SOIL SURVEY

Hennepin County Minnesota

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

Issued April 1974

Major fieldwork for this soil survey was completed in the period 1966-68. Soil names and descriptions were approved in 1969. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1968. 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 Hennepin County Soil and Water Conservation District.

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

HOW TO USE THIS SOIL SURVEY

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

Locating Soils

All the soils of Hennepin 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 in this survey. This guide lists all the soils of the county in alphabetic order by map symbol and gives the capability classification of each. It also shows the page where each soil is described and the page for the woodland group and building site group in which the soil has been placed.

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

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

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

Game managers, sportsmen, and others can find information about soils and wildlife in the section "Suitability of the Soils for 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 sections "Use of the Soils for Town and Country Planning" and "Use of the Soils for Recreation."

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 how the soils formed and how they are classified in the section "Formation and Classification of the Soils."

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

CONTENTS

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SOIL SURVEY OF HENNEPIN COUNTY, MINNESOTA

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

HENNEPIN COUNTY lies in the east-central part of Minnesota (fig. 1). The county is irregular in shape and has a land area of 354,460 acres. The city of Minneapolis, together with the adjacent smaller cities and villages comprising the metropolitan area, occupies a land area of about 120 square miles. The county also contains 105 lakes that cover 30,744 acres. The Mississippi River and two of its tributaries form the major boundaries of the county. An area comprising about 14 square miles lies east of the Mississippi River and is included within the city of Minneapolis, except for an area of about 2 square miles, which comprises the village of St. Anthony.

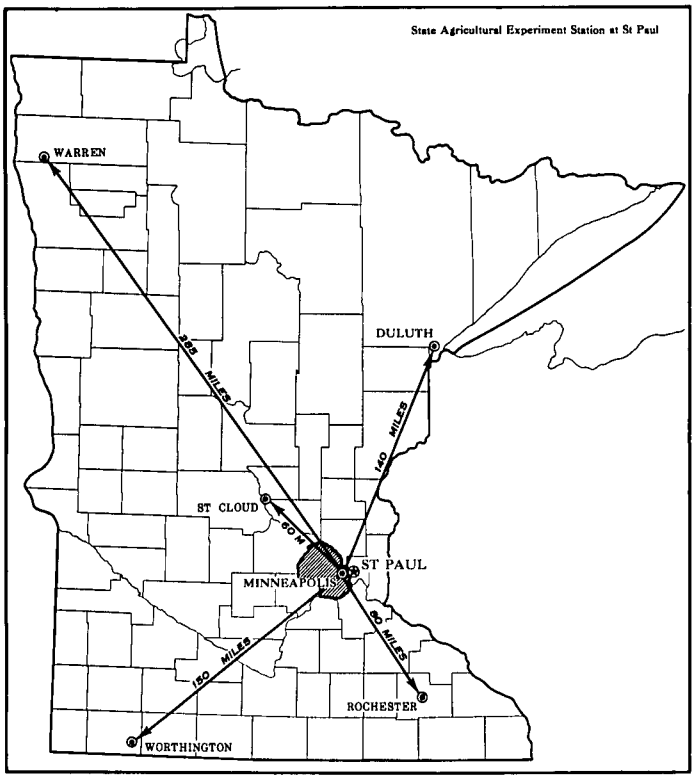

Figure 1.--Location of Hennepin County in Minnesota.

The only place where rivers do not form the boundaries of the county is in the southwestern part, where Hennepin County shares a common boundary with Wright County to the west and Carver County to the south.

The landscape is a product of the continental glaciers that covered the county. It consists mainly of gently rolling to steep hills and many marshes and lakes. There are extensive outwash plains in the county. The largest of these is the broad flat in the northeastern part of the county, which was deposited by the Mississippi River during glacial times.

Hennepin County was an important dairy farming area from the early 1900's to the early 1960's. Since about 1950 farming has been steadily declining because of the expansion of suburban and rural residential and industrial development. In 1968, only about 35 percent of the land in the county was used mainly for farming.

Although this is the soil survey of Hennepin County, a large acreage occupied by the city of Minneapolis and by densely built-up suburban areas was excluded from the survey. The urban development, along with reworking of the soils during construction, made it impractical to classify the soils. Onsite investigation is needed to determine soil characteristics in the metropolitan area.

HOW THIS SURVEY WAS MADE

Soil scientists made this survey to learn what kinds of soil are in Hennepin 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. Hayden and Hamel, for example, are the names of two soil series. All the soils in the United States having the same series name are essentially alike in those characteristics that affect their behavior in the undisturbed landscape.

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

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

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

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

A soil complex consists of areas of two or more soils, so intermingled or so small in size that they cannot be shown separately on the soil map. Each area of a complex contains some of each of the two or more dominant soils, and the pattern and relative proportions are about the same in all areas. An example is Heyder complex, 2 to 6 percent slopes.

An undifferentiated group is made up of two or more soils that could be delineated individually but are shown as one unit because, for the purpose of the soil survey, there is little value in separating them. The pattern and proportion of soils are not uniform. An area shown on the map may be made up of only one of the dominant soils, or of two or more. The name of an undifferentiated group consists of the names of the dominant soils, joined by "and." Erin and Kilkenny loams, 24 to 35 percent slopes, is an example.

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

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

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

On the basis of yield and practice tables and other data, the soil scientists set up trial groups. They test these groups by further study and by consultation with farmers, agronomists, engineers, and others, and then they 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 present methods of use and management.

GENERAL SOIL MAP

The general soil map at the back of this survey shows, in color, the soil associations in Hennepin County. A soil association is a landscape that has a distinctive proportional pattern of soils. It normally consists of one or more major soils and at least one minor soil, and it is named for the major soils. The soils in one association may occur in another, but in a different pattern.

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

Soil patterns for contiguous Hennepin, Wright, and Carver Counties match each other in most places along boundaries common to these counties. As a result of correlation, the Hayden soils of Hennepin County contain fewer areas now recognized as Lester soils than were correlated in Wright and Carver Counties.

The 10 soil associations in Hennepin County are each described in the following pages. The terms for texture used in the descriptive headings of each of the associations apply to the surface layer. For example, in the heading for association 1, the words "moderately fine textured and medium textured" refer to texture of the surface layer.

1. Cordova-Hayden-Nessel Association

Nearly level to gently undulating, moderately fine textured and medium-textured soils that developed in deep, friable, loamy glacial till

This association consists of nearly level soils that contain numerous depressions and of intermingled areas of undulating soils on irregular knolls and slight rises, about 2 to 20 acres in size. Slopes are complex and are less than 150 feet long in most places. Relief is mainly between 3 and 10 feet. The soils formed in deep, friable loam glacial till that is high in content of lime carbonates. The original vegetation was mainly hardwood forest. There were open grassland areas in the wet areas and on some knolls. This association occupies about 7 percent of the county and is in the northwestern part (plate I).

Cordova soils make up about 30 percent; Hayden soils, 20 percent; Nessel soils, 20 percent; and minor soils, about 30 percent of the association. The poorly drained Cordova soils are on broad flats and in swales at a slightly higher elevation. They have a surface layer of silty clay loam and a subsoil of clay loam. Permeability is moderately slow, and available moisture capacity is high. The well drained Hayden soils and the moderately well drained Nessel soils are on knolls and slight rises. They have a surface layer of very dark gray loam and a subsoil of light clay loam. Permeability is moderate, and available moisture capacity is high.

Minor soils in this association include the very poorly drained Glencoe and Peaty muck soils in the wetter depressions, the poorly drained Dundas and Minnetonka soils, and the somewhat poorly drained Shields soils. The moderately well drained Le Sueur soils and the well drained Lester soils occupy the knolls and slight rises near the village of Rogers.

General farming and dairying are the main enterprises. Corn and soybeans are the principal crops, but small acreages of hay and small grain are also grown. Most of the acreage is cleared of trees for farming, but small woodlots and pasture are common. The average farm is between 160 to 200 acres in size.

Drainage and maintenance of soil tilth are the main management needs. More than 50 percent of this association is wet. In some areas suitable tile outlets are lacking. This is the most suitable soil association in the county for intensive corn and soybean production. Wetness and moderate to moderately slow percolation rates pose important limitations for urban use. The low bearing capacity and high frost heaving on the wet soils need special consideration in planning of roads and streets.

2. Hayden-Cordova-Peaty Muck Association

Nearly level to rolling, medium-textured and moderately fine textured soils that developed in glacial till, and level organic soils

This association consists of undulating to rolling soils on low, irregular hills and knolls that are separated by nearly level soils in broad drainageways. The hills and knolls range in size from 2 acres to about 80 acres and are 5 feet to about 40 feet above the adjacent swales and depressions. A natural drainage pattern has not been developed. Water runs off in several directions and collects in closed depressions. Length of slopes ranges mainly from 75 to 200 feet. There are small areas of steeper soils in the association, mainly around lakes and large depressions. The original vegetation on the hills and knolls was hardwood forest. The wetter areas contained tall grasses and sedges. This association occupies about 28 percent of the county.

Hayden soils make up about 40 percent; Cordova soils, about 10 percent; Peaty muck soils, about 5 percent; and minor soils, about 45 percent of the association. The well-drained Hayden soils on low knolls and hills have a surface layer of grayish loam or clay loam and a subsoil of light clay loam. They are moderately permeable and have high available

moisture capacity. The poorly drained Cordova soils in swales and on flats have a surface layer of black silty clay loam and a subsoil of clay loam. They have high available moisture capacity and moderately slow permeability. The very poorly drained Peaty muck soils in depressions consist of deep organic materials.

Important minor soils in this association include the very poorly drained Glencoe soils in depressions; the poorly drained Hamel, Dundas, and Minnetonka soils and the somewhat poorly drained Shields soils in drainageways and on flats; and the moderately well drained Dalbo soils on low knolls and hills.

Most of this association is cropland. The remainder is in scattered tracts of woodland and pasture. Most of the large depressions are undrained. The most important crops are corn, alfalfa, soybeans, and small grain. Dairying was formerly the dominant farm enterprise but is rapidly diminishing.

The major management needs for farming are control of erosion, drainage, and maintenance of soil tilth. About 30 to 45 percent of this association is poorly drained. Wet areas are often closely intermingled with better drained soils and interfere with timely tillage operations on those soils. Many areas have been artificially drained. An important need in many places is good tile outlets.

3. Lester-Peaty Muck Association

Rolling and hilly, medium-textured and moderately fine textured soils that developed in glacial till, and level organic soils

This association consists of rolling to hilly, well-drained soils on hills and knolls that are separated by very poorly drained soils in swales and in large, closed depressions (plate I). The hills and knolls have no particular shape or pattern. Relief ranges from 5 to about 60 feet. Soils are mainly rolling to hilly, but areas of steeper soils occur mainly near large depressions. Length of slopes ranges from 75 to 250 feet. Mixed hardwood forest encroached upon by tall prairie grasses made up the original vegetation on the knolls and hills. This association occupies about 10 percent of the county.

Lester soils make up about 40 percent; Peaty muck soils, about 10 percent; and minor soils, about 50 percent of the association. The well-drained Lester soils have a black loam or clay loam surface layer and a dark yellowish-brown clay loam subsoil. They have high available moisture capacity and moderate permeability. The very poorly drained Peaty muck soils consist of deep organic materials. They have high available moisture capacity and low fertility.

Important minor soils in this association include the very poorly drained Glencoe soils in depressions; the poorly drained Minnetonka, Cordova, Dundas, and Hamel soils in drainageways; and the moderately well drained and well drained Le Sueur, Shorewood, and Kilkenny soils on low knolls and hills.

Most of this association has been cleared of trees for farming, although a few large tracts of timber remain. Dairy farming is the major land use, but this enterprise is declining. Important crops are corn, alfalfa, soybeans, and small grain. Apple growing is a minor enterprise, practiced mainly in Shorewood and Long Lake villages. The main management needs for farming are control of erosion, drainage, and maintenance of natural fertility.

This association is being rapidly developed for urban uses. Slopes pose a moderate to severe limitation for use, and frost heaving is a hazard on the wet soils. High runoff rates can be expected in urban areas.

4. Hayden-Peaty Muck association

Rolling to steep, medium-textured and moderately fine textured soils that developed in glacial till, and level organic soils

This association consists of rolling to steep, well-drained soils on low, irregularly shaped hills that are intermingled with very poorly drained soils in large depressions (plate II). Relief between the hilltops and the depressions is typically 40 to 90 feet. Slopes are complex, and length of slopes ranges mostly from 125 to 300 feet. Water runs off in many directions. The original vegetation was mixed hardwood forest. The association occupies about 10 percent of the county.

Hayden soils make up about 50 percent; Peaty muck soils, about 10 percent; and minor soils, about 40 percent of the association. The Hayden soils are well drained and have a surface layer of very dark grayish-brown loam or clay loam and a subsoil of light clay loam. They have high available moisture capacity and moderate permeability. The very poorly drained Peaty muck soils consist of deep organic materials. They have very high available moisture capacity and low fertility.

Minor soils in this association include Glencoe, Cordova, Dundas, Hamel, Nessel, and Dalbo soils. The very poorly drained Glencoe soils occupy shallow, wet depressions. The poorly drained Hamel, Cordova, and Dundas soils are in drainageways. The moderately well drained Nessel and Dalbo soils occur on low knolls or on the crowns of the larger hills.

About 50 to 75 percent of the sloping areas of this association has been cleared of trees for farming. Irregular tracts of mixed hardwoods are interspersed with open areas. Dairying was formerly the major farm enterprise but is rapidly diminishing because of urban expansion. Alfalfa, corn, small grain, and soybeans are commonly grown on these soils. The major limitation to farming is the steep topography. Control of soil erosion and runoff is the major management need. Steepness of slope and the irregular shape of the hills are the major considerations for urban development.

5. Erin-Kilkenny-Peaty Muck Association

Gently undulating to hilly, medium-textured and moderately fine textured soils that developed in glacial till, and level organic soils

This association consists of gently undulating to hilly, well-drained soils on irregularly shaped hills. The hills are 80 to 150 acres in size and are 30 to 70 feet above very poorly drained soils in large depressions that are commonly connected by drainageways (plate III). Slopes are commonly 100 to 250 feet long but range to 400 feet. This association occupies about 11 percent of the county.

Erin soils make up about 30 percent; Kilkenny soils, 20 percent; Peaty muck soils, about 10 percent; and minor soils, about 40 percent of the association. The Erin and Kilkenny soils are well drained and have a surface layer of loam or clay loam and a subsoil of heavy clay loam. They have high available moisture capacity and moderately slow permeability. The very poorly drained Peaty muck soils consist of deep organic materials. They have very high available moisture capacity and low fertility.

Minor soils include the somewhat poorly drained Lerdal soils on low knolls and slight rises, the poorly drained Dundas and Cordova soils on broad flats and in drainageways, and the poorly drained Hamel soils and very poorly drained Glencoe soils in the deeper swales and drainageways.

Most of this association is cropland. The remainder is woodland, pasture, or slough. The major management needs are control of erosion, maintenance of tilth, and drainage. The soils in this association have severe limitations for the use of onsite sewage disposal systems, because of the moderately slow percolation rates, the high water table, or both. The mineral soils have a moderate to high shrink-swell potential. One of the outstanding features of this association is its natural beauty. The area has numerous broad views where one can observe scenic hills several miles distant.

6. Peaty Muck-Hayden-Burnsville Association

Level organic soils and hilly to steep, moderately fine textured to moderately coarse textured soils that developed in glacial till

This association consists of well-drained to somewhat excessively drained soils on hills and ridges that contain numerous depressions of very poorly drained soils. Local differences in elevation range up to 100 feet or more. The slope pattern is very irregular, and large depressions are closely intermingled with the hills and ridges in no particular pattern. Generally, the higher and steeper hills and ridges are occupied by soils underlain by reddish-brown sandy loam till or grayish-brown gravel and sand. Soils underlain by loam till are generally in the less sloping areas (plate IV). Reddish-brown till is at a depth of less than 20 feet in many places. In places the various till materials are so closely intermingled that they have not been separated in mapping. The original vegetation was mixed hardwoods. This association occupies about 13 percent of the county.

Peaty muck soils make up about 20 percent; Hayden soils, 15 percent; Burnsville soils, 10 percent; and minor soils, about 55 percent of the association. The very poorly drained Peaty muck soils consist of deep organic materials. They have very high available moisture capacity and low fertility. The well-drained Hayden soils formed in loamy glacial till and have a surface layer of very dark gray loam and a subsoil of dark yellowish-brown clay loam. They have moderate permeability and high available moisture capacity. The somewhat excessively drained Burnsville soils have a surface layer of dark grayish-brown sandy loam and a subsoil of dark-brown sandy loam and dark yellowish-brown loam. At a depth of 12 to 24 inches, the subsoil is underlain by calcareous gravel and sand. Burnsville soils have low available moisture capacity and are rapidly permeable in the gravelly underlying material.

Important minor soils in this association include the well-drained Kingsley soils, the somewhat excessively drained Nymore soils, and the excessively drained Salida soils. The Kingsley soils formed in reddish-brown till and are in the higher positions.

Dairying and fruit growing were once the major enterprises. Dairying is practiced now on only a few farms. Most of the soils in the association are used for pasture or woods or are idle. The pasture and woods are mainly on the Burnsville soils. A few fruit and truck farms remain, specializing mainly in raspberry production. The major management needs are control of erosion and drainage. This association is very scenic, with long views overlooking lakes and wooded hills. However, the steep slopes and large depressions are a severe limitation to intensive urban development.

7. Hubbard-Isan-Duelm Association

Nearly level to undulating, coarse-textured and moderately coarse textured soils that developed in deep sand

This association consists of nearly level to undulating, moderately well drained to somewhat excessively drained soils on outwash plains that contain poorly drained soils on broad flats and in scattered depressions. Differences in elevation between the depressions and the slight rises are only a few feet in many places (plate IV). Scattered areas of more sloping soils are in places along the Mississippi River. The native vegetation was tall prairie grasses encroached upon by hardwood forest, mostly scrub oak on the drier soils. This association occupies about 8 percent of the county.

Hubbard soils make up about 20 percent; Isan soils, 20 percent; Duelm soils, 15 percent; and minor soils, about 45 percent of the association. The somewhat excessively drained Hubbard soils are

on the more elevated flats and the low knolls. The poorly drained Isan soils are on broad flats and in drainageways that are slightly lower in elevation than the Duelm soils. The Hubbard and Duelm soils have a surface layer of black to very dark brown loamy sand and a subsoil of sand. Isan soils have a surface layer of black sandy loam and a subsoil of sand. All these soils are underlain by sand at a depth of 12 to 24 inches. They have very low available moisture capacity, low fertility, and rapid or very rapid permeability. Duelm and Isan soils have a seasonally high water table in undrained areas.

Minor soils in this association include the well-drained Anoka and Langola soils and the poorly drained Biscay soils.

Most of this association was formerly used for potato and vegetable production but is being rapidly developed for residences. The major limitations for crop growth are drought, low fertility, and, in places, wetness. The major limitations for urban development are the high water table in many areas and the rapid and very rapid permeability rates. Because of the very permeable sand, pollution of nearby lakes and wells is a serious hazard where septic tanks are used.

8. Estherville-Dickman-Dakota Association

Nearly level to hilly, moderately coarse textured and medium-textured soils underlain by sand and gravel

This association consists of nearly level to hilly, somewhat excessively drained soils on irregularly shaped knolls and on low, rounded hills of outwash plains. The outwash plains include a few intermingled depressions and drainageways. The steeper soils occur along the Minnesota River and the larger depressions. In a few areas, especially the area around Osseo, the soils are mostly nearly level. The original vegetation was tall prairie grasses and an encroachment of mixed hardwoods. This association occupies about 10 percent of the county.

Estherville soils make up about 20 percent; Dickman soils, 15 percent; Dakota soils, 10 percent; and minor soils, about 55 percent of the association. This is the most complex soil association in the county, with a wide range in soil materials. Most of the soils, however, developed in 12 to 30 inches of loamy alluvium over sand or calcareous sand and gravel. The Estherville soils have a surface layer of very dark brown sandy loam and a subsoil of dark yellowish-brown sandy loam. Calcareous sand and gravel occur at a depth of 14 to 24 inches. The Dickman soils are similar to the Estherville soils but are underlain by leached sand. These soils have moderately rapid to rapid permeability and low available moisture capacity. The Dakota soils have a surface layer of black loam and a subsoil of dark yellowish-brown loam. Sand is at a depth of 22 to 30 inches. Permeability is moderately rapid, and available moisture capacity is moderate.

Important minor soils in this association are the well-drained Kasota and Grays soils, the somewhat excessively drained Rasset and Hubbard soils, the excessively drained Salida soils, the moderately well drained Kennebec soils, and the poorly drained Biscay soils. All except the Kennebec and Biscay soils are sloping. The Kennebec and Biscay soils are in drainageways and depressions.

Much of this association has been cleared of trees for cropland. Small areas of woodland remain, mostly on the steeper slopes. Farming is rapidly diminishing because of rapid urban expansion. The hazards of erosion and drought are the main limitations for cultivated crops. Slope is the main limitation for urban expansion. These soils are easy to excavate. Because of the rapid percolation in the sand and gravel layer, pollution of nearby lakes and shallow wells is a serious hazard in areas where septic tanks are used. This association is a good source of sand and gravel.

9. Hubbard-Anoka Association

Undulating to rolling, coarse-textured soils underlain by sand

This association consists of undulating to rolling soils on irregularly shaped knolls of outwash plains and in a few small depressions. Local differences in elevation are mainly 10 to 25 feet. The landscape is more hilly near the lakes. The original vegetation was mixed hardwoods, mainly oaks. This soil association occurs in the northwestern part of the county along the Crow River. It occupies about 1 percent of the county.

Hubbard soils make up about 55 percent; Anoka soils, about 15 percent; and minor soils, about 30 percent of the association. These soils have a surface layer of loamy sand underlain by sand at a depth of 10 to 15 inches. The Anoka soils have thin layers of loamy material in the sand. All the minor soils have rapid to very rapid permeability and low to very low available moisture capacity. The water table is generally at a depth below 10 feet, but small areas of Anoka soils have a water table at a depth of 3 to 5 feet during wet seasons.

Minor soils include the excessively drained Zimmerman and Salida soils, the somewhat excessively drained Estherville and Braham soils, and the well-drained Becker soils. Small areas of stream bottom lands were also included because of their small acreage.

This scenic association has been largely cleared of trees for farming. Scattered tracts of woodland make up about 25 percent of the association. Much of this land has been purchased by the Hennepin County Park Reserve District. Dairying and cash-grain farming were the major farm enterprises. The major limitation to farming is the severe hazard of drought. Except for the bottom-land soils, this association has no severe limitations to urban and commercial development. However, there is a hazard of contamination of nearby lakes and wells in areas where septic tanks are used to dispose of sewage.

10. Mixed Alluvial Land-Marsh-Chaska Association

Nearly level, moderately coarse textured to moderately fine textured soils that formed in alluvium; and marsh

This association consists of nearly level soils on bottom lands along the Minnesota River. The landscape consists of a broad, flat plain dissected by streams that drain from the higher lying uplands and outwash plain. This association occupies about 2 percent of the county.

Mixed alluvial land makes up about 35 percent; Marsh, 35 percent; Chaska soils, 15 percent; and minor soils, about 15 percent of the association. Mixed alluvial land occupies the natural levee or broad ridges next to the river. In the broader areas the soils form a ridge and swale pattern. Mixed alluvial land consists of alternating layers of sandy and loamy material. It is droughty and is subject to flooding. Some areas are frequently flooded. There are large areas of Marsh in the large depressions. The marshes in many places contain organic soils that are more than 5 feet deep. The poorly drained Chaska soils occupy low flats, typically away from the river.

Dorchester soils are the most important minor soils in the association. They are moderately well drained and typically lie between the Mixed alluvial land and the Chaska soils on broad flats.

All the soils in this association are subject to flooding. Most of the Chaska soils have been cleared of trees for farming and are suited to crops, but crops are damaged or destroyed in years of floods. The hazard of flooding prevents use of this association for urban development unless costly flood prevention measures are taken. During wet seasons the water table is within 5 feet of the surface in many places. Soils of this association are better suited to use for wildlife habitat or recreation than to other uses.

DESCRIPTIONS OF THE SOILS

This section describes the soil series and mapping units in Hennepin County. Each soil series is described in considerable 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, detailed and in technical terms, is for scientists, engineers, and others who need to make thorough and precise studies of soils. Unless it is otherwise stated, the colors and consistence given in the descriptions are those of a moist soil.

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

Following the name of each mapping unit is a symbol in parentheses. This symbol identifies the mapping unit on the detailed soil map. Listed at the end of each description of a mapping unit are the capability unit, woodland suitability group, and building site group in which the mapping unit has been placed. The page for the description of each capability unit, woodland suitability group, and building site 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 in describing soils can be found in the Glossary at the back of this survey, and more detailed information about the terminology and methods of soil mapping can be obtained from the Soil Survey Manual (6) 1/.

A given soil series in this county may be identified by a different name in a recently published soil survey of an adjacent county. Such differences in name result from changes in the concepts of soil classification that have occurred since publication. The characteristics of the soil series described in this county are considered to be within the range defined for that series. In those instances where a soil series has one or more features outside the defined range, the differences are explained.

1/ Underscored numbers in parentheses refer to Literature Cited, p. 156.

TABLE 1.--APPROXIMATE ACREAGE AND PROPORTIONATE EXTENT OF THE SOILS

Soil	Area	Extent	Soil	Area	Extent
	Acres	Percent		Acres	Percent
Anoka loamy fine sand, 2 to 6 percent slopes	1,247	0.4	Duelm loamy sand, loamy subsoil variant	369	0.1
Anoka loamy fine sand, 6 to 12 percent slopes	188	.1	Dundas silt loam	3,618	1.3
Becker fine sandy loam	536	.2	Erin loam, 2 to 6 percent slopes	3,074	1.1
Becker loam	191	.1	Erin loam, 6 to 12 percent slopes	2,428	.9
Biscay clay loam	701	.3	Erin loam, 12 to 18 percent slopes	1,284	.5
Biscay clay loam, depressional	285	.1	Erin loam, 18 to 24 percent slopes	1,124	.4
Borrow land	758	.3	Erin clay loam, 2 to 6 percent slopes, eroded	816	.3
Borrow pits	131	(1/)	Erin clay loam, 6 to 12 percent slopes, eroded	2,680	.9
Braham loamy sand, silty subsoil, 2 to 6 percent slopes	232	.1	Erin clay loam, 12 to 18 percent slopes, eroded	1,605	.6
Braham loamy sand, silty subsoil, 6 to 12 percent slopes	185	.1	Erin and Kilkenny loams, 24 to 35 percent slopes	365	.1
Braham loamy fine sand, 2 to 6 percent slopes	382	.1	Estherville sandy loam, 0 to 2 percent slopes	1,959	.7
Braham loamy fine sand, 6 to 12 percent slopes	185	.1	Estherville sandy loam, 2 to 6 percent slopes	2,194	.8
Burnsville sandy loam, 2 to 6 percent slopes	928	.3	Estherville sandy loam, 6 to 12 percent slopes	1,122	.4
Burnsville sandy loam, 6 to 12 percent slopes	1,521	.5	Estherville sandy loam, 12 to 18 percent slopes	237	.1
Burnsville sandy loam, 12 to 18 percent slopes	399	.1	Fill land	1,964	.8
Burnsville sandy loam, 18 to 35 percent slopes	344	.1	Glencoe silty clay loam	10,037	3.5
Burnsville sandy loam, thick solum variant, 2 to 6 percent slopes	353	.1	Grays very fine sandy loam, 2 to 6 percent slopes	257	.1
Burnsville sandy loam, thick solum variant, 6 to 12 percent slopes	180	.1	Grays very fine sandy loam, 6 to 12 percent slopes	158	(1/)
Canisteo clay loam	252	.1	Hamel loam	15,064	5.3
Chaska clay loam	918	.3	Hayden loam, 2 to 6 percent slopes	13,192	4.6
Cordova silty clay loam	14,058	5.0	Hayden loam, 6 to 12 percent slopes	8,222	2.9
Cut and fill land	9,052	3.2	Hayden loam, 12 to 18 percent slopes	3,357	1.2
Dakota loam, 0 to 2 percent slopes	966	.3	Hayden loam, 18 to 24 percent slopes	2,520	.9
Dakota loam, 2 to 6 percent slopes	795	.3	Hayden and Lester loams, 24 to 35 percent slopes	2,106	.8
Dakota loam, loamy substratum, 0 to 2 percent slopes	188	.1	Hayden clay loam, 2 to 6 percent slopes, eroded	6,877	2.4
Dalbo silt loam, 0 to 2 percent slopes	214	.1	Hayden clay loam, 6 to 12 percent slopes, eroded	12,999	4.6
Dalbo silt loam, 2 to 6 percent slopes	589	.2	Hayden clay loam, 12 to 18 percent slopes, eroded	4,622	1.6
Dalbo silt loam, 6 to 12 percent slopes	172	.1	Hayden clay loam, 18 to 24 percent slopes, eroded	789	.3
Dassel sandy loam	802	.3	Heyder sandy loam, 2 to 6 percent slopes	2,998	1.1
Dickman sandy loam, 0 to 2 percent slopes	2,231	.8	Heyder sandy loam, 6 to 12 percent slopes	3,408	1.2
Dickman sandy loam, 2 to 6 percent slopes	1,439	.5	Heyder sandy loam, 12 to 18 percent slopes	918	.3
Dickman sandy loam, 6 to 12 percent slopes	753	.3			
Dorchester loam	383	.1			
Duelm loamy sand	3,507	1.3			

TABLE 1.--APPROXIMATE ACREAGE AND PROPORTIONATE EXTENT OF THE SOILS--Continued

Soil	Area	Extent
	Acres	Percent
Heyder sandy loam, 18 to 24 percent slopes	666	0.2
Heyder complex, 2 to 6 percent slopes	1,032	.3
Heyder complex, 6 to 12 percent slopes	2,712	1.0
Heyder complex, 12 to 18 percent slopes	840	.3
Heyder complex, 18 to 35 percent slopes	1,058	.4
Hubbard loamy sand, 0 to 2 percent slopes	4,583	1.6
Hubbard loamy sand, 2 to 6 percent slopes	2,767	1.0
Hubbard loamy sand, 6 to 12 percent slopes	770	.3
Hubbard loamy sand, 12 to 18 percent slopes	644	.2
Hubbard loamy sand, 18 to 35 percent slopes	1,169	.4
Isan sandy loam	4,043	1.4
Isan sandy loam, depressional	980	.3
Isan sandy loam, loamy subsoil	283	.1
Kasata silty clay loam, 1 to 5 percent slopes	172	.1
Kennebec silt loam	865	.3
Kilkenny loam, 2 to 6 percent slopes	3,118	1.1
Kilkenny loam, 6 to 12 percent slopes	1,552	.5
Kilkenny loam, 12 to 18 percent slopes	717	.3
Kilkenny loam, 18 to 24 percent slopes	324	.1
Kilkenny clay loam, 6 to 12 percent slopes, eroded	1,751	.6
Kilkenny clay loam, 12 to 18 percent slopes, eroded	554	.2
Kingsley complex, 2 to 6 percent slopes	335	.1
Kingsley complex, 6 to 12 percent slopes	833	.3
Kingsley complex, 12 to 18 percent slopes	511	.2
Kingsley complex, 18 to 24 percent slopes	359	.1
Kingsley complex, 24 to 35 percent slopes	454	.2
Lake beaches, loamy	623	.2
Lake beaches, sandy	1,402	.5
Langola loamy sand, 1 to 2 percent slopes	208	.1
Langola loamy sand, 2 to 12 percent slopes	106	(1/)
Langola loamy sand, moderately well drained, 0 to 2 percent slopes	92	(1/)
Lerdal loam, 1 to 4 percent slopes	1,715	.6
Lester loam, 2 to 6 percent slopes	5,710	2.0
Lester loam, 6 to 12 percent slopes	2,044	0.7
Lester loam, 12 to 18 percent slopes	597	.2
Lester loam, 18 to 24 percent slopes	386	.1
Lester clay loam, 2 to 6 percent slopes, eroded	948	.3
Lester clay loam, 6 to 12 percent slopes, eroded	4,006	1.4
Lester clay loam, 12 to 18 percent slopes, eroded	955	.3
Le Sueur loam, 1 to 4 percent slopes	7,772	2.7
Litchfield loamy fine sand	527	.2
Marsh	20,799	7.3
Minnetonka silty clay loam	1,332	.5
Mixed alluvial land	719	.3
Mixed alluvial land, frequently flooded	2,482	.9
Nessel loam, 1 to 4 percent slopes	7,288	2.5
Nymore loamy sand, 2 to 6 percent slopes	8,172	2.9
Nymore loamy sand, 6 to 12 percent slopes	348	.1
Peaty muck	13,271	4.7
Peaty muck over loam	4,443	1.6
Peaty muck over sand	821	.3
Rasset loamy sand, 2 to 6 percent slopes	138	(1/)
Rasset loamy sand, 6 to 12 percent slopes	202	.1
Rasset loamy sand, 12 to 25 percent slopes	204	.1
Salida coarse sandy loam, 2 to 6 percent slopes	173	.1
Salida coarse sandy loam, 6 to 12 percent slopes	531	.2
Salida coarse sandy loam, 12 to 18 percent slopes	549	.2
Salida coarse sandy loam, 18 to 35 percent slopes	1,436	.5
Shields silty clay loam	242	.1
Shorewood silty clay loam, 0 to 2 percent slopes	247	.1
Shorewood silty clay loam, 2 to 6 percent slopes	412	.1
Zimmerman loamy fine sand, 2 to 6 percent slopes	146	.1
Zimmerman loamy fine sand, 6 to 18 percent slopes	135	(1/)
Gravel pits	1,528	.5
Total land area surveyed	283,123	100.0
Total water area in county	30,744	
Approximate metropolitan land area	71,337	
Total area of county	385,204	

1/ Less than 0.05 percent.

Anoka Series

The Anoka series consists of deep, well-drained, sandy soils that formed in 5 to 10 feet or more of alternating layers of fine sand, loamy fine sand, and fine sandy loam. These soils are mainly on long, narrow ridges on outwash plains. Slopes range from 2 to 16 percent, are less than 150 feet long, and extend mainly in one direction. The original vegetation was hardwood forest and a grass understory.

In a representative profile, the surface layer is very dark grayish-brown loamy fine sand about 10 inches thick. The subsoil is about 32 inches thick and consists of alternating layers of fine sand, loamy fine sand, and fine sandy loam. The layers of fine sand are yellowish brown and brown. The finer textured layers are dark yellowish brown and brown. The underlying material is brown fine sand.

Anoka soils have low available moisture capacity, although the available moisture capacity is increased by the finer textured layers. The water table is at a depth below 5 feet in all seasons. Internal drainage and permeability are rapid. The hazard of water erosion is slight, because rainfall soaks rapidly into the porous soil and little of it runs off. Because these soils are sandy and low in content of organic matter, however, they are easily blown. Anoka soils are low in natural fertility, but crops grown on them respond well to fertilizer if adequate moisture is available.

Representative profile of Anoka loamy fine sand, 2 to 6 percent slopes, in a cultivated field, W1/2 NW1/4 SE1/4 sec. 17, T. 119 N., R. 21 W.:

Ap--0 to 10 inches, very dark grayish-brown (10YR 3/2) loamy fine sand, grayish brown (10YR 5/2) when dry; weak, fine, granular structure; very friable; many roots; band of very dark brown (10YR 2/2), discontinuous loamy fine sand in lower part; very strongly acid; clear, wavy boundary.

B2--10 to 20 inches, dark yellowish-brown (10YR 4/4) light loamy fine sand that has common inclusions of dark brown (10YR 3/3) and a few inclusions of very pale brown (10YR 7/3); very weak, coarse, subangular blocky structure; very friable; common roots; medium acid; gradual, smooth boundary.

A'21--20 to 31 inches, yellowish-brown (10YR 5/4) fine sand; a few thin inclusions of light gray (10YR 7/2) and few, fine, faint, grayish-brown (10YR 5/2) mottles; weak, coarse, blocky structure; very friable; few roots; neutral; abrupt, smooth boundary.

B'21t--31 to 37 inches, brown (10YR 4/3) fine sandy loam; dark-brown (10YR 3/3) ped faces; few, fine, distinct, grayish-brown (10YR 5/2) mottles; weak, fine and medium, subangular blocky structure; friable; many clay bridges between sand grains; neutral; abrupt, smooth boundary.

A'22-37 to 40 inches, brown (10YR 5/3) fine sand; few, fine, distinct, grayish-brown (10YR 5/2) mottles; weak, fine, subangular blocky structure; very friable; neutral; abrupt, smooth boundary.

B'22t--40 to 42 inches, dark yellowish-brown (10YR 4/4) fine sandy loam; dark-brown (10YR 3/3) ped faces; few, fine, distinct, grayish-brown (10YR 5/2) mottles; weak, coarse, subangular blocky structure parting to weak, fine and medium, subangular blocky; very friable; few, fine, tubular pores; many clay bridges between sand grains; neutral; abrupt, smooth boundary.

C--42 to 60 inches, brown (10YR 5/3) fine sand; massive; very friable; slightly acid.

The Ap horizon ranges in thickness from 8 to 12 inches and in color from very dark grayish brown or dark grayish brown when moist to grayish brown or light brownish gray when dry. In places the A'2 horizon is loamy fine sand. In most places the A'2 horizon is thicker than the B horizon. Individual horizons range from 1 to 14 inches in thickness. The aggregate thickness of the B2t horizon ranges from 6 to 12 inches within a 60-inch depth, and in some places this horizon includes heavy loamy fine sand. A few clay flows are evident in root channels. In places the C horizon contains strata of olive-brown fine sandy loam.

These soils, as mapped in Hennepin County, have a thicker, darker surface layer than is typical for the Anoka series. In addition, the sand fraction is dominantly fine sand rather than fine sand to very fine sand. These differences, however, do not affect the usefulness and behavior of the soils.

Anoka soils are closely associated with Hubbard, Zimmerman, and Rasset soils. The sand fraction of Anoka soils is finer than that of Hubbard soils, and Anoka soils have finer textured layers in the subsoil and underlying material than Hubbard soils. Anoka soils have fine sandy loam strata that have a combined thickness of more than 6 inches within a 60-inch depth; the thickness of these strata is less than 6 inches in Zimmerman soils.

Anoka loamy fine sand, 2 to 6 percent slopes (AnB).--This soil is on long, narrow ridges, about 5 to 20 acres in size, that lie 2 to 10 feet above the surrounding plain. Slopes are mostly 60 to 120 feet long. This soil has the profile described as representative for the series.

Included in mapping were a few areas of eroded soils that have a brown surface layer and small areas of soils that have a fine sand and fine sandy loam surface layer. Also included, near the village of Spring Park, were areas of a soil that contains layers of silt loam and silty clay loam. In most places these layers are less than 6 inches thick, but in places they are up to 2 feet or more in thickness. Other inclusions consist of a few small tracts near Osseo that have slight seasonal wetness where the water table is at a depth of 4 to 5 feet during wet seasons. In a few places in the northwestern part of the county, this soil is underlain by sand and gravel at a depth of 5 to 10 feet.

Unless irrigated, this Anoka soil is poorly suited to corn and soybeans because of low available moisture capacity. It is moderately well suited to small grain. This is one of the best soils in the county for irrigated potatoes. Maintenance of fertility and control of soil blowing are the major management needs in areas that have been irrigated. (Capability unit IIIs-2; woodland group 3; building site group 2)

Anoka loamy fine sand, 6 to 12 percent slopes (AnC).--This soil occupies low ridges and knolls. Areas are typically 2 to 5 acres in size but range to about 15 acres. Slopes are mainly in one direction and are less than 150 feet long.

Included in mapping were a few eroded spots of soils that have a brown surface layer. Small areas of soils that have a fine sand and fine sandy loam surface layer were also included. Near the village of Spring Park, this soil contains layers of silt loam and silty clay loam; these layers are generally less than 6 inches thick, but in places they are up to 2 feet or more in thickness. A few small sandy areas were included. In a few places in the northwestern part of the county, this soil is underlain by sand and gravel at a depth of 5 to 10 feet.

Unless irrigated, this Anoka soil is poorly suited to corn and soybeans because of low available moisture capacity. It is moderately well suited to small grain. This soil is suited to truck crops, such as irrigated potatoes. In areas where this soil is irrigated, maintenance of fertility and control of soil blowing are the main management needs. (Capability unit IVs-1; woodland group 3; building site group 2)

Becker Series

The Becker series consists of well-drained, nearly level soils that lie along bottom lands of the Crow and Mississippi Rivers. They formed in a 24-inch to 48-inch mantle of loamy alluvium and in the underlying loamy fine sand or sand. The native vegetation was tall prairie grass and mixed hardwoods.

In a representative profile, the surface layer is fine sandy loam about 35 inches thick. The upper 12 inches is very dark brown, the middle part is very dark grayish brown, and the lower 7 inches is dark brown. The subsoil is about 21 inches thick and is brown fine sandy loam that grades to loamy fine sand in the lower part. A thin, very dark brown band occurs in this layer. The underlying material is brown fine sand.

Becker soils have low available moisture capacity, rapid internal drainage, and moderate to moderately rapid permeability. They are subject to occasional flooding, but in most years floodwaters recede in time to allow planting. The water table is within a depth of 5 feet during seasons when the water is high. Crop growth is limited by drought unless rainfall distribution is good. Becker soils are blown fairly easily. The natural fertility is medium, and organic-matter content is moderate. Plants grown on these soils respond to moderate amounts of fertilizer.

Representative profile of Becker fine sandy loam, in a cultivated field, SW1/4 SE1/4 SE1/4 sec. 24, T. 119 N., R. 21 W., Brooklyn Park village:

Ap--0 to 12 inches, very dark brown (10YR 2/2) fine sandy loam; weak, very fine, subangular blocky structure; very friable; few fine roots; slightly acid; clear, smooth boundary.

A12--12 to 28 inches, very dark grayish-brown (10YR 3/2) fine sandy loam; weak, very fine, subangular blocky structure; very friable; few fine roots; few fine pores; slightly acid; gradual, smooth boundary.

A3--28 to 35 inches, dark-brown (10YR 3/3) fine sandy loam; weak, fine, subangular blocky structure parting to weak, very fine, subangular blocky; very friable; common, fine, tubular pores; slightly acid; clear, smooth boundary.

B21--35 to 43 inches, brown (10YR 4/3) light fine sandy loam; weak, very fine and fine, subangular blocky structure; very friable; few, fine, tubular pores; slightly acid; clear, smooth boundary.

B22--43 to 45 inches, very dark brown (10YR 2/2) light fine sandy loam; weak, fine, subangular blocky structure; very friable; few, fine, tubular pores; slightly acid; abrupt, smooth boundary.

B3--45 to 56 inches, brown (10YR 4/3) loamy fine sand; common, fine, faint, grayish-brown (2.5Y 5/2) mottles; weak, fine, subangular blocky structure; very friable; slightly acid; clear, smooth boundary.

IIC--56 to 60 inches, brown (10YR 4/3) fine sand; common, fine, faint, grayish-brown (2.5Y 5/2) mottles; single grain; very friable to loose; slightly acid.

These soils have weakly expressed horizons. The A1 horizon is 14 to 32 inches thick. Color ranges from very dark grayish brown to black. The A3 horizon ranges from 6 to 18 inches in thickness. The texture of the A horizon ranges from loam to fine sandy loam. The B horizon is typically brown but includes olive brown. The thin, very dark brown B22 horizon is not present in all profiles. The B horizon ranges from loam and fine sandy loam to loamy sand or loamy fine sand in texture. Depth to loamy fine sand or coarser material ranges from 20 to 48 inches but is mainly between 36 and 48 inches. The C horizon is typically brown but includes olive brown. Texture ranges from loamy fine sand to fine sand or sand. The soil is leached of carbonates to a depth of 40 to 72 inches. Reaction ranges from slightly acid to neutral.

Becker soils are similar to Dickman soils but have a thicker A horizon and a thicker solum and occur on bottom lands rather than on outwash plains.

Becker fine sandy loam (Ba).--This nearly level soil is on bottom lands. It occurs on low mounds and ridges 75 to 200 feet across and 1 to 3 feet above narrow drainageways. It typically lies just above areas of Mixed alluvial land that are next to the river. The ridges are nearly parallel to the river. Slopes are mostly less than 1 percent except in small areas that are gently sloping. This soil has the profile described as representative for the series.

Included in mapping were patches of soils that have a surface layer of loam and loamy sand. In places the soil in the drainageways is poorly drained.

The major limitations of this soil are flooding and low available moisture capacity. Corn and soybeans are the main crops grown on this soil. It is suited to these crops, but production varies from year to year depending upon rainfall distribution. This soil is well suited to potatoes, but the hazard of flooding is a serious limitation for this use. Some areas of this soil are used for garden and flower crops. (Capability unit IIw-3; woodland group 5; building site group 13)

Becker loam (Bb).--This nearly level soil occupies 5-acre to 60-acre tracts on broad flats of stream bottom lands. In a few places it lies in narrow drainageways at slightly lower elevations than Becker fine sandy loam. This soil has a profile that is similar to that of the soil described as representative for the series, but it has 20 to 30 inches of black friable loam over a subsoil of very dark grayish-brown loam. The underlying sand is at a depth of 36 to 48 inches.

Included in mapping were a few patches of soils that have a surface layer and subsoil of sandy loam. In a few spots the subsoil is silty clay loam or silty clay.

This soil has high available moisture capacity, medium internal drainage, and moderate permeability. The natural fertility and organic-matter content are high. This soil warms up more slowly in spring than Becker fine sandy loam and is not so easy to till. However, if it is worked at the right moisture content, tilth is easy to maintain.

Occasional flooding is the main limitation. This soil is suited to the major crops grown in the county, although in some years crops are lost or damaged by flooding. Corn and soybeans are the main crops grown. (Capability unit IIw-3; woodland group 5; building site group 13)

Biscay Series

The Biscay series consists of poorly drained, loamy soils on stream terraces and outwash plains. These soils formed in 24 to 40 inches of loamy alluvium over stratified sand and gravel. They are on broad flats, in shallow drainageways, and in depressions. The native vegetation was tall prairie grass and sedges.

In a representative profile, the surface layer is black to very dark gray clay loam about 21 inches thick. The subsoil is mottled, olive and olive-gray clay loam about 13 inches thick. The underlying material is mottled, olive-gray loamy sand and light olive-gray coarse sand.

Biscay soils have a moderate available moisture capacity and slow internal drainage. During wet seasons the water table is at a depth of 1 to 3 feet in undrained areas. Biscay soils are moderately to moderately slowly permeable in the subsoil and are rapidly permeable in the underlying material. In occasional years, crop growth is limited by drought. The root zone is about 3 feet deep. Biscay soils are highly fertile, but crops grown on them respond to additional fertilizer. Organic-matter content is high. These soils do not need lime.

Representative profile of Biscay clay loam, in a cultivated field, NE1/4 NE1/4 NE1/4, sec. 9, T. 119 N., R. 21 W.:

Ap--0 to 9 inches, black (10YR 2/1) clay loam, dark gray (10YR 4/1) when dry; weak, medium, subangular blocky structure parting to weak, very fine, subangular blocky; friable; common roots; medium acid; clear, smooth boundary.

A12--9 to 17 inches, black (10YR 2/1) clay loam; weak, medium, subangular blocky structure parting to weak, fine and very fine, subangular blocky; friable; common roots; slightly acid; clear, smooth boundary.

A3--17 to 21 inches, very dark gray (5Y 3/1) and dark-gray (5Y 4/1) clay loam; weak, medium, subangular blocky structure parting to weak, fine and very fine, subangular blocky; friable; few roots; few coatings of grayish brown (2.5Y 5/2) along root channels; medium acid; clear, smooth boundary.

B21g--21 to 25 inches, olive (5Y 4/3) and olive-gray (5Y 4/2) clay loam, olive gray (5Y 4/2) when rubbed; few, fine, faint, light olive-brown (2.5Y 5/4) mottles; moderate, medium, subangular blocky structure parting to moderate, fine and very fine, subangular blocky; friable; few roots; few thin clay films on faces of peds; medium acid; clear, smooth boundary.

B22g--25 to 29 inches, olive-gray (5Y 4/2 and 5Y 5/2) clay loam; few, fine, faint, light olive-brown (2.5Y 5/4) mottles; moderate, medium, subangular blocky structure parting to moderate, fine and very fine, subangular blocky; friable; few roots; common, fine, tubular pores; few thin clay films on faces of peds; medium acid; clear, smooth boundary.

B3g--29 to 34 inches, olive-gray (5Y 4/2 and 5Y 5/2) light clay loam; common, medium, prominent, yellowish-brown (10YR 5/6) mottles; weak, medium and coarse, subangular blocky structure parting to weak, fine, subangular blocky; friable; few roots; medium acid, clear, smooth boundary.

IIC1--34 to 38 inches, olive-gray (5Y 5/2) loamy sand; common, fine, distinct, yellowish-brown (10YR 5/6) mottles; weak, coarse, subangular blocky structure; very friable; slightly acid; clear, smooth boundary.

IIC2--38 to 60 inches, light olive-gray (5Y 6/2) coarse sand; few, fine, distinct, strong-brown (7.5YR 5/6) mottles; single grain; loose; slightly acid.

The A1 horizon is loam or clay loam 12 to 20 inches thick. The A3 horizon is loam or clay loam 3 to 6 inches thick. Texture of the B2 horizon ranges from loam to clay loam. Texture of the C horizon ranges from loamy sand to gravelly coarse sand. The solum ranges from 22 to 38 inches in thickness but is typically 24 to 36 inches thick. Reaction ranges from medium acid to neutral. The C horizon is slightly acid to mildly alkaline.

Biscay soils are closely associated with Dassel soils but are finer textured in the upper part of the solum.

Biscay clay loam (Bc).--This nearly level soil occupies 2-acre to 25-acre tracts in broad, shallow drainageways and on flats. It has the profile described as representative for the series.

Included in mapping were a few small depressions that are ponded during seasons of high rainfall. In a few areas, the soils are mainly calcareous throughout the profile.

Wetness is the major limitation of this soil. It needs tile or surface drainage for good crop production. Because the underlying material is porous, tile lines can be spaced widely apart. In addition to drainage, proper fertilization and tillage at the right moisture content are important.

If properly drained, this soil is suited to all major crops grown in the county. Corn and soybeans are the main crops, and with good management they can be grown year after year. (Capability unit IIw-1; woodland group 6; building site group 9)

Biscay clay loam, depressional (Bd).--This soil occurs in depressions and in narrow drainageways. The depressions are 2 acres to about 20 acres in size and lie 1 to 4 feet below areas of Biscay clay loam. This soil has a profile similar to that described as representative for the series.

Included in mapping were areas of soils that have a surface layer of silty clay loam and many areas that are calcareous. In many areas this Biscay soil has a subsoil of silty clay underlain by loose sand at a depth of 20 to 36 inches.

The main management needs are drainage and maintenance of soil tilth and fertility. In most places adequate tile outlets are lacking. If properly managed, this soil is suited to common farm crops grown in the county. Most of this soil is in marsh or meadow vegetation. (Capability unit IIIw-1; woodland group 7; building site group 12)

Borrow Land

Borrow land (Bo) is a miscellaneous land type that consists of sloping land that has been graded to produce a level site for large buildings. Areas generally range in size from about 2 to 10 acres.

This mapping unit occurs mainly in rolling to steep areas of loamy to clayey till. Most areas have a water table that remains at a depth below 5 feet in all seasons. A few areas are poorly drained, and wet basements can occur on these sites.

Building construction can usually begin in these areas soon after grading without causing settling problems. These areas are poorly suited to septic tank drainfields, as water moves slowly through this material. (Not in a capability unit, woodland group, or building site group)

Borrow Pits

Borrow pits (Bp) is a miscellaneous land type that consists of excavations into hillsides or knolls for the purpose of removing soil for construction uses. The soil is generally loamy or clayey. Most pits are less than 1 acre in size. (Not in a capability unit, woodland group, or building site group)

Braham Series

The Braham series consists of deep, somewhat excessively drained soils. These soils formed in an 18-inch to 40-inch mantle of sandy material and in the underlying loamy till. They occur on knolls and hills, mainly along the edges of sandy stream terraces. Slopes range from 2 to 12 percent, include both simple and complex forms, and are 75 to 200 feet long. The native vegetation was mixed hardwoods.

In a representative profile, the surface layer is very dark grayish-brown loamy fine sand about 12 inches thick. The subsoil consists of two layers. The upper 12 inches is dark grayish-brown loamy fine sand. The lower 22 inches is brown sandy loam that grades to dark yellowish-brown clay loam. The underlying material is calcareous, light olive-brown loam.

Braham soils have low to moderate available moisture capacity. Available moisture capacity is highest in areas where the loamy subsoil is at the shallower depths. Unless rainfall is timely, crop growth is limited by drought. Response to irrigation is good, but the steepness of slope limits the use of irrigation equipment in most areas. The sandy layers are rapidly permeable, but the subsoil and underlying material are moderately permeable. The root zone is deep. The water table is at a depth below 5 feet in all seasons. Internal drainage is medium. These soils are easily blown. They are

low in natural fertility and organic-matter content. Crops respond well to fertilizer if rainfall is timely or if irrigation is provided. Lime is needed in many places.

Representative profile of Braham loamy fine sand, 2 to 6 percent slopes, in a cultivated field, NW1/4 SE1/4 NE1/4, sec. 12, T. 120 N., R. 23 W.:

Ap--0 to 8 inches, very dark grayish-brown (10YR 3/2) loamy fine sand; very weak, very fine, subangular blocky structure; very friable; common roots; medium acid; abrupt, smooth boundary.

A3--8 to 12 inches, very dark grayish-brown (10YR 3/2) heavy loamy fine sand; very weak, fine, subangular blocky structure; very friable; few roots; medium acid; clear, smooth boundary.

B1--12 to 24 inches, dark grayish-brown (10YR 4/2) loamy fine sand; very weak, medium, subangular blocky structure; very friable; few roots; medium acid; clear, smooth boundary.

IIB21--24 to 27 inches, brown (10YR 4/3) fine sandy loam; weak, fine, subangular blocky structure; very friable; few roots; medium acid; clear, smooth boundary.

IIB22--27 to 37 inches, brown (10YR 4/3) sandy clay loam; weak, fine, subangular blocky structure; firm; few roots; few, fine, tubular pores; medium acid; clear, smooth boundary.

IIB3--37 to 46 inches, dark yellowish-brown (10YR 4/4) clay loam; firm; few, fine, tubular pores; about 4 percent coarse fragments, mainly fine shale; slightly acid; clear, smooth boundary.

IIC--46 to 60 inches, light olive-brown (2.5Y 5/4) heavy loam; weak cleavage planes; friable; about 4 percent coarse fragments, mainly igneous shale and limestone; mildly alkaline; calcareous.

The depth of the solum ranges from 40 to 60 inches. The Ap horizon is 7 to 11 inches thick and ranges from very dark grayish brown to black in color. In undisturbed areas the A1 horizon is 4 to 8 inches thick and is black or very dark brown in color. A dark grayish-brown A2 horizon occurs in some profiles. The B1 horizon ranges from dark grayish brown to yellowish brown in color. Distinct, low-chroma mottles occur just above the IIB horizon in some profiles. Texture of the B1 horizon ranges from loamy fine sand to sand. The IIB horizon is typically sandy loam or fine sandy loam in the upper 3 to 8 inches. The rest is clay loam or loam but in some places includes silt loam, silty clay loam, or sandy clay loam. Clay films are on faces of peds in the IIB2 horizon of some profiles. The IIB2 horizon ranges from 10 to 25 inches in thickness. Reaction of the A horizon ranges from medium acid to neutral, and reaction of the B horizon ranges from medium acid to slightly acid.

Braham soils are closely associated with the Anoka, Heyder, Duelm, loamy subsoil variant, and Langola soils. They have continuous, loamy IIB and C horizons in contrast to the loamy sand and sandy loam strata of Anoka soils. They are more sandy in the upper part of the B horizon than Heyder soils and are better drained than Duelm soils, loamy subsoil variant. Braham soils have more silt and clay in the B and C horizons than Langola soils.

Braham loamy sand, silty subsoil, 2 to 6 percent slopes (BsB).--This gently sloping soil occupies 5-acre to 15-acre, irregularly shaped areas on the crowns of low hills. Areas generally are longer than wide. Slope segments range from 75 to 150 feet in length. The profile of this soil is similar to that of the soil described as representative for the series, except that it is underlain by silt loam or silty clay loam rather than by loam at a depth of 18 to 40 inches. There are patches of dark brown at the crests of the steeper slopes, where this soil is eroded.

Included in mapping were spots of soils where the sandy mantle is 40 to 80 inches thick over the silt. A few shallow swales and depressions that were included in mapping are wet for short periods of time.

The main limitations of this soil are low to moderate available moisture capacity and a hazard of soil blowing. The hazard of water erosion is slight. Growth of common farm crops is limited by drought unless rainfall is timely. In areas where irrigation can be provided, this soil is well suited to most crops commonly grown in the county. (Capability unit IIIs-2; woodland group 2; building site group 3)

Braham loamy sand, silty subsoil, 6 to 12 percent slopes (BsC).--This rolling soil occupies 5-acre to 25-acre tracts on the upper sides of low, irregularly shaped hills. Slopes are short. This soil has a profile similar to that of the soil described as representative for the series, except that it is underlain by silt loam or silty clay loam rather than by loam at a depth of 18 to 40 inches.

Included in mapping because of small acreage were small areas of Braham loamy sand, silty subsoil, and Grays very fine sandy loam that have slopes of 12 to 25 percent. A few patches of soils that have a surface layer of fine sandy loam were also included in mapping. In a few places the sand is 40 to 80 inches thick over the silt.

Low available moisture capacity, soil blowing, and water erosion limit the use of this soil. The hazard of erosion is moderate. Small grain and forage crops are better suited to this soil than late-season crops, such as corn and soybeans. In most years, however, they are limited in growth by lack of moisture unless rainfall is timely. Most areas are in permanent grass. (Capability unit IVs-1; woodland group 2; building site group 3)

Braham loamy fine sand, 2 to 6 percent slopes (BtB).--This gently undulating soil occupies 2-acre to 10-acre areas on irregularly shaped knolls and upper hillside slopes. Slope segments are commonly 75 to 150 feet long. This soil has the profile described as representative for the series.

Included in mapping were a few spots of soils that have a loam surface layer. Also included were small patches of soils where the sand is less than 18 inches thick, and other places where it is more than 40 inches thick.

The hazards of drought and soil blowing are severe. Unless rainfall is timely, growth of common farm crops is limited by drought. In areas where irrigation can be provided, this soil is well suited to truck crops, such as potatoes and sweet corn, and to other crops commonly grown in the county. (Capability unit IIIs-2; woodland group 2; building site group 3)

Braham loamy fine sand, 6 to 12 percent slopes (BtC).--This rolling soil is in irregularly shaped, 2-acre to 10-acre areas on side slopes and knolls. Slope segments are 75 to 125 feet long. This soil has a profile similar to that of the soil described as representative for the series.

Included in mapping were a few areas of eroded soils that have a surface layer of dark brown and occur on knolls. Also included were a few areas of soils that have slopes up to 18 percent. In places the texture of the surface layer is loam. There are also small patches of soils where the sand is less than 18 inches thick, and other places where it is more than 40 inches thick.

The hazards of drought and soil blowing are severe. Unless rainfall distribution is good, growth of local farm crops is limited by drought. Irrigation equipment is difficult to use on this soil because of the steep slopes. Most areas are in permanent grass. (Capability unit IVs-1; woodland group 2; building site group 3)

Burnsville Series

The Burnsville series consists of somewhat excessively drained soils that formed in 12 to 24 inches of loam over calcareous gravel and sand. These soils occupy irregular knolls and hills that are 10 to 100 feet above the surrounding swales and sloughs. Slopes are mainly complex, are 75 to 300 feet long, and have gradients of 2 to 35 percent. The native vegetation was mixed hardwoods, mainly oak.

In a representative profile, the surface layer is black sandy loam about 3 inches thick. The subsurface layer is dark grayish-brown heavy loamy sand about 6 inches thick. The subsoil, about 24 inches thick, is dark-brown and dark yellowish-brown sandy loam to sandy clay loam that grades to gravelly loamy coarse sand in the lower part. The underlying material is calcareous, yellowish-brown gravelly coarse sand.

Burnsville soils have low available moisture capacity because of the shallow depth to sand and gravel. Root development is limited to the thin surface layer and subsoil. Unless rainfall is timely, crop growth is limited by drought. The subsoil has moderately rapid permeability. The underlying material is rapidly permeable. Internal drainage is rapid. The water table is at a depth below 5 feet in all seasons and below 10 feet in most places. Because the organic-matter content is low, these soils are fairly easily eroded by water and are easily blown. Erosion is a serious hazard on these soils because the root zone and the available moisture are confined to the surface layer and subsoil. Burnsville soils are low in fertility. Unless moisture distribution is timely or irrigation is provided, crop response to fertilizer is poor to fair. In most places lime is needed to establish legumes.

Representative profile of Burnsville sandy loam, 2 to 6 percent slopes, in a gravel pit, SE. corner NW1/4 NW1/4 NW1/4 sec. 34, T. 117 N., R. 22 W.:

A1--0 to 3 inches, black (10YR 2/1) sandy loam; weak, very fine, subangular blocky structure; very friable; neutral; abrupt, smooth boundary.

A2--3 to 9 inches, dark grayish-brown (10YR 4/2) heavy loamy sand; weak, medium, subangular blocky structure; very friable; 5 percent gravel; neutral; clear, wavy boundary.

B1--9 to 13 inches, dark-brown (10YR 3/3) light sandy loam; many, light brownish-gray (10YR 6/2) when dry; sand grains on faces of peds; weak, medium, subangular blocky structure; very friable; 5 percent gravel; slightly acid; clear, smooth boundary.

B2t--13 to 20 inches, dark yellowish-brown (10YR 4/4) loam; weak to moderate, subangular blocky structure; friable; many, thick, dark yellowish-brown (10YR 3/4) clay films on faces of peds; 10 percent gravel; medium acid; abrupt, wavy boundary.

IIB3t--20 to 24 inches, dark-brown (7.5YR 4/4) gravelly loamy coarse sand; dark-brown (7.5YR 3/2) ped coatings; weak, coarse, subangular blocky structure; loose; 20 percent gravel; mildly alkaline; weakly calcareous; clear, wavy boundary.

IIC--24 to 60 inches, yellowish-brown (10YR 5/4) gravelly coarse sand; single grain; loose; 25 percent gravel; mildly alkaline; strongly calcareous.

The solum is commonly 20 to 30 inches thick, but in places it is as much as 36 inches thick. In undisturbed areas the A1 horizon is 2 to 4 inches thick. The A2 horizon is 2 to 6 inches thick and ranges in color from very dark grayish brown to brown. If cultivated, these soils have a very dark grayish-brown or dark grayish-brown Ap horizon 7 to 10 inches thick. The Ap horizon is sandy loam or light loam. The C horizon is mainly stratified coarse and very coarse sand and fine gravel or deep gravelly sand till. Color ranges from yellowish brown to brown and olive brown. The depth to gravel and sand is 14 to 24 inches. Reaction of the A horizon is neutral to medium acid. The B2 horizon is slightly acid to strongly acid. The C horizon is slightly calcareous to strongly calcareous.

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These Burnsville soils are closely associated with Burnsville soils, thick solum variant, and with Estherville and Salida soils. They have a thinner A1 horizon and B horizon and a more gravelly C horizon than Burnsville soils, thick solum variant. Burnsville soils have a lighter colored Ap horizon than Estherville and Salida soils and a thicker B2 horizon than Salida soils.

Burnsville sandy loam, 2 to 6 percent slopes (BuB).--This gently undulating soil occupies 2-acre to 15-acre, irregularly shaped areas on knolls and hills. Slopes are 60 to 125 feet long. This soil has the profile described as representative for the series. In cultivated areas, the surface layer is dark grayish brown.

