 feet south of the northeast corner of sec. 35, T. 49 N., R. 18 W.:

Oi—0 to 6 inches; reddish brown (5YR 4/4), broken face and rubbed, fibric material; about 90 percent fiber, about 70 percent rubbed; massive; nonsticky; fibers are mainly sphagnum moss; extremely acid; clear wavy boundary.

Oa1—6 to 12 inches; black (10YR 2/1), broken face and rubbed, sapric material; about 10 percent fiber, less than 5 percent rubbed; weak fine granular structure; slightly sticky; fibers are mainly herbaceous; extremely acid; gradual smooth boundary.

Oa2—12 to 46 inches; dark reddish brown (5YR 2/2), broken face and rubbed, sapric material; about 10 percent fibers, less than 5 percent rubbed; massive; slightly sticky; fibers are mainly herbaceous; extremely acid; gradual smooth boundary.

Oa3—46 to 54 inches; black (10YR 2/1), broken face and rubbed, sapric material; less than 10 percent fibers; massive; slightly sticky; fibers are mainly herbaceous; extremely acid; clear smooth boundary.

Oa4—54 to 60 inches; dark reddish brown (5YR 2/2), broken face and rubbed, sapric material; about 10 percent fibers, less than 5 percent rubbed; massive; slightly sticky; fibers are mainly herbaceous; extremely acid; clear smooth boundary.

Oe—60 to 66 inches; dark reddish brown (5YR 3/3), broken face and rubbed, hemic material; about 45 percent fibers, about 25 percent rubbed; massive; nonsticky; fibers are mainly herbaceous; extremely acid.

The organic material is more than 51 inches thick. All parts of the material above a depth of 51 inches range from extremely acid to strongly acid. Typically the fiber is mainly of herbaceous origin in all parts of the organic material. The fiber in the surface layer is commonly derived from sphagnum moss. The surface layer is dominated by fibric, hemic, or sapric material that ranges from light gray to black. The underlying material ranges from black and very dark reddish brown to very dark gray. The underlying material to a depth of 51 inches is predominantly sapric material; however, thin layers of hemic or sapric material are in some places.

Loxley soils formed in organic material of the same origin as Greenwood soils. They are predominantly sapric material, whereas Greenwood soils are predominantly hemic material.

533—Loxley muck (0 to 1 percent slopes). This deep organic soil is in bogs that contain mostly mucky herbaceous organic material. Many areas do not have the extremely acid surface layer of sphagnum material described in the representative profile. This soil is surrounded by loamy, sandy, and gravelly soils on uplands. In a few places, it is along streams and around the outer edges of some of the large bogs. Most areas are nearly circular to irregular in shape, and they range from about 10 to more than 100 acres in size.

Included with this soil in mapping are areas of Beseman and Dawson soils that have loamy and sandy material at a moderately shallow depth. These soils are commonly in a 100- to 200-foot wide rim around islands of mineral soils and around edges of bogs. Also included are areas of medium acid soils that are mainly adjacent to streams. In these areas, thin layers of mineral material are common, and these areas are frequently flooded. Areas of Greenwood soils in a random pattern within the bogs and areas of mineral soils 3 acres in size or less that are indicated on the soil map by a spot symbol are included.

Most areas of this soil are used for lowland brush, hardwoods, and conifers. A few areas, however, are open and consist chiefly of sedge and grass. The high water table and low fertility restrict the choice of crops. Capability unit IVw–2; woodland group 4w1.

Mahtowa series

The Mahtowa series consists of nearly level, poorly drained and very poorly drained soils that formed in reddish brown loam or clay loam glacial till. These soils are in depressions on moraines.

In a representative profile the surface layer is black silt loam about 11 inches thick. The upper 5 inches of the subsoil is olive gray, friable loam; the next 5 inches is grayish brown, friable loam; and the lower 19 inches is reddish brown loam. The underlying material is reddish brown loam.

Permeability is slow, and the available water capacity is high. Organic matter content is high. The availability of phosphorus is medium and of potassium is low. These soils have a high water table during most of the growing season.

Most areas of Mahtowa soils are used for forest and pasture. The major limitation is wetness.

Mahtowa soils in Carlton County are mapped only with Blackhoof soils.

Representative profile of Mahtowa silt loam in an area of Blackhoof and Mahtowa soils, in a pasture on a moraine, 1,640 feet south and 120 feet east of the northwest corner of sec. 4, T. 46 N., R. 16 W.:

A11—0 to 2 inches; dark reddish brown (5YR 2/2) silt loam; friable; recent overwash; abrupt irregular boundary.

A12—2 to 9 inches; black (10YR 2/1) silt loam, dark gray (10YR 4/1) dry; massive in parts, weak medium platy structure in other parts; hard, friable, slightly plastic; many roots; few pores; about 2 percent coarse fragments; slightly acid; abrupt wavy boundary.

A3—9 to 11 inches; black (10YR 2/1) silty clay loam, very dark gray (10YR 3/1) in a few places; weak coarse subangular blocky structure parting to weak thick platy; very hard, firm, plastic; few roots; very few pores; about 2 percent coarse fragments; slightly acid; abrupt irregular boundary.

B21g—11 to 16 inches; olive gray (5Y 5/2) loam; few fine and medium prominent reddish brown mottles and few fine distinct greenish gray mottles; weak thin platy structure; hard, friable, slightly plastic; few roots; about 5 percent 1- to 2-millimeter pores; about 2 percent coarse fragments; neutral; clear wavy boundary.

B22g—16 to 21 inches; grayish brown (2.5Y 5/2) loam; common fine and medium prominent yellowish red (5YR 4/6) and reddish brown (5YR 4/4) mottles and few fine prominent greenish gray mottles; weak thin platy structure; hard, friable, slightly plastic; few roots; about 5 percent 1- to 2-millimeter pores; about 5 percent coarse fragments; neutral; abrupt smooth boundary.

B31—21 to 28 inches; reddish brown (5YR 4/3) loam; few fine distinct dark brown and strong brown mottles; weak thin platy structure parting to weak very fine angular blocky; very hard, friable, plastic; few root channels lined with gray clay films; about 5 percent coarse fragments; neutral; gradual smooth boundary.

B32—28 to 40 inches; reddish brown (5YR 4/3) loam; common fine faint reddish brown mottles; weak thin platy structure parting to weak very fine angular blocky; very hard, friable, plastic; few root channels lined with gray

clay films; about 5 percent coarse fragments, neutral; gradual smooth boundary.

C—40 to 60 inches; reddish brown (5YR 4/3) loam; few lenses of heavy clay loam as much as 2 inches thick; weak thin platy structure parting to weak very fine angular blocky; very hard, friable, plastic; about 5 percent coarse fragments; slightly effervescent; mildly alkaline.

The solum ranges from 36 to 50 inches in thickness. Depth to free carbonates ranges from 36 to 80 inches. An O horizon as much as 4 inches thick is in some places. The A horizon ranges from black to very dark gray. It is 10 to 16 inches thick. In some pedons this horizon is mottled. The A horizon ranges from loam or silt loam to silty clay loam. It is strongly acid to slightly acid. The upper part of the B horizon ranges from dark gray, light brownish gray, or olive gray to light olive gray. It is distinctly or prominently mottled. The upper part of the B horizon is loam, silt loam, or clay loam. It is slightly acid to neutral. The lower part of the B horizon ranges from dark reddish brown to reddish brown, mottled loam or clay loam. This part of the B horizon is slightly acid or neutral. The C horizon ranges from dark reddish brown to reddish brown loam or clay loam. It is neutral to mildly alkaline.

Mahtowa soils are associated on the landscape with Duluth, Dusler, and Blackhoof soils, and they formed in the same kind of parent material as those soils. They have more mottles and are grayer in the upper part of the B horizon than the better drained Duluth and Dusler soils. If present, the muck or peat surface layer of the Mahtowa soils is thinner than is typical of Blackhoof soils.

Merwin series

The Merwin series consists of nearly level, very poorly drained soils that formed in organic material overlying mineral material at a depth of 16 to 51 inches. These soils are in depressions on moraines.

In a representative profile the surface layer is yellowish brown, extremely acid sphagnum peat about 6 inches thick. Below this is dark brown mucky peat about 36 inches thick. The underlying material is dark gray fine sandy loam.

Permeability is moderate to moderately rapid in the organic material and slow to moderately slow in the mineral material. The available water capacity is very high. Organic matter content is very high. The availability of phosphorus and potassium is low. These soils have a high water table during most of the growing season.

Most areas of Merwin soils are used for forest and wildlife habitat. The major limitation is wetness.

Representative profile of Merwin mucky peat, in a bog of black spruce and an understory of heath and sphagnum moss, 2,123 feet west and 2,085 feet north of the southeast corner of sec. 20, T. 46 N., R. 20 W.:

Oi—0 to 6 inches; yellowish brown (10YR 4/4), broken face, fibric material, dark yellowish brown (10YR 3/4), rubbed, light yellowish brown (10YR 6/4) pressed; about 95 percent fiber, about 90 percent rubbed; massive; nonsticky; about 15 percent woody fiber, mostly about 0.5 centimeter in diameter and 25 centimeters long, remainder is sphagnum moss fiber; few 1-centimeter-thick layers of sapric material in lower part; layer is 4 to 12 inches thick within dimensions of pedon; extremely acid; gradual wavy boundary.

Oe—6 to 40 inches; dark brown (7.5YR 3/3), broken face, hemic material, dark brown (7.5 YR 3/2) rubbed and pressed; about 50 percent fiber, about 20 percent rubbed; massive; nonsticky; mostly herbaceous fiber; few charcoal fragments; very strongly acid; gradual smooth boundary.

Oa—40 to 42 inches; very dark gray (10YR 3/1), broken face, rubbed, and pressed, sapric material; about 15 percent fiber, about 5 percent rubbed; massive; slightly sticky; herbaceous fiber; very strongly acid; abrupt smooth boundary.

IIAb—42 to 45 inches; very dark gray (10YR 3/1) loam; massive; friable, sticky; about 2 percent coarse fragments; very strongly acid; abrupt smooth boundary.

IICg—45 to 60 inches; dark gray (5Y 4/1) fine sandy loam; massive; firm, slightly sticky; very strongly acid.

The thickness of the organic material and the depth to the mineral underlying material range from 16 to 51 inches. The fiber is dominantly herbaceous, but in some places fiber of sphagnum moss is dominant in the surface layer. The surface layer consists of fibric, hemic, or sapric material, or any combination of two or more of these materials. It ranges from light gray to black. Hemic material is dominant in the remainder of the organic material part of the profile. It ranges from dark reddish brown or dark brown to brown. A layer of sapric material commonly is immediately above the mineral underlying material. A thin buried soil is in the upper part of the mineral underlying material in some places. The mineral underlying material typically is glacial till. It is also commonly fine sandy loam, sandy loam, or loam. The upper few inches of this material is sandy in some places. The mineral underlying material is extremely acid to neutral.

Merwin soils formed in the same kind of parent material as Greenwood soils. They have mineral material at a depth of 16 to 51 inches, whereas Greenwood soils have mineral material at a depth of more than 51 inches.

535—Merwin mucky peat (0 to 1 percent slopes). This soil is in bogs of mostly herbaceous organic material that is underlain by loamy material at a depth of 16 to 51 inches. This soil is commonly surrounded by nearly level, loamy upland soils; in some large bogs, however, it joins other organic soils. Most areas are nearly circular to oblong, but some are irregular in shape and range from 10 to 100 acres in size. In some areas this soil has a surface layer dominated by well decomposed or slightly decomposed material.

Included with this soil in mapping are areas of soils that are similar to this Merwin soil, but the organic layers above the loamy underlying material are derived

from woody plant material and reaction is medium. These included soils are commonly between Mooselake soils and uplands. Also included are areas of Greenwood soils in a random pattern within the bogs and areas of Beseman soils that commonly are on narrow rims around mapped areas.

Most areas of this soil are used for lowland brush and hardwoods; however, moss, heath, and black spruce are in some areas. A high water table and low fertility restrict the choice of crops. Capability unit IVw–2; woodland group 4w1.

Mooselake series

The Mooselake series consists of nearly level, very poorly drained soils that formed in organic material. These soils are in lowlands or depressions in undulating outwash areas and on undulating moraines.

In a representative profile the surface layer is black, strongly acid woody muck about 6 inches thick. The underlying material is dark reddish brown, medium acid woody mucky peat.

Permeability is moderate to moderately rapid, and the available water capacity is very high. Organic matter content is very high. The availability of phosphorus and potassium is low. These soils have high water table during most of the growing season.

Most areas of Mooselake soils are used for woodland. The major limitation is wetness.

Representative profile of Mooselake mucky peat, in a brushy bog, 2,430 feet north and 120 feet east of the southwest corner of sec. 24, T. 49 N., R. 20 W.:

Oa—0 to 6 inches; black (5YR 2/1), broken face and rubbed, sapric material; about 30 percent fiber, about 15 percent rubbed; weak fine granular structure; nonsticky; woody fiber; strongly acid; clear wavy boundary.

Oe1—6 to 72 inches; dark reddish brown (5YR 2/2), broken face and rubbed hemic material; about 45 percent fiber, about 20 percent rubbed; massive; nonsticky; woody fiber; medium acid; abrupt smooth boundary.

Oe2—72 to 78 inches; dark reddish brown (5YR 2/2), broken face and rubbed, hemic material; about 65 percent fiber, about 45 percent rubbed; massive; nonsticky; mixed herbaceous and hypnum moss fiber; medium acid.

The organic material extends to a depth of more than 51 inches, commonly to a depth of 60 to 100 inches or more. Content of coarse woody fragments ranges from 0 to 10 percent, and the higher content is commonly in the upper part. The surface layer is either sapric, hemic, or fibric material or a combination of two or more of those materials. The underlying material to a depth of at least 51 inches typically is entirely hemic material. However, sapric or fibric material, or both, are present in these tiers in some places, but the total thickness of either is less than 10 inches. The major part of the hemic material within a depth of 51 inches is mostly woody fiber. The hemic material ranges from dark reddish brown or dark brown to very dark brown. The woody fiber is mainly less than 5 millimeters in size. The content of fiber in the woody hemic material ranges from 35 to 65 percent in undisturbed areas and from 15 to 45 percent after rubbing. The content of mineral material ranges from 10 to 25 percent. In places, the hemic material is mostly herbaceous fiber between depths of 35 and 51 inches.

Mooselake soils formed in organic material having the same degree of decomposition as Greenwood soils. They have considerably more woody fibers and are less acid than Greenwood soils.

534—Mooselake mucky peat (0 to 1 percent slopes). This soil is in bogs of mostly woody organic material. It is commonly surrounded by loamy, sandy, and gravelly upland soils; in some large bogs, however, it is in a wide belt between the uplands and other organic soils. Most areas are nearly circular or elongated and range from 40 to more than 500 acres in size.

Included with this soil in mapping are areas of soils that contain woody fibers, are similar in reaction to this Mooselake soil, and are more decomposed throughout the profile than is typical for this soil. These included soils make up a major part of mapped areas, especially in small bogs; more commonly, however, they are adjacent to islands of mineral soils and uplands. Also included are areas of Beseman soils that are adjacent to mineral soils and uplands; areas less than 3 acres in size of mineral soils, which are indicated on the soil map by a spot symbol; and a few areas of soils that have a surface layer of 6 to 12 inches of sphagnum moss.

Most areas of this soil are used for white-cedar, lowland brush, and hardwoods. Very few areas have been cleared, drained, and used for cultivated crops. This is one of the more fertile organic soils in the county, but it has a high water table that limits the choice of crops. Capability unit IVw–2; woodland group 3w1.

Mora series

The Mora series consists of nearly level, somewhat poorly drained soils that formed in fine sandy loam. These soils are in plane to slightly concave positions at the base of slopes, at the heads of shallow waterways, and on nearly level ground moraines.

In a representative profile the surface layer is black fine sandy loam about 4 inches thick. The subsurface layer is grayish brown and yellowish brown fine sandy loam about 7 inches thick. The subsoil is reddish brown fine sandy loam about 47 inches thick. The underlying material is dark reddish brown fine sandy loam.

Permeability is moderately slow, and the available water capacity is moderate. Organic matter content is moderate. The availability of phosphorus is medium and of potassium is low. The subsoil is very dense.

Most areas of Mora soils are used for forest and pasture. The major limitation is wetness.

Representative profile of Mora fine sandy loam, wet (0 to 2 percent slopes), under hardwood forest of maple and elm, 1,050 feet west and 60 feet south of the center of sec. 34, T. 49 N., R. 20 W.:

A1—0 to 4 inches; black (10YR 2/1) fine sandy loam; moderate fine and very fine granular structure; very friable; about 25 percent

roots, mainly 1 millimeter in diameter but ranging from 0.5 to 25 millimeters in diameter; horizon ranges from 2.5 to 12 inches in thickness and averages 4 inches thick; thicker parts are 1 to 2 feet wide; extremely acid; clear wavy boundary.

A21g—4 to 7 inches; grayish brown (2.5Y 5/2) fine sandy loam; common fine distinct brown and prominent strong brown mottles; moderate medium platy structure parting to weak very fine subangular blocky; very friable; many very fine and fine exped open vesicular pores, mostly on upper surface of plates, and a few very fine continuous vertical imped simple tubular pores; few random very fine and fine roots; about 1 percent coarse fragments, mainly 2 to 5 millimeters in diameter; horizon ranges from 2 to 4 inches in thickness, but in places as much as 2 feet wide this horizon is absent; very strongly acid; clear wavy boundary.

A22—7 to 11 inches; yellowish brown (10 YR 5/4) fine sandy loam; many medium distinct strong brown (7.5YR 4/6) mottles; weak medium and thick platy structure; very friable; many very fine and fine exped open vesicular pores, mostly on upper surface of plates, and a few very fine continuous vertical imped simple tubular pores; few random very fine and fine roots; about 5 percent coarse fragments, mainly 2 to 5 millimeters in diameter; few soft dark reddish brown masses; horizon ranges from 2 to 6 inches in thickness but in a few places this horizon is absent; strongly acid; abrupt wavy boundary.

B2t—11 to 21 inches; reddish brown (5YR 4/3) fine sandy loam; many fine faint reddish brown, dark reddish brown, and yellowish red mottles; moderate medium platy structure; friable; very few fine and very fine roots; very few very fine discontinuous vertical inped simple tubular pores; very few thin clay films on upper faces of plates; lower faces of plates have more sand grains and coarse fragments than upper surfaces; few soft dark reddish brown masses; about 5 percent coarse fragments; vertical faces with reddish gray and reddish brown color coat; strongly acid; gradual wavy boundary.

Bx1—21 to 30 inches; reddish brown (5YR 4/3) fine sandy loam; common fine faint dark reddish brown, reddish brown, and dark red mottles; moderate medium platy structure parting to weak very thin platy; firm, ruptures abruptly under slight pressure; very few very fine and fine roots; few micro discontinuous random inped simple tubular pores; few thin clay films on upper faces of plates; about 5 percent coarse fragments, mainly 2 to 10 millimeters in diameter; strongly acid; gradual wavy boundary.

Bx2—30 to 43 inches; reddish brown (5YR 4/3) fine sandy loam; few fine faint yellowish red and dark red mottles; strong medium platy structure parting to moderate very thin platy; firm, ruptures abruptly under medium pressure; very few micro and very fine roots; very few micro discontinuous random inped simple tubular pores; common thin clay films on upper faces of plates and few thin clay films and many exposed sand grains on lower plate surfaces; about 5 percent coarse fragments; medium acid; diffuse smooth boundary.

Bx3—43 to 58 inches; dark reddish brown (5YR 3/4) fine sandy loam; moderate medium and thick platy structure parting to weak thin platy; firm, ruptures abruptly under slight pressure; few discontinuous clay films on upper faces of plates and very few thin black 0.5- to 1.0-millimeter circular coatings; about 5 percent coarse fragments; few discontinuous medium sand lenses as much as 2 inches thick occupy about 10 percent of the pedon, mostly in one part; medium acid; diffuse smooth boundary.

Cx—58 to 85 inches; dark reddish brown (5YR 3/4) fine sandy loam; moderate medium and thick platy structure parting to weak thin platy; firm, ruptures abruptly under slight pressure; about 5 percent coarse fragments; slightly acid.

The solum ranges from 36 to 60 inches in thickness. Free carbonates commonly are at a depth of 6 to 10 feet, but in some places they are in threads at a depth of 5 feet. The depth to the fragipan ranges from about 20 to 30 inches. Mottles are in the horizons between the A1 and Bx horizons. An O horizon ½ inch to 2 inches thick is in some places. The A1 horizon ranges from black to very dark gray. It is 2 to 6 inches thick. The A1 horizon ranges from silt loam or loam to very fine or fine sandy loam. It ranges from extremely acid to slightly acid. The A2 horizon ranges from reddish gray or dark grayish brown to yellowish brown. It is 6 to 12 inches thick. It has distinct or prominent mottles. The A2 horizon ranges from light silt loam or loam to fine sandy loam. It ranges from very strongly acid to slightly acid. The B2 horizon ranges from dark reddish brown to reddish brown and from fine sandy loam to sandy loam or loam. The clay content ranges from 8 to 18 percent. The bulk density ranges from about 1.8 to 2.0 in the Bx horizon, and reaction ranges from strongly acid to neutral. The C horizon ranges from fine sandy loam to sandy loam. It typically ranges from slightly acid to mildly alkaline.

Mora soils in Carlton County are wetter than Mora soils elsewhere. They have distinct or prominent mottles in the A2 horizon, as contrasted to the faint mottles defined in the range for the series. The wetness alters use and behavior because the water table is nearer to the surface during the growing season.

Mora soils formed in the same kind of parent material as Ahmeek, Parent, and Twig soils. They have a grayer or more mottled solum than Ahmeek soils. They are not so gray in the B horizon as Parent and Twig soils.

V166—Mora fine sandy loam, wet (0 to 2 percent slopes). This soil is on moraines. It is adjacent in most places to Ahmeek, Automba, Parent, and Twig soils. Areas range from 5 to 30 acres in size. Surface drainage is slow.

Included with this soil in mapping are areas of soils containing 18 to 25 percent clay in the subsoil and areas containing as little as 5 to 10 percent clay in the subsoil. Also included are 1- to 5-acre areas of stony and very stony soils, which are indicated on the soil map by a spot symbol.

Most areas of this soil are used for trees. A few cleared and drained areas are used for forage and small grain. The choice of crops is restricted by a seasonal high water table. Capability unit IIIw-1; woodland group 2w1.

Nemadji series

The Nemadji series consists of nearly level, somewhat poorly drained soils that formed in sandy material. These soils are on outwash plains and glacial lake plains.

In a representative profile the surface layer is black sand about 2 inches thick. The subsurface layer is reddish gray fine sand about 4 inches thick. The upper 3 inches of the subsoil is dark reddish brown fine sand, the middle 6 inches is reddish brown fine sand, and the lower 24 inches is mottled yellowish red fine sand. The underlying material is reddish brown fine sand.

Permeability is rapid, and the available water capacity is low. Organic matter content is low. The availability of potassium is low. These soils commonly have a high water table from the time that snow melts until early in June and from late in September until the soil freezes.

Most areas of Nemadji soils are used for forest. A few areas are used for cultivated crops. The major limitation is wetness.

Representative profile of Nemadji fine sand, under a mixed deciduous-coniferous forest on a lake plain, 1,580 feet east and 40 feet north of the southwest corner of sec. 13, T. 46 N., R. 18 W.:

O—½ inch to 0; undecomposed and slightly decomposed organic debris; abrupt irregular boundary.

A1—0 to 2 inches; black (5YR 2/1) fine sand; single grained; loose; many uncoated sand grains; many roots; strongly acid; abrupt wavy boundary.

A2—2 to 6 inches; reddish gray (5YR 5/2) fine sand; single grained; loose; nearly all sand grains uncoated; many roots; very strongly acid; abrupt wavy boundary.

B21hir—6 to 9 inches; dark reddish brown (5YR 3/4) fine sand; single grained; loose; nearly all sand grains coated; many roots; horizon is absent in about 10 percent of pedon; very strongly acid; clear wavy boundary.

B22hir—9 to 15 inches; dark reddish brown (5YR 4/4) fine sand; single grained; loose; nearly all sand grains coated; few roots; very strongly acid; clear wavy boundary.

B3—15 to 39 inches; yellowish red (5YR 4/6) fine sand; many fine distinct reddish brown mottles; single grained; loose; about 25 percent irregularly shaped very weakly cemented dark reddish brown (2.5YR 3/4) and dark red (2.5YR 3/6) masses of fine sand about ½ inch to 12 inches across; nearly all sand grains coated; very strongly acid; gradual wavy boundary.

C1—39 to 48 inches; reddish brown (5YR 4/4) fine sand; single grained; loose; very strongly acid; gradual smooth boundary.

C2—48 to 60 inches; reddish brown (2.5 YR 4/4) fine sand; single grained; loose; strongly acid; gradual smooth boundary.

C3—60 to 69 inches; reddish gray (5YR 5/2) fine sand; single grained; loose; medium acid.

The solum ranges from 30 to 50 inches in thickness. Depth to free carbonates is more than 80 inches. The solum and the C horizon do not have coarse fragments. The A1 horizon ranges from black or very dark gray to very dark brown. It is 1 inch to 4 inches thick. The A2 horizon ranges from dark gray, gray, or reddish gray to grayish brown. It is 2 to 7 inches thick. The A horizon ranges from sand or fine sand to loamy sand or loamy fine sand. The B2 horizon typically is sand or fine sand, but it ranges to loamy sand, loamy fine sand, or sand. It is 6 to 12 inches thick. The B3 horizon ranges from reddish brown to brown. Mottles are faint to distinct. In places, as much as 50 percent of the volume of the B3 horizon is weakly cemented masses as much as 18 inches across. The B3 horizon is sand or fine sand and is very strongly acid to medium acid. The C horizon is sand or fine sand and ranges from very strongly acid to medium acid within a depth of 60 inches.

Nemadji soils are associated on the landscape with Omega and Newson soils, and they formed in the same kind of parent material. They have a brighter colored B horizon than the Newson soils and are not so wet. They have mottles in the B horizon whereas the Omega soils do not. Nemadji soils are not so well drained as Omega soils.

186—Nemadji fine sand (0 to 2 percent slopes). This nearly level soil is in low lying areas and rims around wet depressions on outwash plains and along the edge of the lake plain in the eastern part of the county. Most areas on the outwash plain are 3 to 10 acres in size, and most areas along the lake plain are 10 to 50 acres.

Included with this soil in mapping are small areas of Newson soils commonly in depressions. Also included are areas of soils that are adjacent to Cromwell soils and that have a surface layer of sandy loam generally 6 to 12 inches thick; areas of soils on the lake plain where the underlying material commonly contains thin loamy, silty, or clayey strata; and areas of soils in the northwestern part of the county that have brown underlying material.

Most areas of this soil are used chiefly for aspen, birch, and balsam fir. A few cleared areas are used for small grain and forage. The choice of crops is limited because of a high water table. Capability unit IIIw–2; woodland group 2w1.