Included in mapping were small areas of the very droughty Salida soils. Also included were a few areas of soils that are more than 24 inches thick over gravel and sand. In places this Burnsville soil is underlain by loam till at a depth of 4 to 8 feet.

The hazards of soil blowing and water erosion are moderate on this soil. It is also droughty. It is poorly suited to corn and soybeans. Some areas of this soil near the city of Hopkins are used for raspberry production. Most areas are in woodland or pasture or have been developed for homesites. (Capability unit IIIe-3; woodland group 3; building site group 2)

Burnsville sandy loam, 6 to 12 percent slopes (BuC).--This rolling soil occupies 2-acre to 15-acre, irregularly shaped areas on hillsides. Slopes are 60 to 120 feet long. This soil is generally more shallow to gravel and sand than the soil in the profile described as representative for the series. In cultivated areas the surface layer is dark brown.

Included in mapping were small areas of the very droughty Salida soils. Also included were a few areas of soils that are more than 24 inches deep over gravel and sand. In places this Burnsville soil is underlain by loam till at a depth of 4 to 8 feet.

In cultivated areas the hazards of erosion and drought are severe. This soil is poorly suited to corn and soybeans. Near the city of Hopkins, some areas of this soil are used for raspberry production. (Capability unit IVe-4; woodland group 3; building site group 2)

Burnsville sandy loam, 12 to 18 percent slopes (BuD).--This moderately steep soil occupies 2-acre to 15-acre, irregularly shaped areas on hillsides. Slopes are 60 to 120 feet long. This soil is more shallow to gravel and sand than the soil in the profile described as representative for the series. In cultivated areas the surface layer is dark brown.

Included in mapping were a few patches of the very droughty Salida soils. Also included were a few patches of soils that are more than 24 inches deep over gravel and sand. In places this Burnsville soil is underlain by loam till at a depth of 4 to 8 feet.

Drought and the risk of erosion severely limit the use of this soil for intertilled crops. This soil is better suited to permanent vegetation than to cultivated crops, and most of the acreage is in permanent vegetation. (Capability unit VIs-1; woodland group 3; building site group 2)

Burnsville sandy loam, 18 to 35 percent slopes (BuE).--This steep soil occupies 2-acre to 20-acre, irregularly shaped areas on elongated hills and short slopes on hillsides. Slopes are 60 to 150 feet long. This soil is generally more shallow to sand and gravel than the soil in the profile described as representative for the series. The surface layer is very dark grayish brown.

Included in mapping were small patches of droughty Salida soils near the base of the slopes.

This soil is in woodland or pasture. It is too steep and too droughty for cropland. It is better suited to uses where a good plant cover is maintained. (Capability unit VIIs-1; woodland group 3; building site group 2)

Burnsville Series, Thick Solum Variant

The Burnsville series, thick solum variant, consists of somewhat excessively drained soils. These soils formed in 20 to 40 inches of loamy alluvium over sand and gravel. They occupy irregular knolls and hills that lie 10 to 40 feet above the surrounding sloughs and swales. Slopes range from 2 to 12 percent. The original vegetation was mixed hardwood forest.

In a representative profile, the surface layer is black to very dark brown sandy loam about 14 inches thick. The subsoil is about 34 inches thick. It is very dark grayish-brown and dark grayish-brown sandy loam in the upper part and loamy sand in the lower 18 inches. The underlying material is very dark grayish-brown gravelly loamy coarse sand underlain by brown gravelly coarse sand.

These soils have low available moisture capacity, moderately rapid permeability, and rapid internal drainage. The water table is at a depth below 6 feet in all seasons. The organic-matter content is high, and the fertility level is medium. Crops grown on these soils respond to moderate amounts of fertilizer. The root zone is moderately deep.

Representative profile of Burnsville sandy loam, thick solum variant, 2 to 6 percent slopes, in a cultivated field, NW1/4 SE1/4 SW1/4 sec. 31, T. 117 N., R 23 W.:

Ap--0 to 10 inches, black (10YR 2/1) to very dark brown (10YR 2/2) sandy loam, gray (10YR 5/1) when dry; weak, very fine, subangular blocky structure; friable; many roots; neutral; clear, smooth boundary.

A3--10 to 14 inches, very dark brown (10YR 2/2) sandy loam; weak, very fine, subangular blocky structure; friable; many roots; few to common pores; about 5 percent gravel, mainly shale and igneous; slightly acid; clear, smooth boundary.

B21t--14 to 19 inches, very dark grayish-brown (10YR 3/2) sandy loam; weak, very fine to fine, subangular blocky structure; friable; few roots; few pores; common clay bridges between sand grains; about 10 percent gravel, mainly shale; slightly acid; clear, smooth boundary.

B22t--19 to 24 inches, very dark grayish-brown (10YR 3/2) sandy loam; weak, medium, subangular blocky structure; friable; few pores; few, thin clay films on faces of peds and common clay bridges between sand grains; about 10 percent coarse gravel, mainly shale and igneous; medium acid; clear, smooth boundary.

B23t--24 to 30 inches, dark grayish-brown (2.5Y 4/2) sandy loam; weak, medium, subangular blocky structure; friable; few pores; few, thin clay films on faces of peds and common clay bridges between sand grains; about 10 percent gravel, mainly shale; neutral; clear, smooth boundary.

IIB3--30 to 48 inches, very dark grayish-brown (10YR 3/2) loamy coarse sand; weak, subangular blocky structure; friable; 15 percent gravel, mainly shale and igneous; mildly alkaline; calcareous; gradual, wavy boundary.

IIC1--48 to 52 inches, very dark grayish-brown (10YR 3/2) gravelly loamy coarse sand; massive; very friable; about 5 percent gravel, mainly igneous, shale, and limestone; mildly alkaline; calcareous; clear, smooth boundary.

IIC2--52 to 60 inches, brown (10YR 5/3) gravelly coarse sand; single grain; loose; about 25 percent gravel, mainly igneous and shale; mildly alkaline; calcareous.

The solum is 24 to 54 inches thick. The A1 horizon is 6 to 10 inches thick and black or very dark brown in color. Brown and dark yellowish brown are more typical colors for the B horizon than the very dark grayish brown described as representative for the series. The darker colors are characteristic of profiles that have a higher content of shale. The B2 horizon has a distinct clay increase as compared to the A horizon. Thickness of the B3 horizon ranges from 6 to 24 inches, and color ranges from very dark grayish brown to olive brown. Thin lamellae of very dark brown are common in the B3 horizon. Texture of the B3 horizon is sandy loam, coarse sandy loam, loamy coarse sand, or loamy sand. The C horizon consists of loose stratified sand and thin layers of gravelly, shaly coarse sand. The sand ranges in size from fine to very coarse. The solum contains 5 to 15 percent gravel, with about half of the coarse fraction comprised of shale. The C horizon typically contains 5 to 25 percent gravel. Some thin layers contain up to 35 percent gravel.

The A horizon is medium acid to neutral. The B horizon is strongly acid to slightly acid in the upper part and slightly acid to mildly alkaline in the lower part. The C horizon is neutral to mildly alkaline. Depth to carbonates ranges from 26 to 60 inches.

Soils of the Burnsville series, thick solum variant, have a thicker B horizon and have less gravel in the underlying material than associated normal Burnsville and Estherville soils. They have a thicker B horizon than Dickman soils.

Burnsville sandy loam, thick solum variant, 2 to 6 percent slopes (BxB).--This gently sloping soil occupies 5-acre to 20-acre areas on knolls and hills. Slopes are commonly 75 to 125 feet long. This soil commonly occurs above more sloping areas of Burnsville, thick solum variant, and Estherville soils. This soil has the profile described as representative for the series.

Included in mapping were small areas of Estherville and Lester soils.

Most areas of this soil are in woodland. This soil is fair cropland if well managed. The hazards of soil blowing and water erosion are moderate. Crop growth is limited by lack of moisture unless rainfall distribution is good. (Capability unit IIIe-3; woodland group 2; building site group 1)

Burnsville sandy loam, thick solum variant, 6 to 12 percent slopes (BxC).--This gently rolling soil occupies 5-acre to 15-acre areas on knolls and hillsides. Slopes are commonly 75 to 125 feet long. This soil has a profile similar to that described as representative for the series.

Included in mapping were small areas of Estherville and Lester soils.

Most areas of this soil are in woodland. The hazards of water erosion and drought severely limit the use of this soil for intertilled crops. Good management is needed to control erosion. When well managed, this soil is moderately well suited to crops commonly grown in the county. (Capability unit IVe-4; woodland group 2; building site group 1)

Canisteo Series

The Canisteo series consists of deep, poorly drained, calcareous soils that formed in loam glacial till. These soils occupy slightly elevated rims of drainageways and slight rises within wet depressions in undulating areas. The few stones and boulders are principally at the surface. The native vegetation was mixed hardwoods with a grass understory.

In a representative profile, the surface layer is strongly calcareous, black light clay loam about 17 inches thick that grades to very dark gray in the lower part. The subsoil extends to a depth of about 36 inches and is dark-gray to olive-gray clay loam to loam. The underlying material is strongly calcareous, mottled, olive-gray loam.

Canisteo soils have high available moisture capacity, slow internal drainage, and moderate permeability. The water table is at a depth of 1 to 3 feet during wet periods. The root zone is deep. The organic-matter content is high, and natural tilth is good. Canisteo soils are highly fertile, but the high content of lime slows plant uptake of potash and phosphorus.

Representative profile of Canisteo clay loam, in a cultivated field, NE1/4 NE1/4 SE1/4 sec. 27, T. 117 N., R. 23 W.:

A11--0 to 10 inches, black (10YR 2/1) light clay loam; friable; many roots; mildly alkaline; strongly calcareous; clear, smooth boundary.

A12--10 to 14 inches, black (10YR 2/1) light clay loam; very weak, very fine, subangular blocky structure; friable; many roots; mildly alkaline; strongly calcareous; clear, smooth boundary.

A3--14 to 17 inches, very dark gray (10YR 3/1) light clay loam; weak, very fine, subangular blocky structure; friable; few roots; few, very fine, tubular pores; mildly alkaline; strongly calcareous; clear, smooth boundary.

B1g--17 to 20 inches, dark-gray (5Y 4/1) light clay loam; weak, very fine, subangular blocky structure; friable; few roots; few, very fine, tubular pores; mildly alkaline; strongly calcareous; clear, smooth boundary.

B21g--20 to 25 inches, olive-gray (5Y 5/2) light clay loam; weak, very fine, subangular blocky structure; few roots; few, very fine, tubular pores; friable; mildly alkaline; strongly calcareous; clear, smooth boundary.

B22g--25 to 30 inches, olive-gray (5Y 5/2) clay loam; few, fine, faint, light olive-brown (2.5Y 5/6) mottles; very weak, very fine, subangular blocky structure; friable; mildly alkaline; strongly calcareous; clear, smooth boundary.

B23g--30 to 36 inches, olive-gray (5Y 5/2) loam; common, medium, prominent, light olive-brown (2.5Y 5/6) mottles; very weak, very fine, subangular blocky structure; friable; few white lime segregations; mildly alkaline; strongly calcareous; clear, smooth boundary.

C--36 to 60 inches, olive-gray (5Y 5/2) loam; many, medium, prominent, light olive-brown (2.5Y 5/6) mottles; massive; friable; mildly alkaline; strongly calcareous.

The A1 horizon ranges from 8 to 16 inches in thickness, and the A3 horizon ranges from 3 to 8 inches in thickness. The texture is clay loam in most places, but it is loam in some areas. The B2 and C horizons are olive gray in color in most areas but range to grayish brown or gray; gray colors are associated with the more calcareous layers. The C horizon ranges in clay content from 24 to 32 percent, in sand content from 30 to 45 percent, and in gravel content from 2 to 5 percent.

The solum is mildly alkaline, but some horizons are neutral in reaction. The soil is generally slightly calcareous to strongly calcareous throughout, although in some profiles the upper part of the A horizon is leached of free carbonates.

Canisteo soils are calcareous, unlike associated Cordova soils, which are neutral to slightly acid. Canisteo soils also have less development in the B horizon than Cordova soils.

Canisteo clay loam (Ca).--This is a nearly level soil that occupies 2-acre to 10-acre rims adjacent to Glencoe soils and peaty areas.

Included in mapping were small areas of Cordova soils and small areas of Le Sueur soils on slight rises. A few small depressions that contain Glencoe soils were also included. A few spots are underlain by gravel and sand at a depth below 2 feet.

The main management needs are drainage and maintaining soil tilth. In areas that are properly drained and managed, this soil is well suited to growing corn and soybeans year after year. (Capability unit IIw-1; woodland group 6; building site group 10)

Chaska Series

The Chaska series consists of deep, poorly drained soils that formed in deep alluvium. These nearly level soils are in broad, irregularly shaped areas on stream bottom lands. The native vegetation was prairie grasses, sedges, and patches of willow and poplar.

In a representative profile, the surface layer is calcareous, very dark gray clay loam in the upper 10 inches and very dark grayish-brown loam in the lower 23 inches. The underlying material is calcareous, mottled, dark grayish-brown to dark-gray loam that is high in content of very fine sand. Snail shells are present in the lower part of the surface layer and in the underlying material.

Chaska soils have very high available moisture capacity, slow internal drainage, and moderate permeability. These soils are flooded in some years, resulting in serious crop losses. During wet periods, the water table is at a depth of 1 to 3 feet. Chaska soils have a deep root zone. They are very fertile, but crops grown on them respond to applications of fertilizer.

Representative profile of Chaska clay loam, in a cultivated field, SE1/4 NW1/4 NW1/4 sec. 32, T. 116 N., R. 22 W.:

Ap--0 to 10 inches, very dark gray (10YR 3/1) clay loam, high in content of very fine sand; few channels of very dark grayish brown (10YR 3/2), dark grayish brown (10YR 4/2) when dry; weak, very fine, subangular blocky structure; friable; mildly alkaline; calcareous; clear, smooth boundary.

A12--10 to 21 inches, very dark grayish-brown (10YR 3/2) loam, high in content of very fine sand and fine sand; thin seams of grayish-brown (2.5Y 5/2) sandy loam and loamy sand less than 1/4 inch thick; few, fine, prominent, strong-brown (7.5YR 5/8) mottles; weak, very fine, subangular blocky structure; very friable; few pores; few small snail shells; mildly alkaline; calcareous; gradual, smooth boundary.

A13--21 to 33 inches, very dark grayish-brown (2.5Y 3/2) and dark grayish-brown (2.5Y 4/2) loam, very dark grayish brown (2.5Y 3/2) when rubbed;

high in content of very fine sand; common, fine, distinct, light olive-brown (2.5Y 5/6) mottles; weak to moderate, fine, subangular blocky structure; very friable; few lime concentrations and snail shells; mildly alkaline; calcareous; clear, smooth boundary.

Cg--33 to 60 inches, dark-gray (10YR 4/1) and dark grayish-brown (10YR 4/2) loam, high in content of very fine sand; few, fine, distinct, dark-brown (10YR 3/3) mottles; weak, very fine, subangular blocky structure; very friable; few lime concentrations and snail shells; mildly alkaline; calcareous.

The A horizon is 24 to 36 inches thick and is clay loam or loam in texture. The C horizon ranges from very dark gray to grayish brown in color. The soil is mildly alkaline and is weakly calcareous or strongly calcareous throughout. Snail shells are a common feature, and they occur throughout the profile.

These soils, as mapped in Hennepin County, contain less fine sand than presently required for the Chaska series, but this feature does not alter their usefulness and behavior.

Chaska soils are slightly finer textured and are mottled closer to the surface than associated Dorchester soils. Chaska soils have a grayer A horizon than similar Canisteo soils and formed in alluvium rather than glacial till.

Chaska clay loam (Ch).--This nearly level soil lies on bottom lands along the Minnesota River. It occurs at slightly lower elevations than the Dorchester soils, which generally occur between Chaska soils and the river. This is the only Chaska soil mapped in the county.

Included in mapping were a few areas of soils that have a black silty clay loam surface layer 20 to 36 inches deep and occur along the Crow River. Also included were small areas of firm silty clay 18 to 30 inches deep. Areas of soils where the water table is at or near the surface part of the year were also included. These areas mainly border large peat bogs.

The high water table and the hazard of flooding are the major limitations. Most of this soil is used for corn and soybeans. Because of the slope, this soil is hard to drain. In areas where this soil can be drained and protected from flooding, it is well suited to crops commonly grown in the county. (Capability unit IIw-1; woodland group 6; building site group 13)

Cordova Series

The Cordova series consists of deep, poorly drained soils that formed in loam glacial till. These soils are on broad flats and in drainageways throughout the glacial uplands. There are stones and boulders in the soil, mainly near the surface. The native vegetation was mixed hardwood forest.

In a representative profile, the surface layer is black silty clay loam in the upper 9 inches and very dark gray silty clay loam in the lower 3 inches. The subsoil is mottled olive-gray silty clay and clay loam about 15 inches thick. The underlying material is mottled, light olive-gray, calcareous loam.

Cordova soils have high available moisture capacity. Internal drainage is slow, and permeability is moderately slow. During wet periods the water table is at a depth of 1 to 3 feet in undrained areas. The root zone is deep. Natural fertility and organic-matter content are high. Crops grown on these soils respond well to fertilizer. Lime is not generally needed.

Representative profile of Cordova silty clay loam, in a cultivated field, SW1/4 SW1/4 SW1/4 sec. 10, T. 118 N., R. 23 W., Medina village:

Ap--0 to 9 inches, black (N 2/0) light silty clay loam; moderate, very fine and fine, subangular blocky structure; friable; many roots; neutral; clear, smooth boundary.

A3--9 to 12 inches, very dark gray (10YR 3/1) silty clay loam; common inclusions and ped coatings of gray (10YR 5/1); moderate, very fine and fine, blocky structure in very dark gray material; weak, very thin, platy structure in gray material; friable; common roots; common, fine, tubular pores; neutral; clear, smooth boundary.

B21--12 to 17 inches, olive-gray (5Y 4/2) silty clay; moderate, medium, prismatic structure parting to strong, medium and coarse, subangular blocky structure; firm; common roots; fine, tubular pores; few, thick, gray (10YR 5/1), porous coatings on faces of peds; many, thick, very dark gray (10YR 3/1) clay films on faces of peds; slightly acid; clear, smooth boundary.

IIB22t--17 to 22 inches, olive-gray (5Y 4/2) clay loam; few, fine, faint, light olive-brown (2.5Y 5/6) mottles; moderate, coarse, prismatic structure parting to moderate, coarse, subangular blocky structure; friable; few roots; common, fine, tubular pores; common, thick, black (10YR 2/1) clay films on faces of peds; about 5 percent coarse fragments; slightly acid; clear, smooth boundary.

IIB3t--22 to 27 inches, olive-gray (5Y 5/2) clay loam; few, fine, faint mottles of light olive brown (2.5Y 5/6); weak, coarse, prismatic structure parting to weak, coarse, subangular blocky structure; friable; few roots; few, fine, tubular pores; common, thick, very dark gray (10YR 3/1) films on faces of peds and in root channels; about 5 percent coarse fragments; neutral; clear, smooth boundary.

IIC1--27 to 47 inches, olive-gray (5Y 5/2) loam; many, medium, prominent, light olive-brown (2.5Y 5/6) mottles; weak, medium and coarse, subangular blocky structure; friable; few, fine, tubular pores; few, thin, black

(10YR 2/1) clay films in root channels; few white lime concentrations and concretions; about 5 percent coarse fragments; mildly alkaline; strongly calcareous; clear, smooth boundary.

IIC2--47 to 60 inches, light olive-gray (5Y 6/2) loam; many, medium, prominent, light olive-brown (2.5Y 5/6) mottles; weak cleavage planes; friable; few white lime concretions and concentrations; about 5 percent coarse fragments; mildly alkaline; strongly calcareous.

The thickness of the solum ranges from 20 to 42 inches but is commonly between 24 and 36 inches. The upper part of the solum is commonly formed in a 12-inch to 24-inch mantle that is higher in content of silt and clay than the material below. The A horizon is 10 to 18 inches thick. Texture is loam, silt loam, silty clay loam, and clay loam. In undisturbed areas there is a thin A2 horizon in some profiles, but inclusions of dark gray or gray in the lower part of the A horizon are the more common expressions of eluviation. Texture of the upper part of the B2 horizon is silty clay, silty clay loam, or clay loam. The lower part of the B2 horizon is clay loam or loam. In the zone of maximum clay accumulation, the content of clay ranges from 30 to 45 percent but is typically between 32 and 38 percent. The A horizon is neutral to slightly acid, and the B horizon is neutral to medium acid.

Cordova soils are more acid and have stronger structure in the B2 horizon than associated Canisteo soils. Cordova soils have a darker colored Ap horizon and weaker structure in the B2 horizon than associated Dundas soils. Cordova soils are not so fine textured as Minnetonka soils, and they have a thinner dark-colored A horizon than Hamel soils.

Cordova silty clay loam (Co).--This nearly level soil is on flats and in shallow drainageways.

Included in mapping were areas of a more friable soil that has less development in the subsoil. Also included were small areas of Le Sueur soils on slight rises and many scattered depressions of Glencoe soils. Some of the depressions contain a soil that has a platy, gray loam subsurface layer and a plastic, clayey, slowly permeable subsoil.

Drainage and maintenance of tilth are the main management needs on this soil. If properly drained and managed, this soil is suited to all the crops commonly grown in the county. It is well suited to corn and soybeans, and with good management they can be grown year after year. (Capability unit IIw-1; woodland group 6; building site group 10)

Cut and Fill Land

Cut and fill land (Cu) is a miscellaneous land type that consists of areas that have been leveled for buildings such as schools, large churches, and shopping centers. It is in depressions and on knolls. The soil material is generally similar to the soils that are nearby. Areas range in size from 2 acres for a small school to 160 acres or more for industrial parks. Depth to the water table varies from place to place on these soils.

If allowed to settle and compact before construction, this land type supports low buildings satisfactorily. It is well to allow graded land to settle for a year or more before beginning construction.

In many places areas of this land type consist of loamy or clayey material. The natural structure of the soil is destroyed during the grading process. Because permeability is slow, this land type is poorly suited to septic tank drainfields. (Not in a capability unit, woodland group, or building site group)

Dakota Series

The Dakota series consists of well-drained, loamy soils. These soils formed in 22 to 36 inches of loamy alluvium over deep sand. They are nearly level to gently sloping. The native vegetation was tall prairie grasses and mixed hardwoods.

In a representative profile, the surface layer is black loam in the upper 9 inches and dark-brown loam in the lower 5 inches. The subsoil is brown and dark-brown loam about 13 inches thick. The underlying material is stratified, very dark grayish-brown to yellowish-brown and light olive-brown sand.

Dakota soils have moderate to high available moisture capacity, medium internal drainage, and moderately rapid permeability. The water table is at a depth below 5 feet in all seasons and in most places is at a depth below 10 feet. These soils have medium natural fertility and moderate organic-matter content. Unless rainfall is timely or irrigation is supplied, crops grown on Dakota soils respond only to moderate amounts of fertilizer.

Representative profile of Dakota loam, 0 to 2 percent slopes, in a cultivated field, SW1/4 NW1/4 sec. 12, T. 119 N., R. 22 W.:

Ap--0 to 9 inches, black (10YR 2/1) loam; weak, medium and coarse, subangular blocky structure parting to weak, very fine and fine, subangular blocky structure; friable; few roots; slightly acid; abrupt, smooth boundary.

A3--9 to 14 inches, dark-brown (10YR 3/3) loam; very dark grayish-brown (10YR 3/2) coatings on peds; weak, medium and coarse, subangular blocky structure parting to weak, fine and very fine, subangular blocky structure; friable; few roots; few, fine, tubular pores; slightly acid; clear, smooth boundary.

B2--14 to 21 inches, brown (10YR 4/3) loam; dark-brown (10YR 3/3) coatings on peds; weak, medium, subangular blocky structure parting to weak, fine and very fine, subangular blocky structure; friable; few roots; few, fine, tubular pores; about 5 percent gravel, mostly igneous and shale; medium acid; clear, smooth boundary.

B3--21 to 27 inches, dark-brown (10YR 3/3) loam; patchy, very dark grayish-brown (10YR 3/2)

coatings on peds; weak, medium, subangular blocky structure parting to weak, fine and very fine, subangular blocky structure; friable; few roots; about 5 percent gravel, mostly shale; strongly acid; clear, smooth boundary.

IIC1--27 to 40 inches, alternating, thin, 1/2-inch to 5-inch bands of very dark grayish-brown (10YR 3/2), dark yellowish-brown (10YR 4/4), and yellowish-brown (10YR 5/4) sand; single grain; loose; about 15 percent gravel, mostly shale; strongly acid; clear, smooth boundary.

IIC2--40 to 46 inches, alternating 1/2-inch to 3-inch bands of very dark grayish-brown (10YR 3/2), yellowish-brown (10YR 5/4), and brown (10YR 4/3) sand; single grain; loose; about 10 percent gravel, mostly shale; strongly acid; clear, smooth boundary.

IIC3--46 to 60 inches, very dark grayish-brown (10YR 3/2) and light olive-brown (2.5Y 5/4) sand; single grain; loose; about 15 percent gravel, mostly shale; strongly acid.

The Ap horizon is 8 to 11 inches thick and is black to very dark brown in color. The A3 horizon is 4 to 7 inches thick. Texture is commonly loam, but in places in the southern part of the county the A horizon is fine sandy loam. The B horizon ranges from dark brown to yellowish brown in color. Texture of the B2 horizon is loam that ranges from 18 to 28 percent in content of clay. A few thin clay films are on ped faces of the B horizon in some profiles. The B and C horizons contain 0 to 10 percent gravel of mixed lithology but dominated by shale. However, some sandy layers in the C horizon, commonly less than 4 inches thick, contain 10 to 20 percent gravel. The C horizon is mainly sand, but the Dakota loam, loamy substratum, contains loamy strata. Thickness of the loamy material is commonly 26 to 32 inches, but the extreme range is 22 to 36 inches. These soils commonly are leached to a depth of 60 inches or more, but there are free carbonates at a depth ranging from 36 to 60 inches. The A horizon is slightly acid to neutral, the B horizon is medium to strongly acid, and the C horizon is strongly acid to neutral.

These soils, as mapped in Hennepin County, have less translocated clay in the B horizon than is typical for the Dakota series, but this difference does not affect their usefulness or behavior.

Dakota soils are more loamy and are generally deeper to sand than the similar Dickman soils. They are generally finer textured, deeper to coarse material, and less gravelly than associated Estherville soils. Dakota soils are finer textured throughout the solum than Burnsville soils, thick solum variant. They are not so fine textured throughout the solum as Kasota soils.

Dakota loam, 0 to 2 percent slopes (DaA).--This nearly level soil occupies broad flats that are typically 40 to 160 acres in size. It has the profile described as representative for the series.

Included in mapping were small areas of soils that have a surface layer of sandy loam. In a few spots, the subsoil is silt loam. In Fort Snelling State Park this Dakota soil is underlain by limestone bedrock at a depth of 4 to 10 feet. Small areas of Dickman, Dakota, loamy substratum, and Estherville soils were also included in mapping. There are also a few spots of soils that have reddish-brown firm sandy loam till at a depth of about 3 feet.

Most of this soil is cultivated and is used to grow corn and soybeans. It is fairly well suited to these crops, but in most years growth is limited because of lack of moisture. Row crops can be grown year after year. (Capability unit IIs-2; woodland group 2; building site group 1)

Dakota loam, 2 to 6 percent slopes (DaB).--This gently sloping soil occupies 5-acre to 20-acre, irregularly shaped areas on low mounds and ridges. Slopes are mainly in one direction and are less than 125 feet long. This soil has a profile similar to that of the soil described as representative for the series, except that the surface layer is very dark brown loam and the subsoil is thinner.

Included in mapping were a few patches of eroded soils near slope crests that are lower in content of organic matter and are harder to till. Also included were small patches of Dickman soils.

Nearly all of this soil is cultivated, and corn and soybeans are the main crops. The hazard of erosion is moderate. In most places, if erosion is controlled and management is good, row crops can be grown every year, or nearly every year. In most years, however, crop growth is limited because of lack of moisture. (Capability unit IIe-4; woodland group 2; building site group 1)

Dakota loam, loamy substratum, 0 to 2 percent slopes (DbA).--This nearly level soil is in broad, irregularly shaped tracts, typically 10 to 80 acres in size. It occurs in association with Dakota loam. This soil has a profile similar to that of the soil described as representative for the series, except that it contains layers of loam and silt loam in the underlying material. Therefore, this soil has a higher available moisture capacity than is typical for Dakota loam.

Included in mapping were small areas of sandy loams. Scattered intermingled depressions contain Kennebec soils. A few small areas where slopes are 2 to 6 percent were also included with this soil because of small acreage.

This soil is used mainly for crops and has no important limitations to this use. It is farmed intensively to corn and soybeans and is well suited to those crops. Small grain and hay are also grown in small areas. (Capability unit I-1; woodland group 1; building site group 5)

Dalbo Series

The Dalbo series consists of deep, moderately well drained soils that formed in silty and clayey

sediments 2 to 5 feet thick over calcareous loamy till. These soils are in smooth, convex areas and on side slopes of hills and knolls. Slopes range from 0 to 12 percent. The native vegetation was mixed hardwood forest. Dalbo soils are associated mainly with Hayden and Erin soils.

In a representative profile in an undisturbed area, the surface layer is black and very dark gray silt loam about 2 inches thick. The subsurface layer is very dark gray and dark-gray silt loam about 3 inches thick. The subsoil consists of three layers. The combined thickness of these layers is about 26 inches. The upper part is olive-brown silty clay loam. The middle part is olive-brown and olive silty clay. The lower part is olive silty clay loam. The underlying material is calcareous, mottled, light olive-brown and grayish-brown loam.

Dalbo soils have high available moisture capacity, a moderately slowly permeable subsoil, and medium to slow internal drainage. The water table in the more nearly level areas is at a depth of 3 to 5 feet during wet seasons. The root zone is deep, but plant roots develop rather slowly in the firm clayey subsoil. Organic-matter content is low, and fertility is medium.

Representative profile of Dalbo silt loam, 2 to 6 percent slopes, in a wooded area, SE1/4 SE1/4 NE1/4 sec. 17, T. 119 N., R. 23 W.:

A1--0 to 2 inches, black (10YR 2/1) and very dark gray (10YR 3/1) silt loam; weak, very fine and fine, subangular blocky structure; friable; neutral; clear, smooth boundary.

A2--2 to 5 inches, very dark gray (10YR 3/1) and dark-gray (10YR 4/1) heavy silt loam; weak to moderate, medium, platy structure parting to moderate, fine, subangular blocky structure; very friable; slightly acid; clear, smooth boundary.

A&B--5 to 10 inches, olive-brown (2.5Y 4/3) heavy silty clay loam; strong, fine and medium, angular blocky structure; firm; common fine pores; many, thick, light-gray (10YR 6/1), porous coatings on faces of peds; strongly acid; clear, smooth boundary.

B21t--10 to 14 inches, olive-brown (2.5Y 4/3) silty clay; few, fine, faint, dark grayish-brown (2.5Y 4/2) and olive-brown (2.5Y 4/4) mottles; moderate to strong, fine and medium, angular blocky structure parting to strong, very fine, angular blocky structure; firm; plastic and sticky when wet; common, fine, tubular pores; many, medium and thick, very dark grayish-brown (2.5Y 3/2) clay films on faces of peds; common, thin, gray (10YR 5/1), porous coatings on faces of peds; strongly acid; clear, smooth boundary.

B22t--14 to 25 inches, olive (5Y 4/4) silty clay; common, fine and medium, distinct, yellowish-brown (10YR 5/6) mottles; moderate, coarse, prismatic structure parting to strong, coarse, angular blocky structure and strong, very fine, angular blocky structure; firm; plastic and sticky when wet; few, fine, tubular pores; many, thick, very dark brown (10YR 2/2) clay films on faces of peds; strongly acid; gradual, smooth boundary.

B23t--25 to 31 inches, olive (5Y 5/4) silty clay loam; many, fine and medium, distinct, light olive-brown (2.5Y 5/6) mottles; moderate to strong, coarse, prismatic structure parting to coarse, angular blocky structure and moderate, very fine, angular blocky structure; common, fine, tubular pores; many, thick, very dark brown (10YR 2/2) and black (10YR 2/1) clay films on faces of peds and in root channels; slightly acid; clear, wavy boundary.

IIC1--31 to 46 inches, light olive-brown (2.5Y 5/3) loam; many, medium, distinct, olive-gray (5Y 5/2) mottles; weak, fine, subangular blocky structure; friable; few, fine, tubular pores; few, reddish, pinhead-size iron concentrations; light-gray (2.5Y 7/2) lime concentrations along cleavage planes; discontinuous lenses of loamy coarse sand and gravel in upper part of horizon; about 5 percent coarse fragments, limestone, shale, and igneous; a few fragments are more than 3 inches across; mildly alkaline; strongly calcareous; gradual, smooth boundary.

IIC2--46 to 60 inches, grayish-brown (2.5Y 5/2) loam; many, medium, faint, olive-gray (5Y 5/2) and common, medium, distinct, light olive-brown (2.5Y 5/4) mottles; weak cleavage planes; friable; few, reddish, pinhead-size iron concentrations; light-gray (2.5Y 7/2) lime concentrations along cleavage planes; about 5 percent coarse fragments; mildly alkaline; strongly calcareous.

In cultivated fields the Ap horizon is commonly very dark grayish brown or grayish brown. Texture is silt loam or silty clay loam in some places. Some profiles have a dark grayish-brown, brown, or olive-brown B1 horizon. The matrix colors in the upper part of the B2 horizon are typically olive brown but range to dark grayish brown and brown. Texture of the B2 horizon ranges from heavy silty clay loam to silty clay or clay. The horizon of maximum clay content is typically 40 to 55 percent clay, but ranges from 35 to 60 percent clay. In some profiles there is a thin sandy loam layer at the till contact. The C horizon is variable in texture. In some areas it is loam or clay loam glacial till. In others it is silt loam, silty clay loam, silty clay, or clay, but glacial till commonly occurs within a depth of 7 feet. The A horizon is neutral to slightly acid in undisturbed areas and slightly acid to medium acid in cultivated areas. The B2 horizon ranges from slightly acid to very strongly acid.

Dalbo soils are higher in clay content and lower in sand content than associated Lerdal and Nessel soils. They have a thinner A1 horizon and are better drained than the similar Shorewood soils.

Dalbo silt loam, 0 to 2 percent slopes (D1A).--This nearly level soil occupies 2-acre to 40-acre, slightly convex areas on smooth hilltops. Slopes are 50 to 250 feet long. This soil has a profile similar to that of the soil described as representative for the series, except that in cultivated areas the surface layer is very dark grayish brown to very dark gray.

Included in mapping were small areas of Nessel soils. Narrow drainageways and hollows that contain Shields soils were also included.

Much of this soil is in woodland or pasture, but it is suited to all the major crops in the county. Maintenance of tilth is the main management need. (Capability unit IIs-1; woodland group 1; building site group 8)

Dalbo silt loam, 2 to 6 percent slopes (D1B).--This gently sloping soil occupies 2-acre to 5-acre, smooth areas on knolls and above steeper slopes on hilltops. Slopes are commonly 75 to 125 feet long but range from 75 to 400 feet in length. This soil has the profile described as representative for the series. In cultivated areas the surface layer is dark grayish brown.

Included in mapping were small areas of the loamy Nessel and Hayden soils. Narrow drainageways and hollows that contain Shields soils were also included.

Some of this soil is in woodland or pasture, but it is suited to all the major crops in the county. The main management needs are control of erosion and maintenance of tilth. The hazard of erosion is moderate. (Capability unit IIe-2; woodland group 1; building site group 8)

Dalbo silt loam, 6 to 12 percent slopes (D1C).--This rolling soil occupies 2-acre to 15-acre areas on hillsides and knolls. Slopes are commonly 75 to 120 feet long. This soil has a profile similar to that of the soil described as representative for the series, except that in cultivated areas the surface layer is dark grayish brown. A few eroded patches have an olive-brown silty clay loam subsoil exposed.

Included in mapping were small areas of the loamy Hayden soils. Narrow, downslope drains that contain Shields soils were also included.

Most of this soil is in permanent pasture or woodland. If well managed, this soil is fair cropland and is suited to all the major crops grown in the county. The hazard of erosion is severe. Careful management is needed to control erosion in areas where row crops are grown. (Capability unit IIIe-2; woodland group 1; building site group 8)

Dassel Series

The Dassel series consists of deep, poorly drained soils that formed in loamy alluvium overlying deep sand that contains layers of loam and clay. These soils are on broad flats and in drainageways on outwash plains. The native vegetation was prairie grasses and sedges.

In a representative profile, the surface layer is black sandy loam about 10 inches thick. The subsoil is about 23 inches thick and consists of three layers. The upper part is dark grayish-brown sandy loam, the middle part is dark grayish-brown sandy clay loam, and the lower part is olive-gray sandy clay loam. The underlying material is grayish-brown sand.

Dassel soils have low available moisture capacity, but the finer textured layers and the high water table increase the amount of water available to plants. Internal drainage is slow, and permeability is moderate to moderately rapid. The water table is at a depth of 1 to 3 feet during wet periods. The root zone is deep, although the high seasonal water table slows root growth. Drainage is needed if crops are to grow well. Organic-matter content is high, and natural fertility is medium.

Representative profile of Dassel sandy loam, in a cultivated field, NE1/4 SW1/4 SW1/4 sec. 18, T. 119 N., R. 21 W.:

Ap--0 to 10 inches, black (10YR 2/1) light sandy loam; weak, very fine, subangular blocky structure; friable to very friable; few roots; medium acid; abrupt, smooth boundary.

B21g--10 to 17 inches, dark grayish-brown (2.5Y 4/2) light sandy loam; common, fine, prominent, dark-brown (7.5YR 4/4) and yellowish-red (5YR 4/6) mottles; very weak, medium, subangular blocky structure; very friable; few roots; medium acid; clear, wavy boundary.

B22g--17 to 24 inches, dark grayish-brown (2.5Y 4/2) sandy clay loam; common, fine, prominent, yellowish-red (5YR 4/6) and dark reddish-brown (5YR 3/4) mottles; weak to moderate, medium, subangular blocky structure; friable; few roots; root channels have grayish-brown (2.5Y 5/2) coatings; slightly acid; clear, wavy boundary.

B3g--24 to 33 inches, olive-gray (5Y 5/2) sandy clay loam; common, medium, prominent, brown (7.5YR 4/4) mottles; weak, very fine, subangular blocky structure; firm; few roots; slightly acid; clear, smooth boundary.

IIC1--33 to 41 inches, grayish-brown (2.5Y 5/2) sand; few, medium, prominent, yellowish-brown (10YR 5/4) and brown (7.5YR 4/4) mottles; massive; very friable; slightly acid; clear, wavy boundary.

IIC2--41 to 60 inches, grayish-brown (2.5Y 5/2) sand; few, fine, faint, light olive-brown (2.5Y 5/4) mottles; single grain; loose; slightly acid.

The A1 horizon is 10 to 14 inches thick. In many profiles there is a very dark gray loamy sand or sandy loam A3 horizon 3 to 5 inches thick. The content of sand, silt, and clay changes erratically with depth in the B and C horizons. In the B horizon, texture ranges from sand to light clay loam and sandy clay loam. The layers that are sandy loam or finer are typically less than 8 inches thick but ranges to 20 inches in thickness. The total

thickness of the horizons of sandy loam or finer material is typically 6 to 15 inches within a 40-inch depth. The finest layers commonly occur between a 30-inch and 48-inch depth. The sandy layers are mainly fine and medium sand but range to medium and coarse sand. The C horizon is mostly sand, but it contains finer textured strata in some profiles. The A horizon is slightly acid to medium acid. The B and C horizons are slightly acid to strongly acid.

Dassel soils are grayer throughout than the associated Litchfield soils. They have finer textured layers in the B horizon than the similar Isan soils. Dassel soils are more sandy in the upper part of the solum than the similar Biscay soils. Dassel soils lack the continuous loamy C horizon of the similar Isan sandy loam, loamy subsoil.

Dassel sandy loam (Dm).--This nearly level soil is typically located on broad flats about 15 to 120 acres in size. Most areas are at slightly lower elevations than the closely associated Litchfield soils.

Included in mapping were small spots of soils that have a loamy sand surface layer. Also included were small areas, up to 5 acres in size, that have a surface layer of loam and a subsoil of sandy loam underlain by sand at a depth of 18 to 30 inches. A few small areas that are calcareous were also included. In a few places this Dassel soil is underlain by calcareous loam till at a depth of 4 to 5 feet.

Wetness, low available moisture capacity, and soil blowing are the main management limitations. The main crops are corn, soybeans, and potatoes. Drainage is needed for best crop growth on these soils. Tile may be used, but it is difficult to install in the sandy underlying material. In many places shallow ditching is a better way to control the water table. In summer months, when the water table is deep, the moisture available to plants is low to moderate. Growth of such late-season crops as corn and soybeans is limited by lack of moisture. If properly drained, fertilized, and irrigated, this soil is suited to potatoes. (Capability unit IIIw-2; woodland group 6; building site group 9)

Dickman Series

The Dickman series consists of deep, somewhat excessively drained soils that formed in a sandy loam mantle 15 to 30 inches thick and in the underlying sand. These soils are on outwash plains. Slopes are mainly simple and range from 0 to 12 percent. The native vegetation was prairie grass and scattered tracts of oaks.

In a representative profile, the surface layer is very dark brown sandy loam about 11 inches thick. The upper part of the subsoil is brown sandy loam about 7 inches thick. The lower part of the subsoil, to a depth of about 36 inches, is dark yellowish-brown and yellowish-brown sand. The underlying material is light yellowish-brown loose sand.

Dickman soils have low available moisture capacity and rapid internal drainage. Permeability is moderately rapid in the upper part and rapid below a depth of about 18 inches. These soils are droughty and are subject to soil blowing. Crop growth is limited by lack of moisture in most years. Dickman soils have moderate organic-matter content and medium natural fertility.

Representative profile of Dickman sandy loam, 2 to 6 percent slopes, in a cultivated field, NE1/4 SE1/4 SW1/4 sec. 31, T. 116 N., R. 21 W.:

Ap--0 to 9 inches, very dark brown (10YR 2/2) sandy loam; weak, fine, granular structure; very friable; common roots; slightly acid; clear, smooth boundary.

A3--9 to 11 inches, very dark brown (10YR 2/2) sandy loam; weak, fine, subangular blocky structure; very friable; common roots; medium acid; clear, smooth boundary.

B21--11 to 15 inches, brown (10YR 4/3) sandy loam; weak, fine, subangular blocky structure; very friable; few roots; few, fine, tubular pores; few brownish sand fillings in root channels; medium acid; clear, smooth boundary.

B22--15 to 18 inches, brown (10YR 4/3) sandy loam; dark-brown (10YR 3/3) coatings on peds; weak, fine, subangular blocky structure; very friable; few roots; few thin clay films on faces of peds; about 2 percent gravel; medium acid; clear, smooth boundary.

IIB31--18 to 23 inches, dark yellowish-brown (10YR 4/4) sand; massive; loose to very friable; medium acid; clear, smooth boundary.

IIB32--23 to 36 inches, yellowish-brown (10YR 5/4) stratified sand and fine sand; massive; loose; medium acid; clear, smooth boundary.

IIC--36 to 60 inches, light yellowish-brown (10YR 6/4) fine sand; single grain; loose; medium acid.

The A horizon is 8 to 13 inches thick and is typically very dark brown but is black in places. A 2-inch to 5-inch A3 horizon commonly occurs below the A horizon. Color of the B2 horizon ranges from dark brown to yellowish brown. Ped exteriors generally are one value lower in color. Texture in the B2 horizon is sandy loam, fine sandy loam, or loam. The IIB3 horizon is loamy sand, loamy fine sand, fine sand, or sand. Depth to the IIB horizon typically is 16 to 20 inches, but the full range is 14 to 27 inches. The C horizon ranges from brown to light yellowish brown but in places grades to light olive brown with depth. Reaction of the solum ranges from slightly acid to medium acid.

Texture for the series is typically fine sand or sand, but in Hennepin County an estimated 25 to 40 percent of the Dickman soils are underlain by sand, more than 10 percent of which is coarser than medium sand.

Dickman soils are more sandy than the associated Dakota soils. They have a finer sand fraction and are not so coarse in the C horizon as the similar

Estherville soils. They are not so sandy in the B2 horizon as the associated Hubbard and Nymore soils.

Dickman sandy loam, 0 to 2 percent slopes (DnA).--This nearly level soil occupies irregularly shaped tracts 40 to 120 acres in size.

Included in mapping were a few shallow drainageways that contain soils that have a dark surface layer up to 2 feet thick. These swales retain frost longer and, in some years, restrict early field operations. Also included, mainly near Osseo, were small areas of Dakota and Anoka soils.

Most of this soil is cultivated. The hazard of drought is severe, and the hazard of soil blowing is moderate. This soil is suited to most crops grown in the county but is better suited to early crops, such as small grain or irrigated truck crops, than to crops that mature late in the growing season. (Capability unit IIIs-1; woodland group 3; building site group 2)

Dickman sandy loam, 2 to 6 percent slopes (DnB).--This gently sloping soil occupies 2-acre to 10-acre areas on low knolls. Slopes are generally less than 120 feet long. This soil has the profile described as representative for the series.

Included in mapping were small areas of soils that have a surface layer of loam and a thin subsoil of loam. Also included were small areas of Hubbard soils. In the southern part of the county there are thin layers of silt and clay in the underlying material.

Most of this soil is cultivated. The main limitations are the severe drought hazard and the moderate erosion hazard. This soil is suited to most crops grown in the county but is better suited to early crops, such as small grain, or to irrigated truck crops, such as potatoes. (Capability unit IIIe-3; woodland group 3; building site group 2)

Dickman sandy loam, 6 to 12 percent slopes (DnC).--This sloping soil occupies about 2-acre to 10-acre areas on the outwash plains along the Minnesota River. Slopes are 75 to 150 feet long. The surface layer and subsoil are thinner than those of the profile described as representative for the series. In areas near the crests of the steeper slopes, the subsoil has been exposed and is mixed with the dark surface layer. These eroded areas are very dark grayish brown or brown.

Included in mapping were small patches of Hubbard soils, typically on the steeper, most convex parts of the slope. There are thin layers of silt and clay in the underlying material in a few places.

The low available moisture capacity and the hazards of soil blowing and water erosion severely limit the use of this soil for cultivated crops. Row crops should be grown only if good management practices, such as a conservation cropping system and minimum tillage, are used. This soil is well suited to permanent vegetation. (Capability unit IVe-4; woodland group 3; building site group 2)

Dorchester Series

The Dorchester series consists of deep, loamy, moderately well drained, nearly level soils on bottom lands along the Minnesota River. These soils formed in deep, loamy sediments that are high in content of very fine sand. The native vegetation was mixed hardwood forest.

In a representative profile, the surface layer is very dark gray loam that grades to very dark grayish-brown loam with depth and is about 36 inches thick. The underlying material consists of mottled, very dark gray and dark-gray loam.

Dorchester soils have high available moisture capacity, medium internal drainage, and moderate to moderately rapid permeability. The water table is at a depth of 3 to 5 feet during wet seasons. These soils are subject to occasional flooding. Dorchester soils have moderate organic-matter content and are very fertile.

Representative profile of Dorchester loam, in a cultivated area, NE1/4 SW1/4 SW1/4 sec. 32, T. 116 N., R. 22 W.:

Ap--0 to 14 inches, very dark gray (10YR 3/1) heavy loam, high in content of very fine sand; weak, medium, subangular blocky structure; friable; few, dark grayish-brown (10YR 4/2), sandy coatings along faces of peds; few snail shells; mildly alkaline; weakly calcareous; gradual, smooth boundary.

A12--14 to 25 inches, very dark grayish-brown (10YR 3/2) loam, high in content of very fine sand and fine sand; few, thin seams of grayish brown (2.5Y 5/2) and light olive brown (2.5Y 5/4); weak, coarse, subangular blocky structure; friable; many, fine, tubular pores; mildly alkaline; weakly calcareous; gradual, smooth boundary.

A13--25 to 36 inches, very dark grayish-brown (10YR 3/2) loam, high in content of very fine sand; few, fine, faint, dark-brown (7.5YR 4/4) and dark grayish-brown (2.5Y 4/2) mottles; weak, fine and very fine, subangular blocky structure; friable; many, fine, tubular pores; mildly alkaline; weakly calcareous; gradual, smooth boundary.

C1--36 to 44 inches, very dark gray (10YR 3/1) and dark-gray (10YR 4/1) light loam, high in content of very fine sand; common, fine, faint, dark-brown (7.5YR 3/3) mottles; weak, fine and very fine, subangular blocky structure; friable; common, fine tubular pores; few, fine snail shell fragments; mildly alkaline; weakly calcareous; gradual, smooth boundary.

C2--44 to 56 inches, very dark gray (10YR 3/1) loam, high in content of very fine sand; common, fine, distinct, dark-brown (7.5YR 3/3) mottles; weak, very fine, subangular blocky structure; friable; few white lime segregations; mildly alkaline; weakly calcareous; gradual, smooth boundary.

C3--56 to 60 inches, dark-gray (10YR 4/1) and dark-brown (10YR 3/3) loamy very fine sand; weak,

coarse, subangular blocky structure; very friable; mildly alkaline; weakly calcareous.

The A horizon is very dark gray or very dark grayish-brown loam or light clay loam. Thickness ranges from 20 to 40 inches. The upper part of the C horizon ranges from very dark gray to dark grayish brown in color. It is loam in most places, but the lower part is commonly coarse textured. Thin, coarse-textured strata occur in the C horizon of some profiles. Clay content in the C horizon ranges from 18 to 25 percent. Sand content ranges from 30 to 50 percent; 75 percent or more of the sand fraction is finer than fine sand and less than 5 percent is coarser than fine sand. Reaction is typically mildly alkaline, although some profiles have neutral layers. Except for the neutral layers, the soils are weakly to strongly calcareous. There are snail shells in some layers.

These soils, as mapped in Hennepin County, are slightly darker colored in the upper horizons and contain more sand than is currently allowed in the Dorchester series. These differences, however, do not alter their usefulness and behavior.

Dorchester soils are better drained than the associated Chaska soils. They lack the high seasonal water table of Chaska soils.

Dorchester loam (Do).--This nearly level soil is on broad flats along the Minnesota River. It typically lies between areas of Mixed alluvial land, which occurs next to the river, and areas of Chaska soils, which are farther back from the river. Areas of this soil range in size from about 10 to 100 acres. Most of these areas are longer than they are wide, and the long axis tends to parallel the river.

Included in mapping were a few small sandy spots. The few depressions and some of the drainageways that cross this soil contain Chaska soils.

Most of this soil is cultivated. Occasional flooding is the main limitation. Corn and soybeans are well suited to this soil. (Capability unit IIw-3; woodland group 5; building site group 13)

Duelm Series

The Duelm series consists of deep, moderately well drained soils. These soils formed in deep, medium and coarse sand 4 feet to more than 20 feet thick. In most places there is reddish-brown till below the sand. Duelm soils generally are on broad flats, but in a few places they are in narrow drainageways. The native vegetation was tall prairie grass and scattered patches of oak.

In a representative profile, the surface layer is very dark brown loamy sand about 11 inches thick. The upper 11 inches of the subsoil is dark-brown and brown medium and coarse sand. The lower part of the subsoil, extending to a depth of about 54 inches, is grayish-brown to light olive-brown sand. The underlying material is light brownish-gray sand.

Duelm soils have very low available moisture capacity. The water table is at a depth of 3 to 5 feet during wet seasons and tends to improve the moisture supply. Duelm soils have rapid internal drainage and rapid to very rapid permeability. Runoff is slow. These sandy soils are easily blown. Organic-matter content is moderate. Duelm soils have low natural fertility. Areas heavily cropped to potatoes have a strongly acid to very strongly acid surface layer in many places. Lime is needed for many crops.

Representative profile of Duelm loamy sand, in a cultivated field, SE1/4 SE1/4 NE1/4 sec. 35, T. 119 N., R. 21 W.:

Ap--0 to 11 inches, very dark brown (10YR 2/2) loamy sand, dark grayish brown (10YR 4/2) when dry; weak, coarse, subangular blocky structure parting to weak, very fine, subangular blocky structure; very friable; many roots; medium acid; clear, smooth boundary.

B2--11 to 22 inches, dark-brown (10YR 3/3) and brown (10YR 4/3) sand, brown (10YR 5/3) and pale brown (10YR 6/3) when dry; few tongues of very dark grayish brown (10YR 3/2); very weak, medium and coarse, subangular blocky structure; very friable; few sand grains coated with clay; few roots and pores; very strongly acid; clear, smooth boundary.

B31g--22 to 30 inches, grayish-brown (2.5Y 5/2) and light olive-brown (2.5Y 5/6) sand, light yellowish brown (2.5Y 6/4) and yellow (2.5Y 7/6) when dry; few, fine, faint, strong-brown (7.5YR 5/6) mottles; very weak, coarse, subangular blocky structure parting to very weak, very fine, subangular blocky structure; very friable; few roots; about 5 percent gravel; very strongly acid; clear, smooth boundary.

B32g--30 to 54 inches, grayish-brown (2.5Y 5/2), light olive-brown (2.5Y 5/4), and yellowish-brown (10YR 5/6) coarse sand, light gray (2.5Y 7/2), pale yellow (2.5Y 7/3), and yellow (10YR 7/6) when dry; single grain; loose; a few lenses contain about 15 percent gravel; about 2 percent black concretions; very strongly acid; clear, smooth boundary.

C--54 to 60 inches, light brownish-gray (2.5Y 6/2) sand, light gray (2.5Y 7/2) when dry; single grain; loose; medium acid.

The Ap horizon ranges from 9 to 12 inches in thickness. It is typically very dark brown in color but ranges to black. An A3 horizon is present in some profiles. It is up to 4 inches in thickness, is very dark grayish brown in color, and is loamy sand or sand in texture. Texture of the upper part of the B horizon is sand, coarse sand, loamy coarse sand, or loamy sand. The lower part is coarse sand or sand. Fifteen percent or more of the soil by volume does not pass the No. 40 sieve. Content of gravel ranges from 2 to 10 percent. There are thin layers, up to 10 inches in thickness, that are finer sand or that contain a greater coarse fraction in

some profiles. These soils are leached of carbonates at a depth below 5 feet. Reaction of the A horizon ranges from slightly acid to very strongly acid. The B and C horizons are medium acid to very strongly acid.

Duelm soils are browner in the upper part of the solum than the associated Isan soils. They have a grayer C horizon than the associated Hubbard soils and are mottled in the lower part of the B horizon. Duelm soils formed in coarser sand and lack the loamy layers of the similar Litchfield soils.

Duelm loamy sand (Dp).--This nearly level soil typically occupies broad tracts 1 to 3 feet above Isan soils. In a few places this soil is in shallow drainageways below Hubbard soils. Areas are irregular in shape. They are mainly 10 to 40 acres but range from 2 to 100 acres in size.

Included in mapping were areas of soils in drainageways. These soils have a black surface layer 14 to 24 inches thick and are more loamy than this Duelm soil. They retain frost longer, often making it more difficult to work the surrounding soils early in spring. Also included were small areas of Hubbard and Isan soils. Included in the east half of the southwest quarter of section 33, Champlin Township, were areas of soils that have a 6-inch to 14-inch layer of gravelly loamy sand at a depth of 12 to 24 inches. In a few spots there is reddish-brown sandy loam within a depth of 4 feet.

The main limitations of this soil are drought, soil blowing, and low fertility. Unless rainfall distribution is good, growth of such crops as corn and soybeans is severely limited by drought in most years. This soil is well suited to irrigated truck crops, and much of it is used for that purpose. The major crop is potatoes. Soil blowing can be controlled by mulch tillage practices and by use of a winter cover crop. (Capability unit IVs-2; woodland group 4; building site group 2)

Duelm Series, Loamy Subsoil Variant

The Duelm series, loamy subsoil variant, consists of deep, moderately well drained soils that formed in 18 to 40 inches of sand over loam till. These nearly level soils are on broad flats. The native vegetation was tall prairie grass and scattered patches of oak.

In a representative profile, the surface layer is very dark brown loamy sand about 21 inches thick. The subsoil is 13 inches thick. The upper part is brown loamy sand, and the lower part is dark-brown gravelly loamy coarse sand. The underlying material is grayish-brown loam that contains lenses of loamy sand and sandy clay loam.

These soils have low to moderate available moisture capacity, depending on the depth to loam. The water table, which is at a depth of 3 to 5 feet during wet seasons, tends to improve the moisture supply. The internal drainage is moderate. Permeability is rapid to very rapid in the sandy layers and moderate in the loam. The sandy surface layer is easily blown. Organic-matter content is moderate. These soils have low natural fertility.

Representative profile of Duelm loamy sand, loamy subsoil variant, SE1/4 SE1/4 SW1/4 sec. 13, R. 21 W., T. 119 N.:

Ap--0 to 9 inches, very dark brown (10YR 2/2) loamy sand, dark grayish brown (10YR 4/2) when dry; very weak, medium and fine, subangular blocky structure; very friable; many roots; medium acid; clear, smooth boundary.

A12--9 to 16 inches, very dark brown (10YR 2/2) loamy sand, dark grayish brown (10YR 4/2) when dry; a few channels of dark brown (10YR 3/3); weak, medium and fine, subangular blocky structure; very friable; many roots; medium acid; clear, smooth boundary.

A3--16 to 21 inches, very dark brown (10YR 2/2) loamy sand, dark grayish brown (10YR 4/2) when dry; patches and channels of brown (10YR 4/3); weak, medium and fine, subangular blocky structure; very friable; few roots and pores; medium acid; clear, smooth boundary.

B21--21 to 29 inches, brown (10YR 4/3) loamy sand, pale brown (10YR 6/3) when dry; fine patches of very dark grayish brown (10YR 3/2) and very dark brown (10YR 2/2); few, fine, distinct, grayish-brown (10YR 5/2) mottles; weak, medium and fine, subangular blocky structure; very friable; 5 to 10 percent fine gravel; many pores; few roots; medium acid; clear, smooth boundary.

IIB22--29 to 34 inches, dark-brown (7.5YR 4/4) gravelly loamy coarse sand, light yellowish brown (10YR 6/4) when dry; many, fine, distinct, grayish-brown (2.5Y 5/2) mottles; very weak, very fine, subangular blocky structure; very friable; few cobbles; medium acid, clear, smooth boundary.

IIIC1--34 to 40 inches, grayish-brown (2.5Y 5/2) loam with lenses of sandy clay loam, light gray (10YR 7/2) when dry; many, fine and medium, distinct, light olive-brown (2.5Y 5/6) mottles and few, fine, faint, dark-brown (7.5YR 3/4) mottles; weak, medium to coarse, subangular blocky structure; friable; many pores; 5 to 10 percent hard gravel, 2 percent shale; few black concretions; medium acid; clear, smooth boundary.

IIIC2--40 to 60 inches, grayish-brown (2.5Y 5/2) and light olive-brown (2.5Y 5/6) loam with lenses of sandy clay loam and loamy sand, light gray (2.5Y 7/2) and yellow (2.5Y 7/6) when dry; very weak, medium and coarse, subangular blocky structure; friable; medium acid; clear, smooth boundary.

IIIC3--60 to 66 inches, grayish-brown (2.5Y 5/2) and light olive-brown (2.5Y 5/4) loam with patches and lenses of sandy clay loam, light gray (2.5Y 7/2) and pale yellow (2.5Y 7/4) when dry; weak, oblique cleavage planes; friable to firm; mildly alkaline; weakly calcareous.

The A horizon ranges from 14 to 22 inches in thickness. In the B21 horizon, 15 percent or more of the soil by volume does not pass the No. 40 sieve. The content of gravel ranges from 2 to 10 percent. The IIB horizon ranges from 3 inches to about 12 inches in thickness. The content of gravel ranges from 20 to 50 percent. From 5 to 20 percent of the gravel consists of cobblestones. Depth to the loamy C horizon ranges from 18 to 40 inches. The A and B horizons are medium acid to slightly acid. The C horizon ranges from medium acid to neutral in the upper part and becomes mildly alkaline below. Depth to carbonates ranges from 48 to 72 inches.

Duelm soils, loamy subsoil variant, have a browner B horizon than the associated Isan soils. They have a darker, thicker A horizon and are not so well drained as the associated Braham soils. In addition, they contain a gravelly, cobbly layer that is lacking in Braham soils.

Duelm loamy sand, loamy subsoil variant (Ds).--This nearly level soil is on broad flats. Areas are irregular in shape and range in size from 5 acres to about 80 acres. This soil is closely associated with the Isan soil, loamy subsoil.

Included in mapping were small areas of soils where the sand is less than 18 inches thick or more than 40 inches thick. Small areas of Isan soils were also included in the few scattered drainageways and depressions.

Most of this soil is in woodland or has been developed for homesites. The few areas of cropland are used mainly for late crops, of which corn and soybeans are the most important. Growth of corn and soybeans is limited by drought in most years because of lack of moisture. The main limitations of this soil are drought, soil blowing, and low natural fertility. If irrigated, this soil is well suited to truck crops, such as potatoes and sweet corn. (Capability unit IIIs-2; woodland group 2; building site group 3)

Dundas Series

The Dundas series consists of deep, poorly drained, moderately fine textured soils that formed in calcareous loamy till. These nearly level soils lie on flats and in narrow drainageways. There are stones and boulders in the soil, mainly near the surface. The native vegetation was mixed hardwood forest and a grass understory.

In a representative profile, the surface layer is very dark gray silt loam about 8 inches thick. This layer is gray when dry. The subsurface layer is gray silty clay loam about 2 inches thick. The subsoil is olive-gray clay loam about 24 inches thick. The underlying material is olive-gray, calcareous loam.

Dundas soils have a high available moisture capacity, slow internal drainage, and moderately slow permeability. The water table is at a depth of 2 to 3 1/2 feet during wet seasons. The root zone is deep. Organic-matter content is low. These soils have medium fertility levels, and crops grown on them respond well to fertilizer. Lime is needed in some places.

Representative profile of Dundas silt loam, in a cultivated field, NE1/4 NE1/4 NE1/4 sec. 12, T. 118 N., R. 23 W.:

Ap--0 to 8 inches, very dark gray (10YR 3/1) silt loam, gray (10YR 5/1) when dry; weak, very fine, granular structure; friable; common roots; neutral; abrupt, smooth boundary.

A2--8 to 10 inches, gray (10YR 5/1) light silty clay loam; few light olive-brown (2.5Y 5/6) mottles along root channels; weak, very fine, subangular blocky structure; friable; neutral; clear, smooth boundary.

B1g--10 to 12 inches, olive-gray (5Y 4/2) silty clay loam; few, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, very fine, subangular blocky structure; friable; many, thick, light-gray (10YR 6/1), porous coatings on faces of peds; slightly acid; clear, wavy boundary.

B21tg--12 to 18 inches, olive (5Y 4/3) heavy clay loam; few, fine, faint, light olive-brown (2.5Y 5/6) mottles; strong, medium and coarse, prismatic structure parting to strong, very fine, angular blocky structure; firm; common, fine, tubular pores; many, thick, very dark gray (10YR 3/1) clay films on faces of peds; about 5 percent coarse fragments; medium acid; clear, smooth boundary.

B22tg--18 to 25 inches, olive-gray (5Y 5/2) heavy clay loam; few, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, coarse, prismatic structure parting to strong, coarse, angular blocky structure; firm; common, fine, tubular pores; many, thick, black (10YR 2/1) and very dark gray (10YR 3/1) clay films on faces of peds; few black (10YR 2/1) clay films in root channels; about 5 percent coarse fragments; medium acid; clear, smooth boundary.

B3tg--25 to 34 inches, olive-gray (5Y 5/2) clay loam; common, fine, distinct, light olive-brown (2.5Y 5/6) mottles; moderate, coarse, prismatic structure; friable; common, fine and very fine, tubular pores; common, thick, black (10YR 2/1) clay films on faces of peds and in root channels; about 5 percent coarse fragments; slightly acid; clear, smooth boundary.