Newson series

The Newson series consists of nearly level, poorly drained and very poorly drained soils that formed in sandy material. These soils are on outwash plains and glacial lake plains.

In a representative profile (fig. 11) the surface layer is black mucky loamy sand about 5 inches thick. The underlying material is grayish brown and reddish brown sand.

Permeability is rapid, and the available water capacity is low. Organic matter content is high. The availability of potassium is low. These soils have a high water table during most of the growing season.

Most areas of Newson soils are used for forest. A few drained areas are used for cultivated crops. The major limitation is wetness.

Representative profile of Newson mucky loamy sand, under willow and alder on a lake plain, 1,426 feet west and 1,420 feet south of the northeast corner of sec. 20, T. 46 N., R. 17 W.:

A1—0 to 5 inches; black (N 2/0) mucky loamy sand; weak fine granular structure; slightly plastic; many roots; strongly acid; abrupt wavy boundary.

B2g—5 to 26 inches; grayish brown (10YR 5/2) sand; few large prominent strong brown (7.5YR 4/6) mottles and few medium prominent yellowish red (5YR 5/6) mottles; single grained; loose; about 20 percent random irregularly shaped bodies of black (N 2/0) mucky loam about 2 to 10 inches across; common fine roots; strongly acid; diffuse smooth boundary

C1g—26 to 62 inches; grayish brown (10YR 5/2) sand; single grained; loose; about 10 percent random irregularly shaped masses of black (N 2/0) mucky loam and very dark gray (5Y 3/1) loam ½ inch to 2 inches across; very few roots; strongly acid; diffuse smooth boundary.

C2—62 to 70 inches; reddish brown (5YR 4/4) sand; single grained; loose; medium acid.

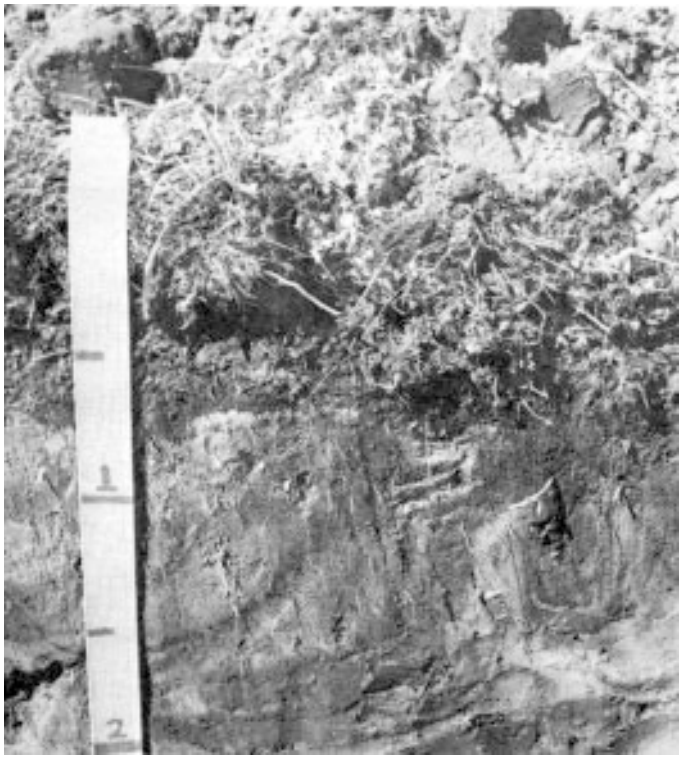


Figure 11.—**Profile of a Newson soil.**

The solum ranges from 20 to 30 inches in thickness. The depth to free carbonates is more than 60 inches. The depth to horizons in which matrix has chroma of 4 or more exceeds 30 inches. The pedon typically does not have gravel between depths of 10 and 40 inches, but in places is as much as 5 percent gravel, either in discrete subhorizons or dispersed throughout the sandy matrix, between these depths. An O horizon as much as 4 inches thick is in some places. The A1 horizon ranges from black or very dark gray to very dark brown. It is 3 to 6 inches thick. It typically is mucky sand or mucky loamy sand but ranges to fine sand, loamy fine sand, sandy loam, or fine sandy loam. The A1 horizon is strongly acid to medium acid. The B2g and C1g horizons range from dark gray, gray, or grayish brown to reddish gray. Faint to prominent mottles are in the C1g horizon. The B2g and C1g horizons typically are sand but range to coarse sand or fine sand. The C horizon to a depth of 40 inches typically is strongly acid, but it ranges to medium acid or slightly acid below this depth. The C2 horizon typically is sand, but it ranges from fine sand to coarse sand. Thin, finer textured layers are in this horizon below a depth of 40 inches in places.

Newson soils are associated on the landscape with Nemadji and Omega soils, and they formed in the same kind of parent material as those soils. They have a grayer B horizon and are wetter than Nemadji and Omega soils.

274—Newson mucky loamy sand (0 to 1 percent slopes). This wet, sandy soil is in low lying areas on outwash plains and glacial lake plains. Most areas are irregular in shape and range from 5 to 20 acres in size.

Included with this soil in mapping are small areas of soils that are adjacent to Cromwell soils and that have a sandy loam surface layer 12 to 24 inches thick. Also included are areas of soils on the lake plain in the eastern part of the county and the lowland north of the village of Cromwell that have thin layers of loamy, silty, and clayey material in the underlying sandy material.

Most areas of this soil are used for lowland trees and shrubs. A few cleared and drained fields are used for forage and small grain. The choice of crops is limited by a high water table. Capability unit IVw–1; woodland group 4w2.

Omega series

The Omega series consists of nearly level to hilly, somewhat excessively drained soils that formed in

sandy material. These soils are on outwash plains and lake plains.

In a representative profile about 2 inches of undecomposed and decomposed forest litter overlies a subsurface layer of reddish gray loamy sand about 1 inch thick. The subsoil is reddish brown loamy sand and sand about 21 inches thick. The underlying material is light reddish brown fine sand.

Permeability is rapid, and the available water capacity is low. Organic matter content is low. The availability of potassium is low.

Most areas of Omega soils are used for forest. A few areas are used for cultivated crops. The major limitation is the hazard of drought.

Representative profile of Omega loamy sand, 0 to 2 percent slopes, in a forest dominated by jack pine and a few aspen on an outwash plain, 36 feet south and 111 feet east of the northwest corner of sec. 36, T. 49 N., R. 18 W.:

O1—2 inches to 1 inch; undecomposed and partly decomposed forest litter; abrupt wavy boundary.

O2—1 inch to 0; black (N 2/0) highly decomposed forest litter and about 10 percent sand; weak very fine and fine granular structure; very friable; few charcoal fragments; many white and yellow fungal mycelia; many roots; very strongly acid; abrupt wavy boundary.

A2—0 to 1 inch; reddish gray (5YR 5/2) loamy sand; single grained; very friable; about 90 percent of the horizon is discontinuous; many roots; sand grains uncoated; very strongly acid; abrupt wavy boundary.

B21hir—1 to 3 inches; dark reddish brown (5YR 3/3) loamy sand; weak fine subangular blocky structure; very friable; about 90 percent of the horizon is discontinuous; many roots; nearly all sand grains coated; very strongly acid; abrupt wavy boundary.

B22hir—3 to 10 inches; reddish brown (5YR 4/4) loamy sand; weak fine subangular blocky structure; very friable; about 3 percent roots; nearly all sand grains coated; strongly acid; clear wavy boundary.

B3—10 to 22 inches; reddish brown (5YR 5/3) sand; single grained; loose; few roots; sand grains very thinly coated; medium acid; clear wavy boundary.

C—22 to 60 inches; light reddish brown (5YR 6/3) fine sand; single grained; loose; few 2- to 3-millimeter thick color bands below a depth of 36 inches; sand grains uncoated; neutral.

The solum ranges from 15 to 30 inches in thickness. Loamy sand, loamy fine sand, fine sand, or sand that is more than 10 percent very fine sand, silt, and clay extends to a depth of 10 to 20 inches. In places, there is an A1 horizon that is as much as 3 inches thick. It ranges from black or very dark gray to very dark brown. The A2 horizon commonly is discontinuous, but it is present in some part of all soils in this series. It ranges from reddish gray or gray to grayish brown. The A horizon is very strongly acid or strongly acid. The B2 horizon ranges from dark reddish brown to reddish brown. The darker color is in the upper part of the horizon. The B2 horizon is very strongly acid or strongly acid. The C horizon is sand or fine sand and is medium acid to neutral.

Omega soils are associated on the landscape with Nemadji and Newson soils, and they formed in the same kind of parent material. They do not have the mottles in the B horizon that the wetter Nemadji and Newson soils have.

188—**Omega loamy sand, 0 to 2 percent slopes.** This nearly level soil is on the outwash plain. It is in irregularly shaped areas that are 20 to 40 acres in size, and it is adjacent to Nemadji and Newson soils. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Nemadji, Newson, Cromwell, and Cloquet soils. The Nemadji soils are in shallow, elongated drainageways. The Newson soils are in depressions, which are indicated on the soil map by a spot symbol if they are 1 to 3 acres in size. The Cromwell and Cloquet soils are in a random pattern. Also included are a few small areas of undulating soils that have short slopes and areas of soils in the northwest part of the county that have brown underlying material.

Most areas of this soil are used for aspen, birch, red pine, and jack pine. A few cleared areas are used for forage and small grain. Because of the low available water capacity of this soil, crop production is generally restricted. Capability unit IVs–1; woodland group 2s1.

188C—**Omega loamy sand, 2 to 12 percent slopes.** This undulating soil is on the outwash plain. It is in irregularly shaped areas that are 10 to 50 acres in size, and it is adjacent to Nemadji and Newson soils. Slopes are generally 150 to 250 feet long. The maximum relief is about 30 feet.

Included with this soil in mapping are small areas of Newson, Cloquet, and Cromwell soils. The Newson soils are in depressions, which are indicated on the soil map by a spot symbol if they are 1 acre to 3 acres in size. The Cloquet and Cromwell soils are in a random pattern. Also included are a few areas of nearly level and hilly soils.

Most areas of this soil are used for aspen, birch, red pine, and jack pine. A few areas are cleared and used for forage and small grain, but production potential is poor because the available water capacity is low. The hazard of erosion is moderate where the plant cover has been removed. Capability unit VIs–1; woodland group 2s1.

188E—**Omega loamy sand, 12 to 25 percent slopes.** This hilly soil is on the outwash plain. It is in irregularly shaped areas that are 10 to 50 acres in size, and it is adjacent to Omega soils that have slopes of less than 12 percent. The relief is about 80 feet.

Included with this soil in mapping are small areas of Cloquet, Emmert, and Cromwell soils. The Cromwell soils are on foot slopes, and the Cloquet and Emmert soils are in a random pattern.

Most areas of this soil are used for aspen, birch, red pine, and jack pine. A few cleared areas are used for pasture. Because of the slope, there is a severe hazard of erosion if the vegetative cover has been removed.

This soil is very droughty because available water capacity is low. Capability unit VIIs-1; woodland group 2s1.

Ontonagon series

The Ontonagon series consists of nearly level to hilly, well drained and moderately well drained soils that formed in clayey material. These soils are on lake plains.

In a representative profile the surface layer is very dark gray silty clay about 3 inches thick. The subsurface layer is pinkish gray silty clay about 3 inches thick. It tongues into the subsoil to a depth of about 12 inches. The subsoil is reddish brown, very firm clay about 18 inches thick. The underlying material is reddish brown calcareous clay.

Permeability is very slow, and the available water capacity is moderate. Organic matter content is low. The availability of phosphorus is low and of potassium is high.

Most areas of Ontonagon soils are used for forest. Some areas are used for pasture. The major limitations are the clayey texture and the hazard of erosion on the sloping soils.

Representative profile of Ontonagon silty clay, 0 to 2 percent slopes, in pasture on a lake plain, about 400 feet east and 100 feet south of the northwest corner of sec. 1, T. 47 N., R. 16 W.:

A1—0 to 3 inches; very dark gray (10YR 3/1) silty clay; weak fine subangular blocky structure; hard, friable, slightly plastic; many roots; few charcoal fragments, few gray (10YR 5/1) peds of silty clay; slightly acid; abrupt wavy boundary.

A&B—3 to 6 inches; about 75 percent tongues of pinkish gray (5YR 6/2) silty clay and 25 percent reddish brown (2.5YR 4/4) clay; few fine distinct yellowish red mottles; weak fine and medium platy structure; hard, friable; strongly acid; abrupt irregular boundary.

B21t—6 to 13 inches; reddish brown (2.5YR 4/4) clay; weak medium prismatic structure parting to strong very fine and fine subangular blocky; extremely hard, very firm, very plastic; few vertical tongues of silty clay extend to a depth of 10 to 12 inches, ⅛ to ½ inch wide at top, becoming more narrow as depth increases; few thin clay films on faces of peds; medium acid; gradual wavy boundary.

B22t—13 to 24 inches; reddish brown (2.5YR 4/4) clay; weak medium and coarse prismatic structure parting to strong fine angular and subangular blocky; extremely hard, very firm, very plastic; many thin clay films on faces of peds; few slickensides; neutral; abrupt irregular boundary.

C1ca—24 to 32 inches; reddish brown (2.5YR 4/4) clay; strong fine angular and subangular blocky structure; extremely hard, very firm, very plastic; common threads and hard concretions of lime; many slickensides; moderately alkaline; strongly effervescent; gradual smooth boundary.

C2—32 to 60 inches; reddish brown (2.5YR 4/4) clay; strong coarse angular blocky structure; extremely hard, very firm, very plastic; few threads and concretions of lime; many slickensides; strongly effervescent; moderately alkaline.

The thickness of the solum and the depth to carbonates generally are 15 to 24 inches but range from 12 to 30 inches in a few places. The upper 6 inches varies in texture within short distances, ranging from silt loam to clay. The soils that have a surface layer of clay have the least prominent A2 horizon. The A1 horizon ranges from black to very dark gray. It is 1 inch to 3 inches thick. The A horizon ranges from strongly acid to slightly acid. The B2 horizon is about 60 to 90 percent clay. The B horizon ranges from medium acid in the upper part to moderately alkaline in the lower part. Slickensides are in the B horizon, but they are more common in the C horizon. The C horizon is about 10 to 20 percent free carbonates.

Ontonagon soils are associated on the landscape with Bergland soils, and they formed in the same kind of parent material. They have a thinner A horizon than Bergland soils. They do not have mottles or have fewer mottles in the B horizon than the wetter Bergland soils.

303—Ontonagon silty clay, 0 to 2 percent slopes. This nearly level soil is on the lake plain in the east-central part of the county. Areas are irregular in shape, and they range from 20 to more than 100 acres in size. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Bergland soils in drainageways and depressions. The depressions that are 1 acre to 3 acres in size are indicated on the soil map by a spot symbol. Also included are ½- to 5-acre areas of soils that are similar to this Ontonagon soil but that do not have a pinkish gray subsurface layer.

Most areas of this soil are used for aspen and birch. A few areas have been cleared and are used for forage and small grain. The choice of crops is limited because the clayey subsoil is very slowly permeable and has a limited rooting zone. Capability unit IIIs-1; woodland group 4c1.

303C—Ontonagon silty clay, 2 to 12 percent slopes. This undulating soil is in long, narrow areas that are 10 to 50 acres in size and that are adjacent to drainageways. Most slopes are 50 to 300 feet long. Maximum relief is about 20 feet.

Included with this soil in mapping are areas of wet alluvial soils at the bottom of drainageways. Also included are areas of nearly level and hilly Ontonagon soils.

Most areas of this soil are used for aspen and birch. A few cleared areas are used chiefly for forage. Runoff is medium to rapid, and the hazard of erosion is moderate if the vegetation has been removed. Capability unit IVe–1; woodland group 4c1.

303E—Ontonagon silty clay, 12 to 25 percent slopes. This hilly soil is in long, narrow areas that are 10 to

50 acres in size and that are adjacent to drainageways. Slopes are 100 to 300 feet long. Maximum relief is about 100 feet. This soil has a profile similar to the one described as representative of the series, but it is thinner and is calcareous at a depth of 12 to 18 inches in many of the areas that have convex slopes.

Included with this soil in mapping are areas of wet alluvial soils at the bottom of drainageways. Also included are small areas of hilly Campia soils.

Most areas of this soil are used for aspen and birch. A few cleared areas are used chiefly for grasses and legumes. Because surface runoff is very rapid, the hazard of erosion is severe if the plant cover has been removed. Capability unit VIe–1; woodland group 4c1.

Parent series

The Parent series consists of nearly level, very poorly drained and poorly drained soils that formed in fine sandy loam. These soils are in depressions on moraines and drumlins.

In a representative profile the surface layer is black silty clay loam and very dark gray loam about 12 inches thick. The upper 6 inches of the subsoil is mottled yellowish brown fine sandy loam, and the lower 35 inches is reddish brown fine sandy loam. The underlying material is reddish brown fine sandy loam.

Permeability is moderately slow, and the available water capacity is moderate. Organic matter content is high. The availability of phosphorus is high and of potassium is low. These soils have a high water table during most of the growing season.

Most areas of Parent soils are used for pasture, forest, and wildlife habitat. The major limitation is wetness.

Parent soils in Carlton County are mapped only with Twig soils.

Representative profile of Parent silty clay loam, in an area of Twig and Parent soils, under lowland brush on a nearly level moraine, 1,056 feet south and 65 feet east of the northwest corner of sec. 32, T. 47 N., R. 20 W.:

A1—0 to 6 inches; black (10YR 2/1) light silty clay loam; strong fine and medium granular structure parting to moderate fine and very fine subangular blocky; friable; many very fine and fine random roots; few charcoal fragments; less than 1 percent coarse fragments; slightly acid; clear wavy boundary.

A3—6 to 12 inches; very dark gray (10YR 3/1) loam; common medium distinct very dark grayish brown (10YR 3/2) mottles; weak thick platy structure parting to very fine subangular blocky; friable; about 1 percent coarse fragments; few wormcasts and wormholes; few very fine vertical roots; less than 1 percent coarse fragments; slightly acid; clear irregular boundary.

B21—12 to 18 inches; yellowish brown (10YR 5/4) fine sandy loam; common fine distinct olive brown mottles; weak fine and medium subangular blocky structure; very friable; few very fine vertical roots; less than 1 percent coarse fragments; neutral; abrupt irregular boundary.

IIB22—18 to 37 inches; reddish brown (5YR 4/3) fine sandy loam; common medium distinct strong brown (7.5YR 5/6) mottles; moderate thin platy structure; friable; moderately thick very dark gray clay films along root channels; few thin reddish brown clay films on upper faces of plates; very few very fine vertical roots; about 5 percent coarse fragments; neutral; gradual smooth boundary.

IIB3—37 to 53 inches; reddish brown (5YR 4/3) fine sandy loam; common medium distinct strong brown (7.5YR 5/6) mottles; moderate thin platy structure; friable; thin very dark gray clay films along root channels; very few thin reddish brown clay films on upper faces of plates; very few very fine vertical roots; about 10 percent coarse fragments; mildly alkaline; gradual smooth boundary.

IIC—53 to 60 inches; reddish brown (5YR 4/3) fine sandy loam; moderate thin platy structure; friable; about 10 percent coarse fragments; moderately alkaline.

The solum typically is 40 to 55 inches thick, but it ranges from 30 to 60 inches in thickness. The solum is very strongly acid to slightly acid in the upper part and slightly acid to mildly alkaline in the lower part. An O horizon as much as 4 inches thick is in some places. The A horizon typically ranges from about 4 to 16 inches in thickness; the average thickness, however, is 10 inches or more in pedons of maximum size. The A horizon ranges from silt loam, loam, or fine sandy loam to light silty clay loam. The lower part is mottled. The upper part of the B horizon ranges from yellowish brown or dark yellowish brown to dark gray or gray. It is mottled and ranges from loam to fine sandy loam. The lower part of the B horizon ranges from dark reddish gray or reddish gray to reddish brown. It is commonly mottled and ranges from sandy loam to fine sandy loam. Clay films range from very few to few and are on the upper faces of the plates and in root channels. The C horizon ranges from sandy loam to fine sandy loam.

Parent soils in Carlton County typically do not have the grayish color in the upper part of the B horizon that is defined in the range for the series, but this difference does not alter use and behavior.

Parent soils are associated on the landscape with Twig soils, and they formed in the same kind of parent material. They do not have the muck or peat surface layer more than 4 inches thick that Twig soils have.

Spooner series

The Spooner series consists of nearly level, poorly drained and somewhat poorly drained soils that formed in silty lacustrine material on glacial lake plains.

In a representative profile the surface layer is black silt loam about 7 inches thick. The subsurface layer is grayish brown silt loam about 3 inches thick. The upper 10 inches of the subsoil is dark grayish brown and olive gray, friable and firm light silty clay loam, and

the lower 10 inches is pale brown and light grayish brown, very friable silt loam. The underlying material is light gray and yellowish brown calcareous silt loam.

Permeability is moderate, and the available water capacity is high. Organic matter content is medium. The availability of potassium is moderate. These soils have a seasonal high water table.

Most areas of Spooner soils are used for crops, pasture, and forest. The major limitation is wetness.

Representative profile of Spooner silt loam, in a nearly level hayfield 50 feet east and 1,320 feet south of the northwest corner of sec. 5, T. 47 N., R. 16 W.:

Ap—0 to 7 inches; black (10YR 2/1) silt loam, gray (10YR 5/1) dry; moderate fine subangular blocky structure parting to weak very fine and fine granular; friable, slightly sticky and slightly plastic; many fine and very fine random roots; most older roots have brown and yellowish red coatings; few wormcasts; slightly acid; abrupt smooth boundary.

A2g—7 to 10 inches; grayish brown (2.5Y 5/2) silt loam; common fine prominent strong brown mottles; weak thin platy structure; very friable, slightly sticky and slightly plastic; few very fine random roots; common fine and very fine discontinuous tubular vertical pores; slightly acid; clear smooth boundary.

B21tg—10 to 16 inches; dark grayish brown (10YR 4/2) light silty clay loam; common fine prominent strong brown mottles; weak medium prismatic structure parting to strong medium subangular blocky; firm, sticky and plastic; few very fine random roots; common thin clay films on faces of peds; slightly acid; gradual smooth boundary.

B22tg—16 to 20 inches; olive gray (5Y 5/2) light silty clay loam; few fine prominent yellowish brown mottles; moderate very fine subangular blocky structure; friable, slightly sticky and slightly plastic; few very fine random roots; few thin clay films on faces of peds; neutral; abrupt wavy boundary.

IIB31—20 to 23 inches; pale brown (10YR 6/3) loamy very fine sand; single grained; loose; few very fine random roots; neutral; abrupt wavy boundary.

IIIB32—23 to 30 inches; variegated light brownish gray (10YR 6/2) and pale brown (10YR 6/3) silt loam; massive parting to moderate fine and medium platy structure; very friable; few very fine and fine roots; few very fine discontinuous vertical tubular pores; mildly alkaline; very slightly effervescent in the lower part; clear smooth boundary.

IIIC—30 to 60 inches; variegated light gray (10YR 7/1) and yellowish brown (10YR 5/4) silt loam; few medium faint yellowish brown (10YR 5/6) mottles; massive parting to moderate medium platy structure; friable; few very fine and fine discontinuous vertical tubular pores; few thin strata of pinkish gray (5YR 6/2) very fine sandy loam; strongly effervescent; seams of soft carbonates; mildly alkaline.

The solum ranges from 22 to 40 inches in thickness. Depth to carbonates ranges from 25 to 60 inches. The Ap horizon ranges from black or very dark gray to very dark brown. It is strongly acid to neutral. The B2 horizon ranges from dark grayish brown or grayish brown to olive gray. It typically is heavy silt loam or silty clay loam, and it is 18 to 35 percent clay and 50 to 75 percent silt. The B2 horizon is slightly acid to neutral. Clay films range from very few to few and from thin to moderately thick. The C horizon is chiefly silt loam, but thin strata of very fine sand to silty clay are common. The C horizon ranges from mildly alkaline to moderately alkaline.

Spooner soils are associated on the landscape with Campia soils, and they formed in similar parent material. They have a grayer colored B horizon and are wetter than Campia soils.

147—Spooner silt loam (0 to 2 percent slopes). This soil is on the broad flats of a lake plain. Areas are 40 to 400 acres in size and are irregularly shaped.

Included with this soil in mapping are areas of soils that are chiefly very fine sand to very fine sandy loam throughout and areas of soils that have a reddish brown subsoil and underlying material. Also included are a few circular areas of very poorly drained soils in depressions. These areas range from 1 acre to 3 acres in size and are indicated on the soil map by a spot symbol.

Most areas of this soil are used chiefly for small grain and forage crops. Drainage helps to increase yields on this soil. Capability unit IIIw–1; woodland group 2wl.

Twig series

The Twig series consists of nearly level, very poorly drained soils that formed in organic material, loamy sediment, and fine sandy loam glacial till. These soils are in depressions on moraines and drumlins.

In a representative profile (fig. 12) the surface layer is black and reddish brown muck about 12 inches thick. Below this is a black mucky silt loam layer about 6 inches thick that is underlain by a very firm and very dense, black silt loam layer about 2 inches thick. The subsurface layer is dark gray loam about 6 inches thick. It also is very firm and very dense. The upper 10 inches of the subsoil is gray fine sandy loam, and the lower 12 inches is reddish brown fine sandy loam. The underlying material is dark reddish brown fine sandy loam.

Permeability is very slow, and the available water capacity is moderate to high. Organic matter content is very high. The availability of phosphorous is high and of potassium is low. These soils have a high water table during most of the growing season and have a dense layer that also restricts root development and permeability.

Most areas of Twig soils are used for pasture, forest, and wildlife habitat. The major limitation is wetness.

Representative profile of Twig muck in an area of Twig and Parent soils, in a pasture of reed canarygrass

Figure 12.—**Profile of a Twig soil.**

1,188 feet north and 40 feet east of the southwest corner of sec. 19, T. 47 N., R. 20 W.:

Oa1—0 to 3 inches; black (10YR 2/1), broken face and rubbed, sapric material; trace of fiber; moderate fine and very fine granular structure; slightly sticky; many roots; about 20 percent mineral material; extremely acid; gradual wavy boundary.

Oa2—3 to 8 inches; dark reddish brown (5YR 2/2), broken face and rubbed, sapric material; about 40 percent fiber, about 10 percent rubbed; weak coarse platy structure; very friable, nonsticky; many roots; about 10 percent mineral material; herbaceous fiber; extremely acid; gradual smooth boundary.

Oe—8 to 12 inches; reddish brown (5YR 4/4), broken face, hemic material, dark reddish brown (5YR 3/4) rubbed; about 80 percent fiber, about 35 percent rubbed; weak coarse structure; very friable, nonsticky; many roots; about 30 percent mineral material; herbaceous fiber; extremely acid; clear smooth boundary.

A11—12 to 18 inches; black (10YR 2/1) mucky silt loam; massive parting to weak very fine and fine granular structure; friable, sticky; many charcoal fragments; about 10 percent woody fragments, 5 to 10 centimeters in diameter and 20 to 70 centimeters in length; extremely acid; clear smooth boundary.

A12—18 to 20 inches; black (10YR 2/1) silt loam; massive; very firm, very hard, very dense; very few very fine and fine vertical pores; thin pebble band in upper part; very strongly acid; abrupt wavy boundary.

A2g—20 to 26 inches; dark gray (10YR 4/1) loam; many medium prominent olive brown (2.5Y 4/4) and yellowish red (5YR 5/6) mottles; massive; very firm, very hard, very dense; very few very fine and fine vertical pores; about 5 percent coarse fragments; extremely acid; clear wavy boundary.

IIB2g—26 to 36 inches; gray (10YR 5/1) fine sandy loam; many fine distinct reddish gray mottles and common fine prominent yellowish red mottles; moderate thin platy structure; friable; few thin clay films on upper faces of peds; common moderately thick gray clay films in vertical root channels; few root channels surrounded by dark reddish brown; about 5 percent coarse fragments; extremely acid; gradual wavy boundary.

IIB3—36 to 48 inches; reddish brown (5YR 4/3) fine sandy loam; few fine faint yellowish red mottles; moderate thin platy structure; friable; few moderately thick gray clay films along root channels; about 10 percent coarse fragments; extremely acid; gradual smooth boundary.

IIC—48 to 72 inches; dark reddish brown (5YR 4/3) fine sandy loam; weak thin platy structure; friable; few moderately thick gray clay films in root channels in upper part; about 10 percent coarse fragments; extremely acid.

The solum ranges from 30 to 50 inches in thickness. The O horizon ranges from 6 to 15 inches in thickness. The upper part of the mineral sediment overlying the glacial till ranges from 0 to 20 inches in thickness. The O horizon is either sapric material or hemic material, or a combination of both. These materials range from black to reddish brown or brown and are extremely acid or very strongly acid. The fiber is mostly of herbaceous origin. The A1 horizon ranges from black to very dark gray. This horizon is mottled in some places. The A2 horizon ranges from dark gray to gray. It has distinct or prominent mottles and it is massive and firm or very firm. Bulk density ranges from 1.8 to 2.0 grams per cubic centimeter. The A horizon ranges from fine sandy loam or loam to silt loam. It is extremely acid or very strongly acid. The upper part of the B horizon ranges from dark grayish brown or grayish brown to reddish gray. It commonly has distinct or prominent mottles. The lower part of the B horizon ranges from dark reddish brown to reddish brown. It commonly has mottles. The B horizon typically is fine sandy loam or sandy loam, but it ranges to loam. It ranges from extremely acid to very strongly acid. The C horizon typically is sandy loam or fine sandy loam, but it ranges to light loam. It is extremely acid to medium acid.

Twig soils are associated on the landscape with Parent soils, and they formed in the same kind of parent material. They are wetter than Parent soils. They have an O horizon that is 6 to 15 inches thick, and such a horizon is thinner or is absent in Parent soils.

990—Twig and Parent soils (0 to 1 percent slopes). These soils are in drainageways and depressions. Surface runoff is very slow. Most areas are circular or elongated and range from about 3 to 20 acres in size. In most places these soils are surrounded by Ahmeek and Automba soils. Some areas of this unit are predominantly Twig muck, some are predominantly Parent silty clay loam, and others are about equal parts of Twig and Parent soils. Commonly, the Twig soils are in the center or in the slightly lower part of the mapped areas.

Included with these soils in mapping are areas of Mora and Beseman soils. The Mora soils are on rims or islands, and the Beseman soils are in low lying areas that are typically near the center of the mapped areas.

Very few areas of these soils are drained and used for cultivated crops. Most areas are in sedges, grasses, and lowland hardwoods. The water table is too near the surface during most of the growing season for the commonly grown crops. Capability unit IVw–1; woodland group 4w2.

Udorthents

1020—Udorthents (25 to 60 percent slopes). These very steep soils are in the basin formerly occupied by Glacial Lake Duluth in the eastern part of Carlton County and are adjacent to Ontonagon soils on the top of ridges. Clayey soils are in the interior of the lake basin, and loamy soils are on the outer edges. The areas are along deeply entrenched streams that have cut into the stratified, calcareous, reddish brown clayey lake sediment and reddish brown loamy till. Relief from the top of the ridges to the bottom of the streams is commonly 75 to 200 feet. The steep slopes restrict soil formation to the upper 10 to 12 inches of the clayey and loamy material. Typically, the surface layer and subsoil are thin and are neutral in reaction.

Included with these soils in mapping are areas of very steep soils that formed in calcareous, grayish silty material or in noncalcareous, reddish brown sandy material. Also included in many places between foot slopes and streams are long, narrow areas of nearly level alluvial soils that commonly have a thin, black, clayey surface layer and a reddish brown, clayey subsoil. In places these alluvial soils contain buried, thin layers of coarser textured material and thin layers of dark material that is high in content of organic matter.

Most areas of these soils are in aspen, birch, and balsam fir. The surface layer is bare in 1- to 2-acre areas where the streams undercut the valley walls. There is considerable sliding and creeping downslope, even on tree-covered areas. The chief concern of management is erosion. Capability unit VIIe–2; woodland group 5c1.

Warman series

The Warman series consists of nearly level, very poorly drained soils that formed in loamy material overlying gravelly and sandy material. These soils are in depressions and drainageways on outwash plains and and river terraces.

In a representative profile the surface layer is black mucky loam about 8 inches thick. The upper 8 inches of the subsoil is dark gray, mottled loam, and the lower 4 inches is grayish brown, mottled silt loam. The underlying material is reddish brown gravelly coarse sand.

Permeability is moderate in the loamy material and very rapid in the gravelly material. The available water capacity is low to moderate. Organic matter content is high. The availability of phosphorus is moderate and of potassium is low.

Most areas of Warman soils are used for forest and pasture. The major limitation is wetness.

Representative profile of Warman mucky loam, on an outwash plain under a forest dominated by black ash, 2,800 feet east and 1,000 feet south of the northwest corner of sec. 16, T. 48 N., R. 17 W.:

A11—0 to 4 inches; black (10YR 2/1) mucky loam; moderate fine granular structure; very friable; many roots; common woody fragments; strongly acid; abrupt wavy boundary.

A12—4 to 8 inches; black (10YR 2/1) mucky loam; moderate fine granular structure; very friable; common pebbles in upper part; many roots; strongly acid; clear wavy boundary.

B1g—8 to 16 inches; dark gray (10YR 4/1) loam; few fine distinct yellowish brown mottles and few fine prominent yellowish red mottles; massive; firm; few roots; very few tubular pores; slightly acid; clear wavy boundary.

B2g—16 to 20 inches; grayish brown (10YR 5/2) silt loam; many fine distinct yellowish brown mottles, many fine prominent gray mottles, and few fine prominent yellowish red mottles; weak thin platy structure; very friable; common vesicular pores; few roots; neutral; abrupt smooth boundary.

IIC—20 to 60 inches; reddish brown (5YR 4/4) gravelly coarse sand; single grained; loose; about 50 percent gravel, mostly 2 to 30 millimeters in size; neutral.

The thickness of the solum and depth to the IIC horizon ranges from 18 to 40 inches. The depth to free carbonates is more than 70 inches. In the solum, the content of clay is 6 to 18 percent and the content of fine and coarser sand is 15 to 50 percent. In some places there is an O horizon as much as 8 inches thick. The A horizon ranges from black to very dark gray. It ranges from 4 to 12 inches in thickness and it typically is mottled. The A horizon typically is loam or silt loam, but it ranges to very fine sandy loam or fine sandy loam. It is very strongly acid to medium acid. The upper 8 inches of the profile is 12 percent or more organic matter. The upper part of the B horizon ranges from dark gray or grayish brown to dark grayish brown. The lower part ranges from reddish gray to grayish brown. The B horizon is distinctly or prominently mottled. It typically is loam or silt loam, but it ranges to fine sandy loam or very fine sandy loam. The B horizon ranges from strongly acid to slightly acid in the upper part and medium acid to neutral in the lower part. The IIC horizon typically is gravelly coarse sand, but it ranges to stratified gravel and sand. It is slightly acid to neutral.

Warman fine sandy loam is less wet, has less organic matter in the A horizon, and has brighter colors in the B horizon than the range defined for the series. Because of these differences, forage and trees are better suited to this soil than to Warman soils elsewhere.

Warman soils are associated on the landscape with Cloquet soils, and they formed in similar parent material. They are wetter and have a grayer B horizon than Cloquet soils.

V337—Warman fine sandy loam (0 to 2 percent slopes). This nearly level, somewhat poorly drained soil is on outwash plains. Areas are irregularly shaped and 3 to 10 acres in size. This soil is adjacent to Cloquet and Emmert soils. It formed in parent material similar to that in which Warman mucky loam formed, but it is not so wet, the surface layer is thinner, the subsoil is browner, and the content of organic matter, which is moderate, is lower.

Included with this soil in mapping are small areas of Warman mucky loam and Cloquet soils. Also included are areas of soils that have a loam subsoil that is about 25 percent clay and areas of soils that have a subsoil that contains more sand than this Warman soil.

Most areas of this soil are used for trees. A few cleared and drained areas are used for forage and small grain. The high water table restricts the choice of crops. Capability unit IIw–1; woodland group 2w1.

337—Warman mucky loam (0 to 1 percent slopes). This soil is in drainageways and depressions on outwash plains and river terraces. It is adjacent to Cloquet and Emmert soils in most places. It has the profile described as representative of the series.

Included with this soil in mapping are small areas of Warman fine sandy loam on rims around depressions or in slightly higher areas and areas of soils that have 8 to 12 inches of muck on the surface. Also included in some areas are soils that have a clay loam subsoil.

Most areas of this soil are used for lowland hardwoods, brush, and swamp grasses. Because the water table is high, the choice of crops is restricted. Capability unit IVw–1; woodland group 4w2.

Waskish series

The Waskish series consists of nearly level, very poorly drained soils that formed in organic material. These soils are on raised bogs.

In a representative profile the surface layer is reddish brown peat about 2 inches thick. Below this is a reddish brown mucky peat about 2 inches thick. The underlying material is extremely acid, reddish brown peat to a depth of 64 inches. Below this is reddish brown mucky peat.

Permeability is rapid, and the available water capacity is very high. Organic matter content is very high. The availability of phosphorus and potassium is low. These soils have a high water table during most of the growing season.

Most areas of Waskish soils are used for forest. The major limitation is wetness.

Representative profile of Waskish peat, on the crest of a raised bog under a dense stand of black spruce, 400 feet north and 50 feet west of center of sec. 25, T. 48 N., R. 20 W.:

Oi1—0 to 2 inches; brown (5YR 5/3), broken face, fibric material, light reddish brown (5YR 6/3) rubbed, and white (5YR 8/1) pressed; about 95 percent fiber, 90 percent rubbed; massive; nonsticky; fibers mainly sphagnum moss; extremely acid; clear wavy boundary.

Oe—2 to 4 inches; dark reddish brown (5YR 2/2), broken face, rubbed, and pressed, hemic material; about 60 percent fiber, about 35 percent rubbed; massive; nonsticky; fibers mainly sphagnum moss; extremely acid; clear wavy boundary.

Oi2—4 to 42 inches; reddish brown (5YR 4/3), broken face, fibric material, light reddish brown (5YR 6/4) pressed and rubbed; about 95 percent fiber, about 90 percent rubbed; massive; nonsticky; fibers mainly sphagnum moss; extremely acid; gradual smooth boundary.

Oi3—42 to 64 inches; reddish brown (5YR 5/4), broken face, fibric material, light reddish brown (5YR 6/4) pressed and rubbed; about 95 percent fiber, about 90 percent rubbed; massive; nonsticky; fibers mainly sphagnum moss; extremely acid; clear smooth boundary.

Oi4—64 to 66 inches; reddish brown (5YR 4/4), broken face, rubbed, and pressed, fibric material; about 80 percent fiber, 60 percent rubbed; massive; nonsticky; fibers mainly herbaceous, about 10 percent sphagnum moss; extremely acid.

Organic soil material extends to a depth of more than 63 inches and commonly to a depth ranging from 10 to 20 feet. Content of woody fragments ranges from 0 to 20 percent in the upper 63 inches, and most fragments are in the upper few inches. Fibric material is dominant in all parts of the upper 63 inches, and this material extends to a depth of as much as 8 feet in some places. The sapric material mainly is only in the upper part, and the maximum aggregate thickness of this material is less than 5 inches. Hemic material mainly is only in the lower part, and its maximum aggregate thickness is less than 10 inches. The fibric material ranges from dark reddish brown to light reddish brown or from dark brown to pale brown. The content of fiber typically is more than 90 percent, but is as little as 75 percent in a few places. The content of fiber after rubbing ranges from 60 to 95 percent. The fiber is mostly to entirely derived from sphagnum mosses. Content of fiber derived from herbaceous and woody plants is less than 10 percent of the fiber volume. Content of mineral matter in the fibric material typically ranges from 2 to 5 percent.

Waskish soils are associated on the landscape with Lobo soils, and they formed in similar parent material. They have a thicker layer of fibric material than Lobo soils.

538—Waskish peat (0 to 1 percent slopes). This extremely acid soil is commonly at the highest elevation within bogs. Most areas are circular or elongated and range from 300 to 400 acres in size. Most areas are near the center of the bogs, but some are near the edge. The sphagnum material commonly ranges from 5 to 6

feet in thickness, but in a few places it is slightly thicker.

Included with this soil in mapping are areas of Lobo and Greenwood soils, commonly at the edge of mapped areas.

Some areas of this soil are used for the production of horticultural peat, and other areas are woodland. The soil is too wet and too low in fertility for most crops. Capability unit VIIw–1; woodland group 4w1.

Use and management of the soils

This section describes the management and predicted yields of the crops commonly grown in Carlton County. The capability classification used by the Soil Conservation Service is explained, and the soils are grouped according to their suitability for hay and pasture, woodland, wildlife habitat, recreation, and community development. Use of soils for recreation and engineering is discussed, and use of soil information in town and country planning is briefly explained.

Crops, hay, and pasture

About 10 percent of Carlton County is used for hay and pasture. Less than 1 percent of the county is used for corn and small grain. A small acreage is used for potatoes, cabbage, sweet corn, strawberries, and other fruits and vegetables; several thousand acres is suitable for the production of these and other special crops. The kinds of crops suited to Carlton County are limited because the summer is short, cool, and humid.

The main considerations in managing soils for cultivated crops, hay, and pasture are maintaining fertility and controlling erosion, but drainage and removal of stones are also needed. Other considerations are fertility requirements of the specific plants, suitability of plants to soils and climatic conditions, and weed and brush control. Generally the management of soil and crops involves a combination of several practices.

Capability grouping

Capability grouping shows, in a general way, the suitability of soils for most kinds of field crops. The groups are made according to the limitations of the soils when used for field crops, the risk of damage when they are used, and the way they respond to treatment. The grouping does not take into account major and generally expensive landforming that would change slope, depth, or other characteristics of the soils; does not take into consideration possible but unlikely major reclamation projects; and does not apply to 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, all kinds of soils are grouped at three levels: the capability class, subclass, and unit. These are discussed in the following paragraphs.

CAPABILITY CLASSES, the broadest groups, are designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use.

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.

CAPABILITY UNITS are soil groups within the subclasses. The soils in one capability unit are enough alike to be suited to the same crops and pasture plants, to require similar management, and to have similar productivity and other responses to management. Thus, the capability unit is a convenient grouping for making many statements about management of soils. Capability units are generally designated by adding an Arabic numeral to the subclass symbol, for example, IIe–4 or IIIe–6. 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.

In the following pages the capability classes, subclasses, and units in Carlton County are described.

Class I. Soils that have few limitations that restrict their use (none in Carlton County).

Class II. Soils that have some limitations that reduce the choice of plants or that require moderate conservation practices.

- Subclass IIc. Soils that are limited by the cool climate or short growing season.
  - Unit IIc–1. Deep, nearly level, well drained and moderately well drained soils that have a loamy surface layer; on uplands.
- Subclass IIw. Soils that are moderately limited by wetness.
  - Unit IIw–1. Deep, nearly level, somewhat poorly drained soils that have a loamy surface layer.

Class III. Soils that have severe limitations that reduce the choice of plants, require special conservation practices, or both.

- Subclass IIIe. Soils that are subject to a moderate or severe hazard of erosion if they are not protected.
  - Unit IIIe–1. Deep, undulating, well drained and moderately well drained soils that have a loamy surface layer; on uplands.
  - Unit IIIe–2. Deep, gently undulating, somewhat excessively drained soils that have a

loamy surface layer and subsoil and sandy underlying material.

Subclass IIIs. Soils that are severely limited by droughtiness or other unfavorable conditions within the root zone.

Unit IIIs–1. Deep, nearly level, somewhat excessively drained soils that have a loamy surface layer and subsoil and sandy or gravelly sand underlying material.

Unit IIIs–2. Deep, nearly level, well drained and moderately well drained clayey soils; on uplands.

Subclass IIIw. Soils that are severely limited by wetness.

Unit IIIw–1. Deep, nearly level, somewhat poorly drained and poorly drained soils that have a loamy or clayey surface layer.

Unit IIIw–2. Deep, nearly level, somewhat poorly drained soils that have a sandy surface layer and subsoil and sandy or clayey underlying material.

Class IV. Soils that have very severe limitations that reduce the choice of plants, require very careful management, or both.

Subclass IVe. Soils that are subject to very severe hazard of erosion if they are not protected.

Unit IVe–1. Deep, undulating soils that have a clayey surface layer; on uplands.

Unit IVe–2. Deep, undulating soils that have gravelly sand underlying material.

Subclass IVs. Soils that are very severely limited by droughtiness.

Unit IVs–1. Deep, nearly level and undulating soils that have gravelly sand or sandy underlying material.

Subclass IVw. Soils that are very severely limited by wetness.

Unit IVw–1. Deep, nearly level, very poorly drained mineral soils; in depressions.

Unit IVw–2. Deep, nearly level, poorly drained and very poorly drained organic soils; on lowlands.

Class V. Soils that are not likely to erode but have other limitations, impractical to remove, that limit their use largely to pasture, woodland, or wildlife habitat (none in Carlton County).

Class VI. Soils that have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture, woodland, or wildlife habitat.

Subclass VIe. Soils that are subject to a very severe hazard of erosion if they are not protected.

Unit VIe–1. Deep, hilly soils that have a loamy or clayey surface layer; on uplands.

Subclass VIs. Soils that are very severely limited by droughtiness.

Unit VIs–1. Deep, undulating soils that have a sandy surface layer.

Subclass VIw. Soils that are very severely limited by wetness and flooding.

Unit VIw–1. Deep, nearly level, wet soils that are subject to flooding.

Class VII. Soils that have very severe limitations that make them unsuited to cultivation and restrict their use largely to pasture, woodland, or wildlife habitat.

Subclass VIIe. Soils that are subject to a very severe hazard of erosion if they are not protected.

Unit VIIe–1. Deep, hilly soils that have gravelly underlying material.

Unit VIIe–2. Deep, steep soils that have a loamy or clayey surface layer; on uplands.

Subclass VIIs. Soils that are very severely limited by droughtiness.

Unit VIIs–1. Deep, hilly and steep soils that have gravelly and sandy underlying material.

Unit VIIs–2. Very shallow organic material overlying bedrock.

Subclass VIIw. Soils that are very severely limited by wetness.

Unit VIIw–1. Deep, extremely acid organic soils.

Unit VIIw–2. Very shallow organic material overlying bedrock.

Class VIII. Soils and landforms that have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife habitat, water supply, or esthetic purposes (none in Carlton County).

Hay and pasture groups of soils

The soils in Carlton County have been placed in eight hay and pasture groups. The soils in the county and the hay and pasture groups in which they have been placed are listed in the Guide to Mapping Units at the back of this survey. Predicted yields for pasture and hayland are given in table 2.

Hay and pasture group 1

This group consists of nearly level to undulating, well drained and moderately well drained soils that have a loamy to clayey surface layer and subsoil. Available water capacity is low to high. These soils are neither too wet nor too dry for hay and pasture, but the surface layer and subsurface layer are very strongly acid to medium acid. The subsoil retards the downward movement of water through the soil, and permeability ranges from very slow to moderate. The soils are generally dry enough to allow grazing until late in May or early in June without appreciable damage to the turf. The soils in this group have few limitations for forage.

Many grasses and legumes are well suited to these soils. Some of the suited grasses and legumes are bromegrass, alfalfa, birdsfoot trefoil, reed canarygrass, timothy, Kentucky bluegrass, and red clover and white clover.

The management for forage includes properly liming and fertilizing for the specific plants grown, grazing at the proper time based on forage species, and using proper stocking rates.

Hay and pasture group 2

This group consists of hilly, well drained and moderately well drained soils that have a loamy to clayey surface layer and subsoil. Available water capacity is mainly moderate to high. The surface layer and subsoil generally are very strongly acid to medium acid. Slopes are 12 to 25 percent. In places the soils are too steep for machinery, and these soils are better suited to permanent pasture and hay than to other uses. These soils also have more rapid runoff and a more severe hazard of erosion than less sloping soils.

Many grasses and legumes are well suited to these soils. Some of the suited species are birdsfoot trefoil, bromegrass, reed canarygrass, timothy, orchardgrass, Kentucky bluegrass, red clover and white clover, and alfalfa. Kentucky bluegrass and white clover are well suited to permanent pasture.

These species establish naturally if shrub growth is controlled. They provide excellent forage in spring and fall, but growth slows down appreciably in July and August.

Hay and pasture group 3

This group consists of nearly level, somewhat poorly drained and poorly drained soils that have mainly a loamy surface layer and subsoil. Some soils, however, are sandy throughout, or they are loamy and are underlain by gravelly sand. Unless the soil has been limed, the surface layer and subsurface layer are very strongly acid to slightly acid. A high water table is present for significant periods during the growing season and limits the use of these soils for forage.

Undrained areas of these soils are commonly too wet to grow and manage high quality hay. These soils are suitable for grasses and legumes such as reed canarygrass, Garrison creeping foxtail, redtop, and birdsfoot trefoil.

The soils in this group need adequate surface and subsurface drainage. Some of the hay and pasture species that are well suited to these soils are alfalfa, bromegrass, birdsfoot trefoil, timothy, orchardgrass, bluegrass, red clover and white clover, ladino, and alsike.

Hay and pasture group 4

This group consists of nearly level, poorly drained and very poorly drained soils that have a mainly loamy to clayey surface layer and subsoil. Some soils, however, are sandy throughout or are loamy and are underlain by gravelly sand. Some areas adjacent to rivers or streams are subject to flooding, and the soils in these areas have a generally strongly acid to very strongly acid surface layer and subsurface layer. During a major part of the growing season, all of these soils have a high water table that limits the use of the soils for forage.

Cleared and undrained areas are generally in reeds, sedges, and similar plants. The soils are too wet to support machinery, except during droughty periods in midsummer.

If these soils are drained by a surface or subsurface system, many hay and pasture species are suited. Some of the suitable species are reed canarygrass, Garrison creeping foxtail, redtop, Kentucky bluegrass, white clover, and birdsfoot trefoil.

Hay and pasture group 5

This group consists of nearly level, very poorly drained, organic soils. Available water capacity is mainly very high, but it ranges from moderate to very high. The soils are strongly acid to extremely acid. A few areas adjacent to rivers or streams are subject to flooding. During a major part of the growing season, all of these soils have a high water table that limits the use of these soils for forage.

If drained, these soils are suited to forage. Some of the suitable hay and pasture species are reed canarygrass, Garrison creeping foxtail, Kentucky bluegrass, and birdsfoot trefoil.

Hay and pasture group 6

Most of the soils in this group are nearly level and undulating and are excessively drained and somewhat excessively drained. They mainly have a sandy or loamy surface layer and subsoil, and they are underlain by sand or gravelly sand at a depth of about 2 feet or less. In places, however, the soils are loamy throughout and are well drained and moderately well drained. These soils are in an intricate pattern on the landscape with other droughty soils. Available water capacity is low to very low. The surface layer and subsurface layer are generally very strongly acid to slightly acid. Most of these soils are too dry in midsummer for forage to grow well, and this is a major limitation.

Intermediate wheatgrass, bromegrass, alfalfa, and birdsfoot trefoil are suited to these soils.

In addition to lime and the common fertilizers, small amounts of boron sometimes benefit alfalfa on these droughty soils.

Hay and pasture group 7

This group consists of hilly soils that are mainly excessively drained and somewhat excessively drained. Most of the soils have a sandy or loamy surface layer and subsoil and are underlain by sand or gravelly sand at a depth of about 2 feet or less. In some places, however, the soils are loamy throughout and are well drained and moderately well drained. These soils are in an intricate pattern on the landscape with other droughty soils. Available water capacity is low to very low. The surface layer and subsurface layer are very strongly acid to slightly acid. In places these soils are too steep for machinery. These steep soils are better suited to permanent pasture than to hay.

Intermediate wheatgrass, bromegrass, alfalfa, and birdsfoot trefoil are suitable for these soils. Kentucky bluegrass and white clover are suitable for permanent pasture.

The suitable species for permanent pasture generally establish themselves if shrub growth is controlled, and they provide some forage in spring and fall.

Hay and pasture group 8

This group consists of very steep, gravelly, loamy, and clayey soils and soils that are very shallow over

bedrock. The soils have very low available water capacity, or they have a severe hazard of erosion. Because of these factors, the soils are severely limited and are generally unsuited to pasture or hay.