C1--34 to 40 inches, olive-gray (5Y 5/2) loam; many, medium, prominent, light olive-brown (2.5Y 5/6) mottles; weak, coarse, prismatic structure; friable; common, fine, tubular pores; few, thick, black (10YR 2/1) clay films in root channels; mildly alkaline; weakly calcareous; clear, smooth boundary.

C2--40 to 60 inches, olive-gray (5Y 5/2) and light olive-brown (2.5Y 5/6) loam; very weak, coarse, subangular blocky structure; friable; few lime concentrations and concretions; about 5 percent coarse fragments; thin layer of silt loam

in upper part; mildly alkaline; strongly calcareous.

The solum ranges from 26 to 54 inches in thickness but is commonly 30 to 42 inches thick. The Ap horizon is 7 to 9 inches thick and loam or silt loam in texture. In uncultivated areas the A1 horizon is 4 to 8 inches thick and black in color. The A2 horizon is gray to dark grayish-brown silty clay loam, loam, and silt loam 2 to 8 inches thick. The B2 horizon is commonly olive gray, but in some places it is dark grayish brown and has distinct mottles. The B2 horizon has a marked increase in clay content as compared to the A horizon. The texture of the B2 horizon ranges from clay loam or silty clay loam to silty clay or clay. The upper 20 inches of the B horizon range from 30 to 35 percent in content of clay and is more than 15 percent fine sand and coarser. The zone of maximum clay content ranges from 30 to 45 percent clay but is commonly 33 to 38 percent clay. Coarse fragments in the lower part of the solum and in the C horizon range from 2 percent to about 5 percent. The A horizon is neutral to medium acid, and the B horizon is slightly acid to very strongly acid.

Dundas soils have a lighter colored Ap horizon and a more strongly developed B horizon than associated Cordova soils. Dundas soils are not so fine textured as the similar Shields soils.

Dundas silt loam (Du).--This nearly level soil is on flats and in shallow drainageways. Areas are mostly 2 to 5 acres in size, but some are as large as 15 acres.

Included in mapping were small areas of Nessel or Le Sueur soils, which are on slight rises. Small areas of Cordova soils that are darker colored than this soil were also included

Most of this soil is in small, irregular areas and is farmed with the surrounding soils. Because this soil is moderately slowly permeable, tile drains need rather close spacing. A good tile outlet is needed. If properly drained and managed, this soil is well suited to row crops, and they can be grown nearly every year. (Capability unit IIw-2; woodland group 6; building site group 11)

Erin Series

The Erin series consists of deep, well-drained, moderately fine textured soils that formed in calcareous shaly till. The shaly till is underlain by friable, calcareous, loamy till at a depth of 3 to 20 feet. There are stones and boulders on and in these soils. These soils have convex slopes and are on smooth, irregularly shaped hills. Slope forms are both simple and complex and range from 2 to 35 percent. The native vegetation was mixed hardwood forest.

In a representative profile, the surface layer in undisturbed areas is black and very dark gray loam about 3 inches thick. The subsurface layer is dark-gray loam about 4 inches thick. The subsoil, about 27 inches thick, is olive-brown and light olive-brown clay loam. The underlying material is light olive-brown, calcareous loam.

Erin soils have high available moisture capacity. Permeability is moderately slow, and internal drainage is medium. The water table is at a depth below 5 feet in all seasons. The root zone is deep. Organic-matter content is low. These soils have medium fertility, and crops grown on them respond well to fertilizer. In places lime is needed.

Representative profile of Erin loam, 2 to 6 percent slopes, in a wooded tract, SW1/4 SW1/4 sec. 1, T. 118 N., R. 24 W., Independence village:

A1--0 to 3 inches, black (10YR 2/1) and very dark gray (10YR 3/1) loam that is high in content of silt; moderate, medium, granular structure; friable; many roots; neutral; clear, smooth boundary.

A2--3 to 7 inches, dark-gray (10YR 4/1) loam that is high in content of silt, light brownish gray (10YR 6/2) when dry; moderate, medium, subangular blocky structure; very friable; common, very dark gray worm casts; common roots; neutral; clear, smooth boundary.

A&B--7 to 11 inches, olive-brown (2.5Y 4/3) clay loam, grayish brown (2.5Y 5/2) when rubbed; strong, very fine and fine, angular blocky structure; firm; few very fine pores; many, thick, light-gray (10YR 6/1), porous coatings on faces of peds; about 5 percent coarse fragments; neutral; clear, smooth boundary.

B21t--11 to 19 inches, olive-brown (2.5Y 4/3) clay loam; strong, fine and medium, angular blocky structure; firm; few, very fine, tubular pores; common, thin, very dark grayish-brown (10YR 3/2) clay films on faces of peds; many, light-gray (10YR 7/1), porous coatings on faces of peds; about 5 percent coarse fragments; strongly acid; clear, smooth boundary.

B22t--19 to 29 inches, light olive-brown (2.5Y 5/4) clay loam; moderate, medium, prismatic structure parting to strong, medium and coarse, angular blocky structure; firm; few to common, fine tubular pores; many, thick, very dark brown (10YR 2/2) clay films on faces of peds and in root channels; about 5 percent coarse fragments; strongly acid; clear, smooth boundary.

B3t--29 to 34 inches, light olive-brown (2.5Y 5/4) clay loam; few, fine, faint, light olive-brown (2.5Y 5/6) mottles; strong, coarse, prismatic structure parting to strong, coarse, angular blocky structure; firm; few, fine pores; many, thick, very dark brown (10YR 2/2) clay films on faces of peds and in root channels; few reddish concentrations; medium acid; clear, smooth boundary.

C1--34 to 40 inches, light olive-brown (2.5Y 5/4) loam; weak, coarse, prismatic structure; friable; few, fine, tubular pores; few, thick, very dark brown (10YR 2/2) clay films on faces

of peds and in root channels; mildly alkaline; strongly calcareous; clear, smooth boundary.

C2--40 to 60 inches, light olive-brown (2.5Y 5/4) loam; common, medium and fine, yellowish-brown (10YR 5/8) mottles; weak, coarse, angular blocky structure; friable; few, very dark brown (10YR 2/2) root channels; mildly alkaline; weakly calcareous.

Erin soils have strong horizonation. The solum ranges from 28 to 54 inches in thickness but is commonly 32 to 42 inches thick. The A1 horizon is 2 to 4 inches thick. The A2 horizon is 3 to 6 inches thick and is dark-gray or dark grayish-brown loam or silt loam. The Ap horizon is 7 to 9 inches thick and is very dark grayish brown or dark grayish brown. The B2 horizon is typically olive brown and light brown but is brown in some places. It ranges from clay loam to light clay. Clay content ranges from 35 to 42 percent, and sand content ranges from 20 to 35 percent. The C horizon is loam or light clay loam. Sand content ranges from 25 to 45 percent. The B and C horizons commonly contain 3 to 8 percent coarse fragments. In some places reddish, tubular iron segregations and mottles occur in the lower part of the B horizon and in the C horizon. Reaction of the A horizon ranges from slightly acid to neutral, and reaction of the B horizon ranges from strongly acid to neutral.

Erin soils are higher in sand and coarse fragments and lower in clay than the similar Dalbo soils. Erin soils have a lighter colored A horizon than the associated Kilkenny soils and are higher in clay content than the similar Hayden soils.

Erin loam, 2 to 6 percent slopes (EnB).--This gently undulating soil occupies 12-acre to 40-acre areas on irregular hillsides and knolls. Slopes are commonly 75 to 125 feet long. In many places the slope is in several directions. This soil has the profile described as representative for the series. In cultivated areas the surface layer is very dark gray or very dark grayish brown. A few scattered patches of the brown subsoil are exposed.

Included in mapping were a few patches of Dalbo soils that are higher in clay content and lower in sand content. Areas of Dundas and Cordova soils were included in shallow drainageways and depressions.

If well managed, this soil is good cropland and is suitable for all major crops in the county. The main management needs are control of erosion and maintenance of tilth. (Capability unit IIe-2; woodland group 1; building site group 7)

Erin loam, 6 to 12 percent slopes (EnC).--This rolling soil occurs in 2-acre to 25-acre areas on hillsides and knolls. Slopes are commonly between 75 and 150 feet long. In cultivated areas the surface layer is dark grayish brown to very dark grayish brown and a few scattered patches of the brown clay loam subsoil are exposed.

Included in mapping in convex areas were small patches of Dalbo soils. Areas of Dundas and Cordova soils were also included in shallow drainageways and depressions.

This soil is fair cropland and is suited to all major crops in the county. The main management needs are control of erosion and maintenance of tilth. Most areas are in permanent pasture or woodland. (Capability unit IIIe-2; woodland group 1; building site group 7)

Erin loam, 12 to 18 percent slopes (EnD).--This moderately steep soil occupies 2-acre to 15-acre areas on hillsides and knolls. Slopes are typically 60 to 125 feet long. The surface layer and subsoil are commonly thinner than those in the profile described as representative for the series. In cultivated areas the surface layer is dark grayish-brown or very dark grayish-brown, friable loam. A few scattered patches of the brown clay loam subsoil are exposed.

Included in mapping were small patches of Dalbo soils. Areas of Dundas and Cordova soils were also included in shallow drainageways and depressions.

Because of the rapid runoff, erosion is difficult to control on this soil. If common management practices are used, intertilled crops should be grown only occasionally. This soil is better suited to hay and pasture crops or to woodland than to most other crops. Most areas are in woodland or permanent pasture. (Capability unit IVe-2; woodland group 1; building site group 7)

Erin loam, 18 to 24 percent slopes (EnE).--This steep soil occupies 2-acre to 10-acre areas on hillsides. Slopes are commonly up to 100 feet long and are broken by shallow downslope drainageways. In some places there are small, 2-acre to 3-acre, gently sloping areas on crests and sideslope benches. This soil has a thinner surface layer and subsoil than those in the profile described as representative for the series. A few areas have been cultivated, and the brownish subsoil is exposed in those areas.

Included in mapping were small areas of a soil that has a thick, dark surface layer. This soil is near the base of the slopes.

Steepness of slopes severely limits the use of this soil for common crops. It erodes rapidly if not protected, and machinery is hard to operate on the steep slopes. This soil is suited to uses that keep it covered with plants. (Capability unit VIe-1; woodland group 1; building site group 7)

Erin clay loam, 2 to 6 percent slopes, eroded (ErB2).--This gently undulating soil occupies 2-acre to 40-acre areas on irregular hillsides and knolls. Slopes are commonly 75 to 125 feet long. Because this soil is eroded, the surface layer in cultivated areas is clay loam that is a mixture of the very dark grayish-brown surface layer and the brown subsoil.

Included in mapping were small patches of Dalbo soils. Areas of Dundas and Cordova soils, too small to be separated in mapping, were also included in shallow drainageways and depressions.

If well managed, this soil is good cropland and is suitable for all the major crops in the county. The main management needs are control of erosion and maintenance of tilth. (Capability unit IIe-2; woodland group 1; building site group 7)

Erin clay loam, 6 to 12 percent slopes, eroded (ErC2).--This rolling soil occupies 2-acre to 25-acre areas on irregular hillsides and knolls. Slopes are commonly 75 to 150 feet long. Because this soil is eroded, the surface layer in cultivated areas is clay loam that is a mixture of the very dark grayish-brown surface layer and the brown subsoil. The dry color is much lighter. This soil has less organic matter and is less friable than Erin loams.

Included in mapping were small patches of Dalbo soils. Areas of Dundas and Cordova soils were also included in the shallow drainageways and depressions.

This soil is suited to all the major crops grown in the county. The hazard of erosion is severe. Good management is needed to control erosion and runoff. (Capability unit IIIe-2; woodland group 1; building site group 7)

Erin clay loam, 12 to 18 percent slopes, eroded (ErD2).--This moderately steep soil occupies 2-acre to 15-acre areas on narrow hillsides and knolls. Slopes are commonly 60 to 125 feet long. The surface layer and subsoil are commonly thinner than those in the profile described as representative for the series. Because this soil is eroded, the surface layer in cultivated areas is clay loam that is a mixture of the very dark grayish-brown surface layer and the brown subsoil. The dry color is much lighter. This soil is lower in organic matter and is less friable than Erin loams.

Included in mapping were small patches of Dalbo soils. Areas of Dundas and Cordova soils were also included in shallow drainageways and depressions.

Because of the rapid runoff, erosion is difficult to control on this soil. If common management practices are used, intertilled crops should be grown only occasionally. This soil is better suited to hay and pasture crops or to woodland and recreational uses than to most other uses. (Capability unit IVe-2; woodland group 1; building site group 7)

Erin and Kilkenny loams, 24 to 35 percent slopes (EsF).--These very steep soils occupy 2-acre to 15-acre areas on hillsides and in ravines that are typically adjacent to lakes and sloughs. Slopes are 50 to 100 feet long and are broken by shallow downslope drainageways that contain poorly drained soils that have a dark surface layer.

About 50 percent of this unit is Erin loam and 50 percent is Kilkenny loam. The surface layer of the Erin soil is thinner and is lighter colored than the surface layer of the Kilkenny soil. The Erin and Kilkenny soils have a profile similar to that described as representative for their respective series, except that the surface layer and subsoil are thinner.

Included in mapping were small areas of soils on hillsides that have less than 24 percent slopes and a few 1-acre to 2-acre areas of gently rolling soils on hilltops.

The hazard of erosion is very severe. Small slumps occur downslope. The very steep, short slopes commonly limit these soils to the production of timber, to use as wildlife habitat, and to improvement of the natural beauty of the area. Most of this mapping unit is in woodland. (Capability unit VIIe-1; woodland group 1; building site group 7)

Estherville Series

The Estherville series consists of somewhat excessively drained soils that formed in 12 to 24 inches of sandy loam alluvium over calcareous, stratified gravel and sand. These soils are on stream terraces and glacial outwash plains. Slopes range from 0 to 18 percent and include both complex and simple forms. The native vegetation was prairie grass and thin stands of oak and brush.

In a representative profile, the surface layer is very dark brown sandy loam about 12 inches thick that is dark brown in the lower part. The subsoil is dark yellowish-brown sandy loam about 8 inches thick. The underlying material is calcareous, dark-brown to light olive-brown coarse sand that contains gravel and small amounts of shale.

Estherville soils have a low available moisture capacity because of their shallow depth. Root development is confined to the surface layer and subsoil. Growth of crops is limited by severe drought in most years. Permeability is moderately rapid in the upper part of these soils and rapid below a depth of about 20 inches. Fertility is low, and organic-matter content is moderate. These soils are susceptible to soil blowing.

Representative profile of Estherville sandy loam, 0 to 2 percent slopes, in a cultivated field, SW1/4 NW1/4 NE1/4 sec. 12, T. 119 N., R. 22 W.:

Ap--0 to 8 inches, very dark brown (10YR 2/2) heavy sandy loam; weak, very fine, subangular blocky structure; very friable; many roots; medium acid; clear, smooth boundary.

A3--8 to 12 inches, dark-brown (10YR 3/3) sandy loam; very dark grayish-brown (10YR 3/2) coatings on peds; weak, very fine and fine, subangular blocky structure; friable; few roots; common, very fine, tubular pores; medium acid; clear, smooth boundary.

B2--12 to 20 inches, dark yellowish-brown (10YR 3/4) coarse sandy loam; weak, fine, subangular blocky structure; very friable; few roots; few, fine, tubular pores; about 10 percent gravel, mainly igneous; slightly acid; clear, smooth boundary.

IIC1--20 to 27 inches, dark-brown (10YR 3/3) gravelly coarse sand; single grain; loose; about 20 percent gravel; neutral; clear, smooth boundary.

IIC2--27 to 34 inches, dark grayish-brown (2.5Y 4/2) gravelly coarse sand; common, fine, faint, grayish-brown (2.5Y 5/2) coatings; single

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grain; loose; about 25 percent gravel; slightly calcareous; mildly alkaline; clear, smooth boundary.

IIC3--34 to 60 inches, light olive-brown (2.5Y 5/4) gravelly coarse sand; single grain; loose; about 25 percent gravel, about half of which is shale; mildly alkaline; strongly calcareous.

Combined thickness of the A and B horizons ranges from 14 to 24 inches but is commonly 16 to 20 inches. The Ap horizon ranges from 8 to 10 inches in thickness, from black to very dark brown in color, and from sandy loam to coarse sandy loam or loam in texture. Texture of the B horizon is sandy loam, coarse sandy loam, or loam, with a 10 to 18 percent clay content in the extreme range. The sand fraction commonly ranges from 50 to 70 percent. The C horizon is gravelly coarse sand or coarse sand with a gravel content of 10 to 50 percent. In most places the gravel content is 20 to 35 percent. There are thin strata that contain more gravel, thin strata of medium and fine sand, and discontinuous strata of shaly sand and gravel in some places. Content of gravel in the solum ranges from 5 to 15 percent. The gravel is commonly 2 to 5 millimeters in size. Reaction of the A and B horizons ranges from medium acid to neutral. The C horizon is neutral to moderately alkaline or is strongly calcareous.

Estherville soils are higher in coarse sand and gravel than the associated Dickman soils and are calcareous in the C horizon. Estherville soils have a darker colored Ap horizon and a more friable B horizon than the similar Burnsville soils. They have a thinner B horizon and a more gravelly C horizon than the Burnsville sandy loam, thick solum variant. Estherville soils are finer textured and deeper over gravel and sand than the associated Salida soils.

Estherville sandy loam, 0 to 2 percent slopes (EtA).--This nearly level soil occupies areas from 2 acres to more than 100 acres in size on broad flats. This soil has the profile described as representative for the series.

Included in mapping were small areas of Dickman soils. Also included, near Fort Snelling State Park, were areas of soils underlain by limestone bedrock at a depth of 2 to 5 feet.

Drought is a severe hazard, and soil blowing is a moderate hazard. This soil is poorly suited to corn and soybeans because of its low available moisture capacity. It is fairly well suited to irrigated truck crops in areas where water is available. (Capability unit IIIs-1; woodland group 3; building site group 2)

Estherville sandy loam, 2 to 6 percent slopes (EtB).--This gently undulating soil occupies 2-acre to 15-acre areas on irregular mounds and ridges. Areas generally are long and narrow. Slopes are typically 60 to 125 feet long.

Included in mapping, near Fort Snelling State Park, were areas of soils underlain by limestone bedrock at a depth of 2 to 4 feet. Also included were a few strongly convex knobs occupied by the very shallow Salida soils and some small areas of soils underlain by sand. There are a few drainageways and depressions that contain finer textured soils that have a thicker surface layer and subsoil than this Estherville soil. These areas retain frost longer and restrict early field operations.

The severe hazard of drought and the moderate hazards of soil blowing and water erosion are the main limitations. This soil is poorly suited to such row crops as corn and soybeans because of its low available moisture capacity. It is better suited to early crops, such as small grain. (Capability unit IIIe-3; woodland group 3; building site group 2)

Estherville sandy loam, 6 to 12 percent slopes (EtC).--This rolling soil occupies narrow strips, 75 to 125 feet wide and 2 to 10 acres in size, on knolls and hillsides. Shallow downslope drainageways and a few gullies give the surface a wavy appearance. In cultivated areas the surface layer is dark brown.

Included in mapping were small areas of Salida soils that generally occupy small, strongly convex knobs. Near the base of the slopes, the soils are thicker and darker colored. Also included were a few small areas of soils that are underlain by sand.

The hazards of drought and erosion severely limit the use of this soil for the production of corn and soybeans. It is better suited to early season crops such as small grain. Many areas are in permanent vegetation. (Capability unit IVe-4; woodland group 3; building site group 2)

Estherville sandy loam, 12 to 18 percent slopes (EtD).--This moderately steep soil occupies 2-acre to 10-acre areas on hillsides. Slopes are 60 to 150 feet long. The slopes are broken by downslope drainageways and a few shallow gullies. In cultivated areas the surface layer is dark brown. These cultivated areas are lower in organic matter and are generally more shallow to sand and gravel than the darker areas.

Included in mapping, on the most convex parts of the slopes, were small patches of Salida soils. A few patches are underlain by sand. At the base of the slopes and in the drainageways, the soils are darker and the surface layer and subsoil are thicker.

This moderately steep, shallow soil is severely limited for intertilled crops. Because of the steepness of slopes, this soil is better suited to permanent plant cover, such as pasture or woodland, than to most other uses. Most areas are in pasture or woodland. (Capability unit VIs-1; woodland group 3; building site group 2)

Fill Land

Fill land (Fd) is a miscellaneous land type that consists of soil material that has been used to fill in depressions. Areas range from about 1 acre to about 20 acres in size. The fill material ranges

from about 2 feet to more than 10 feet in thickness. In most places the soil material has been removed from the nearby slopes.

Most areas of this land type are loamy, but some are clayey; however, fill areas include such refuse as concrete, iron, and rubber. The underlying material is mainly very poorly drained. Many areas of Fill land are underlain by deep peaty muck.

In areas where peaty muck underlies Fill land, the fill areas are subject to continual settling. Large buildings generally need to be built on pilings set on solid material to insure a stable foundation. Even so, settling of the fill occurs around the building, causing sidewalks and access roads to deteriorate rapidly. Sewerlines and waterlines are easily broken in such settling fill.

In many places this land type has been developed for building sites. In areas where it consists of loamy to clayey material, manipulation has destroyed the natural structure. Permeability is slow in this material, and therefore it is poorly suited to septic tank drainfields (plate IV). In many places this land type is well suited to parks and playgrounds. (Not in a capability unit, woodland group, or building site group)

Glencoe Series

The Glencoe series consists of deep, very poorly drained, loamy soils. These soils formed in loamy colluvium over calcareous loamy till. They lie in shallow depressions and in places in drainageways. The native vegetation was dominantly sedges and wetsite grasses.

In a representative profile, the surface layer is about 30 inches thick. The upper 13 inches is black silty clay loam that is high in organic matter. The next 9 inches is black clay loam. The lower 8 inches is very dark gray loam. The subsoil is very dark gray to dark-gray loam about 6 inches thick. The underlying material is calcareous, gray, friable loam.

Glencoe soils have high available moisture capacity, very slow internal drainage, and moderate to moderately slow permeability. The water table is near the surface during wet seasons. Glencoe soils must be drained if they are to be used for cropland. The soils are high in organic-matter content and natural fertility.

Representative profile of Glencoe silty clay loam, in a cultivated field, NW1/4 SE1/4 SE1/4 sec. 21, T. 119 N., R. 23 W., Corcoran village:

A11--0 to 13 inches, black (N 2/0) silty clay loam that is high in content of organic matter; common, fine, distinct, dark-brown (7.5YR 4/4) mottles; weak, very fine, subangular blocky structure; friable; few fine roots; neutral; clear, smooth boundary.

A12--13 to 22 inches, black (N 2/0) light clay loam; common, fine, distinct, dark-brown (7.5YR 4/4) mottles; weak, very fine and fine, subangular blocky structure; friable; common fine roots; common, fine, tubular pores; about 2 percent coarse fragments; neutral; clear, smooth boundary.

A3--22 to 30 inches, very dark gray (10YR 3/1) loam; many, fine, prominent, dark-brown (7.5YR 4/4) mottles; weak, fine, subangular blocky structure; friable; few fine roots; common, fine, tubular pores; about 2 percent coarse fragments; neutral; clear, smooth boundary.

B2g--30 to 36 inches, very dark gray (10YR 3/1) to dark-gray (10YR 4/1) light loam; common, fine and medium, prominent, olive-brown (2.5Y 4/4) and olive-gray (5Y 4/2) mottles; weak, very fine, subangular blocky structure; friable; few very fine roots; about 2 percent coarse fragments; neutral; clear, smooth boundary.

C1g--36 to 48 inches, gray (5Y 5/1) loam that is high in content of silt; many, fine and medium, prominent, light olive-brown (2.5Y 5/6) mottles; weak, very fine, subangular blocky structure; friable; about 2 percent coarse fragments; few small pockets of iron pyrite 4 inches in diameter; neutral; clear, smooth boundary.

C2g--48 to 60 inches, gray (5Y 6/1) loam; many, fine and medium, prominent, light olive-brown (2.5Y 5/6) mottles; weak cleavage planes; friable; about 2 percent coarse fragments; few small patches of iron pyrite 4 inches in diameter; mildly alkaline; weakly calcareous.

The thickness of the solum is commonly 36 to 54 inches but ranges from 30 to 60 inches. The A1 horizon is 18 to 30 inches thick. In some places there is an O horizon up to 12 inches in thickness. Texture of the A horizon is commonly clay loam or silty clay loam but is loam in places. Dark-colored tongues of the A horizon are typical in the B horizon. Texture of the B horizon is loam, clay loam, or silty clay loam. Sand content ranges from 20 to 35 percent, but the extreme range is 15 to 40 percent. More than 15 percent of the sand fraction is coarser than very fine sand. The percentage of coarse fragments throughout the soil is less than 5 percent. Reaction of the solum is slightly acid to neutral. The C horizon is neutral to moderately alkaline and strongly calcareous.

Glencoe soils have a thicker A horizon and a more friable B horizon than associated Cordova soils. They have a less developed B horizon than similar Hamel soils and occur in depressions rather than in drainageways.

Glencoe silty clay loam (Gc).--This nearly level soil occupies depressions and sluggish drainageways throughout most of the county.

Included in mapping were small areas of shallow peat over loam. Also included were a few sandy and gravelly pockets in the underlying material. A few inclusions are of a soil that has a slowly permeable silty clay subsoil and underlying material which extends to a depth of 3 to 5 feet.

This soil must be drained before it is used for cropland. Tile drains work well in this soil if a

good outlet is available. Shallow ditches or tile inlets are needed to remove surface water that collects after heavy rainfalls. With good management, corn and soybeans can be grown year after year. Small grain tends to lodge on this soil. Alfalfa is easily drowned out and generally does not last more than 1 year. (Capability unit IIIw-1; woodland group 7; building site group 12)

Grays Series

The Grays series consists of deep, well-drained soils that formed in 4 to 8 feet of calcareous, silty sediments. Dense, calcareous, light olive-brown, loamy till underlies the silt. These soils are gently sloping to moderately steep. Slopes are mostly simple. The native vegetation was tall prairie grass encroached on by mixed hardwoods.

In a representative profile, the surface layer is very dark grayish-brown very fine sandy loam about 7 inches thick. The subsoil, about 18 inches thick, is yellowish-brown, light olive-brown, and dark yellowish-brown light silty clay loam that grades to silt loam in the lower part. The underlying material is mottled, light olive-brown, calcareous silt loam.

Grays soils have high moisture capacity, moderate permeability, and medium internal drainage. The water table is at a depth below 5 feet in all seasons. These silty soils are easily eroded by water. They are easy to till but need good management to maintain good tilth. However, since the organic-matter content is low to moderate, the cultivated surface layer tends to seal over during rains and form a crust on drying. Fertility is medium.

Representative profile of Grays very fine sandy loam, 2 to 6 percent slopes, in a cultivated field, SW1/4 SW1/4 NW1/4 sec. 23, T. 116 N., R. 22 W.:

Ap--0 to 7 inches, very dark grayish-brown (10YR 3/2) very fine sandy loam; few inclusions of dark yellowish brown (10YR 4/4); cloddy; very friable; slightly acid; smooth, abrupt boundary.

B21t--7 to 11 inches, yellowish-brown (10YR 5/4) light silty clay loam; faces of peds are dark brown (10YR 4/3); moderate, medium and coarse, subangular blocky structure; many, fine, tubular pores; few, thin, very dark gray (10YR 3/1) clay films on faces of peds; neutral; gradual, smooth boundary.

B22t--11 to 18 inches, light olive-brown (2.5Y 5/4) silt loam to light silty clay loam; moderate, medium and coarse, subangular blocky structure; friable; many, very fine and fine, tubular pores; common, thin, very dark grayish-brown (10YR 3/2) clay films on faces of peds; neutral; gradual, smooth boundary.

B23t--18 to 25 inches, dark yellowish-brown (10YR 4/4) silt loam; moderate, coarse, subangular blocky structure; friable; many, fine, tubular pores; common, thick, very dark brown (10YR 2/2) clay films on faces of peds and in root channels; neutral; gradual, smooth boundary.

C1--25 to 45 inches, light olive-brown (2.5Y 5/4) silt loam; few, fine, distinct, grayish-brown (2.5Y 5/2) mottles; moderate, medium, platy structure parting to moderate, fine and medium, angular blocky; friable; common very dark grayish-brown (10YR 3/2) and very dark brown (10YR 2/2) clay fillings in root channels; common, light-gray lime concentrations; mildly alkaline; strongly calcareous; gradual, smooth boundary.

C2--45 to 60 inches, light olive-brown (2.5Y 5/4) silt loam; few, fine, faint, grayish-brown (2.5Y 5/2) mottles; weak, coarse, platy structure parting to weak, fine and medium, angular blocky; friable; few very dark grayish-brown (2.5Y 3/2) clay fillings in root channels of upper part; common light-gray lime concretions; mildly alkaline; strongly calcareous.

The solum ranges from 20 to 36 inches in thickness but is commonly 24 to 30 inches thick. The Ap horizon is 7 to 9 inches thick and ranges from very fine sandy loam to fine sandy loam, loam, or silt loam in texture. In uncultivated areas the A1 horizon is 2 to 4 inches thick and is underlain by a dark grayish-brown A2 horizon 3 to 5 inches thick. A few profiles are very fine sandy loam in part of the B2 horizon. Less than 15 percent of the soil by volume in the B horizon is coarser than very fine sand. The sand is mainly very fine and fine. The C horizon is light olive-brown or grayish-brown very fine sandy loam or silt loam. There are thin seams of silty clay loam and fine sand in some places. A few coarse fragments occur throughout the profile in some places but comprise less than 2 percent of the soil by volume. Reaction of the solum ranges from slightly acid to neutral.

Grays soils are higher in silt content and are lower in sand and coarse fragment content than the similar Hayden soils. Grays soils are higher in sand content and lower in clay content than the similar Dalbo soils. Grays soils are more silty in the A horizon and in the upper part of the B horizon than the associated Braham soils that have a silty subsoil.

Grays very fine sandy loam, 2 to 6 percent slopes (GyB).--This gently sloping soil occurs on 2-acre to 15-acre, irregularly shaped tracts on knolls and low hills. The landscape generally has a smooth appearance. Slopes are mainly simple and are mostly 80 to 150 feet long. This soil has the profile described as representative for the series.

Included in mapping were small patches of soils that have a surface layer and subsoil of fine sandy loam or loamy fine sand 18 inches deep. Also included in places was a soil that has thin layers of silty clay in the underlying material. A small acreage of nearly level Grays soils was also included. In a few places this Grays soil is underlain by sand and gravel mostly at a depth of 4 to 10 feet. In spots, however, the gravel and sand are nearer the surface.

This soil is well suited to all crops commonly grown in the county. The major management needs are control of erosion and maintenance of fertility. With good management, corn and soybeans can be grown nearly every year. (Capability unit IIe-1; woodland group 1; building site group 5)

Grays very fine sandy loam, 6 to 12 percent slopes (GyC).--This rolling soil occupies 2-acre to 15-acre, irregularly shaped areas on knolls and hills. Slopes are mainly in one direction and are 75 to 125 feet long. In many cultivated areas the steeper parts of the slopes are dark brown. When this soil is dry, the color is much lighter. These browner areas have been eroded and thus are lower in organic-matter content and natural fertility.

Included in mapping were small patches of soils where the surface layer and upper part of the subsoil are loamy fine sand or fine sandy loam to a depth of 18 inches. There are thin layers of clay in the underlying material in places. In a few spots the underlying material is fine sandy loam. In a few small areas, this Grays soil is underlain by sand and gravel at a depth of 4 to 10 feet. In places the gravel and sand are nearer the surface.

This soil is suited to all the major crops grown in the county. The hazard of erosion is severe, and control of erosion is the main management need. In many places the areas are too small in size to contour farm or to terrace. Using minimum tillage practices or growing a sod crop more often are other ways to reduce erosion. (Capability unit IIIe-1; woodland group 1; building site group 5)

Hamel Series

The Hamel series consists of deep, poorly drained soils that formed in loamy colluvium over loamy till. These soils occupy the deeper drainageways between knolls and hills throughout most of the county. The native vegetation was mainly sedges, grasses, and scattered popple trees.

In a representative profile, the surface layer is about 22 inches thick and consists of two parts. The upper part is very dark gray loam about 13 inches thick. The lower part is black heavy loam about 9 inches thick. The subsoil is about 19 inches thick. The upper part is very dark gray clay loam, the middle part is dark olive-gray heavy loam, and the lower part is dark-gray loam. The underlying material is calcareous, mottled, olive-gray loam that contains a thin sandy layer and is underlain by light olive-gray loam.

Hamel soils have high available moisture capacity, moderately slow permeability, and slow internal drainage. The water table is at a depth of 1 to 3 feet during wet seasons. The organic-matter content and fertility are high. The root zone is deep.

Representative profile of Hamel loam, in a cultivated field, SE1/4 SE1/4 NW1/4 sec. 6, T. 118 N., R. 22 W., Plymouth village:

A11--0 to 13 inches, very dark gray (10YR 3/1) loam; weak, medium and fine, subangular blocky structure parting to weak to moderate, very fine, subangular blocky; friable; common roots; medium acid; clear, smooth boundary.

A12--13 to 22 inches, black (N 2/0) heavy loam; few inclusions of very dark gray (10YR 3/1) and dark gray (10YR 4/1); moderate, fine and medium, subangular blocky structure parting to moderate, very fine, subangular blocky; very friable; common roots; few, fine, tubular pores; slightly acid; clear, smooth boundary.

B21tg--22 to 28 inches, very dark gray (10YR 3/1) clay loam; weak, coarse, prismatic structure parting to moderate, medium and coarse, subangular blocky; firm; few roots; common, fine, tubular pores; many, thick, black (10YR 2/1) clay films on faces of peds; about 5 percent coarse fragments; slightly acid; clear, smooth boundary.

B22tg--28 to 34 inches, dark olive-gray (5Y 3/2) heavy loam; weak, coarse, prismatic structure parting to moderate, coarse, subangular blocky; friable; few roots; common, fine, tubular pores; common, thick, black (10YR 2/1) and very dark gray (10YR 3/1) clay films on faces of peds and in root channels; about 5 percent coarse fragments; slightly acid; clear, smooth boundary.

B3tg--34 to 41 inches, dark-gray (5Y 4/1) loam; common, medium, prominent, dark greenish-gray (5BG 4/1) mottles; moderate, coarse, prismatic structure parting to moderate, coarse, subangular blocky structure; friable; common, fine, tubular pores; common, thick, very dark gray (10YR 3/1) clay films on faces of peds and black (10YR 2/1) clay films in root channels; neutral; clear, smooth boundary.

C1--41 to 46 inches, olive-gray (5Y 4/2) loam; many, fine, distinct, olive (5Y 5/3) mottles and prominent yellowish-brown (10YR 5/8) mottles; very weak, coarse, subangular blocky structure; friable; about 5 percent coarse fragments; mildly alkaline; slightly calcareous; abrupt, smooth boundary.

IIC2--46 to 51 inches, olive-gray (5Y 4/2) loamy coarse sand; many, fine, prominent, olive (5Y 5/3) and yellowish-brown (10YR 5/8) mottles; very weak, coarse, subangular blocky structure; very friable; mildly alkaline; slightly calcareous; abrupt, smooth boundary.

IIIC3--51 to 60 inches, light olive-gray (5Y 6/2) loam; common, fine and medium, prominent, olive (5Y 5/3) and strong-brown (7.5YR 5/8) mottles; very weak, coarse, subangular blocky structure; friable; few, black, old root channels; few light-gray (2.5Y 7/2) lime concentrations; few reddish "iron pipes"; about 5 percent coarse fragments; mildly alkaline; strongly calcareous.

The solum ranges from 36 to 72 inches in thickness but is commonly 36 to 54 inches thick. The A horizon is typically 16 to 24 inches thick but ranges to 36 inches. It is typically black loam,

light clay loam, or silty clay loam, but in places there is a very dark gray or very dark grayish-brown loam layer of overwash up to 12 inches thick. The average clay content of the B horizon is less than 35 percent. The B horizon ranges from weak to strong, coarse, prismatic structure to moderate to strong, medium and coarse, subangular blocky structure. The C horizon is dark olive gray to light olive gray. In places there are thin, coarse-textured layers in the C horizon. Reaction ranges from medium acid to neutral in the A and B horizon. The C horizon is mildly alkaline and is slightly to strongly calcareous.

Hamel soils have a thicker A1 horizon than the similar Cordova soils. They have a more developed B horizon that contains translocated clay than the similar Glencoe soils and occur in drainageways rather than in closed depressions.

Hamel loam (Ha).--This nearly level soil occupies 1-acre to 3-acre areas in short, narrow drainageways on side slopes and 5-acre to 30-acre areas in long, winding drainageways between knolls and hills.

Included in mapping were small areas of Glencoe soils. Also included in places were small areas of Le Sueur soils that lie at the base of steep slopes.

If properly drained and managed, this soil is suited to all crops commonly grown in the county. Tile drainage and good outlets are needed. This soil is well suited to corn and soybeans. Because areas of this soil are so irregular in shape, it is generally farmed with the surrounding soils. (Capability unit IIw-1; woodland group 5; building site group 10)

Hayden Series

The Hayden series consists of deep, well-drained, loamy soils that formed in loamy glacial till. These gently sloping to very steep soils are in convex areas on knolls and hillsides. The hills and knolls are 5 to 300 acres in size and lie 5 to 80 feet above the surrounding drainageways and depressions. Slopes are mainly complex, range from 2 to 35 percent, and are 75 to 250 feet long. There are stones and boulders near the surface. The native vegetation was mixed hardwood forest.

In a representative profile, the surface layer is very dark gray loam about 7 inches thick. The subsoil is about 29 inches thick. The upper part is dark yellowish-brown and yellowish-brown light clay loam. The lower part is light olive-brown loam. The underlying material is light olive-brown, calcareous loam.

Hayden soils have high available moisture capacity and moderate permeability. Internal drainage is medium. The water table is at a depth below 5 feet in all seasons. Hayden soils have low organic-matter content and medium natural fertility. The subsoil in most places is high in phosphorus. Roots penetrate the soil deeply and easily. The surface layer is easily eroded.

Representative profile of Hayden loam, 2 to 6 percent slopes, in a cultivated field, SW1/4 SW1/4 NW1/4 sec. 20, T. 118 N., R. 22 W.:

Ap--0 to 7 inches, very dark gray (10YR 3/1) loam, light brownish gray (10YR 6/2) when dry; weak, very fine, granular structure; friable; many roots; neutral; abrupt, smooth boundary.

B1t--7 to 14 inches, dark yellowish-brown (10YR 4/4) light clay loam; weak, fine, subangular blocky structure; friable; few roots; few to common, fine, tubular pores; many, thick, light brownish-gray (10YR 6/2), porous coatings on faces of peds; few, thin, very dark brown (10YR 2/2) clay films on faces of peds; few fine shale fragments; slightly acid; clear, smooth boundary.

B22t--14 to 22 inches, yellowish-brown (10YR 5/4) light clay loam; very weak, fine, prismatic structure parting to moderate to strong, medium and coarse, subangular blocky structure; friable; few roots; many, fine, tubular pores; common, thin, dark grayish-brown (10YR 4/2) clay films on faces of peds; common, thin, light-gray (10YR 7/2), porous coatings on vertical faces of peds; about 5 percent coarse fragments; slightly acid; clear, smooth boundary.

B23t--22 to 31 inches, light olive-brown (2.5Y 5/4) loam; very weak, medium, prismatic structure parting to moderate, coarse, subangular blocky structure; friable; few roots; many, fine, tubular pores; common, thick, very dark grayish-brown (10YR 3/2) clay films on faces of peds; about 5 percent coarse fragments; slightly acid; clear, smooth boundary.

B3t--31 to 36 inches, light olive-brown (2.5Y 5/4) loam; weak, coarse, subangular blocky structure; friable; common, fine, tubular pores; common, thick, very dark grayish-brown (10YR 3/2) clay films on faces of peds; about 5 percent of volume consists of very dark brown (10YR 2/2) clay fillings in root channels; about 5 percent coarse fragments; neutral; clear, smooth boundary.

C1--36 to 48 inches, olive-brown (2.5Y 5/4) loam; weak, coarse, subangular blocky structure; friable; few fine pores; few black (10YR 2/1) clay fillings in root channels; few red iron concretions and few black manganese concretions; few light-gray lime concretions; about 5 percent coarse fragments; mildly alkaline; strongly calcareous; clear, smooth boundary.

C2--48 to 60 inches, light olive-brown (2.5Y 5/4) loam; common, fine, prominent, yellowish-brown (10YR 5/8) mottles; weak cleavage planes; friable; few fine tubular pores; few, fine, very dark grayish-brown (10YR 3/2) clay fillings in root channels of upper part; common white lime concretions and concentrations; mildly alkaline; strongly calcareous.

Thickness of the solum ranges from 20 to 48 inches but is commonly 28 to 36 inches. The Ap horizon is very dark gray to dark grayish brown. In cultivated areas the A1 horizon is 3 to 5 inches thick and is black or very dark gray. The A2 horizon, where present, is 3 to 8 inches thick and is very dark gray to grayish brown. The B2 horizon generally is dark yellowish brown but is yellowish brown and olive brown in places. The B2 horizon has a marked increase in clay content as compared to the A horizon. The finest textured part of the B horizon ranges from 22 to 35 percent clay but is typically 28 to 33 percent clay. Sand content ranges from 30 to 45 percent, with 25 to 50 percent of the sand fraction coarser than fine sand. The C horizon contains 18 to 24 percent clay and 35 to 50 percent sand. High-chroma mottles are common throughout the C horizon. In some areas there are iron oxide concretions. In the eastern part of the county, there is a IIC horizon of reddish-brown loamy or sandy material at a depth of 4 to 20 feet. The A horizon is slightly acid to neutral. The B horizon is medium acid to neutral.

Hayden soils are not so fine textured as the similar Erin soils. They are finer textured throughout the profile than the associated Heyder soils. Hayden soils are not mottled in the B2 horizon as are the associated Nessel soils. They are finer textured and lower in content of gravel and cobblestones than the similar Kingsley soils and have a lighter colored Ap horizon than the associated Lester soils.

Hayden loam, 2 to 6 percent slopes (HbB).--This gently undulating soil occupies 2-acre to 15-acre, irregularly shaped areas on knolls and hillsides. Slopes are 75 to 125 feet long. The slope in most places is in several directions. This soil has the profile described as representative for the series.

Included in mapping were a few, small, eroded patches of soils that have a surface layer of dark-brown clay loam. Also included were a few patches of Dalbo soils that have convex slopes. Included in narrow, concave drainageways were areas of the poorly drained Dundas and Cordova soils. A few scattered depressions contain areas of Glencoe soils.

The main management needs are control of erosion and maintenance of tilth. The hazard of erosion is moderate. This soil is well suited to all crops commonly grown in the county. If management is good, this soil is suited to row crops nearly every year. (Capability unit IIe-1; woodland group 1; building site group 5)

Hayden loam, 6 to 12 percent slopes (HbC).--This rolling soil occupies 2-acre to 15-acre, irregularly shaped areas on hillsides and knolls. Slopes are commonly 75 to 125 feet long. In most places the slope is in several directions. This soil has a profile similar to that described as representative for the series, except that the surface layer is dark grayish brown and is much lighter colored when dry. A few scattered patches of dark yellowish-brown clay loam subsoil are exposed in cultivated fields.

Included in mapping were a few patches of Dalbo soils. There are areas of Dundas and Cordova soils in shallow drainageways. Areas of Glencoe soils were also included in the few scattered depressions.

Most areas of this soil are in permanent pasture or woodland. This soil is good cropland and is suited to all crops commonly grown in the county. The hazard of erosion is severe. Good management is required to reduce erosion and runoff. (Capability unit IIIe-1; woodland group 1; building site group 5)

Hayden loam, 12 to 18 percent slopes (HbD).--This hilly soil occupies 2-acre to 15-acre, irregularly shaped areas on hillsides and knolls. Slopes are typically 60 to 125 feet long. Some areas are on the side slopes of low hills, and slope is mainly in one direction. Slopes are in several directions, however, in most areas. This soil has a profile similar to that described as representative for the series, except that the surface layer is dark grayish brown and is much lighter colored when dry. There are a few scattered exposures of the dark-brown clay loam subsoil. The surface layer and the subsoil are commonly thinner than those in the profile described as representative for the series.

Included in mapping were small patches of Dalbo soils that occupy convex positions. Areas of Dundas and Cordova soils occupy shallow drainageways and depressions.

Most areas of this soil are in permanent pasture or woodland. The hazard of erosion severely limits the use of this soil for cultivated crops. If common management practices are used, intertilled crops should be grown only occasionally. This soil is better suited to hay and pasture than to most other crops. (Capability unit IVe-1; woodland group 1; building site group 5)

Hayden loam, 18 to 24 percent slopes (HbE).--This steep soil occupies 2-acre to 10-acre areas on hillsides. Slopes are commonly 50 to 100 feet long and are broken by shallow downslope drainageways. This soil has a thinner surface layer and subsoil than those described as representative for the series.

Included in mapping were a few, small, 2-acre to 3-acre, gentle crests and side-slope benches.

Most areas of this soil are in permanent pasture or woodland. Steepness of slope severely limits its use for common farm crops. If not protected by plant cover, this soil erodes rapidly. It is difficult to operate machinery on the steep slopes. This soil is most productive when managed for grazing or woodland or maintained in its natural state for recreational use and for wildlife habitat. (Capability unit VIe-1; woodland group 1; building site group 5)

Hayden clay loam, 2 to 6 percent slopes, eroded (HcB2).--This gently undulating soil occupies 2-acre to 15-acre, irregularly shaped areas on knolls and hillsides. Slopes are 75 to 125 feet long. In most

places the slope is in several directions. Because this soil is eroded, the surface layer in cultivated areas has been mixed with the subsoil and is very dark grayish-brown or dark grayish-brown clay loam. It is much lighter colored when dry. In places the brownish subsoil is exposed.

Included in mapping were small patches of Dalbo soils that have convex slopes. Also included were areas of poorly drained Dundas and Cordova soils in narrow drainageways that cross this soil and areas of Glencoe soils in scattered depressions.

The main limitations are maintenance of tilth and control of erosion. This soil is well suited to all the crops commonly grown in the county. If the soil is well managed, row crops can be grown on it nearly every year. (Capability unit IIe-1; woodland group 1; building site group 5)

Hayden clay loam, 6 to 12 percent slopes, eroded (HcC2).--This rolling soil occupies 2-acre to 15-acre, irregularly shaped areas on knolls and hillsides. Slopes are commonly 75 to 125 feet long. Because this soil is eroded, the surface layer is clay loam that is a mixture of the dark grayish-brown material from the original surface layer and the dark yellowish-brown subsoil. The color is much lighter when dry. In places small patches are exposed that consist mainly of the brownish subsoil. This soil contains less organic matter and is less friable than Hayden loams.

Included in mapping were small patches of Dalbo soils that occupy convex positions. Also included were areas of Dundas and Cordova soils in shallow drainageways. Small, scattered depressions that contain areas of Glencoe soils were also included.

This soil is good cropland and is suited to all the crops commonly grown in the county. The hazard of erosion is severe. Good management is needed to control erosion and runoff. (Capability unit IIIe-1; woodland group 1; building site group 5)

Hayden clay loam, 12 to 18 percent slopes, eroded (HcD2).--This hilly soil occupies 2-acre to 15-acre areas on hillsides and knolls. Slopes are commonly 60 to 125 feet long. The slope is generally in several directions. Because this soil is eroded, the surface layer is clay loam that is a mixture of the dark grayish-brown material from the original surface layer and the dark yellowish-brown subsoil. In places the surface layer is mainly material from the dark-brown subsoil. The dry color is much lighter. This soil is lower in organic-matter content and is less friable than Hayden loams.

Included in mapping were a few, calcareous, olive-brown, bald patches near the crest of slopes. Included in convex areas were small patches of Dalbo soils. Areas of Dundas and Cordova soils were included in the few shallow drainageways and depressions.

This soil is severely limited for cultivated crops because of the steepness of slopes and the hazard of severe erosion. Careful management is needed if intertilled crops are grown. Corn should be grown only occasionally. Soybeans are not suited, because they loosen the soil and increase erosion. This soil is well suited to hay and pasture crops, which protect the soils. It is also well suited to trees. (Capability unit IVe-1; woodland group 1; building site group 5)

Hayden clay loam, 18 to 24 percent slopes, eroded (HcE2).--This steep soil occupies 2-acre to 10-acre areas on hillsides. Slopes are commonly 50 to 90 feet long. Slopes are broken by shallow downslope drainageways and occasional deep ravines. Because this soil is eroded, the surface layer is clay loam that is a mixture of the grayish-brown surface layer and the dark yellowish-brown subsoil. In a few areas the surface layer is dark brown and consists mainly of material from the subsoil. This soil has a thinner surface layer and subsoil than the one described as typical for the series. A few, small, calcareous, olive-brown bald patches occur near the crest of slopes. This soil is lower in organic-matter content and is less friable than Hayden loams.

Steepness of slopes severely limits the use of this soil for farming. This soil erodes rapidly in areas where the vegetative cover is sparse. It is better suited to pasture or woodland or to recreational or wildlife uses than to most other uses. (Capability unit VIe-1; woodland group 1; building site group 5)

Hayden and Lester loams, 24 to 35 percent slopes (HdF).--These very steep soils occupy 2-acre to 10-acre areas on hillsides, on sides of deep ravines, and on slopes adjacent to lakes and sloughs. Slopes are commonly 50 to 120 feet long. About 70 percent of this unit is Hayden loam, and 30 percent is Lester loam. The surface layer of the Hayden loam is thinner and lighter colored than that of the Lester loam. The Hayden and Lester loams have a profile similar to that described as representative for their respective series, except that they have a thinner surface layer and subsoil.

Included in mapping were shallow downslope drainageways that contain poorly drained soils that have a thick, dark surface layer. A few areas of gently rolling soils on hilltops were included with this mapping unit in some places. Small slumps occur down slope.

Most areas of these soils woodland. The hazard of erosion is very severe. The very steep, short slopes commonly limit the use of these soils to woodland, wildlife habitat, and enhancement of the natural beauty of the area. (Capability unit VIIe-1; woodland group 1; building site group 5)

Heyder Series

The Heyder series consists of deep, well-drained soils that formed in loamy glacial till. These soils have convex slopes and are on knolls and hills. The hills and knolls are 5 to 200 acres in size and lie 5 to 80 feet above the surrounding drainageways and depressions. Slopes range from 2 to 35 percent and are 75 to 250 feet long. Stones and boulders

are mainly near the surface. The native vegetation was mixed hardwoods.

In a representative profile, the surface layer is dark grayish-brown sandy loam about 10 inches thick. The subsoil is dark yellowish-brown sandy loam or sandy clay loam about 20 inches thick that is light olive brown in the lower 5 inches. There are thin seams of loamy sand in some subsoil layers. The underlying material is calcareous, light olive-brown loam.

Heyder soils have high available moisture capacity, medium internal drainage, and moderate permeability. The water table is at a depth below 5 feet in all seasons. Organic-matter content is low. The surface layer is fairly easily eroded by water. Heyder soils have a deep root zone. They have medium fertility, but crops grown on them respond to fairly large amounts of additional fertilizer.

Representative profile of Heyder sandy loam, 2 to 6 percent slopes, in a cultivated field, SW1/4 NW1/4 SW1/4 sec. 19, T. 119 N., R. 23 W.:

Ap--0 to 10 inches, dark grayish-brown (10YR 4/2) sandy loam; weak, very fine, subangular blocky structure; very friable; few roots; slightly acid; abrupt, smooth boundary.

B&A--10 to 15 inches, dark yellowish-brown (10YR 4/4) sandy clay loam; weak, fine, subangular blocky structure; friable; few roots; few, fine, tubular pores; many, thick, light-gray (10YR 6/1), porous coatings on faces of peds; medium acid; clear, smooth boundary.

B11--15 to 20 inches, dark yellowish-brown (10YR 4/4) sandy clay loam; weak, medium, subangular blocky structure; friable to firm; few roots; few, fine, tubular pores; many, thin, light-gray (10YR 6/1), porous coatings on faces of peds; medium acid; clear, smooth boundary.

B12--20 to 25 inches, dark yellowish-brown (10YR 4/4) sandy loam; thin seams of loamy sand; weak, very fine, subangular blocky structure; very friable; few, fine, tubular pores; medium acid; clear, smooth boundary.

B2t--25 to 30 inches, light olive-brown (2.5Y 5/4) sandy clay loam; weak to moderate, medium and coarse, subangular blocky structure; friable; few, fine, tubular pores; many, thick, very dark brown (10YR 2/2) clay films on faces of peds; few fine root channels; about 5 percent coarse fragments, mainly shale; slightly acid; clear, smooth boundary.

C--30 to 60 inches, light olive-brown (2.5Y 5/4) loam; a few thin strata of loamy sand and sandy loam; weak cleavage planes; friable; common light-gray lime segregations and few white lime concretions; common sand-size shale particles; about 5 percent coarse fragments; mildly alkaline; strongly calcareous.

The solum is 28 to 60 inches thick. The Ap horizon is 7 to 10 inches thick and is very dark grayish-brown to grayish-brown sandy loam or loamy sand. The A1 horizon is 2 to 4 inches thick and is black or very dark gray. The A2 horizon is 4 to 8 inches thick and is dark grayish brown or grayish brown. The B1 horizon is brown or dark yellowish brown in color. It is typically sandy loam or sandy clay loam in texture but in places is loamy sand. About 20 to 30 percent of the sand fraction is coarser than medium sand. The B2 horizon shows a marked increase in clay content as compared to the A horizon. The finest textures range from heavy sandy loam to loam or sandy clay loam that contains 18 to 27 percent clay. Sand content typically is 40 to 55 percent, but it ranges from 35 to 60 percent. In many areas there is a IIC horizon of reddish-brown loamy or sandy material at a depth of 4 to 20 feet. The A horizon is slightly acid to neutral, and the B horizon is medium acid to slightly acid. The C horizon is weakly to strongly calcareous.

Heyder soils are more sandy throughout than the associated Hayden soils. They have a thinner sandy mantle than the similar Braham soils. They are finer textured and contain less gravel than the similar Kingsley soils.

Heyder sandy loam, 2 to 6 percent slopes (HeB).--This gently sloping soil occupies 2-acre to 25-acre, irregularly shaped areas on knolls and hillsides. Slopes are 75 to 125 feet long. In most places the slope is in several directions. This soil has the profile described as representative for the series.

Included in mapping were small patches of soils that have a surface layer of loamy sand, loam, or coarse sandy loam. A few areas of soils that have a surface layer of mainly loamy sand were also included. These soils are near the Mississippi outwash plains. In spots, the loamy sand extends into the subsoil. The subsoil and underlying material in many areas include pockets and lenses of sandy loam, loamy sand, or gravel and sand. In a few areas these inclusions comprise up to 20 percent of the mapping unit. Also included were areas of Nessel, Dundas, and, in a few places, Hamel soils in narrow drainageways and depressions.

If well managed, this soil is good cropland and is suited to all the major crops grown in the county. The hazard of erosion is moderate. The patches and spots of included soils that have a loamy sand surface layer are susceptible to drought and soil blowing. (Capability unit IIe-1; woodland group 1; building site group 5)

Heyder sandy loam, 6 to 12 percent slopes (HeC).--This rolling soil occupies 2-acre to 15-acre, irregularly shaped areas on hillsides and knolls. Slopes are commonly between 75 and 125 feet long. The slope is typically in several directions. There are areas where this soil has a dark-brown surface layer consisting of a mixture of the original surface layer and the subsoil.

Included in mapping were small patches of soils that have a surface layer of loamy sand, loam, or coarse sandy loam. A few areas of soils that have a surface layer of mainly loamy sand were also included. These soils are near the Mississippi outwash plains. In spots the loamy sand extends into the subsoil. The subsoil and underlying material

in many areas include pockets and lenses of sandy loam, loamy sand, or gravel and sand. These inclusions in some areas comprise up to 20 percent of the mapping unit. Also included were areas of Nessel, Dundas, and, in a few places, Hamel soils in narrow drainageways and depressions. These areas are too small to be shown separately in mapping.

Most of this soil is cultivated and is suited to all the major crops grown in the county. The hazard of erosion is severe. Good management is required to control erosion and runoff. (Capability unit IIIe-1; woodland group 1; building site group 5)

Heyder sandy loam, 12 to 18 percent slopes (HeD).--This moderately steep soil occupies 2-acre to 15-acre, irregularly shaped areas on hillsides. Slopes are commonly 60 to 100 feet long. In cultivated areas, the surface layer is a mixture of the original surface layer and the subsoil and is dark brown.

Included in mapping were small patches of soils that have a surface layer of loamy sand, loam, or coarse sandy loam. The subsoil and underlying material in many areas include pockets and lenses of sandy loam, loamy sand, or gravel and sand. These inclusions comprise up to 20 percent of the mapping unit in some areas. Also included were occasional downslope drainageways that contain areas of Nessel, Dundas, and Hamel soils.

Most areas of this soil are in permanent pasture or woodland. The severe hazard of erosion limits its use for cultivated crops, such as corn and soybeans. If common management practices are used, these crops should be grown only occasionally. This soil is generally better suited to hay and pasture crops than to other crops. (Capability unit IVe-1; woodland group 1; building site group 5)

Heyder sandy loam, 18 to 24 percent slopes (HeE).--This steep soil occupies 2-acre to 10-acre areas on hillsides. Slopes are commonly 50 to 100 feet long and are broken by shallow downslope drainageways. There are small areas where slopes are less than 18 percent and greater than 24 percent. In cultivated areas the surface layer is dark brown and is a mixture of the original surface layer and the subsoil. In addition, the surface layer and subsoil are thinner than is typical for the series.

Included in mapping were small patches of soils that have a surface layer of loamy sand, loam, or coarse sandy loam. The subsoil and underlying material in many areas include pockets and lenses of sandy loam, loamy sand, and gravel and sand. In places these inclusions comprise up to 20 percent of the mapping unit. Also included were narrow drainageways that contain areas of Nessel, Dundas, and Hamel soils.

Most areas of this soil are in woodland or permanent pasture. In areas where the plant cover is sparse, this soil erodes easily. Steepness of slopes and severe hazard of erosion severely limit the use of this soil for common farm crops. This soil is more productive if managed for grazing or maintained in its natural condition for recreational use and wildlife habitat than if used for most other purposes. (Capability unit VIe-1; woodland group 1; building site group 5)

Heyder complex, 2 to 6 percent slopes (H1B).--Soils of this complex are gently sloping, and they occupy irregular areas on knolls and hills. Size of the areas is 2 to 15 acres. Slopes are 70 to 120 feet long. The slopes extend in several directions. In cultivated areas the surface layer is dark grayish brown. A few, small patches of the brownish subsoil are exposed in cultivated fields. About 15 to 35 percent of this complex consists of sandy soils underlain by calcareous gravel and sand at a depth of 1 to 3 feet. About 40 to 60 percent is Heyder sandy loam, about 25 percent is Hayden loam, and the rest is Dundas and Cordova soils in scattered depressions and drainageways. The Heyder and Hayden soils have a profile similar to that described as representative for their respective series.

Included in mapping were a few areas of soils along the Crow River, a few miles north of Rockford, that have a surface layer of black or very dark brown.

Drought and erosion are slight to moderate hazards on the soils of this complex. Crop growth is spotty because of variations in the soils within short distances. These soils are suited to all the locally grown farm crops. The sand and gravel deposits are a source of construction materials. (Capability unit IIe-3; woodland group 2; building site group 4)

Heyder complex, 6 to 12 percent slopes (H1C).--This rolling complex occupies irregular areas on rolling knolls and hillsides. Size of the areas is 2 to 15 acres. Slopes are mostly 75 to 150 feet long and extend in more than one direction in many places. In cultivated areas, the surface layer is very dark grayish-brown sandy loam or loam and there are many eroded patches near the crest of slopes. The eroded spots are mostly dark brown. When dry, these soils are much lighter in color. About 20 to 45 percent of this complex consists of sandy soils underlain by calcareous gravel and sand at a depth of 1 to 3 feet. The remainder is Hayden and other Heyder soils.

Included in mapping were a few depressions and drainageways that contain areas of Dundas and Cordova soils. In a few areas along the Crow River, the surface layer is black to very dark brown.

Many areas of these soils are in woodland or pasture. If cultivated, they are droughty and are subject to erosion. Good crop growth is spotty unless rainfall is timely. Good management is required to reduce erosion and runoff. The sand and gravel deposits are a source of construction materials. (Capability unit IVe-3; woodland group 2; building site group 4)

Heyder complex, 12 to 18 percent slopes (H1D).--The soils of this complex are hilly and occupy

2-acre to 10-acre irregular areas on hillsides. Slopes are 60 to 150 feet long. In places slopes extend in several directions. In cultivated areas the surface layer is dark-brown sandy loam or loam. A few patches of the dark-brown subsoil are exposed near crests of slopes. This soil is much lighter in color when dry. About 25 to 60 percent of this complex consists of a sandy soil underlain by calcareous gravel and sand at a depth of 1 to 3 feet. The remainder is Hayden and other Heyder soils. Heyder soils contain many pockets of gravel and sand in the underlying material.

Included in mapping were small patches of a soil that has a surface layer of loamy sand. A few, narrow, downslope drainageways contain areas of Dundas and Cordova soils.

Most of this complex is in woodland or pasture. Steepness of slopes and the hazards of erosion and drought severely limit its use for cropland. This complex is better suited to pasture, woodland, or recreational uses. The sand and gravel deposits are a source of construction materials. (Capability unit VIe-1; woodland group 2; building site group 4)

Heyder complex, 18 to 35 percent slopes (H1E).--The soils in this complex occupy 2-acre to 10-acre, irregular areas on hillsides. Slopes are 60 to 150 feet long. About 25 to 65 percent of this complex consists of sandy soils underlain by calcareous sand and gravel at a depth of 1 to 3 feet. The remainder is Hayden and other Heyder soils.

Included in mapping were small patches of a soil that has a loamy sand surface layer.

Most areas of these soils are in woodland or permanent pasture and are too steep to use for cultivated crops. They erode rapidly if exposed, and machinery is difficult to use. This complex is better suited to woodland, pasture, recreation, or wildlife habitat than to cultivated crops. (Capability unit VIIe-1; woodland group 2; building site group 4)

Hubbard Series

The Hubbard series consists of deep, somewhat excessively drained, sandy soils that formed in sand. These soils occur on topography that ranges from broad flats to steep hillsides. They are mainly on stream and glacial outwash plains. Slopes range from 0 to 35 percent and are mostly simple. The native vegetation was tall prairie grass and a few thin stands of oak and brush.

In a representative profile, the surface layer is loamy sand about 12 inches thick. It is black in the upper part and very dark grayish brown in the lower part. The subsoil is yellowish-brown and brown sand about 28 inches thick. The underlying material is loose, brown and grayish-brown sand.

Hubbard soils have very low available moisture capacity and rapid to very rapid permeability and internal drainage. The water table is usually at a depth below 5 feet in all seasons and, in most places, at a depth below 10 feet. The root zone is deep. Unless these soils are irrigated, crop growth is severely limited by drought in most years. Because these soils are so sandy, they are easily blown. The natural fertility is low. Organic-matter content is moderately low.

Representative profile of Hubbard loamy sand, 0 to 2 percent slopes, in a cultivated field, NE1/4 NE1/4 NW1/4 sec. 32, T. 120 N., R. 21 W., Champlin Township:

Ap--0 to 9 inches, black (10YR 2/1) loamy sand; weak, fine, granular structure; very friable; slightly acid; clear, smooth boundary.

A3--9 to 12 inches, very dark grayish-brown (10YR 3/2) loamy coarse sand; very weak, very fine and fine, subangular blocky structure; very friable; 5 percent gravel; slightly acid; clear, smooth boundary.

B2--12 to 26 inches, yellowish-brown (10YR 5/4) sand; very weak, fine and medium, subangular blocky structure; very friable; few sand grains have thin clay coatings; 5 percent gravel; slightly acid; gradual, smooth boundary.