Predicted yields

In table 2, the predicted yields under a high level of management are given for the principal crops in Carlton County. This high level of management produces

TABLE 2.—*Predicted average yields per acre of principal crops*

[Absence of a figure indicates the crop ordinarily is not grown or the soil is not suited to that crop]

Soil	Corn silage	Oats	Grass-legume		Bluegrass pasture
			Hay	Pasture	
	Tons	*Bu*	*Tons*	*AUM* [1]	*AUM* [1]
Ahmeek loam, 0 to 2 percent slopes	14	80	[2] 4.5	[2] 6.0	3.0
Ahmeek loam, 2 to 12 percent slopes	10	70	[2] 4.5	[2] 6.0	3.0
Ahmeek loam, 12 to 25 percent slopes				[3] 5.2	2.4
Ahmeek-Omega complex, 0 to 2 percent slopes	6	60	[2] 3.0	[3] 3.0	2.0
Ahmeek-Omega complex, 2 to 12 percent slopes	5	50	[2] 3.0	[3] 3.0	2.0
Ahmeek-Omega complex, 12 to 25 percent slopes				[3] 2.5	1.5
Allendale loamy fine sand	9	65	[2] 3.0	[3] 5.0	3.5
Alstad fine sandy loam	14	80	[2] 4.5	[3] 6.0	4.5
Alstad Variant loam	14	80	[4] 4.0	[4] 5.5	
Automba fine sandy loam, 0 to 2 percent slopes	14	80	[2] 4.5	[2] 6.0	3.0
Automba fine sandy loam, 2 to 6 percent slopes	14	80	[2] 4.5	[2] 6.0	3.0
Bergland clay	14	45	[4] 3.5	[4] 5.2	
Beseman muck	12	60	[4] 4.5	[4] 6.7	
Blackhoof and Mahtowa soils	14	80	[4] 4.0	[4] 5.5	
Borofolists					
Borosaprists					
Campia silt loam, 0 to 2 percent slopes	14	80	[2] 4.5	[2] 6.0	3.0
Campia silt loam, 2 to 12 percent slopes	13	70	[2] 4.5	[2] 6.0	3.0
Campia silt loam, 12 to 25 percent slopes				[3] 4.0	2.4
Campia-Ontonagon complex, 2 to 12 percent slopes	12	40	[2] 3.5	[2] 5.2	3.0
Cloquet fine sandy loam, 0 to 2 percent slopes	8	70	[2] 3.0	[3] 3.0	2.0
Cloquet fine sandy loam, 2 to 12 percent slopes	7	65	[2] 3.0	[3] 3.0	2.0
Cloquet fine sandy loam, 12 to 25 percent slopes				[3] 2.5	1.5
Cloquet-Emmert complex, 25 to 60 percent slopes					
Cromwell sandy loam, 0 to 2 percent slopes	12	75	[2] 3.0	[3] 5.0	4.0
Cromwell sandy loam, 2 to 6 percent slopes	12	75	[2] 3.0	5.0	4.0
Cushing fine sandy loam	14	80	[2] 4.5	[2] 6.0	3.0
Dawson muck	12	60	[4] 4.5	[4] 6.7	
Duluth very fine sandy loam, 0 to 2 percent slopes	14	80	[2] 4.5	[2] 6.0	3.0
Duluth very fine sandy loam, 2 to 12 percent slopes	12	75	[2] 4.5	[2] 6.0	3.0
Duluth very fine sandy loam, 12 to 25 percent slopes				[3] 5.2	2.4
Duluth very fine sandy loam, 25 to 35 percent slopes					
Dusler silt loam	14	80	[2] 4.5	[3] 6.0	4.5
Emmert gravelly fine sandy loam, 1 to 12 percent slopes	5	30	[2] 2.0	[3] 2.0	1.0
Emmert gravelly fine sandy loam, 12 to 25 percent slopes				[3] 1.5	.8
Fluvaquents					
Greenwood mucky peat	12	60	[4] 3.5	[4] 5.2	
Greenwood peat	12	60	[4] 4.5	[4] 6.7	
Hibbing silt loam, 0 to 2 percent slopes	14	80	[2] 4.5	[2] 6.0	3.0
Hibbing silt loam, 2 to 12 percent slopes	10	70	[2] 4.5	[2] 6.0	3.0
Lobo peat					
Loxley muck	12	60	[4] 4.5	[4] 6.7	
Merwin mucky peat	12	60	[4] 4.5	[4] 6.7	
Mooselake mucky peat	12	60	[4] 5.0	[4] 7.5	
Mora fine sandy loam, wet	14	80	[2] 4.5	[3] 6.0	4.5
Nemadji fine sand	10	65	[2] 3.0	[3] 5.0	3.5
Newson mucky loamy sand	9	55	[4] 3.5	[4] 5.2	
Omega loamy sand, 0 to 2 percent slopes	6	60	[2] 2.5	[3] 2.5	1.2
Omega loamy sand, 2 to 12 percent slopes	5	50	[2] 2.5	[3] 2.5	1.2
Omega loamy sand, 12 to 25 percent slopes				[3] 2.0	1.0
Ontonagon silty clay, 0 to 2 percent slopes	14	45	[2] 3.5	[2] 5.2	3.0
Ontonagon silty clay, 2 to 12 percent slopes	12	40	[2] 3.5	[2] 5.2	3.0
Ontonagon silty clay, 12 to 25 percent slopes				[3] 4.2	2.4
Spooner silt loam	14	90	[2] 4.5	[3] 6.0	4.5
Twig and Parent soils	14	80	[4] 4.0	[4] 5.5	
Udorthents					
Warman fine sandy loam	10	65	[2] 3.0	[3] 5.0	3.5
Warman mucky loam	10	60	[4] 3.5	[4] 5.2	
Waskish peat					

[1] Animal-unit-month. The amount of forage or feed required to maintain one animal unit for a period of 30 days. In range or pasture management, one cow, one horse, one mule, five sheep, or five goats equal one unit.

[2] Yields based on alfalfa and bromegrass.

[3] Yields based on birdsfoot trefoil and bromegrass.

[4] Yields based on reed canarygrass.

about the maximum yields. Some farmers, however, may exceed these yields.

For all yield predictions, it is assumed that the management will be applied for a sufficient period to allow the yields to reflect the major effects of the practices. All hay yields are based on first- and second-year stands and two cuttings during the year.

The predicted yields are averages for a period of 10 years. Year-to-year fluctuations in moisture and other cropping factors can reduce or increase the yields by 20 percent. Predictions are based on records, interviews with farmers, and observations of technicians of the Soil Conservation Service, the Extension Service, and the University of Minnesota Agricultural Experiment Station. The prevailing climate, the characteristics of the soils, and the results of different kinds of management were considered.

To obtain satisfactory yields of small grain and corn silage, several practices are assumed: installation and maintenance of tile or surface drainage systems where needed; use of recommended varieties and proper seeding rates; control of weeds by using normal tillage or cultivation and by herbicides when conditions warrant; control of disease and insects; timeliness of farming operations within practical limits; fertilization according to soil tests and use of adequate lime, nitrogen, phosphate, and potassium to maintain the content of plant nutrients; and use of erosion control practices where needed.

To obtain satisfactory yields of hay and pasture, the following practices are assumed: properly renovating or preparing seedbeds; using recommended varieties and proper seeding rates; properly inoculating legume seeds; controlling weeds and brush by mowing or by the use of herbicides when necessary; liming and fertilizing according to soil tests to obtain optimum growth; clipping tall growth after the initial grazing period to obtain good regrowth; using seasonal or rotational grazing and cutting hay at the proper time; and installing and maintaining tile or surface drainage where needed.

To obtain satisfactory yields of bluegrass pasture, assumed practices are use of white clover, adequate fertilizers, rotational grazing, weed control, and clipping.

Woodland [2]

At the turn of the century, the timber industry was an important segment of the economy in Carlton County. Conifers—eastern white pine, red pine, and jack pine—were the main species logged.

Periodically, large wildfires in the Moose Lake and Cloquet areas burned thousands of acres of forest. Many of the original stands of pine and hardwood were succeeded by aspen and paper birch. Aspen, which for many years was considered a weed tree, has become an important species in the pulp and timber industry. It grows rapidly, reproduces vegetatively from root suckering, and is relatively easy to establish naturally. Eastern white pine, which was probably the most valuable species harvested, is subject to blister rust disease; consequently, red pine is the main species planted for saw log production.

About 72 percent of the county is in forest. Slightly more than half is privately owned, and the rest is in public ownership. Aspen make up 35 percent of the forest, and northern hardwoods consisting of sugar maple, paper birch, northern red oak, and American basswood make up 20 percent. Other species on the upland soils are balsam fir, red and white pine, white spruce, and jack pine. On the very poorly drained mineral and organic soils, black spruce, tamarack, black ash, and northern white-cedar are predominant.

The forest industry remains an important segment of the county's economy. Two major pulp mills and a match plant are in Cloquet, and small sawmills are located throughout the county.

Woodland groups

The soils in Carlton County have been placed in woodland groups to assist owners and managers in the use of soils for wood crops. Each group is made up of soils that are suited to the same kind of trees; that have about the same potential productivity; and that have similar hazards and limitations for forest management. Each group is identified by a three part symbol, such as 2o1.

The first part of the symbol, a number, indicates the potential productivity of the soils for important trees. The number 1 indicates very high productivity; 2, high; 3, moderately high; 4, moderate; and 5, low.

The second part of the symbol, a letter, indicates the major kind of soil limitation. The letter *w* indicates excessive water in or on the soil; *d*, restricted root depth; *c*, clay in the upper part of the soil; *s*, sandy texture; and *r*, steep slopes. The letter *o* indicates no significant limitations or restrictions. If a soil has more than one limitation, priority in placing the soil into a limitation class is in the order in which the letters are listed above.

The third part of the symbol, another number, is used to differentiate groups that have the same first and second parts but that have somewhat different properties or require somewhat different management.

The woodland groups used in Carlton County are described on the following pages.

Woodland group 2o1

This group consists of well drained and moderately well drained upland soils that have a loamy surface layer and a loamy to clayey subsoil and underlying material. Permeability is moderate to slow, and available water capacity is moderate to high. Slopes are 0 to 12 percent.

American basswood, aspen, eastern white pine, northern red oak, red pine, and white spruce should be favored in existing stands. American basswood, northern red oak, red pine, white pine, and white spruce are suitable for planting.

Woodland group 2r1

This group consists of well drained and moderately well drained upland soils that have a loamy surface

[2] JOHN HULTGREN, woodland conservationist, Soil Conservation Service, helped to prepare this section.

layer, subsoil, and underlying material. Permeability is moderate to slow, and available water capacity is moderate to high. Slopes are mainly 12 to 25 percent, but in places they are as steep as 35 percent.

American basswood, aspen, eastern white pine, northern red oak, red pine, and white spruce should be favored in existing stands. American basswood, northern red oak, red pine, and white spruce are suitable for planting.

Woodland group 2s1

This group consists of excessively drained and somewhat excessively drained upland soils that have a sandy to loamy surface layer, a sandy to loamy subsoil, and sandy to gravelly underlying material. Permeability is moderate to very rapid, and available water capacity is low. Slopes range from 0 to 25 percent, but most are less than 12 percent.

Eastern white pine, jack pine, and red pine should be favored in existing stands. Jack pine and red pine are suitable for planting.

Woodland group 2w1

This group consists of somewhat poorly drained and poorly drained, nearly level soils that mainly have a loamy surface layer, subsoil, and underlying material in most places. In places, the soils are sandy throughout, are clayey between depths of 20 and 40 inches, or are underlain by gravelly material. Permeability is moderate to slow, and available water capacity is high. These soils have a high water table during much of the growing season.

Aspen, American basswood, northern red oak, eastern white pine, and white spruce should be favored in existing stands. White spruce is suitable for planting.

Woodland group 3w1

The only soil in this group is Mooselake mucky peat. It is a very poorly drained organic soil of woody origin. Permeability is moderately rapid to moderate, and available water capacity is very high. A high water table during most of the growing season restricts the number of species that grow on this soil.

Black spruce, northern white-cedar, and tamarack should be favored in existing stands. Black spruce and northern white-cedar are suitable for planting.

Woodland group 4c1

This group consists of well drained and moderately well drained upland soils that have a clayey surface layer, subsoil, and underlying material. Permeability is very slow, and available water capacity is moderate. Slopes are 0 to 25 percent.

Aspen, eastern white pine, and white spruce should be favored in existing stands. White pine and white spruce are suitable for planting.

Woodland group 4w1

This group consists of very poorly drained organic soils mainly of nonwoody origin. In most of the soils permeability is rapid and the available water capacity is very high. However, permeability is moderately slow in soils that have a loamy subsoil and the available water capacity is moderate in soils where sand is near the surface. The high water table during most of the growing season limits the growth and the kind of trees suited to these soils. The soils in raised bogs have very low fertility.

Black spruce and tamarack should be favored in existing stands. Black spruce is suitable for planting.

Woodland group 4w2

This group consists of poorly drained and very poorly drained soils on lowlands. The soils are mainly loamy, but some have a surface layer of muck and others are sandy or clayey or have gravelly underlying material. Permeability is moderately slow to very slow, and available water capacity is moderate to high. A water table is near the surface during most of the growing season.

Black ash, black spruce, and tamarack should be favored in existing stands. Black ash and black spruce are suitable for planting.

Woodland group 4s1

This group consists of somewhat excessively drained and excessively drained upland soils that have a loamy surface layer, a gravelly sand to loamy subsoil, and gravelly underlying material. Permeability is very rapid to moderate, and available water capacity is low to very low. Slopes are 1 to 60 percent.

Jack pine and red pine should be favored in existing stands. Red pine and jack pine are suitable for planting.

Woodland group 5c1

Udorthents are the only soils in this group. They are somewhat excessively drained and have a clayey to loamy surface layer and a clayey to loamy subsoil and underlying material. Permeability is moderate to very slow, and the available water capacity is moderate to high. Slopes range from 25 to 60 percent.

Aspen, eastern white pine, and red pine should be favored in existing stands. Jack pine or red pine is suitable for planting on south-facing slopes, and eastern white pine, red pine, or white spruce is suitable for planting on north-facing slopes.

Woodland group 5d1

This group consists of excessively drained and very poorly drained soils that are very shallow to bedrock or contain many boulders and cobbles. Available water capacity is very low. Slopes are generally 0 to 12 percent. Tree growth is limited by a restricted rooting depth.

Jack pine, red pine, and northern white-cedar should be favored in existing stands on uplands, and black spruce and northern white-cedar should be favored in existing stands in lower lying areas.

Woodland management and productivity

Table 3 contains information useful to woodland owners or forest managers in planning the use of soils for wood crops. Estimates of productivity and limitations for woodland use are given by woodland groups.

The potential productivity of merchantable trees on a soil is expressed as a site index. This index is the average height, in feet, that dominant and codominant trees of a given species attain in 50 years. The site index applies to fully stocked, even-aged, unmanaged stands.

Yield data, in cords, have been developed by site index classes for most commercial species. Conversions of site index into volumetric growth and yield are based on research for aspen (*4*), red pine (*8*), eastern white pine (*11*), white spruce (*12*), black spruce (*6*), tamarack (*9*), jack pine (*5*), northern white-cedar (*10*), and northern red oak (*7*).

In table 3 the soils are also rated for a number of factors to be considered in management. The ratings of slight, moderate, and severe are used to indicate the degree of major soil limitations.

Ratings of the hazard of erosion indicate the risk of loss of soil in well-managed woodland. The risk is *slight* if the expected soil loss is small; *moderate* if some measures are needed to control erosion during logging and road construction; and *severe* if intensive management or special equipment and methods are needed to prevent excessive loss of soil.

Ratings of equipment limitation reflect the characteristics and conditions of the soil that restrict use of the equipment generally needed in woodland management or harvesting. A rating of *slight* indicates that use of equipment is not limited to a particular kind of equipment or time of year; *moderate* indicates a short seasonal limitation or a need for some modification in management or equipment; *severe* indicates a seasonal limitation, a need for special equipment or management, or a hazard in the use of equipment.

Seedling mortality ratings indicate the degree that the soil affects expected mortality of planted tree seedlings when plant competition is not a limiting factor. The ratings are for seedlings from good planting stock that are properly planted during a period of sufficient rainfall. A rating of *slight* indicates that the expected mortality of the planted seedlings is less than 25 percent; *moderate,* 25 to 50 percent; and *severe,* more than 50 percent.

Considered in the ratings of windthrow hazard are characteristics of the soil that affect the development of tree roots and the ability of soil to hold trees firmly. A rating of *slight* indicates that trees in wooded areas are not expected to be blown down by commonly occurring winds; *moderate,* that some trees are blown down during periods of excessive soil wetness and strong winds; and *severe,* that many trees are blown down during periods of excessive soil wetness and moderate or strong winds.

Ratings of plant competition indicate the degree to which undesirable plants are expected to invade or grow if openings are made in the tree canopy. The invading plants compete with native plants or planted seedlings by impeding or preventing their growth. A rating of *slight* indicates little or no competition from other plants; *moderate* indicates that plant competition is expected to hinder the development of a fully stocked stand of desirable trees; *severe* means that plant competition is expected to prevent the establishment of a desirable stand unless the site is intensively prepared, weeded, or otherwise managed for the control of undesirable plants.

Wildlife

Soils directly affect the kind and amount of vegetation that is available to wildlife as food and cover, and they affect the development of water impoundments. The kind and abundance of wildlife that populate an area depend largely on the amount and distribution of food, cover, and water. If any one of these elements is missing, inadequate, or inaccessible, wildlife is scarce or does not inhabit the area.

If the soils have the potential, wildlife habitat can be created or improved by planting appropriate vegetation, by properly managing the existing plant cover, and by fostering the natural establishment of desirable plants.

The information in the section can be used in—

1. Planning the use of parks, wildlife refuges, nature study areas, and other developments for wildlife.
2. Selecting soils that are suitable for creating, improving, or maintaining specific elements of wildlife habitat.
3. Determining the intensity of management needed for each element of the habitat.
4. Determining areas that are suitable for acquisition to manage for wildlife.

Wildlife groups

The soils in Carlton County have been placed in nine wildlife groups. These groups contain soils that have similar properties and similar suitabilities for wildlife habitat. The nine wildlife habitat suitability groups in Carlton County are described on the following pages. The soils and the wildlife groups in which they have been placed are listed in the Guide to Mapping Units at the back of this survey.

Wildlife group 1

This group consists of nearly level to undulating, well drained and moderately well drained soils that have a loamy to clayey surface layer and subsoil. Permeability is moderate to very slow, and available water capacity is low to high. These soils have few limitations for upland wildlife habitat management. These soils are suitable for the establishment, growth, and reproduction of a wide variety of plants for woodland wildlife habitat. These soils are also suitable for the establishment, growth, and reproduction of a wide variety of plants for open-land wildlife habitat. These soils are poorly suited to wetland wildlife habitat. Most of the nearly level areas have convex slopes, and these areas require major site alteration to develop shallow-water areas.

TABLE 3.—*Predicted yields and limitations of the soils for wood crops*

[The symbol < means less than]

Woodland group	Potential soil productivity			Limitations for woodland management				
	Important trees	Site index	Yearly growth	Erosion hazard	Equipment limitations	Seedling mortality	Windthrow hazard	Plant competition
			Cords per acre					
2o1	Red pine	60	0.7	Slight	Slight	Moderate to severe.	Slight	Moderate to severe.
	Aspen	75	.7					
	Eastern white pine	55	.5					
	Northern red oak	60	.5					
	White spruce	59	.7					
	American basswood	60	.5					
2r1	Red pine	60	.7	Moderate	Moderate	Moderate to severe.	Slight	Moderate to severe.
	Aspen	70	.7					
	Eastern white pine	55	.5					
	Northern red oak	60	.5					
	White spruce	59	.7					
	American basswood	60	.5					
2s1	Red pine	56	.6	Slight to severe.	Slight to severe.	Moderate to severe.	Slight to moderate.	Slight to moderate.
	Eastern white pine	54	.5					
	Jack pine	60	.5					
2w1	Aspen	75	.7	Slight	Slight	Slight to moderate.	Moderate to severe.	Moderate to severe.
	White spruce	55	.6					
	Northern red oak	55	.5					
	Eastern white pine	55	.6					
	American basswood	40	.5					
3w1	Northern white-cedar	30	.3	Slight	Severe	Severe	Severe	Severe.
	Black spruce	35	.4					
	Tamarack	46	.5					
4c1	White spruce	44	.5	Slight to moderate.	Moderate	Severe	Severe	Severe.
	Aspen	60	.5					
	Eastern white pine	46	.4					
4w1	Black spruce	26	.2	Slight	Severe	Severe	Severe	Severe.
	Tamarack	36	.5					
4w2	Black spruce	30	.3	Slight	Severe	Severe	Severe	Severe.
	Black ash	46	.3					
	Tamarack	42	.5					
4s1	Red pine	44	.3	Slight to severe.	Slight to severe.	Moderate to severe.	Slight to moderate.	Slight to moderate.
	Jack pine	48	.3					
5c1	Aspen	44	.4	Severe	Moderate to severe.	Severe	Severe	Severe.
	Eastern white pine	40	.3					
	Red pine	43	.3					
5d1	Red pine	<36	.4	Slight to moderate.	Moderate to severe.	Severe	Severe	Severe.
	White pine	<40	.3					
	Jack pine	<40	.3					
	Black spruce [1]	<25	.2					
	Northern white-cedar [1]	<15	.1					

[1] Very poorly drained areas.

Wildlife group 2

This group consists of hilly, well drained and moderately well drained soils that have a loamy to clayey surface layer and subsoil. Permeability is moderate to very slow, and available water capacity is moderate to high. Slope is the main limitation to the use of these soils for wildlife habitat.

The soils in this group are mainly suitable for the establishment, growth, and reproduction of a wide variety of plants for woodland wildlife habitat. In places, however, the slopes are too steep for the use of equipment. These areas also have rapid runoff and a severe hazard of erosion if disturbed, and renovation or reseeding for grain and seed production is difficult. These soils are favorable for grasses and legumes for open-land wildlife habitat, but the soils are unsuited to grain and seed crops because of rapid runoff and the severe hazard of erosion. Because of the slope, these

soils are commonly unsuited to development of wetland wildlife habitat. Generally, it is impractical to develop shallow-water areas on these soils.

Wildlife group 3

This group consists of nearly level, somewhat poorly drained and poorly drained soils that mainly have a loamy surface layer and subsoil. In some places, however, the soils are sandy throughout or the underlying material is gravelly to clayey. Permeability is slow to rapid, and the available water capacity is low to high. A water table is at a depth of 1½ to 2½ feet during much of the growing season.

These soils are suitable for the establishment, growth, and reproduction of a wide variety of plants for woodland wildlife habitat. The soils are suitable for the growth of a wide variety of plants for wetland wildlife habitat. Because the soils are nearly level and have a high water table, much of the acreage is favorable for the development of shallow-water areas. The soils in this group are suitable for some grasses and legumes and grain and seed plants, but the kinds of plants are limited to those that tolerate some wetness. Redtop, brome, birdsfoot trefoil, white ladino, alsike clover, and millet are some of the suited plants.

Wildlife group 4

This group consists of nearly level, poorly drained and very poorly drained soils that mainly have a loamy to clayey surface layer and subsoil. In some places, however, the soils are sandy or clayey throughout or have gravelly underlying material. Permeability is moderately slow to very slow, and available water capacity is moderate to high. These soils have a water table at a depth of less than 1 foot during most of the growing season. In many places, they are frequently ponded or flooded.

These soils are poorly suited to upland wildlife habitat but are suitable for wetland wildlife habitat. The soils in this group are unsuitable for many domestic grasses, legumes, and grain and seed plants and for many tree, shrub, and herbaceous species. Only plants that tolerate wet conditions, such as black ash, dogwood, and alder, are suitable. Much of the acreage of these soils is suited to the development of shallow-water areas. The soils also are suitable for sedges, rushes, cattails, and other wetland plants.

Wildlife group 5

This group consists of nearly level, very poorly drained organic soils. Permeability is rapid to moderately slow, and available water capacity is moderate to very high. Some of these soils are extremely acid.

The soils in this group are severely limited for upland wildlife habitat, but some areas are suitable for wetland wildlife habitat. The soils in this group are too wet for grain and most domestic grasses and legumes. Wetness, and in some places fertility, also limits the number of woodland species that grow and reproduce. Much of the acreage of these soils is suited to the development of shallow-water areas. Most of the soils also are suitable for sedges, rushes, cattails, and other wetland plants, but on raised bogs the soils are too acid for satisfactory growth and production of these plants.

Wildlife group 6

This group consists of nearly level to undulating, excessively drained and somewhat excessively drained soils that have a loamy surface layer and subsoil and sandy or gravelly underlying material. Permeability is moderate in the upper part of the soils and rapid to very rapid in the lower part. Available water capacity is low.

These soils are too dry during part of the growing season for use as upland wildlife habitat. These soils are fairly well suited to woodland wildlife habitat. A wide variety of species of domestic grain or seed crops is suited to these soils. These soils generally are impractical for use as wetland wildlife habitat.

Wildlife group 7

This group consists mainly of nearly level to hilly, excessively drained and somewhat excessively drained soils that have a sandy to loamy surface layer and subsoil and sandy or gravelly underlying material. In a few places, however, the soil is loamy throughout and is well drained. In most places permeability is very rapid to moderate and available water capacity is very low to low. These soils are limited for use as wildlife habitat by droughtiness.

The soils in this group are mainly suitable for the establishment and growth of a wide variety of plants for woodland wildlife habitat, but reproduction of some plants is generally limited. Jack pine and red pine are commonly planted. These soils are unsuited to grain or seed production because of steep slopes or very low available water capacity. They are fairly well suited to legumes and grasses. These soils are impractical for use as wetland wildlife habitat.

Wildlife group 8

This group consists of steep, excessively drained to well drained soils that have a loamy to clayey surface layer and a gravelly sand to clayey subsoil. Permeability is rapid to very slow, and available water capacity is very low to high. Because of the steep slopes, most of the rainfall runs off very rapidly, the use of machinery is severely restricted, and erosion is a hazard.

These soils are severely limited for wetland and openland wildlife habitat. Most of these soils are suitable for establishment, growth, and reproduction of a wide variety of plants for wildlife habitat, but growth rates are restricted by excessive runoff or very low available water capacity.

Wildlife group 9

This group consists of nearly level to undulating, excessively drained and very poorly drained soils that are very shallow over bedrock. Available water capacity is very low. These soils are severely limited for wildlife habitat.

These soils are poorly suited to the production of plants for wildlife habitat. The very poorly drained soils provide some wetland wildlife food and cover, but

most areas are not suitable for shallow-water development. The use of fire for management of vegetation is restricted on these soils because so much of the soil material over the bedrock is organic and could be destroyed by burning.

Suitability for wildlife habitat

In table 4, the soils of Carlton County are rated for elements of wildlife habitat by wildlife habitat suitability groups. The elements of habitat are associated with three kinds of wildlife habitat, which are briefly described in the following paragraphs.

Woodland habitat consists of hardwoods or conifers, or a mixture of both, and associated shrubs, grasses, legumes, and wild herbaceous plants. Examples of wildlife attracted to this habitat are ruffed grouse, woodcock, thrushes, woodpeckers, tree squirrels, raccoon, deer, and black bear.

Open-land habitat consists of cropland, pasture, meadow, and areas that are overgrown with grasses, herbs, shrubs, and vines. These areas produce grain and seed crops, grasses and legumes, and wild herbaceous plants. The kinds of wildlife attracted to these areas are meadowlark, field sparrow, orioles, wrens, bluebirds, cottontail rabbit, red fox, and woodchuck.

Wetland habitat consists of water-tolerant plants in open, marshy, or swampy shallow-water areas. Examples of wildlife attracted to this habitat are ducks, geese, herons, shore birds, muskrat, mink, and beaver.

The potential of the soil for the elements of wildlife habitat is rated good, fair, poor, or very poor. A rating of *good* means that the element of wildlife habitat or the kind of habitat is easily created, improved, or maintained. Few or no limitations affect management, and satisfactory results can be expected if the soil is used for the designated purpose. A rating of *fair* means that the element of wildlife habitat or kind of habitat can be created, improved, or maintained in most places. Moderate intensity of management and fairly frequent attention are required for satisfactory results. A rating of *poor* means that limitations are severe for the designated element or kind of wildlife habitat. Habitat can be created, improved, or maintained in most places, but management is difficult and requires intensive effort. A rating of *very poor* means that restrictions for the element of wildlife habitat or kind of wildlife are very severe, and that unsatisfactory results can be expected. Wildlife habitat is impractical or even impossible to create, improve, or maintain on soils having such a rating.

The elements of wildlife habitat are briefly described in the following paragraphs.