B3--26 to 40 inches, brown (10YR 5/3) sand; very weak, coarse, subangular blocky structure; very friable; about 5 percent gravel; slightly acid; gradual, smooth boundary.

C1--40 to 48 inches, brown (10YR 5/3) sand; single grain; loose; about 5 percent gravel; neutral; gradual, smooth boundary.

C2--48 to 60 inches, grayish-brown (10YR 5/2) and brown (10YR 5/3) coarse sand; single grain; loose; neutral.

The thickness of the solum ranges from 24 to 48 inches but is commonly 30 to 40 inches. The A1 horizon is black or very dark brown loamy sand or sand. It is typically 8 to 10 inches thick but ranges up to 14 inches in thickness. Texture of the B horizon ranges from loamy sand or loamy coarse sand to sand or coarse sand. The sand fraction of Hubbard soils is dominated by medium sand, but typically the coarse sand and the fine sand fraction are about equal. The coarse and very coarse sand content ranges from 5 to 35 percent throughout the profile. Gravel content is typically less than 15 percent, but in some areas there are thin layers that contain up to 25 percent gravel. Reaction of the A horizon ranges from very strongly acid to slightly acid. The B horizon is slightly acid to medium acid, and the C horizon is slightly acid to neutral.

Hubbard soils have a thicker A horizon and a darker colored Ap horizon than associated Nymore soils. Hubbard soils lack the loamy bands of the associated Rasset soils. Hubbard soils are not mottled in the lower part of the B horizon and lack the loamy, calcareous C horizon of associated Duelm soils. Hubbard soils are more sandy in the A horizon and in the upper part of the B horizon and generally have coarser sand in the C horizon than the associated Dickman soils. They contain less

gravel throughout the profile than the similar Salida soils.

Hubbard loamy sand, 0 to 2 percent slopes (HuA).--This nearly level soil occupies 2-acre to 20-acre tracts on terrace flats that generally are long and narrow. In places it consists of small, low mounds intermingled with narrow drainageways. This soil has the profile described as representative for the series.

Included in mapping were a few patches of a soil that has a surface layer of sandy loam. Also included were areas of a soil that contains a few thin bands of sandy loam, loamy sand, or gravel in the subsoil and underlying material.

This soil has severe hazards of drought and soil blowing. Shallow swales retain frost longer and restrict early field operations. In very wet years, the water table is at a depth of 4 to 5 feet in many areas in the villages of Brooklyn Park and Brooklyn Center and in Champlin Township. This soil is poorly suited to cultivated crops because of its very low available moisture capacity. Many areas are used for irrigated crops. (Capability unit IVs-2; woodland group 4; building site group 2)

Hubbard loamy sand, 2 to 6 percent slopes (HuB).--This gently sloping soil occupies 2-acre to 15-acre areas on mounds and ridges. Slopes are 75 to 150 feet long. In cultivated areas the surface layer includes areas that are very dark grayish brown. In narrow drainageways the surface layer is darker and finer textured than on the convex parts of the slope.

Included in mapping were areas of soils that contain thin bands of loamy sand and sandy loam in the subsoil and underlying material. In some places there are small areas of Dickman soils. Some included areas of soils are underlain by calcareous sand and gravel within a depth of 48 inches.

The hazards of drought and soil blowing are severe. This soil is poorly suited to cultivated crops because of its very low available moisture capacity. It is suited to irrigated crops. (Capability unit IVs-2; woodland group 4; building site group 2)

Hubbard loamy sand, 6 to 12 percent slopes (HuC).--This rolling soil occupies 2-acre to about 15-acre strips on knolls and hills. Slopes range from 75 to 150 feet long. In cultivated areas the surface layer is very dark grayish brown or dark brown.

Included in mapping were small areas of soils that have slopes of less than 6 percent and more than 12 percent. Also included were a few patches of soils that have a surface layer of sandy loam and sand and a few areas of soils that have thin bands of loamy sand and sandy loam in the subsoil and underlying material. There are also small areas of Dickman soils, mainly in the southern part of the county. A few included areas of soils are underlain by calcareous sand and gravel within a depth of 36 to 48 inches.

The severe hazard of drought limits the use of this soil for farm crops commonly grown in the county. The hazard of soil blowing is also severe. Crops grown on this soil respond well to irrigation, but irrigation systems may be difficult to move because of the steepness of slopes. Gullies form easily in this soil, and drainageways and gullies need to be seeded and maintained in grass. (Capability unit VIs-1; woodland group 4; building site group 2)

Hubbard loamy sand, 12 to 18 percent slopes (HuD).--This moderately steep soil occupies 2-acre to about 10-acre areas on hillsides, mainly near lakes and streams. Areas generally are long and narrow and 75 to 150 feet wide. In cultivated areas the surface layer is very dark grayish brown or dark brown.

Included in mapping were small areas of Rasset and Nymore soils. Also included were a few areas of soils that are underlain by calcareous sand and gravel within a depth of 48 inches. There are small depressions that contain Kennebec soils.

The severe hazard of drought and the steepness of slopes severely limit the use of this soil for farm crops commonly grown in the county. Most areas are in pasture or scrub oak. This soil is better suited to permanent vegetation than to cultivated crops. It is well suited to evergreens. (Capability unit VIIs-1; woodland group 4; building site group 2)

Hubbard loamy sand, 18 to 35 percent slopes (HuE).--This steep soil occupies 2-acre to about 10-acre areas on hillsides, mainly near large depressions and streams. Areas generally are long and narrow and 70 to about 150 feet wide. A few drainageways and gullies give the surface a wavy appearance. In cultivated areas the surface layer is very dark brown. Near the base of the slopes, the dark surface layer is up to 3 feet thick.

Included in mapping were a few areas of soils that are underlain by calcareous sand and gravel within a depth of 48 inches. Also included were a few areas of Nymore loamy sand.

Most areas of this very droughty soil are in pasture or are covered by a sparse woods of scrub oak. This soil is not suited to common cultivated crops, because of the very severe hazards of erosion and droughtiness. It is well suited to permanent vegetation than to cultivated crops. It is well suited to evergreens. (Capability unit VIIs-1; woodland group 4; building site group 2)

Isan Series

The Isan series consists of deep, poorly drained, sandy soils that formed in deep sand. These nearly level soils are on broad flats and in drainageways and depressions on outwash plains. The native vegetation was prairie grasses and sedges.

In a representative profile, the surface layer is about 16 inches thick. The upper 10 inches is black

sandy loam. The lower part is very dark gray loamy sand. The subsoil and the underlying material are grayish-brown sand mottled with gray and olive brown.

Isan soils have low available moisture capacity, but the high water table improves the amount of water available for crops. The water table is within 3 1/2 feet of the surface during wet seasons. These soils are wet in spring, and they warm up slowly unless they are drained. Although these soils are wet in spring, the water table is usually deep, and corn and soybeans suffer from lack of moisture unless rainfall distribution is good. Because of the high water table, Isan soils have slow internal drainage. Permeability is rapid. Isan soils have a deep root zone and are easy to till. These sandy soils are easily blown. Organic-matter content is high. These soils have low natural fertility. They are leached to a depth below 5 feet. Unless irrigation is supplied, crops grown on these soils respond only to small or moderate amounts of fertilizer.

Representative profile of Isan sandy loam, in a cultivated field, SW1/4 SE1/4 SW1/4 sec. 9, T. 119 N., R. 21 W.:

A1--0 to 10 inches, black (10YR 2/1) sandy loam; few, distinct, brown (7.5YR 4/4) mottles in lower part; weak, fine and medium, subangular blocky structure parting to weak, very fine, subangular blocky structure; friable; common roots; medium acid; clear, smooth boundary.

A3--10 to 16 inches, very dark gray (10YR 3/1) loamy sand; few, fine, distinct, dark grayish-brown (2.5Y 4/2) and dark yellowish-brown (10YR 4/4) mottles, mainly along the root channels; weak, medium and coarse, subangular blocky structure; very friable; few, fine, common roots; few, fine, tubular pores; medium acid; clear, wavy boundary.

B1--16 to 20 inches, grayish-brown (2.5Y 5/2) sand; common, fine and medium, distinct, olive-brown (2.5Y 4/4) and dark-gray (10YR 4/1) mottles; massive; very friable; few roots; few, fine, tubular pores; medium acid; clear, smooth boundary.

B2--20 to 30 inches, grayish-brown (2.5Y 5/2) sand; common, large, faint, light olive-brown (2.5Y 5/4) and common, medium, distinct, olive-brown (2.5Y 4/4) mottles; massive; very friable; few roots; few, very fine, tubular pores; medium acid; gradual, smooth boundary.

C1--30 to 46 inches, grayish-brown (2.5Y 5/2) sand; many, large, prominent, olive-brown (2.5Y 4/4) mottles; massive; very friable; few roots; about 2 percent gravel; medium acid; gradual, smooth boundary.

C2--46 to 60 inches, grayish-brown (2.5Y 5/2) coarse sand; many, large, prominent, yellowish-brown (10YR 5/6) mottles; single grain; loose; medium acid.

The A1 horizon is 8 to 14 inches thick and is sandy loam or loamy sand. The B horizon is generally grayish brown or olive gray but is gray in depressional areas. Texture of that part of the B horizon just below the A3 horizon is loamy sand in some places, but it is sand or light loamy sand below that depth. The C horizon ranges from grayish brown to light olive gray or gray. The texture is typically sand, and more than 15 percent of the soil by volume does not pass the No. 40 sieve. The sand is mainly medium in size. Content of gravel ranges from 0 to 10 percent, although thin layers of coarser material are included. Reaction of the A and B horizons ranges from slightly acid to strongly acid. Reaction of the C horizon ranges from strongly acid to neutral; it is neutral mainly in depressions.

Also in the Isan series are soils that have a C horizon of loam or heavy sandy loam. These soils are outside the range of the Isan series, but because of their small extent they are correlated as Isan sandy loam, loamy subsoil.

Isan soils have a grayer solum than the associated Duelm soils. Isan soils lack the loamy layers of the associated Dassel soils.

Isan sandy loam (Is).--This nearly level soil occurs typically on broad, flat plains. Areas are irregular in shape and are mainly 10 to about 150 acres in size. In places this soil lies below Duelm or Hubbard soils and is in shallow drainageways 75 to 150 feet wide. This soil has the profile described as representative for the series.

Included in mapping were a few small areas of soils that have a surface layer of black loam and very dark brown loamy sand. In a few drainageways, the dark surface layer is up to 2 feet thick. In a few places the upper part of the underlying material to a depth of 18 to 24 inches is sandy loam. Also included were small spots of Dassel soils that have loamy layers in the underlying material; small, scattered, depressions that are subject to ponding; small areas of Duelm soils; and a few spots of soils that have reddish-brown sandy loam at a depth of 30 to 40 inches.

Many areas of this soil are used for growing potatoes. Soybeans are also an important crop. With proper management, which includes drainage, fertilization, and irrigation, this soil is well suited to corn and soybeans. (Capability unit IIIw-2; woodland group 6; building site group 9)

Isan sandy loam, depressional (It).--This soil is in shallow depressions, generally 1 to 3 feet below areas of Isan sandy loam. Areas range from 2 acres to about 60 acres in size and are irregular in shape. In places this soil lies in narrow drainageways. This soil has a profile similar to that described as representative for the series, except that the black surface layer is 12 to 18 inches thick.

Included in mapping were small areas of soils that have a surface layer of loam. In places a thin layer of peat up to 18 inches thick lies on the surface. Small areas of Biscay clay loam, depressional, were also included. In places there are areas of

soils that have layers of loam and clay in the underlying material. In areas where this Isan soil is closely associated with Isan sandy loam, loamy subsoil, there is gray loam at a depth of 30 inches to about 50 inches.

Most of this soil is in marsh or meadow vegetation. Areas used for cropland have a hazard of ponding, in addition to a high water table. They also have a slight hazard of soil blowing. The hazard of drought depends upon control of the water table. (Capability unit IVw-1; woodland group 7; building site group 12)

Isan sandy loam, loamy subsoil (Iv).--This nearly level soil lies on broad flats, typically next to areas of Duelm loamy sand, loamy subsoil variant, or Hubbard soils that are at slightly higher elevations. Areas are irregular in shape and range from 5 acres to about 80 acres in size. This soil has a profile similar to that described as representative for the series, except that it is underlain by gray loam at a depth of 18 to 40 inches.

Included in mapping were small areas of Duelm loamy sand, loamy subsoil variant, that are on slight rises. Small areas of soils that have a subsoil of sandy loam were included. Small areas, less than 2 acres in size, of the loamy Canisteo soils were also included. In places the loamy material is at a depth of more than 40 inches.

Most areas are in timber or brush. A few areas are in cropland, mainly corn and soybeans. The major management needs are drainage and maintenance of fertility. Shallow ditches usually drain this soil adequately. This soil is well suited to truck crops. (Capability unit IIIw-2; woodland group 5; building site group 10)

Kasota Series

The Kasota series consists of well-drained soils that formed in 20 to 36 inches of silty clay over sand. The native vegetation was tall prairie grass encroached upon by mixed hardwoods. These nearly level to gently sloping soils occupy outwash plains of the Minnesota River.

In a representative profile, the surface layer is black silty clay loam about 10 inches thick. The subsoil is about 22 inches thick. The upper 8 inches is brown light silty clay. The major part is olive-brown silty clay, and the lower 4 inches is dark yellowish-brown sand. The underlying material is brown, loose, calcareous sand that contains small amounts of gravel.

Kasota soils have moderate available moisture capacity and medium to slow internal drainage. The subsoil has moderately slow permeability, but the permeability of the loose sand underlying material is very rapid. The water table is at a depth below 5 feet, and in most places it is below 10 feet in all seasons. Root growth is slowed by the clayey subsoil. These soils are fairly resistant to erosion because they are fairly high in clay and organic-matter content. Soil loss is serious on these soils, however, because of the shallow depth to the sand below. Fertility is high.

Representative profile of Kasota silty clay loam, 1 to 5 percent slopes, in a cultivated field, SW1/4 SE1/4 SE1/4 sec. 31, T. 116 N., R. 21 W.:

Ap--0 to 10 inches, black (10YR 2/1) silty clay loam; moderate, fine and medium, subangular blocky structure; friable; common roots; slightly acid; abrupt, smooth boundary.

B1t--10 to 18 inches, brown (10YR 4/3) light silty clay; moderate, fine, angular blocky structure parting to strong, very fine, angular blocky structure; friable; few roots; many, fine, tubular pores; many, thick, dark grayish-brown (10YR 4/2) clay films on faces of peds; medium acid; clear, smooth boundary.

B21t--18 to 23 inches, olive-brown (2.5Y 4/4) light silty clay; strong, fine and medium, angular blocky structure; friable; few fine roots; many, fine, tubular pores; many, thick, dark grayish-brown (2.5Y 4/2) clay films on faces of peds; medium acid; clear, smooth boundary.

B22t--23 to 28 inches, olive-brown (2.5Y 4/4) silty clay; strong, medium and coarse, prismatic structure parting to strong, very fine, subangular blocky structure; firm; few fine roots; common, fine, tubular pores; many, thick, dark grayish-brown (2.5Y 4/2) clay films on faces of peds; few very dark gray (10YR 3/1) clay fillings in root channels; medium acid; clear, smooth boundary.

IIB3--28 to 32 inches, dark yellowish-brown (10YR 4/4) sand; weak, coarse, subangular blocky structure; very friable; common thick clay bridges between sand grains; about 2 percent gravel, mainly shale; slightly acid; clear, smooth boundary.

IIC1--32 to 36 inches, brown (10YR 5/3) coarse sand; single grain; loose; about 15 percent gravel; weakly calcareous; mildly alkaline; clear, smooth boundary.

IIC2--36 to 60 inches, brown (10YR 5/3) sand; 15 percent very coarse sand and fine gravel; single grain; loose; calcareous.

The A horizon is commonly silty clay loam, but in some places it is loam, clay loam, or silty clay. Thickness ranges from 8 to 11 inches. Texture of the B2 horizon is silty clay or clay. The increase in clay in the B horizon is believed to be due partly to differences in the parent material. The C horizon consists of deep sand or stratified sand and gravel. Depth to the IIB horizon ranges from 20 to 40 inches but is commonly 24 to 36 inches. The solum ranges from slightly acid to medium acid in reaction. The upper part of the C horizon is generally leached of carbonates. In areas where the underlying material contains an appreciable amount of gravel, free carbonates occur within a depth of 50 inches.

Kasota soils are finer textured than associated Dakota soils. They are underlain by coarser material than similar Shorewood soils.

Kasota silty clay loam, 1 to 5 percent slopes (KaB).--This nearly level to gently sloping soil occurs on small, irregular knolls and in broad swales. Areas are mostly less than 10 acres in size.

Included in mapping were areas in drainageways that have a surface layer of black silt loam 18 to 24 inches thick. A few small areas of Dakota and Dickman soils and a few, small, wet, clayey depressions were also included.

This soil has a slight hazard of erosion and is slightly droughty. If properly managed, it is well suited to all the crops commonly grown in the area. If management is good, corn and soybeans can be grown every year. (Capability unit IIe-4; woodland group 1; building site group 1)

Kennebec Series

The Kennebec series consists of deep, moderately well drained, silty soils that formed in colluvium. These nearly level soils occupy small depressions and drainageways on rolling, sandy outwash plains and stream terraces. The native vegetation was tall prairie grass encroached upon by mixed hardwoods.

In a representative profile, the surface layer is very dark brown heavy silt loam about 35 inches thick. The underlying material is very dark brown silt loam.

Kennebec soils have high available moisture capacity, moderate to moderately rapid permeability, and medium internal drainage. The water table is usually at a depth below 5 feet in all seasons. The root zone is deep. These soils are high in organic-matter content and very high in fertility.

Representative profile of Kennebec silt loam, in a cultivated field, NE1/4 NW1/4 sec. 35, T. 116 N., R. 22 W.:

Ap--0 to 10 inches, very dark brown (10YR 2/2) heavy silt loam; weak, very fine, subangular blocky structure; friable; many roots; neutral; clear, gradual boundary.

A12--10 to 17 inches, very dark brown (10YR 2/2) silt loam; weak, very fine, subangular blocky structure; very friable; many roots; few, fine, tubular pores; neutral; clear, gradual boundary.

A13--17 to 32 inches, very dark brown (10YR 2/2) silty clay loam; common, fine, distinct, dark yellowish-brown (10YR 3/4) mottles; weak, very fine, subangular blocky structure; very friable; few roots; common, fine, tubular pores; slightly acid; clear, gradual boundary.

A14--32 to 35 inches, very dark brown (10YR 2/2) silt loam; common, fine, distinct, dark yellowish-brown (10YR 3/4) mottles; weak, very fine, subangular blocky structure; very friable; few roots; common, fine, tubular pores; slightly acid; clear, abrupt boundary.

C1--35 to 37 inches, very dark grayish-brown (10YR 3/2) fine sandy loam; common, fine, distinct, dark yellowish-brown (10YR 3/4) mottles; weak, very fine, subangular blocky structure; very friable; few roots; few, fine, tubular pores; neutral; clear, abrupt boundary.

C2--37 to 60 inches, very dark brown (10YR 2/2) silt loam; common, fine, distinct, dark yellowish-brown (10YR 3/4) mottles or iron concentrations; weak, very fine, subangular blocky structure; friable; few roots; common, fine, tubular pores; neutral.

Thickness of the dark-colored sediments ranges from 40 to 100 inches but is commonly 48 to 72 inches. These sediments are underlain by sand or gravelly sand. Texture of the A horizon and the C1 and C2 horizons is commonly silt loam, but in places it is silty clay loam. In some places, mainly in the northern part of the county, texture is loam. Thin seams, 2 to 4 inches thick, of fine sandy loam or loamy fine sand are common within the dark-colored layers. The more sandy layers are very dark grayish brown. Reaction of the solum ranges from slightly acid to neutral.

Kennebec soils are not so well drained and are finer textured than associated Becker soils.

Kennebec silt loam (Ke).--This nearly level soil occupies small depressions and drainageways below areas of sloping, sandy soils. Near the edges of the depressions or drainageways, the silt loam is covered in many places with a thin mantle of sandier material washed in from the slopes above. Areas of this soil are irregular in shape and are mostly 2 to 5 acres in size.

Included in mapping were areas of a soil that is more loamy than this Kennebec soil. In a few places the soil is underlain by sand at a depth of 36 inches. In a few places the water table is within a depth of 5 feet during wet seasons.

This soil is well suited to corn and soybeans. Most areas are so small, however, that they are farmed with the nearby sandy soils. This soil is not suited to alfalfa, because the soil tends to pond early in spring before the frost season ends. (Capability unit I-1; woodland group 5; building site group 9)

Kilkenny Series

The Kilkenny series consists of deep, well-drained soils that formed in calcareous shaly loam or clay loam till. The shaly till is underlain by friable, calcareous, loamy till. These soils have convex slopes and are on smooth, irregular hills. The hills range in size from 8 to 1,500 acres and rise from 30 to 80 feet above the surrounding swales and sloughs. Slopes are both simple and complex and range from 2 to 35 percent. These soils are at the highest elevations in the county, mainly in the west-central part. There are few stones and boulders near the surface. The native vegetation was mixed hardwoods and a grass understory.

In a representative profile, the surface layer is black loam about 9 inches thick. The subsoil is

clay loam about 33 inches thick. The upper part is olive brown, and the lower part is light olive brown. The underlying material is light olive-brown, calcareous loam.

Kilkenny soils have high available moisture capacity, moderately slow permeability, and medium internal drainage. The water table is at a depth below 5 feet in all seasons. Kilkenny soils have a deep root zone, but roots grow somewhat slowly in the dense subsoil. These soils are highly fertile and are high in organic-matter content. Crops grown on them respond well to additions of fertilizer. Lime is needed in places.

Representative profile of Kilkenny loam, 2 to 6 percent slopes, in a cultivated field, NW1/4 NE1/4 NW1/4 sec. 20, T. 118 N., R. 23 W., Medina village:

Ap--0 to 9 inches, black (10YR 2/1) loam, dark gray (10YR 4/1) when dry; weak, very fine, granular structure; friable; neutral; clear, smooth boundary.

B21t--9 to 14 inches, olive-brown (2.5Y 4/3) clay loam; moderate, very fine, subangular blocky structure; firm; common roots; common, fine, tubular pores; few, thin, very dark grayish-brown (2.5Y 3/2) clay films on faces of peds; common, thick, light-gray (10YR 6/1), porous coatings on faces of peds; about 5 percent coarse fragments, mainly shale; slightly acid; clear, smooth boundary.

B22t--14 to 21 inches, olive-brown (2.5Y 4/3 to 4/4) clay loam; moderate, medium and coarse, prismatic structure parting to strong, medium and coarse, angular blocky structure; firm; few roots; common, fine, tubular pores; many, thick, very dark grayish-brown (2.5Y 3/2) clay films on faces of peds; about 5 percent coarse fragments, mostly shale; slightly acid; clear, smooth boundary.

B23t--21 to 33 inches, olive-brown (2.5Y 4/4) clay loam; moderate, medium and coarse, prismatic structure parting to strong, medium and coarse, subangular blocky structure; firm; few roots; common, very fine and fine, tubular pores; many, thick, very dark grayish-brown (2.5Y 3/2) clay films on faces of peds; about 5 percent coarse fragments, mainly shale; medium acid; gradual, smooth boundary.

B3t--33 to 42 inches, light olive-brown (2.5Y 5/4) clay loam; few, fine, faint, strong-brown (7.5YR 5/8) mottles; weak, coarse, prismatic structure parting to moderate, coarse, subangular blocky; firm to friable; few roots; common, fine and very fine, tubular pores; common, thick, very dark brown (10YR 2/2) clay films on faces of peds; many black (10YR 2/1) clay films in root channels; about 5 percent coarse fragments, mainly igneous, with some shale; slightly acid; clear, smooth boundary.

C--42 to 60 inches, light olive-brown (2.5Y 5/4) heavy loam; few, fine, distinct, grayish-brown (2.5Y 5/2) and yellowish-brown (10YR 5/8) mottles; weak, coarse, subangular blocky structure; friable; few, fine, tubular pores; few light-gray lime segregations; about 5 percent coarse fragments, mainly shale, with some igneous and limestone fragments; mildly alkaline; calcareous.

The solum ranges from 28 to 54 inches in thickness but is commonly 32 to 42 inches. The Ap horizon is 5 to 10 inches in thickness, black to very dark brown in color, and typically loam or clay loam in texture. In some profiles it is silty clay loam. The B2 horizon has a distinct increase in clay content as compared to the A horizon. Texture ranges from clay loam to clay. The finest layer is commonly the upper part of the B2 horizon. The B and C horizons commonly contain 3 to 8 percent coarse fragments. In some profiles reddish, tubular iron segregations and mottles occur in the lower part of the B horizon and in the C horizon. Reaction of the A horizon ranges from slightly acid to neutral. Reaction of the B horizon ranges from strongly acid to neutral.

Kilkenny soils are higher in content of sand and coarse fragments and lower in content of clay than the similar Shorewood soils. They have a darker colored Ap horizon than the associated Erin soils. They are higher in content of clay than the similar Lester soils.

Kilkenny loam, 2 to 6 percent slopes (KkB).--This gently undulating soil occupies 2-acre to 40-acre areas on convex hillsides and knolls. Slopes are commonly 75 to 150 feet long. This soil has the profile described as representative for the series.

Included in mapping were scattered patches of Shorewood soils that are higher in content of clay and lower in content of sand than this Kilkenny soil. Areas of Dundas and Cordova soils occur in shallow drainageways and depressions.

The main management needs are maintenance of tilth and control of erosion. This soil is suited to all the farm crops commonly grown in the county. Row crops can be grown nearly every year if the soil is well managed. (Capability unit IIe-2; woodland group 1; building site group 7)

Kilkenny loam, 6 to 12 percent slopes (KkC).--This rolling soil occupies 2-acre to 25-acre areas on convex hillsides and knolls. Slopes are commonly between 75 and 150 feet long. This soil has a profile similar to that described as representative for the series, except that a few scattered patches of the brown clay loam subsoil are exposed.

Included in mapping were small patches of Shorewood soils that are higher in clay content and lower in sand content than this Kilkenny soil. Areas of Cordova and Dundas soils occur in small, shallow drainageways and depressions.

Most areas of this soil are in permanent pasture or woodland. This soil is good cropland and is suited to all major crops in the county. The hazard of erosion is moderate to severe. Good management is required to reduce erosion and runoff. (Capability unit IIIe-2; woodland group 1; building site group 7)

Kilkenny loam, 12 to 18 percent slopes (KkD).--This hilly soil occupies 2-acre to 15-acre areas on hillsides and knolls. Slopes are typically 60 to 125 feet long. This soil has a profile similar to that described as representative for the series, except that the surface layer and subsoil are commonly thinner.

Included in mapping were a few scattered patches of soils that have a surface layer of very dark grayish-brown clay loam.

Most areas of this soil are in permanent pasture or woodland. It has a severe hazard of erosion if cultivated. Intertilled crops, such as corn and soybeans, should be grown only occasionally if common management practices are used. This soil is better suited to hay and pasture crops and to woodland, recreation, or wildlife uses. (Capability unit IVe-2; woodland group 1; building site group 7)

Kilkenny loam, 18 to 24 percent slopes (KkE).--This steep soil occupies 2-acre to 10-acre areas on hillsides. Slopes are commonly 60 to 100 feet long and are broken by shallow downslope drainageways. This soil has a profile similar to that described as representative for the series, except that the surface layer and subsoil are commonly thinner.

Included in mapping were a few scattered patches of Shorewood soils that are higher in clay content and lower in sand content than this Kilkenny soil. A few, small, 2-acre to 3-acre areas of gently sloping soils on crests and sideslope benches were also included. There are also small areas where slopes are less than 18 percent and greater than 24 percent.

Most areas of this soil are in woodland or permanent pasture. Steepness of slopes and a severe hazard of erosion severely limit the use of this soil for common farm crops. It is more productive if managed for permanent vegetation, such as pasture and woodland, than for most other uses. (Capability unit VIe-1; woodland group 1; building site group 7)

Kilkenny clay loam, 6 to 12 percent slopes, eroded (K1C2).--This rolling soil occupies 2-acre to 25-acre areas on side slopes and knolls. Slopes are commonly 75 and 150 feet long. Because this soil is eroded, the surface layer is very dark grayish-brown clay loam that is a mixture of the original surface layer and the subsoil. This soil has less organic matter and is less friable than Kilkenny loams.

Included in mapping were small patches of Shorewood soils that are higher in clay content and lower in sand content than this Kilkenny soil. Also included were areas of Dundas and Cordova soils in shallow drainageways and depressions.

Most areas of this soil are in permanent pasture or woodland. This soil is good cropland and is suited to all major crops in the county. The hazard of erosion is moderate to severe. Good management is required to reduce erosion and runoff. (Capability unit IIIe-2; woodland group 1; building site group 7)

Kilkenny clay loam, 12 to 18 percent slopes, eroded (K1D2).--This hilly soil occupies 2-acre to 15-acre areas on narrow hillsides and knolls. Slopes are commonly 60 to 125 feet long. Because this soil is eroded, the surface layer is very dark brown clay loam that is a mixture of the original surface layer and the subsoil. The surface layer and subsoil are commonly thinner than those of the profile described as representative for this series. This soil is lower in organic matter and is less friable than Kilkenny loams.

Included in mapping were small patches of Shorewood soils that are higher in clay content and lower in sand content than this Kilkenny soil. Also included were areas of Dundas and Cordova soils in shallow drainageways and depressions.

The hazard of erosion severely limits the use of this soil for cropland. Intertilled crops should be grown only occasionally and only in areas where management practices are used to control erosion. This soil is well suited to hay and pasture crops that protect the soil. (Capability unit IVe-2; woodland group 1; building site group 7)

Kingsley Series

The Kingsley series consists of deep, well-drained, moderately coarse textured soils that formed in deep, reddish-brown sandy loam glacial till. These soils occupy knolls and hills of a glacial moraine. Slopes range from 2 to 35 percent. Stones and boulders are common throughout the soil. The native vegetation was mixed hardwoods.

In a representative profile, the surface layer is black loam about 3 inches thick. The subsurface layer is very dark grayish-brown and dark-brown sandy loam about 11 inches thick. The subsoil is reddish-brown heavy sandy loam about 20 inches thick. This layer is friable when moist and brittle when dry. The underlying material is reddish-brown sandy loam. Gravel and cobblestones are common.

Kingsley soils have moderate available moisture capacity, moderate permeability, and medium internal drainage. The water table is at a depth below 5 feet in all seasons and in most places is at a depth below 10 feet. These soils are fairly easily eroded by water because the surface layer is more permeable than the subsoil. The root zone is deep. Fertility is medium, and organic-matter content is low.

Representative profile of a Kingsley loam in an area of Kingsley complex, 2 to 6 percent slopes, in a wooded tract, SE1/4 NE1/4 SW1/4 sec. 16, T. 116 N., R. 21 W.:

0--2 inches to 0, black (10YR 2/1) leaf mulch; many roots; neutral; abrupt, smooth boundary.

A1--0 to 3 inches, black (10YR 2/1) loam, high in content of organic matter; weak, very fine, granular structure; very friable; many roots; neutral; clear, irregular boundary.

A21--3 to 7 inches, very dark grayish-brown (10YR 3/2) coarse sandy loam; weak, very fine, subangular blocky structure; very friable; many roots; about 15 percent coarse fragments, mostly basalt and granite; slightly acid; clear, wavy boundary.

A22--7 to 14 inches, dark-brown (7.5YR 4/3) sandy loam; weak, medium, subangular blocky structure; very friable; many roots; few, fine, tubular pores; about 10 percent coarse fragments,

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mostly basalt and granite; slightly acid; clear, wavy boundary.

B21t--14 to 25 inches, reddish-brown (5YR 4/4) heavy coarse sandy loam; moderate, medium and coarse, subangular blocky structure; friable; many roots; common, thin, dark reddish-brown (5YR 3/2) clay films on faces of peds; many, thin, dark reddish-brown (5YR 3/4), porous coatings on faces of peds; about 10 percent coarse fragments, mostly basalt and granite; strongly acid; clear, smooth boundary.

B22t--25 to 34 inches, reddish-brown (5YR 4/4) heavy sandy loam; moderate, medium, platy structure parting to moderate, very fine, subangular blocky structure; very brittle when dry, friable; many roots and fine tubular pores; common, thin, dark reddish-brown (5YR 3/2) clay films on faces of peds; few, thin, dark reddish-brown (5YR 3/4), porous coatings on faces of peds; about 15 percent coarse fragments, mostly basalt and granite; medium acid; gradual, smooth boundary.

C--34 to 60 inches, reddish-brown (5YR 4/4) sandy loam; moderate, fine and medium, platy structure; very friable; few roots; about 10 percent coarse fragments, mostly basalt and granite; medium acid.

The A1 horizon is 2 to 4 inches in thickness and is black or very dark brown in color. Texture ranges from loamy coarse sand, sandy loam, or coarse sandy loam to loam. The A2 horizon is very dark grayish brown to brown and is 4 to 12 inches thick. The Ap horizon is very dark grayish brown or dark grayish brown and is 6 to 10 inches thick. Texture ranges from coarse sandy loam to loamy coarse sand. The B2 horizon is commonly dark reddish brown but in some places is brown or dark brown. There are thin lenses of brown loamy coarse sand in some places. The B2 horizon shows a distinct increase in clay content as compared with the A horizon. Clay content ranges from 10 to 18 percent, and silt content ranges from 15 to 30 percent. Consistence of the B2 horizon is friable when moist and hard and brittle when dry; however, the B2 horizon does not qualify as a fragipan. Texture of the C horizon is sandy loam to loamy coarse sand. In some places there are thin, 1/4-inch to 2-inch lenses of light olive-brown sandy loam or loam in the C horizon.

The A horizon contains 5 to 10 percent gravel, mainly granite and basalt. The B and C horizons contain 5 to 20 percent gravel, but in most places they contain 10 to 15 percent cobblestones and gravel.

The A horizon is slightly acid to neutral, and the B horizon is strongly acid to medium acid. The C horizon is medium acid to slightly acid. Depth to free carbonates is typically more than 60 inches, but in some profiles free carbonates occur between depths of 40 and 60 inches.

Kingsley soils are redder in color and contain less clay and silt and more sand and gravel than the similar Hayden and Heyder soils. They lack the thick sandy mantle and cobbly layer of the associated Langola soils.

Kingsley complex, 2 to 6 percent slopes (KnB).--These gently sloping soils occupy 5-acre to 20-acre, irregular areas on knolls and hilltops. Slopes are mainly 75 to 150 feet long and generally extend in several directions. In cultivated areas the surface layer is very dark grayish brown. About 50 to 75 percent of this complex has a profile similar to that described as representative for the Kingsley series, about 10 to 20 percent has a yellowish-brown sandy loam subsoil underlain by sand and gravel at a depth of less than 2 feet, and about 10 to 20 percent is underlain by sand and gravel at a depth of 24 to 40 inches.

Included in mapping were small spots of a deep, silty soil and a few spots of a Nymore soil. Small depressions and narrow drainageways contain a very dark brown, permeable, silty soil that is underlain in places by reddish-brown sandy loam at a depth of 3 to 5 feet. A few depressions are wet. These minor inclusions comprise about 5 to 10 percent of the complex.

Much of this complex is in woodland or pasture. It is suited to all crops grown in the county. Because of variations in soil depth and texture, crop growth is spotty. The hazard of erosion is moderate. If these soils are well managed, crops can be grown nearly every year. Near the city of Hopkins, they are commonly used for growing raspberries. (Capability unit IIe-3; woodland group 2; building site group 4)

Kingsley complex, 6 to 12 percent slopes (KnC).--These rolling soils occupy 2-acre to 20-acre, irregular areas on knolls and hillsides. Slopes are typically 75 to 150 feet long and extend in several directions. In cultivated areas the surface layer is very dark grayish brown. In most cultivated areas, patches of the dark reddish-brown subsoil have been exposed near the crest of slopes. These areas are low in organic-matter content and natural fertility and are in poorer tilth. About 45 to 75 percent of this complex has a profile similar to that described as representative for the Kingsley series, about 10 to 20 percent includes sandy, more friable soils that are underlain by sand and gravel at a depth of less than 2 feet, and about 10 to 25 percent is underlain by sand and gravel at a depth of 24 to 40 inches.

Included in mapping were a few spots of a Nymore soil. A few patches of a deep silty soil were included on the convex slopes. Depressions and swales contain a deep, very dark brown, silty soil. A few depressions are wet. In many places there is 2 to 3 feet of loamy sand near the base of the slopes and in narrow drainageways. These minor inclusions comprise about 5 to 10 percent of the complex.

Many areas of these soils are in woodland or pasture. They are suited to all crops commonly grown in the county. Because of their rapid runoff, these soils are easily eroded. The hazard of erosion is severe. Near the city of Hopkins, these soils are commonly used for growing raspberries. (Capability unit IVe-3; woodland group 2; building site group 4)

Kingsley complex, 12 to 18 percent slopes (KnD).--These hilly soils occupy 5-acre to 20-acre, irregular areas on knolls and on sides of hills and ridges. In most places slopes are 75 to 150 feet long. In the few cultivated areas, the surface layer is very dark grayish brown. Near slope crests many patches of the dark reddish-brown subsoil have been exposed by erosion. These eroded patches contain many pebbles and cobblestones on the surface. The eroded areas are low in organic-matter content and fertility and are more difficult to till. About 45 to 75 percent of this complex has a profile similar to that described as representative for the Kingsley series, about 10 to 30 percent is underlain by sand and gravel at a depth of 24 to 40 inches, and about 10 to 15 percent consists of sandy soils that have a subsoil of friable, yellowish-brown sandy loam or loamy sand underlain by sand and gravel at a depth of 12 to 24 inches.

Included in mapping were many places in drainageways that contain 2 to 3 feet of sandy material washed in from the surrounding slopes. A few shallow depressions were included that contain mostly deep, permeable, silty soils. A few of these depressions are wet. These minor inclusions comprise about 5 to 10 percent of the complex.

Most of these soils are in woodland and pasture. The main management needs are controlling erosion and maintaining fertility. The erosion hazard is severe. In most areas slopes are too irregular to contour farm or terrace. It is difficult to operate farm machinery on these moderately steep slopes. In most places this complex is well suited to uses that keep the soil covered with plants. In areas where erosion can be controlled, row crops can be grown occasionally. (Capability unit VIe-1; woodland group 2; building site group 4)

Kingsley complex, 18 to 24 percent slopes (KnE).--These steep soils occupy hills and ridges and, in most places, lie near large depressions. Areas are irregular and commonly are between 5 and 20 acres in size. Slopes are mostly 75 to 200 feet long and extend in several directions. About 45 to 75 percent of this complex has a profile similar to that described as representative for the Kingsley series, about 10 to 30 percent is underlain by sand and gravel at a depth of about 24 to 40 inches, and about 10 to 15 percent consists of sandy soils that have a subsoil of dark yellowish-brown sandy loam less than 2 feet thick over sand and gravel.

Included in mapping were small spots of Nymore soils. In some places, near the base of the slopes, there is 2 to 3 feet of loamy sand that has been washed in from the slopes above.

These soils are too steep for operation of most modern farm equipment and are too easily eroded to grow cultivated crops. They are well suited to woodland or pasture or to recreational and wildlife uses. (Capability unit VIIe-1; woodland group 2; building site group 4)

Kingsley complex, 24 to 35 percent slopes (KnF).--These very steep soils occupy high hills and ridges. Slopes are mainly 75 to 200 feet long and extend mainly in one direction. About 45 to 75 percent of this complex has a profile similar to that described as representative for the Kingsley series, about 10 to 30 percent is underlain by sand and gravel at a depth of about 24 to 40 inches, and about 10 to 15 percent consists of sandy soils that have a dark yellowish-brown sandy loam subsoil that is less than 2 feet thick over sand and gravel.

In places, small spots of Nymore soils were included. In some places near the base of the slopes, there is 2 to 3 feet of loamy sand that has been washed in from the slopes above.

Most areas of these soils are in woodland. The very steep slopes are a severe limitation to farm and urban uses. These soils are well suited to enhancement of the natural beauty of the area, wildlife habitat, and recreational uses. (Capability unit VIIe-1; woodland group 2; building site group 4)

Lake Beaches

These miscellaneous land types are Lake beaches, sandy, and Lake beaches, loamy.

Lake beaches, sandy (Lc).--This land type consists of poorly drained, gravelly and sandy materials around the shoreline of lakes and sloughs. The soil material is sandy and was deposited through wave action. Areas are mostly 20 to 80 feet wide. The native vegetation consisted of reeds, sedges, and willows.

The soil material is variable, but it is generally dark colored in the surface layer and is light sandy loam, coarse loamy sand, or coarse sand to a depth of 30 to 60 inches. Most areas are underlain by calcareous loamy till. Drainage ranges from poor to very poor. In most seasons the water table is within a 4-foot depth. In years of high rainfall, some areas are submerged. Reaction ranges from slightly alkaline to neutral.

This land type is too gravelly and sandy and too low in fertility to be productive as farmland. (Capability unit VIw-1; woodland group 6; building site group 9)

Lake beaches, loamy (Ld).--This land type consists of deep, poorly drained or very poorly drained, loamy or silty soil material deposited along the shoreline of lakes and sloughs. The soil material is loamy sediments and was deposited through wave action on the shores of lakes and former lakes. The native vegetation was reeds, sedges, and willows.

The soil material is variable, but the surface layer generally is black loam or silt loam 20 to 48 inches thick. The underlying material is calcareous gray loam. A few patches that have a surface layer of sandy loam were included in mapping.

Most areas of this land type are undrained. The water table is usually within a 3-foot depth. Because the areas are around lakes and sloughs, adequate outlets are generally lacking. A few areas are drained and farmed with the associated bog

soils. This land type is good for crops if it is drained. The surface layer is high in organic-matter content. The available moisture capacity and natural fertility are high. (Capability unit IIIw-1; woodland group 6; building site group 12)

Langola Series

The Langola series consists of deep, moderately well drained and well drained soils that formed in a sandy mantle 18 to 40 inches thick and are underlain by dark reddish-brown sandy loam till. These soils are on the broad outwash plain in the northeastern part of the county. Slopes are mainly simple and range from 0 to 12 percent. The native vegetation was mixed hardwoods and tall prairie grass. Stones and boulders are scattered on and in the soil.

In a representative profile, the surface layer is very dark brown loamy sand about 8 inches thick. The subsoil is about 32 inches thick. The upper part is a mixture of very dark brown and dark yellowish-brown loamy sand. The lower part is dark yellowish-brown to brown and reddish-brown, cobbly and gravelly sandy loam. The underlying material is reddish-brown sandy loam.

Langola soils have low to moderate available moisture capacity and medium internal drainage. The sandy layers are rapidly permeable, but the underlying material is only moderately permeable. In some wet seasons the water table is at a depth of 3 to 5 feet but is usually at a depth below 5 feet in all seasons. Langola soils have a shallow to moderately deep root zone because root growth is limited to the sandy material above the cobbly layer. They have moderate organic-matter content and low natural fertility.

Representative profile of Langola loamy sand, 1 to 2 percent slopes, in a cultivated field, NE1/4 NE1/4 NW1/4 sec. 3, T. 120 N., R. 21 W.:

Ap--0 to 8 inches, very dark brown (10YR 2/2) loamy sand; weak, very fine and fine, subangular blocky structure; very friable; many roots; medium acid; clear, wavy boundary.

B1--8 to 15 inches, very dark brown (10YR 2/2), dark grayish-brown (10YR 4/2), and brown (10YR 4/3) loamy sand, very dark grayish brown (10YR 3/2) when rubbed; weak, medium and coarse, subangular blocky structure; very friable; few roots; few thin clay bridges between sand grains; medium acid; clear, smooth boundary.

B21--15 to 18 inches, dark yellowish-brown (10YR 4/4) loamy sand; weak, medium and coarse, subangular blocky structure; very friable; few roots; few, fine, tubular pores; thin, patchy, brown (10YR 4/3) and dark-brown (10YR 3/3) clay flows; slightly acid; clear, smooth boundary.

IIB22--18 to 24 inches, dark yellowish-brown (10YR 4/4) gravelly sandy loam; weak, medium, subangular blocky structure; very friable; few roots; few, very fine, tubular pores; common, thick, patchy, dark-brown (10YR 3/3) clay films on faces of peds; about 30 percent coarse fragments, mainly igneous; slightly acid; clear, wavy boundary.

IIB23--24 to 29 inches, brown (7.5YR 4/4) cobbly loamy coarse sand; weak, medium and coarse, subangular blocky structure; very friable; few roots; few, fine, tubular pores; few thin clay films on faces of peds; about 60 percent coarse fragments, mostly igneous; few black concretions; slightly acid; clear, wavy boundary.

IIB24--29 to 40 inches, reddish-brown (5YR 4/4) sandy loam; weak, coarse, subangular blocky structure; friable; few, fine, tubular pores; about 15 percent coarse fragments, mostly igneous; slightly acid; clear, smooth boundary.

IIC--40 to 60 inches, reddish-brown (5YR 4/4) sandy loam; weak, coarse, subangular blocky structure grading to platy; friable; slightly acid.

The solum ranges from 20 to 40 inches in thickness. The A horizon is 7 to 11 inches in thickness, very dark brown or black in color, and loamy fine sand or loamy sand in texture. Texture of the B1 and B21 horizons is sand, loamy sand, or loamy fine sand. The IIB22 and IIB23 horizons are commonly dark yellowish brown and brown, but they are very dark grayish brown in some places. They consist of cobbly gravelly loamy sand or sandy loam. About 30 to 70 percent of the soil by volume consists of cobblestones, and the rest of the coarse material is gravel and sand in varying sizes. The gravelly cobbly layer ranges in thickness from 4 to 24 inches but is commonly 8 to 24 inches thick. The IIB24 horizon is reddish-brown or dark-brown sandy loam or loamy sand that contains 5 to 20 percent coarse fragments. The C horizon is reddish brown, dark brown, or brown and ranges from coarse sandy loam to loamy coarse sand in texture. The C horizon contains 5 to 20 percent coarse fragments. In some places there are gray and strong-brown mottles in the lower part of the IIB horizon and in the C horizon. Depth to the top of the IIB horizon ranges from 18 to 40 inches. The solum is slightly acid to medium acid throughout.

As mapped in Hennepin County, these soils have more silt and clay in the solum and some have grayer colors than the defined range of the Langola series. These differences do not appreciably affect their usefulness or behavior.

Langola soils have a thicker cobbly layer than the similar Duelm soil, loamy subsoil variant, and they are underlain by reddish-brown sandy loam rather than calcareous, grayish-brown loam. Langola soils have a thicker, darker colored sandy mantle than the associated Kingsley soils. They have a distinct cobbly layer in the lower part of the subsoil that is lacking in Kingsley soils.

Langola loamy sand, 1 to 2 percent slopes (LgA).--This nearly level soil occurs on flats near the Mississippi River. Areas tend to be longer than they are wide and range in size from 5 acres to about 80

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

Included in mapping were small areas of fine sandy loam and a few small spots of Kingsley soils. Also included were areas of soils in which the brown underlying material is loam or silt loam and, in a few places, silty clay loam. There are also small areas of Hubbard soils.

Most areas of this soil are in grass or woodland or have been developed for residences. A few areas are in cropland. The major crops are corn and soybeans, but small grain and hay occupy smaller acreages. This soil is droughty and is easily blown. (Capability unit IIIs-2; woodland group 2; building site group 3)

Langola loamy sand, 2 to 12 percent slopes (LgB).--This gently sloping to sloping soil occurs above drainageways. Other Langola soils occur on flats above this soil. Slopes extend mainly in one direction and are less than 150 feet long. This soil has a profile similar to that described as representative for the series, except that it includes areas that have a surface layer of dark grayish brown.

Included in mapping were areas of soils that have a sandy loam surface layer and are yellowish-brown sandy loam in the upper part of the subsoil. In a few places the brown underlying material is loam or silt loam and, in a few small spots, silty clay loam. Small areas of Hubbard soils and a few spots of Kingsley soils were also included.

Most areas of this soil are in grass or woodland or have been developed for homesites. A small acreage is in cropland. Corn and soybeans are the most important crops, but a small acreage is used for hay and small grain. The hazards of drought and soil blowing severely limit the use of this soil. On the steeper slopes, this soil is better suited to uses that keep it continuously covered with plants. (Capability unit IIIs-2; woodland group 2; building site group 3)

Langola loamy sand, moderately well drained, 0 to 2 percent slopes (Lh).--This nearly level soil occurs on low, slightly elevated knolls and on flats. Areas are irregular in shape and range in size from 2 acres to about 20 acres. In places the surface layer is black. The lower part of the subsoil is mottled. In wet seasons the water table is at a depth of 3 to 5 feet.

Included in mapping were small areas of soils that have a fine sandy loam surface layer. Also included were small areas of soils, less than 1 acre in size, that have a black loam surface layer and a reddish-brown sandy loam subsoil and underlying material. There are also small areas of Duelm soils. The few small depressions included with this Langola soil contain wet sandy soils underlain by reddish-brown sandy loam at a depth of 30 to 60 inches.

This soil is used mainly for corn and soybeans. The hazards of drought and soil blowing are moderate to severe. This soil is fairly well suited to small grain. It is well suited to irrigated specialty crops, such as potatoes. A few areas are wooded. (Capability unit IIIs-2; woodland group 2; building site group 3)

Lerdal Series

The Lerdal series consists of deep, somewhat poorly drained soils that formed in a calcareous, loamy mantle of till 3 to 20 feet thick. Lerdal soils occur at the highest elevations in the county, mainly in the west-central part of the county. They occupy slight rises and knolls on broad hilltops. Slopes are mainly complex and range from 1 to 4 percent. Occasional stones and boulders occur near the surface. The native vegetation was mixed hardwoods and a grass understory.

In a representative profile, the surface layer is black loam about 10 inches thick. The subsurface layer is very dark gray loam about 3 inches thick. In cultivated areas the surface layer dries to dark gray. The subsoil is clay loam about 34 inches thick. The upper part is dark grayish brown, the middle part is dark grayish brown and olive brown, and the lower part is olive and olive gray. The underlying material is mottled, olive-gray loam.

Lerdal soils have high available moisture capacity. They have moderately slow permeability and medium to slow internal drainage. The water table is at a depth of 3 to 5 feet during wet seasons, but during dry seasons it is at a greater depth. The root zone is deep, but roots grow slowly in the dense subsoil. Fertility is medium, and the organic-matter content is high.

Representative profile of Lerdal loam, 1 to 4 percent slopes, in a cultivated field, NE1/4 NE1/4 NE1/4 sec. 6, T. 118 N., R. 23 W.:

Ap--0 to 10 inches, black (10YR 2/1) loam, dark gray (10YR 4/1) when dry; cloddy; friable; few roots; neutral; abrupt, smooth boundary.

A2--10 to 13 inches, very dark gray (10YR 3/1) loam, dark gray (10YR 4/1) when dry; few inclusions of light gray (10YR 6/1) when dry; few, fine, faint, olive-brown (2.5Y 4/3) mottles; moderate, fine, subangular blocky structure; friable; few roots; common, fine, tubular pores; neutral; clear, smooth boundary.

B1tg--13 to 18 inches, dark grayish-brown (2.5Y 4/2) clay loam; moderate, fine and medium, subangular blocky structure; friable; few roots; few, fine, tubular pores; few, medium, very dark gray (10YR 3/1) clay films on faces of peds; common, medium, dark-gray (10YR 4/1), porous coatings on faces of peds; neutral; clear, smooth boundary.

B21tg--18 to 25 inches, dark grayish-brown (2.5Y 4/2) and olive-brown (2.5Y 4/3) clay loam; strong, medium and coarse, angular blocky structure; firm; few roots; few, fine, tubular pores; many, thick, very dark gray (10YR 3/1) clay films on faces of peds; about 5 percent coarse fragments, mostly shale; slightly acid; clear, smooth boundary.

B22tg--25 to 37 inches, very dark grayish-brown (2.5Y 4/2) clay loam; common, fine, distinct, light olive-brown (2.5Y 5/6) mottles; strong, coarse, prismatic structure parting to strong, coarse, angular blocky structure; firm; few fine roots oriented along cleavage planes; common, very fine, tubular pores; many, thick, very dark gray (10YR 3/1) clay films on faces of peds; about 5 percent coarse fragments, mostly shale; slightly acid; gradual, smooth boundary.

B3tg--37 to 47 inches, olive (5Y 5/3) and olive-gray (5Y 5/2) clay loam; common, medium, distinct, light olive-brown (2.5Y 5/4) and dark-brown (7.5YR 4/4) mottles; strong, coarse, prismatic structure parting to strong, coarse, angular blocky structure; friable; common, very fine, tubular pores; many, thick, very dark gray (10YR 3/1) clay films on faces of peds and in root channels; about 5 percent coarse fragments, mostly shale; neutral; clear, smooth boundary.

C--47 to 60 inches, olive-gray (5Y 5/2) loam; common, fine, prominent, light olive-brown (2.5Y 5/6) mottles; weak cleavage planes; friable; few black stains and concretions; few black (10YR 2/1) clay films in root channels; few white lime concentrations; mildly alkaline; strongly calcareous.

The solum ranges from 30 to 60 inches in thickness but it is commonly 36 to 48 inches in thickness. The Ap horizon is 7 to 10 inches thick and ranges from black to very dark gray or very dark brown in color. Texture is commonly loam but in places is silt loam, clay loam, or silty clay loam. The A2 horizon is very dark gray to dark grayish brown and is 3 to 6 inches thick. Texture ranges from loam to light clay loam. The B2 horizon has a distinct increase in clay content as compared to the A horizon. Texture of the finest textured layer is clay loam or light clay. Sand content ranges from 20 to 35 percent, and there is a wide range in sand size. The B horizon commonly contains about 3 to 8 percent coarse fragments. The C horizon is olive gray to light olive brown. Texture is typically loam but ranges to light clay loam. Coarse fragments comprise about 5 percent of the soil by volume.

The A horizon is slightly acid to neutral. The B horizon ranges from strongly acid to neutral but is commonly slightly acid to medium acid. The C horizon is mildly alkaline and strongly calcareous.

As mapped in Hennepin County, the A horizon of these soils is slightly thicker than the defined range for the Lerdal series, but this does not alter the usefulness or behavior of these soils.

Lerdal soils contain more clay and silt than similar Le Sueur soils. They are lower in clay content and higher in sand content than similar Shorewood soils. Lerdal soils have a grayer B horizon than associated Kilkenny soils. They are better drained and finer textured than the associated Cordova soils.

Lerdal loam, 1 to 4 percent slopes (LmB).--This nearly level to gently undulating soil occupies 2-acre to 15-acre rises and low knolls on the tops of large hills. It lies 1 to 4 feet above Dundas and Cordova soils, which occupy flats and drainageways. Slopes are mainly less than 150 feet long.

Included in mapping were a few drainageways that contain areas of Cordova and Dundas soils.

If well managed, this soil is good cropland and is suitable for all the major crops grown in the county. Row crops can be grown year after year. Maintenance of tilth is the most important need of management. (Capability unit IIs-1; woodland group 1; building site group 7)

Lester Series

The Lester series consists of deep, well-drained, loamy soils that formed in calcareous till. These soils are on glacial uplands in convex areas of irregular hills and knolls, which rise 5 to 40 feet above the surrounding swales and sloughs. Slopes are both simple and complex and range from 2 to 35 percent. There are stones and boulders near the surface. The original vegetation was mixed hardwoods.

In a representative profile, the surface layer is black loam about 8 inches thick. The subsoil is dark yellowish-brown and light olive-brown clay loam about 24 inches thick. The underlying material is light olive-brown, calcareous loam.

Lester soils have high available moisture capacity and moderate permeability. The internal drainage is medium. The water table is at a depth below 5 feet in all seasons. The root zone is deep. Lester soils have high organic-matter content and natural fertility.

Representative profile of Lester loam, 2 to 6 percent slopes, in a wooded pasture, NW1/4 NW1/4 NW1/4 sec. 17, T. 117 N., R. 24 W.:

Ap--0 to 8 inches, black (10YR 2/1) loam; moderate, very fine, subangular blocky structure; friable; common fine pores and roots; common inclusions of dark-gray (10YR 4/1), porous loam; neutral; clear, smooth boundary.

B1--8 to 10 inches, very dark brown (10YR 2/2) heavy loam, very dark grayish brown (10YR 3/2) when rubbed; moderate, fine, subangular blocky structure; very friable; common fine roots and pores; common, medium, light-gray (10YR 6/1), porous coatings on faces of peds; slightly acid; clear, smooth boundary.

B21t--10 to 15 inches, dark yellowish-brown (10YR 4/4) clay loam; moderate, fine and medium, subangular blocky structure; friable; few roots; common, fine, tubular pores; common, thin, very dark grayish brown (10YR 3/2) clay films on faces of peds; common, medium, light-gray (10YR 6/1), porous coatings on faces of peds; about 4 percent coarse fragments, mostly igneous and shale; strongly acid; clear, smooth boundary.

B22t--15 to 21 inches, dark yellowish-brown (10YR 4/4) clay loam; moderate, coarse, angular blocky structure; friable; few roots; common very fine pores; common, thick, very dark grayish-brown (10YR 3/2) clay films on faces of peds; about 4 percent coarse fragments, mostly igneous and shale; strongly acid; clear, smooth boundary.

B23t--21 to 26 inches, light olive-brown (2.5Y 5/4) clay loam; few, fine, prominent, yellowish-brown (10YR 5/8) mottles; moderate, coarse, angular blocky structure; friable; few roots; common, fine, tubular pores; common, thin, very dark grayish-brown (10YR 3/2) clay films on faces of peds; about 5 percent coarse fragments, mostly igneous and shale; strongly acid; clear, smooth boundary.

B3t--26 to 32 inches, light olive-brown (2.5Y 5/4) light clay loam; common, medium, prominent, yellowish-brown (10YR 5/8) mottles; moderate, medium and coarse, subangular blocky structure; friable; common, fine, tubular pores; few, thick, very dark grayish-brown (10YR 3/2) clay films on faces of peds; few clay films in root channels; slightly acid; clear, smooth boundary.

C1--32 to 46 inches, light olive-brown (2.5Y 5/4) loam; common, fine, prominent, yellowish-brown (10YR 5/8) mottles; weak, coarse, subangular blocky structure; friable; few, fine, tubular pores; few, thin, very dark grayish-brown (10YR 3/2) clay films in root channels; common white lime concretions and concentrations; mildly alkaline; strongly calcareous; clear, smooth boundary.

C2--46 to 60 inches, light olive-brown (2.5Y 5/4) loam; common, fine, prominent, yellowish-brown (10YR 5/8) mottles; weak cleavage planes; friable; few, fine, tubular pores; few, fine, very dark grayish-brown (10YR 3/2) clay fillings in root channels of upper part; common white lime concentrations and concretions; mildly alkaline; strongly calcareous.

The solum ranges in thickness from 20 to 54 inches, but is commonly 28 to 40 inches. In cultivated areas the A horizon is black loam about 8 to 10 inches thick. An A2 horizon is present in some places. The B2 horizon ranges in color from dark yellowish brown to yellowish brown, brown, olive brown, and light olive brown. Texture ranges from heavy loam to clay loam. Clay content ranges from 25 to 35 percent in the finest textured layer, and sand content ranges from 30 to 45 percent. In some places there are reddish-brown iron oxide segregations in the B3 and C horizons. About 2 to 5 percent of the B and C horizons consists of coarse fragments of mixed lithology. Reaction of the A horizon is slightly acid to neutral. The B horizon is commonly medium acid or slightly acid but ranges from strongly acid to neutral. The C horizon is weakly to strongly calcareous.

Lester soils have a darker Ap horizon and a more friable B horizon than associated Hayden soils. Lester soils are not so fine textured as the similar Shorewood soils. Lester soils have a browner B horizon that lacks mottles, in contrast to the associated Le Sueur soils, which are mottled in the lower part of the B horizon.

Lester loam, 2 to 6 percent slopes (LrB).--This gently undulating soil occupies 2-acre to 25-acre areas on knolls and hilltops. Slopes are commonly 75 to 125 feet long and generally extend in several directions. This soil has the profile described as representative for the series.

Included in mapping were small areas of Shorewood soils. Small areas of Dundas and Cordova soils, less than 2 acres in size, are in shallow drainageways and depressions.

This soil is among the best soils in the county and is suited to all major crops if well managed. The main management needs are maintenance of tilth and control of erosion. The hazard of erosion is slight to moderate. With good management, row crops can be grown nearly every year. (Capability unit IIe-1; woodland group 1; building site group 5)

Lester loam, 6 to 12 percent slopes (LrC).--This rolling soil occupies 2-acre to 15-acre areas on hillsides and knolls. Slopes are commonly 75 to 125 feet long. The clay loam subsoil is exposed in some cultivated areas.

Included in mapping were patches of calcareous, olive-brown soils near slope crests. Small areas of Shorewood soils were also included. Areas of Cordova and Dundas soils are in the shallow drainageways and depressions.

Most areas of this soil are in permanent pasture or woodland. This soil is fair to good cropland and is suited to all crops commonly grown in the county. The hazard of erosion is moderate to severe. Management is required to reduce erosion and water runoff. (Capability unit IIIe-1; woodland group 1; building site group 5)

Lester loam, 12 to 18 percent slopes (LrD).--This hilly soil occupies 2-acre to 15-acre areas on hillsides and knolls. Slopes are typically 60 to 100 feet long. This soil has a profile similar to that described as representative for the series, except that the surface layer and the subsoil are commonly thinner. Patches of the clay loam subsoil are exposed in cultivated fields.

Included in mapping were small patches of Shorewood soils. Areas of Cordova and Dundas soils are in shallow drainageways and depressions.

Most areas of this soil are in pasture or woodland. It can be used for cropland if it is well managed. The hazard of erosion is severe. Intertilled crops, such as corn and soybeans, should be grown only occasionally and only in areas where management is good. This soil is better suited to permanent pasture, woodland, or recreational uses. (Capability unit IVe-1; woodland group 1; building site group 5)

Lester loam, 18 to 24 percent slopes (LrE).--This steep soil occupies 2-acre to 10-acre areas on hillsides. Slopes are commonly 50 to 100 feet long and are broken by shallow downslope drainageways. This soil has a profile similar to that described as representative for the series, except that it has a thinner surface layer and subsoil. Patches of the clay loam subsoil are exposed in cultivated fields.

Included in mapping were a few patches of soils that are calcareous at the surface. Small patches of Shorewood soils were also included. There are small areas of Le Sueur soils near the base of slopes in many places. A few, small, 2-acre to 3-acre, gently sloping areas on crests and sideslope benches were included.

Most areas of this soil are in woodland or permanent pasture. Steepness of slopes and the hazard of erosion severely limit the use of this soil for common farm crops. This soil is better suited to grazing or woodland or, if maintained in its natural state, for recreational use and wildlife habitat. (Capability unit VIe-1; woodland group 1; building site group 5)

Lester clay loam, 2 to 6 percent slopes, eroded (LsB2).--This gently undulating soil occupies 2-acre to 25-acre areas on irregular knolls and hilltops. Slopes are commonly 75 to 125 feet long and in most places extend in several directions. Because this soil is eroded, the surface layer is very dark grayish-brown clay loam that is a mixture of material from the original surface layer and the subsoil. This layer is higher in clay content and lower in organic-matter content and is less friable than is typical for the Lester series.

Included in mapping were small patches of Shorewood soils. Areas of Dundas and Cordova soils are in shallow drainageways and depressions.

The main management needs of this soil are control of erosion and maintenance of tilth. The hazard of erosion is slight to moderate. With good management, row crops can be grown nearly every year. (Capability unit IIe-1; woodland group 1; building site group 5)

Lester clay loam, 6 to 12 percent slopes, eroded (LsC2).--This rolling soil occupies 2-acre to 15-acre areas on knolls and hillsides. Slopes are commonly between 75 and 125 feet long and commonly extend in more than one direction. Because this soil is eroded, the surface layer is very dark grayish-brown clay loam that is a mixture of the original surface layer and the subsoil. This layer has a higher clay content and less organic matter and is less friable than is typical for the Lester series.