Wild herbaceous plants are native or naturally established herbaceous grasses, legumes, and forbs, including weeds, that provide food and cover for wildlife. Examples are sedges, goldenrod, reedgrass, clover, and ragweed. Major soil properties that affect the growth of these plants are depth of the root zone, texture of the surface layer, available water capacity, wetness, surface stoniness, and flood hazard. Soil temperature and moisture are also considerations.

Hardwood trees and the associated woody understory provide cover for wildlife and produce nuts or other fruit, buds, catkins, twigs, bark, or foliage that wildlife eat. Examples of native plants are oak, aspen, cherry mountainash, dogwood, sumac, hazelnut, blackberry, viburnum, and blueberry. Examples of fruit-producing shrubs that are commercially available and suitable for planting on soils rated good are highbush cranberry, juneberry, and crabapple. Major soil properties that affect growth of hardwood trees and shrubs are depth of the root zone, available water capacity, and wetness.

Coniferous plants are cone-bearing trees, shrubs, or ground cover that furnish habitat or supply food in the form of browse, seeds, or fruitlike cones. Examples are pine, spruce, fir, yew, cedar, and juniper. Major soil properties that affect the growth of coniferous plants are depth of the root zone, available water capacity, and wetness.

Grain and seed crops are seed-producing annuals used by wildlife. Examples are wheat, oats, barley, millet, buckwheat, and sunflowers. The major soil properties that affect the growth of grain and seed crops are depth of the root zone, texture of the surface layer, available water capacity, wetness, slope, surface

TABLE 4.—*Suitability for wildlife habitat*

Wildlife groups	Woodland habitat			Open-land habitat		Wetland habitat	
	Wild herbaceous plants	Hardwood trees	Coniferous plants	Grain and seed crops	Grasses and legumes	Wetland plants	Shallow-water areas
Group 1	Good to fair	Good	Good	Good to fair	Good to fair	Poor to very poor.	Poor to very poor.
Group 2	Good to fair	Good	Good	Poor	Fair	Very poor	Very poor.
Group 3	Good	Good to fair	Good to fair	Fair to poor	Good to fair	Good to fair	Good to poor.
Group 4	Poor	Poor	Poor	Very poor	Poor	Good	Good.
Group 5	Poor to very poor.	Poor to very poor.	Poor to very poor.	Very poor	Poor to very poor.	Good to poor	Good to poor.
Group 6	Good to fair	Fair	Fair	Fair	Good	Very poor	Very poor.
Group 7	Fair to poor	Poor to very poor.	Poor to very poor.	Poor to very poor.	Fair to poor	Very poor	Very poor.
Group 8	Fair to poor	Good to very poor.	Good to very poor.	Very poor	Very poor	Very poor	Very poor.
Group 9	Poor to very poor.	Poor to very poor.	Poor to very poor.	Very poor	Very poor	Good to very poor.	Very poor.

stoniness, and flood hazard. Soil temperature and moisture are also considerations.

Grasses and legumes are domestic perennial grasses and herbaceous legumes that are planted for wildlife food and cover. Examples are fescue, bluegrass, bromegrass, timothy, orchardgrass, clover, alfalfa, and trefoil. Major soil properties that affect the growth of grasses and legumes are depth of the root zone, texture of the surface layer, available water capacity, wetness, surface stoniness, flood hazard, and slope. Soil temperature and moisture are also considerations.

Wetland plants are annual and perennial wild herbaceous plants that grow on moist or wet sites, exclusive of submerged or floating aquatics. They produce food or cover for wildlife that use wetland as habitat. Examples of wetland plants are smartweed, rushes, sedges, reeds, wildrice, cordgrass, and cattail. Major soil properties affecting wetland plants are texture of the surface layer, wetness, reaction, salinity, slope, and surface stoniness.

Shallow-water areas are bodies of surface water that have an average depth of less than 5 feet and are useful to wildlife. They can be naturally wet areas, or they can be created by dams or levees or by water-control devices in marshes or streams. Examples are muskrat marshes, waterfowl feeding areas, wildlife watering developments, beaver ponds, and other wildlife ponds. Major soil properties affecting shallow-water areas are depth to bedrock, wetness, surface stoniness, slope, and permeability. The availability of a dependable water supply is important if water areas are to be developed.

Recreation

The many lakes and streams, the wooded hills, and the scenery in Carlton County provide ample opportunity for recreation. Landowners in the county have an opportunity to develop new facilities for camping, picnicking, fishing, hunting, and other outdoor activities.

This section can be used to help determine the suitability for recreational purposes of the various soils in the county.

Recreation groups of soils

The soils in Carlton County are placed in seven recreation groups. The soils in a recreation group have similar properties and similar limitations for recreational use. The soils in the county and the recreation groups in which they have been placed are listed in the Guide to Mapping Units at the back of this survey. The recreation groups in Carlton County are described in the following paragraphs.

Recreation group 1

In this group are somewhat excessively drained and well drained soils that have a silt loam, fine sandy loam, or sandy loam surface layer. Permeability is moderate. The water table is below a depth of 5 feet.

The soils in this group are generally suitable for recreational use in summer. However, in some places the soils are too steep for all the various uses. Control of runoff and erosion is a major concern, and avoiding extensive grading on the Cromwell and Cloquet soils in this group is also necessary.

Recreation group 2

In this group are well drained and moderately well drained soils that have a loamy surface layer. Permeability is more rapid in the surface layer and subsurface layer than in the slowly permeable and moderately slowly permeable subsoil. Normally, the water table is below a depth of 5 feet, but it is perched above the slowly permeable subsoil for short periods following heavy rain. The soils are typically nearly level or undulating, but they are also hilly or steep in places.

Recreation group 3

Borosaprists are the only soils in this group. They are excessively drained and are very shallow over bedrock. The soils typically are nearly level and undulating.

Recreation group 4

In this group are somewhat poorly drained and poorly drained, nearly level soils. The water table typically is at a depth of 1 foot to 4 feet during the season of use, and it generally is highest early in spring and late in fall. The surface layer ranges from sandy to loamy, and it provides good trafficability for only part of summer.

Recreation group 5

In this group are excessively drained and somewhat excessively drained soils that have a sandy surface layer. Permeability is rapid and very rapid. The water table is below a depth of 5 feet.

The soils in this group are well suited to many recreational uses, but the soils tend to be dusty or soft during dry weather. The soils are not sticky when wet. Control of runoff and erosion on the steeper soils is a major concern, and avoiding grading on the Emmert soils in this group is also necessary.

Recreation group 6

In this group are mainly well drained and moderately well drained soils that have a clayey surface layer. Permeability is very slow. The water table is commonly below a depth of 5 feet. Also in this group are very steep soils that have a loamy surface layer.

Because slopes are steep or the surface layer is too clayey, these soils are severely limited for most recreational uses.

Recreation group 7

In this group are poorly drained and very poorly drained, nearly level soils. The water table typically is at a depth of less than 1 foot during at least part of the season of use. This group consists of wet mineral soils, organic soils, and soils subject to flooding.

Unless modified, the soils in this group are severely limited for recreational use in summer.

Limitations of the soils for recreation

The soils in Carlton County are rated in table 5 by recreational groups according to limitations that affect

their suitability in summer for use as camp areas, picnic areas, playgrounds, and paths and trails. The ratings are based on such restrictive soil features as flooding, wetness, slope, and texture of the surface layer. Not considered in these ratings, but important in evaluating a site, are location and accessibility of the area, size and shape of the area and its scenic quality, the ability of the soil to support vegetation, access to water, potential available water impoundment sites, and either access to public sewerlines or capacity of the soil to absorb septic tank effluent. Soils subject to flooding are limited, in varying degree, for recreational use by the duration of flooding and the season of occurrence. Onsite assessment of height, duration, and frequency of flooding is essential in planning recreational facilities. Location, esthetic value, and suitability for vegetation are important factors, but they are not considered in the table.

In table 5 the limitations of soils are rated as slight, moderate, or severe. *Slight* means that the soil properties are generally favorable and that the limitations are minor and easily overcome. *Moderate* means that the limitations can be overcome or alleviated by planning, design, or special maintenance. *Severe* means that soil properties are unfavorable and that limitations can be offset only by costly soil reclamation, special design, intensive maintenance, limited use, or by a combination of these measures.

The information in table 5 can be supplemented by additional information in other parts of this survey. Especially helpful are interpretations for septic tank absorption fields and for dwellings and local roads and streets, given in table 7.

Camp areas require such site preparation as shaping and leveling tent and parking areas, stabilizing roads and intensively used areas, and installing sanitary facilities and utility lines. Camp areas are subject to heavy foot traffic and some vehicular traffic. The best soils for this use have mild slopes and are not wet nor subject to flooding during the period of use. The surface has few or no stones or boulders, absorbs rainfall readily but remains firm, and is not dusty when dry. Strong slopes and stones or boulders can greatly increase the cost of constructing camping sites.

Picnic areas are subject to heavy foot traffic. Most vehicular traffic is confined to access roads and parking areas. The best soils for use as picnic areas are firm when wet, are not dusty when dry, are not subject to flooding during the period of use, and do not have slopes or stones or boulders that increase the cost of shaping sites or of building access roads and parking areas.

Playgrounds require soils that can withstand intensive foot traffic. The best soils are almost level and not wet nor subject to flooding during the season of use. The surface is free of stones or boulders, is firm after rain, and is not dusty when dry. If shaping is required to obtain a uniform grade, the depth of the soil over rock should be sufficient to allow necessary grading.

The design and layout of paths and trails for walking, horseback riding, and bicycling should require little or no cutting and filling. The best soils for this use are those that are not wet, are firm after rain, are not dusty when dry, and are not subject to flooding more than once during the period of use. They should have moderate slopes and have few or no stones or boulders on the surface.

TABLE 5.—*Degree of soil limitation and major features affecting recreation uses*

Recreation group	Camp areas	Picnic areas	Playgrounds	Paths and trails
1	Slight if slopes are less than 6 percent. Moderate if slopes are 6 to 12 percent. Severe if slopes are more than 12 percent.	Slight if slopes are less than 6 percent. Moderate if slopes are 6 to 12 percent. Severe if slopes are more than 12 percent.	Slight if slopes are less than 2 percent. Moderate if slopes are 2 to 6 percent. Severe if slopes are more than 6 percent.	Slight if slopes are less than than 18 percent. Moderate if slopes are 18 to 25 percent. Severe if slopes are more than 25 percent.
2	Moderate if slopes are less than 12 percent: percs slowly. Severe if slopes are more than 12 percent.	Slight if slopes are less than 6 percent. Moderate if slopes are 6 to 12 percent. Severe if slopes are more than 12 percent.	Moderate if slopes are less than 6 percent: percs slowly. Severe if slopes are more than 6 percent.	Slight if slopes are less than 18 percent. Moderate if slopes are 18 to 25 percent. Severe if slopes are more than 25 percent.
3	Slight if slopes are less than 6 percent. Moderate if slopes are 6 to 12 percent. Severe if slopes are more than 12 percent.	Slight if slopes are less than 6 percent. Moderate if slopes are 6 to 12 percent. Severe if slopes are more than 12 percent.	Severe: depth to rock	Slight if slopes are less than 18 percent. Moderate if slopes are 18 to 25 percent. Severe if slopes are more than 25 percent.
4	Moderate: wet	Moderate: wet	Moderate: wet	Moderate: wet.
5	Moderate if slopes are less than 12 percent: too sandy. Severe if slopes are more than 12 percent.	Moderate if slopes are less than 12 percent: too sandy. Severe if slopes are more than 12 percent.	Moderate if slopes are less than 6 percent: too sandy. Severe if slopes are more than 6 percent.	Moderate if slopes are less than 25 percent: too sandy. Severe if slopes are more than 25 percent.
6	Severe: too clayey	Severe: too clayey	Severe: too clayey	Severe: too clayey.
7	Severe: wet	Severe: wet	Severe: wet	Severe: wet.

Engineering uses of the soils [3]

This section is useful to those who need information about soils used as structural material or as foundation upon which structures are built. Among those who can benefit from this section are planning commissions, town and city managers, land developers, engineers, contractors, and farmers.

[3] RONALD H. HANSEN, engineer, Soil Conservation Service, helped to prepare this section.

Among properties of soils highly important in engineering are permeability, strength, compaction characteristics, drainage, shrink-swell potential, grain size, plasticity, and soil reaction. Also important are depth to the water table, depth to bedrock, and slope. These properties, in various degrees and combinations, affect construction and maintenance of roads, airports, pipelines, foundations for small buildings, irrigation systems, ponds and small dams, and systems for disposal of sewage and refuse.

TABLE 6.—*Estimated soil properties*

[An asterisk in the first column indicates that at least one mapping unit is made of two or more kinds of soil. The soils in such
tions for referring to other series as indicated. The symbol < means less than;

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	USDA texture	Classification		Coarse fraction greater than 3 inches	Percentage less than 3 inches passing sieve—	
				Unified	AASHTO		No. 4 (4.7 mm)	No. 10 (2.0 mm)
	Ft	*In*				*Pct*		
*Ahmeek:								
21, 21C, 21E	>5	0–16	Loam and fine sandy loam	ML	A–4	0–5	90–100	85–100
975, 975C, 975E. For Omega part, see Omega series.		16–60	Fine sandy loam	SM	A–4 or A–2	0–5	85–100	75–95
Allendale: 22	1½–2½	0–7	Loamy fine sand	SM	A–2	0	95–100	95–100
		7–31	Fine sand	SM, SP–SM, SP	A–3	0	95–100	95–100
		31–60	Clay	CH	A–7	0	100	100
Alstad: 292	1½–2½	0–9	Fine sandy loam	ML	A–4	0–2	85–98	90–100
		9–37	Clay loam	CL, ML	A–4 or A–6	0–2	85–98	90–100
		37–60	Loam	CL, ML	A–4 or A–6	0–2	85–98	90–100
Alstad Variant: V292	<1	0–19	Loam	ML	A–4	0–2	85–98	90–100
		19–45	Loam and clay loam	ML, CL	A–4 or A–6	0–2	85–98	90–100
		45–60	Loam	ML, CL	A–4 or A–6	0–2	85–98	90–100
Automba: 43, 43B	>5	0–24	Fine sandy loam	ML	A–4		90–100	80–90
		24–46	Fine sandy loam	ML or SM	A–4	0–4	90–100	80–90
		46–60	Fine sandy loam	SM	A–4	0–4	90–100	80–90
Bergland: 305	<1	0–6	Clay	CH	A–7	0	100	99–100
		6–25	Clay	CH	A–7	0	100	99–100
		25–60	Clay	CH	A–7	0	100	99–100
Beseman: 531	<1	0–36	Muck (sapric)	Pt		(2)	(2)	(2)
		36–60	Loam	CL, ML, SM, SC	A–4 or A–2	0–2	75–100	65–100
*Blackhoof: 980	<1	0–11	Muck (sapric)	Pt		(2)	(2)	(2)
For Mahtowa part, see Mahtowa series.		11–15	Silty clay loam	CL, ML	A–4 or A–6	0–2	95–100	88–98
		15–60	Loam	CL, ML	A–4 or A–6	0–2	95–100	88–98
Borofolists: 1073.[5]								
Borosaprists: 1074.[5]								
*Campia: 367, 367C, 367E, 976C.	>5	0–7	Silt loam	ML	A–4	0	100	100
		7–24	Silty clay loam	CL	A–6	0	100	100
For Ontonagon part of 976C, see Ontonagon series.		24–60	Silt loam and very fine sandy loam.	ML	A–4	0	100	100
*Cloquet: 355, 355C, 355E, 977G.	>5	0–8	Fine sandy loam and silt loam	SM	A–4	0–3	90–100	80–95
		8–14	Sandy loam	SM	A–4	0–3	90–100	80–95
For Emmert part of 977G, see Emmert series.		14–60	Gravelly coarse sand	GW, GP, or SP	A–1	0–10	40–85	35–75
Cromwell: 268, 268B	>5	0–15	Sandy loam	SM	A–2 or A–4	0	90–100	85–100
		15–60	Sand	SM or SP	A–1, A–3	0	90–100	85–100
Cushing: 204	>5	0–8	Fine sandy loam	ML	A–4	0–2	90–100	90–100
		8–36	Loam and clay loam	CL, ML, SC	A–4 or A–6	0–2	90–100	90–100
		36–68	Loam	ML, CL, SC	A–4 or A–6	0–2	90–100	90–100

See footnotes at end of table.

Information in this section of the soil survey can be helpful to those who—

1. Select potential residential, industrial, commercial, and recreational areas.
2. Evaluate alternate routes for roads, highways, pipelines, and underground cables.
3. Seek sources of gravel, sand, or clay.
4. Plan farm drainage systems, irrigation systems, ponds, terraces, and other structures for controlling water and conserving soil.
5. Correlate performance of structures already built with properties of the kinds of soil on which they are built, for the purpose of predicting performance of structures on the same or similar kinds of soil in other locations.
6. Predict the trafficability of soils for cross-country movement of vehicles and construction equipment.
7. Develop preliminary estimates pertinent to construction in a particular area.

Most of the information in this section is presented in tables 6 and 7, which show, respectively, several

significant in engineering

mapping units may have different properties and limitations, and for this reason it is necessary to follow carefully the instruc-
> means greater than. Absence of an entry means data were not estimated]

Percentage less than 3 inches passing sieve—Continued		Liquid limit	Plasticity index	Permeability	Available water capacity	Reaction	Shrink-swell potential	Corrosivity to—	
No. 40 (0.42 mm)	No. 200 (0.074 mm)							Uncoated steel	Concrete
		Pct		*In/hr*	*In/in of soil*	*pH*			
70–90	50–60	14–20	[1] NP–5	0.6–2.0	0.15–0.20	5.1–6.0	Low	Moderate	Moderate.
65–90	30–40	14–20	NP–5	0.2–0.6	0.07–0.13	5.1–7.3	Low	Moderate	Moderate.
75–85	20–35	NP		6.0–20.0	0.10–0.12	5.1–5.5	Low	Low	Moderate.
50–85	2–10	NP		6.0–20.0	0.06–0.08	5.1–6.0	Low	Low	Moderate.
100	95–98	65–90	35–55	0.06–0.20	0.10–0.14	7.4–7.8	High	High	Low.
85–95	55–85	16–24	NP–3	0.6–2.0	0.16–0.24	5.1–6.0	Low	High	Moderate.
85–95	55–75	20–30	2–12	0.2–0.6	0.15–0.19	5.6–7.3	Low to moderate	High	Moderate.
85–95	55–75	20–30	2–12	0.2–0.6	0.14–0.18	7.4–8.4	Low to moderate	High	Low.
85–95	50–80	20–30	NP–6	2.0–6.0	0.12–0.23	5.1–5.5	Low	High	Moderate.
85–95	50–75	20–30	2–12	0.20–0.6	0.14–0.18	5.6–6.0	Low to moderate	High	Moderate.
85–95	50–75	20–30	2–12	0.20–0.6	0.14–0.18	6.6–7.8	Low to moderate	High	Low.
70–85	50–60	14–20	NP–1	0.6–2.0	0.12–0.23	5.1–6.0	Low	Low	Moderate.
70–85	45–55	15–25	NP–3	0.2–0.6	0.07–0.13	5.6–6.5	Low	Low	Moderate.
65–80	35–45	14–20	NP–1	0.2–0.6	0.07–0.11	6.6–7.8	Low	Low	Low.
99–100	90–98	70–90	40–55	0.06–0.20	0.13–0.16	5.1–6.0	High	High	Moderate.
99–100	90–98	70–90	40–55	0.06–0.20	0.10–0.14	6.0–7.3	High	High	Low.
99–100	90–98	70–90	40–55	<0.06	0.10–0.14	7.3–8.4	High	High	Low.
[2]	[2]			0.2–6.0	0.43	4.0–5.0	Low [3]	High	High.
55–95	25–75	15–24	0–12	0.2–0.6	0.11–0.18	4.5–7.3	Low to moderate	High	High.
[2]	[2]			6.0–20.0	0.35–0.48	5.1–6.5	Low [3]	High	Moderate.
80–90	50–80	20–40	2–12	<0.06–0.2	[1] 0.07–0.09	5.1–6.5	Low	High	Moderate.
80–90	50–80	20–30	2–12	0.2–0.6	0.07–0.13	6.1–7.3	Low	High	Moderate.
90–100	70–95	15–25	NP–3	0.6–2.0	0.18–0.23	4.5–6.1	Low	Moderate	Moderate.
90–100	85–95	20–40	10–20	0.6–2.0	0.14–0.21	5.6–7.3	Low	Moderate	Moderate.
85–100	50–90	2–30	NP–5	0.6–2.0	0.18–0.23	6.1–7.8	Low	Moderate	Low.
55–75	35–50		NP	0.6–2.0	0.20–0.22	4.5–6.0	Low	Low	High.
55–75	35–50		NP	0.6–2.0	0.18–0.21	4.5–6.0	Low	Low	High.
10–45	0–5		NP	>20.0	0.02–0.04	5.6–6.5	Low	Low	Moderate.
55–85	30–50		NP	0.6–2.0	0.16–0.18	4.5–6.0	Low	Low	Moderate.
45–70	2–15		NP	6.0–20.0	0.05–0.07	5.0–6.0	Low	Low	Moderate.
70–90	50–80	14–20	0–1	0.6–2.0	0.12–0.23	5.0–5.5	Low	Moderate	Moderate.
85–95	45–70	20–35	4–12	0.2–0.6	0.14–0.18	5.6–6.5	Low to moderate	Moderate	Moderate.
85–95	45–70	20–35	4–12	0.2–0.6	0.14–0.18	6.6–7.8	Low to moderate	Moderate	Low.

TABLE 6.—*Estimated soil properties*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	USDA texture	Classification		Coarse fraction greater than 3 inches	Percentage less than 3 inches passing sieve—	
				Unified	AASHTO		No. 4 (4.7 mm)	No. 10 (2.0 mm)
	Ft	*In*				*Pct*		
Dawson: 536	<1	0–30	Muck (sapric)	Pt		(2)	(2)	(2)
		30–60	Sand	SW, SM, SP	A–1, A–2, A–3	0	95–100	90–100
Duluth: 504, 504C, 504E, 504G.	>5	0–13	Very fine sandy loam	ML	A–4	0–2	95–100	85–98
		13–64	Loam	CL, ML	A–4 or A–6	0–2	95–100	85–98
		64–72	Loam	CL, ML	A–4 or A–6	0–2	95–100	85–98
Dusler: 502	1–4	0–15	Silt loam	ML	A–4	0–2	95–100	85–98
		15–55	Loam	ML, CL	A–4 or A–6	0–2	95–100	85–98
		55–60	Loam	ML, CL	A–4 or A–6	0–2	95–100	90–100
Emmert: 12C, 12E	>5	0–9	Gravelly fine sandy loam	SM, SW–SM	A–2	0–10	75–85	65–75
		9–60	Very gravelly coarse sand	GW, GP, SP	A–1	0–10	35–60	25–40
Fluvaquents: 1005.[5]								
Greenwood: 530, 549	<1	0–20	Peat (fibric)	Pt		0	(2)	(2)
		20–70	Mucky peat (hemic)	Pt		0	(2)	(2)
Hibbing: 254, 254C	>5	0–6	Silt loam	ML	A–4	0	95–100	90–100
		6–70	Clay	CL, CH	A–7	0	95–100	90–100
		70–75	Clay	CL, CH	A–7	0	95–100	90–100
Lobo: 537	<1	0–42	Peat (fibric)	Pt		0	(2)	(2)
		42–60	Mucky peat (hemic)	Pt		0	(2)	(2)
Loxley: 533	<1	0–60	Muck (sapric)	Pt		0	(2)	(2)
Mahtowa	<1	0–11	Silt loam	ML	A–4	0	100	95–100
Mapped only with Blackhoof soils.		11–21	Loam	CL, ML	A–4 or A–6	0–2	95–100	90–98
		21–60	Loam	CL, ML	A–4 or A–6	0–2	95–100	90–98
Merwin: 535	<1	0–42	Peat muck (hemic)	Pt		0	(2)	(2)
		42–60	Loam	CL, ML, SM	A–4 or A–6	0–5	85–100	80–100
Mooselake: 534	<1	0–60	Mucky peat (hemic)	Pt		0	(2)	(2)
Mora: V166	1–4	0–11	Fine sandy loam	SM, ML	A–4	0–5	95–100	95–100
		11–58	Fine sandy loam	SM	A–2, A–4	0–5	85–95	80–90
		58–60	Fine sandy loam	SM	A–2, A–4	0–5	85–95	80–90
Nemadji: 186	1–4	0–9	Fine sand	SM	A–4 or A–2	0	100	100
		9–60	Fine sand	SM, SP–SM	A–1, A–2, or A–3	0	100	100
Newson: 274	<1	0–5	Mucky loamy sand	SM or OL	A–2	0	100	100
		5–60	Sand	SP	A–3	0	100	95–100
Omega: 188, 188C, 188E	>5	0–10	Loamy sand	SM	A–2	0	95–100	90–100
		10–60	Fine sand	SP or SM	A–3	0	95–100	90–100
Ontonagon: 303, 303C, 303E.	>5	0–6	Silty clay	CL	A–6	0	100	99–100
		6–24	Clay	CH	A–7	0	100	99–100
		24–60	Clay	CH	A–7	0	100	99–100
Parent	<1	0–12	Silty clay loam and loam	ML	A–4	2	95–100	90–100
Mapped only with Twig soils.		12–18	Fine sandy loam	SM	A–2 or A–4	0–5	90–95	80–90
		18–60	Fine sandy loam	SM	A–2 or A–4	0–5	85–95	80–90
Spooner: 147	1–4	0–10	Silt loam	SM or ML	A–4	0	100	100
		10–20	Silty clay loam	ML or CL	A–4 or A–6	0	100	100
		20–60	Silt loam	ML	A–4	0	100	100
*Twig: 990	<1	0–12	Muck (sapric)	Pt		0	(2)	(2)
For Parent part, see Parent series.		12–18	Mucky silt loam	OL	A–4	0	100	100
		18–26	Loam	ML	A–4	0	90–100	90–100
		26–60	Fine sandy loam	SM	A–2 or A–4	0–5	85–100	80–95
Udorthents: 1020.[5]								
Warman:								
V337	1–4	0–9	Fine sandy loam	SM	A–4	2–5	95–98	85–95
		9–18	Fine sandy loam	SM	A–4	2–5	95–98	85–95
		18–60	Gravelly coarse sand	GW, GP	A–1	0–10	35–60	25–40
337	<1	0–8	Mucky loam	OL	A–4	0	95–100	90–98
		8–20	Loam	ML	A–4	0	95–100	90–98
		20–60	Gravelly coarse sand	GW, GP, SP	A–1	0–10	40–85	35–75
Waskish: 538	<1	0–60	Peat (fibric)	Pt		0	(2)	(2)

[1] NP = Nonplastic.
[2] Not suitable for engineering sieve analysis.
[3] Surface subsidence will be high due to consolidation and oxidation of the organic matter when these soils are drained.