Included in mapping were patches of calcareous, olive-brown, bald soils near the slope crests. Small patches of Shorewood soils were also included. Areas of Dundas and Cordova soils occur in shallow drainageways and depressions.

The hazard of erosion is a moderate to severe limitation to the use of this soil for cultivated crops. This soil is suited to all the crops grown in the county, except that good management is needed to control runoff and erosion. (Capability unit IIIe-1; woodland group 1; building site group 5)

Lester clay loam, 12 to 18 percent slopes, eroded (LsD2).--This hilly soil occupies 2-acre to 15-acre areas on hillsides and knolls. Slopes are commonly 50 to 100 feet long. Because this soil is eroded, the surface layer is very dark grayish-brown clay loam that is a mixture of the original surface layer and the subsoil. This layer is higher in clay content, is lower in organic-matter content, and is less friable than is typical for the Lester series. The surface layer and the subsoil are commonly thinner than is typical for the series.

Included in mapping were patches of calcareous, olive-brown, bald soils near the slope crests. In a few places these patches comprise from 10 to 20 percent of a given area. Also included were a few small patches of Shorewood soils. Cordova and Dundas soils are in occasional shallow drainageways and depressions. There are small areas of soils that have slopes of less than 12 percent and greater than 18 percent.

Because of the severe hazard of erosion, this soil is not well suited to cultivated crops. Intertilled crops, such as corn and soybeans, should be grown only occasionally and only in areas where good management practices are used. Uses that keep the soil covered with plants all year are better. (Capability unit IVe-1; woodland group 1; building site group 5)

Le Sueur Series

The Le Sueur series consists of deep, moderately well drained, loamy soils that formed in calcareous till. These soils occur on the glacial uplands, typically on slight rises and knolls 2 to 15 acres in size and 1 to 4 feet above the closely intermingled Cordova soils. A few tracts occur on tops of broad hills. Slopes are both simple and complex and range from 1 to 4 percent. There are a few stones and boulders near the surface. The native vegetation was mixed hardwoods and a grass understory.

In a representative profile, the surface layer is black loam about 13 inches thick. The subsoil is mostly dark grayish-brown and olive-brown clay loam about 23 inches thick. The underlying material is calcareous, light brownish-gray loam.

Le Sueur soils have high available moisture capacity. They have moderate permeability and medium internal drainage. Roots grow fairly easily in these soils, and the root zone is deep. The water table is at a depth of 3 to 5 feet during wet seasons but is at a greater depth during dry seasons. The organic-matter content is high. Le Sueur soils have high natural fertility, but crops grown on them respond well to potash, phosphate, and nitrogen fertilizers. Lime is needed in some areas.

Representative profile of Le Sueur loam, 1 to 4 percent slopes, in a wooded pasture, SE1/4 NW1/4 SW1/4 sec. 34, T. 117 N., R. 24 W.:

A1--0 to 9 inches, black (10YR 2/1) loam, dark gray (10YR 4/1) when dry; weak, very fine and fine, subangular blocky structure; very friable; many roots; few igneous pebbles; neutral; clear, smooth boundary.

A3--9 to 13 inches, black (10YR 2/1) loam mixed with dark gray (10YR 4/1), very dark gray (10YR 3/1) when rubbed; moderate, fine, subangular blocky structure; very friable; common roots; fine, tubular pores; few igneous pebbles; slightly acid; clear, smooth boundary.

B1--13 to 17 inches, very dark grayish-brown (2.5Y 3/2) loam; moderate, medium, subangular blocky structure parting to moderate, very fine, subangular blocky structure; friable; common roots; fine, tubular pores; common, thick, light brownish-gray (10YR 6/2), porous coatings on faces of peds; about 2 percent coarse fragments, mostly igneous; slightly acid; clear, smooth boundary.

B21t--17 to 21 inches, dark grayish-brown (2.5Y 4/2) light clay loam; moderate, coarse, subangular blocky structure parting to moderate, fine, subangular blocky structure; friable; few roots; common, fine, tubular pores; thin, light brownish-gray (10YR 6/2), porous coatings on faces of peds; common, thick, very dark grayish-brown (10YR 3/2) and black (10YR 2/1) clay films on faces of peds; about 2 percent coarse fragments, mostly igneous and shale; medium acid; clear, smooth boundary.

B22t--21 to 28 inches, olive-brown (2.5Y 4/3) clay loam; moderate, medium and coarse, prismatic structure parting to moderate, coarse, subangular blocky structure; friable; few roots; common, fine, tubular pores; common, thick, very dark grayish-brown (10YR 3/2) clay films on faces of peds; about 2 percent coarse fragments, mostly igneous and fine shale; medium acid; clear, smooth boundary.

B23t--28 to 32 inches, light olive-brown (2.5Y 5/4) light clay loam (32 percent clay); moderate, medium and coarse, prismatic structure parting to moderate, coarse, subangular blocky structure; friable; few roots; common, fine tubular pores; common, thick, very dark grayish-brown (10YR 3/2) clay films on faces of peds; thick, black (10YR 2/1) clay films in root channels; about 4 percent coarse fragments, mostly igneous and shale; medium acid; clear, smooth boundary.

B3t--32 to 36 inches, grayish-brown (2.5Y 5/2) light clay loam grading to olive gray (5Y 5/2); moderate, coarse, prismatic structure parting to moderate, coarse, subangular blocky structure; friable; few roots; common, fine, tubular pores; few, thick, black (10YR 2/1) clay films on faces of peds and in root channels; about 5 percent coarse fragments, mostly igneous and shale; slightly acid; clear, smooth boundary.

C--36 to 60 inches, light brownish-gray (2.5Y 6/2) heavy loam; common, fine, prominent, light olive-brown (2.5Y 5/6) mottles; few cleavage planes; friable; few, fine, tubular pores; few, thick, black (10YR 2/1) clay films on cleavage planes and in root channels of upper part; common light gray (2.5Y 7/2) lime concentrations; about 5 percent coarse fragments, mostly igneous, shale, and limestone; mildly alkaline; strongly calcareous.

The solum ranges from 24 to 48 inches in thickness but is commonly 28 to 36 inches thick. The A1 horizon is 5 to 10 inches thick, and the A3 horizon is 3 to 6 inches thick. The A horizon is typically loam but in places is light clay loam or silty clay loam. Distinct, high-chroma mottles are few to common in the lower part of the B2 horizon and in some places are present in the upper part of the B2 horizon. The B2 horizon is light clay loam to heavy loam. Clay content ranges from 27 to 35 percent but typically is 30 to 35 percent in the finest textured layer. Sand content ranges from 30 to 45 percent, and 25 to 50 percent of the sand fraction is coarser than fine sand. Color of the C horizon ranges from yellowish brown and light brownish gray to olive gray. Yellowish-brown and light olive-brown mottles are common. The B and C horizons contain about 2 to 5 percent fragments of mixed lithology, but calcareous fragments are absent in the B horizon. Reaction of the A horizon ranges from slightly acid to neutral. The B horizon is typically medium acid to slightly acid but ranges from neutral to strongly acid.

Le Sueur soils have a grayer B horizon than associated Lester soils, and they are mottled in the lower part of the B horizon. They are lower in clay and sand content than similar Shorewood soils. The B horizon of Le Sueur soils is lower in clay content, has a weaker structure, and is more friable than similar Lerdal soils.

Le Sueur loam, 1 to 4 percent slopes (LtB).--This nearly level to gently sloping soil typically occupies rises on low knolls. Some areas are in shallow drainageways. There are a few crescent-shaped areas near the base of steep slopes. In most places this soil is closely associated with the poorly drained Cordova soils, which lie in slightly lower positions. Areas range in size from 2 to 15 acres.

Included in mapping were small patches of Shorewood and Cordova soils.

The main management need of this soil is maintenance of tilth. It is well suited to all the major crops grown in the county. It is especially well suited to continuous corn and soybean production. (Capability unit I-1; woodland group 1; building site group 6)

Litchfield Series

The Litchfield series consists of deep, moderately well drained, sandy soils that formed in sandy alluvium that contains thin layers of loam. These soils are in broad, level areas on the Mississippi River outwash plain in the northeastern part of the

county. The native vegetation was tall prairie grass and scattered patches of oaks.

In a representative profile, the surface layer is very dark grayish-brown loamy fine sand about 9 inches thick. The subsoil, about 24 inches thick, consists of alternating layers of dark grayish-brown, dark-brown, and dark yellowish-brown fine sand, loamy fine sand, and fine sandy loam. The underlying material is yellowish-brown and light olive-brown fine sand or sand that contains many, large, grayish-brown mottles.

Litchfield soils have low available moisture capacity and medium to rapid internal drainage. They are rapidly permeable. The water table is at a depth of 3 to 5 feet during wet seasons. This somewhat improves the supply of moisture to plants. Roots develop rapidly and grow deep. The surface layer is easily blown. The organic-matter content is moderate, and the natural fertility is low.

Representative profile of Litchfield loamy fine sand, in a cultivated field, NW1/4 NE1/4 NW1/4 sec. 20, T. 119 N., R. 21 W.:

Ap--0 to 9 inches, very dark grayish-brown (10YR 3/2) loamy fine sand; fine reticulate inclusions of dark grayish brown (10YR 4/2) and brown (10YR 4/3); cloddy; common fine roots; medium acid; clear, abrupt boundary.

B1--9 to 15 inches, dark grayish-brown (10YR 4/2) and brown (10YR 4/3) loamy fine sand and fine sand; few, fine, distinct, grayish-brown (2.5Y 5/2) and dark yellowish-brown (10YR 3/4) mottles; weak, fine and medium, subangular blocky structure; common roots; medium acid; clear, abrupt boundary.

B21t--15 to 24 inches, dark-brown (10YR 3/3) and dark yellowish-brown (10YR 3/4) fine sandy loam; many, medium, prominent, grayish-brown (2.5Y 5/2) mottles and faint, dark yellowish-brown (10YR 4/4) mottles; weak, medium and coarse, subangular blocky structure; very friable; few roots; many, very fine, tubular pores; few, thin, patchy clay films on faces of peds; medium acid; clear, smooth boundary.

B3--24 to 33 inches, dark yellowish-brown (10YR 4/4) sand; many, medium and large, prominent, grayish-brown (2.5Y 5/2) mottles and common, fine and medium, prominent, yellowish-brown (10YR 5/8) mottles; weak, coarse, subangular blocky structure; friable; weakly cemented; few roots; medium acid; clear, smooth boundary.

C1--33 to 38 inches, yellowish-brown (10YR 5/4) fine sand; common, large, prominent, grayish-brown (2.5Y 5/2) mottles and faint yellowish-brown (10YR 5/8) mottles; massive; very friable; medium acid; clear, smooth boundary.

C2--38 to 60 inches, light olive-brown (2.5Y 5/4) sand; many, medium and large, prominent, yellowish-brown (10YR 5/8) mottles and faint, grayish-brown (2.5Y 5/2) mottles; single grain; loose; medium acid.

The Ap horizon is very dark brown or very dark grayish brown. In places the A horizon is 12 to 14 inches thick. The B and C horizons consist of alternating strata of fine sand to sand, loamy fine sand, loamy sand, fine sandy loam, loam, silt loam, and light clay loam. The strata of silt loam, loam, and light clay loam are less common and are thinner than the strata of sandy loam and fine sandy loam. The combined thickness of the bands of fine sandy loam or finer within a 40-inch depth ranges from 4 to 12 inches but is commonly 5 to 9 inches. These bands occur mainly at a depth between 15 and 48 inches. Some areas have weakly cemented horizons. The C horizon is dominantly grayish brown in color but ranges from dark grayish brown to light olive brown. Reaction of the solum ranges from strongly acid to medium acid.

These soils, as mapped in Hennepin County, have a thinner, darker colored A horizon and contain more medium and coarse sand than the defined range for the Litchfield series. However, these differences do not alter the usefulness and behavior of these soils.

Litchfield soils have finer sand and have finer textured layers in the B and C horizons than associated Duelm soils. They lack the continuous, thick, loamy C horizon of the similar Duelm loamy sand, loamy subsoil variant. Litchfield soils are browner and not so mottled throughout as the associated Dassel soils. Litchfield soils are mottled in the B horizon, but Rasset soils are not. They also lack the shaly layers that are present in the associated Rasset soils.

Litchfield loamy fine sand (Lu).--This nearly level soil occurs on broad flats and slight rises, mainly within areas of Dassel soils. A few areas lie in narrow drainageways below Anoka soils. Areas range in size from 2 to about 120 acres.

Included in mapping were small areas of soils that have a sandy loam, loam, and silt loam surface layer. Areas of soils that have a silt loam surface layer and subsoil that extend to a depth of 18 inches to about 25 inches were also included. Small, scattered depressions contain areas of Biscay clay loam, depressional, or Kennebeck soils.

Most areas of this soil are in cropland. The hazards of drought and soil blowing are severe. Corn and soybean growth is limited by drought in most years unless rainfall is timely. This soil is good to fair for small grain and is well suited to specialty crops, such as irrigated potatoes. (Capability unit IIIs-1; woodland group 3; building site group 2)

Marsh

Marsh (Ma) consists of shallow lakes and ponds that contain reeds, sedges, and other aquatic vegetation. Most areas are wet all year long, and the soil material is too wet to be classified. Most areas occur as borders around lakes or along streams and rivers and are unfeasible to drain.

This land type consists mostly of areas of deep Peaty muck. Areas of Peaty muck over loam, Peaty

muck over sand, Glencoe soils, and a depressional Isan soil also occur.

In some areas wild hay can be cut along the marshy edges. Most areas are poor for pasture. Marsh is well suited to providing food and cover for certain types of wildlife. (Capability unit VIIIw-1; woodland group 7; building site group 12)

Minnetonka Series

The Minnetonka series consists of deep, poorly drained soils that formed in 30 to 60 inches of calcareous, clayey sediments. In most places a 2-foot to 3-foot layer of silty sediments lies between the clayey sediments and the underlying loamy till. These soils are on broad flats and in drainageways. The native vegetation was prairie grass encroached upon by mixed hardwoods. There are a few stones and boulders, mainly near the surface. These soils occupy scattered tracts and are associated mainly with the Lester, Hayden, and Shorewood soils.

In a representative profile, the surface layer is black silty clay loam about 13 inches thick. The subsoil is mostly firm, olive-gray silty clay about 22 inches thick. The underlying material is calcareous, olive-gray silty clay loam.

Minnetonka soils have high available moisture capacity, slow internal drainage, and slow permeability. The water table is at a depth of 1 to 3 feet during wet periods. The root zone is limited by the high water table. The organic-matter content and natural fertility are high.

Representative profile of Minnetonka silty clay loam, in a cultivated field, SE1/4 NE1/4 NE1/4 sec. 33, T. 118 N., R. 23 W., Orono village:

Ap--0 to 8 inches, black (10YR 2/1) light silty clay loam; weak, very fine, subangular blocky structure; friable; many roots; slightly acid; clear, smooth boundary.

A12--8 to 13 inches, black (10YR 2/1) heavy silty clay loam; lower part of the horizon contains patches and thin seams of gray (10YR 5/1); moderate, very fine, subangular blocky structure; friable; many roots; slightly acid; clear, smooth boundary.

B1tg--13 to 18 inches, very dark gray (10YR 3/1) silty clay intermingled with olive gray (5Y 4/2); strong, very fine, subangular blocky structure; firm; few roots; few, fine, tubular pores; common, thick, black (10YR 2/1) and very dark gray (10YR 3/1) clay films on faces of peds; slightly acid; clear, smooth boundary.

B21tg--18 to 25 inches, olive-gray (5Y 4/2) silty clay; weak, fine, prismatic structure parting to strong, very fine, subangular blocky; firm; few fine roots and pores; many, thick, black (10YR 2/1) and very dark gray (10YR 3/1) clay films on faces of peds and in root channels; slightly acid; clear, smooth boundary.

B22tg--25 to 31 inches, olive-gray (5Y 5/2 and 5Y 4/2) silty clay; few, fine, distinct, olive (5Y 5/6) mottles; weak, medium, prismatic structure; firm; few fine roots; common, fine, tubular pores; many, thick, black (10YR 2/1) and very dark gray (10YR 3/1) clay films on faces of peds and in root channels; neutral; clear, smooth boundary.

B3tg--31 to 35 inches, olive-gray (5Y 5/2) silty clay loam; few, fine, distinct, olive (5Y 5/6) mottles; weak, very fine, subangular blocky structure; friable; few, fine, tubular pores; few, medium, very dark gray (10YR 3/1) and black (10YR 2/1) clay films on faces of peds and in root channels; neutral; clear, smooth boundary.

C1g--35 to 40 inches, olive-gray (5Y 5/2) silty clay loam; common, fine, prominent, olive (5Y 5/6) mottles; moderate, very fine, subangular blocky structure; friable; few, thin, black (10YR 2/1) clay films in root channels; common, fine, light-gray lime concentrations; few black concretions; mildly alkaline; strongly calcareous.

C2g--40 to 60 inches, olive-gray (5Y 5/2) silty clay loam; few thin strata of very fine sandy loam; common, fine, prominent, yellowish-brown (10YR 5/6) mottles that increase in size and abundance with increasing depth; weak, coarse, subangular blocky structure parting to weak, very fine, subangular blocky structure; friable; common, fine, light-gray lime concentrations; mildly alkaline; strongly calcareous.

A thin, distinct A2 horizon that dries to gray or grayish brown occurs in some places. The B horizon is typically olive gray but ranges from dark gray to olive and light olive brown. The zone of maximum clay content in the B2 horizon ranges from silty clay to clay. The C horizon is olive gray or light olive gray and is variable in texture. It ranges from heavy silty clay loam or silty clay to silt loam or light silty clay loam or to clay loam or loam glacial till. The glacial till occurs within a depth of 10 feet in most places. Reaction of the A horizon ranges from slightly acid to neutral, and reaction of the B horizon ranges from medium acid to neutral. Depth to lime carbonates ranges from 26 to 40 inches.

Minnetonka soils have a finer textured B horizon than the similar Cordova soils. They have a thicker, darker colored A horizon than associated Shields soils.

Minnetonka silty clay loam (Mt).--This nearly level soil is in broad tracts up to about 100 acres in size and in shallow drainageways.

Included in mapping were small rises of Shorewood and Le Sueur soils. In a few places the underlying material is made up of layers of sand, silt, and clay.

The main needs of management are drainage and maintenance of soil tilth. This soil can be drained, but tile must be spaced rather closely to insure good drainage. A good tile outlet is important. If properly drained and managed, this soil is

suited to all crops grown in the county. Row crops can be grown year after year under a high level of management. (Capability unit IIw-2; woodland group 6; building site group 11)

Mixed Alluvial Land

These miscellaneous land types are Mixed alluvial land and Mixed alluvial land, frequently flooded.

Mixed alluvial land (Mu).--This land type consists of moderately well drained, mixed alluvial soils that vary greatly in color, texture, and reaction. These nearly level soils occupy 5-acre to 150-acre tracts on stream bottom lands that are subject to varying frequency of flooding. Many areas are dissected by old stream channels, resulting in short, narrow ridges that have a corrugated appearance. They are continually being changed by additions of new deposits, by scouring, and by changes in stream channels. The soil material consists of stratified, recently deposited alluvium. There are fairly extensive areas of this land type on the Minnesota River bottom lands, and scattered tracts occur along the Mississippi River and Crow River bottom lands. The native vegetation was bottom-land hardwoods and grass.

The soil material of this land type is too recent for a profile to have formed, but it is faintly to distinctly mottled. Although texture is extremely variable, it is commonly coarse to medium, and there are stratified layers of sand. Along the Minnesota River the sand fraction is dominated by fine and very fine sand, in comparison to fine and medium sand along the Mississippi and Crow Rivers. Reaction ranges from mildly alkaline to moderately alkaline. The water table is at a depth of 2 to 5 feet during wet periods.

The hazard of flooding limits the use of this land type for farming. If properly fertilized and managed, it is suited to most crops commonly grown in the county in years when it is not flooded. The available moisture capacity ranges from low to moderate, and crops suffer from drought in most years unless rainfall distribution is good. This land type warms up early in spring and is easy to till. Roots penetrate the soil material easily. (Capability unit IIw-3; woodland group 5; building site group 13)

Mixed alluvial land, frequently flooded (Mx).--This nearly level land type consists of moderately well drained to very poorly drained, mixed alluvial soils that vary greatly in color, texture, and reaction. They occupy 5-acre to about 150-acre tracts on stream bottom lands that are frequently flooded. Most areas are frequently dissected by old stream channels, resulting in short, narrow ridges that have a corrugated appearance. The water table is generally high. Runoff is slow.

The soil material consists of recently deposited alluvium that is subject to continual change by additions of new deposits, by scouring, and by changes in stream channels. There are extensive areas of this land type on the bottom lands along the Minnesota River. A few scattered areas occur along the Mississippi and Crow Rivers. The native vegetation was mixed bottom-land hardwoods and aquatic reeds, grasses, and sedges.

The soil material of this land type is too recent for a profile to have formed. Although texture is extremely variable, it is generally medium and there are stratified layers of coarser material. Reaction ranges from mildly alkaline to moderately alkaline.

Included in mapping were a few narrow drainageways that are below steep slopes on the glacial upland and are subject to spring overflow. These areas are finer textured and have a darker colored surface layer than those on the river bottom lands.

Because of the hazard of flooding, the use of this land type for farming and residential development is severely limited. It is better suited to recreational uses and wildlife habitat than to most other uses. Almost all of this land type is in permanent vegetation. (Capability unit VIw-1; woodland group 5; building site group 13)

Nessel Series

The Nessel series consists of deep, moderately well drained, loamy soils that formed in calcareous till. These nearly level to gently sloping soils occur on slight rises, low knolls, and broad hilltops. There are stones and boulders, mainly near the surface. The native vegetation was mixed hardwoods.

In a representative profile, the surface layer is very dark gray loam about 7 inches thick. The subsoil is about 29 inches thick. The upper part is light olive-brown and olive-brown clay loam. The lower 5 inches is grayish-brown and light olive-brown heavy loam. The underlying material is calcareous, light olive-brown loam.

Nessel soils have high available moisture capacity and medium internal drainage. The water table is at a depth of 3 to 5 feet during wet seasons. Nessel soils are moderately permeable. The root zone is deep. Organic-matter content is low, and fertility is medium. The subsoil is medium to high in phosphorus. Lime is needed in some places.

Representative profile of Nessel loam, 1 to 4 percent slopes, in a wooded pasture, NE1/4 NW1/4 NW1/4 sec. 18, T. 119 N., R. 23 W.:

Ap--0 to 7 inches, very dark gray (10YR 3/1) loam, light gray (10YR 6/1) when dry; weak, thin, platy structure parting to weak, very fine, subangular blocky structure; very friable; common roots; slightly acid; abrupt, smooth boundary.

A&B--7 to 13 inches, olive-brown (2.5Y 4/4) light clay loam; moderate, very fine and fine, subangular blocky structure; friable; few roots; common fine pores; many, thick, porous, dark grayish-brown (2.5Y 4/2), grainy coatings on faces of peds, light gray (10YR 7/1) when dry; medium acid; clear, smooth boundary.

B1--13 to 22 inches, olive-brown (2.5Y 4/4) light clay loam; moderate, coarse, subangular blocky structure; friable; few roots; common, fine, tubular pores; many, medium, porous, dark grayish-brown (2.5Y 4/3), grainy coatings on faces of peds, light gray (10YR 7/1) when dry; about 4 percent coarse fragments, mostly shale; medium acid; clear, smooth boundary.

B2t--22 to 31 inches, light olive-brown (2.5Y 5/4) light clay loam; many, fine and medium, distinct, grayish-brown (2.5Y 5/2) mottles and few, fine, distinct, reddish-brown (5YR 4/4) mottles; moderate, coarse, prismatic structure parting to strong, coarse, subangular blocky structure; friable; few roots; common, fine, tubular pores; common, thick, patchy, very dark brown (10YR 2/2) clay films on faces of peds and in root channels; about 5 percent coarse fragments, mostly shale; medium acid; clear, smooth boundary.

B3t--31 to 36 inches, grayish-brown (2.5Y 5/2) and light olive-brown (2.5Y 5/6) heavy loam; moderate, coarse, subangular blocky structure; friable; few, thin, black (10YR 2/1) and very dark brown (10YR 2/2) clay films on faces of peds and in root channels; common light-gray lime segregations; about 5 percent coarse fragments, mostly shale and igneous; neutral; clear, smooth boundary.

C--36 to 60 inches, light olive-brown (2.5Y 5/4) loam; few, fine, distinct, grayish-brown (2.5Y 5/2) mottles; few weak cleavage planes; friable; common light-gray lime segregations; about 5 percent coarse fragments, mostly igneous, shale, and limestone; few reddish concentrations; mildly alkaline; strongly calcareous.

The solum ranges from 20 to 48 inches in thickness but is commonly 28 to 36 inches thick. The Ap horizon is 7 to 9 inches thick, is very dark gray to dark grayish brown in color, and is loam or silt loam in places. In some places the B1 horizon is mottled. Clay content of the B horizon ranges from 27 to 35 percent, but it commonly is 30 to 35 percent clay in the finest textured B horizon. Sand content ranges from 30 to 45 percent, and 25 to 50 percent of the sand fraction is coarser than fine sand. Consistence ranges from friable to firm. The B and C horizons contain about 2 to 5 percent coarse fragments. Reaction of the A horizon ranges from slightly acid to neutral. The B horizon is typically medium acid or slightly acid, but it ranges from strongly acid to neutral.

Nessel soils have a thinner, grayer A horizon than associated Le Sueur soils. They are lower in clay content and higher in sand content than similar Dalbo soils. Nessel soils have a grayer, more mottled B horizon than the associated Hayden soils. They have a grayer A horizon and a more friable B horizon that is lower in clay content than the similar Lerdal soils.

Nessel loam, 1 to 4 percent slopes (NeB).--This nearly level to gently sloping soil occupies 2-acre to 10-acre rises in areas of low relief and on a few hilltops that are above Hayden soils on the side slopes. In many places this soil is closely associated with Cordova and Dundas soils, which occur at slightly lower elevations. Slopes are mainly less than 150 feet long.

Included in mapping were small patches of the moderately slowly permeable Dalbo soils, which are in convex positions. Small patches of Dundas soils in shallow swales were also included.

This soil is among the best soils for crops in the county if it is well managed. Maintenance of tilth is the major need of management. Tilth can be improved and maintained by timely tillage and by growing crops using minimum tillage practices or growing occasional sod crops. (Capability unit I-1; woodland group 1; building site group 6)

Nymore Series

The Nymore series consists of deep, somewhat excessively drained, sandy soils that formed in deep sand. These soils are on outwash plains in the southeastern part of the county. Slopes range from 2 to 12 percent. The native vegetation was mixed hardwoods.

In a representative profile, the surface layer is very dark grayish-brown loamy sand about 9 inches thick. The subsoil is dark yellowish-brown and yellowish-brown sand about 27 inches thick. The underlying material is yellowish-brown sand.

Nymore soils have very low available moisture capacity and rapid to very rapid permeability and internal drainage. The water table is at a depth below 10 feet in all seasons. The root zone is deep. Nymore soils are low in organic-matter content and natural fertility.

Representative profile of Nymore loamy sand, 2 to 6 percent slopes, in a cultivated field, SW1/4 NW1/4 SW1/4 sec. 21, T. 117 N., R. 22 W., Minnetonka village:

Ap--0 to 9 inches, very dark grayish-brown (10YR 3/2) loamy sand, grayish brown (10YR 5/2) when dry; weak, very fine, granular structure; common roots; many bleached sand grains; about 5 percent very fine gravel; neutral; abrupt, smooth boundary.

B21--9 to 22 inches, dark yellowish-brown (10YR 4/4) sand; weak, medium, subangular blocky structure; very friable; few roots; about 15 percent very fine gravel in upper part, grading to about 5 percent in lower part; slightly acid; gradual, smooth boundary.

B22--22 to 36 inches, yellowish-brown (10YR 5/4) sand; single grain; loose; few fine roots; about 5 percent very fine gravel; slightly acid; gradual, smooth boundary.

C1--36 to 50 inches, yellowish-brown (10YR 5/4) sand; single grain; few fine roots; about 5

percent very fine gravel; neutral; gradual, smooth boundary.

C2--50 to 60 inches, yellowish-brown (10YR 5/4) coarse sand, grading to light olive brown (2.5Y 5/4); single grain; loose; about 5 percent very fine gravel; neutral.

The solum ranges from 30 to 50 inches in thickness but is commonly 30 to 40 inches thick. The A horizon ranges from black to very dark gray, very dark brown, and very dark grayish brown. The black horizons are less than 6 inches in thickness. Texture ranges from loamy sand to sand. The B horizon ranges from dark brown to yellowish brown. Sand grains are commonly coated with thin clay films. A few, thin, very dark brown loamy sand layers up to one-half inch in thickness occur in some places. The sand fraction is dominated by medium sand. Content of very coarse sand is typically less than 10 percent. The gravel content is commonly less than 10 percent, but in some places there are thin layers that are up to 25 percent gravel. The A and B horizons are medium acid to neutral, and the C horizon is slightly acid to neutral. Lime carbonates typically do not occur within a depth of 60 inches.

Nymore soils lack the thin, loamy layers of the associated Rasset soils. They have a thinner A1 horizon and a lighter colored Ap horizon than the associated Hubbard soils. They formed in coarser sand and lack the thin, loamy bands of the associated Zimmerman soils.

Nymore loamy sand, 2 to 6 percent slopes (NyB).--This gently undulating soil occupies 2-acre to 20-acre tracts on hills and knolls. Areas are irregular in shape, and slopes extend in several directions. This soil has the profile described as representative for the series.

Included in mapping were areas of soils where the underlying material contains gravelly layers. Small areas of Rasset and Burnsville soils were also included in mapping. In shallow drainageways this Nymore soil generally has a deeper, more loamy surface layer.

Most areas of this soil are in woodland or have been developed for homesites. In cultivated areas, this soil has severe hazards of drought and soil blowing. Growth of common crops, such as corn and soybeans, is limited in most years because of lack of moisture. This soil is better suited to permanent vegetation or to irrigated garden crops. It is well suited to evergreens. (Capability unit IVs-2; woodland group 4; building site group 2)

Nymore loamy sand, 6 to 12 percent slopes (NyC).--This rolling soil occupies 2-acre to 40-acre tracts on hills and knolls. Areas are irregular in shape, and slopes extend in several directions.

Included in mapping were areas of soils where the underlying material contains thin, gravelly layers. Also included were small areas of Burnsville and Rasset soils.

Most areas of this soil are in woodland or pasture or have been developed for homesites. A few areas are cultivated. The hazard of drought is severe. Growth of corn and soybeans is limited by lack of moisture. This soil is better suited to permanent vegetation or to small, irrigated gardens. It is well suited to evergreens. (Capability unit VIs-1; woodland group 4; building site group 2)

Peaty Muck

Peaty muck consists of organic soils in depressions and drainageways. It is made up of Peaty muck, Peaty muck over sand, and Peaty muck over loam.

Peaty muck (Pa).--This soil occurs in wet depressions throughout the county. The largest areas are on former lake bottoms, where the soil materials consist mainly of peaty muck deposits that are 3 1/2 to 10 feet or more in thickness. On glacial uplands the organic deposits are mainly very dark brown in color and show a fiber content of 10 to 30 percent when rubbed. A few areas of Peaty muck occur on the nearly level sand plain in the northeastern part of the county. In these areas the organic materials are mostly black in color throughout their depth and contain few fibers. Sand occurs at a depth of 3 1/2 to 10 feet. Nearly all areas of this soil are associated with nearby loamy or clayey soils, such as the Hayden and Erin, and are underlain mostly by loam, clay loam, or silty clay loam.

Included in mapping were deposits of marl near the borders of a few lakes and along some of the streams in the county, such as Elm Creek. Also included were small areas where mineral soils occur within a depth of 40 inches and some bogs that are underlain by highly organic sedimentary material at a depth of 3 or 4 feet.

This soil is too wet for crops unless it is artificially drained. Bogs to be drained need a thorough preliminary investigation to determine the thickness of the peaty muck deposits. Settling occurs after the drainage is installed. Available moisture capacity is very high.

Because of the low position of this soil on the landscape, frosts late in spring and early in fall are a hazard. They are also a hazard in drained bogs. Fire in peat is hard to extinguish. This soil in some of the larger bogs is subject to blowing if row crops, such as corn or soybeans, are grown.

Peaty muck is well supplied with calcium, but it is low in content of available potassium and phosphorus. It is generally high in available nitrogen, but the content varies with drainage, seasonal temperature, and past cropping practices. Most areas are slightly acid or neutral.

Most areas of this soil are wet and marshy much of the year but often dry out in midsummer. Unless drained, this soil is poor for pasture and hay. If properly drained and fertilized, it is suited to corn and soybeans and is well suited to truck crops and lawn sod. (Capability unit IIIw-3; woodland group 7; building site group 12)

Peaty muck over sand (Pb).--This soil is in depressions on sandy stream terraces. It consists mainly of peaty muck deposits that are 12 to 50 inches thick over sand. In most places the soil is black in color and shows a fiber content of less than 5 percent when rubbed.

Included in mapping were small areas of Isan soils and of Biscay clay loam, depressional.

Unless artificially drained, this soil is too wet for crops. Bogs to be drained need a thorough preliminary investigation to determine the thickness of the peaty muck deposits. Settling occurs after the drainage is installed. Available moisture capacity is very high.

Because of the low position of this soil on the landscape, frosts late in spring and early in fall are a hazard. They are also a hazard in drained bogs. Fire in peat is hard to extinguish. This soil in some of the larger bogs is subject to blowing if row crops, such as corn or soybeans, are grown.

This soil is well supplied with calcium, but it is low in content of available potassium and phosphorus. It is generally high in available nitrogen, but the content varies with drainage, seasonal temperature, and past cropping practices. Most areas are slightly acid to neutral.

Shallow ditches are needed to lower the water table. Ditches are hard to install in some places because the underlying loose sand tends to flow, causing the ditches to cave and slough. The peaty muck layer thins rapidly if farmed intensively. In areas where the layer of peaty muck is thin when first drained and cultivated, the depth to sandy material may be shallow after a few years of cultivation. If properly drained, this soil is fairly well suited to corn and soybeans and is well suited to truck crops and lawn sod. (Capability unit IVw-1; woodland group 7; building site group 12)

Peaty muck over loam (Pm).--This soil is in depressions and drainageways on the glacial uplands. The depth of the peaty muck ranges from 12 to 42 inches in drained areas and from 12 to 50 inches in undrained areas. The underlying material consists of olive-gray or gray loam, silty clay loam, or clay loam. In most places this soil is more decomposed than Peaty muck. The color in most places is black or very dark brown. This soil shows a fiber content of 2 to 15 percent when rubbed.

Included in mapping were places where a thin layer of mineral soil, washed in from nearby slopes, covers the soil. Small areas of Glencoe soils and Peaty muck were also included.

Unless it is artificially drained, this soil is too wet for crops. Bogs to be drained need a thorough preliminary investigation to determine the thickness of the peaty muck deposits. Settling occurs after the drainage is installed. Available moisture capacity is very high.

Because of the low position of this soil on the landscape, frosts late in spring and early in fall are a hazard. They are also a hazard in drained bogs. Fire in peat is hard to extinguish. This soil in some of the larger bogs is subject to blowing if row crops, such as corn or soybeans, are grown.

This soil is well supplied with calcium, but it is low in content of available potassium and phosphorus. It is generally high in available nitrogen, but the content varies with drainage, seasonal temperature, and past cropping practices. Most areas are slightly acid to neutral.

If properly drained, this soil is suited to corn and soybeans. The drained soil is also well suited to truck crops and lawn sod. (Capability unit IIIw-3; woodland group 7; building site group 12)

Rasset Series

The Rasset series consists of deep, somewhat excessively drained, sandy soils that formed in deep sand that has thin strata of more loamy material. These soils are on glacial outwash plains. Slopes range from 2 to 25 percent. The native vegetation was tall prairie grass encroached upon by hardwoods.

In a representative profile, the surface layer is black and very dark brown loamy sand about 6 inches thick. The subsurface layer is very dark brown to dark grayish-brown loamy sand and sand about 13 inches thick. The subsoil, about 24 inches thick, consists of dark grayish-brown to light olive-brown loamy sand to sandy clay loam. This layer contains a few thin strata of sand and shale particles. The underlying material is light olive-brown and brown sand and loamy sand.

Rasset soils have low available moisture capacity and natural fertility. They have rapid permeability and internal drainage. The water table is at a depth below 10 feet in all seasons. Rasset soils have a deep root zone. They are easily blown because they are sandy and are low in organic-matter content.

Representative profile of Rasset loamy sand, 2 to 6 percent slopes, in a wooded pasture, SE1/4 SE1/4 NE1/4 sec. 21, T. 116 N., R. 22 W., Eden Prairie village:

A11--0 to 3 inches, black (10YR 2/1) loamy sand; weak, fine, granular structure; very friable; many roots; strongly acid; clear, smooth boundary.

A12--3 to 6 inches, very dark brown (10YR 2/2) loamy sand; weak, very fine and fine, subangular blocky structure; very friable; common roots; medium acid; clear, smooth boundary.

A21--6 to 11 inches, very dark grayish-brown (10YR 3/2) loamy sand or sand, grayish brown (10YR 5/2) when dry; few inclusions of very dark gray (10YR 3/1), 2 to 3 inches across; weak, medium and fine, subangular blocky structure; very friable; few roots; few, thin, light-gray (10YR 6/1) coatings on sand grains; very dark brown (10YR 2/2) worm casts and root channels; medium acid; clear, smooth boundary.

A22--11 to 19 inches, dark grayish-brown (10YR 4/2) sand, light brownish gray (10YR 6/2) when dry;

weak, medium and coarse, subangular blocky structure; very friable to loose; few roots; slightly acid; clear, smooth boundary.

B2t--19 to 23 inches, dark grayish-brown (2.5Y 4/2) and dark-brown (10YR 4/3) loamy sand and loamy coarse sand; weak, medium and coarse, subangular blocky structure; very friable; few roots; few thin clay films on faces of peds; medium acid; clear, smooth boundary.

A'21--23 to 25 inches, dark-brown (10YR 4/3) medium sand to loamy sand; weak, medium and coarse, subangular blocky structure; very friable; few roots; medium acid; abrupt, smooth boundary.

B'21t--25 to 29 inches, dark-brown (10YR 4/3) loamy sand grading to sandy loam; streaks of grayish-brown (10YR 5/2) coarse and very coarse sand; weak, coarse, subangular blocky structure; very friable; few roots; common, medium, very dark grayish-brown (10YR 3/2) and dark-brown (10YR 3/3) clay films on faces of peds; about 5 percent coarse and very coarse, sand-size shale particles; medium acid; abrupt, smooth boundary.

A'22--29 to 37 inches, dark-brown (10YR 4/3) sand; weak, fine and medium, subangular blocky structure; very friable; few roots; about 5 percent coarse and very coarse, sand-size shale fragments; medium acid; abrupt, smooth boundary.

B'22t--37 to 43 inches, light olive-brown (2.5Y 5/4) sandy clay loam; weak, coarse, subangular blocky structure; friable; common, thin, very dark grayish-brown (10YR 3/2) clay films on faces of peds and in root channels; about 5 percent very coarse, sand-size shale particles; medium acid; abrupt, smooth boundary.

C1--43 to 54 inches, light olive-brown (2.5Y 5/4) sand; common, fine, distinct, yellowish-brown (10YR 5/6) mottles; very weak, medium, subangular blocky structure; loose; about 5 percent coarse fragments, mostly shale; slightly acid; abrupt, smooth boundary.

C2--54 to 60 inches, brown (10YR 4/3) loamy sand; very weak, medium, subangular blocky structure; very friable; slightly acid.

The Ap horizon is very dark brown or very dark grayish brown and is 7 to 10 inches thick. The A2 horizon ranges from very dark grayish brown to brown. Texture of the A1 and Ap horizons is typically loamy sand but in places is sandy loam. The B horizons occur as alternating bands that range from loamy coarse sand to light clay loam in texture and are separated by coarser textured A2 horizons. The sand size in these horizons is mainly medium. In many places fine shale and igneous gravel comprise from 5 to 15 percent of the soil by volume in the B2 horizon. About 50 to 75 percent of the coarse fraction consists of shale. The loamy sand and sandy loam bands range up to 12 inches in thickness, but the loam and light clay loam bands are generally 1 to 2 inches thick and occur less commonly. The C horizon ranges from dark grayish brown to light olive brown in color. It generally consists of fine and medium sands, but the texture ranges from loamy sand to very coarse sand. The A horizon is strongly acid to neutral. The B and C horizons are medium acid to neutral.

Rasset soils developed in coarser sand and contain more coarse fragments than associated Anoka soils. They have loamy layers in the B and C horizons that are lacking in the associated Nymore and Hubbard soils. Rasset soils also have a thinner A horizon than Hubbard soils. They are not so strongly mottled in the B horizon and contain more gravel in the bands of finer textured material than the associated Litchfield soils.

Rasset loamy sand, 2 to 6 percent slopes (RsB).--This gently sloping soil is on the crowns of low hills. Areas are irregular in shape and 5 to 20 acres in size. Slopes are mostly 75 to 125 feet long. This soil has the profile described as representative for the series. In cultivated areas the surface layer is very dark grayish brown and is about 9 inches thick.

Included in mapping were small patches of soils that have a sandy loam surface layer. Also included were a few, small, wet depressions and some small spots of Braham loamy sand, silty subsoil.

The severe hazards of drought and soil blowing limit the use of this soil for farming. This soil lacks sufficient available moisture capacity for consistently good production of corn and soybeans. It is better suited to small grain and pasture. (Capability unit IIIs-2; woodland group 3; building site group 2)

Rasset loamy sand, 6 to 12 percent slopes (RsC).--This rolling soil is on the crowns and sides of large hills. Areas are irregular in shape and are mostly between 5 and 40 acres in size. Slopes are mainly 75 to 200 feet long. In cultivated areas the surface layer is very dark grayish brown.

Included in mapping were small patches of Braham loamy sand, silty subsoil. A few wet depressions containing loamy soils were also included.

The hazards of drought and erosion severely limit the use of this soil for cultivated crops. It is better suited to small grain and pasture. (Capability unit IVs-1; woodland group 3; building site group 2)

Rasset loamy sand, 12 to 25 percent slopes (RsD).--This moderately steep to steep soil occupies hillsides. Areas are irregular in shape and are mostly less than 10 acres in size. Slopes are 75 to 150 feet long. This soil has a profile similar to that described as representative for the series, except that the surface layer and subsoil are commonly thinner. In cultivated areas the surface layer is very dark grayish brown.

Included in mapping were small patches of Braham loamy sand, silty subsoil.

The hazards of drought and erosion and the steepness of slopes severely limit the use of this soil for cultivated crops. Gullies form rapidly in this soil if it is cultivated. It is better suited to

uses that keep the soil covered with plants all year long. (Capability unit VIIs-1; woodland group 3; building site group 2)

Salida Series

The Salida series consists of deep, excessively drained, sandy and gravelly soils that formed in 6 to 14 inches of alluvium over calcareous gravel and sand. These soils are on knolls and hills on stream terraces and outwash plains. Slopes are both simple and complex and range from 2 to 35 percent. The native vegetation was prairie grasses that are encroached upon by oaks in some places.

In a representative profile, the surface layer is black coarse sandy loam about 10 inches thick. The subsoil is very dark grayish-brown gravelly loamy sand about 4 inches thick. The underlying material is dark grayish-brown to brown gravelly loamy sand.

Salida soils have very low available moisture capacity. Permeability and internal drainage are very rapid. The water table is deep in all seasons. The root zone is shallow and is limited to the surface layer and thin subsoil. These sandy soils are low in natural fertility and organic-matter content.

Representative profile of Salida coarse sandy loam, 2 to 6 percent slopes, in a cultivated field, SE1/4 NE1/4 SE1/4 sec. 3, T. 119 N., R. 24 W.:

Ap--0 to 10 inches, black (10YR 2/1) coarse sandy loam; weak, very fine, granular structure; friable; common roots; neutral; abrupt, smooth boundary.

B--10 to 14 inches, very dark grayish-brown (10YR 3/2) gravelly loamy sand; weak, very fine, granular structure; very friable; common roots; about 15 percent gravel; neutral; clear, smooth boundary.

C1--14 to 18 inches, dark grayish-brown (10YR 4/2) gravelly loamy coarse sand; single grain; loose; few roots; about 20 percent gravel; mildly alkaline; strongly calcareous; clear, smooth boundary.

C2--18 to 60 inches, grayish-brown (10YR 5/2) and brown (10YR 4/3) gravelly loamy coarse sand; single grain; loose; about 25 percent gravel; mildly alkaline; strongly calcareous.

The solum commonly is 8 to 14 inches thick, but it is thinner in areas where the surface layer has been eroded. The Ap horizon is black or very dark brown coarse sandy loam or loamy coarse sand 7 to 10 inches thick. The B horizon is commonly discontinuous. It is 3 to 6 inches in thickness and very dark grayish brown to dark yellowish brown in color. Texture ranges from gravelly loamy sand to coarse sandy loam. Texture of the C horizon is gravelly loamy coarse sand or gravelly sand. Gravel content throughout the profile ranges from 10 to 60 percent but is commonly 20 to 40 percent. Reaction of the A and B horizons is commonly neutral but ranges from slightly acid to mildly alkaline. The A horizon is weakly calcareous in places where it is mildly alkaline. The C horizon is mildly alkaline and strongly calcareous.

Salida soils contain more gravel throughout than the associated Hubbard and Nymore soils. Salida soils are more sandy and more shallow to sand and gravel than the associated Estherville soils.

Salida coarse sandy loam, 2 to 6 percent slopes (SaB).--This gently undulating soil occupies 2-acre to 10-acre tracts on outwash knolls and ridges. Slopes are 75 to 120 feet long. This soil has the profile described as representative for the series.

Included in mapping were small patches of soils that have a surface layer of dark grayish brown or dark brown. Also included were a few patches of soils that have a surface layer of brown, calcareous loamy gravel and sand that holds little water. There are also small patches of Estherville soils in downslope drainageways. In places the underlying material contains common stones and boulders 3 to 12 inches in diameter.

The hazard of drought is severe, and therefore this soil is not well suited to cultivated crops. Crop growth is limited in most years by lack of moisture. The hazards of soil blowing and water erosion are slight to moderate. (Capability unit IVs-2; woodland group 4; building site group 2)

Salida coarse sandy loam, 6 to 12 percent slopes (SaC).--This rolling soil occupies 2-acre to 10-acre strips, 75 to 125 feet wide, on outwash plains. Shallow downslope drainageways and occasional gullies give the surface a wavy appearance. This soil has a profile similar to that described as representative for the series, except that in places the surface layer is very dark grayish brown to dark brown. Near the base of the slopes, the soil is thicker.

Included in mapping were a few patches of dark-brown, calcareous loamy gravel and sand. These areas hold little moisture. Also included were small areas of Estherville soils in narrow drainageways. In places the underlying material contains common stones and cobblestones 3 to 12 inches in diameter.

The hazard of drought severely limits the use of this soil for common farm crops. Crop growth is limited by lack of moisture. The hazards of soil blowing and water erosion are moderate. This soil is better suited to permanent vegetation than to most other uses. (Capability unit VIs-1; woodland group 4; building site group 2)

Salida coarse sandy loam, 12 to 18 percent slopes (SaD).--This moderately steep soil occupies 2-acre to 10-acre strips, 60 to 120 feet wide, on outwash plains. Shallow downslope drainageways give the surface a wavy appearance. This soil has a profile similar to that described as representative for the series, except that there are areas that have a very dark brown surface layer and cultivated fields have a surface layer that is very dark grayish brown or dark brown. Near the base of the slopes and in the drainageways, the soil is darker and the surface layer and subsoil are thicker.

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Included in mapping were a few patches of brown calcareous loamy gravel and sand. Also included were a few patches of Burnsville and Estherville soils. In a few places near the glacial uplands, this Salida soil is underlain by loamy till within a depth of 4 to 8 feet. A few areas are underlain by sand. In places the underlying material contains common stones and cobblestones 3 to 12 inches in diameter.

Most areas of this soil are in permanent pasture. It is better suited to permanent vegetation than to most other uses because of its severe hazards of drought and erosion. (Capability unit VIIs-1; woodland group 4; building site group 2)

Salida coarse sandy loam, 18 to 35 percent slopes (SaE).--This steep to very steep soil occupies 2-acre to 10-acre strips, 60 to 200 feet wide, on outwash plains. Shallow downslope drainageways and a few gullies give the surface a wavy appearance. This soil has a profile similar to that described as representative for the series, except that some areas have a dark-brown surface layer. Near the base of the slopes, the surface layer and subsoil are thicker.

Included in mapping were a few areas of Burnsville soils and a few small patches of Estherville soils. Also included, in Fort Snelling State Park, was a very steep sandy soil underlain by limestone at a depth of 6 to 24 inches. Near the glacial uplands, a few included areas are underlain by loamy till within a depth of 4 to 8 feet.

Most areas of this soil are in permanent pasture. This steep, very droughty soil is better suited to permanent vegetation than to most other uses. Gullies should be shaped and seeded to grass before they become difficult to stabilize. (Capability unit VIIs-1; woodland group 4; building site group 2)

Shields Series

The Shields series consists of deep, somewhat poorly drained, clayey soils that formed in 30 to 60 inches of calcareous sediments overlying calcareous loam till. In many places a 2-foot to 3-foot layer of silty sediment lies between the clay sediment and the loam till. These soils lie on broad flats and in shallow drainageways. The native vegetation was mixed hardwood forest. There are a few stones and boulders near the surface.

In a representative profile, the surface layer is very dark gray silty clay loam about 5 inches thick. The subsurface layer is dark-gray silt loam about 3 inches thick. The subsoil is very dark gray and olive-gray clay about 28 inches thick. The underlying material is olive-gray, calcareous clay.

Shields soils have high available moisture capacity, slow internal drainage, and slow permeability. The water table is at a depth of 1 to 3 feet during wet periods. The root zone is deep, but it is restricted by the high water table. Organic-matter content is low, and natural fertility is medium. Lime is needed in some places.

Representative profile of Shields silty clay loam, in a wooded tract, NE1/4 NW1/4 NE1/4 sec. 8, T. 118 N., R. 23 W.:

A1--0 to 5 inches, very dark gray (10YR 3/1) silty clay loam; weak, very fine, subangular blocky structure; friable; common roots; medium acid; clear, smooth boundary.

A2--5 to 8 inches, dark-gray (10YR 4/1) silt loam, gray (10YR 6/1) when dry; few, fine, faint, dark grayish-brown (10YR 4/2) mottles; moderate, thin, platy structure; friable; common roots; medium acid; clear, smooth boundary.

B1--8 to 11 inches, very dark gray (10YR 3/1) heavy silty clay loam; moderate to strong, medium, subangular blocky structure; firm; few roots and fine tubular pores; many, thick, porous, gray (10YR 6/1) coatings on faces of peds; strongly acid; clear, smooth boundary.

B21tg--11 to 15 inches, very dark gray (10YR 3/1) clay; few, fine, faint, very dark grayish-brown (2.5Y 3/2) and distinct olive-brown (2.5Y 4/6) mottles; moderate, coarse, prismatic structure parting to strong, coarse, angular blocky structure; firm; few roots; few, fine, tubular pores; many, thick, black (10YR 2/1) clay films on faces of peds; strongly acid; clear, smooth boundary.

B22tg--15 to 21 inches, olive-gray (5Y 4/2) clay; few, fine, olive-brown (2.5Y 4/6) mottles; moderate, coarse, prismatic structure parting to strong, coarse, angular blocky structure; very firm; few roots along cleavage planes; few, fine, tubular pores; many, thick, black (10YR 2/1) clay films on faces of peds; strongly acid; clear, smooth boundary.

B23tg--21 to 29 inches, olive-gray (5Y 4/2) clay; few, fine, faint, olive-brown (2.5Y 4/6) mottles; moderate, coarse, prismatic structure parting to strong, coarse, angular blocky structure; firm; few roots along vertical cleavage planes; few, fine, tubular pores; many, thick, black (10YR 2/1) clay films on faces of peds and in root channels; medium acid; clear, smooth boundary.

B3tg--29 to 36 inches, olive-gray (5Y 4/2) clay; few, fine, faint, olive (5Y 4/3) mottles; moderate, coarse, prismatic structure parting to strong, coarse, angular blocky structure; firm; few roots along vertical cleavage planes; few, fine, tubular pores; many, thick, black (10YR 2/1) clay films on ped faces and in root channels; neutral; clear, abrupt boundary.

Cg--36 to 60 inches, olive-gray (5Y 5/2) clay; many, fine, distinct, olive (5Y 5/4) mottles; moderate, very fine, subangular blocky structure; firm; few, thin, black (10YR 2/1) clay films in root channels; common white lime concentrations; mildly alkaline; strongly calcareous.

The solum is 30 to 48 inches thick. The A1 horizon is 3 to 6 inches thick. The A2 horizon is silty clay loam or silt loam 2 to 8 inches thick. The Ap horizon is 7 to 9 inches thick and has a

characteristic abrupt lower boundary. Tonguing of A2 material into the B horizon is expressed by very thick dark-gray and gray coatings on faces of peds. Texture of the B2 horizon is silty clay or clay. Clay content in the finest textured layer ranges from 45 to 60 percent. Sand content is less than 10 percent and is typically less than 5 percent. Texture of the C horizon is variable, ranging from clay to silty clay loam, silt loam, or loam. In places where the C horizon is heavy silty clay loam or clay, it terminates at a depth of less than 72 inches and commonly less than 54 inches. Silty sediments do not occur in all areas, but where they do occur, they are up to 4 feet in thickness. Loamy till commonly occurs within a depth of 10 feet. The A horizon is medium acid to neutral. The B horizon is neutral to strongly acid, and the C horizon is weakly to strongly calcareous.

As mapped in Hennepin County, these soils are darker in color in the upper part of the B horizon than the defined range for the Shields series. This difference, however, does not alter their usefulness or behavior.

Shields soils have a thinner, lighter colored A horizon than the associated Minnetonka soils. They are higher in clay content and lower in sand content than similar Dundas soils.

Shields silty clay loam (Sh).--This nearly level soil occupies flats and shallow drainageways. Areas are mostly 2 to 5 acres in size, but a few tracts are up to 15 acres in size.

Included in mapping were small areas of Dalbo soils on slight rises and a few small areas of clayey soils in depressions.

This soil needs drainage to be productive. Because water is removed slowly by tile drains, tiles need to be closely spaced to be effective. If properly drained and managed, this soil is moderately well suited to crops grown in the county. An occasional sod crop helps tile drains to remove excess water more rapidly. (Capability unit IIw-2; woodland group 6; building site group 11)

Shorewood Series

The Shorewood series consists of deep, moderately well drained soils that formed in calcareous clayey sediments 2 to 5 feet thick over calcareous loamy till. In many places a 1-foot to 3-foot layer of silty sediment occurs between the clay and the loamy till. These are nearly level to gently sloping soils in smooth, convex positions on hills and knolls. Slopes are mostly simple. The native vegetation was mixed hardwoods. Shorewood soils are associated mainly with Hayden and Erin soils.

In a representative profile, the surface layer is black silty clay loam about 10 inches thick. The subsoil is about 23 inches thick and consists of three layers. The upper part is very dark grayish-brown silty clay; the middle part is olive-brown silty clay, and the lower part is light olive-brown silty clay. The underlying material is light olive-brown clay loam.

Shorewood soils have high available moisture capacity, moderately slow permeability, and medium to slow internal drainage. The water table in the more nearly level areas is at a depth of 3 to 5 feet during wet periods. The root zone is deep, but plant roots develop slowly in the firm, clayey subsoil. The surface layer is high in organic-matter content. Shorewood soils are very fertile, but crops grown on them respond well to additional fertilizer.

Representative profile of Shorewood silty clay loam, 0 to 2 percent slopes, in a cultivated field, 240 feet east and 320 feet north of the southwest corner, SE1/4 SE1/4 SW1/4 sec. 28, T. 117 N., R. 23 W.:

Ap--0 to 10 inches, black (10YR 2/1) silty clay loam; strong, very fine, subangular blocky structure; friable; neutral; clear, smooth boundary.

B1--10 to 18 inches, very dark grayish-brown (2.5Y 3/2) silty clay; strong, fine, subangular blocky structure; firm; few pores; common, patchy, grainy coatings on ped faces; medium acid; clear, smooth boundary.

B2t--18 to 30 inches, olive-brown (2.5Y 4/4) silty clay; strong, medium, subangular blocky and angular blocky structure; firm; common pores; thick, moderately patchy, black and very dark brown clay films on ped faces; slightly acid; clear, smooth boundary.

B3t--30 to 33 inches, light olive-brown (2.5Y 5/4) silty clay; moderate, coarse, subangular blocky structure; firm; common pores; thin, patchy, black clay films on vertical ped faces; few black organic stains; neutral, clear, smooth boundary.

C--33 to 60 inches, light olive-brown (2.5Y 5/4) clay loam; weak, fine and medium, subangular blocky structure; firm; many pores; few, fine, black, old root channel fillings; common, medium, prominent, yellowish-brown (10YR 5/8) iron oxide concretions; calcareous; moderately alkaline.

The solum is 28 to 40 inches thick. The A horizon is black, very dark brown, or very dark gray. The B2 horizon ranges from dark grayish brown to light olive brown and yellowish brown in color. Texture is typically silty clay that is 40 to 50 percent clay, but clay content ranges from 35 to 60 percent. Sand content is less than 15 percent and centers around 5 percent. The C horizon is grayish brown to light olive brown. Texture is silty clay, silty clay loam, clay loam, silt loam, or loam, depending upon thickness of the sediments. There is commonly loamy till within a depth of 7 feet. The A horizon is slightly acid to neutral, and the B horizon is neutral to medium acid.

Shorewood soils are lower in sand content and typically higher in clay content than similar Kilkenny, Le Sueur, and Lerdal soils. They have a thicker and darker colored A horizon than the associated Dalbo soils. They are better drained than the associated Minnetonka soils.

Shorewood silty clay loam, 0 to 2 percent slopes (SwA).--This nearly level soil is in 2-acre to 5-acre areas on slight rises of low relief and in 2-acre to 25-acre areas on smooth hilltops. This soil has the profile described as representative for the series.

Included in mapping were a few patches of soils that have a silt loam and silty clay surface layer. In a few places the surface layer is loam, and there are thin seams of sandy loam in the upper part of the subsoil. Also included were small areas of Le Sueur soils. The few drainageways included contain poorly drained Minnetonka soils.

If well managed, this soil is good cropland and is suited to all the major crops grown in the county. Maintenance of tilth is the main management need. Tilth can be maintained by timely tillage, using minimum-tillage practices, and by returning large amounts of crop residue to the soil. (Capability unit IIs-1; woodland group 1; building site group 8)

Shorewood silty clay loam, 2 to 6 percent slopes (SwB).--This gently sloping soil occupies 2-acre to 15-acre areas on smooth knolls and hilltops. Slopes are 75 to 200 feet long. This soil has a profile similar to that described as representative for the series, except that the surface layer is very dark brown in many places.

Included in mapping were patches of soils that have a surface layer of silt loam and silty clay. A few patches of soils have a loam surface layer and thin sandy loam layers in the upper part of the subsoil. Also included were small areas of the loamy Le Sueur and Lester soils. The few drainageways contain the poorly drained Minnetonka soils. There is also a small acreage of Shorewood soils that have slopes of 6 to 12 percent.

If well managed, this soil is good cropland and is suited to all the major crops grown in the county. The main management needs are control of erosion and maintenance of tilth. The hazard of erosion is slight to moderate. (Capability unit IIe-2; woodland group 1; building site group 8)

Zimmerman Series

The Zimmerman series consists of deep, excessively drained, sandy soils that formed in deep, fine, wind-worked sand. These soils occupy sides of knolls near the Crow River in the northwestern part of the county. Slopes are mostly complex and range from 2 to 18 percent. The native vegetation was mixed hardwoods.

In a representative profile, the surface layer is dark grayish-brown loamy fine sand about 9 inches thick. The subsurface layer is dark grayish-brown and brown sand about 11 inches thick. The subsoil is stratified, very dark grayish-brown to brown fine sand, loamy sand, and sandy loam about 34 inches thick. The underlying material is olive-brown fine sand.

Zimmerman soils have very low available moisture capacity and rapid internal drainage and permeability. The water table is at a depth below 10 feet in all seasons. Crop growth is severely limited by drought unless rainfall distribution is good. Because the surface layer is sandy and low in organic-matter content, it is easily blown. Zimmerman soils have low natural fertility, but crops grown on them respond well to additional fertilizer if moisture is available.

Representative profile of Zimmerman loamy fine sand, 2 to 6 percent slopes, in a cultivated field, SE1/4 SE1/4 SW1/4 sec. 30, T. 120 N., R. 23 W.:

Ap--0 to 9 inches, dark grayish-brown (10YR 4/2) loamy fine sand, light brownish gray (10YR 6/2) when dry; weak, very fine, granular structure; very friable; common fine roots; neutral; clear, smooth boundary.

A2--9 to 20 inches, dark grayish-brown (10YR 4/2) and brown (10YR 5/3) fine sand; weak, very fine, granular structure; very friable; few roots; slightly acid; abrupt, broken boundary.

B2t--20 to 21 inches, very dark grayish-brown (10YR 3/2) loamy fine sand, weak, very fine, subangular blocky structure; very friable; few fine roots; slightly acid; abrupt, broken boundary.

A'21--21 to 28 inches, brown (10YR 5/3) fine sand; weak, very fine, granular structure; very friable to loose; slightly acid; abrupt, smooth boundary.

B'21t--28 to 34 inches, dark-brown (10YR 3/3) loamy fine sand with nets of dark grayish-brown (10YR 4/2); weak, fine, subangular blocky structure; very friable; common clay bridges between sand grains; neutral; abrupt, smooth boundary.

A'22--34 to 50 inches, brown (10YR 5/3) fine sand; weak, very fine, granular structure; very friable to loose; neutral; abrupt, smooth boundary.

B'22t--50 to 54 inches, brown (10YR 5/3) sandy loam; few, fine, distinct, grayish-brown (10YR 5/2) mottles; weak, very fine, subangular blocky structure; friable; common, thin, dark-brown (10YR 3/3) clay films on faces of peds; neutral; clear, smooth boundary.

C--54 to 60 inches, olive-brown (2.5Y 4/4) fine sand; single grain; loose; neutral.

The solum is commonly from 40 to 60 inches thick but ranges to 80 inches. The Ap horizon is very dark grayish-brown to dark-brown loamy fine sand or fine sand. Sand in the A horizon is mainly fine and medium, but there are small amounts of very fine sand and less than 1 percent coarse sand. The B horizon consists of thin, irregular, discontinuous, 1/3-inch to 5-inch bands that occur at depths between 20 and 60 inches. Those that are sandy loam are less than 6 inches in aggregate thickness within a 60-inch depth. The B horizons are separated by A2 horizons. Texture of the B horizon is commonly loamy fine sand, but it ranges from fine sand to light fine sandy loam or sandy loam. Less than 5 percent of the sand fraction is coarser than medium sand, and the very coarse sand fraction is less than 1 percent. Reaction of the solum ranges from medium

acid to neutral, but it is commonly medium acid or slightly acid.

Zimmerman soils have sandy loam bands that have a combined thickness of less than 6 inches, whereas the associated Anoka soils have a composite thickness of more than 6 inches. Zimmerman soils have thin, loamy bands in the B horizon, and they formed in finer sands than the associated Nymore soils.

Zimmerman loamy fine sand, 2 to 6 percent slopes (ZmB).--This gently undulating soil occupies 2-acre to 15-acre areas on low mounds and knolls on stream terraces. Slopes are 75 to 150 feet long and in most places extend in several directions. This soil has the profile described as representative for the series.