significant in engineering—Continued

Percentage less than 3 inches passing sieve—Continued		Liquid limit	Plasticity index	Permeability	Available water capacity	Reaction	Shrink-swell potential	Corrosivity to—	
No. 40 (0.42 mm)	No. 200 (0.074 mm)							Uncoated steel	Concrete
		Pct		*In/hr*	*In/in of soil*	*pH*			
(2)	(2)			0.2–0.6	0.35–0.48	4.0–5.0	Low [3]	High	High.
25–70	2–20		NP	6.0–20.0	0.05–0.07	4.5–6.5	Low	High	High.
85–95	65–90		NP	0.6–2.0	0.19–0.23	5.1–6.0	Low	Moderate	Moderate.
85–95	55–75	20–40	4–12	0.06–0.2	0.14–0.18	5.6–7.3	Moderate	Moderate	Low.
85–95	55–75	20–30	4–12	0.06–0.2	0.14–0.18	6.6–7.8	Moderate	Moderate	Low.
85–95	55–85	16–24	0–3	0.6–2.0	0.16–0.24	5.0–5.5	Low	High	Moderate.
85–95	55–75	20–30	4–12	0.06–0.2	0.15–0.19	5.6–6.5	Low	High	Moderate.
85–95	55–75	20–30	4–12	0.06–0.2	0.14–0.18	6.6–7.8	Low	High	Low.
20–55	5–15		NP	6.0–20.0	0.06–0.10	5.1–6.5	Low	Low	Moderate.
10–25	0–5		NP	20.0	0.02–0.04	5.5–6.5	Low	Low	Moderate.
(2)	(2)			>6.0	0.58–0.70	3.5–4.5	Low [3]	High	High.
(2)	(2)			0.6–6.0	0.48–0.58	4.0–5.0	Low [3]	High	High.
80–95	50–75	15–25	0–4	0.6–2.0	0.20–0.22	4.5–6.0	Low	High	Moderate.
85–100	70–90	40–60	20–35	0.06–0.2	0.10–0.14	5.1–7.8	Moderate	High	Moderate.
85–100	70–90	40–60	20–35	0.06–0.2	0.09–0.13	7.4–8.4	Moderate	High	Moderate.
(2)	(2)			>6.0	0.55–0.65	3.4–4.5	Low [3]	High	High.
(2)	(2)			0.6–6.0	0.45–0.55	4.0–4.5	Low [3]	High	High.
(2)	(2)			0.2–6.0	0.35–0.48	4.0–5.0	Low [3]	High	High.
90–95	76–85	20–30	NP–4	0.6–2.0	0.18–0.24	5.1–6.5	Low	High	Moderate.
80–95	50–80	20–30	2–12	0.06–0.2	0.17–0.19	6.1–7.3	Low	High	Moderate.
80–95	50–80	20–30	2–12	0.06–0.2	0.14–0.19	6.6–7 8	Low	High	Moderate.
(2)	(2)			0.6–6.0	0.48–0.58	4.0–5.0	Low [3]	High	High.
70–95	35–75	14–30	0–12	0.06–0.6	0.07–0.19	5.1–7.3	Moderate	High	High.
(2)	(2)			0.6–6.0	0.48–0.58	5.0–6.5	Low [3]	High	High.
85–95	50–65	15–25	1–3	0.6–2.0	0.20–0.24	4.5–6.5	Low	Moderate	Low.
70–80	30–50	14–20	NP–1	0.2–0.6	[4] 0.07–0.13	4.5–7.3	Low	Moderate	Low.
70–80	30–50	14–20	NP–1	0.2–0.6	[4] 0.07–0.13	6.1–7.8	Low	Moderate	Low.
75–95	10–45	NP	NP	6.0–20.0	0.07–0.10	4.5–6.0	Low	Moderate	High.
45–95	2–10	NP	NP	6.0–20.0	0.05–0.07	5.1–6.0	Low	Moderate	High.
50–90	15–35	NP	NP	0.6–6.0	0.07–0.22	4.5–6.0	Low [3]	High	High.
45–90	1–5	NP	NP	6.0–20.0	0.05–0.07	4.5–6.0	Low	High	High.
70–90	10–20	NP	NP	6.0–20.0	0.10–0.12	4.5–4.4	Low	Low	Moderate.
70–90	2–10	NP	NP	6.0–20.0	0.05–0.07	5.1–7.3	Low	Low	Moderate.
95–100	90–98	30–40	10–20	0.2–0.6	0.18–0.20	4.5–6.0	Moderate	High	Moderate.
99–100	90–98	65–90	35–55	0.06–0.2	0.10–0.14	5.0–7.8	High	High	Low.
99–100	90–98	65–90	35–55	<0.06	0.10–0.14	7.4–8.0	High	High	Low.
75–85	50–75	20–30	NP–6	0.6–2.0	0.20–0.22	4.5–6.5	Low	High	Low.
65–75	30–50	10–20	NP–4	0.6–2.0	0.16–0.18	5.6–7.3	Low	High	Low.
65–75	25–45	10–20	NP–4	0.02–0.6	0.10–0.12	6.1–7.8	Low	High	Low.
90–100	35–80	20–40	1–10	2.0–6.0	0.20–0.22	6.1–7.8	Low	High	Low.
90–100	75–90	20–40	5–15	0.6–2.0	0.17–0.19	6.1–7.8	Low to moderate	High	Low.
90–100	75–90	20–40	1–10	0.6–2.0	0.20–0.22	7.4–8.4	Low	High	Low.
(2)	(2)			0.6–6.0	0.35–0.48	4.0–5.0	Low [3]	High	High.
85–95	60–85			0.06–0.6	0.22–0.24	4.0–5.0	Moderate	High	High.
80–90	50–65	14–20	NP–2	<0.06	[4] 0.07–0.10	4.0–5.0	Low	High	High.
70–90	30–45	14–20	NP–2	0.2–0.6	0.11–0.16	4.0–6.0	Very low	High	High.
80–90	35–45	10–20	NP–2	0.6–2.0	0.12–0.16	5.6–6.0	Low	Moderate	Moderate.
80–90	35–45	10–20	NP–2	0.6–2.0	0.10–0.14	6.1–6.5	Low	Moderate	Moderate.
10–25	0–5	NP	NP	>20.0	0.30	6.6–7.3	Low	Moderate	Moderate.
85–95	50–85			0.6–2.0	0.20–0.22	4.5–6.0	Moderate	High	High.
85–95	50–85			0.6–2.0	0.17–0.19	5.1–7.3	Low	High	Moderate.
10–45	0–5	NP	NP	>20.0	0.02–0.04	6.1–7.3	Low	High	Low.
(2)	(2)			6.0	0.55–0.65	3.0–4.5	Low [3]	High	High.

[4] Because of high bulk density that restricts root penetration, these layers supply a limited amount of moisture to plants.
[5] Too variable to rate

TABLE 7.—*Engineering interpretations*

[An asterisk in the first column indicates that at least one mapping unit is made of two or more kinds of soil. The soils in such mapping other series as indicated. "Shrink-swell" and some of the other terms that describe restrictive soil features are defined

Soil series and map symbols	Degree and kind of limitations for—					
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets
*Ahmeek:						
21, 975	Severe: percs slowly.	Slight	Slight	Slight	Slight	Moderate: frost action.
21C, 975C	Severe: percs slowly.	Severe: slope	Moderate: slope.	Moderate: slope.	Slight	Moderate: frost action.
21E, 975E	Severe: slope	Severe: slope	Severe: slope	Severe: slope	Moderate: slope.	Severe: slope
For Omega parts of 975, 975C, and 975E, see Omega series.						
Allendale: 22	Severe: wet	Slight	Severe: wet	Severe: wet	Severe: wet	Severe: wet; low strength.
Alstad: 292	Severe: wet	Slight	Severe: wet	Severe: wet	Severe: wet	Severe: frost action.
Alstad Variant: V292	Severe: wet	Slight	Severe: wet	Severe: wet	Severe: wet	Severe: wet
Automba:						
43	Severe: percs slowly.	Slight	Slight	Slight	Slight	Moderate: frost action.
43B	Severe: percs slowly.	Moderate: slope.	Slight	Slight	Slight	Moderate: frost action.
Bergland: 305	Severe: wet	Slight	Severe: wet; too clayey.	Severe: wet	Severe: wet	Severe: shrink-swell; low strength.
Beseman: 531	Severe: wet	Severe: excess humus.	Severe: wet	Severe: low strength.	Severe: wet	Severe: low strength.
*Blackhoof: 980	Severe: wet	Severe: excess humus.	Severe: wet	Severe: wet	Severe: wet	Severe: wet
For Mahtowa part, see Mahtowa series.						
Borofolists: 1073	Severe: depth to rock.	Severe: depth to rock.	Severe: depth to rock.	Severe: depth to rock.	Severe: depth to rock.	Severe: depth to rock.
Borosaprists: 1074	Severe: wet; depth to rock.	Severe: wet; depth to rock.	Severe: wet; depth to rock.	Severe: wet; depth to rock.	Severe: wet; depth to rock.	Severe: wet; depth to rock.
*Campia:						
367	Slight	Moderate: seepage.	Slight	Slight	Slight	Moderate: frost action.
367C, 976C	Moderate: slope.	Severe: slope	Moderate: slope.	Moderate: slope.	Slight	Moderate: frost action.
For Ontonagon part of 976C, see Ontonagon series.						
367E	Severe: slope	Severe: slope	Severe: slope	Severe: slope	Slight	Severe: slope
*Cloquet:						
355	Slight [1]	Severe: seepage.	Moderate: small stones.	Slight	Severe: seepage.	Slight
355C	Moderate [1]: slope.	Severe: seepage.	Moderate: small stones.	Moderate: slope.	Severe: seepage.	Moderate: slope.
355E	Severe [1]: slope.	Severe: seepage.	Severe: slope	Severe: slope	Severe: seepage.	Severe: slope
977G	Severe [1]: slope.	Severe: slope	Severe: slope	Severe: slope	Severe: slope	Severe: slope
For Emmert part, see Emmert series.						
Cromwell: 268, 268B	Slight [1]	Severe: seepage.	Severe: cut-banks cave.	Slight	Severe: seepage.	Slight
Cushing: 204	Severe: percs slowly.	Slight	Slight	Slight	Slight	Moderate: frost action.
Dawson: 536	Severe: wet	Severe: excess humus.	Severe: wet	Severe: low strength.	Severe: wet	Severe: low strength; wet.
Duluth:						
504	Severe: percs slowly.	Slight	Slight	Slight	Slight	Moderate: frost action.
504C	Severe: percs slowly.	Severe: slope	Moderate: slope.	Moderate: slope.	Slight	Moderate: frost action.
504E	Severe: slope	Severe: slope	Severe: slope	Severe: slope	Moderate: slope.	Severe: slope
504G	Severe: slope	Severe: slope	Severe: slope	Severe: slope	Severe: slope	Severe: slope

of the soils

units may have different properties and limitations, and for this reason it is necessary to follow carefully the instructions for referring to in the Glossary. See text for definitions of "slight," "moderate," "good," "fair," and other terms used to rate soils]

Suitability as source of—			Soil features affecting—				
Road fill	Sand and gravel	Topsoil	Pond reservoir area	Embankments, dikes, and levees	Drainage for crops and pasture	Irrigation	Terraces and diversions
Fair: frost action	Unsuited	Fair: thin layer.	Favorable	Piping	Not needed	Percs slowly	Not needed.
Fair: frost action	Unsuited	Fair: thin layer.	Favorable	Piping	Not needed	Slope	Complex slope.
Fair: frost action	Unsuited	Poor: slope	Steep slope	Piping	Not needed	Slope	Complex slope.
Poor: shrink-swell; low strength.	Unsuited	Poor: too sandy.	Favorable	Low strength	Percs slowly	Fast intake; percs slowly.	Not needed.
Fair: wet	Unsuited	Fair: thin layer.	Favorable	Favorable	Percs slowly	Wet	Not needed.
Poor: wet	Unsuited	Poor: wet	Favorable	Favorable	Percs slowly	Wet	Not needed.
Fair: frost action	Unsuited	Fair: thin layer.	Favorable	Piping	Not needed	Percs slowly	Not needed.
Fair: frost action	Unsuited	Fair: thin layer.	Favorable	Piping	Not needed	Slope	Percs slowly.
Poor: shrink-swell; low strength.	Unsuited	Poor: too clayey.	Favorable	Low strength	Percs slowly	Wet	Not needed.
Poor: low strength.	Unsuited	Poor: wet	Seepage	Compressible	Favorable	Wet	Not needed.
Poor: wet	Unsuited	Poor: wet	Favorable	Favorable	Percs slowly	Wet	Not needed.
Poor: depth to rock.	Unsuited	Poor: thin layer.	Depth to rock.	Depth to rock.	Not needed	Rooting depth.	Rock outcrops.
Poor: wet; depth to rock.	Unsuited	Poor: wet	Depth to rock.	Depth to rock.	Depth to rock.	Wet	Depth to rock.
Fair: frost action	Unsuited	Good	Seepage	Piping	Not needed	Favorable	Not needed.
Fair: frost action	Unsuited	Fair: slope	Seepage	Piping	Not needed	Slope	Favorable.
Poor: frost action	Unsuited	Poor: slope	Seepage	Piping	Not needed	Slope	Slope.
Good	Good	Fair: thin layer.	Seepage	Seepage	Not needed	Seepage	Not needed.
Good	Good	Fair: slope	Seepage	Seepage	Not needed	Seepage	Rooting depth.
Fair: slope	Good	Poor: slope	Seepage	Seepage	Not needed	Slope	Slope.
Poor: slope	Good	Poor: slope	Seepage	Seepage	Not needed	Steep slope	Steep slope.
Good	Good for sand.	Good	Seepage	Seepage	Not needed	Favorable	Too sandy.
Fair: frost action	Unsuited	Good	Favorable	Low strength	Not needed	Percs slowly	Not needed.
Poor: low strength; wet.	Poor: wet	Poor: wet	Seepage	Compressible	Favorable	Wet	Not needed.
Fair: frost action	Unsuited	Fair: small stones.	Favorable	Low strength	Not needed	Percs slowly	Not needed.
Fair: frost action	Unsuited	Fair: slope	Favorable	Low strength	Not needed	Slope	Percs slowly.
Poor: slope	Unsuited	Poor: slope	Slope	Low strength	Not needed	Slope	Slope.
Poor: slope	Unsuited	Poor: slope	Steep slope	Steep slope	Not needed	Steep slope	Steep slope.

TABLE 7.—*Engineering interpretations*

Soil series and map symbols	Degree and kind of limitations for—					
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets
Dusler: 502	Severe: percs slowly.	Slight	Severe: wet	Severe: wet	Severe: wet	Severe: wet
Emmert:						
12C	Moderate [1]: slope.	Severe: seepage.	Moderate: small stones.	Moderate: slope.	Severe: seepage.	Moderate: slope.
12E	Severe [1]: slope.	Severe: slope.	Severe: slope.	Severe: slope.	Severe: seepage.	Severe: slope.
Fluvaquents: 1005	Severe: wet	Severe: floods.	Severe: wet	Severe: wet	Severe: wet	Severe: wet.
Greenwood: 530, 549	Severe: wet	Severe: wet	Severe: wet	Severe: low strength; wet.	Severe: wet	Severe: low strength; wet.
Hibbing:						
254	Severe: percs slowly.	Slight	Severe: too clayey.	Moderate: shrink-swell.	Severe: too clayey.	Severe: low strength.
254C	Severe: percs slowly.	Severe: slope.	Severe: too clayey.	Severe: shrink-swell.	Severe: too clayey.	Severe: low strength.
Lobo: 537	Severe: wet	Severe: excess humus.	Severe: wet	Severe: wet	Severe: wet	Severe: low strength; wet.
Loxley: 533	Severe: wet	Severe: excess humus.	Severe: wet	Severe: low strength; wet.	Severe: wet	Severe: low strength; wet.
Mahtowa	Severe: wet	Severe: wet	Severe: wet	Severe: wet	Severe: wet	Severe: wet
Mapped only with Blackhoof soils.						
Merwin: 535	Severe: wet	Severe: excess humus.	Severe: wet	Severe: low strength; wet.	Severe: wet	Severe: low strength; wet.
Mooselake: 534	Severe: wet	Severe: excess humus.	Severe: wet	Severe: low strength.	Severe: wet	Severe: low strength.
Mora: V166	Severe: wet	Slight	Severe: wet	Severe: wet	Severe: wet	Severe: frost action.
Nemadji: 186	Severe: wet	Severe: wet	Severe: cut-banks cave.	Severe: wet	Severe: wet	Moderate: wet.
Newson: 274	Severe: wet	Severe: wet	Severe: cut-banks cave.	Severe: wet	Severe: wet	Severe: wet
Omega:						
188	Slight [1]	Severe: seepage.	Severe: cut-banks cave.	Slight	Severe: seepage.	Slight
188C	Moderate [1]: slope.	Severe: seepage.	Severe: cut-banks cave.	Moderate: slope.	Severe: seepage.	Moderate: slope.
188E	Severe [1]: slope.	Severe: seepage.	Severe: cut-banks cave.	Severe: slope.	Severe: seepage.	Severe: slope.
Ontonagon:						
303	Severe: percs slowly.	Slight	Severe: too clayey.	Severe: shrink-swell.	Severe: too clayey.	Severe: low strength.
303C, 303E	Severe: percs slowly.	Severe: slope.	Severe: too clayey.	Severe: shrink-swell.	Severe: too clayey.	Severe: low strength.
Parent	Severe: wet	Slight	Severe: wet	Severe: wet	Severe: wet	Severe: wet
Mapped only with Twig soils.						
Spooner: 147	Severe: wet	Slight	Severe: wet	Severe: wet	Severe: wet	Severe: frost action.
*Twig: 990	Severe: wet	Severe: excess humus; wet.	Severe: wet	Severe: wet	Severe: wet	Severe: frost action; wet.
For Parent part, see Parent series.						
Udorthents: 1020	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
Warman:						
V337	Severe: wet	Severe: seepage.	Severe: wet	Severe: wet	Severe: wet	Severe: frost action.
337	Severe: wet	Severe: seepage.	Severe: wet	Severe: wet	Severe: wet	Severe: frost action.
Waskish: 538	Severe: wet	Severe: excess humus.	Severe: wet	Severe: low strength; wet.	Severe: wet	Severe: low strength; wet.

[1] Pollution is hazard to water supplies.

of the soils—Continued

Suitability as source of—			Soil features affecting—				
Road fill	Sand and gravel	Topsoil	Pond reservoir area	Embankments, dikes, and levees	Drainage for crops and pasture	Irrigation	Terraces and diversions
Poor: wet	Unsuited	Poor: wet	Favorable	Low strength	Percs slowly	Wet	Not needed.
Good	Good	Poor: too sandy.	Seepage	Seepage	Not needed	Seepage	Rooting depth.
Fair: slope	Good	Poor: too sandy.	Seepage	Seepage	Not needed	Slope	Slope.
Poor: wet	Unsuited	Poor: wet	Variable	Variable	Floods	Wet	Wet.
Poor: low strength	Unsuited	Poor: wet	Seepage	Compressible	Favorable	Wet	Not needed.
Poor: low strength	Unsuited	Poor: thin layer.	Favorable	Compressible	Not needed	Percs slowly	Not needed.
Poor: low strength	Unsuited	Poor: thin layer.	Slope	Compressible	Not needed	Percs slowly	Percs slowly.
Poor: low strength	Unsuited	Poor: wet	Seepage	Compressible	Poor outlets	Wet	Not needed.
Poor: low strength; wet.	Unsuited	Poor: wet	Seepage	Compressible	Favorable	Wet	Not needed.
Poor: wet	Unsuited	Poor: wet	Favorable	Favorable	Percs slowly	Wet	Not needed.
Poor: low strength; wet.	Unsuited	Poor: wet	Seepage	Compressible	Favorable	Wet	Not needed.
Poor: low strength	Unsuited	Poor: wet	Seepage	Compressible	Favorable	Wet	Not needed.
Poor: frost action	Unsuited	Poor: wet	Favorable	Piping	Percs slowly	Wet	Not needed.
Fair: wet	Fair for sand	Poor: too sandy.	Seepage	Seepage	Favorable	Wet	Not needed.
Poor: wet	Good for sand.	Poor: too sandy.	Seepage	Seepage	Favorable	Wet	Not needed.
Good	Good for sand.	Poor: too sandy.	Seepage	Seepage	Not needed	Seepage	Not needed.
Good	Good for sand.	Poor: too sandy.	Seepage	Seepage	Not needed	Seepage	Not needed.
Fair: slope	Good for sand.	Poor: too sandy; slope.	Seepage	Seepage	Not needed	Slope	Slope.
Poor: low strength	Unsuited	Poor: too clayey.	Favorable	Low strength	Not needed	Percs slowly	Not needed.
Poor: low strength	Unsuited	Poor: too clayey.	Favorable	Low strength	Not needed	Percs slowly	Percs slowly.
Poor: wet	Unsuited	Poor: wet	Favorable	Piping	Percs slowly	Wet	Not needed.
Poor: frost action	Unsuited	Poor: thin layer.	Favorable	Piping	Favorable	Wet	Not needed.
Poor: frost action; wet.	Unsuited	Poor: wet	Favorable	Piping	Percs slowly	Wet	Not needed.
Severe: slope	Unsuited	Poor: slope	Steep slope	Steep slope	Not needed	Steep slope	Steep slope.
Fair: wet	Good	Fair: wet	Seepage	Seepage	Favorable	Wet	Not needed.
Poor: wet	Fair	Poor: wet	Seepage	Seepage	Favorable	Wet	Not needed.
Poor: low strength; wet.	Unsuited	Poor: wet	Seepage	Seepage	Poor outlets	Wet	Not needed.

estimated soil properties significant to engineering and interpretations for various engineering uses.

This information, along with the soil map and other parts of this publication, can be used to make interpretations in addition to those given in table 7, and it also can be used to make other useful maps.

This information, however, does not eliminate the need for further investigations at sites selected for engineering works, especially works that involve heavy loads or that require excavations to a depth greater than that shown in the tables, generally a depth of more than 6 feet. Also, inspection of sites, especially the small ones, is needed because many delineated areas of a given soil mapping unit may contain small areas of other kinds of soil that have strongly contrasting properties and different suitabilities or limitations for soil engineering.

Some of the terms used in this soil survey have different meanings in soil science and in engineering. The Glossary defines many of these terms.

Engineering soil classification systems

The two systems most commonly used in classifying samples of soils for engineering are the Unified system used by the SCS engineers, Department of Defense, and others, and the AASHTO system adopted by the American Association of State Highway and Transportation Officials.

In the Unified system soils are classified according to particle size distribution, plasticity index, liquid limit, and content of organic matter (*2*). 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, CL–ML.

The AASHTO system is used to classify soils according to those properties that affect use in highway construction and maintenance (*1*). In this system, a soil is placed in one of seven basic groups ranging from A–1 through A–7 on the basis of grain-size distribution, liquid limit, and plasticity index. In group A–1 are gravelly soils of high bearing strength, or the best soils for subgrade (foundation). At the other extreme, in group A–7, are clay soils that have low strength when wet and that are the poorest soils for subgrade. Where laboratory data are available to justify a further breakdown, the A–1, A–2, and A–7 groups are divided as follows: A–1–a, A–1–b, A–2–4, A–2–5, A–2–6, A–2–7, A–7–5, and A–7–6. Group indexes range from 0 for the best material to 20 or more for the poorest. The estimated AASHTO classification is given in table 6 for all soils mapped in the survey area.

Soil properties significant to engineering

Estimates of several soil properties significant in engineering are given in table 6. These estimates are made for typical soil profiles, by layers sufficiently different to have different significance for soil engineering. The estimates are based on field observations made in the course of mapping, on test data for these and similar soils, and on experience with the same kinds of soil in other counties. Following are explanations of some of the columns in table 6.

Depth to seasonal high water table is distance from the surface of the soil to the highest level that ground water reaches in the soil in most years.

Soil texture is described in table 6 in the standard terms used by the U.S. Department of Agriculture. These terms take into account relative percentages of sand, silt, and clay in soil material that is less than 2 millimeters in diameter. "Loam," for example, is soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the soil contains gravel or other particles coarser than sand, an appropriate modifier is added, as for example, "gravelly loamy sand." "Sand," "silt," "clay," and some of the other terms used in USDA textural classification are defined in the Glossary of this soil survey.

Liquid limit and plasticity index indicate the effect of water on the strength and consistence of soil material. As the moisture content of a clayey soil is increased from a dry state, the material changes from a semisolid to a plastic. If the moisture content is further increased, the material changes from a plastic to a liquid. The plastic limit is the moisture content at which the soil material changes from a semisolid to a plastic; and the liquid limit, from a plastic to a 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.

Permeability is that quality of a soil that enables it to transmit water or air. It is estimated on basis of those soil characteristics observed in the field, particularly structure and texture. The estimates in table 6 do not take into account lateral seepage or such transient soil features as a plowpan or a surface crust.

Available water capacity is the ability of soils to hold water for use by most plants. It is commonly defined as the difference between the amount of water in the soil at field capacity and the amount at the wilting point of most crops.

Reaction is the degree of acidity or alkalinity of a soil, expressed in pH values. The pH value and terms used to describe soil reaction are explained in the Glossary.

Shrink-swell potential is the relative change in volume to be expected of soil material with changes in moisture content, that is, the extent to which the soil shrinks as it dries out or swells when it gets wet. Extent of shrinking and swelling is influenced by the amount and kind of clay in the soil. Shrinking and swelling of soils causes much damage to building foundations, roads, and other structures. A *high* shrink-swell potential indicates a hazard to maintenance of structures built in, on, or with material having this rating.

Corrosivity, as used in table 6, pertains to potential soil-induced chemical action that dissolves or weakens uncoated steel or concrete. Rate of corrosion of uncoated steel is related to soil properties such as drainage, texture, total acidity, and electrical conductivity of the soil material. Corrosivity for concrete is influenced mainly by the content of sodium or magnesium

sulfate, but also by soil texture and acidity. Installations of uncoated steel that intersect soil boundaries or soil horizons are more susceptible to corrosion than installations entirely in one kind of soil or in one soil horizon. A corrosivity rating of *low* means that there is a low probability of soil-induced corrosion damage. A rating of *high* means that there is a high probability of damage, so that protective measures for steel and more resistant concrete should be used to avoid or minimize damage.

Engineering interpretations of the soils

The estimated interpretations in table 7 are based on the engineering properties of soils shown in table 6, on test data for soils in this survey area and others nearby or adjoining, and on the experience of engineers and soil scientists with the soils of Carlton County. In table 7, ratings are used to summarize limitation or suitability of the soils for all listed purposes other than for drainage for crops and pasture, irrigation, ponds and reservoirs, embankments, and terraces and diversions. For these particular uses, table 7 lists those soil features not to be overlooked in planning, installation, and maintenance.

Soil limitations are indicated by the ratings slight, moderate, and severe. *Slight* means soil properties generally favorable for the rated use, or in other words, limitations that are minor and easily overcome. *Moderate* means that some soil properties are unfavorable but can be overcome or modified by special planning and design. *Severe* means soil properties so unfavorable and so difficult to correct or overcome as to require major soil reclamation, special designs, or intensive maintenance. For some uses, the rating of severe is divided to obtain ratings of severe and very severe.