Included in mapping were small areas of soils that have a surface layer of sand. In a few places this Zimmerman soil is underlain by loam at a depth within 48 inches.

The hazards of drought and soil blowing severely limit the use of this soil. Because of its very low available moisture capacity, it is poorly suited to corn and soybeans. This soil is fair for small grain and pasture. It is well suited to irrigated truck crops, but the areas are too small for large-scale operations. (Capability unit IVs-2; woodland group 4; building site group 2)

Zimmerman loamy fine sand, 6 to 18 percent slopes (ZmC).--This rolling soil occupies 2-acre to 10-acre areas on knolls of stream terraces. It typically occupies strips 75 to 125 feet wide on side slopes. Shallow downslope drainageways and occasional gullies give the surface a wavy appearance. This soil has a profile similar to that described as representative for the series, except that it includes patches of soils that have a dark-brown surface layer.

Included in mapping were small areas of soils that have a surface layer of sand. In narrow drainageways crossing through this Zimmerman soil, the surface layer is darker and is generally finer textured. In spots, loamy till occurs within a 48-inch depth. In places there are thin, loamy bands in the subsoil and underlying material.

The severe hazards of drought and soil blowing limit the use of this soil. Because of the steepness of slopes, irrigation equipment is difficult to move. In areas where general farming is practiced, this soil is better suited to early crops or permanent vegetation than to most other uses. It is poorly suited to corn and soybeans because of its very low available moisture capacity. (Capability unit VIs-1; woodland group 4; building site group 2)

USE AND MANAGEMENT OF THE SOILS

This section describes use and management of the soils for crops and pasture. It also discusses uses of the soils as woodland and as wildlife habitat, explains uses of the soils for engineering, and gives facts about uses of the soils for town and country planning and for recreation.

Use of the Soils for Crops and Pasture

For the cultivated soils in Hennepin County, management practices are needed that control erosion, improve drainage, and preserve tilth and fertility. The main practices that are needed are conservation cropping systems, drainage, fertilization, minimum tillage, terracing, contour farming, and contour stripcropping.

A few soils in the county have few if any limitations for farming. Erosion is a hazard on about 50 percent of the acreage in the county if the soils are cultivated. Management practices are needed to control erosion.

The use of conservation cropping systems is an important management practice in the county. Conservation cropping systems needed for specific areas of soils depend upon the other management practices used in combination with the cropping system. Consider, for example, Lester soils having slopes of 8 percent that are 200 feet long. If these soils are farmed up and down hill and if no other management practices are used, the conservation cropping system needs to consist mainly of sod crops to control erosion. If the same soils are farmed on the contour and row crops are plow planted, the cropping system can consist mainly of row crops.

In many places minimum tillage practices can reduce soil loss 50 percent or more by improving soil tilth. Soils in good tilth are better aerated and absorb greater amounts of rainfall, which increases the available moisture supply for crops. Soil aeration is also important to the utilization of fertilizer.

On the loamy and clayey soils in the county, such practices as working the soil at the right moisture content, keeping tillage to a minimum, and supplying large amounts of crop residue are also helpful in maintaining and preserving tilth, which in turn helps to control erosion.

Wetness is a hazard on about 30 percent of the land in the county, and drainage is needed if the soils are cultivated. Tile drains work fairly well in most areas in the county. Ditches that provide outlets for tile drains are needed in some areas, especially in the northwestern part of the county.

Drought is a hazard on about 20 percent of the acreage. Soils that have low available moisture capacity are difficult to improve to a large degree with management practices. Either early crops that use moisture available early in spring or irrigation is necessary for growing the most profitable crops in the county, such as corn and soybeans. Many droughty soils have a sandy surface layer and

therefore have an additional hazard of soil blowing. Such sandy soils as Hubbard loamy sand need a cropping system that provides a cover of residue in winter and early in spring, when soil blowing is most likely to occur.

For information concerning the various combinations of management practices suitable for a specific farm or field, consult the local representative of the Soil Conservation Service.

The soils in Hennepin County vary widely in their need for lime and fertilizer. Most crops grown on them, however, respond to additions of fertilizer. The Hayden, Erin, and other mineral soils that formed in loam are medium to moderately high in phosphate and moderately low to medium in potash. Wet, poorly drained soils, such as those of the Cordova and Minnetonka series, are generally high in content of organic matter and nitrogen. The poorly drained soils warm up slowly in spring, however, and a starter fertilizer that contains nitrogen is needed to get corn off to a fast start. Corn responds well to high rates of nitrogen on soils that have high moisture storage capacity, such as those of the Lester and Cordova series. Some of the soils need lime to bring reaction to a level at which other plant foods will be most readily available. On such mildly alkaline soils as the Canisteo and Chaska, adding lime would be harmful to crops. The kind and amount of fertilizer and lime needed depend on the kind of soil, the crops to be grown, and past management.

Soil tests can be obtained through the University of Minnesota Soil Testing Laboratory, which provides laboratory analyses and interprets the results of the tests. It is best to have the soils tested once during the cropping system, or about every 3 to 5 years, to determine the need for lime and fertilizer.

The soil map is useful in selecting soil samples for testing, because it shows the boundaries of the different soils. Reliable test results cannot be obtained if samples from different kinds of soil are mixed together or are from the same kind of soil that has had widely different management. The largest area that should be represented by one soil sample is about 10 acres. Information about taking soil samples for testing can be obtained from the county agent or from the local representative of the Soil Conservation Service.

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 if 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 the slope, depth, or other characteristics of the soils; does not take into consideration possible but unlikely major reclamation projects; and does not apply to horticultural crops or other crops that require special management.

Those familiar with the capability classification can infer from it much about the behavior of soils if 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 (8)

In the capability system, all kinds of soil are grouped at three levels, the capability class, subclass, and unit. These are discussed in the following paragraphs.

CAPABILITY CLASSES, the broadest groups, are designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use, defined as follows:

Class I. Soils have few limitations that restrict their use.

Class II. Soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.

Class III. Soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.

Class IV. Soils have very severe limitations that reduce the choice of plants, require very careful management, or both.

Class V. Soils are not likely to erode but have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife habitat. (No soils in Class V are in Hennepin County.)

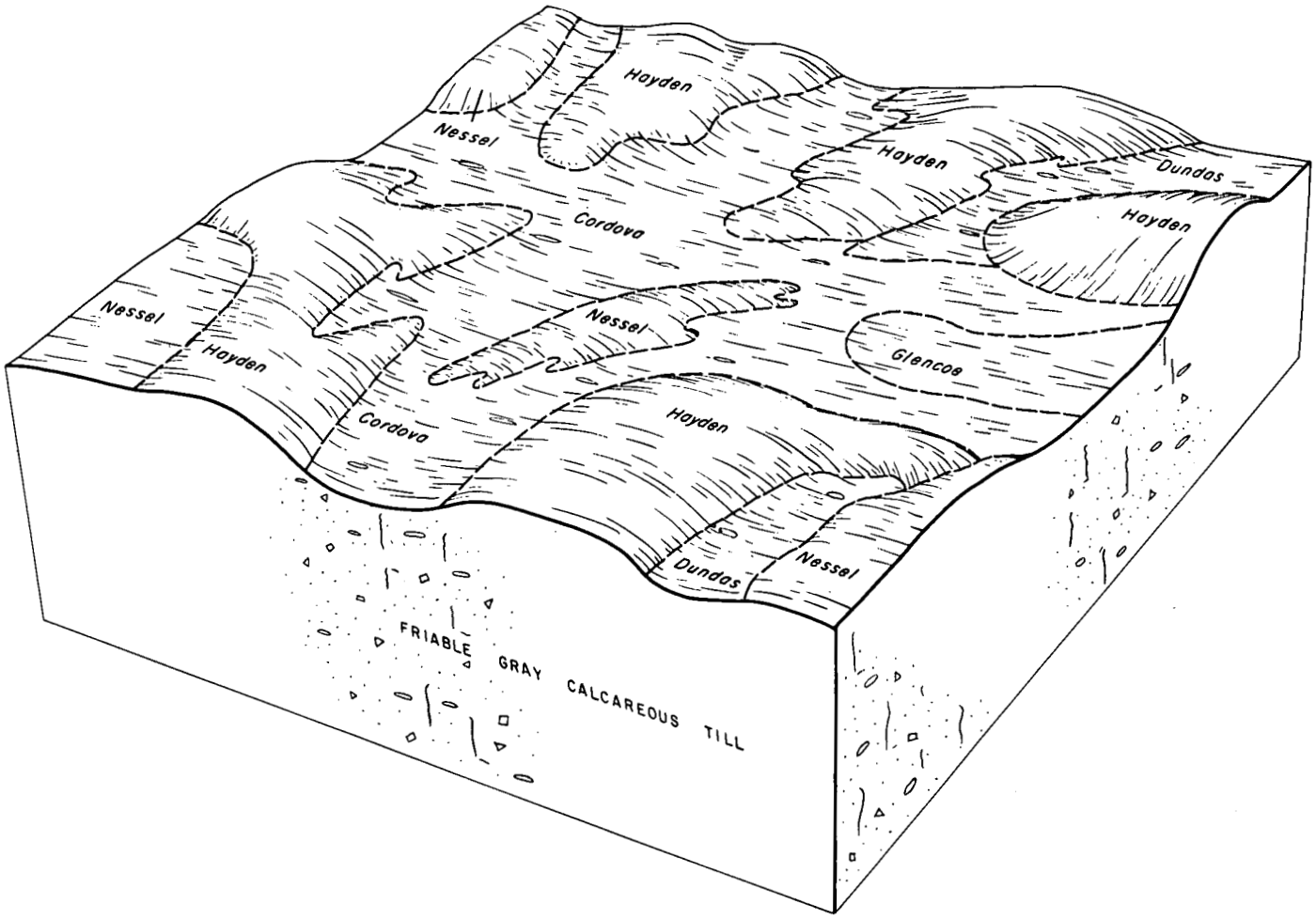
Class VI. Soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wildlife habitat.

Class VII. Soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to pasture or range, woodland, or wildlife habitat.

Class VIII. Soils and landforms have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife habitat, water supply, or esthetic purposes.

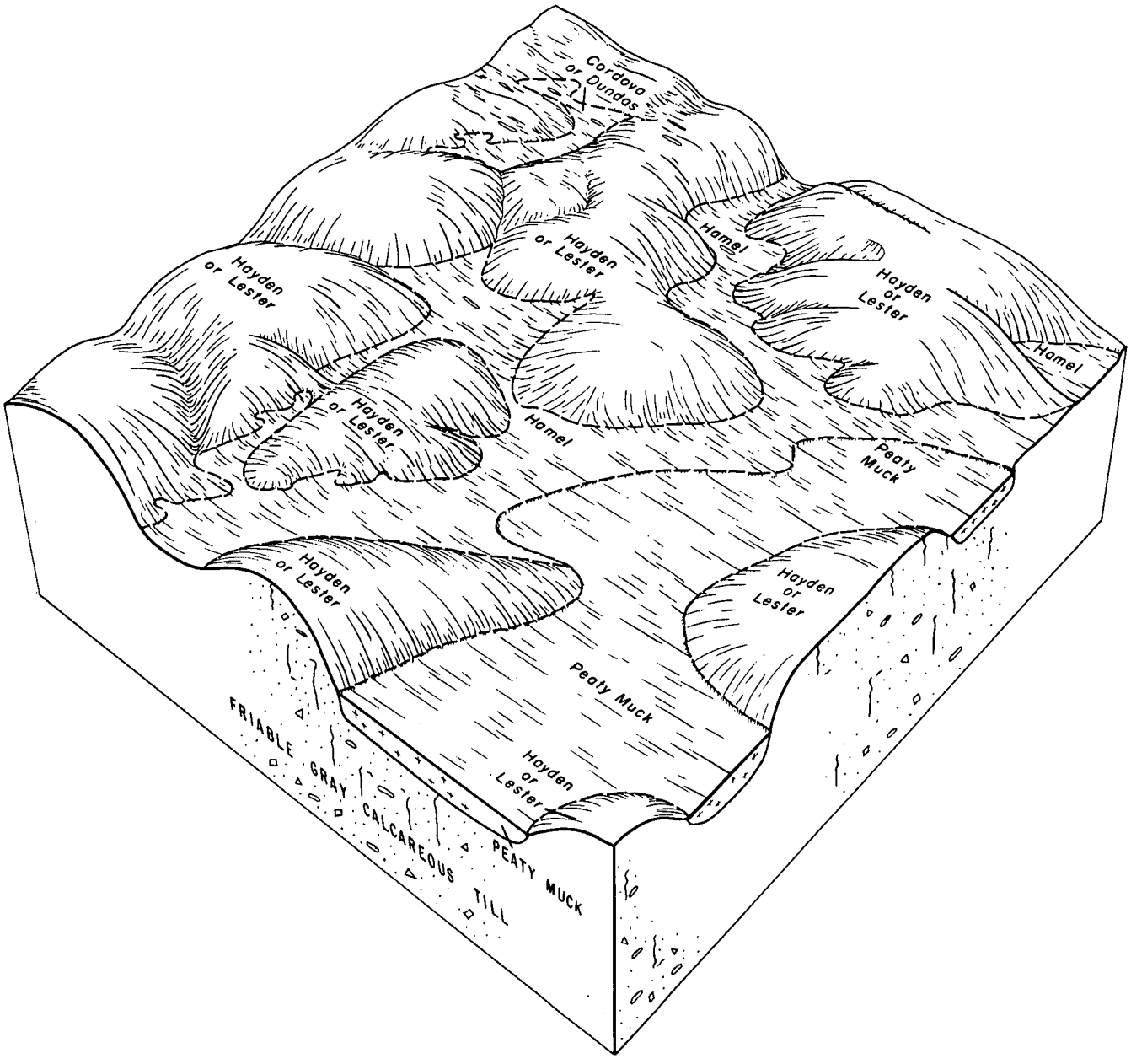
CAPABILITY SUBCLASSES are soil groups within one class; they are designated by adding a small letter, e, w, s, or c, to the class numeral, for example, IIe. The letter e shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; w shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); s shows that the soil is limited mainly because it is shallow, droughty, or stony; and c, used in only some parts of the United States but not in Hennepin County, shows that the chief limitation is climate that is too cold or too dry.

In class I there are no subclasses, because the soils of this class have few limitations. Class V (none in Hennepin County) can contain, at the most, only the subclasses indicated by w, s, and c, because the soils in class V are subject to little or no erosion, although they have other limitations that restrict their use largely to pasture, range, woodland, wildlife habitat, or recreation.

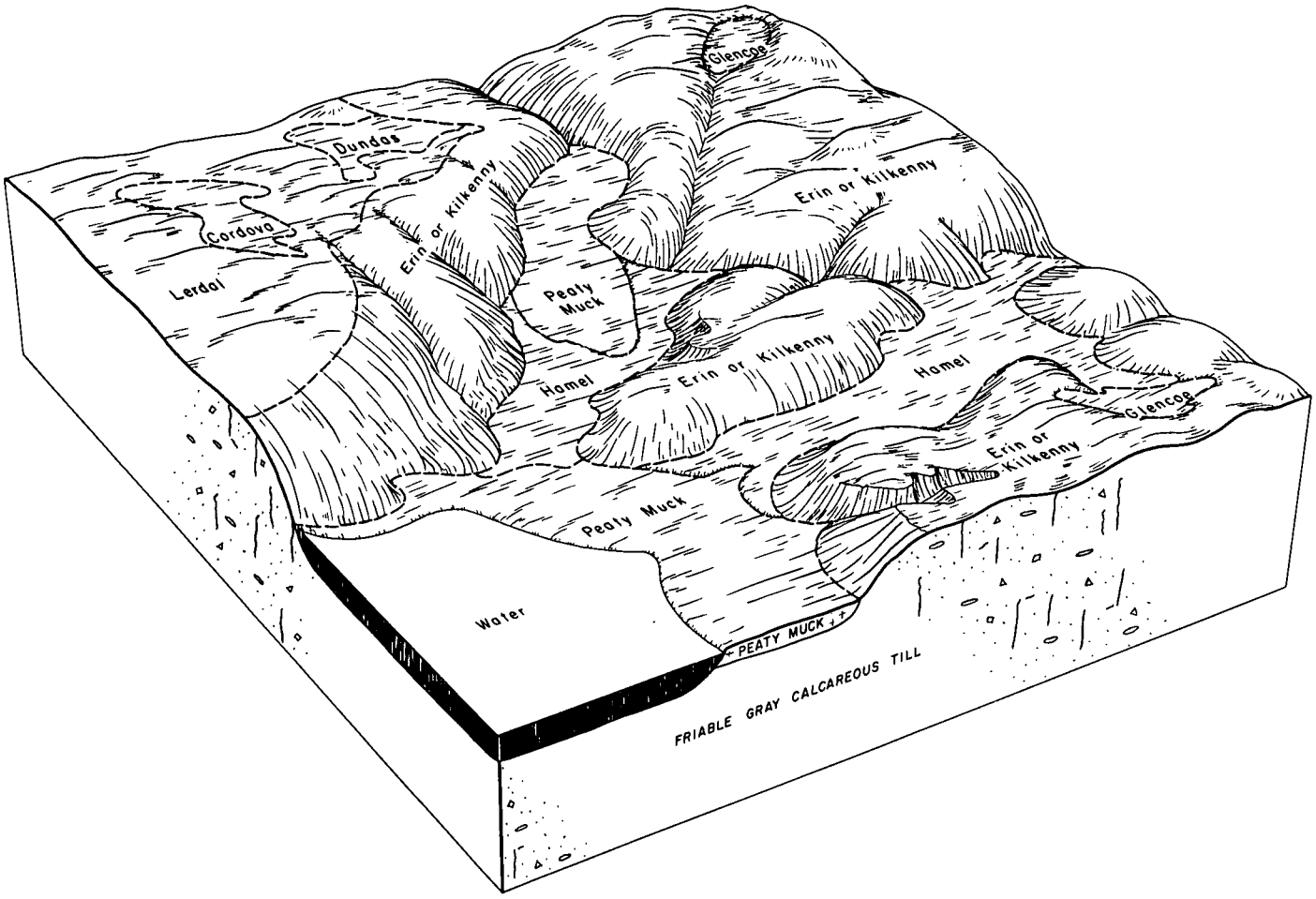


Typical pattern of soils in association 1.

PLATE II



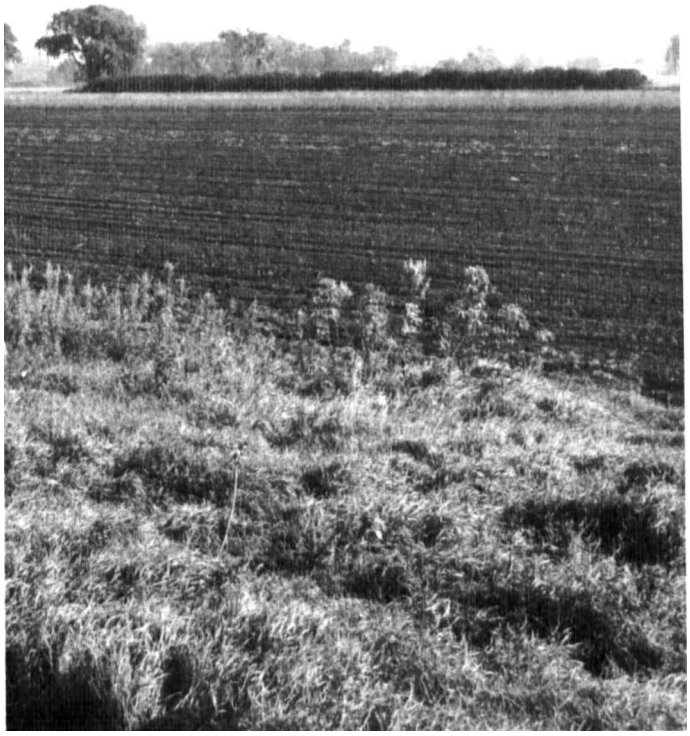
Typical pattern of soils in associations 3 and 4.



Typical pattern of soils in association 5.

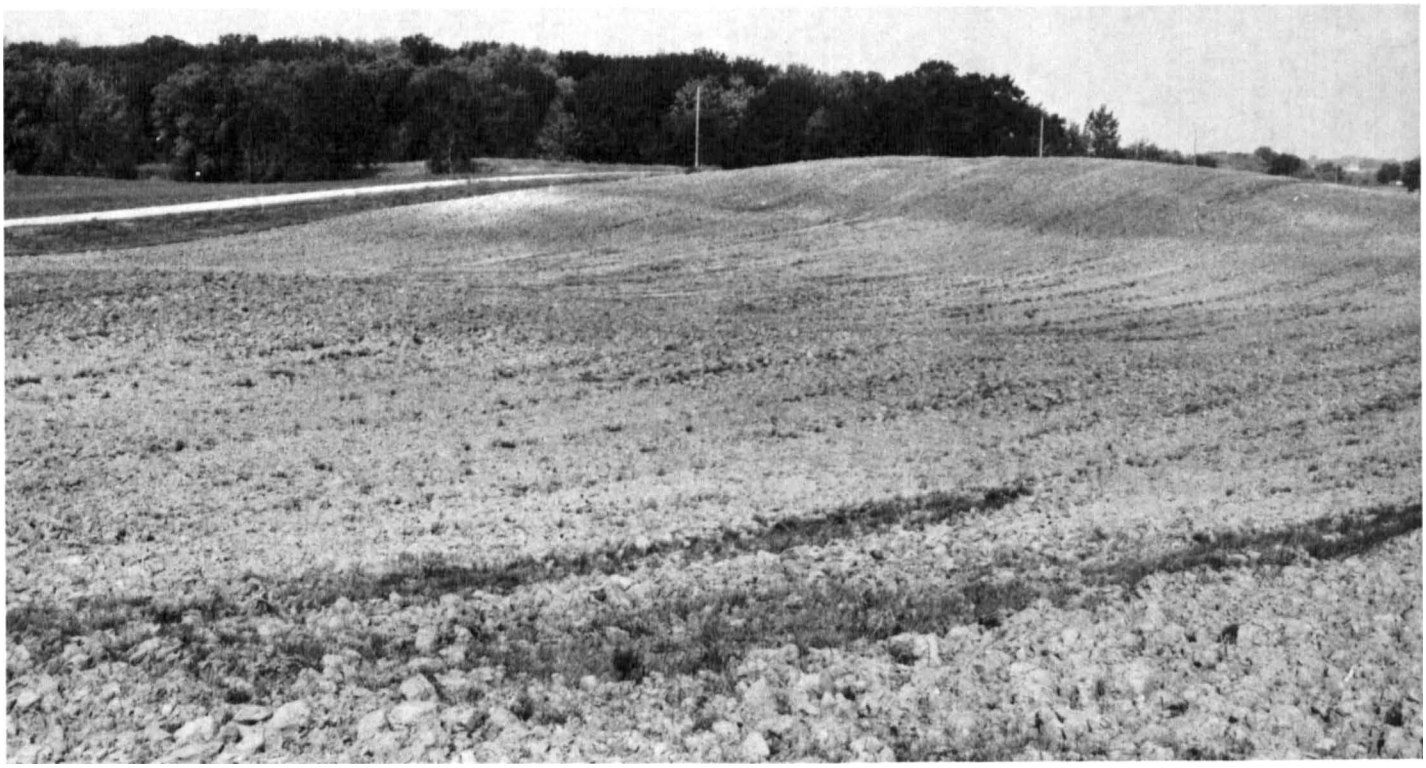
PLATE IV

Typical landscape in association 6. Hayden soils are on the low knolls in the foreground. Burnsville and Kingsley soils are on the wooded hills in the background.

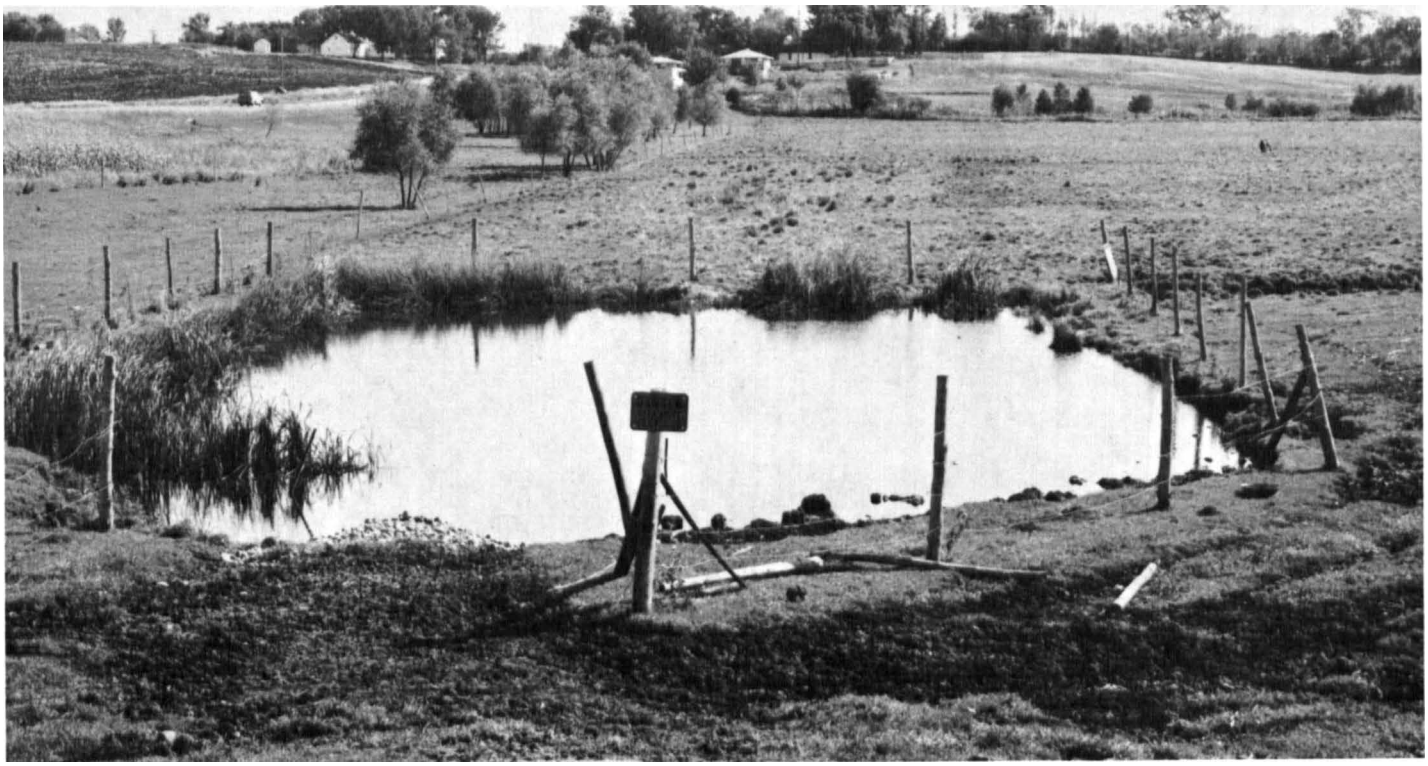


Typical landscape in association 7, showing an area of nearly level, sandy soils.

Septic tank effluent that has seeped from an area of slowly permeable Fill land, consisting of Hayden soils. Coarse grass marks the path of the effluent downslope and into the stream below.



A recently plowed field of Dundas and Hayden soils. The Dundas soil, in the shallow drainageway in the foreground, has a grayish color and is hard to keep in good tilth. The Hayden soils, which are in capability class III, are on the knoll in the background.



Pit used for watering livestock in an area of soils of capability unit IIIw-1.

PLATE VI

Typical landscape of Erin and Kilkenny soils of capability unit IVe-2, showing the irregular topography.

Severely eroded and gullied Dickman soils of capability unit IVe-4.

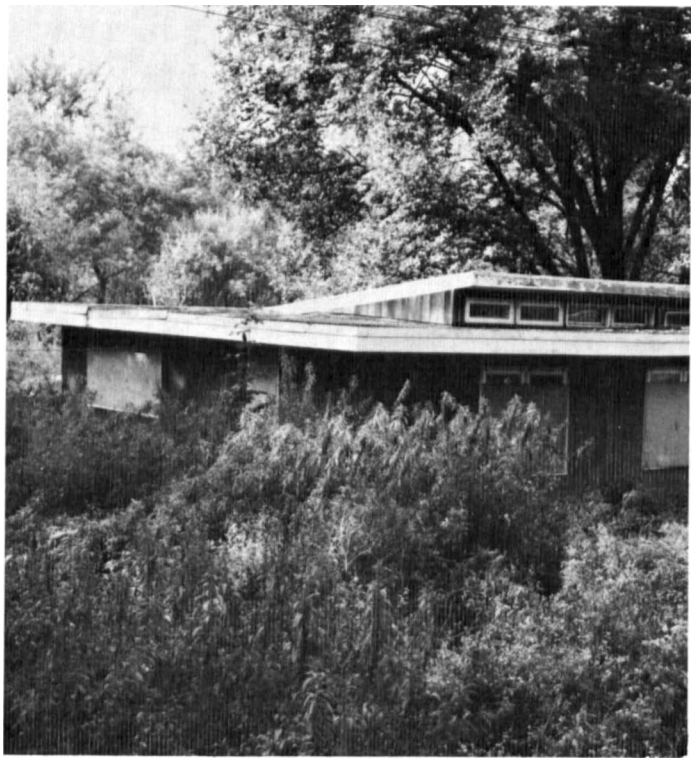
Kingsley soils used for residential development. The soils on the hillside in the foreground have severe limitations to use for homesites because of their steep slopes. Those in the background have only slight limitations because they have slopes of 2 to 6 percent, and they are used as sites for homes.

A slowly permeable Erin soil used as a septic tank filter field. This soil is not suited to use as a filter field. Coarse grass in the center of the picture indicates the seepage of effluent.

Water standing in an abandoned basement excavation in an area of Cordova soils. If this site is used for a house that has a basement, the level of the water table has to be lowered or the basement raised above the level of the seasonal high water table. The high water table keeps drainage fields for septic tanks from functioning properly.

PLATE VIII

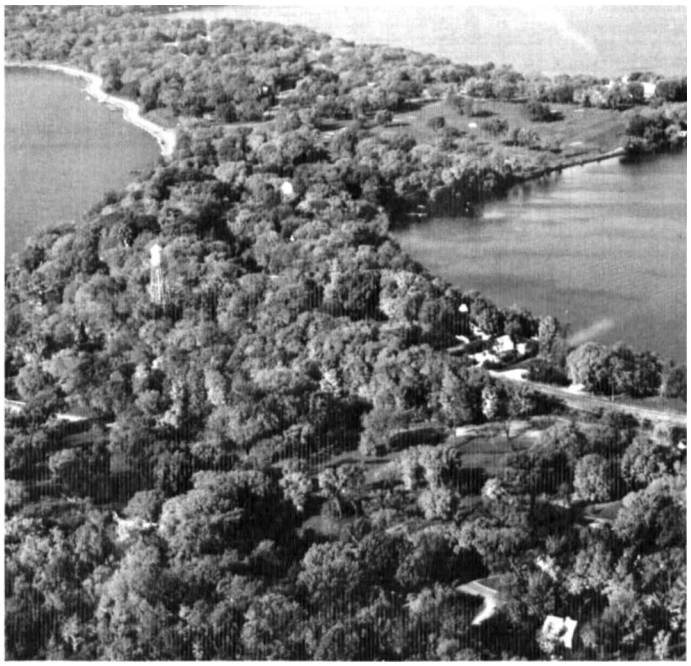
Bituminous surface of a parking lot that has been broken up by frost heave. Much of this parking lot is on Hamel loam, which is highly susceptible to frost heave.



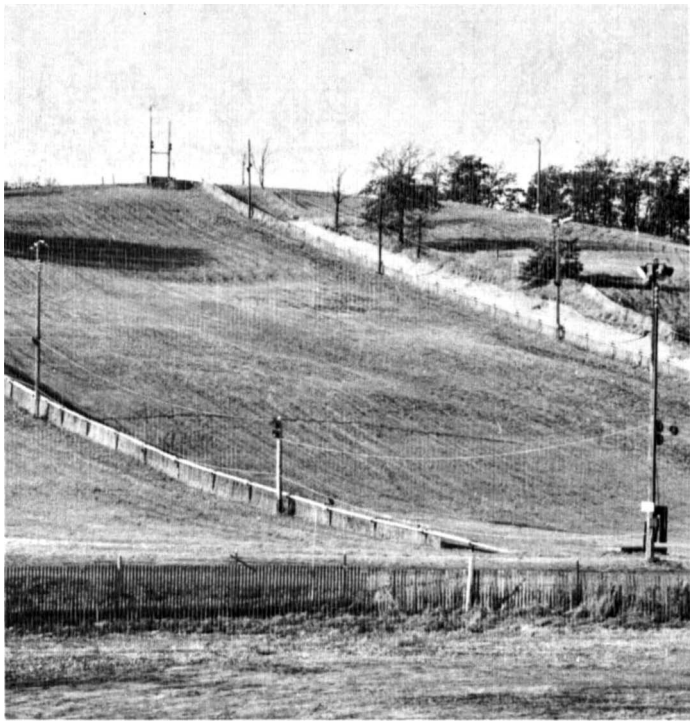
Home located on Peaty muck. This home has been abandoned because of wetness and the breakup of the foundation.

Small lake, created by making an excavation in an area of Peaty muck, is used for skating and boating. The open area below the homes is also Peaty muck, but it has been covered with loamy material to improve the bearing capacity to allow development for a park.

Golf course developed in poorly drained and very poorly drained areas of Peaty muck, which are poorly suited to development for homesites. The Peaty muck was covered with a layer of mineral soil to provide better support for foot traffic.



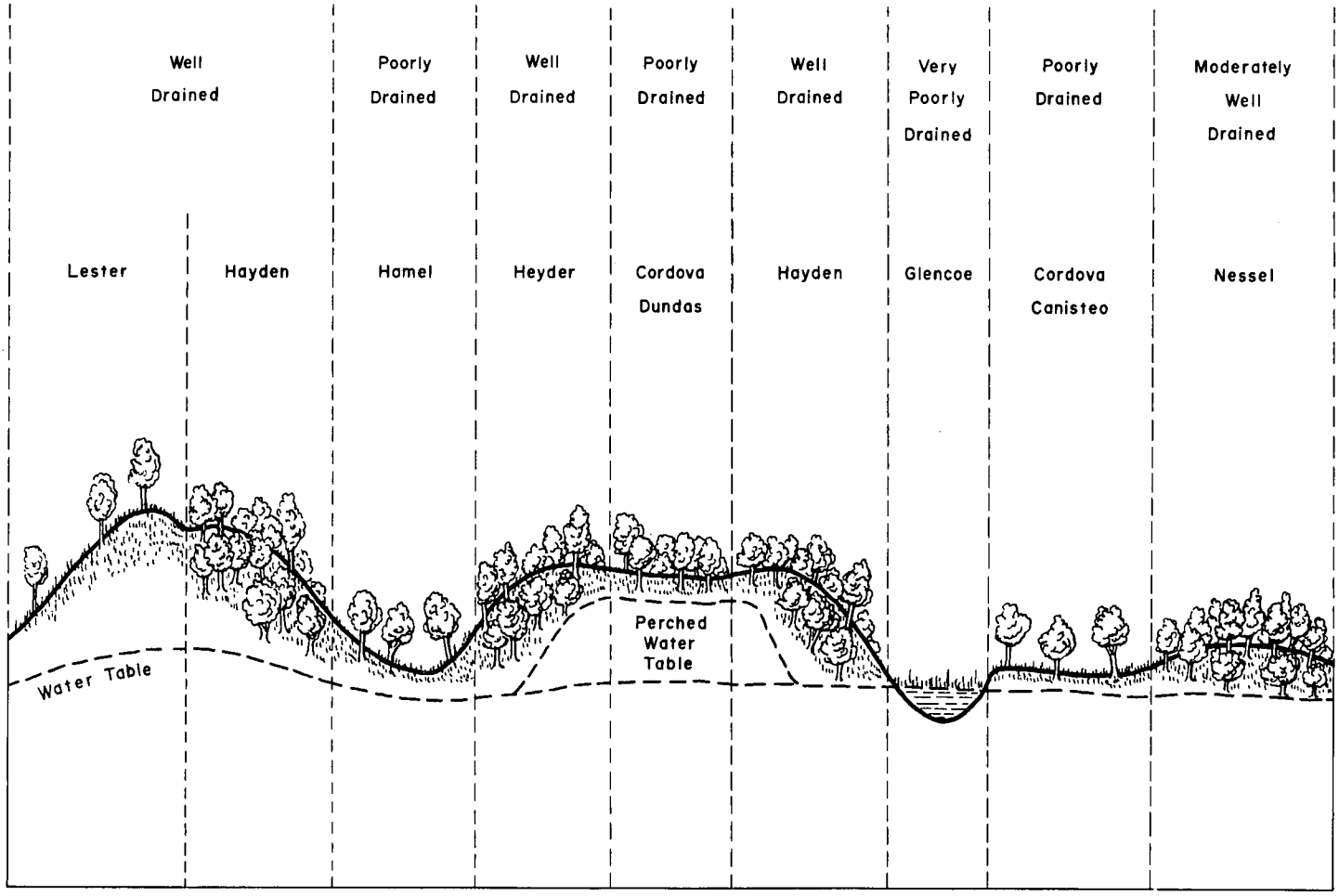
Lake Minnetonka, with its many bays, is a major source of recreation.



Ski run near Bush Lake on soils of the Kingsley complex, 24 to 35 percent slopes.

Layer of gray till that is 10 to 15 feet thick over red till. The red till contains many rills in the lower part of the road cut.

PLATE X



Topography, drainage, and vegetation of the major soils in Hennepin County.

CAPABILITY UNITS are soil groups within one subclass. 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-3. Thus, in one symbol, the Roman numeral designates the capability class, or degree of limitation; the small letter indicates the subclass, or kind of limitation, as defined in the foregoing paragraph; and the Arabic numeral specifically identifies the capability unit within each subclass.

Management by Capability Units

In the following pages the capability units of Hennepin County are described and suggestions for use and management of the soils are given. The names of soil series are mentioned in each capability unit, but this does not mean that all mapping units of a series are in that particular capability unit. The capability unit in which each soil in Hennepin County has been placed is given in the "Guide to Mapping Units" at the back of this soil survey.

Capability Unit I-1

This unit consists of deep, nearly level to gently sloping, moderately well drained and well drained soils of the Dakota, Kennebec, Le Sueur, and Nessel series. The Le Sueur and Nessel soils formed in calcareous loamy till. They have a friable loam surface layer and a clay loam subsoil. The Kennebec soil formed in silty alluvium, and the Dakota soil formed in loamy alluvium. These soils have high available moisture capacity and moderate permeability. They have few limitations that restrict their use.

Soils of this unit warm up more slowly and dry off after rains more slowly than the nearby more sloping soils, but drainage is not needed. They are moderately difficult to till, and they can be satisfactorily tilled only within a narrow range of moisture content. The Le Sueur soil, because it is higher in content of organic matter, is easier to maintain in good tilth than the Nessel soil. The Le Sueur and Nessel soils, if worked when too wet, are easily compacted and become hard and cloddy upon drying. The surface layer of the Nessel soil tends to seal over after heavy rains and to crust on drying. This process slows aeration of the soil. Because these soils are nearly level to gently sloping, they are not easily eroded.

These soils are well suited to cultivated crops. They are not susceptible to erosion and drought, and poor drainage is not a limitation. Most areas are used for corn and soybeans. Oats, other small grain, and hay are also grown. About 25 percent of the area of these soils is in pasture or trees. These are among the most productive soils in the county and can be farmed intensively under a high level of management.

The main management needs are maintenance of tilth and fertility. Fall plowing is beneficial, because it allows clods to freeze and thaw in winter and thus produces a spring seedbed of improved tilth.

Capability Unit IIe-1

This unit consists of deep, well-drained, gently sloping soils of the Grays, Hayden, Heyder, and Lester series. The surface layer is sandy loam, very fine sandy loam, loam, or light clay loam. The eroded Hayden and Lester soils have light clay loam texture. The subsoil of the Hayden, Heyder, and Lester soils is friable and is loamy in texture. The subsoil of the Grays soils is silty.

Permeability is moderate, and available moisture capacity is high. Water and air move easily through the soils. The Heyder soil has a slightly lower available moisture capacity than the other soils in this unit. These soils warm up fairly early in spring and can be worked fairly soon after rainfall.

The Grays and Hayden soils are low in content of organic matter and have poor natural tilth. Their surface layer tends to seal during rains and to crust on drying. This process slows aeration of the soils. These soils are easily eroded by water and can be maintained in only fair tilth. The Lester soil is higher in organic-matter content, is less erodible, and can generally be kept in better tilth. All the soils compact if they are worked when too wet, and when the soils dry, hard clods form that are difficult to break. The Heyder soil is also low in organic-matter content, but because it is more sandy it is easier to manage than the other soils in this unit.

Most areas of these soils are cultivated. Corn, soybeans, oats, and hay are the main crops. Under good management, these soils are among the most productive in the county. A few areas are in pasture and woodland. The main management needs are control of erosion and maintenance of tilth. The hazard of erosion is moderate. Drought and wetness are not hazards.

Most of the areas are too irregular in shape or too small in size to be suited to contour farming or terracing. Minimum tillage practices are better alternatives in many areas to control erosion. In areas where these practices are used, row crops can be grown nearly every year. In areas where conventional tillage practices are used, an occasional sod crop controls erosion. Fall plowing is beneficial on these soils unless minimum tillage practices are used. Fall plowing allows clods to freeze and thaw in winter and thus produce a spring seedbed of improved tilth. Drainageways should be seeded and maintained in grass.

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Capability Unit IIe-2

This unit consists of deep, moderately well drained and well drained, gently sloping soils of the Dalbo, Erin, Kilkenny, and Shorewood series. These soils have a surface layer of silt loam, loam, or silty clay loam and a subsoil of firm silty clay loam, clay loam, or silty clay. They have high available moisture capacity and moderately slow permeability.

The surface layer is easily eroded. It tends to seal during rains and to crust on drying. Good tilth is hard to maintain. The Kilkenny and Shorewood soils are higher in content of organic matter and can be maintained in better tilth. Water enters the soils of this unit slowly. They are hard to till and can be satisfactorily tilled only within a narrow range of moisture content. If worked when wet, the soils compact easily and form hard clods upon drying.

These soils are suited to all the crops grown in the county. The main crops are corn, hay, and small grain. Because these soils are harder to maintain in good tilth, a higher proportion of hay crops is grown on them than on the soils in capability unit IIe-1. A few areas are in permanent pasture or trees. Pasture plants and trees grow well.

On these soils there is no hazard of wetness or drought, but there is a moderate erosion hazard. In places contour stripcropping can be used to control erosion, but in most places slopes are too irregular to permit effective contour farming. These soils are not well suited to terraces, because the firm clayey subsoil is exposed during terrace construction. Care must be taken to stockpile the surface soil and replace it in the terrace channel after construction. Minimum tillage practices are better alternatives to control erosion in many places. In areas where these soils are terraced or minimum tillage practices are used, row crops can be grown nearly every year. In areas where conventional tillage practices are used, sod crops are needed in the rotation to help control erosion. Fall plowing is beneficial on these soils, as it allows freezing and thawing during winter to break clods and thus improve tilth in spring.

Capability Unit IIe-3

This unit consists of deep, well-drained, gently sloping soils of the Heyder and Kingsley series. The subsoil is mainly sandy loam or sandy clay loam. Included with these soils are sandy soils that are underlain by sand and gravel at a depth of 12 to 40 inches. The underlying material of the Heyder and Kingsley soils contains pockets of sand and gravel. The available moisture capacity, permeability, and infiltration rate are variable. The organic-matter content is low.

These soils warm up fairly early in spring and dry off soon after rains. In most places they are fairly easy to till, although surface rocks and pebbles are a nuisance to tillage in areas of the Kingsley soils.

Many areas of these soils are used for cultivated crops, but some areas are in pasture or woodland. These soils are suited to corn, soybeans, small grain, and hay. Because the available moisture capacity is variable, crop growth is spotty. In places near Hopkins, the swales and more nearly level areas are used for growing raspberries and strawberries.

On these soils there are slight to moderate hazards of drought and water erosion. In most places slopes are too irregular to contour farm or terrace. Use of minimum tillage or growth of occasional sod crops are better practices for controlling erosion on these soils. They are suited to either fall or spring plowing.

Capability Unit IIe-4

This unit consists of gently sloping soils of the Dakota and Kasota series. The Dakota soil is deep, is well drained, and has a friable loam surface layer and subsoil. At a depth of 20 to 30 inches, these soils are underlain by deep sand. The organic-matter content in the surface layer is moderate. These soils have moderate available moisture capacity and moderately rapid permeability. Water moves fairly easy into and through the soil. The Dakota soil warms up early in spring and dries off fairly soon after rains. It is fairly easy to till. In the western part of the city of Bloomington, this soil contains a high amount of fine and very fine sand and is easily eroded by water.

The Kasota soil has a surface layer of silty clay loam and a subsoil of silty clay. It is underlain by sand at a depth of 24 to 60 inches. Organic-matter content is high, permeability is moderately slow, and available moisture capacity is moderate. Areas of the Kasota soil are so small in most places that they are farmed with the nearby soils. The Kasota soil has somewhat higher available moisture capacity than the Dakota soil. The Kasota soil is difficult to till and to maintain in good tilth.

Most areas of these soils are cultivated. They are suited to all the crops grown in the county, but the main crops are corn and soybeans. The hazards of drought and erosion are the main limitations. Most areas are too irregular in shape, too small in size, or too short of slope to contour farm or terrace. These soils are well suited to minimum tillage practices. Plowing in spring helps to reduce erosion. If conventional tillage practices are used, sod crops in the rotation help to control erosion. Waterways need to be seeded and maintained in grass. Because of the moderate available moisture capacity, crops grown on these soils respond to only moderate amounts of fertilizer.

Capability Unit IIw-1

This unit consists of nearly level, poorly drained soils of the Biscay, Canisteo, Chaska, Cordova, and Hamel series. The water table is at a depth of

1 to 3 feet during wet periods. These are medium to moderately fine textured soils. The organic-matter content is high, and permeability is moderate to moderately slow. Except for the soil of the Biscay series, all the soils are underlain by deep loam and have high available moisture capacity. The Biscay soil is underlain by sand at a depth of 20 to 36 inches and has moderate available moisture capacity. The Chaska soil is flooded in some years.

Unless artificially drained, these soils are not well suited to crops. They warm up slowly in spring and dry off slowly after rains. Water stands on the surface for short periods after rainfall. These soils are moderately difficult to till, and they can be satisfactorily tilled only within a narrow range of moisture content. All the soils compact if they are worked when wet. Most undrained areas are in poor tilth, and water and air enter the soil slowly. If these soils are properly drained and managed, they are among the most productive soils in the county. Row crops can be grown year after year. A system of tile drains and good drainage outlets are needed. Surface inlets or shallow ditches are needed to remove surface water from the depressions that are included with these soils. The Chaska soil is difficult to drain because of flooding and lack of grade.

Maintenance of tilth is important to the management of these soils. Fall plowing is beneficial. It allows freezing and thawing during winter, thus breaking clods and providing a spring seedbed of improved tilth.

Some undrained areas of these soils are in permanent pasture and are brushy and partly wooded. Under good management, these soils are well suited to pasture because they hold moisture well throughout the growing season. Grazing in spring and after heavy rains should be delayed until the soils are firm.

Capability Unit IIw-2

This unit consists of deep, poorly drained and somewhat poorly drained, nearly level soils of the Dundas, Minnetonka, and Shields series. The Dundas soil has a silt loam surface layer and a clay loam subsoil. The Minnetonka and Shields soils have a silty clay loam surface layer and a silty clay or clay subsoil. The Minnetonka soil has high organic-matter content, and the Dundas and Shields soils have a low organic-matter content in the surface layer. These soils have high available moisture capacity and moderately slow to slow permeability. Air and water enter and move through the soils slowly.

These soils are difficult to till. The Dundas and Shields soils have poor structure. The surface layer seals during heavy rains and forms a crust upon drying. The soils in this group can be satisfactorily tilled only within a narrow range of moisture content. Unless drained, they seldom dry to the proper moisture content for tillage. Most of the time, they are worked when too wet and the surface layer in most cultivated areas has thus been severely compacted and is in poor tilth (plate V).

Because these soils are slowly permeable, they are difficult to drain with tile. Tile drains need to be very close together to be effective. Surface ditches generally are needed to remove surface water in the small depressions that are included in areas of these soils.

If properly drained and well managed, these soils are suited to all crops grown in the county. They are well suited to intensive cultivation of row crops in areas where good tilth can be maintained.

These soils are well suited to pasture because they hold moisture well throughout the growing season. Many pastures are partly wooded or brushy, however, and provide poor grazing. These areas need to be cleared and managed to provide good grazing by planting tall grasses and legumes, such as bromegrass and alfalfa or bluegrass. Grazing should be delayed after heavy rains until the soils are firm.

Capability Unit IIw-3

This unit consists of nearly level, deep soils of the Becker and Dorchester series and Mixed alluvial land. These soils are well drained to moderately well drained and have moderate to rapid permeability. The Dorchester soil is deep loam and has high available moisture capacity and natural fertility. The Becker soils have a loamy surface layer and subsoil and are underlain by sand at a depth of 36 to 48 inches. Becker loam has moderate available moisture capacity, and Becker fine sandy loam has low available moisture capacity. Mixed alluvial land occurs along all the major rivers in the county and consists of stratified layers of sand and silt. It has low to moderate available moisture capacity.

All of these soils are subject to flooding. The Dorchester soil is fairly difficult to till. The Becker soils are easy to till and to maintain in good tilth.

The soils of this unit are used mainly for corn and soybeans. Dorchester and Becker loams are well suited to this purpose. Mixed alluvial land and Becker fine sandy loam are moderately well suited to this use, but crop growth is limited by drought unless rainfall distribution is good. In some years crops are damaged or destroyed by floods. All the soils in this group are suited to either fall or spring plowing.

Most areas of these soils are not used for pasture, but they can provide good pasture if cleared and seeded to grasses and legumes that tolerate wetness. Areas near streambanks need to be stabilized in some places to prevent cutting into pastures at sharp turns in the river.

Capability Unit IIs-1

This unit consists of nearly level soils of the Dalbo, Lerdal, and Shorewood series. These are deep,

medium to moderately fine textured, somewhat poorly drained to moderately well drained soils. They have high available moisture capacity and moderately slow permeability. Air and water move through the soil too slowly for the optimum growth of plants. The organic-matter content ranges from low to high. The Shorewood and Lerdal soils have high natural fertility. The natural fertility of the Dalbo soil is medium.

These soils warm up slowly in spring and dry off slowly after rains. Water does not stand on the surface after rains, however, and drainage generally is not needed. These soils are fairly difficult to till and can be satisfactorily tilled only within a narrow range of moisture content. Because these soils dry off slowly, they are often worked when wet. Thus, they are easily compacted and are commonly in poor tilth. The Dalbo soil is low in organic-matter content. It tends to seal over during heavy rains and to form a hard crust upon drying. This process slows the intake of water and air.

Many areas of these soils are cultivated, but most areas are in pasture or woodland. If well managed, these soils are fairly well suited to all the crops grown in the county. The main crops are corn, soybeans, small grain, and hay.

The main management need on these soils is maintenance of soil tilth. Under good management, these soils can be maintained in fair tilth by such practices as using minimum tillage, tilling at the right moisture content, and returning large amounts of crop residue to the soil. Fall plowing is desirable on these soils, because this allows freezing and thawing in winter to break clods. This improves the tilth of the spring seedbed. Spring tillage should be limited to what is necessary to control weeds.

Capability Unit IIs-2

This unit consists only of Dakota loam, 0 to 2 percent slopes. This is a deep, well-drained, nearly level soil. The surface layer and the subsoil are friable loam. This soil is underlain by deep sand at a depth of 20 to 30 inches. It has moderate available moisture capacity and moderately rapid permeability. Water and air move easily into and through the soil. The content of organic matter in the surface layer is moderate.

This soil warms up early in spring and dries off fairly soon after rains. It is fairly easy to till and can be maintained in good tilth. The range of moisture content for satisfactory tillage is wide, but the soil is slightly sticky when wet and can become compacted if not worked at the right moisture content. Most of the rain that falls on this soil is absorbed. Runoff is low.

This soil is suited to all farm crops commonly grown in the county. Most areas are used to grow corn and soybeans and are well suited to these crops. The main limitation is the moderate available moisture capacity. This soil is well suited to either fall or spring plowing and to minimum tillage practices that help to maintain tilth and reduce the cost of production. Row crops can be grown year after year. Crops grown on this Dakota soil respond only to moderate amounts of fertilizer because of the moderate available moisture capacity. Crops respond well to irrigation.

A few areas of this soil are in woodland or pasture. It is fairly good for pasture, but supplemental pasture is generally needed in summer.

Capability Unit IIIe-1

This unit consists of deep, well-drained, rolling soils of the Grays, Hayden, Heyder, and Lester series. The surface layer is sandy loam, very fine sandy loam, loam, or clay loam. The eroded Hayden and Lester soils have a clay loam surface layer. The subsoil of Hayden, Heyder, and Lester soils is loam, and the subsoil of the Grays soil is silt.

These soils are moderately permeable and have high available moisture capacity. Water and air move through the soils easily. The soils warm up fairly early in spring and can be worked fairly soon after rains. Because of the greater amount of runoff, the moisture available for plant growth is somewhat lower than in more nearly level soils.

Grays and Hayden soils are low in organic-matter content and have poor natural tilth. The surface layer tends to seal during rains and to crust on drying. This slows aeration of the soil and the further absorption of rainfall. The Grays and Hayden soils are easily eroded by water and can generally be maintained in only fair tilth. Lester soils, which are fairly high in organic-matter content, are not so easily eroded and can be maintained in better tilth than the Hayden soils. The Hayden and Lester soils are moderately difficult to till. The Heyder soil is also low in organic-matter content. Because it has a more sandy surface layer, it is easier to till and to maintain in good tilth than the other soils in the group, although a slight crust tends to form on the surface after heavy rains. The Grays soil is easy to till if the moisture content is right. It is a good practice to avoid working the soils in this unit when they are too wet, because they compact and form hard clods upon drying, which slows aeration and absorption of rainfall.

These soils are well suited to all the cultivated crops commonly grown in the county. Corn, small grain, and hay are the main crops. Most areas of these soils are cultivated, but some areas are in pasture and woodland.

The main management need is control of erosion. The hazard of erosion is moderate. Rainfall runs off rapidly on these soils, and only a moderate amount enters the soil during heavy rains. Management practices that improve water intake and control erosion are needed. Most areas are too irregular or are too short of slope to contour farm or terrace. In many areas minimum tillage practices are better alternatives to control erosion. These practices should be used in combination with sod crops.

Wherever possible, it is best to till these soils across the slope. If standard tillage practices are used, a higher proportion of sod crops is needed to control erosion. Fall plowing is beneficial because it allows clods to freeze and thaw during winter, which produces a spring seedbed of improved tilth. However, crop residue should be left on the surface to control erosion. Drainageways and gullies should be shaped, seeded, and maintained in grass.

Under good management, these soils can provide good pasture. Some pastures are now producing poor forage because they are wooded and brushy.

Capability Unit IIIe-2

This unit consists of deep, moderately well drained and well drained, rolling soils of the Dalbo, Erin, and Kilkenny series. The Erin and Kilkenny soils have a loam or clay loam surface layer and a clay loam subsoil. The Dalbo soil has a silt loam surface layer and a silty clay loam to silty clay subsoil. All the soils have high available moisture capacity and moderately slow permeability.

The surface layer of the Dalbo and Erin soils seals during rains and forms a crust on drying, which slows aeration and the further absorption of rainfall. The surface layer is easily eroded on these rolling slopes. The Kilkenny soils, which are higher in content of organic matter, are not quite so easily eroded. The range of moisture content for satisfactory tillage is narrow. If worked when too wet, the soils in this group are easily compacted and hard clods are formed upon drying.

On these soils there is a moderate to severe hazard of erosion. Drought and wetness are not hazards.

These soils are suited to all the crops grown in the county. However, row crops need management practices to control erosion. In most places the slopes are too irregular or too short or the areas are too small in size for contour farming or stripcropping. Wherever possible, it is best to farm these soils across the slope. The soils are not well suited to terracing, because of the firm subsoil, which is exposed during terrace construction. The surface layer should be stockpiled and replaced in the terrace channel after construction. In many places minimum tillage practices and a rotation containing sod crops are better alternatives to control erosion. The cropping system selected depends upon the practices used. If no management practices are used, sod crops need to be grown most of the time in order to control erosion. Plowing in the fall is beneficial because this allows freezing and thawing during winter to break clods and thus improve tilth in spring. However, crop residue should be left on the surface to control erosion. Gullies and drainageways need to be shaped, seeded, and maintained in grass.

These soils are suitable for pasture. Some pastures are now producing poor forage because they are wooded and brushy.

Capability Unit IIIe-3

This unit consists of gently sloping soils of the Burnsville, Dickman, and Estherville series and the Burnsville series, thick solum variant. These soils have a sandy loam surface layer and subsoil. Except for the Burnsville variant, they are underlain by coarse-textured material at a depth of 14 to 24 inches. The Burnsville and Estherville soils are underlain by stratified sand and gravel. The Dickman soil is underlain by sand. The Burnsville variant is underlain by gravelly sand at a depth of 20 to 40 inches. The soils in this unit have low available moisture capacity and rapid to moderately rapid permeability. The content of organic matter ranges from low to high.

These soils warm up early in spring and dry off soon after rains. They absorb rainfall easily and have low runoff. They are easy to till. Because of the shallow depth to sand and gravel, erosion seriously reduces the available moisture capacity. Therefore, runoff and erosion need to be carefully controlled. If cultivated, the soils are easily blown. If soil blowing is not controlled, young plants are easily damaged by blowing sand. The hazard of drought is severe, and the hazards of soil blowing and water erosion are moderate.

Because of lack of moisture, the soils in this unit are not well suited to corn and soybeans. They are better suited to early crops, such as small grain.

These soils need management practices to control water erosion and soil blowing. If no other management practices are used, sod crops should be grown fairly often to control water erosion. Keeping the soil covered with plants over winter and delaying tillage until just before planting controls soil blowing. Stubble mulch tillage practices that keep the surface rough and trashy are well suited to these soils. Terraces are generally not suited to this group of soils, because of the shallow depth to sand and gravel. Contour farming is a good practice in areas where slopes are uniform. Gullies and drainageways need to be shaped, seeded, and maintained as grassed waterways.

If fertilized and cleared of brush, these soils produce fairly good pasture in spring and fall. Because they are droughty, they produce little forage in summer. Pastures of alfalfa and bromegrass are more drought resistant than pastures of bluegrass. Overgrazing must be avoided to prevent erosion and maintain the sod.

Capability Unit IIIw-1

This unit consists of soils of the Biscay and Glencoe series and Lake beaches, loamy. The Biscay and Glencoe soils occupy shallow depressions. The Biscay soil is clay loam underlain by gravel and sand at a depth of 24 to 40 inches. It is moderately slowly permeable and has moderate available moisture capacity. The Glencoe soil is deep silty clay loam over loam. It has high available moisture capacity

and moderate to moderately slow permeability. Lake beaches, loamy, occur around the borders of lakes and large marshes, some of which have been drained. The surface layer of Lake beaches, loamy, is loam or silt loam and it is underlain by deep, silty or loamy material.

Unless drained, these soils generally contain marsh and sedge vegetation. Drainage is necessary on these soils before they can be cropped successfully. Tile drains work well in areas where suitable outlets are available. In many places ditches or tile inlets are needed to remove surface water during heavy rains. Suitable outlets are commonly lacking on the depressional Biscay soil, and few such areas have been drained. Although the soils in this group have a high content of organic matter, they compact if worked when too wet and form hard clods on drying. The range of moisture content for satisfactory tillage is narrow.

If these soils are properly drained, they are well suited to intensive cropping to corn and soybeans. Many areas, however, are small and are farmed with the surrounding soils. In years of intensive rainfall, crops in the shallow depressions can be damaged or destroyed by ponding. Oats can be grown on these soils, but lodging generally is a serious problem. It is important to maintain good tilth on these soils so that water can enter and drain through them easily.

Undrained areas can be improved for pasture by planting to reed canarygrass and similar grasses. These soils are good for stock watering pits (plate V).

Capability Unit IIIw-2

This unit consists of deep, nearly level, poorly drained soils of the Dassel and Isan series. One of the Isan soils is underlain by deep sand at a depth of 12 to 20 inches. The other Isan soil is underlain by loam at a depth of 20 to 40 inches. The Dassel soil is underlain by deep sand that contains thin layers of finer textured material. All the soils have a sandy loam surface layer. Permeability is moderate to moderately rapid in the Dassel soil and in the Isan soil that has a loamy subsoil. It is rapid in the other Isan soil. The organic-matter content is high.

Unless drained, these soils warm up slowly in spring and dry off somewhat slowly after rains. Because they are sandy, however, they have a wide range of moisture content for satisfactory tillage. Compaction generally is not a problem on these soils. One of the Isan soils has low available moisture capacity, but it generally is too wet in spring. During the dry summer months, when the water table is deep, crop growth may be limited by lack of moisture. Because they have finer textured underlying material, the Dassel soil and the Isan soil that has a loamy subsoil hold greater amounts of water for plant growth. They too are generally too wet in spring and lack moisture for crops during summer. For best crop production on these soils, it is important to control the water table. Shallow ditches are generally all that is needed to lower the water table sufficiently for good crop growth.

Tile drains can be used on these soils, but caving of tile trenches is a hazard. In addition, the tile lines tend to fill with sand. Tile should be installed when the water table is deep, and the tile should be blinded with topsoil or covered with building paper to keep out the sand.

If properly drained and managed, the Dassel soil and Isan soil that has a loamy subsoil are suited to all the crops grown in the county. Because they are nearly level, they are generally used for corn and soybeans. The other Isan soil, because it has lower available moisture capacity, is not so well suited to row crops as the other soils in this unit.

These soils can provide fair to good pasture in spring and fall. Fertilizing improves production.

Capability Unit IIIw-3

This unit consists of Peaty muck and Peaty muck over loam. These are organic soils in low, wet depressions. They have very high available moisture capacity, but they are low in natural fertility. Most areas are undrained and are in marsh grass or in pasture that consists mainly of coarse grasses.

Drainage is needed to crop these soils successfully. Both ditches and tile are needed in the large areas. If properly drained and fertilized, these soils are well suited to corn, soybeans, and garden crops. Most drained areas are farmed to corn for grain, soybeans, and corn for silage. These soils are not well suited to small grain and alfalfa. Small grain lodges easily, and alfalfa is easily damaged by wetness. The soils are well suited to lawn sod, and row crops can be grown year after year. In some years, however, crops are damaged by early and late frosts. In places where drainage outlets are not adequate, ponding occurs in some years and results in severe crop losses.

On the Peaty muck soil, tiles can be placed far apart because water moves rapidly through the soil. However, the tile should be placed deep enough to compensate for settling after drainage has been installed.

A cover crop of winter rye protects the soil from erosion in areas where soil blowing is a problem.

Undrained areas are suitable for pasture if they are well managed. These soils are well suited to reed canarygrass because it forms a tough, dense sod that can support grazing animals and haying equipment even though the soils are partly wet.

Capability Unit IIIs-1

This unit consists of nearly level, somewhat excessively drained soils of the Dickman and Estherville series and moderately well drained soils of the Litchfield series. The Estherville and Dickman soils have a sandy loam surface layer and subsoil.

The Estherville soil is underlain by sand and gravel at a depth of 14 to 24 inches, and the Dickman soils are underlain by sand at a similar depth. The Litchfield soil has a loamy sand surface layer and is underlain by deep sand that contains thin layers of finer textured material. The soils in this unit have moderate organic-matter content.

These soils warm up early in spring and can be tilled soon after rains. Good tilth is easy to maintain. Most of the rainfall is absorbed by the soil. Because they are sandy, these soils are easily blown. Young plants are often damaged by windblown sand. The main limitation of these soils is low available moisture capacity. Therefore, they are well suited to early crops, such as small grain. Unless rainfall distribution is good, corn and soybeans are damaged by drought in most years. Soil blowing can be controlled by keeping the soil covered with plants over winter and by plowing or tilling the soil just before planting. Minimum tillage practices are suitable for these soils.

Because the available moisture capacity is low, crops grown on these soils respond only to moderate amounts of fertilizer unless rainfall is timely or irrigation has been provided. The soils are well suited to irrigation.

These soils are not generally used for pasture. However, if properly fertilized and managed, they can provide good pasture in spring and fall. Pastures consisting of alfalfa and bromegrass produce more forage than pastures of permanent bluegrass.

Capability Unit IIIs-2

This unit consists of deep, nearly level to gently sloping soils of the Anoka, Braham, Langola, and Rasset series and the Duelm series, loamy subsoil variant. These soils have a sandy surface layer. At a depth of 18 to 40 inches, the Braham and Duelm soils are underlain by loam. The Langola soils are underlain by sandy loam. The Anoka and Rasset soils are underlain by deep sand that contains thin layers of finer textured materials. These soils have low to moderate available moisture capacity, depending upon the depth to the sandy loam and loam. They absorb water easily, and the underlying material is permeable to air and water.

The soils in this unit are easy to till and warm up early in spring. They dry off soon after rains. They are subject to soil blowing if not covered with plants.

The hazard of drought is severe, and the hazard of soil blowing is moderate. These soils are not well suited to cultivated crops, because of lack of moisture. They are better suited to early crops, such as small grain. Unless rainfall is timely or irrigation has been provided, growth of corn and soybeans is generally limited by lack of moisture. Not many areas are cultivated. Most areas are in pasture or woodland.

Over winter these soils need a protective cover of crop residue or grass to control erosion late in winter and early in spring. They are well suited to minimum tillage practices that keep the surface rough and trashy, thereby reducing soil blowing. These soils are well suited to irrigation. Generally, crops grown on them respond only to moderate amounts of fertilizer.

These soils provide good pasture in spring and early in fall, but they do not produce the forage needed in midsummer. Applications of phosphate and potash reduce killing of legumes in winter.

Capability Unit IVe-1

This unit consists of moderately steep soils of the Hayden, Heyder, and Lester series. The surface layer of the Hayden and Lester soils ranges from loam to light clay loam in texture. The light clay loam surface layer is associated with the eroded soils. Almost all of the cultivated areas of these soils have been eroded. The subsoil is friable to firm loam or clay loam. The Heyder soil has a surface layer of sandy loam and a subsoil of sandy loam or sandy clay loam. Soils in this unit are well drained and have moderate permeability. They have high available moisture capacity, but the amount of moisture available for plant growth is lower than in the more nearly level soils because of the steeper slopes that cause rapid runoff.

These soils warm up early in spring and can be worked fairly soon after rains. With the exception of the Heyder soil, they are fairly difficult to till. Most of the cultivated areas are low in organic matter and are in poor tilth. The Lester and Hayden soils compact if worked when too wet and form hard clods upon drying. The Heyder soil, which is more sandy, can be maintained in better tilth than the other soils in this group. The surface layer of the Hayden soils tends to seal over during rains and to crust on drying, slowing aeration of the soil and absorption of additional rainfall.

These soils are suited to cultivated crops, but because of the severe hazard of erosion, such row crops as corn should be grown only occasionally and then only under good management. Areas where these soils are an important part of a field are better suited to hay crops. Planting row crops on the contour and using minimum tillage reduce soil loss, increase aeration, and improve rainfall absorption. Gullies and drainageways need to be shaped, seeded to grass, and maintained.

If these soils are fertilized and well managed, they provide good permanent pasture. Pastures consisting of alfalfa and bromegrass produce more forage than pastures of bluegrass. Overgrazing increases the risk of erosion. Many pastures produce poor forage because they are wooded and brushy.

Capability Unit IVe-2

This unit consists of deep, well-drained, moderately steep soils of the Erin and Kilkenny series. These soils have a surface layer of loam and clay loam and a subsoil of firm clay loam. The available

moisture capacity is high, and permeability is moderately slow. Because of the steepness of slopes and low organic-matter content, Erin soils are easily eroded by water. Tilth is generally poor, and water enters these soils slowly. A large part of the rainfall runs off.

These soils are difficult to till and have a narrow range of moisture content for suitable tillage. If worked when wet, they compact easily and form hard clods upon drying. Production in many years is reduced by compaction.

Because these soils have rapid runoff and are easily eroded, they are not well suited to row crops, sucn as corn and soybeans. They are better suited to small grain, hay, and pasture. Row crops should not be grown unless the soils are farmed across the slope and management practices are used to control erosion. These soils are generally too steep and their slopes too short for terracing (plate VI). Suitable practices to control erosion are farming across the slope, contour stripcropping where practicable, and using minimum tillage practices along with a high percentage of sod crops. Gullies and drainageways need to be shaped, seeded, and maintained in grass. In some places engineering structures are needed before vegetation can be established.

If these soils are fertilized and grazing is managed, they provide good pasture in spring and fall. Alfalfa is more productive than bluegrass. To prevent erosion, care is needed to avoid overgrazing. Many pastures produce poor forage because they are wooded and brushy.

Capability Unit IVe-3

This unit consists of deep, well-drained, rolling soils of the Heyder and Kingsley series. The surface layer ranges from loam to loamy sand. The subsoil is mainly sandy loam and loam. The underlying material contains pockets of sand and gravel. Included with these soils are sandy soils that are underlain by gravel at a depth of 12 to 40 inches. Because the soil materials are variable, the available moisture capacity and permeability differ greatly within a distance of a few feet. The organic-matter content is low.

These soils warm up fairly early in spring and dry off soon after rains. The Heyder soil is fairly easy to till. The Kingsley soil has numerous surface rocks and pebbles that are a hindrance to tillage.

Most areas of the Kingsley soil are in woodland or pasture, and some are being developed for urban uses. Many areas of the Heyder soil are cultivated. Both soils are suited to corn, soybeans, small grain, and hay. They are well suited to pasture and trees.

On these soils there is a severe hazard of erosion and a moderate hazard of drought. Management practices are needed to control erosion. In most places slopes are too irregular to contour farm or terrace. Stones and boulders are an additional hindrance to terrace construction on the Kingsley soil. Using minimum tillage practices in combination with a high proportion of sod crops is a better method of controlling erosion in many places. These soils are suited to either fall or spring plowing. In cultivated areas gullies and waterways need to be shaped, seeded, and maintained in grass.

Capability Unit IVe-4

This unit consists of somewhat excessively drained, rolling soils of the Burnsville, Dickman, and Estherville series and the Burnsville series, thick solum variant. All of these soils have a sandy loam surface layer and subsoil. They are underlain by sand or gravel and sand. The depth to the coarse material ranges from 14 to 24 inches, except for the Burnsville variant, which is slightly deeper. The soils in this group have moderately rapid to rapid permeability. The available moisture capacity is low.

These soils are easy to till. They warm up early in spring and dry off soon after rains.

Because of steepness of slope and shallow depth to coarse material, there are severe hazards of drought and erosion on these soils (plate VI). Consequently, they are poorly suited to cultivated crops. Most areas are in woodland or pasture or have been developed for urban uses. If these soils are cultivated, practices are needed to control erosion. To keep erosion to a minimum, it is desirable to spring plow or to use minimum tillage practices. Areas that are too irregular to contour farm or to farm across the slope are not suited to cultivation. Terraces are generally not suitable on the Burnsville and Estherville soils, because of the shallow depth to sand and gravel. Even with good management practices, row crops such as corn should be grown only occasionally. Gullies and drainageways should be shaped, seeded, and maintained as grassed waterways.

These soils are fairly good for pasture early in spring and early in fall. In midsummer, forage production is low. Pastures of alfalfa and bromegrass are more drought resistant than bluegrass. In some areas pastures are brushy and produce poor forage. Overgrazing should be avoided.

Capability Unit IVw-1

This unit consists of a depressional Isan soil and of Peaty muck over sand. These soils occur in depressions. The natural fertility is low. The Peaty muck layer is underlain by sand within a depth of 50 inches in undrained areas. The Isan soil is sandy loam underlain by sand within a depth of 20 inches.

These soils are very poorly drained. A few areas have been drained, but most areas are in marsh vegetation. Drainage outlets are generally lacking. Unless drained, these soils are not suitable for crops. Tiles are difficult to install and maintain. Tile trenches cave easily, and tiles may fill with sand after installation. It is a good practice to install tiles when the water table is low to keep caving and sloughing of tile trenches to a mimimum. Blinding the tile with loam or covering it with building paper helps to prevent tile lines from filling with sand. Tile lines can be placed far apart because water moves easily through these soils. Tile lines and ditches should be placed at a

shallow depth because these soils can be overdrained.

If drained, these are fair soils for crops. Crop growth is limited by drought if the water table is not controlled. Drained areas are well suited to garden crops, including onions, potatoes, and other vegetables. There is a greater hazard of frost on these soils than the surrounding soils.

Capability Unit IVs-1

This unit consists of somewhat excessively drained, rolling soils of the Anoka, Braham, and Rasset series. The Anoka and Rasset soils have a loamy sand surface layer and are underlain by deep sand that contains thin layers of finer textured material. They have low available moisture capacity and are rapidly permeable. Braham soils are loamy sand underlain by deep loam at a depth of 18 to 40 inches. They have low to moderate available moisture capacity and are moderately permeable in the deep underlying material. The organic-matter content of the soils in this unit is low.

These soils absorb rainfall easily. They warm up early in spring and dry off soon after rains. They are easy to till, and maintenance of tilth is not a problem.

On these soils there are severe hazards of drought and soil blowing and a moderate hazard of water erosion.

These soils are not well suited to cultivated crops, but all the common crops in the county can be grown on them. They are better suited to early crops, such as small grain. In most years late-maturing crops, such as corn and soybeans, are limited in growth by lack of moisture unless rainfall is timely. These soils respond well to irrigation but are generally too steep to be irrigated with large-scale equipment. Most areas are in permanent vegetation.

Conservation practices are needed to control erosion. If the soils are farmed up and down the slope, sod crops are needed more often. Row crops can be grown nearly every year if the soils are contour farmed or terraced. Soil blowing can be reduced by keeping the soil covered with plants over winter. Tillage should be delayed until just before planting. Minimum tillage practices that keep the surface rough and trashy are well suited to these soils, and their use reduces both soil blowing and water erosion. Gullies need to be shaped and seeded to form grassed waterways.

These soils produce fair pasture in spring and early in fall if fertilized and if grazing is controlled to protect the sod. During the warm summer months, production of forage is low. Many areas are brushy or wooded.

Capability Unit IVs-2

This unit consists of deep, moderately well drained to excessively drained, nearly level to gently sloping soils of the Duelm, Hubbard, Nymore, Salida, and Zimmerman series. Most of these soils have a surface layer of loamy sand or sand and are underlain by sand at a depth of 12 to 18 inches. The soils in this unit have very low available moisture capacity and rapid or very rapid permeability. Water enters and passes through the soil rapidly, and little is held for plant use.

These soils warm up early in spring, dry off soon after rains, and are very easy to till. They are subject to soil blowing, and young plants are often damaged by blowing sand.

The hazards of drought and soil blowing are severe. Consequently, these soils are not well suited to corn and soybeans unless irrigation is supplied. These soils are well suited to irrigation. Extensive areas in the Osseo area were once used for potatoes. Soil blowing can be controlled by keeping the soil covered with plants over winter and by using minimum tillage practices that keep the surface rough and trashy.

Crops grown on these soils respond only to small to moderate amounts of fertilizer unless irrigation is supplied or rainfall is timely. Potash and phosphate help to prevent winter killing of legumes.

Most areas of the Nymore, Zimmerman, and Salida soils are in brushy woodland or pasture. Because these soils are droughty, it is difficult to keep a good sod cover on them and they are poorly suited to permanent pasture. They are better suited to alfalfa and bromegrass than to the less drought-resistant bluegrass.

Capability Unit VIe-1

This unit consists of steep, well-drained soils of the Erin, Hayden, Heyder, Kilkenny, Kingsley, and Lester series. Most of these soils have a loam or clay loam surface layer and a sandy loam to clay loam subsoil. The Heyder and Kingsley soils have a sandy loam surface layer and some of them are sandy soils that are underlain by sand and gravel. The soils in this group, except for the Heyder and Kingsley soils, have high available moisture capacity. Heyder and Kingsley soils are variable, but they generally have moderate available moisture capacity.

These soils warm up early in spring. Because they are steep, rainfall runs off rapidly. Steepness of slopes severely limits their use for common farm crops. The hazard of erosion is severe, and operation of modern farm machinery is difficult on these slopes. These soils are better suited to hay crops and pasture. They should be maintained in woods or pasture, and permanent vegetation should be established in areas that are now cultivated. Gullies need to be shaped and seeded to grass. Some gullies need to be stabilized with engineering structures before grass can be established. Alfalfa and bromegrass pasture produces more forage than does bluegrass pasture. Grazing must be controlled to maintain good sod.

Capability Unit VIw-1

This unit consists of Lake beaches, sandy, and Mixed alluvial land, frequently flooded. Lake beaches, sandy, consists of poorly drained, gravelly and sandy material around the shoreline of lakes and sloughs. In years of high rainfall, some areas are submerged. Mixed alluvial land, frequently flooded, is on flood plains and is moderately well drained to

very poorly drained. In old stream channels these soils are seasonally ponded or are very wet throughout the year. On the slightly elevated ridges and mounds between the channels, they are more sandy and are better drained. Many of the areas on the flood plains are brushy and wooded and are pastured. Fertility is low. Most areas are in marsh vegetation.

These soils are too wet, too frequently flooded, or too sandy and gravelly to be suitable for cultivated crops. A row crop can be grown occasionally on some of the drier alluvial soils. Draining the wet soils is not practical so long as the flooding hazard exists, and protection against flooding is costly.

The better drained alluvial soils make good pasture if cleared and well managed. Pastures need to be renovated and reseeded occasionally, particularly if infertile sediments bury the sod. They should be seeded to grasses and legumes that tolerate wetness. If used as a companion crop, oats should be clipped or pastured. Otherwise, they are likely to lodge and to kill the new seedlings. Pasture should not be grazed early in spring or after overflow, because of the danger of the turf being trampled. Stabilizing streambanks keeps streams from cutting into cropland and pasture at sharp turns.

Capability Unit VIs-1

This unit consists of rolling, sandy soils of the Hubbard, Nymore, Salida, and Zimmerman series and of moderately steep soils of the Burnsville and Estherville series. Hubbard, Nymore, and Zimmerman soils are underlain by sand. The other soils in the group are underlain by sand and gravel. The soils in this unit have low or very low available moisture capacity.

The hazards of drought and erosion are severe. Therefore, these soils are not suited to cultivated crops.

These soils provide fair pasture early in spring and in fall, but production is low during the dry summer months. If these soils are used for pasture or hay, good management is needed to maintain the sod cover. Pastures of alfalfa and bromegrass are more resistant to drought and provide more forage than pastures of bluegrass, which produces low yields of forage during warm summer months.

Gullies should be shaped and seeded to grass for use as waterways. Some gullies may require engineering structures to stabilize them enough to allow grasses to grow.

Capability Unit VIIe-1

This unit consists of well-drained, steep and very steep soils of the Erin, Hayden, Heyder, Kilkenny, Kingsley, and Lester series. Most of these soils have a loam surface layer and clay loam subsoil. The Heyder and Kingsley soils generally have a sandy loam surface layer and subsoil, but in places they are loamy sand underlain by sand and gravel. The soils in this unit, except for the Heyder and Kingsley soils, have high available moisture capacity. Heyder and Kingsley soils are variable but generally have moderate available moisture capacity. These soils have a very severe hazard of erosion because of very rapid runoff.

The soils in this unit are too steep to cultivate. They are better suited to permanent vegetation such as pasture or woods than to cultivated crops. These soils generally do not provide good pasture, because they are so steep. They are difficult to renovate and improve because it is hard to operate farm machinery on the steep slopes. In some places gullies occur in these soils that require engineering structures to stabilize them. These soils are well suited to trees.

Capability Unit VIIs-1

This unit consists of moderately steep to very steep, somewhat excessively drained to excessively drained soils of the Burnsville, Hubbard, Rasset, and Salida series. The Burnsville soil is underlain by sand and gravel at a depth of 14 to 24 inches, and the Salida soils, at a depth of 6 to 14 inches. The other soils are underlain by deep sand at a depth of 12 to 18 inches. The Rasset soil contains thin layers of finer textured material in the sand. The soils in this unit have low or very low available moisture capacity and low natural fertility. The hazards of drought and erosion are severe.

These soils are too steep and too droughty for cultivated crops. If they are used for pasture or hay, it is difficult to maintain a good cover of vegetation on them. It is important to prevent overgrazing on these soils if they are pastured, because the soil is easily damaged. In some places there are gullies that require engineering structures to stabilize them. The soils are better suited to woodland or wildlife habitat.

Capability Unit VIIIw-1

Marsh makes up this capability unit. This land type occurs along the edges of lakes, shallow depressions, and ponds. Not all of the soil materials have been identified, but in most areas they consist of Peaty muck. Areas of mineral soils also occur. The vegetation consists of cattails, rushes, sedges, willows, and other plants that grow in wet areas. The water level fluctuates during the season. Some areas are dry if rainfall is less than normal.

Marsh is too wet for crops, pasture, or trees. In places, during prolonged dry spells, the edges of the areas of Marsh can be cut for wild hay. Most areas are unfeasible to drain. Drained areas of Marsh generally require management similar to that needed for soils in capability units IIIw-1 and IIIw-3.

Estimated Yields

In table 2 are estimated long-term average acre yields for the principal crops grown in Hennepin County under two levels of management. These yields are based on records and observations of representatives of the Soil Conservation Service, the Cooperative Extension Service, and the University of Minnesota. They are also based on interviews with farmers.

TABLE 2.--ESTIMATED AVERAGE ACRE YIELDS OF PRINCIPAL CROPS UNDER TWO LEVELS OF MANAGEMENT

[Yields in columns A are those expected under ordinary management; those in columns B are expected under improved management. Absence of a yield value indicates the crop ordinarily is not grown or the soil is not suited to it]

Soil	Corn for grain		Corn for silage		Soybeans		Oats		Rotation hay	
	A	B	A	B	A	B	A	B	A	B
	Bu.	Bu.	Tons	Tons	Bu.	Bu.	Bu.	Bu.	Tons	Tons
Anoka loamy fine sand, 2 to 6 percent slopes-	40	55	8	10	14	20	35	50	1.25	2.5
Anoka loamy fine sand, 6 to 12 percent slopes	35	50	7	9	12	18	30	45	1.25	2.5
Becker fine sandy loam	50	70	10	13	20	27	40	55	1.75	3.0
Becker loam	60	85	13	17	25	32	50	65	2.0	3.5
Biscay clay loam:										
Inadequately drained	50	--	10	--	17	--	35	--	1.5	----
Adequately drained	65	85	13	17	22	30	45	65	2.0	3.0
Biscay clay loam, depressional:										
Inadequately drained	--	--	--	--	--	--	--	--	----	----
Adequately drained	60	80	11	15	20	28	40	60	----	3.0
Braham loamy sand, silty subsoil, 2 to 6 percent slopes	40	55	8	11	15	20	40	55	2.0	3.0
Braham loamy sand, silty subsoil, 6 to 12 percent slopes	35	50	7	10	13	18	35	50	1.75	2.75
Braham loamy fine sand, 2 to 6 percent slopes	40	55	8	11	14	20	40	55	2.0	3.0
Braham loamy fine sand, 6 to 12 percent slopes	35	50	7	10	13	18	35	50	1.75	2.75
Burnsville sandy loam, 2 to 6 percent slopes-	40	50	8	11	13	18	35	50	1.5	2.5
Burnsville sandy loam, 6 to 12 percent slopes	35	45	7	10	13	16	30	45	1.25	2.25
Burnsville sandy loam, 12 to 18 percent slopes	30	40	5	8	10	14	25	40	1.0	2.0
Burnsville sandy loam, 18 to 35 percent slopes	--	--	--	--	--	--	--	--	.75	1.5
Burnsville sandy loam, thick solum variant, 2 to 6 percent slopes	45	60	9	13	16	23	40	60	1.5	2.75
Burnsville sandy loam, thick solum variant, 6 to 12 percent slopes	40	55	8	11	14	20	35	55	1.25	2.5
Canisteo clay loam:										
Inadequately drained	45	--	9	--	20	--	40	--	2.0	----
Adequately drained	60	85	12	18	26	36	50	75	3.0	4.5
Chaska clay loam:										
Inadequately drained	50	--	7	--	17	--	35	--	1.75	----
Adequately drained	60	80	12	18	22	32	45	65	2.5	4.0
Cordova silty clay loam:										
Inadequately drained	50	--	10	--	22	--	45	--	2.0	----
Adequately drained	65	90	13	18	28	36	55	75	3.0	4.5
Dakota loam, 0 to 2 percent slopes	45	65	10	13	20	28	45	65	2.0	3.5
Dakota loam, 2 to 6 percent slopes	45	65	9	13	18	28	40	65	2.0	3.5
Dakota loam, loamy substratum, 0 to 2 percent slopes	65	85	11	16	24	35	55	75	2.5	4.0
Dalbo silt loam, 0 to 2 percent slopes	60	80	12	16	21	30	45	70	3.0	4.25
Dalbo silt loam, 2 to 6 percent slopes	55	75	11	15	20	30	45	70	3.0	4.25
Dalbo silt loam, 6 to 12 percent slopes	50	70	10	14	19	28	40	65	2.75	4.0
Dassel sandy loam:										
Inadequately drained	40	--	7	--	16	--	35	--	1.5	---
Adequately drained	55	75	10	14	20	30	45	65	2.0	3.5
Dickman sandy loam, 0 to 2 percent slopes	40	50	9	11	14	20	40	55	1.5	2.5
Dickman sandy loam, 2 to 6 percent slopes	40	50	8	11	13	18	38	55	1.5	2.75

TABLE 2.--ESTIMATED AVERAGE ACRE YIELDS OF PRINCIPAL CROPS UNDER TWO LEVELS OF MANAGEMENT--Continued

Soil	Corn for grain		Corn for silage		Soybeans		Oats		Rotation hay	
	A	B	A	B	A	B	A	B	A	B
	Bu.	Bu.	Tons	Tons	Bu.	Bu.	Bu.	Bu.	Tons	Tons
Dickman sandy loam, 6 to 12 percent slopes---	35	45	7	10	10	15	35	50	1.25	2.5
Dorchester loam----------	60	80	12	18	22	32	40	55	2.25	3.5
Duelm loamy sand----------	35	50	8	11	14	20	35	50	1.25	2.25
Duelm loamy sand, loamy subsoil variant------	45	60	9	12	17	24	42	58	2.0	3.0
Dundas silt loam:										
Inadequately drained----------	45	--	9	--	18	--	40	--	2.0	----
Adequately drained----------	60	80	12	17	22	32	50	65	2.75	4.25
Erin loam, 2 to 6 percent slopes----------	55	80	12	16	20	31	45	70	3.0	4.5
Erin loam, 6 to 12 percent slopes----------	45	75	10	15	19	29	40	65	2.75	4.25
Erin loam, 12 to 18 percent slopes----------	35	65	8	13	15	25	30	55	2.5	3.75
Erin loam, 18 to 24 percent slopes----------	--	--	--	--	--	--	--	--	2.0	3.25
Erin clay loam, 2 to 6 percent slopes, eroded----------	50	80	11	16	20	31	40	70	3.0	4.5
Erin clay loam, 6 to 12 percent slopes, eroded----------	40	70	9	14	17	26	35	60	2.75	4.25
Erin clay loam, 12 to 18 percent slopes, eroded----------	35	65	7	12	14	23	30	55	2.5	3.75
Erin and Kilkenny loams, 24 to 35 percent slopes----------	--	--	--	--	--	--	--	--	----	----
Estherville sandy loam, 0 to 2 percent slopes----------	35	50	8	11	15	20	38	50	1.75	2.75
Estherville sandy loam, 2 to 6 percent slopes----------	35	50	8	11	13	18	35	50	1.5	2.5
Estherville sandy loam, 6 to 12 percent slopes----------	30	45	6	9	12	17	30	45	1.25	2.25
Estherville sandy loam, 12 to 18 percent slopes----------	20	30	5	8	10	15	25	40	1.0	2.0
Glencoe silty clay loam:										
Inadequately drained----------	--	--	--	--	--	--	--	--	----	----
Adequately drained----------	55	80	11	17	24	32	45	75	1.5	4.0
Grays very fine sandy loam, 2 to 6 percent slopes----------	65	90	13	18	25	36	55	80	3.0	4.5
Grays very fine sandy loam, 6 to 12 percent slopes----------	55	85	11	17	23	33	45	75	2.75	4.25
Hamel loam:										
Inadequately drained----------	50	--	10	--	22	--	45	--	2.0	----
Adequately drained----------	65	90	13	18	28	36	55	75	3.0	4.5
Hayden loam, 2 to 6 percent slopes----------	60	85	12	17	22	33	50	75	3.0	4.5
Hayden loam, 6 to 12 percent slopes----------	50	80	10	16	19	31	45	70	2.75	4.25
Hayden loam, 12 to 18 percent slopes---------	40	70	8	14	17	28	35	60	2.25	3.75
Hayden loam, 18 to 24 percent slopes---------	--	--	--	--	--	--	--	--	2.0	3.25
Hayden and Lester loams, 24 to 35 percent slopes----------	--	--	--	--	--	--	--	--	----	----
Hayden clay loam, 2 to 6 percent slopes, eroded----------	55	85	11	17	20	33	45	75	3.0	4.5
Hayden clay loam, 6 to 12 percent slopes, eroded----------	45	75	9	15	18	30	40	65	2.75	4.25
Hayden clay loam, 12 to 18 percent slopes, eroded----------	35	65	7	13	16	26	30	55	2.25	3.75
Hayden clay loam, 18 to 24 percent slopes, eroded----------	--	--	--	--	--	--	--	--	2.0	3.25
Heyder sandy loam, 2 to 6 percent slopes-----	50	70	10	14	20	28	40	60	2.25	3.25
Heyder sandy loam, 6 to 12 percent slopes----	40	60	9	12	16	25	35	55	2.0	3.0
Heyder sandy loam, 12 to 18 percent slopes---	30	50	7	10	12	21	30	50	1.5	2.5
Heyder sandy loam, 18 to 24 percent slopes---	--	--	--	--	--	--	--	--	1.25	2.25

TABLE 2.--ESTIMATED AVERAGE ACRE YIELDS OF PRINCIPAL CROPS UNDER TWO LEVELS OF MANAGEMENT--Continued

Soil	Corn for grain		Corn for silage		Soybeans		Oats		Rotation hay	
	A	B	A	B	A	B	A	B	A	B
	Bu.	Bu.	Tons	Tons	Bu.	Bu.	Bu.	Bu.	Tons	Tons
Heyder complex, 2 to 6 percent slopes	50	70	10	14	20	28	40	60	2.25	3.25
Heyder complex, 6 to 12 percent slopes	40	60	9	12	16	25	35	55	2.0	3.0
Heyder complex, 12 to 18 percent slopes	30	50	7	10	12	20	30	50	1.5	2.5
Heyder complex, 18 to 35 percent slopes	--	--	--	--	--	--	--	--	----	----
Hubbard loamy sand, 0 to 2 percent slopes	35	45	7	10	14	18	30	45	1.0	2.0
Hubbard loamy sand, 2 to 6 percent slopes	35	45	7	10	13	18	30	45	1.0	2.0
Hubbard loamy sand, 6 to 12 percent slopes	30	40	6	9	11	15	25	40	.75	1.75
Hubbard loamy sand, 12 to 18 percent slopes	--	--	--	--	--	--	--	--	.75	1.5
Hubbard loamy sand, 18 to 35 percent slopes	--	--	--	--	--	--	--	--	.5	1.0
Isan sandy loam:										
Inadequately drained	35	--	7	--	11	--	35	--	1.0	----
Adequately drained	40	50	9	12	14	20	45	55	1.25	2.5
Isan sandy loam, depressional:										
Inadequately drained	--	--	--	--	--	--	--	--	-----	----
Adequately drained	40	60	8	11	15	25	40	50	1.25	2.5
Isan sandy loam, loamy subsoil:										
Inadequately drained	40	--	7	--	16	--	35	0	1.5	----
Adequately drained	55	75	10	14	20	30	45	55	2.0	3.5
Kasota silty clay loam, 1 to 5 percent slopes	55	75	11	15	22	30	45	70	2.0	3.5
Kennebec silt loam	65	85	12	16	24	34	50	70	2.5	4.0
Kilkenny loam, 2 to 6 percent slopes	60	85	12	17	23	34	50	75	3.0	4.5
Kilkenny loam, 6 to 12 percent slopes	50	80	10	16	21	32	40	70	2.75	4.25
Kilkenny loam, 12 to 18 percent slopes	40	70	8	14	12	29	30	60	2.5	3.75
Kilkenny loam, 18 to 24 percent slopes	--	--	--	--	--	--	--	--	2.0	3.25
Kilkenny clay loam, 6 to 12 percent slopes, eroded	45	75	9	15	20	30	35	65	2.75	4.25
Kilkenny clay loam, 12 to 18 percent slopes, eroded	35	65	7	13	17	28	30	55	2.5	3.75
Kingsley complex, 2 to 6 percent slopes	50	70	10	14	20	29	40	60	2.25	3.25
Kingsley complex, 6 to 12 percent slopes	40	60	9	12	16	25	35	55	2.0	3.0
Kingsley complex, 12 to 18 percent slopes	30	50	7	10	12	21	30	50	1.5	2.5
Kingsley complex, 18 to 24 percent slopes	--	--	--	--	--	--	--	--	1.25	2.25
Kingsley complex, 24 to 35 percent slopes	--	--	--	--	--	--	--	--	----	----
Lake beaches, sandy:										
Inadequately drained	35	--	6	--	10	--	25	--	.5	----
Adequately drained	30	40	9	13	12	15	40	60	1.0	2.0
Lake beaches, loamy:										
Inadequately drained	50	--	8	--	18	--	35	--	.75	----
Adequately drained	65	85	12	17	25	34	50	75	1.5	2.5
Langola loamy sand, 1 to 2 percent slopes	35	55	8	11	14	20	40	55	1.75	2.75
Langola loamy sand, 2 to 12 percent slopes	30	50	7	10	12	18	35	50	1.75	2.75
Langola loamy sand, moderately well drained, 0 to 2 percent slopes	40	60	8	11	16	23	40	55	1.75	2.75
Lerdal loam, 1 to 4 percent slopes	65	85	13	18	24	36	55	75	3.0	4.5
Lester loam, 2 to 6 percent slopes	65	90	13	18	25	36	55	80	3.0	4.5
Lester loam, 6 to 12 percent slopes	55	85	11	17	23	33	45	75	2.75	4.25
Lester loam, 12 to 18 percent slopes	45	75	9	15	19	31	35	65	2.5	3.75
Lester loam, 18 to 24 percent slopes	--	--	--	--	--	--	--	--	2.0	3.25
Lester clay loam, 2 to 6 percent slopes, eroded	60	90	12	18	24	35	50	80	3.0	4.5
Lester clay loam, 6 to 12 percent slopes, eroded	50	80	10	16	21	32	40	70	2.75	4.25
Lester clay loam, 12 to 18 percent slopes, eroded	40	70	8	14	18	30	30	55	2.5	3.75

TABLE 2.--ESTIMATED AVERAGE ACRE YIELDS OF PRINCIPAL CROPS UNDER TWO LEVELS OF MANAGEMENT--Continued

Soil	Corn for grain		Corn for silage		Soybeans		Oats		Rotation hay	
	A	B	A	B	A	B	A	B	A	B
	Bu.	Bu.	Tons	Tons	Bu.	Bu.	Bu.	Bu.	Tons	Tons
Le Sueur loam, 1 to 4 percent slopes	70	90	14	18	28	36	60	80	3.0	4.5
Litchfield loamy fine sand	45	60	9	12	16	22	40	55	1.75	2.75
Marsh	--	--	--	--	--	--	--	--	----	----
Minnetonka silty clay loam:										
Inadequately drained	50	--	9	--	20	--	40	--	2.0	----
Adequately drained	65	85	12	16	26	34	50	70	2.75	4.25
Mixed alluvial land	45	65	9	13	18	26	45	65	2.5	3.75
Mixed alluvial land, frequently flooded	--	--	--	--	--	--	--	--	----	----
Nessel loam, 1 to 4 percent slopes	60	85	12	17	24	34	50	75	3.0	4.5
Nymore loamy sand, 2 to 6 percent slopes	30	45	7	10	12	17	30	45	1.0	2.0
Nymore loamy sand, 6 to 12 percent slopes	25	40	6	9	11	16	25	40	.75	1.75
Peaty muck:										
Inadequately drained	--	--	--	--	--	--	--	--	----	----
Adequately drained	50	70	10	14	20	28	--	--	----	----
Peaty muck over loam:										
Inadequately drained	--	--	--	--	--	--	--	--	----	----
Adequately drained	55	75	11	15	22	30	--	--	----	----
Peaty muck over sand:										
Inadequately drained	--	--	--	--	--	--	--	--	----	----
Adequately drained	50	70	10	14	20	28	--	--	----	----
Rasset loamy sand, 2 to 6 percent slopes	40	50	8	11	14	21	35	50	1.25	2.25
Rasset loamy sand, 6 to 12 percent slopes	35	45	7	10	13	19	30	45	1.0	2.0
Rasset loamy sand, 12 to 25 percent slopes	25	40	6	9	11	15	25	40	.75	1.75
Salida coarse sandy loam, 2 to 6 percent slopes	25	35	6	7	10	14	30	40	1.0	2.0
Salida coarse sandy loam, 6 to 12 percent slopes	20	30	5	6	9	13	25	35	1.0	1.75
Salida coarse sandy loam, 12 to 18 percent slopes	15	25	5	6	8	12	20	30	.75	1.5
Salida coarse sandy loam, 18 to 35 percent slopes	--	--	--	--	--	--	--	--	----	----
Shields silty clay loam:										
Inadequately drained	40	--	8	--	16	--	35	--	2.0	----
Adequately drained	55	75	11	15	20	28	45	65	2.5	4.0
Shorewood silty clay loam, 0 to 2 percent slopes	65	85	13	17	27	35	50	75	2.75	4.25
Shorewood silty clay loam, 2 to 6 percent slopes	60	80	12	16	25	33	50	75	2.75	4.25
Zimmerman loamy fine sand, 2 to 6 percent slopes	35	50	6	13	16	18	30	45	1.0	2.0
Zimmerman loamy fine sand, 6 to 18 percent slopes	30	45	5	11	14	16	25	40	.75	1.75

Yields are not given for crops that are considered as unsuitable for a particular soil. The major crops can be grown on such soils, but because the soils are droughty, steep, severely eroded, poorly drained, or susceptible to flooding, the crops are not likely to be successful. For soils on which adequate drainage makes a considerable difference in suitability for crops, yields are given with and without adequate drainage. The yields for components of soil complexes or undifferentiated units are the same unless stated otherwise.

The yield figures represent an average to be expected over a period of 10 years. They do not take into account abnormal crop seasons or past management on a particular farm. Considered in making the estimates were the prevailing climate, the characteristics of the soils, and the influence of different kinds of management on the soils. The figures are useful chiefly in judging the increases that can be expected from improved management and from draining the soils.

In columns A are yields to be expected under ordinary management. The management used to obtain these yields consists of a cropping system that is made up mainly of cultivated crops, but on many farms corn is alternated with oats or soybeans. Where corn is grown, all available manure and starter fertilizer are applied. Little or no fertilizer is applied to small grain or to hay meadow. A legume meadow is grown for 2 years in 6. The population of corn plants per acre ranges from 14,000 to 16,000. Three cuttings are obtained from alfalfa for hay each year. Few or no practices are used for control of erosion.

Yields given in columns B are those expected under improved management. The requirements of good management vary according to the soils, but under this level of management, crops suited to the soils are grown in a cropping system. Commercial fertilizers, lime, and manure are applied, proper tillage methods are used, and all organic material is returned to the soils. Also weeds, insects, and diseases are adequately controlled. The productivity and workability of the soils are maintained or improved, water is adequately controlled, and plant nutrients and soil moisture are conserved. Lime, phosphate, and potash are applied according to results of soil tests. Corn, 1 year or more after a legume, receives about 100 pounds of nitrogen per acre. Under improved management the population of corn plants per acre ranges from 18,000 to 20,000. Three cuttings are obtained from alfalfa for hay each year.

Use of the Soils as Woodland[2/]

Hennepin County is within the region known on original vegetation maps as the Big Woods in the Northern United States. The northern upland hardwood and oak types covered most of the county at the time of settlement. Native species are elm, basswood, sugar maple, ironwood, oak, and ash.

Originally the county was forested except for two grassland areas. The largest of these areas was on the flat sandy plain near Osseo and Champlin. The other was on the rolling plains near the Minnesota River in the southern part of the county. Even here, scattered tracts of timber occurred, which consisted mainly of bur oak.

The bottom-land hardwood type is along the flood plains and consists of cottonwood, ash, soft maple, and hackberry.

Presently, the woodland in the county is mostly in small woodlots. Wood production in Hennepin County is limited. Many woodland areas are grazed. A few tracts are managed to produce maple syrup.

Woodland Suitability Groups

More effective management of woodland can be planned if the soils are grouped according to those characteristics that affect the growth of trees and the management of stands. The soils of Hennepin County have been placed in seven woodland suitability groups. Each group is made up of soils that are suited to the same species of trees, that require about the same management, and that have about the same potential productivity.

Productivity for a species can be estimated by determining the site index, which is the average height, in feet, that the dominant trees of a given species will reach at 50 years of age. Table 3 gives estimated productivity of selected species by site index.

The woodland suitability groups in the county are shown in table 4. The table lists the important kinds of trees and their site index and gives the kinds of trees that are suitable for planting. The major limitations of the woodland suitability groups are also rated. The ratings are based largely on the experience and judgment of local soil scientists and foresters. These limitations are defined in the following paragraphs.

Seedling mortality refers to the expected loss of naturally occurring or planted seedlings, as a result of unfavorable soil characteristics. Mortality is slight if the expected loss is less than 25 percent. It is moderate if the expected loss is between 25 to 50 percent. Mortality is severe if the expected loss is more than 50 percent.

Plant competition refers to problems of establishing a desired species because of encroachment of competing vegetation. Competition is slight if competing vegetation does not cause mortality or restrict growth of seedlings. It is moderate if the plant invaders delay but do not prevent the establishment of a normal, fully stocked stand of desirable species. Competition is severe if grass, brush, or undesirable trees prevent adequate regeneration. Intensive site preparation and maintenance are needed.

Equipment limitation refers to the soil characteristics that restrict or prohibit the use of equipment commonly used in tending and harvesting trees.

2/ Prepared with the help of JOHN HULTGREN, woodland conservationist, Soil Conservation Service.

TABLE 3.--ANNUAL PRODUCTION PER ACRE FOR STATED KINDS OF TREES AND SITE INDEXES

Production (cords per acre per year) 1/	Site indexes for--			
	Red pine, white spruce	White pine, balsam fir, upland oak, ash, elm	Jack pine, northern hardwoods, poplar, white birch	Tamarack
> 0.7	>60	> 65	> 70	> 55
0.6-0.7	55	60	65	50
0.5-0.6	50	55	60	45
>0.5	>45	<50	< 55	< 35

1/ Trees greater than 6 inches in diameter at breast height.

The equipment limitation is slight if there are no restrictions on the type of equipment or on the time of year that the equipment can be used. The limitation is moderate if the use of equipment is restricted by slope or because of wetness of soils for no more than 3 months, or if the use of equipment damages tree roots to some extent. The limitation is severe if the use of normal equipment is restricted or limited for more than 3 months per year.

The erosion hazard is the degree of potential loss of soil by wind or water. Vegetative cover, slope, and soil properties are important factors. The hazard is slight if erosion is no problem. It is moderate if normal measures are needed to prevent unnecessary loss of soil. It is severe if special care and methods are needed to minimize loss and deterioration of the soil.

Windthrow hazard indicates the danger of trees being blown over from high-velocity winds. The ability of trees to windstand wind is reflected by those soil characteristics that influence the development of the tree root system. A rating of slight indicates that trees are not expected to be blown down in forested areas by commonly occurring wind. A rating of moderate indicates that the root development of designated species is adequate for stability except during periods of excessive wetness or greatest wind velocity. A rating of severe indicates that the soils do not permit adequate tree rooting for stability.

The soils in the county have been placed in seven woodland suitability groups described below. To find the woodland suitability group for any given soil, refer to the "Guide to Mapping Units" at the back of this survey.

Woodland Suitability Group 1

This group consists of deep and moderately deep, medium-textured to moderately fine textured soils of the Dakota, Dalbo, Erin, Grays, Hayden, Heyder, Kasota, Kilkenny, Lerdal, Lester, Le Sueur, Nessel, and Shorewood series. The Lerdal soil is somewhat poorly drained, but all the other soils in this group are well drained or moderately well drained. The largest acreage of soils in this group has slopes of 2 to 12 percent, but slopes range from 0 to 35 percent. Natural fertility is medium to high, the organic-matter content ranges from low to high, and the available moisture capacity is high. Permeability is moderate to moderately slow.

Woodland Suitability Group 2

This group consists of moderately deep to deep, moderately well drained to somewhat excessively drained soils of the Braham, Dakota, Heyder, Kingsley, and Langola series, and of the Burnsville series, thick solum variant, and the Duelm series, loamy subsoil variant. The Braham, Duelm, loamy subsoil variant, and Langola soils have a sandy surface layer and are underlain by finer material at a depth of 18 to 40 inches. The Dakota soils have a surface layer and subsoil of loam and are underlain by sand at a depth of 20 to 36 inches. Burnsville soil, thick solum variant, has a surface layer and subsoil of sandy loam and is underlain by coarse sand at a depth of 24 to 40 inches. Slope ranges from 0 to 35 percent. These soils have low to high available moisture capacity and low to medium natural fertility. The organic-matter content ranges from low to high. Permeability is moderate to moderately rapid.

Woodland Suitability Group 3

This group consists of soils of the Anoka, Burnsville, Dickman, Estherville, Litchfield, and Rasset series. These soils are moderately coarse textured and coarse textured. They are moderately well drained to somewhat excessively drained. Slopes range from 0 to 25 percent. These soils have low available moisture capacity and rapid to moderately rapid permeability. The organic-matter content is low to moderate. Fertility is low to medium.

TABLE 4.--INTERPRETATIONS BY WOODLAND SUITABILITY GROUPS

Woodland suitability group and map symbols	Important kinds of trees and site index	Seedling mortality	Plant competition	Erosion hazard	Equipment limitation	Windthrow hazard	Kinds of trees suitable for planting
Group 1: DbA, DlA, DlB, DlC, EnB, EnC, EnD, EnE, ErB2, ErC2, ErD2, EsF, GyB, GyC, HbB, HbC, HbD HbE, HcB2, HcC2, HcD2, HcE2, HdF, HeB, HeC, HeD, HeE, KaB, KkB, KkC, KkD, KkE, KlC2, KlD2, LmB, LrB, LrC, LrD, LrE, LsB2, LsC2, LsD2, LtB, NeB, SwA, SwB.	Basswood (65-70), sugar maple (50-55), red oak (65-70), white oak (65-70), and red pine (60-70).	Slight-----	Severe-----	Slight to moderate.	Slight to moderate.	Slight-----	All slopes: black walnut, red pine, white pine, and spruce. South- and west-facing slopes of more than 12 percent: red pine, redcedar, jack pine, and green ash.
Group 2: BsB, BsC, BtB, BtC, BxB, BxC, DaA, DaB, Ds, HlB, HlC, HlD, HlE, KnB, KnC, KnD, KnE, KnF, LgA, LgB, Lh.	Oaks (55-60), red pine (55-60), white pine (55-60), and sugar maple (50-55).	Slight to moderate.	Slight to severe.	Slight to moderate.	Slight to moderate.	Slight-----	All slopes: red pine, white pine, and white spruce. South- and west-facing slopes of more than 12 percent: red pine, jack pine, and redcedar.
Group 3: AnB, AnC, BuB, BuC, BuD, BuE, DnA, DnB, DnC, EtA, EtB, EtC, EtD, Lu, RsB, RsC, RsD.	White oak (45-55), red pine (50-55), white pine (50-55), and jack pine (55-60).	Moderate---	Slight to moderate.	Slight to moderate.	Slight to moderate.	Slight-----	All slopes: white pine, white spruce, red pine, and redcedar. South- and west-facing slopes of more than 12 percent: red pine and redcedar.
Group 4: Dp, HuA, HuB, HuC, HuD, HuE, NyB, NyC, SaB, SaC, SaD, SaE, ZmB, ZmC.	Bur oak (40-50), red pine (50-55), white pine (50-55), and jack pine (55-60).	Moderate to severe.	Slight-----	Slight to severe.	Slight to moderate.	Slight-----	Red pine, white pine, jack pine, and ponderosa pine.

467-556 O - 74 - 7

TABLE 4.--INTERPRETATIONS BY WOODLAND SUITABILITY GROUPS--Continued

Woodland suitability group and map symbols	Important kinds of trees and site index	Seedling mortality	Plant competition	Erosion hazard	Equipment limitation	Windthrow hazard	Kinds of trees suitable for planting
Group 5: Ba, Bb, Do, Ha, Iv, Ke, Mu, Mx.	Oaks, elm, ash, and silver maple (60-70); aspen and cottonwood (70-80).	Slight to moderate.	Severe-----	Slight-----	Slight-----	Slight-----	Cottonwood, silver maple, and black walnut.
Group 6: Bc, Ca, Ch, Co, Dm, Du, Is, Lc, Ld, Mt, Sh.	Oaks, elm, ash, and silver maple (55-60); aspen and cottonwood (60-70).	Moderate to severe.	Severe-----	Slight-----	Moderate---	Moderate---	Cottonwood and silver maple
Group 7: Bd, Gc, It, Ma, Pa, Pb, Pm.	None----------	Severe-----	Severe-----	Slight-----	Severe-----	Severe-----	None.

Woodland Suitability Group 4

This group consists of soils of the Duelm, Hubbard, Nymore, Salida, and Zimmerman series. These soils are droughty loamy sand underlain by sand or sand and gravel within a depth of 12 inches. Slopes range from 0 to 35 percent but are typically 2 to 12 percent. The Duelm soils have a slight seasonally high water table at a depth of 3 to 5 feet during wet seasons. All of these soils have low available moisture capacity and rapid to very rapid permeability. The organic-matter content is low to moderate. Fertility is low to medium.

Woodland Suitability Group 5

This group consists of soils of the Becker, Dorchester, Hamel, Isan, and Kennebec series and Mixed alluvial land. These are mostly medium textured to moderately coarse textured, well drained and moderately well drained, nearly level soils on bottom lands that are subject to occasional flooding or ponding. Mixed alluvial land, frequently flooded, however, is flooded more often and is poorly drained in places. These soils have low to high available moisture capacity. Established trees, however, are not adversely affected by the low available moisture capacity, because of the location of the soils on the landscape. Permeability ranges from moderate to rapid. Fertility ranges from medium to high. The organic-matter content is moderate to high.

Woodland Suitability Group 6

This group consists of soils of the Biscay, Canisteo, Chaska, Cordova, Dassel, Dundas, Isan, Minnetonka, and Shields series and Lake beaches. With the exception of the Biscay, Dassel, and Isan soils and Lake beaches these soils are deep and are loamy to clayey. The Biscay soil has a moderately fine textured surface layer but is underlain by sand or sand and gravel at a depth of 24 to 40 inches. The other soils are moderately coarse textured to coarse textured. Most of these soils are poorly drained, but the Shields soil is somewhat poorly drained, and Lake beaches, loamy, is very poorly drained in some places. The water table is at a depth of 1 to 3 1/2 feet during wet periods. The available moisture capacity is high in the loamy to clayey soils and moderate to high in the more sandy soils. Most of these soils have medium to high fertility, but the Isan soils and Lake beaches, sandy, have low fertility.

Woodland Suitability Group 7

This group consists of the soils of the Biscay, Glencoe, and Isan series and of Marsh and Peaty muck. The soils range from deep, loamy soils in small depressions to extensive areas of organic soils, marsh, and old river channels. The water table is near the surface much of the year. These soils are normally too wet to grow trees or shrubs without artificial drainage.

Suitability of the Soils for Wildlife[2/]

The soils of Hennepin County have the potential to provide excellent habitat for various species of wildlife. Habitat alone, however, does not assure the presence of wildlife populations. Other factors such as native range and land-use patterns have a significant effect.

Different soils have different potential for producing various elements of wildlife habitat, and there is a distinct relationship between different types of plants on various soils and the animals associated with these plants. For example, the Hayden, Cordova, and Peaty muck soils of soil association 2 have a high potential to produce habitat elements that the ring-necked pheasant requires. Hayden and Cordova soils are well suited to grasses and legumes that the pheasant uses for nesting and escape cover. They are also well suited to food plants and to woody plants for winter cover. Undrained Peaty muck soils can produce cattails, sedges, and water-tolerant grasses used for nesting and winter cover. If drained, Peaty muck soils are well suited to such row crops as corn and soybeans, which are excellent food for pheasant. On the other hand, the woodland production potential of drained Peaty muck soils is low, so the habitat potential for deer is somewhat limited.

The principal species of wildlife in Hennepin County are ring-necked pheasant, several species of waterfowl, white-tailed deer, gray squirrel, fox squirrel, muskrat, and mink. Their numbers are somewhat related to the soil associations in the county and to land use. The soil associations are described in the section "General Soil Map," and their location is shown on the general soil map at the back of this soil survey.

Table 5 rates the soil associations in the county for their potential of producing various kinds of wildlife. The ratings assume that proper management will be provided. Additional information is given in the following paragraphs.

Hennepin County is a poor to fair range for pheasants primarily because of climatic limitations. The higher populations of pheasants are on the Cordova, Hayden, and Nessel soils of soil association 1, on the Hayden, Cordova, and Peaty muck soils of soil association 2, and on the Lester, Hamel, and

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[3/] JOHN W. BEDISH, biologist, Soil Conservation Service, helped prepare this section.

TABLE 5.--HABITAT POTENTIAL OF SOIL ASSOCIATIONS FOR STATED KINDS OF WILDLIFE

Soil association	Upland game		Waterfowl and furbearers	Big game
	Pheasants	Squirrels and rabbits	Ducks, mink, and muskrats	Deer
1. Cordova-Hayden-Nessel	High	High	High	High.
2. Hayden-Cordova-Peaty muck	High	High	High	High.
3. Lester-Peaty muck	Medium	High	High	High.
4. Hayden-Peaty muck	Medium	High	Medium to high-	Medium.
5. Erin-Kilkenny-Peaty muck	Medium	Medium	Medium	Medium.
6. Peaty muck-Hayden-Burnsville	Low	Low	Low 2/	Low.
7. Hubbard-Isan-Duelm	Low	Low	Low 2/	Low.
8. Estherville-Dickman-Dakota	Low to medium-	Low	Low 2/	Medium.
9. Hubbard-Anoka	Low	Low	Low 2/	Low.
10. Mixed alluvial land-Marsh-Chaska	High	High	Low to medium-	High.

1/ Ratings reflect only the potential of the soils to produce the habitat and does not reflect the climate and native range of the wildlife species named.

2/ Very poorly drained soils have a high potential for development of wetland habitat.

Peaty muck soils of soil association 3 in the western part of the county.

The county contains many marshes and lakes that provide excellent habitat for waterfowl, mink, and muskrats. The Cordova, Hayden, and Nessel soils of soil association 1 and the Hayden, Cordova, and Peaty muck soils of soil association 2 have a high potential for producing waterfowl habitat. The many, low, wet depressions in these associations are well suited to dugout ponds. The ponds improve the habitat for waterfowl, and many more ponds are desirable.

Many of the lakes in the county, mainly Minnetonka, Medicine, and Independence Lakes, provide good fishing. The principal sport fish are northern pike and pan fish, including bluegill, croppie, and sunfish.

The small deer population in the county mainly inhabits the wooded areas along the rivers that border the county.

Rabbits and squirrels are found throughout the county, but the higher populations are in the more heavily wooded areas.

Wildlife populations can be increased by using such conservation practices as rotating crops, planting crops in strips, and seeding ditchbanks and field borders to provide a variety of cover that is attractive and beneficial to wildlife. Improving farmstead windbreaks and seeding odd areas to grasses, legumes, shrubs, and trees provide food and cover for many species of wildlife. Protecting areas from overgrazing and fire are additional practices that improve the wildlife habitat.

Engineering Uses of the Soils

Some soil properties are of special interest to engineers because they affect the construction and maintenance of roads, airports, pipelines, building foundations, facilities for water storage, erosion control structures, drainage systems, and sewage disposal systems. Among the properties most important to engineers are permeability, shear strength, compaction characteristics, drainage, shrink-swell characteristics, particle size, plasticity, and reaction. Depth to the water table, depth to bedrock, and topography are also important.

The information in this publication can be used to--

1. Make studies that will aid in selecting and developing industrial, business, residential, and recreational sites.
2. Make preliminary estimates of the soil properties that affect the planning of

4/ Reviewed by RICHARD D. WENBERG, assistant State conservation engineer, Soil Conservation Service.

agricultural drainage systems, farm ponds, irrigation systems, and terraces or diversions.

3. Make preliminary evaluations that will aid in selecting locations for highways, airports, pipelines, and cables and in planning detailed investigations at the selected locations.
4. Locate probable sources of sand and gravel and other construction material.
5. Correlate performance with soil mapping units to develop information that will be useful in planning engineering practices and in designing and maintaining engineering structures.
6. Determine the suitability of soils for cross-country movement of vehicles and construction equipment.
7. Supplement other published information, such as maps, reports, and aerial photographs, that is used in preparation of engineering reports for a specific area.
8. Develop other preliminary estimates for construction purposes.

With the soil map for identification of soil areas, the engineering interpretations reported here can be useful for many purposes. It should be emphasized, however, that these interpretations do not eliminate the need for onsite investigation.

Some of the terms used by soil scientists have a special meaning in soil science that may not be familiar to engineers. These terms are defined in the Glossary. Most of the information in this subsection is in tables 6, 7, and 8.

Engineering Classification Systems

Two systems of classifying soils for engineering purposes are in general use--the AASHO system (1) and the Unified system (9). Both are used in this survey.

Most highway engineers classify soil material in accordance with the system approved by the American Association of State Highway Officials (AASHO). In this system all soil material is classified in seven principal groups. The classification is based on mechanical analysis and plasticity index data. The groups range from A-1, which consists of soils that have the highest bearing capacity and are the best for subgrade, to A-7, which consists of soils that have the lowest strength when wet and are the poorest for subgrade. Within each group the relative engineering value of the soil material is indicated by a group index number. The numbers range from 0, for the best material, to 20, for the poorest. The group index number is shown in parentheses following the soil group symbol in the column headed AASHO in table 6.

Some engineers prefer to use the Unified system. In this system soils are identified according to their size, gradation, plasticity, and liquid limit. There are four classes of coarse-grained soils, six classes of fine-grained soils, four classes of mixed fine- and coarse-grained soils, and three classes of highly organic soils.

Table 6 shows the AASHO and the Unified classification of specified soils in the county, as determined by laboratory tests.

Engineering Test Data

Soil samples representing six soil series in the county were tested by the Minnesota Department of Highways in cooperation with the U.S. Department of Commerce, Bureau of Public Roads. The soil samples were taken from major horizons of representative profiles. Not all horizons were sampled. The tests were made in accordance with standard procedures. The test results are given in table 6.

Engineering Properties of the Soils

Estimates of properties significant in engineering are given in table 7. The estimates are based on test data in table 6 and on test data from other counties. Where test data were not available, estimates were based on comparison with similar soils that have been tested. The estimates in table 7 are for the soils as they occur in their natural state and not for areas that have been altered by cut and fill operations. Soils in the survey area are deep enough over bedrock that bedrock does not affect their use.

Engineering Interpretations

Estimates of the suitability of soils for various engineering uses are given in table 8. Properties that are important to the selection, design, and application of various engineering practices were considered. Evaluations were based on test data and field performance. Engineers should not apply specific values to estimates of bearing capacity of soils.

Some soil properties are favorable for one engineering use but not for another. For example, a slowly permeable underlying material would be favorable for a pond site but unfavorable for a septic tank filter field. (See subsection "Use of the Soils for Town and Country Planning.")

Frost action is a serious limitation in Hennepin County. Soils should not be compacted when they contain frost. The depth of frost penetration is commonly 4 feet or more. Winter grading is possible in gravelly and sandy material when no frost is present.

Uniformity of material is important in grading design. Frost heaving occurs if there is high capillary action in a material that is in close proximity to a water table. Differential frost heaving occurs when capillary action is quite variable from one material to an adjacent one. Some deposits of glacial till contain lenses and pockets of silt and fine sand that are susceptible to frost

TABLE 6.--ENGINEERING

[Tests performed by Minnesota Department of Highways, in cooperation with U.S. Department of Commerce, Highway

Soil name and location	Parent material	Minnesota report No. SS68	Depth from surface	Moisture-density data 1/		Mechanical analysis 2/	
				Maximum dry density	Optimum moisture	Percentage passing sieve--	
						3/8 inch	No. 4 (4.7 mm.)
			Inches	Pounds per cubic foot	Percent		
Anoka loamy fine sand:							
Sec. 17, T. 119 N., R. 21 W.	Glacial outwash, stratified sand.	586	0-11	111	12	---	---
		587	20-31	109	14	---	---
		588	31-37	111	13	---	---
		589	42-50	122	15	---	---
Cordova silty clay loam:							
Sec. 10, T. 118 N., R. 23 W.	Glacial till of Mankato age.	583	0-9	95	24	---	100
		584	17-22	107	18	100	99
		585	27-40	109	16	100	99
Dalbo silt loam:							
Sec. 17, T. 119 N., R. 23 W.	Lacustrine sediment over glacial till.	590	2-5	119	23	---	---
		591	14-25	89	29	---	---
		592	31-42	110	17	95	92
Duelm loamy sand:							
Sec. 35, T. 119 N., R. 21 W.	Mississippi terrace medium sand.	571	0-11	116	12	---	100
		572	11-22	117	11	100	99
		573	30-37	125	11	92	85
		574	37-46	104	12	100	99
Hayden loam:							
Sec. 20, T. 118 N., R. 22 W.	Calcareous loam glacial till.	575	0-7	109	16	100	99
		576	14-22	96	22	100	99
		577	22-31	102	18	99	99
		578	31-36	105	18	97	96
Kilkenny loam:							
Sec. 20, T. 118 N., R. 23 W.	Glacial till (end moraine).	579	0-9	92	24	100	99
		580	14-21	83	32	99	98
		581	33-42	86	29	97	95
		582	42-48	96	24	99	97

1/ Based on AASHO Designation T 99-57, Method C (1).

2/ Mechanical analyses according to AASHO Designation T 88-57 (1). Results by this procedure frequently may differ somewhat from results that would have been obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHO procedure, the fine material is analyzed by the hydrometer method, and the various grain-size fractions are calculated on the basis of all the material, including that coarser than 2 millimeters in diameter. In the SCS soil survey procedure, the fine material is analyzed by the pipette method, and the material coarser than 2 millimeters in diameter is excluded from calculations of grain-size fractions. The mechanical analyses used in this table are not suitable for use in naming textural classes for soils.

TEST DATA

Bureau of Public Roads (BPR), in accordance with standard procedures of the American Association of State Officials (AASHO)]

Mechanical analysis 2/--Continued							Liquid limit	Plasticity index	Classification	
Percentage passing sieve--Continued			Percentage smaller than--						AASHO	Unified 3/
No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	0.05 mm.	0.02 mm.	0.005 mm.	0.002 mm.				
							Percent			
---	97	24	18	12	7	6	(4/)	(4/)	A-2-4(0)	SM
---	98	22	14	10	8	7	(4/)	(4/)	A-2-4(0)	SM
---	97	30	22	16	12	8	(4/)	(4/)	A-2-4(0)	SM
---	98	20	12	8	6	4	(4/)	(4/)	A-2-4(0)	SM
99	94	77	66	51	29	16	39	12	A-6(8)	OL
97	90	50	44	36	28	25	39	21	A-6(7)	CL
96	86	57	51	39	26	14	31	12	A-6(6)	CL
---	99	93	89	69	36	20	33	11	A-6(8)	CL
---	---	98	94	86	62	46	68	37	A-7-5(20)	CH
88	75	50	44	38	22	18	35	16	A-6(3)	CL
99	70	19	18	14	10	7	(4/)	(4/)	A-2-4(0)	SM
98	71	13	12	10	8	7	(4/)	(4/)	A-2-4(0)	SM
76	34	5	5	5	3	2	(4/)	(4/)	A-1-b(0)	SP-SM
99	67	1	2	2	2	1	(4/)	(4/)	A-3(0)	SP
97	85	50	41	28	17	14	28	6	A-4(2)	ML
98	91	62	56	42	33	27	43	21	A-7-6(10)	CL
97	89	59	51	42	28	23	40	18	A-6(8)	CL
94	85	54	47	36	22	18	33	12	A-6(5)	CL
98	91	69	62	48	29	20	41	13	A-7-6(8)	ML
97	90	77	73	62	51	36	64	31	A-7-5(20)	MH-CH
94	86	73	70	61	44	34	58	26	A-7-5(18)	MH
94	85	64	59	49	32	27	48	22	A-7-6(12)	ML-CL

3/ SCS and BPR have agreed to consider that all soils having plasticity indexes within two points of A-line are to be given a borderline classification. An example of a borderline classification obtained by this use is ML-CL.

4/ Nonplastic.