Soil suitability is rated by the terms *good, fair,* and *poor,* which have, respectively, meanings approximately parallel to the terms slight, moderate, and severe.

Following are explanations of some of the columns in table 7.

Septic tank absorption fields are subsurface systems of tile or perforated pipe that distribute effluent from a septic tank into natural soil. The soil material from a depth of 18 inches to 6 feet is evaluated. The soil properties considered are those that affect both absorption of effluent and construction and operation of the system. Properties that affect absorption are permeability, depth to water table or rock, and susceptibility to flooding. Slope is a soil property that affects difficulty of layout and construction and also the risk of erosion, lateral seepage, and downslope flow of effluent. Large rocks or boulders increase construction costs.

Sewage lagoons are shallow ponds constructed to hold sewage within a depth of 2 to 5 feet long enough for bacteria to decompose the solids. A lagoon has a nearly level floor, and sides, or embankments, of compacted soil material. The assumption is made that the embankment is compacted to medium density and the pond is protected from flooding. Properties are considered that affect the pond floor and the embankment. Those that affect the pond floor are permeability, content of organic matter, and slope, and if the floor needs to be leveled, depth to bedrock becomes important. The soil properties that affect the embankment are the engineering properties of the embankment material as interpreted from the Unified soil classification and the amounts of stones, if any, that influence the ease of excavation and compaction of the embankment material.

Shallow excavations are those that require digging or trenching to a depth of less than 6 feet, as for example, excavations for pipelines, sewer lines, phone and power transmission lines, basements, open ditches, and cemeteries. Desirable soil properties are good workability, moderate resistance to sloughing, gentle slopes, absence of rock outcrops or big stones, and freedom from flooding or a high water table.

Dwellings, as rated in table 7, are not more than three stories high and are supported by foundation footings placed in undisturbed soil. The features that affect the rating of a soil for dwellings are those that relate to capacity to support load and resist settlement under load, and those that relate to ease of excavation. Soil properties that affect capacity to support load are wetness, susceptibility to flooding, density, plasticity, texture, and shrink-swell potential. Those that affect excavation are wetness, slope, depth to bedrock, and content of stones and rocks.

Sanitary landfill is a method of disposing of refuse in dug trenches. The waste is spread in thin layers, compacted, and covered with soil throughout the disposal period. Landfill areas are subject to heavy vehicular traffic. Some soil properties that affect suitability for landfill are ease of excavation, hazard of polluting ground water, and trafficability. The best soils have moderately slow permeability, withstand heavy traffic, and are friable and easy to excavate. Unless otherwise stated the ratings in table 7 apply only to a depth of about 6 feet, and therefore limitation ratings of *slight* or *moderate* may not be valid if trenches are much deeper than that. For some soils, reliable predictions can be made to a depth of 10 or 15 feet, but regardless of that, every site should be investigated before it is selected.

Local roads and streets, as rated in table 7, have an all-weather surface expected to carry automobile traffic all year. They have a subgrade of underlying soil material; a base consisting of gravel, crushed rock, or soil material stabilized with lime or cement; and a flexible or rigid surface, commonly asphalt or concrete. These roads are graded to shed water and have ordinary provisions for drainage. They are built mainly from soil at hand, and most cuts and fills are less than 6 feet deep.

Soil properties that most affect design and construction of roads and streets are load supporting capacity and stability of the subgrade, and the workability and quantity of cut and fill material available. The AASHTO and Unified classifications of the soil material, and also the shrink-swell potential, indicate traffic supporting capacity. Wetness and flooding affect stability of the material. Slope, depth to hard rock, content of stones and rocks, and wetness affect ease of excavation and amount of cut and fill needed to reach an even grade.

Road fill is soil material used in embankments for roads. The suitability ratings reflect the predicted performance of soil after it has been placed in an embankment that has been properly compacted and provided with adequate drainage and the relative ease of excavating the material at borrow areas.

Sand and gravel are used in great quantities in many kinds of construction. The ratings in table 7 provide guidance about where to look for probable sources. A soil rated as a *good* or *fair* source of sand or gravel generally has a layer at least 3 feet thick, the top of which is within a depth of 6 feet. The ratings do not take into account thickness of overburden, location of the water table, or other factors that affect mining of the materials, and neither do they indicate quality of the deposit.

Topsoil is used for topdressing an area where vegetation is to be established and maintained. Suitability is affected mainly by ease of working and spreading the soil material, as for preparing a seedbed; natural fertility of the material, or the response of plants when fertilizer is applied; and absence of substances toxic to plants. Texture of the soil material and its content of stone fragments are characteristics that affect suitability, but also considered in the ratings is damage that can result at the area from which topsoil is taken.

Pond reservoir areas hold water behind a dam or embankment. Soils suitable for pond reservoir areas have low seepage, which is related to their permeability and depth to fractured or permeable bedrock or other permeable material.

Embankments, dikes, and levees require soil material resistant to seepage and piping and of favorable stability, shrink-swell potential, shear strength, and compactibility. Presence of stones or organic material in a soil are among factors that are unfavorable.

Drainage for crops and pasture is affected by such soil properties as permeability, texture, and structure; depth to claypan, rock, or other layers that influence rate of water movement; depth to the water table; slope; stability in ditchbanks; susceptibility to stream overflow; salinity or alkalinity; and availability of outlets for drainage.

Irrigation of a soil is affected by such features as slope; susceptibility to stream overflow, water erosion or soil blowing; soil texture; content of stones; accumulations of salts and alkali; depth of root zone; rate of water intake at the surface; permeability of soil layers below the surface layer and in fragipans or other layers that restrict movement of water; amount of water held available to plants; and need for drainage, or depth to water table or bedrock.

Terraces and diversions are embankments, or ridges, constructed across the slope to intercept runoff so that it soaks into the soil or flows slowly to a prepared outlet. Features that affect suitability of a soil for terraces are uniformity and steepness of slope; depth to bedrock or other unfavorable material; presence of stones; permeability; and resistance to water erosion, soil slipping, and soil blowing. A soil suitable for these structures provides outlets for runoff and is not difficult to vegetate.

Town and country planning

This section serves as a guide to help homesite buyers, realtors, developers, planning commissions, health departments, and various governmental agencies make land-use decisions.

The soils in Carlton County are placed in community development groups according to their properties and limitations. Important properties considered are natural soil drainage, texture, permeability, and depth to water table. The kinds of uses considered are foundations for buildings of three stories or less, local roads and streets, shallow excavations, lawns and gardens, houses with basements, and septic tank absorption fields.

Control of erosion and runoff are needed in land-use planning. Where development is intensive, a plan for erosion control is needed before construction begins to avoid or lessen the hazards of soil erosion, runoff, and sedimentation. Urban development can be adapted to the site and landscape. Grading and exposure of bare soil should be limited, and appropriate erosion control practices should be applied to the site.

Most factors that influence development are noted in each of the seven community development groups described on the following pages. The major soil limitations are defined for each group. Engineering tables list detailed information for each soil. Such economic factors as the distance from a street or road are not considered. The community development group into which each soil in the county is placed can be found in the "Guide to Mapping Units" at the end of this survey.

The soil limitations described are expressed as slight, moderate, and severe. *Slight* means the limitations are minor and are easily overcome. *Moderate* means that some soil properties are unfavorable but can be overcome or modified by special planning and design. *Severe* indicates soil properties so unfavorable and so difficult to correct or overcome that major soil reclamation, special design, or intensive maintenance is required.

These interpretations do not eliminate the need for detailed onsite investigation. Also, engineers and others should not apply specific values to the estimates given for bearing capacity of soils.

Community development group 1

In this group are excessively drained and somewhat excessively drained, sandy and loamy soils that are underlain by sandy material or gravelly sand material. These soils have slight to very severe limitations for community development.

The seasonal high water table is below a depth of 5 feet. Permeability is rapid to very rapid in the underlying material. Bearing capacity is low to high. Shear strength is medium to high. Shrink-swell potential is low. Potential frost action is low. Slopes range from 0 to 60 percent.

Limitations for local roads and streets, for dwellings that have basements, and for septic tank filter fields are slight if the slope is 0 to 6 percent, moderate if 6 to 12 percent, and severe if more than 12 percent. Limitations for excavations are moderate if the slope

is less than 12 percent and severe if more than 12 percent. Limitations for lawns and gardens are moderate if the slope is less than 12 percent and severe if more than 12 percent.

The hazard of erosion on the soils increases as the steepness and length of slope increase. Septic tank filter fields function well, but because the underlying material is rapidly permeable, there is a hazard of pollution. Sidewall stability is poor in the underlying material, and caving is a hazard during excavation. The sandy soils are so difficult to vegetate that additional fertilizer and water are needed to establish good plant cover.

Community development group 2

In this group are well drained and moderately well drained, loamy soils. These soils have slight to severe limitations for most types of community development.

The seasonal high water table is generally below a depth of 5 feet, but it is often perched above a claypan or fragipan for a few days after rain. Permeability is moderate to slow. Bearing capacity is low to high. Shear strength is low medium. Shrink-swell potential is low to moderate. Potential frost action is moderate. Slopes range from 0 to 35 percent.

Limitations for excavations and for dwellings that have basements are slight to moderate if the slope is less than 12 percent and severe if more than 12 percent. Limitations for local roads and streets are moderate if the slope is less than 12 percent and severe if more than 12 percent. Limitations for septic tank filter fields are slight to severe because of slope or permeability. Limitations for lawns and gardens are slight if the slope is less than 12 percent.

Most soils in this group are limited for community development because the percolation rates are too slow for septic tank filter fields to function properly. The hazard of erosion increases with an increase in the steepness and length of slope. Normally, tile drainage is used around foundations.

Community development group 3

In this group are well drained and moderately well drained, clayey soils.

The seasonal high water table is generally below a depth of 5 feet, but it is often perched above the claypan for a few days after rain. Permeability is slow and very slow. Bearing capacity is low to medium. Shear strength is low to high. Shrink-swell potential is high. Potential frost action is moderate. Slopes range from 0 to 60 percent.

Limitations for local roads and streets, excavations, lawns and gardens, dwellings that have basements, and septic tank filter fields are severe.

Soils in this group are severely limited for community development because the percolation rates are too slow for septic tank filter fields to function properly. Foundations and roads are subject to structural damage because of the shrink-swell potential of these clayey soils.

Community development group 4

In this group are mainly somewhat poorly drained and poorly drained, loamy soils. These soils have severe limitations for most types of community development. Some sandy soils are also in this group.

The seasonal high water table is generally at a depth of 1 to 4 feet. Permeability is slow to moderately rapid. Bearing capacity is low to high. Shear strength is low to high. Shrink-swell potential is low to high. Potential frost action is moderate to high. Slopes range from 0 to 2 percent.

Limitations for foundations, local roads and streets, excavations, lawns and gardens, dwellings that have basements, and septic tank filter fields are severe.

Limitations of soils in this group are caused mainly by a moderately high fluctuating water table. Shallow excavations often expose the water table, and there is a hazard of caving in the underlying material. Basement seepage is a concern. Roads and streets can be structurally damaged by frost action. In places septic tank filter fields do not function properly during wet periods. There is a hazard of contaminating ground water, especially in the sandy soils.

Community development group 5

This group consists of very poorly drained mineral soils. These soils have severe limitations for community development.

The seasonal high water table is generally at a depth of less than 1 foot. Permeability is rapid to very slow. Bearing capacity is low to high. Shear strength is low to high. Shrink-swell potential is low to high. Potential frost action is high. Slopes range from 0 to 2 percent.

Limitations for all types of development are severe as a result of wetness. The high frost action potential is a hazard for roads and parking lots. Drainage is needed for most construction projects.

Community development group 6

In this group are very poorly drained organic soils. These soils have severe limitations for community development.

The seasonal high water table is generally at the surface. Permeability varies widely. Bearing capacity is poor. Shear strength is poor. Potential frost action is high. Slopes are 0 to 2 percent.

These soils are very severely limited for all types of development because of the high water table and the very poor strength of the organic material. Soils in this group have a low bulk density, are very compressible, and generally are unsuited to construction. The soils in this group are generally better suited to open space, wildlife habitat, and natural areas than to other uses.

Community development group 7

In this group are excessively drained and very poorly drained soils that are very shallow and shallow over bedrock. They are severely limited for community development.

The seasonal high water table is generally near the surface in areas that have concave slopes. Permeability is restricted by bedrock. Bearing capacity and shear strength are high in bedrock. Shrink-swell potential

is low. Potential frost action is low to high. Slopes are nearly level to undulating.

Limitations for all types of community development are severe because of the shallow depth to bedrock. Excavations for basements and utilities are difficult. Septic tank filter fields do not function properly on these soils.

Formation and classification of the soils

In this section the factors that have affected the formation and morphology of the soils in Carlton County are discussed. Then the current system of soil classification is explained and the soil series are placed in higher categories. The soil series in the county, including a profile representative of each series, are described in the section "Descriptions of the soils."

Factors of soil formation

Five factors have determined the formation of soils in Carlton County: parent material; time; climate; plants and animals, chiefly plants; and relief, or lay of the land. Except for time, each of these consists of many individual factors. Climate, for example, is made up of temperature, the amount of sunshine, the amount and distribution of rainfall, and other factors. Moreover, one group of factors influences another. Vegetation is largely, though not entirely, controlled by climate. The degree of horizon development, which reflects the age of the soil, depends partly on relief. Characteristics of any soil are determined by and can be explained by the interaction of these five factors. The five factors are discussed on the following pages.

Parent material

Organic material, glacial till, outwash sediment, and glacial lake sediment make up the parent material of the soils in Carlton County. The differences between these parent materials account for many of the differences among the soils in the county. For example, some of the soils are sandy because their parent material was sandy, and others are clayey because their parent material was clayey. In the paragraphs that follow, the different kinds of parent material are discussed.

Organic material.—The organic soils formed in partly decomposed plant tissue. Herbaceous, woody, and mossy organic materials make up the major kinds of parent material of the organic soils of Carlton County. These materials together with the relief or surface-water flow within the bog determine to a large degree the kind and amount of natural vegetation that grows. For example, the soils that formed in woody material are less acid and are often upslope from the soils that formed in herbaceous material. The soils that formed in mossy material are extremely acid and are near the watershed divide within the bog.

Glacial till.—Glacial ice from the Superior and Des Moines Lobes deposited unsorted, nonstratified till in Carlton County (*16*). The last three phases, or major ice advances, of the Superior Lobe left most of the till in the county. They are the Automba Phase, followed by the Split Rock Phase, followed shortly by the Nickerson Phase. Till from the Des Moines Lobe and its St. Louis Sublobe occurs only in the northwestern corner of the county.

Automba Till is reddish brown fine sandy loam. Typically it is about 8 percent clay, 30 percent silt, 35 percent fine and very fine sand, and 27 percent medium to coarse sand. Bulk density generally ranges from 1.9 to 2.1. Coarse fragments generally make up 10 to 20 percent, by volume, of the till. Basalt, gabbro, red sandstone, shale, and felsite are the major kinds of rock in this till. Drumlins and moraines are the major landforms. Soils of the Ahmeek and Mora series are examples of the kind of soil formed in Automba Till.

Split Rock and Nickerson Till are similar in physical and chemical properties. The till is reddish brown and in most places is loam. On the average it is 20 percent clay, 45 percent silt, and 35 percent sand. Bulk density generally ranges from 1.7 to 1.9. Coarse fragments generally make up about 1 to 10 percent, by volume. Basalt, gabbro, red sandstone, shale, and felsite are the major kinds of rock in this till. The major landforms are moraines that reach an elevation of about 1,300 feet for the Split Rock Phase and 1,200 feet for the Nickerson Phase. Soils of the Duluth and Dusler series formed in the loam till. In some places, however, this reddish brown till is about 40 percent clay, 40 percent silt, and 20 percent sand. Hibbing soils formed in this finer textured till.

Alborn Till, deposited by the St. Louis Sublobe of the Des Moines Lobe, ranges from reddish brown or dark brown to olive brown in well drained areas. The amounts of clay, silt, and sand, and coarse fragments are similar to the Split Rock and Nickerson Till. However, granite, shale, and limestone fragments are common. In most places the till contains 10 to 15 percent calcium and magnesium carbonates. The major landforms are moraines that reach an elevation of about 1,320 feet. Soils of the Alstad and Cushing series formed in Alborn Till.

Outwash sediment.—The Sawyer and Cloquet outwash plains and the valleys of all of the rivers except those in the southeastern part of the county have outwash sediment. Typically these areas have 1 to 2 feet of loamy material underlain by sand and gravel. Cromwell and Cloquet soils, for instance, formed in loamy material underlain by sand and gravel.

Glacial lake sediment.—Water-sorted sediment from Glacial Lakes Nemadji and Duluth is the parent ma-

terial of soils in the eastern part of the county. This material ranges from sand to clay. Most of the lake sediment is reddish brown, but in the Wrenshall area it is brown to olive brown. Except for the sandy beaches, the lake sediment contains calcium and magnesium carbonate. Ontonagon and Bergland soils formed in the reddish brown clay sediment. Campia and Spooner soils formed in the brown to olive brown silt loam sediment.

Time

The soils in Carlton County vary in degree of development, depending on the length of time that the soil-forming forces have been active. The oldest surfacial till in Carlton County, Automba Till in which the Ahmeek soils formed, may be about 18,000 years old. The Split Rock Till is about 16,000 years old, and the Nickerson Till is about 11,000 to 12,000 years old. Because of the cold climate adjacent to the ice lobes, soil formation probably was not intense until after the melting of the last ice lobe. This may account for some of the similarity between the Duluth soils on the Split Rock Till and on the younger Nickerson Till.

Climate

Climate is a major factor in determining the kinds of soil that form in different kinds of parent material. It determines the vegetation and influences the rate and intensity of the physical, chemical, and biological relationships in the soil profile, chiefly through the effects of precipitation and temperature. In turn, the effects of climate and vegetation vary according to the topography and the length of time the parent material has been in place.

Carlton County has a subhumid, continental climate. Conditions vary widely between summer and winter. The climate is essentially uniform throughout the county except in the northeastern part, which is influenced by Lake Superior to some degree. The precipitation and temperature are described in detail in the section "General nature of the county."

Plants and animals

Plants, animals, bacteria, and other organisms are active in soil-forming processes. The changes they bring about depend chiefly on the life processes peculiar to each. The kinds of plants and animals that live on and in the soil are affected by climate, parent material, relief, and age of the soil.

The vegetation in Carlton County about 16,000 to 12,000 years ago was tundra *(16)*. This was followed by a spruce forest until about 8,000 years ago. The spruce forest was slowly replaced by pine and northern hardwoods. With the succession of vegetation from treeless tundra to boreal forest, the soil profiles became progressively more weathered and the major horizons became more distinct. However, mixing of the horizons by tree windthrow and by animals and recycling of nutrients tended to offset the intensity of leaching and differentiation of horizons.

Small animals, such as earthworms and insects, influence the formation of soils by mixing the organic matter in the soil and helping to break down remains of plants. Bacteria, actinomycetes, fungi, algae, and other micro-organisms hasten the weathering of rocks and the decomposition of organic matter.

Relief

Relief, through its effect on drainage, aeration, and erosion, is an important factor in formation of soils. Most of the peat and muck soils in Carlton County originated in enclosed depressions and wet drainageways. The lack of aeration and accumulation of the remains of plants has raised the surface of many of the enclosed bogs until the surface-water flow from the bogs breached the uplands and now drains into the rivers and creeks.

Differences in relief can account for the development of different soils in the same parent material such as the Udorthents and Ontonagon soils. The steep soils, such as Udorthents, have more surface runoff and thus have less water for percolation through the profile than Ontonagon soils. In addition, Udorthents creep and slide down the slope. These factors of relief make the profile thinner.

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 to 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.

The narrow categories of classification, such as those used in detailed soil surveys, allow us to organize and apply knowledge about soils in managing farms, fields, and woodlands; 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 system of soil classification currently used was adopted by the National Cooperative Soil Survey in 1965. Because this system is under continual study, readers interested in developments of the current system should search the latest literature available *(15)*.

The current system of classification has six categories. Beginning with 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. In table 8, the soil series of Carlton County are placed in five categories of the current system. Classes of the current system are briefly defined in the following paragraphs.

ORDER. Ten soil orders are recognized. The properties used to differentiate among 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 climates. Each order is named with a word of three or four syllables ending in *sol* (Moll-i-sol).

SUBORDER. Each order is subdivided into suborders that are based primarily on those soil characteristics that seem to produce classes with the greatest genetic similiarity. 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 water-logging, or soil differences resulting from the climate or vegetation. The names of suborders have two syllables. The last syllable indicates the order. An example is *Aquoll* (*Aqu,* meaning water or wet, and *oll,* from *Mollisol*).

GREAT GROUP. Soil suborders are separated into great groups on the basis of uniformity in the kinds and sequence of major soil horizons and features. The horizons used to make separations are those in which clay, iron, or humus have accumulated; those that have pans that interfere with growth of roots, movement of water, or both; and a thick, dark colored surface horizon. The features used are the self-mulching properties of clay, temperature, major differences in chemical composition (mainly calcium, magnesium, sodium, and potassium), dark red and dark brown colors associated with basic rocks, and the like. The names of

TABLE 8.—*Classification of soil series*

Series	Family	Subgroup	Order
Ahmeek	Coarse-loamy, mixed, frigid	Typic Fragiochrepts	Inceptisols.
Allendale [1]	Sandy over clayey, mixed, frigid	Aqualfic Haplorthods	Spodosols.
Alstad [1]	Fine-loamy, mixed	Aquic Futroboralfs	Alfisols.
Alstad Variant	Fine-loamy, mixed, frigid	Aeric Ochraqualfs	Alfisols.
Automba	Coarse-loamy, mixed	Glossic Eutroboralfs	Alfisols.
Bergland	Very-fine, mixed, nonacid, frigid	Arenic Haplaquepts	Inceptisols.
Beseman	Loamy, mixed, dysic	Terric Borosaprists	Histosols.
Blackhoof	Fine-loamy, mixed, nonacid, frigid	Histic Humaquepts	Inceptisols.
Borofolists	(2)	(2)	Histosols.
Borosaprists	(2)	(2)	Histosols.
Campia [1]	Fine-silty, mixed	Typic Glossoboralfs	Alfisols.
Cloquet	Coarse-loamy over sandy or sandy-skeletal, mixed, frigid	Typic Dystrochrepts	Inceptisols.
Cromwell	Sandy, mixed, frigid	Typic Dystrochrepts	Inceptisols.
Cushing	Fine-loamy, mixed	Glossic Eutroboralfs	Alfisols.
Dawson	Sandy or sandy-skeletal, mixed, dysic	Terric Borosaprists	Histosols.
Duluth	Fine-loamy, mixed	Glossic Futroboralfs	Alfisols.
Dusler	Fine-loamy, mixed, frigid	Aeric Glossaqualfs	Alfisols.
Emmert	Sandy-skeletal, mixed, frigid	Typic Udorthents	Entisols.
Fluvaquents	(2)	(2)	Entisols.
Greenwood	Dysic	Typic Borohemists	Histosols.
Hibbing	Fine, mixed	Typic Futroboralfs	Alfisols.
Lobo	Dysic, frigid	Hemic Sphignofibrists	Histosols.
Loxley	Dysic	Typic Borosaprists	Histosols.
Mahtowa	Fine-loamy, mixed, frigid	Typic Haplaquolls	Mollisols.
Merwin	Loamy, mixed, dysic	Terric Borohemists	Histosols.
Mooselake	Euic	Typic Borohemists	Histosols.
Mora [1]	Coarse-loamy, mixed	Aquic Fragiboralfs	Alfisols.
Nemadji	Mixed, frigid	Spodic Udipsamments	Entisols.
Newson	Mixed, frigid	Humaqueptic Psammaquents	Entisols.
Omega	Mixed, frigid	Spodic Udipsamments	Entisols.
Ontonagon	Very-fine, mixed	Glossic Eutroboralfs	Alfisols.
Parent [1]	Coarse-loamy, mixed, frigid	Typic Haplaquolls	Mollisols.
Spooner	Fine-silty, mixed, frigid	Typic Ochraqualfs	Alfisols.
Twig	Coarse-loamy, mixed, acid, frigid	Histic Humaquepts	Inceptisols.
Udorthents	(2)	(2)	Entisols.
Warman [1]	Coarse-loamy over sandy or sandy-skeletal, mixed, nonacid, frigid.	Histic Humaquepts	Inceptisols.
Waskish	Dysic, frigid	Typic Sphagnofibrists	Histosols.

[1] These soils are taxadjuncts. The reasons for excluding them from the series with which they are here identified are as follows:
Allendale soils lack spodic horizons; in this county they are classified as Aquic Eutroboralfs.
Alstad soils have lower chroma and more tonguing in the B horizon than is defined in the range for the series; in this county they are classified as Typic Glossaqualfs.
Campia soils have a higher degree of base saturation in the B horizon than is defined in the range for the series; in this county they are classified as Typic (Glossic) Eutroboralfs.
Mora soils are wetter than is defined in the range for the series.
Parent soils have higher chroma in the B horizon than is defined in the range for the series; in this county they are classified as Mollic Haplaquepts.
Warman fine sandy loam does not have a histic epipedon, and in this county it is classified as Aeric Haplaquepts.

[2] Not classified in lower categories.

great groups have three or four syllables and are made by adding a prefix to the name of the suborder. An example is *Haplaquoll* (*Hapl*, meaning simple horizons, *aqu* for wetness or water, and *oll*, from *Mollisol*).

SUBGROUP. Great groups are subdivided 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 of the range of any other great group, suborder, or order. The names of subgroups are derived by placing one or more adjectives before the name of the great group. An example is *Typic Haplaquoll* (a typical Haplaquoll).

FAMILY. Soil families are separated within a subgroup primarily on the basis of properties important to the growth of plants or on the behavior of soils when used for engineering. Among the properties considered are texture, mineralogy, reaction, soil temperature, permeability, thickness of horizons, and consistence. The adjectives are the class names for texture, mineralogy, and so on, that are used as family differentiae. An example is the coarse-loamy, mixed, frigid family of Typic Haplaquolls.

General nature of the county

This section provides general information about Carlton County. It describes the climate, rural development, transportation and markets, and water resources.

Climate [4]

Carlton County is near the center of the North American continent, and this location is the chief factor in determining the climate of the county. Summers are warm because the county is heated under a summer sun that shines for long hours at a high elevation. Because southerly winds bring up warm, moist air from the Gulf of Mexico, summer is the season of greatest precipitation. Winters are in sharp contrast as the county cools rapidly under less effective solar heating that results from short days and the low sun. Prevailing northerly winds cause additional cooling, and because the air masses are relatively dry, winter is the season of least precipitation. Table 9 gives temperature and precipitation data for Carlton County.

Approximately 71 percent, almost 22 inches, of the annual precipitation occurs from April to September. Measurable precipitation of 0.01 inch can be expected on about 135 days per year, 15 of which have one-half inch or more. Rainfall of about 1 inch an hour can be expected once in 2 years. Table 9 lists the highest and lowest precipitation expected to occur 1 year in 10 for each month. Annual amounts ranged from 19.60 inches in 1918 to 41.40 inches in 1953. The greatest amount at Cloquet in any month was 9.73 inches in July 1944. About 34 thunderstorms occur on an average each year, some accompanied by hail and damaging winds. Tornadoes occur in Carlton County; two were reported between 1961 and 1971.

[4] By EARL L. KUEHMAST, climatologist for Minnesota, National Weather Service, United States Department of Commerce.

TABLE 9.—*Temperature and precipitation*

[Data from Cloquet, based on period 1941–1970, except as indicated]

Month	Temperature				Precipitation				
						One year in 10 will have— (based on data 1911–1972)		Snow cover [1]	
	Normal daily high	Normal daily low	Normal highest	Normal lowest	Total	Less than—	More than—	Days with snow cover 1 inch or more	Average depth of snow on days with snow cover
	°F	°F	°F	°F	Inches	Inches	Inches		Inches
January	18.7	−1.9	37	−29	1.09	0.29	2.09	30	10.0
February	23.6	7.4	41	−25	.82	.29	1.63	28	13.8
March	36.2	12.8	52	−15	1.66	.35	2.73	27	13.1
April	51.6	27.8	73	11	2.44	1.05	4.25	6	2.5
May	65.0	36.8	84	23	3.67	1.55	5.66	(2)	2.0
June	73.8	47.0	88	31	4.55	1.47	6.80	----	----
July	79.6	52.7	91	39	4.00	1.46	6.88	----	----
August	77.4	51.7	90	36	3.84	1.21	5.72	----	----
September	66.3	43.6	89	26	3.22	.98	5.83	----	----
October	56.2	34.4	75	17	2.21	.62	4.77	(2)	2.0
November	37.6	20.7	55	4	1.57	.36	3.17	9	3.0
December	23.5	5.8	41	−19	1.20	.24	2.13	27	5.9
Year	50.8	27.9	[3] 92	[4] −32	30.27	22.61	35.11		

[1] Data from Moose Lake, period 1940–1972.
[2] Less than 0.5 day.
[3] All-time highest temperature was 105° F on July 11, 12, and 13, 1936.
[4] All-time lowest temperature was −45° F on January 12, 1912.

Drought occurs whenever the supply of water for crops, either in the form of rainfall or soil moisture, becomes inadequate. Each day that there is inadequate moisture in the root zone is defined as a drought day. Severe drought conditions have occurred in four of the years between 1931 and 1970 in northeastern Minnesota; 1936 was the worst, and the other years were 1931, 1934, and 1948.

The mean temperature in December, January, and February is 11.8° F. One of the coldest winters was 1916–17, when the average temperature of the winter months was 1.8°. Winter averages 50 days with a reading of 0° or lower. The first measurable snowfall occurs about mid-October in 1 year out of 10, and the last occurs early in May in 1 year out of 10. Annual snowfall at Moose Lake averaged 39.5 inches. The extremes ranged from 65.4 inches in 1964-1965 to 14.6 inches in 1967–1968. Information on snow cover and average depths is given in table 9.

The mean temperature in June, July, and August is 63.6° F. Daily highs are in the upper seventies, and the daily lows are in the upper forties. Temperatures of 100° or higher occur about once in 30 years, and temperatures of 90° or higher occur about three times a year. The range of temperatures is shown in table 9 in the columns that show probabilities of very high and very low temperatures.

The freeze-free period is relatively short for staple crops of the county. The probability of certain temperatures occurring in the spring and fall is shown in table 10 (*3*). For example, in 5 years out of 10, a temperature of 32° or lower can be expected to occur after June 6.

Long-term records of humidity, cloudiness, and winds are not available for Carlton County. Data recorded at Duluth, Minnesota, show that the average windspeed and prevailing direction in winter is 12.1 mph from the northwest, and in summer it is 10.9 mph from the east. Humidity at noon averages about 60 percent in summer and 70 percent in winter. On the average there are 76 clear days, 103 partly cloudy days, and 186 cloudy days.

Rural development

There were 28,072 people in Carlton County in 1970, and more than one-half of that total lived outside cities and villages. Less than 5 percent of the people living in the county were engaged in farming.

More than two-thirds of those engaged in farming worked off the farm either part time or full time. However, the income generated by farming is important to the economy of the county.

Most of the acreage in the county is used for woodland. Pasture and hay make up the second most extensive acreage. A small part of the county is used for cultivated crops. Of the area used for cultivated crops in 1970, 352 acres was in corn, 3,428 acres was in small grain, and 466 acres was in potatoes. The acreage used for cultivated crops has been stable over the last 10 years.

Livestock numbers have decreased in the last 10 years. There has been a shift toward more beef cattle and fewer dairy cattle.

Transportation and markets

Several railroads serve Carlton County. All of the county's urban areas except Esko are served by railroad.

Interstate Highway 35 crosses the county in a northeasterly direction. U.S. Highway 210 crosses the county east-west. State, county, and township roads provide a network for travel throughout most of the county.

Several pipelines provide gas and oil. A pipeline from Lake Superior to Cloquet provides water to that community and its industries.

The three major wood-using industries in Cloquet provide markets for a good share of the forest products grown in the county. Most of the milk produced in the county is marketed in Duluth. Livestock is taken by truck to St. Paul.

Water resources

About one-third of all the precipitation in the county finds its way into two major watersheds. The eastern half of the county drains into Lake Superior, and the western half drains into the Mississippi River. The rivers and streams provide some of the better trout fishing in Minnesota.

Rice Portage Lake is the largest of the 74 lakes in county. The lakes have a total surface area of 9,142

TABLE 10.—*Probabilities of last freezing temperature in spring and first in fall*

[All data from Cloquet, Minnesota]

Probability	Dates for given probabilities and temperature				
	16° F or lower	20° F or lower	24° F or lower	28° F or lower	32° F or lower
Spring:					
1 year in 10 later than	May 2	May 14	May 22	June 3	June 21
2 years in 10 later than	April 26	April 9	May 17	May 29	June 16
5 years in 10 later than	April 16	May 28	May 8	May 20	June 6
Fall:					
1 year in 10 earlier than	October 11	September 29	September 19	September 8	August 10
2 years in 10 earlier than	October 17	October 4	September 24	September 13	August 19
5 years in 10 earlier than	October 29	October 15	October 5	September 22	September 4

acres. Most of the lake basins were formed by ice blocks in glacial drift.

Ground water quality and quantity is generally suitable for domestic use in Carlton County. A ground water inventory of the Kettle River watershed showed that the availability and quality of ground water depends on the nature and thickness of glacial drift deposits and the nature of underlying bedrock (*13*). Outwash deposits such as those in the Omega-Cloquet-Cromwell association are the most readily available sources of ground water. Also, thick glacial till deposits such as those in the Duluth-Dusler association generally provide moderate to large yields of ground water. The thin glacial deposits such as those in the Duluth-Blackhoof-Mahtowa and Automba-Mora associations in the southwestern part of the county generally provide poor yields of water.

Most of the wells in the county are less than 100 feet deep. They are generally deeper in the Ontonagon association.

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Glossary

Available water capacity (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 moisture capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil. The capacity, in inches, in a 60-inch profile or to a limiting layer is expressed as—

	Inches
Very low	0 to 3
Low	3 to 6
Moderate	6 to 9
High	More than 9

Bedrock. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

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.

Claypan. A slowly permeable soil horizon that contains much more clay than the horizons above it. A claypan is commonly hard when dry and plastic or stiff when wet.

Coarse fragments. Mineral or rock particles up to 3 inches (2 millimeters to 7.5 centimeters) in diameter.

Complex slope. Irregular or variable slope. Planning or constructing terraces, diversions, and other water-control measures is difficult.

Complex, soil. A mapping unit of two or more kinds of soil occurring in such an intricate pattern that they cannot be shown separately on a soil map at the selected scale of mapping and publication.

Compressible. Excessive decrease in volume of soft soil under load.

Concretions. Grains, pellets, or nodules of various sizes, shapes, and colors consisting of concentrated compounds or cemented soil grains. The composition of most concretions is unlike that of the surrounding soil. Calcium carbonate and iron oxide are common compounds 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; little affected by moistening.

Cord. A unit of measure of stacked wood. A standard cord consists of wood cut in lengths of 4 feet, piled in a stack that is 4 feet high and 8 feet long. Variations in these dimensions are allowed, depending on the product being handled. The volume of a standard cord is 128 cubic feet.

Cutbanks cave. Unstable walls of cuts made by earthmoving equipment. The soil sloughs easily.

Depth to rock. Bedrock at a depth that adversely affects the specified use.

Drainage class (natural). Refers to the frequency and duration of periods of saturation or partial saturation during soil formation, 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 classes of natural soil drainage are recognized:

Excessively drained.—Water is removed from the soil very rapidly. Excessively drained soils are commonly very coarse textured, rocky, or shallow. Some are steep. All are free of the mottling related to wetness.

Somewhat excessively drained.—Water is removed from the soil rapidly. Many somewhat excessively drained soils are sandy and rapidly pervious. Some are shallow. Some are so steep that much of the water they receive is lost as runoff. All are free of the mottling related to wetness.

Well drained.—Water is removed from the soil readily, but not rapidly. It is available to plants throughout most of the growing season, and wetness does not inhibit growth of roots for significant periods during most growing seasons. Well drained soils are commonly medium textured. They are mainly free of mottling.

Moderately well drained.—Water is removed from the soil somewhat slowly during some periods. Moderately well drained soils are wet for only a short time during the growing season, but periodically for long enough that most mesophytic crops are affected. They commonly have a slowly pervious layer within or directly below the solum, or periodically receive high rainfall, or both.

Somewhat poorly drained.—Water is removed slowly enough that the soil is wet for significant periods during the growing season. Wetness markedly restricts the growth of mesophytic crops unless artificial drainage is provided. Somewhat poorly drained soils commonly have a slowly pervious layer, a high water table, additional water from seepage, nearly continuous rainfall, or a combination of these.

Poorly drained.—Water is removed so slowly that the soil is saturated periodically during the growing season or remains wet for long periods. Free water is commonly at or near the surface for long enough during the growing season that most mesophytic crops cannot be grown unless the soil is artificially drained. The soil is not continuously saturated in layers directly below plow depth. Poor drainage results from a high water table, a slowly pervious layer within the profile, seepage, nearly continuous rainfall, or a combination of these.

Very poorly drained.—Water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season. Unless the soil is artificially drained, most mesophytic crops cannot be grown. Very poorly drained soils are commonly level or depressed and are frequently ponded. Yet, where rainfall is high and nearly continuous, they can have moderate or high slope gradients, as for example in "hillpeats" and "climatic moors."

Drift (geology). Material of any sort deposited by geologic processes in one place after having been removed from another; includes drift materials deposited by glaciers and by streams and lakes associated with them.

Erosion. The wearing away of the land surface by running water, wind, ice, or other geologic agents and by such processes as gravitational creep.

Erosion (geologic). Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.

Erosion (accelerated). Erosion much more rapid than geologic erosion, mainly as a result of the activities of man or other animals or of a catastrophe in nature, for example, fire, that exposes a bare surface.

Esker (geology). A narrow, winding ridge of stratified gravelly and sandy drift deposited by a stream flowing in a tunnel beneath a glacier.

Fast intake. The rapid movement of water into the soil.

Favorable. Favorable soil features for the specified use.

Fertility, soil. The quality that enables a soil to provide plant nutrients, in adequate amounts and in proper balance, for the growth of specified plants when light, moisture, temperature, tilth, and other growth factors are favorable.

Fibers. A fragment or piece of plant tissue excluding live roots that is large enough to be retained on a 100-mesh sieve (openings 0.15 millimeter in diameter) and retains recognizable cellular structure of the plant from which it came.

Fibric soil material (peat). The least decomposed of all organic soil material. Peat contains a large amount of well preserved fiber that is readily identifiable according to botanical origin. Peat has the lowest bulk density and the highest water content at saturation of all organic soil material.

Field moisture capacity. The moisture content of a soil, expressed as a percentage of the ovendry weight, after the gravitational, or free, water has drained away; the field moisture content 2 or 3 days after a soaking rain; also called normal field capacity, normal moisture capacity, or capillary capacity.

Fragipan. A loamy, brittle subsurface horizon low in porosity and content of organic matter and low or moderate in clay but high in silt or very fine sand. A fragipan appears cemented and restricts roots. When dry, it is hard or very hard and has a higher bulk density than the horizon or horizons above. When moist, it tends to rupture suddenly under pressure rather than to deform slowly.

Frost action. Freezing and thawing of soil moisture. Frost action can damage structures and plant roots.

Glacial drift (geology). Pulverized and other rock material transported by glacial ice and then deposited. Also the assorted and unassorted material deposited by streams flowing from glaciers.

Glacial outwash (geology). Gravel, sand, and silt, commonly stratified, deposited by melt water as it flows from glacial ice.

Glacial till (geology). Unassorted, nonstratified glacial drift consisting of clay, silt, sand, and boulders transported and deposited by glacial ice.

Ground moraine (geology). Glacial till accumulated beneath the advancing ice and deposited from it during its dissolution, rather than aggregated in a thickened belt at the ice edge; the deposit is relatively thin and characteristically forms an undulating plain with gently sloping swells, sags, and closed depressions.

Habitat. The natural abode of a plant or animal; refers to the kind of environment in which a plant or animal normally lives, as opposed to the range or geographical distribution.

Hemic soil material (mucky peat). Organic soil material intermediate in degree of decomposition between the less decomposed fibric and the more decomposed sapric material.

Horizon, soil. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. The major horizons of mineral soil are as follows:

O horizon.—An organic layer, fresh and decaying plant residue, at the surface of a mineral soil.

A horizon.—The mineral horizon, formed or forming at or near the surface, in which an accumulation of humified organic matter is mixed with the mineral material. Also, a plowed surface horizon most of which was originally part of a B horizon.

A2 horizon.—A mineral horizon, mainly a residual concentration of sand and silt high in content of resistant minerals as a result of the loss of silicate clay, iron, aluminum, or a combination of these.

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 a combination of these; (2) by prismatic or blocky structure; (3) by redder or browner colors than those in the A horizon; or (4) by a combination of these. The combined A and B horizons are generally called the solum, or true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

C horizon.—The mineral horizon or layer, excluding indurated bedrock, that is little affected by soil-forming processes and does not have the properties typical of the A or B horizon. The material of a C horizon may be either like or unlike that from which the solum is presumed to have formed. If the material is known to differ from that in the solum the Roman numeral II precedes the letter C.

R layer.—Consolidated rock beneath the soil. The rock commonly underlies a C horizon, but can be directly below an A or a B horizon.

Large stones. Rock fragments 10 inches (25 centimeters) or more across. Large stones adversely affect the specified use.

Lime. Chemically, lime is calcium oxide (CaO), but its meaning has been extended to include all limestone-derived materials applied to neutralize acid soils. Agricultural lime can be obtained as ground limestone, hydrated lime, or burned lime, with or without magnesium minerals. Basic slag, oyster shells, and marl also contain calcium.

Low strength. Inadequate strength for supporting loads.

Mineral soil. Soil that is mainly mineral material and low in organic material. Its bulk density is greater than that of organic soil.

Moraine (geology). An accumulation of earth, stones, and other debris deposited by a glacier. Types are terminal, lateral, medial, and ground.

Mottling, soil. Irregular spots of different colors that vary in number and size. Mottling generally indicates poor aeration and impeded 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 of the diameter along the greatest dimension. Fine indicates less than 5 millimeters (about 0.2 inch); medium, from 5 to 15 millimeters (about 0.2 to 0.6 inch); and coarse, more than 15 millimeters (about 0.6 inch).

Muck. Dark colored, finely divided, well decomposed organic soil material mixed with mineral soil material. The content of organic matter is more than 20 percent.

Organic soil. A general term applied to a soil or to a soil horizon that consists primarily of organic matter, such as peat soils, muck soils, and mucky peat soil layers.

Peat. Unconsolidated material, largely undecomposed organic matter, that has accumulated under excess moisture.

Pedon. The smallest volume that can be called "a soil." A pedon is three dimensional and large enough to permit study of all horizons. Its area ranges from about 10 to 100 square feet (1 square meter to 10 square meters), depending on the variability of the soil.

Percs slowly. The slow movement of water through the soil adversely affecting the specified use.

Permeability. The quality that enables the soil to transmit water or air, measured as the number of inches per hour that water moves through the soil. Terms describing permeability are very slow (less than 0.06 inch), slow (0.06 to 0.20 inch), moderately slow (0.2 to 0.6 inch), moderate (0.6 to 2.0 inches), moderately rapid (2.0 to 6.0 inches), rapid (6.0 to 20 inches), and very rapid (more than 20 inches).

pH value. (See **Reaction, soil**). A numerical designation of acidity and alkalinity in soil.

Piping. Moving water forms subsurface tunnels or pipelike cavities in the soil.

Plastic limit. The moisture content at which a soil changes from a semisolid to a plastic state.

Plow layer. The soil ordinarily moved in tillage; equivalent to surface soil.

Poor outlets. Surface or subsurface drainage outlets difficult or expensive to install.

Profile, soil. A vertical section of the soil extending through all its horizons and into the parent material.

Reaction, soil. The degree of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degree of acidity or alkalinity is expressed as—

	pH		pH
Extremely acid	Below 4.5	Neutral	6.6 to 7.3
Very strongly acid	4.5 to 5.0	Mildly alkaline	7.4 to 7.8
Strongly acid	5.1 to 5.5	Moderately alkaline	7.9 to 8.4
Medium acid	5.6 to 6.0	Strongly alkaline	8.5 to 9.0
Slightly acid	6.1 to 6.5	Very strongly alkaline	9.1 and higher

Relief. The elevations or inequalities of a land surface, considered collectively.

Rooting depth. Shallow root zone. The soil is shallow over a layer that greatly restricts roots. See Root zone.

Runoff. The precipitation discharged in stream channels from a drainage area. The water that flows off the land surface without sinking in is called surface runoff; that which enters the ground before reaching surface streams is called ground-water runoff or seepage flow from ground water.

Sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

Sandy soils. A broad term for soils of the sand and loamy sand classes; material with more than 70 percent sand and less than 15 percent clay.

Sapric soil material (muck). The most highly decomposed of all organic soil material. Muck has the least amount of plant fiber, the highest bulk density, and the lowest water content at saturation of all organic soil material.

Seepage. The rapid movement of water through the soil. Seepage adversely affects the specified use.

Sequum. A sequence consisting of an illuvial horizon and the overlying eluvial horizon.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Small stones. Rock fragments 3 to 10 inches (7.5 to 25 centimeters) in diameter. Small stones adversely affect the specified use.

Soil. A natural, three-dimensional body at the earth's surface that is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

Soil separates. Mineral particles less than 2 millimeters in equivalent diameter and ranging between specified size limits. The names and sizes of separates recognized in the United States are as follows: very coarse sand (2.0 millimeters to 1.0 millimeter); coarse sand (1.0 to 0.5 millimeter); medium sand (0.5 to 0.25 millimeter); fine sand (0.25 to 0.10 millimeter); very fine sand (0.10 to 0.05 millimeter); silt (0.005 to 0.002 millimeter); and clay (less than 0.002 millimeter).

Sphagnum. A group of mosses that grow in moist places. By annual increments of growth, deep layers of fibrous and highly absorbent peat may be built up. Sphagnum grows best in cool, humid regions.

Stratified. Arranged in strata, or layers. The term refers to geologic material. Layers in soils that result from the processes of soil formation are called horizons; those inherited from the parent material are called strata.

Structure, soil. The arrangement of primary soil particles into compound particles or aggregates that are separated from adjoining aggregates. 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 grained (each grain by itself, as in dune sand) or massive (the particles adhering without any regular cleavage, as in many hardpans).

Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.

Substratum. The part of the soil below the solum.

Variant, soil. A soil having properties sufficiently different from those of other known soils to justify a new series name, but the limited geographic soil area does not justify creation of a new series.

Water table. The upper limit of the soil or underlying rock material that is wholly saturated with water.

Water table, apparent. A thick zone of free water in the soil. An apparent water table is indicated by the level at which water stands in an uncased borehole after adequate time is allowed for adjustment in the surrounding soil.

Water table, artesian. A water table under hydrostatic head, generally beneath an impermeable layer. When this layer is penetrated, the water level rises in an uncased borehole.

Water table, perched. A water table standing above an unsaturated zone. In places an upper, or perched, water table is separated from a lower one by a dry zone.

GUIDE TO MAPPING UNITS

For a full description of a mapping unit, read the description of both the mapping unit and the soil series to which the mapping unit belongs.

Map symbol	Mapping unit	Described on page	Capability unit	Hay and pasture group	Woodland group	Wildlife group	Recreation group	Community development group
12C	Emmert gravelly fine sandy loam, 1 to 12 percent slopes	29	IVs-1	7	4s1	7	5	1
12E	Emmert gravelly fine sandy loam, 12 to 25 percent slopes	29	VIIs-1	7	4s1	7	5	1
21	Ahmeek loam, 0 to 2 percent slopes	11	IIc-1	1	2o1	1	2	2
21C	Ahmeek loam, 2 to 12 percent slopes	11	IIIe-1	1	2o1	1	2	2
21E	Ahmeek loam, 12 to 25 percent slopes	11	VIe-1	2	2r1	2	2	2
22	Allendale loamy fine sand	12	IIIw-2	3	2w1	3	4	4
43	Automba fine sandy loam, 0 to 2 percent slopes	15	IIc-1	1	2o1	1	2	2
43B	Automba fine sandy loam, 2 to 6 percent slopes	15	IIIe-1	1	2o1	1	2	2
147	Spooner silt loam	42	IIIw-1	3	2w1	3	4	4
V166	Mora fine sandy loam, wet	37	IIIw-1	3	2w1	3	4	4
186	Nemadji fine sand	37	IIIw-2	3	2w1	3	4	4
188	Omega loamy sand, 0 to 2 percent slopes	39	IVs-1	6	2s1	7	5	1
181C	Omega loamy sand, 2 to 12 percent slopes	39	VIs-1	6	2s1	7	5	1
188E	Omega loamy sand, 12 to 25 percent slopes	39	VIIs-1	7	2s1	7	5	1
204	Cushing fine sandy loam	24	IIc-1	1	2o1	1	2	2
254	Hibbing silt loam, 0 to 2 percent slopes	31	IIc-1	1	2o1	1	2	3
254C	Hibbing silt loam, 2 to 12 percent slopes	31	IIIe-1	1	2o1	1	2	3
268	Cromwell sandy loam, 0 to 2 percent slopes	22	IIIs-1	6	2s1	6	1	1
268B	Cromwell sandy loam, 2 to 6 percent slopes	23	IIIe-2	6	2s1	6	1	1
274	Newson mucky loamy sand	38	IVw-1	4	4w2	4	6	5
292	Alstad fine sandy loam	13	IIw-1	3	2w1	3	4	4
V292	Alstad Variant loam	14	IVw-1	4	4w2	4	7	5
303	Ontonagon silty clay, 0 to 2 percent slopes	40	IIIs-1	1	4c1	1	6	3
303C	Ontonagon silty clay, 2 to 12 percent slopes	40	IVe-1	1	4c1	1	6	3
303E	Ontonagon silty clay, 12 to 25 percent slopes	40	VIe-1	2	4c1	2	6	3
305	Bergland clay	16	IIIw-1	4	4w2	4	7	5
337	Warman mucky loam	45	IVw-1	4	4w2	4	7	5
V337	Warman fine sandy loam	45	IIw-1	3	2w1	3	4	4
355	Cloquet fine sandy loam, 0 to 2 percent slopes	21	IIIs-1	6	2s1	6	1	1
355C	Cloquet fine sandy loam, 2 to 12 percent slopes	21	IVe-2	6	2s1	6	1	1
355E	Cloquet fine sandy loam, 12 to 25 percent slopes	21	VIIe-1	7	2s1	7	1	1
367	Campia silt loam, 0 to 2 percent slopes	19	IIc-1	1	2o1	1	1	2
367C	Campia silt loam, 2 to 12 percent slopes	19	IIIe-1	1	2o1	1	1	2
367E	Campia silt loam, 12 to 25 percent slopes	20	VIe-1	2	2r1	2	1	2
502	Dusler silt loam	28	IIIw-1	3	2w1	3	4	4
504	Duluth very fine sandy loam, 0 to 2 percent slopes	26	IIc-1	1	2o1	1	2	2
504C	Duluth very fine sandy loam, 2 to 12 percent slopes	26	IIIe-1	1	2o1	1	2	2
504E	Duluth very fine sandy loam, 12 to 25 percent slopes	26	VIe-1	2	2r1	2	2	2
504G	Duluth very fine sandy loam, 25 to 35 percent slopes	26	VIIe-2	8	2r1	8	2	2
530	Greenwood mucky peat	30	IVw-2	5	4w1	5	7	6
531	Beseman muck	17	IVw-2	5	4w1	5	7	6
533	Loxley muck	33	IVw-2	5	4w1	5	7	6
534	Mooselake mucky peat	35	IVw-2	5	3w1	5	7	6
535	Merwin mucky peat	34	IVw-2	5	4w1	5	7	6
536	Dawson muck	25	IVw-2	5	4w1	5	7	6
537	Lobo peat	32	VIIw-1	5	4w1	5	7	6
538	Waskish peat	45	VIIw-1	5	4w1	5	7	6
549	Greenwood peat	30	IVw-2	5	4w1	5	7	6
975	Ahmeek-Omega complex, 0 to 2 percent slopes	11	IVs-1	6	---	7	---	---
	Ahmeek part	--	------	---	2o1	---	2	2
	Omega part	--	------	---	2s1	---	5	1

GUIDE TO MAPPING UNITS--Continued

Map symbol	Mapping unit	Described on page	Capability unit	Hay and pasture group	Woodland group	Wildlife group	Recreation group	Community development group
975C	Ahmeek-Omega complex, 2 to 12 percent slopes	11	VIs-1	6	---	7	---	---
	Ahmeek part	--	------	---	2o1	---	2	2
	Omega part	--	------	---	2s1	---	5	1
975E	Ahmeek-Omega complex, 12 to 25 percent slopes	11	VIIs-1	7	---	7	---	---
	Ahmeek part	--	------	---	2r1	---	2	2
	Omega part	--	------	---	2s1	---	5	1
976C	Campia-Ontonagon complex, 2 to 12 percent slopes	20	IIIe-1	1	---	1	---	---
	Campia part	--	------	---	2o1	---	1	2
	Ontonagon part	--	------	---	4c1	---	6	3
977G	Cloquet-Emmert complex, 25 to 60 percent slopes	21	VIIs-1	8	4s1	8	---	1
	Cloquet part	--	------	---	---	---	1	---
	Emmert part	--	------	---	---	---	5	---
980	Blackhoof and Mahtowa soils	18	IVw-1	4	4w2	4	7	5
990	Twig and Parent soils	44	IVw-1	4	4w2	4	7	5
1005	Fluvaquents	29	VIw-1	4	4w2	4	7	5
1020	Udorthents	44	VIIe-2	8	5c1	8	6	3
1073	Borofolists	18	VIIs-2	8	5d1	9	3	7
1074	Borosaprists	18	VIIw-2	8	5d1	9	7	7

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