TABLE 7.--ESTIMATED SOIL PROPERTIES

Borrow land (Bo), Borrow pits (Bp), Cut and fill land (Cu), and Fill land (Fd) are omitted from this
in the first column indicates that at least one mapping unit in this series is made up of two or
reason it is necessary to follow carefully the instructions

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	Classification		
			Dominant USDA texture	Unified	AASHO
	Feet	Inches			
Anoka: AnB, AnC	5	0-10	Loamy fine sand, fine sand.	SM-SP	A-2
		10-20	Loamy fine sand	SM-SP	A-2 or A-3
		20-60	Bands of fine sandy loam, loamy fine sand, and fine sand.	SM-SP or SM	A-2 or A-3
Becker:					
Ba	3	0-28	Fine sandy loam	SM	A-2 or A-4
		28-45	Loamy fine sand or fine sandy loam.	SM	A-2
		45-60	Sand or loamy fine sand.	SP or SM-SP	A-3
Bb	3	0-36	Loam	ML	A-4
		36-45	Sandy loam	SM	A-4
		45-60	Sand	SP	A-3
Biscay:					
Bc	2	0-17	Clay loam	OL	A-6 or A-7
		17-34	Clay loam	CL	A-6 or A-7
		34-60	Sand and gravel	SP	A-2 or A-1
Bd	0	0-18	Clay loam	OL	A-6 or A-7
		18-36	Clay loam, clay, or sandy clay loam.	CL or CH	A-6 or A-7
		36-60	Sand and gravel	SP	A-2 or A-1
Braham:					
BsB, BsC	5	0-10	Loamy fine sand	SM	A-2
		10-27	Loamy fine sand	SM	A-2
		27-47	Fine sandy loam	SM	A-2 or A-4
		47-60	Silt loam or silty clay loam.	ML-CL or CL	A-4 or A-6
BtB, BtC	5	0-8	Loamy fine sand	SM	A-2
		8-27	Loamy fine sand	SP-SM	A-2 or A-3
		27-60	Loam, sandy clay loam, or clay loam.	CL or ML-CL	A-6
Burnsville: BuB, BuC, BuD, BuE	5	0-9	Sandy loam or loamy sand.	SM	A-2
		9-20	Loam, sandy loam	SC	A-2 or A-6
		20-60	Sand and gravel	GW or SW	A-1
Burnsville, thick solum variant: BxB, BxC.	5	0-10	Sandy loam	SM	A-2 or A-4
		10-30	Sandy loam	SM-SC or SC	A-2 or A-6
		30-60	Sand	SP	A-1 or A-2

table because their properties are variable and should be determined through onsite investigation. An asterisk more kinds of soil. The soils in such mapping units may have different properties and limitations, and for this for referring to other series that appear in the first column of this table]

Percentage passing sieve--			Permeability	Available moisture capacity	Reaction	Shrink-swell potential	Corrosivity	
No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)					Metal	Concrete
			Inches/hr.	Inches/inch of soil	pH value			
100	100	10-25	2.0-6.3	0.06	4.5-6.5	Low---------	Low--------	High.
100	100	5-20	6.3+	0.06	5.6-7.3	Low---------	Low--------	Moderate.
100	100	5-30	6.3+	0.06-0.10	5.6-7.3	Low---------	Low--------	Low to moderate.
100	95-100	30-45	2.0-6.3	0.14	6.1-6.5	Low---------	Low--------	Moderate.
100	95-100	15-30	6.3+	0.06	6.6-7.3	Low---------	Low--------	Low.
100	95-100	2-10	6.3+	0.02	6.6-7.8	Low---------	Low--------	Low.
95-100	95-100	55-65	0.63-2.0	0.18	6.1-7.3	Moderate----	Moderate---	Low.
95-100	95-100	35-50	2.0-6.3	0.14	6.6-7.8	Low---------	Low--------	Low.
95-100	90-100	2-5	6.3+	0.02	7.4-7.8	Low---------	Low--------	Low.
95-100	95-100	55-80	0.63-2.0	0.20	5.60-7.3	Moderate----	Moderate----	Low.
95-100	85-95	55-80	0.20-2.0	0.17	5.60-7.3	Moderate----	Moderate---	Low.
85-95	50-90	2-5	6.3+	0.02	7.4-7.8	Low---------	Moderate---	Low.
95-100	95-100	60-85	0.20-0.63	0.20	6.6-7.8	High--------	High-------	Low.
95-100	85-95	65-85	0.20-0.63	0.17	6.6-7.8	High--------	High-------	Low.
85-95	50-90	2-5	6.3+	0.02	6.6-7.8	Low--------	High------	Low.
95-100	95-100	20-35	2.0-6.3	0.10	6.1-7.3	Low---------	Low--------	Low.
100	100	20-35	6.3+	0.06	5.6-7.3	Low---------	Low--------	Low.
100	100	30-50	2.0-6.3	0.14	6.0-7.3	Low---------	Low--------	Low.
100	100	50-85	0.63-2.0	0.20	7.4-7.8	Moderate----	Moderate---	Low.
100	100	10-20	2.0-6.3	0.06	5.6-6.5	Low---------	Low--------	Moderate.
100	100	10-20	6.3+	0.04	5.6-6.5	Low---------	Low--------	Low to moderate.
95-100	95-100	60-80	0.63-2.0	0.17	7.4-7.8	Moderate----	Low--------	Low.
90-100	85-95	20-35	2.0-6.3	0.13	5.6-6.0	Low---------	Low--------	Moderate.
70-90	60-80	25-50	2.0-6.3	0.15	5.1-6.5	Low to moderate.	Low--------	Moderate.
30-60	20-50	0-5	6.3+	0.02	7.4-7.8	Low---------	Low--------	Low.
95-100	95-100	25-45	2.0-6.3	0.13	6.0-7.0	Low--------	Low--------	Low.
95-100	90-95	30-50	2.0-6.3	0.14	5.1-6.0	Low--------	Low--------	Moderate.
75-85	60-80	0-5	6.3+	0.02	7.4-7.8	Low--------	Low--------	Low.

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	Classification		
			Dominant USDA texture	Unified	AASHO
	Feet	Inches			
Canisteo: Ca	1	0-14	Clay loam	OH	A-7
		14-30	Clay loam	CL or ML-CL	A-7 or A-6
		30-60	Loam	CL or ML-CL	A-6
Chaska: Ch	1	0-21	Clay loam, loam	CL or OL	A-6
		21-33	Loam	CL or ML-CL	A-6
		33-60	Loam	ML-CL or CL	A-6
Cordova: Co	1	0-12	Silty clay loam	OH	A-7
		12-27	Silty clay loam, clay loam, or silty clay.	CL or CH	A-7
		27-60	Loam	CL	A-6
Dakota:					
DaA, DaB	5	0-9	Loam	CL	A-6
		9-27	Loam	CL	A-6
		27-60	Coarse sand	SP	A-2 or A-1
DbA	5	0-10	Loam	CL	A-6
		10-32	Loam	CL	A-6
		32-60	Bands of fine sand, fine sandy loam, loamy fine sand, and silt loam.	ML, ML-CL, or SM.	A-4 or A-2
Dalbo: DlA, DlB, DlC	3	0-10	Silt loam, silty clay loam.	ML or CL	A-7 or A-6
		10-31	Silty clay, silty clay loam.	MH or CH	A-7
		31-60	Loam	ML or CL	A-6 or A-4
Dassel: Dm	2	0-10	Sandy loam	SM	A-2 or A-4
		10-17	Sandy loam	SM	A-2
		17-33	Sandy clay loam	SC or CL	A-6
		33-60	Sand	SP	A-2 or A-3
Dickman: DnA, DnB, DnC	5	0-11	Sandy loam	SM	A-2 or A-4
		11-18	Sandy loam	SM	A-2 or A-4
		18-60	Medium or coarse sand	SP	A-2 or A-3
Dorchester: Do	3	0-14	Loam	ML-CL or CL	A-4 or A-6
		14-60	Loam	ML-CL, CL, or SM	A-4
Duelm: Dp	3	0-11	Loamy sand	SM	A-2
		11-60	Sand	SP	A-1 or A-3
Duelm, loamy subsoil variant: Ds	3	0-16	Loamy sand	SM	A-2
		16-29	Loamy sand	SM-SP	A-2 or A-3
		29-34	Gravelly loamy coarse sand.	GP or SP	A-1
		34-60	Loam	CL	A-6
Dundas: Du	2	0-10	Silt loam	ML or CL	A-4
		10-34	Clay loam, silty clay loam.	CL or CH	A-7
		34-60	Loam	CL	A-6

SIGNIFICANT IN ENGINEERING--Continued

Percentage passing sieve--			Permeability	Available moisture capacity	Reaction	Shrink-swell potential	Corrosivity	
No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)					Metal	Concrete
			Inches/hr.	Inches/inch of soil	pH value			
95-100	90-100	65-85	0.63-2.0	0.23	7.4-7.8	Moderate----	High-------	Low.
90-95	90-95	65-85	0.63-2.0	0.20	7.4-7.8	Moderate----	High-------	Low.
90-95	90-95	55-70	0.63-2.0	0.17	7.4-7.8	Moderate----	High-------	Low.
100	100	85-95	0.63-2.0	0.22	6.6-7.3	Moderate----	High-------	Low.
100	100	85-95	0.63-2.0	0.20	7.4-7.8	Moderate----	High-------	Low.
100	100	65-80	0.63-6.3	0.20	7.4-7.8	Moderate----	High-------	Low.
100	100	65-80	0.20-0.63	0.20	6.0-7.3	Moderate----	High-------	Low.
95-100	95-100	50-90	0.20-0.63	0.17	5.6-7.3	Moderate to high.	High-------	Moderate.
90-100	90-100	55-70	0.63-2.0	0.17	7.4-7.8	Moderate----	High-------	Low.
100	95-100	50-70	2.0-6.3	0.18	5.6-6.5	Moderate----	Low--------	Low.
100	95-100	50-70	2.0-6.3	0.16	5.1-6.0	Moderate----	Low--------	Moderate to low.
85-95	75-85	2-5	6.3+	0.02	5.1-6.5	Low---------	Low--------	Moderate.
100	95-100	50-70	2.0-6.3	0.18	6.1-6.5	Moderate----	Low--------	Low.
100	95-100	50-70	0.63-2.0	0.16	5.6-6.5	Moderate----	Low--------	Moderate to low.
95-100	85-95	15-80	2.0-6.3	0.14	5.1-6.6	Low---------	Low--------	Moderate to low.
100	100	85-95	0.63-2.0	0.18	6.1-7.3	Moderate----	High-------	Low.
100	100	85-95	0.2-0.63	0.17	5.1-6.0	High--------	High-------	Low.
100	100	60-85	0.20-2.0	0.17	7.4-7.8	Moderate----	High to moderate.	Low.
100	95-100	25-40	2.0-6.3	0.13	5.1-6.0	Low---------	High--------	High.
100	95-100	15-25	6.3+	0.10	5.1-6.0	Low---------	High-------	High.
100	100	40-75	0.63-2.0	0.16	5.6-6.5	Moderate----	High-------	Moderate.
95-100	85-95	2-5	6.3+	0.02	5.6-6.5	Low---------	High-------	Moderate.
100	90-100	25-45	2.0-6.3	0.13	5.1-6.0	Low---------	Low--------	Moderate.
100	90-100	25-40	2.0-6.3	0.11	5.6-6.5	Low---------	Low--------	Moderate.
95-100	75-85	2-5	6.3+	0.02	6.1-7.3	Low---------	Low--------	Moderate.
100	100	60-85	0.63-2.0	0.18	7.4-7.8	Moderate----	Low--------	Low.
100	100	55-75	0.63-6.3	0.16	7.4-7.8	Moderate----	Low--------	Low.
95-100	95-100	15-25	2.0-6.3	0.07	5.1-6.0	Low---------	Low--------	High.
90-100	90-100	2-5	6.3+	0.03	5.1-6.0	Low---------	Low--------	High.
95-100	95-100	15-25	2.0-6.3	0.06	5.6-6.6	Low---------	Low--------	Moderate.
95-100	95-100	5-20	6.3+	0.04	5.6-6.6	Low---------	Low--------	Moderate.
40-60	10-25	2-5	6.3+	0.02	5.6-6.6	Low---------	Low--------	Moderate.
95-100	95-100	55-70	0.63-2.0	0.16	6.6-7.8	Moderate----	Moderate---	Low.
100	100	80-90	0.63-2.0	0.18	6.0-7.3	Low---------	Moderate----	Low.
100	95-100	75-90	0.2-0.63	0.17	5.1-6.0	Moderate to high.	High--------	Moderate.
95-100	90-100	55-70	0.63-2.0	0.17	7.4-7.8	Moderate----	High-------	Low.

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	Classification		
			Dominant USDA texture	Unified	AASHO
	Feet	Inches			
*Erin: EnB, EnC, EnD, EnE, ErB2, ErC2, ErD2, EsF. For properties of the Kilkenny part in mapping unit EsF, refer to Kilkenny series in this table.	5	0-7	Loam	ML or CL	A-4 or A-6
		7-34	Clay loam	CL or CH	A-7
		34-60	Loam	CL	A-6
Estherville: EtA, EtB, EtC, EtD	5	0-8	Sandy loam	SM	A-2 or A-4
		8-20	Sandy loam	SM	A-2 or A-4
		20-60	Sand or gravel	SP or GP	A-1 or A-2
Glencoe: Gc	0	0-22	Silty clay loam or clay loam.	OH-OL	A-7
		22-36	Loam	CL	A-6
		36-60	Loam	CL or ML-CL	A-6
Grays: GyB, GyC	5+	0-7	Very fine sandy loam	SM or ML	A-4
		7-25	Silt loam or silty clay loam.	ML-CL or CL	A-6 or A-4
		25-60	Silt loam	ML or ML-CL or CL	A-4 or A-6
Hamel: Ha	1-2	0-22	Loam	OL or CL	A-6
		22-34	Clay loam	CL or CH	A-7 or A-6
		34-41	Loam	CL	A-6
		41-60	Loam	ML-CL or CL	A-6
*Hayden: HbB, HbC, HbD, HbE, HcB2, HcC2, HcD2, HcE2, HdF. For properties of the Lester part in mapping unit HdF, refer to the Lester series in this table.	5	0-7	Loam	ML or CL	A-4 or A-6
		7-36	Clay loam, loam	CL	A-6 or A-7
		36-60	Loam	CL-ML or CL	A-6
Heyder: HeB, HeC, HeD, HeE	10	0-10	Sandy loam	SM or SC	A-4 or A-2-4
		10-30	Sandy clay loam	CL	A-6
		30-60	Loam or sandy loam	CL, ML-CL, or SM	A-4
Heyder complex: H1B, H1C, H1D, H1E.	10	(1/)	(1/)	(1/)	(1/)
Hubbard: HuA, HuB, HuC, HuD, HuE	5	0-12	Loamy sand	SM	A-2
		12-60	Sand	SP	A-3
Isan: Is	1-2	0-10	Sandy loam	SM	A-2
		10-16	Loamy sand	SM	A-2
		16-60	Sand	SP	A-3

See footnotes at end of table.

SIGNIFICANT IN ENGINEERING--Continued

Percentage passing sieve--			Permeability	Available moisture capacity	Reaction	Shrink-swell potential	Corrosivity	
No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)					Metal	Concrete
			Inches/hr.	Inches/inch of soil	pH value			
95-100	95-100	70-80	0.63-2.0	0.17	6.0-7.3	Low to moderate.	Moderate---	Low.
95-100	90-95	70-85	0.20-0.63	0.17	5.1-6.5	High-------	Moderate---	Moderate.
95-100	90-95	60-75	0.20-0.63	0.17	7.4-7.8	Moderate to high.	Moderate---	Low.
90-100	75-100	25-35	2.0-6.3	0.14	6.1-6.5	Low--------	Low--------	Low.
85-100	60-90	20-35	2.0-6.3	0.11	6.1-7.3	Low--------	Low--------	Low.
40-90	40-90	0-5	6.3+	0.02	6.6-7.8	Low--------	Low--------	Low.
100	95-100	70-90	0.20-2.0	0.22	6.6-7.3	Moderate---	High-------	Low.
100	95-100	70-85	0.06-2.0	0.18	6.6-7.3	Moderate to high.	High-------	Low.
100	95-100	65-80	0.63-2.0	0.17	7.4-7.8	Moderate---	High-------	Low.
100	100	45-60	0.63-2.0	0.18	6.1-7.3	Low--------	Low--------	Low.
100	100	70-90	0.63-2.0	0.21	6.1-7.3	Moderate---	Low--------	Low.
100	100	50-85	0.63-2.0	0.18	7.4-7.8	Moderate to low.	Low--------	Low.
100	100	55-75	0.63-2.0	0.20	6.5-7.3	Low--------	High-------	Low.
100	100	75-90	0.20-0.63	0.18	6.1-7.3	Moderate to high.	High-------	Low.
100	95-100	70-85	0.20-0.63	0.17	5.6-7.3	Moderate to high.	High-------	Low.
95-100	90-95	55-70	0.63-2.0	0.17	7.4-7.8	Moderate---	High-------	Low.
95-100	90-100	50-70	0.63-2.0	0.18	6.1-7.3	Low--------	Moderate---	Low.
95-100	90-100	60-75	0.63-2.0	0.18	5.6-7.3	Moderate---	Moderate---	Moderate.
90-100	90-98	50-70	0.63-2.0	0.17	7.4-7.8	Moderate---	Moderate to low.	Low.
98-100	100	20-45	0.63-2.0	0.15	6.1-7.3	Low--------	Low--------	Low.
98-100	100	50-70	0.63-2.0	0.16	5.6-6.5	Moderate---	Moderate---	Moderate.
95-100	90-95	40-70	0.63-2.0	0.16	7.4-7.8	Moderate---	Low--------	Low.
(1/)	(1/)	(1/)	(1/)	(1/)	(1/)	Low to moderate.	Low--------	Low to moderate.
100	95-100	12-20	2.0-6.3	0.06	5.6-6.5	Low--------	Low--------	Moderate.
100	95-100	0-5	6.3+	0.03	5.6-6.5	Low--------	Low--------	Moderate.
100	95-100	15-35	2.0-6.3	0.16	5.1-6.0	Low--------	High-------	High.
100	95-100	12-20	6.3+	0.06	5.1-6.5	Low--------	High-------	High.
100	95-100	2-5	6.3+	0.03	5.6-7.3	Low--------	High-------	Moderate.

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	Classification		
			Dominant USDA texture	Unified	AASHO
	Feet	Inches			
Isan (Continued)					
It	0-1	0-14	Sandy loam	SM	A-2
		14-18	Loamy sand	SM	A-2
		18-60	Coarse sand	SP	A-3
Iv	1	0-10	Sandy loam	SM	A-2 or A-4
		10-28	Loamy sand	SM	A-2
		28-32	Gravelly loamy sand	SP	A-2 or A-1
		32-60	Loam	CL	A-6
Kasota: KaB	5	0-10	Silty clay loam	CL	A-7 or A-6
		10-28	Silty clay	MH or CH	A-7
		28-60	Gravel and sand	SP	A-1
Kennebec: Ke	5+	0-60	Silt loam	ML	A-4
Kilkenny: KkB, KkC, KkD, KkE, K1C2, K1D2.	5	0-9	Loam	ML-CL or CL	A-6
		9-42	Clay loam	CL, CH, or MH	A-7
		42-60	Loam	CL or ML-CL	A-7 or A-6
Kingsley: KnB, KnC, KnD, KnE[2/], KnF.	5+	0-14	Sandy loam	SM	A-2
		14-34	Sandy loam	SM-SC or SC	A-2 or A-4
		34-60	Sandy loam	SM-SC or SC	A-2
Lake beaches:					
Lc	1-2	0-36	Loamy sand, sandy loam, sand.	SM	A-2
		36-60	Loam	ML-CL or CL	A-6
Ld	1-2	0-24	Loam, silt loam	OL	A-6 or A-4
		24-40	Loam, silt loam	OL or ML	A-6 or A-4
		40-60	Loam	ML-CL or CL	A-6
Langola: LgA, LgB, Lh	5	0-8	Loamy sand	SM	A-2
		8-24	Loamy sand, sandy loam	SM	A-2 or A-3
		24-29	Gravelly loamy sand	GP or SP	A-1
		29-60	Sandy loam	SM or SC	A-2
Lerdal: LmB	3	0-13	Loam	CL	A-6
		13-47	Clay loam	CL or CH	A-7
		47-60	Loam	CL or ML-CL	A-7 or A-6
Lester: LrB, LrC, LrD, LrE, LsB2, LsC2, LsD2.	5	0-8	Loam and clay loam	ML or CL	A-6
		8-32	Clay loam	CL	A-6 or A-7
		32-60	Loam	CL or ML-CL	A-6

See footnotes at end of table.

SIGNIFICANT IN ENGINEERING--Continued

Percentage passing sieve--			Permeability	Available moisture capacity	Reaction	Shrink-swell potential	Corrosivity	
No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)					Metal	Concrete
			Inches/hr.	Inches/inch of soil	pH value			
100	95-100	20-35	2.0-6.3	0.16	6.1-6.5	Low	High	Moderate.
100	95-100	12-20	6.3+	0.06	6.1-7.3	Low	High	Moderate.
100	95-100	2-5	6.3+	0.03	6.6-7.3	Low	High	Low.
100	95-100	30-40	2.0-6.3	0.16	5.1-6.0	Low	High	High.
100	95-100	15-25	6.3+	0.06	5.1-6.0	Low	High	High.
80-95	50-75	2-5	6.3+	0.04	5.1-6.0	Low	High	High.
95-100	95-100	60-75	0.63-2.0	0.16	6.6-7.3	Moderate	High	Low.
100	100	60-85	0.63-2.0	0.20	6.0-7.3	Moderate to high.	Low	Low.
100	100	80-95	0.20-0.63	0.18	5.6-6.5	High	Moderate	Low.
80-95	70-95	2-5	6.3+	0.02	6.5-7.4	Low	Low	Low.
95-100	95-100	60-70	0.63-6.3	0.20	6.0-6.5	Moderate	Moderate	Low.
95-100	95-100	65-80	0.20-0.63	0.17	6.1-7.3	Moderate to high.	Low	Low.
95-100	90-95	70-85	0.20-0.63	0.17	5.1-7.3	High	Moderate	Moderate.
95-100	90-95	60-75	0.20-0.63	0.17	6.6-7.8	Moderate to high.	Moderate	Low.
95-100	95-100	20-35	0.63-2.0	0.12	6.1-6.5	Low	Low	Moderate.
90-100	85-95	25-40	0.63-2.0	0.13	5.2-6.0	Low to moderate.	Low	Moderate.
90-100	85-95	25-35	0.63-2.0	0.12	5.6-6.5	Low	Low	Moderate.
95-100	95-100	12-30	2.0-6.3	0.08	6.5-7.3	Low	High	Low.
95-100	90-95	50-70	0.63-2.0	0.17	7.4-7.8	Moderate	High	Low.
100	100	60-80	0.63-2.0	0.21	6.5-7.3	Low to moderate.	High	Low.
100	100	60-80	0.63-2.0	0.19	6.5-7.8	Low to moderate.	High	Low.
95-100	90-95	50-70	0.63-2.0	0.17	7.4-7.8	Moderate	High	Low.
95-100	90-100	12-30	2.0-6.3	0.08	5.6-6.5	Low	Low	Moderate.
85-95	90-100	12-30	2.0-6.3+	0.06	5.6-6.5	Low	Low	Moderate.
40-75	10-25	2-5	6.3+	0.02	5.6-6.5	Low	Low	Moderate.
85-95	80-90	25-35	0.63-2.0	0.14	6.1-6.5	Moderate	Low	Moderate.
100	95-100	60-80	0.63-2.0	0.20	6.1-7.3	Low	High	Low.
95-100	95-100	75-90	0.20-0.63	0.18	5.6-7.3	Moderate to high.	High	Moderate.
90-95	90-95	60-75	0.20-0.63	0.17	7.4-7.8	Moderate to high.	High	Low.
95-100	95-100	55-70	0.63-2.0	0.18	6.1-6.5	Low to moderate.	Low	Low.
95-100	95-100	60-75	0.63-2.0	0.17	5.6-7.3	Moderate	Moderate	Moderate.
95-100	90-95	55-70	0.63-2.0	0.17	7.4-7.8	Moderate	Moderate to low.	Low.

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	Classification		
			Dominant USDA texture	Unified	AASHO
	Feet	Inches			
Le Sueur: LtB	3	0-13	Loam	CL or ML	A-6
		13-36	Clay loam	CL	A-7
		36-60	Loam	CL or ML-CL	A-6
Litchfield: Lu	2	0-15	Loamy fine sand	SM	A-2
		15-24	Fine sandy loam	SM	A-2
		24-60	Fine and medium sand	SP	A-2 or A-3
Marsh: Ma	0	(1/)	(1/)	(1/)	(1/)
Minnetonka: Mt	1	0-13	Silty clay loam	OH or CL	A-7
		13-35	Silty clay	CH or MH	A-7
		35-60	Silty clay loam	ML, CL, or CH	A-7, A-6, or A-4
Mixed alluvial land:					
Mu	0-2	(1/)	(1/)	(1/)	(1/)
Mx	0	(1/)	(1/)	(1/)	(1/)
Nessel: NeB	3	0-7	Loam	ML or CL	A-4 or A-6
		7-31	Clay loam	CL	A-7
		31-60	Loam	CL or ML-CL	A-6
Nymore: NyB, NyC	10	0-9	Loamy sand	SM or SM-SP	A-2
		9-60	Sand	SP	A-2 or A-3
Peaty muck: Pa, Pb, Pm	0	(3/)	(3/)	(3/)	(3/)
Rasset: RsB, RsC, RsD	10	0-6	Loamy sand	SM-SP or SM	A-2
		6-19	Loamy sand or sand	SM-SP or SM	A-2 or A-3
		19-60	Alternating bands of loamy sand, sand, and sandy loam.	SM-SP or SM	A-2 or A-3
Salida: SaB, SaC, SaD, SaE	10	0-10	Coarse sandy loam	SM	A-2
		10-60	Sand and gravel	SP	A-1 or A-2
Shields: Sh	1	0-8	Silty clay loam	CL	A-7 or A-6
		8-36	Silty clay or clay	CH or MH	A-7
		36-60	Clay	CL or CH	A-7 or A-6
Shorewood: SwA, SwB	3	0-18	Silty clay loam or silty clay.	MH	A-7
		18-33	Silty clay	CH	A-7
		33-60	Clay loam	ML, CL, or CH.	A-6 or A-7
Zimmerman: ZmB, ZmC	10	0-9	Loamy fine sand	SM	A-2
		9-60	Fine sand or loamy fine sand.	SM-SP	A-3 or A-2

1/ Soils are not classified. Properties are variable and some cannot be safely estimated.

2/ The sandy and gravelly soils of this series have not been classified.

SIGNIFICANT IN ENGINEERING--Continued

Percentage passing sieve--			Permeability	Available moisture capacity	Reaction	Shrink-swell potential	Corrosivity	
No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)					Metal	Concrete
			Inches/hr.	Inches/inch of soil	pH value			
95-100	95-100	70-85	0.63-2.0	0.18	6.1-6.5	Moderate	Moderate	Low.
95-100	95-100	70-80	0.63-2.0	0.17	5.6-7.3	Moderate	Moderate	Low.
95-100	95-100	55-70	0.63-2.0	0.17	7.4-7.8	Moderate	Moderate	Low.
95-100	95-100	15-35	2.0-6.3	0.15	5.0-6.5	Low	Low	High.
95-100	95-100	20-35	6.3+	0.14	5.0-6.5	Low	Low	Moderate to high.
95-100	95-100	2-5	6.3+	0.02	5.5-6.5	Low	Low	Moderate.
(1/)	(1/)	(1/)	(1/)	(1/)	(1/)	(1/)	High	Low.
100	100	80-95	0.20-0.63	0.21	6.0-7.3	Moderate to high.	High	Low.
100	100	85-95	0.06-0.20	0.18	5.6-7.3	High	High	Moderate.
100	100	55-90	0.06-2.0	0.17	7.4-7.8	Moderate to high.	High	Low.
(1/)	(1/)	(1/)	(1/)	(1/)	6.5-7.8	Low	Variable	Low.
(1/)	(1/)	(1/)	(1/)	(1/)	6.5-7.8	Low	Variable	Low.
100	100	60-80	0.63-2.0	0.18	6.1-7.3	Low	Moderate	Low.
95-100	95-100	65-80	0.63-2.0	0.17	5.2-6.5	Moderate	Moderate	Moderate.
95-100	95-100	55-75	0.63-2.0	0.17	7.4-7.8	Moderate	Moderate	Low.
100	95-100	10-20	2.0-6.3	0.04	5.6-7.3	Low	Low	Moderate.
100	95-100	2-5	6.3+	0.02	5.6-7.3	Low	Low	Moderate.
(3/)	(3/)	(3/)	(3/)	0.25	(3/)	(3/)	High	Low.
100	100	10-20	6.3+	0.05	6.1-7.3	Low	Low	Moderate.
100	100	5-15	6.3+	0.04	5.6-6.5	Low	Low	Low.
95-100	95-100	2-35	6.3+	0.02-0.10	5.6-7.3	Low	Low	Moderate.
85-95	40-70	20-30	6.3+	0.08	6.6-7.3	Low	Low	Low.
60-90	30-80	2-5	6.3+	0.02	7.4-7.8	Low	Low	Low.
100	100	80-95	0.20-2.0	0.20	6.0-6.5	Moderate	High	Low.
100	100	85-95	0.06-0.20	0.17	5.1-6.5	High	High	Moderate.
100	80-100	55-90	0.06-2.0	0.17	7.4-7.8	Moderate to high.	High	Low.
100	100	80-95	0.63-2.0	0.21	6.1-7.3	Moderate	High	Low.
100	100	85-95	0.20-0.63	0.17	5.6-6.5	High	High	Moderate.
100	85-95	55-90	0.20-2.0	0.17	7.4-7.8	Moderate to high.	High to moderate.	Low.
90-100	90-100	12-20	6.3+	0.04	5.6-6.5	Low	Low	Moderate.
90-100	90-100	5-10	6.3+	0.04	5.6-6.5	Low	Low	Moderate.

3/ Organic material, not suitable for engineering uses.

467-556 O - 74 - 8

[Borrow land (Bo), Borrow pits (Bp), Cut and fill land (Cu), and Fill land (Fd) are omitted from this table
the first column indicates that at least one mapping unit in this series is made up of two or more kinds of
is necessary to follow carefully the instructions for referring to other series that appear in the first

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Anoka: AnB, AnC----	Poor----------	Fair for sand: fine sand and bands of loamy sand and sandy loam. Poor for gravel.	Fair: fair shear strength; poor compaction characteristics; low compressibility; fair bearing capacity.	Good drainage; low susceptibility to frost action; fair bearing capacity; highly erodible; fair stability.
Becker: Ba----------	Good----------	Fair for sand below a depth of 2 to 3 feet; some fines in sand. Poor for gravel.	Fair in upper 36 inches; good below that depth: good bearing capacity; subject to occasional flooding.	Seasonal high water table; subject to occasional flooding; low susceptibility to frost action; fair stability.
Bb----------	Good----------	Fair for sand below a depth of 3 feet; some fines in sand. Poor for gravel.	Fair to poor in upper 40 inches; good below that depth: good bearing capacity; subject to occasional flooding.	Subject to occasional flooding; moderate susceptibility to frost action; fair stability.
Biscay: Bc----------	Fair to good----------	Good for sand, but is difficult to excavate in places. Generally poor for gravel.	Poor in upper 36 inches; good below that depth: good bearing capacity; good compaction characteristics and shear strength; high water table may hinder excavation.	High water table; high susceptibility to frost action.
Bd----------	Fair----------	Good for sand, but is difficult to excavate in places. Generally poor for gravel.	Poor in upper 3 feet; good below that depth: good bearing capacity; good compaction characteristics and shear strength; high water table may hinder excavation; seasonally ponded.	High water table; high susceptibility to frost action; high shrink-swell potential to depth of 3 feet; seasonally ponded.

See footnote at end of table.

because their properties are variable and should be determined through onsite investigation. An asterisk in soil. The soils in such mapping units may have different properties and limitations, and for this reason it column of this table]

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Porous sand----------	Porous sand; high permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed; high intake rate.	Difficult to establish; high erodibility.
Occasionally flooded; high organic-matter content; porous, sandy substratum.	Medium permeability in upper 2 to 3 feet when compacted; high permeability below that depth; poor resistance to piping; occasionally flooded.	Not needed----------	Not needed----------	Generally not needed.
Occasionally flooded; high organic-matter content; porous, sandy substratum below a depth of 3 feet.	Medium permeability in upper 3 feet when compacted; poor resistance to piping; occasionally flooded; high permeability below a depth of 3 feet.	Not needed----------	Not needed----------	Generally not needed.
High organic-matter content; moderate to moderately slow permeability in upper 3 feet; substratum is porous sand.	Low permeability in upper 3 feet when compacted; good stability and resistance to piping; high water table; high permeability below depth of 3 feet when compacted.	Needed; rapid permeability in substratum; tile can be widely spaced; caving can be a hazard in some areas.	Not needed----------	Not needed.
High organic-matter content; upper 3 feet has moderate permeability; substratum is porous sand; suited to dugout ponds.	Low permeability in upper 3 feet when compacted; good stability and resistance to piping; high water table; seasonally ponded; high permeability below depth of 3 feet when compacted.	Needed; rapid permeability in substratum; tile can be widely spaced; caving can be a hazard in some areas.	Not needed----------	Not needed.

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Braham: BsB, BsC----------	Poor----------	Poor for sand: less than 40 inches deep to finer material. Not suitable for gravel.	Good to depth of 1½ to 3½ feet: erodes easily; good shear strength and compaction characteristics; low compressibility. Underlying material is fair to poor: fair to poor bearing capacity, shear strength, and stability.	Good drainage; high susceptibility to frost action; fair stability; highly erodible if exposed on embankments; moderate shrink-swell potential below depth of 1½ to 3½ feet.
BtB, BtC----------	Poor----------	Poor for sand: less than 3½ feet deep to finer material. Not suitable for gravel.	Good to depth of 1½ to 3½ feet: erodes easily; good shear strength and compaction characteristics; low compressibility. Underlying material is fair to good: fair bearing capacity and shear strength.	Good drainage; moderate susceptibility to frost action; fair stability in upper 1½ to 3½ feet; highly erodible if exposed on embankments; some seepage in cuts; moderate shrink-swell potential below depth of 1½ to 3½ feet.
Burnsville: BuB, BuC, BuD, BuE.	Fair----------	Generally poor for sand; good for gravel.	Very good: excellent shear strength; good bearing capacity and stability; low compressibility.	Good drainage; good stability; low susceptibility to frost action; low shrink-swell potential; large boulders in some areas; rolling to steep topography.
Burnsville, thick solum variant: BxB, BxC.	Fair----------	Fair: poorly graded sand and gravel containing 5 to 20 percent shale.	Fair to depth of 30 inches; good below that depth: good shear strength, bearing capacity, and stability; low compressibility.	Good drainage; good stability; low susceptibility to frost action; low shrink-swell potential.

See footnote at end of table.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Upper 1½ to 3½ feet is porous sand; material below has moderate permeability 1/.	High permeability when compacted in upper 1½ to 3½ feet; moderate permeability when compacted and poor stability and resistance to piping below depth of 1½ to 3½ feet.	Not needed----------	Sandy to depth of 1½ to 3½ feet; subject to soil blowing and water erosion; difficult to establish vegetation; highly erodible in underlying silt.	Sandy to depth of 1½ to 3½ feet; subject to soil blowing and water erosion; difficult to establish vegetation; highly erodible in underlying silt.
Upper 1½ to 3½ feet is porous sand; material below has moderate permeability 1/.	High permeability in upper 1½ to 3½ feet when compacted; low permeability when compacted and fair stability and resistance to piping below depth of 1½ to 3½ feet.	Not needed----------	Sandy to depth of 1½ to 3½ feet; subject to soil blowing and water erosion; difficult to establish vegetation.	Sandy to depth of 1½ to 3½ feet; subject to soil blowing and water erosion; difficult to establish vegetation.
Porous sand and gravel.	Moderate permeability in upper 1½ feet when compacted; high permeability below that depth when compacted.	Not needed----------	Not needed; shallow over gravel and sand.	Droughty soil; difficult to establish vegetation.
Porous sand and gravel.	Moderate permeability in upper 2½ feet when compacted; high permeability below that depth when compacted.	Not needed----------	Not needed; moderately deep over gravel and sand.	Droughty soil; difficult to establish vegetation.

TABLE 8.--ENGINEERING INTERPRETATIONS

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Canisteo: Ca--------	Fair----------	Not suited----------	Fair: high water table; fair stability; fair to poor bearing capacity; moderate shrink-swell potential.	High water table; high susceptibility to frost action; fair to poor bearing capacity; moderate shrink-swell potential.
Chaska: Ch----------	Fair to good----------	Poor for sand: sand is fine and very fine. Not suitable for gravel.	Poor: high organic-matter content; high water table; moderate shrink-swell potential; poor shear strength; fair to poor bearing capacity; occasionally flooded.	Subject to occasional flooding; high water table; high susceptibility to frost action; high organic-matter content.
Cordova: Co---------	Fair----------	Not suited----------	Poor in plastic subsoil; fair in till substratum: moderate shrink-swell potential; fair to poor bearing capacity; high water table; fair stability.	High organic-matter content in surface layer; high water table; poor to fair stability; high susceptibility to frost action.
Dakota:				
DaA, DaB----------	Good----------	Fair for sand below depth of 24 to 36 inches; sand includes some shale. Poor for gravel.	Fair to depth of 30 inches; good below that depth: low shrink-swell potential; good shear strength; low compressibility; fair compaction characteristics.	Moderate susceptibility to frost action; moderate shrink-swell potential to depth of 2 to 3 feet.
DbA----------	Good----------	Poor for sand: underlying sand has finer textured bands. Not suitable for gravel.	Fair: fair bearing capacity, shear strength, and stability.	Moderate susceptibility to frost action; moderate shrink-swell potential.

See footnote at end of table.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Moderate permeability; high organic-matter content 1/.	Low permeability when compacted; fair to good stability; fair resistance to piping; high water table.	Needed; moderate permeability.	Not needed----------	Drainage needed before construction.
Subject to occasional flooding; high organic-matter content; moderate permeability in upper 4 feet; rapid permeability below that depth.	Moderate permeability when compacted; poor stability and resistance to piping; occasionally flooded.	Needed, but suitable outlets are lacking in places; flood control needed.	Not needed----------	Generally not needed.
Moderately slow permeability; high organic-matter content.	Low permeability when compacted; fair to good stability; fair resistance to piping; high water table.	Needed; moderately slow permeability.	Not needed----------	Drainage needed before construction.
Moderate organic-matter content; moderately rapid permeability in upper 2 to 3 feet; porous sand below that depth.	Low permeability in upper 2 to 3 feet when compacted; fair stability and resistance to piping in upper 2 to 3 feet; high permeability below that depth when compacted.	Not needed----------	Sand is at depth of 2 to 3 feet; highly erodible.	Sand is at depth of 2 to 3 feet; highly erodible.
Moderate organic-matter content; moderate to rapid permeability in upper 3 feet; porous, sandy bands below that depth.	Low permeability in upper 3 feet when compacted; fair stability and resistance to piping in upper 3 feet; poor resistance to piping and high permeability below that depth when compacted.	Not needed----------	Bands of sand are at depth of 3 feet.	Bands of sand are at depth of 3 feet.

TABLE 8.--ENGINEERING INTERPRETATIONS

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Dalbo: DlA, DlB, DlC.	Fair----------	Not suited----------	Poor to depth of 2 to 5 feet: very plastic, clayey soils; poor shear strength; high compressibility. Fair in loamy material below: fair bearing capacity and shear strength.	Seasonally high water table; high compressibility and shrink-swell potential; moderate susceptibility to frost action.
Dassel: Dm----------	Good----------	Fair for sand: underlying sand generally contains finer textured bands. Not suitable for gravel.	Fair: high water table; fair stability and workability; moderate shrink-swell potential in fine-textured bands.	High susceptibility to frost action; high water table; fair stability; moderate shrink-swell potential in fine-textured bands.
Dickman: DnA, DnB, DnC.	Good----------	Good for sand below depth of 24 inches; poor for gravel.	Good: good bearing capacity and shear strength; low compressibility and shrink-swell potential.	Good drainage; low susceptibility to frost action; good stability; low shrink-swell potential.
Dorchester: Do------	Good----------	Poor for sand: sand is fine and very fine. Not suitable for gravel.	Poor: fair to poor bearing capacity and shear strength; occasionally flooded.	Subject to flooding; fair stability; seasonally high water table; moderate susceptibility to frost action.
Duelm: Dp----------	Poor----------	Good for sand; poor for gravel: occasional lenses and pockets.	Good: fair to good stability; good shear strength and bearing capacity; low shrink-swell potential and compressibility.	Seasonally high water table; good stability; low compressibility and shrink-swell potential; low susceptibility to frost action.

See footnote at end of table.

OF THE SOILS--Continued

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Moderately slow permeability in clay to depth of 2 to 5 feet; moderate permeability below that depth.	Low permeability when compacted; fair to good resistance to piping in upper 2 to 5 feet; fair to poor resistance to piping below that depth; some areas have 2 to 4 feet of silt below clay.	Not needed----------	Firm, plastic, clayey subsoil; some areas have 2 to 4 feet of highly erodible silt below clay.	Firm, plastic, clayey subsoil; some areas have 2 to 4 feet of highly erodible silt below clay.
Porous sand bands within depth of 2 feet; high organic-matter content.	High permeability when compacted; poor resistance to piping; high water table; finer textured bands generally not thick enough to be used for embankment material.	Needed; tile not required; hazard of sloughing and caving; suitable for shallow ditches with wide bottoms.	Not needed----------	Generally not needed.
Porous sand; moderate organic-matter content.	High permeability when compacted; poor stability and resistance to piping.	Not needed----------	Porous sand at depth of 2 feet; moderately erodible above depth of 2 feet; highly erodible below that depth.	Porous sand at depth of 2 feet; moderately erodible above depth of 2 feet; highly erodible below that depth.
Subject to occasional flooding; moderate organic-matter content; moderate permeability in upper 4 feet; rapid permeability below that depth.	Subject to occasional flooding; moderate permeability when compacted; poor stability and resistance to piping.	Not needed; occasionally flooded.	Not needed----------	Generally not needed.
Porous sand---------	High permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed----------	Not needed.

TABLE 8.--ENGINEERING INTERPRETATIONS

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Duelm, loamy subsoil variant: Ds.	Poor----------	Poor for sand: less than 40 inches to finer material. Not suitable for gravel.	Good in upper 1½ to 3½ feet: good bearing capacity and shear strength. Fair below depth of 1½ to 3 feet: fair to good bearing capacity; fair shear strength and workability.	Fair stability; seasonally high water table; moderate susceptibility to frost action; some seepage in cuts.
Dundas: Du----------	Fair----------	Not suited----------	Poor to depth of 3 feet: plastic clay loam subsoil. Fair in till substratum: fair to good stability and shear strength; fair to poor bearing capacity; high water table.	High water table; plastic clay loam subsoil; low bearing capacity; moderate to high shrink-swell potential; high susceptibility to frost action.
*Erin: EnB, EnC, EnD, EnE, ErB2, ErC2, ErD2, EsF: For properties of Kilkenny soils in mapping unit EsF, refer to Kilkenny series in this table.	Fair in the noneroded soils; poor in the eroded soils.	Not suited----------	Fair: fair to good compaction characteristics; moderate to high shrink-swell potential; fair shear strength, workability, and bearing capacity; plastic subsoil.	Good drainage; fair bearing capacity; moderate to high shrink-swell potential; moderate susceptibility to frost action; generally rolling to hilly topography.
Estherville: EtA, EtB, EtC, EtD.	Fair to good----------	Fair for sand: good for gravel below depth of 18 to 24 inches; poorly to well-graded sand and gravel.	Good: good stability, shear strength, compaction characteristics, and bearing capacity; low compressibility; low shrink-swell potential.	Good drainage; good stability and shear strength; low susceptibility to frost action; low shrink-swell potential.
Glencoe: Gc----------	Fair----------	Not suited----------	Poor: very high organic-matter content in surface layer; high water table; moderate to high shrink-swell potential; poor to fair stability.	Very high organic-matter content in surface layer; high water table; ponded during wet seasons; low bearing capacity; high susceptibility to frost action.

See footnote at end of table.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Porous sands to depth of 1½ to 3½ feet; moderate permeability below that depth 1/.	High permeability when compacted and poor resistance to piping in upper 1½ to 3½ feet; low permeability when compacted and good resistance to piping below depth of 1½ to 3½ feet.	Not needed----------	Not needed----------	Generally not needed.
Moderately slow permeability in upper 3 feet; moderate permeability below that depth 1/.	Low permeability when compacted; fair to good stability; fair resistance to piping; high water table.	Needed; plastic subsoil with moderately slow permeability.	Not needed----------	Plastic, clayey subsoil; drainage needed before construction.
Moderately slow permeability 1/.	Low permeability when compacted; fair to good stability; good resistance to piping.	Not needed----------	Firm clay loam subsoil; fair to poor workability.	Firm clay loam subsoil; fair to poor workability.
Porous sand and gravel.	High permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed; high intake rate.	Droughty soil; difficult to establish vegetation.
Moderately slow permeability; very high organic-matter content; suitable for dugout ponds.	Low permeability when compacted; fair to good stability; fair resistance to piping; high water table; seasonally ponded; very high organic-matter content.	Needed; moderate to moderately slow permeability; surface ditches may be needed in addition to tile.	Not needed----------	Not needed.

TABLE 8.--ENGINEERING INTERPRETATIONS

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Grays: GyB, GyC----	Good----------	Not suited----------	Fair to poor: fair to poor bearing capacity, shear strength, and stability.	Good drainage; high susceptibility to frost action; fair stability; moderate shrink-swell potential.
Hamel: Ha----------	Good----------	Not suited----------	Poor in upper 2 to 3 feet: high organic-matter content in surface layer; fair below depth of 2 to 3 feet: fair bearing capacity, stability, and shear strength; high water table.	High organic-matter content in surface layer; high water table; high susceptibility to frost action; plastic subsoil.
* Hayden: HbB, HbC, HbD, HbE, HcB2, HcC2, HcD2, HcE2, HdF. For properties of Lester soil in mapping unit HdF, refer to Lester series in this table.	Fair in the noneroded soils, poor in the eroded soils.	Not suited----------	Fair to good: fair stability and compaction characteristics; moderate shrink-swell potential; fair workability, shear strength, and bearing capacity.	Good drainage; moderate susceptibility to frost action; moderate shrink-swell potential; fair bearing capacity; generally rolling to hilly topography.
Heyder: HeB, HeC, HeD, HeE-	Poor----------	Poor for sand: sand occurs as occasional thin lenses and pockets. Not suitable for gravel.	Fair to good: fair to good bearing capacity; good workability; fair shear strength and stability.	Good drainage; moderate susceptibility to frost action; moderate shrink-swell potential; fair to good bearing capacity; fair stability.
H1B, H1C, H1D, H1E-	Poor----------	Variable: source of gravel below depth of 5 to 20 feet in places.	Fair to good: variable material.	Good drainage; good bearing capacity; variable materials may cause differential heaving; generally rolling to hilly topography.

See footnote at end of table.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Moderate permeability; silt; slowly permeable material may be encountered at depth of 5 to 10 feet; poor resistance to piping.	Moderate permeability when compacted; poor stability, compaction characteristics, and resistance to piping.	Not needed----------	Highly erodible silt-	Highly erodible silt.
Moderately slow permeability; high organic-matter content to a depth of 2 feet or more 1/.	High organic-matter content to depth of 2 feet or more; high water table; low permeability when compacted; fair to good stability; fair resistance to piping.	Needed; moderately slow permeability.	Not needed----------	Drainage needed before construction.
Moderate permeability 1/.	Low permeability when compacted; fair to good stability; fair resistance to piping.	Not needed----------	Irregular topography makes construction difficult.	Fertilizer and mulch help establish sod rapidly.
Moderate to rapid permeability; some pockets and lenses of porous sand.	Moderate permeability when compacted; fair stability; fair to poor resistance to piping.	Not needed----------	Irregular topography makes construction difficult.	Moderately erodible; fertilizer and mulch help establish sod rapidly.
Moderate to rapid permeability; pockets and lenses of porous sand and gravel.	Variable material; moderate to high permeability when compacted; fair stability; poor resistance to piping.	Not needed----------	Pockets of sand or gravel may occur within depth of 2 feet; irregular topography.	Moderately erodible in loamy material; highly erodible in sand and gravel.

TABLE 8.--ENGINEERING INTERPRETATIONS

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Hubbard: HuA, HuB, HuC, HuD, HuE.	Poor----------	Good for sand: poorly graded sand. Poor for gravel.	Good: good bearing capacity, shear strength, and stability; low compressibility and shrink-swell potential.	Good drainage, stability, and shear strength; low susceptibility to frost action; low shrink-swell potential.
Isan: Is----------	Good----------	Good for sand, but excavation may be difficult; poor for gravel.	Good: good bearing capacity and shear strength; low compressibility; high water table may make excavation difficult.	High water table; fair stability; moderate to high susceptibility to frost action.
It----------	Good----------	Good for sand, but excavation may be difficult; poor for gravel.	Good: good bearing capacity and shear strength; low compressibility; high water table may make excavation difficult; seasonally ponded.	High water table; fair stability; moderate to high susceptibility to frost action; seasonally ponded.
Iv----------	Good----------	Poor for sand: generally less than 40 inches to finer material; not suitable for gravel.	Good to depth of 1½ to 3½ feet: good bearing capacity and shear strength. Fair below depth of 1½ to 3½ feet: fair shear strength; high water table.	High water table; fair stability; high susceptibility to frost action.
Kasota: KaB--------	Fair----------	Good for sand below depth of 2 to 4 feet; upper part is finer textured material. Poor for gravel.	Poor to depth of 2 to 4 feet: plastic, clayey soil. Good below depth of 2 to 4 feet: good bearing capacity and shear strength; low compressibility.	Good drainage; moderate susceptibility to frost action; high shrink-swell potential and poor shear strength in upper 2 to 4 feet; good shear strength below that depth.

See footnote at end of table.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Porous sand---------	High permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed; porous sand.	Sand is highly erodible in cuts; droughty; difficult to establish vegetation.
Porous sand---------	High permeability when compacted; poor stability and resistance to piping; high water table.	Needed; tile not well suited; high hazard of sloughing and caving; suited to shallow ditches with wide bottoms.	Not needed----------	Generally not needed.
Porous sand; suited to dugout ponds.	High permeability when compacted; poor stability and resistance to piping; high water table; seasonally ponded.	Needed; tile not well suited; high hazard of sloughing and caving; suited to shallow ditches with wide bottoms.	Not needed----------	Not needed.
Porous sand in upper $1\frac{1}{2}$ to $3\frac{1}{2}$ feet; slow to moderate permeability below that depth.	High permeability when compacted; poor resistance to piping in upper $1\frac{1}{2}$ to $3\frac{1}{2}$ feet; low permeability when compacted and fair resistance to piping below that depth; high water table.	Needed; $1\frac{1}{2}$ to $3\frac{1}{2}$ feet of sand over loamy material; tile suited; high hazard of sloughing and caving.	Not needed----------	Generally not needed.
High organic-matter content: moderately slow permeability in silty clay of upper 2 to 4 feet; porous sand below that depth.	High organic-matter content; low permeability when compacted and fair to poor resistance to piping in upper 2 to 4 feet; high permeability when compacted and poor resistance to piping below that depth.	Not needed----------	Firm, plastic, clayey soil to depth of 2 to 4 feet; porous sand below that depth.	Firm, plastic, clayey soil to depth of 2 to 4 feet; highly erodible sand below that depth.

TABLE 8.--ENGINEERING INTERPRETATIONS

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Kennebec: Ke-------	Good----------	Good: sand or gravel occurs below depth of 40 inches.	Poor to fair to a depth of more than 4 feet: poor to fair stability and shear strength. Good in substratum: good stability and shear strength; low compressibility.	High susceptibility to frost action to a depth of more than 4 feet; poor to fair stability; moderately high water table; high organic-matter content to depth of 4 feet or more.
Kilkenny: KkB, KkC, KkD, KkE, KlC2, KlD2.	Good in the noneroded soils; fair in the eroded soils.	Not suited----------	Fair: plastic subsoil; moderate to high shrink-swell potential; fair to good compaction characteristics; fair shear strength, workability, and bearing capacity.	Good drainage; moderate susceptibility to frost action; moderate to high shrink-swell potential; fair bearing capacity; generally rolling to hilly topography.
Kingsley: KnB, KnC, KnD, KnE, KnF.	Poor----------	Fair: deposits of sand and gravel occur in places.	Fair to good: good bearing capacity, shear strength, and stability; fair workability; some boulders present.	Good drainage; some cobblestones and boulders present; low to moderate shrink-swell potential; moderate susceptibility to frost action; generally hilly topography.
Lake beaches: Lc----------	Poor----------	Poor: generally less than 30 inches of sand and fine gravel.	Poor to good: high water table; variable soil; check each site.	High water table; may be submerged in wet years; moderate to high susceptibility to frost action.
Ld----------	Good----------	Not suited---------	Poor: high organic-matter content in surface layer; fair stability below a depth of 4 feet; high water table.	High organic-matter content in surface layer; high water table; low bearing capacity; high susceptibility to frost action.

See footnote at end of table.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
High organic-matter content in upper 4 feet or more; moderate to moderately rapid permeability in upper 4 feet; porous sand and gravel below that depth.	High organic-matter content in upper 4 feet or more; high permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed----------	Generally not needed.
Moderately slow permeability; high organic-matter content 1/.	Low permeability when compacted; fair to good stability; good resistance to piping; high organic-matter content.	Not needed----------	Firm clay loam subsoil; fair to poor workability.	Firm clay loam subsoil; fair to poor workability.
Moderate to rapid permeability; some pockets of porous sand and gravel; some cobblestones present.	Variable material; moderate to high permeability when compacted; fair stability; fair to poor resistance to piping; some cobblestones and boulders present.	Not needed----------	Cobblestones and other stones may hinder construction.	Pockets and streaks of sand and gravel are highly erodible.
Porous sand; may be submerged in wet years; suited to dugout ponds.	High permeability when compacted; poor stability and resistance to piping; high water table.	Generally not recommended; porous sand.	Not needed----------	Generally not needed.
High organic-matter content; moderate permeability; may be submerged in wet years; suited to dugout ponds.	Moderate permeability when compacted; poor stability and resistance to piping; high organic-matter content; high water table.	Needed, but suitable outlets are lacking in places: moderate permeability.	Not needed----------	Generally not needed.

467-556 O - 74 - 9

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Langola: LgA, LgB----------	Poor----------	Poor for sand: generally less than 40 inches deep over finer material. Not suitable for gravel.	Fair to good: good bearing capacity, shear strength, and stability; fair workability.	Good drainage; low to moderate susceptibility to frost action; moderate shrink-swell potential; some seepage in cuts.
Lh----------	Poor----------	Poor for sand: generally less than 40 inches deep over finer material. Not suitable for gravel.	Fair to good: good bearing capacity, shear strength, and stability; fair workability; seasonally high water table.	Moderate susceptibility to frost action; low to moderate shrink-swell potential; seasonally high water table.
Lerdal: LmB----------	Fair to good----------	Not suited----------	Fair: plastic subsoil; moderate to high shrink-swell potential; fair bearing capacity, shear strength, and workability; seasonally high water table.	Moderate to high shrink-swell potential; moderate susceptibility to frost action; seasonally high water table.
Lester: LrB, LrC, LrD, LrE, LsB2, LsC2, LsD2.	Good in the noneroded soils; fair in the eroded soils.	Not suited----------	Fair to good: fair stability, bearing capacity, and shear strength; moderate shrink-swell potential.	Good drainage; fair shear strength and bearing capacity; moderate susceptibility to frost action and shrink-swell potential; generally rolling to hilly topography.
Le Sueur: LtB-------	Good----------	Not suited----------	Fair: fair stability, shear strength, and bearing capacity; moderate shrink-swell potential; seasonally high water table.	Fair bearing capacity; moderate susceptibility to frost action and shrink-swell potential; seasonally high water table.

See footnote at end of table.

OF THE SOILS--Continued

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Porous sand in upper 1½ to 3½ feet; moderate permeability below that depth.	High permeability when compacted and poor resistance to piping in upper 1½ to 3½ feet; moderate to high permeability when compacted and fair to poor resistance to piping below that depth.	Not needed----------	Sandy to depth of 1½ to 3½ feet; subject to soil blowing and water erosion; vegetation difficult to establish.	Sandy to depth of 1½ to 3½ feet; subject to soil blowing and water erosion; vegetation difficult to establish.
Porous sand in upper 1½ to 3½ feet; moderate permeability below that depth.	High permeability when compacted and poor resistance to piping in upper 1½ to 3½ feet; moderate to high permeability when compacted and fair to poor resistance to piping below that depth.	Not needed----------	Not needed----------	Generally not needed.
Moderately slow permeability; high organic-matter content 1/.	Low permeability when compacted; fair to good stability and resistance to piping; high organic-matter content.	Not needed----------	Firm, plastic clay loam subsoil; fair workability.	Firm, plastic clay loam subsoil; fair workability.
Moderate permeability; high organic-matter content 1/.	Low permeability when compacted; fair to good stability; fair resistance to piping; high organic-matter content.	Not needed----------	Irregular topography makes construction difficult.	No major limitations.
Moderate permeability; high organic-matter content 1/.	Low permeability when compacted; fair to good stability; fair resistance to piping; high organic-matter content.	Not needed----------	Generally not used---	No major limitations.

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Litchfield: Lu------	Poor----------	Fair for sand: sand has bands of sandy loam and loamy sand. Poor for gravel.	Fair to good: fair shear strength, stability, and workability; good bearing capacity; low compressibility..	Good bearing capacity; low shrink-swell potential; moderate susceptibility to frost action; seasonally high water table.
Marsh: Ma----------	Poor----------	Not suited----------	Poor: high water table; low bearing capacity.	High water table; ponded most of the year; low bearing capacity.
Minnetonka: Mt------	Fair----------	Not suited----------	Poor to depth of 2 to 5 feet: very plastic, clayey soil; high compressibility; poor shear strength. Fair below a depth of 3 to 5 feet: fair bearing capacity and shear strength; high water table.	High water table; high susceptibility to frost action and shrink-swell potential; poor shear strength in upper 2 to 5 feet.
Mixed alluvial land: Mu----------	Poor----------	Poor for sand: sand occurs in bands with finer material. Poor for gravel.	Poor to good: variable soil texture; check each site; occasional flooding.	Occasional flooding; high water table; moderate to high susceptibility to frost action.
Mx----------	Poor----------	Poor for sand: sand occurs in bands with finer material. Poor for gravel.	Poor to fair: variable soil texture; check each site; frequent flooding.	Frequent flooding; high water table; moderate to high susceptibility to frost action.
Nessel: NeB---------	Fair----------	Not suited----------	Fair: moderate shrink-swell potential; seasonally high water table; fair bearing capacity, shear strength, and workability.	Fair bearing capacity; moderate susceptibility to frost action; moderate shrink-swell potential; seasonally high water table.

See footnote at end of table.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Porous sand---------	Porous sand; high permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed; porous sand.	Generally not needed.
Variable material; generally peaty; check each site; very high organic-matter content; suitable for dug-out ponds.	Variable material; generally peaty; very high organic-matter content; ponded most of the year.	Most areas have no suitable outlets; check each site.	Not needed----------	Not needed.
High organic-matter content; slow permeability.	High organic-matter content; low permeability when compacted; fair to good resistance to piping in upper 2 to 5 feet; fair to poor resistance to piping below; some areas have 2 to 4 feet of silt below clay; high water table.	Slow permeability in plastic clayey subsoil; tile needs close spacing.	Not needed----------	Firm, plastic, clayey subsoil; drainage needed before construction.
Subject to occasional flooding; porous soil.	Variable material; check each site; poor resistance to piping; subject to occasional flooding.	Not needed----------	Not needed----------	Generally not used.
Subject to frequent flooding; porous soil.	Variable material; check each site; poor resistance to piping; subject to frequent flooding.	Frequent flooding; drainage not advisable.	Not needed----------	Generally not used.
Moderate permeability 1/.	Low permeability when compacted; fair to good stability; fair resistance to piping.	Not needed----------	Generally not needed-	Clay loam subsoil; fertilizer and mulch help to establish sod rapidly.

TABLE 8.--ENGINEERING INTERPRETATIONS

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Nymore: NyB, NyC----	Very poor----------	Good for sand: poorly graded sand. Poor for gravel.	Good: good bearing capacity, shear strength, and stability; low shrink-swell potential and compressibility.	Good drainage, shear strength, and stability; low susceptibility to frost action; low shrink-swell potential.
Peaty muck: Pa----------	Poor when used alone; fair to good if mixed with mineral soil.	Not suited----------	Poor: organic soils; low bearing capacity; high water table.	High water table; seasonally ponded; organic soil; remove to depth of mineral soil.
Pb----------	Poor when used alone; fair to good if mixed with mineral soil.	Fair: sand or gravel occurs at depth of 18 to 40 inches; excavation may be difficult.	Poor to depth of 2 to 4 feet; good below that depth: excavation may be difficult.	High water table; seasonally ponded; organic soil; remove to depth of mineral soil.
Pm----------	Poor when used alone; fair to good if mixed with mineral soil.	Not suited----------	Poor to depth of 2 to 4 feet; fair below that depth: excavation may be difficult.	High water table; seasonally ponded; organic soil; remove to depth of mineral soil.
Rasset: RsB, RsC, RsD.	Poor----------	Fair for sand: sand has bands of sandy loam and loamy sand; poor for gravel.	Good: good bearing capacity, shear strength, and stability; low shrink-swell potential and compressibility.	Good drainage, shear strength, and stability; low shrink-swell potential; low to moderate susceptibility to frost action.
Salida: SaB, SaC, SaD, SaE.	Poor----------	Fair for sand; good for gravel: poorly to well-graded gravel.	Good: good bearing capacity, shear strength, and stability; low shrink-swell potential and compressibility.	Good drainage; low susceptibility to frost action and shrink-swell potential; good shear strength; generally rolling topography.

See footnote at end of table.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Porous sand---------	Porous sand; high permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed; porous sand; high intake rate.	Sand is highly erodible in cuts; droughty; difficult to establish vegetation.
Porous, organic soil; very high organic-matter content; suited to dugout ponds.	Porous, organic soil; high compressibility; very high organic-matter content; high water table.	Needed; suitable for open-ditch and tile drainage; differential settling of tile lines may occur.	Not needed----------	Not needed.
Very high organic-matter content; porous, organic soil in upper 2 to 4 feet; porous sand and gravel below that depth; suited to dugout ponds.	Porous, organic soil in upper 2 to 4 feet: very high organic-matter content; high compressibility. Porous sand and gravel below that depth: high water table.	Needed; tile not recommended; suitable for open-ditch water table control.	Not needed----------	Not needed.
Porous, organic soil in upper 2 to 4 feet; moderate permeability below that depth; very high organic-matter content; suited to dugout ponds.	Porous, organic soil in upper 2 to 4 feet; low permeability below when compacted; high compressibility; very high organic-matter content; high water table.	Needed; suitable for open-ditch water table control and for tile drainage.	Not needed----------	Not needed.
Porous sand---------	Porous sand; high permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed; porous sand; high intake rate.	Sand is highly erodible in cuts; droughty; difficult to establish vegetation.
Porous sand and gravel.	Porous sand and gravel; high permeability when compacted; poor resistance to piping.	Not needed----------	Not needed; porous sand and gravel; high intake rate.	Droughty; difficult to establish and maintain vegetation.

TABLE 8.--ENGINEERING INTERPRETATIONS

Soil series and map symbols	Suitability as a source of--			Soil features affecting use for--
	Topsoil	Sand and gravel	Highway subgrade material	Highway location
Shields: Sh---------	Fair----------	Not suited----------	Poor to depth of 2 to 5 feet: very plastic, clayey soil; poor shear strength; high compressibility. Fair in loamy material below depth of 2 to 5 feet: fair bearing capacity and shear strength; high water table.	High water table; high susceptibility to frost action; high shrink-swell potential; poor shear strength in upper 2 to 5 feet.
Shorewood: SwA, SwB-	Fair----------	Not suited----------	Poor to depth of 2 to 5 feet: very plastic, clayey soil; poor shear strength; high compressibility; fair in loamy material below depth of 2 to 5 feet: fair bearing capacity and shear strength.	Moderate susceptibility to frost action; high shrink-swell potential; poor shear strength; seasonally high water table.
Zimmerman: ZmB, ZmC-	Poor----------	Fair for sand: mainly fine sand; poor for gravel.	Fair: fair bearing capacity, shear strength, stability, and workability; poor compaction characteristics.	Good drainage; fair bearing capacity; low shrink-swell potential and susceptibility to frost action; highly erodible.

1/ Bottom of reservoir should be scarified and compacted.

Soil features affecting use for--Continued				
Farm ponds and sewage lagoons		Agricultural drainage	Terraces and diversions	Waterways
Reservoir areas	Embankments			
Slowly permeable clays in upper 2 to 5 feet; moderately permeable material below that depth.	Low permeability when compacted; fair to good resistance to piping below that depth; some areas have 2 to 4 feet of silt below clay; high water table.	Slow permeability in subsoil; tile may not work well.	Not needed----------	Firm, plastic, clayey subsoil; drainage needed before construction.
High organic-matter content; moderately slow permeability in clay of upper 2 to 5 feet; moderate permeability below that depth.	High organic-matter content; low permeability when compacted; fair to good resistance to piping in upper 2 to 5 feet; fair to poor resistance below that depth; some areas have 2 to 4 feet of silt below clay.	Not needed----------	Firm, plastic, clayey subsoil; some areas have 2 to 4 feet of highly erodible silt below clay.	Firm, plastic, clayey subsoil; some areas have 2 to 4 feet of highly erodible silt below clay.
Porous sand---------	Porous sand; high permeability when compacted; poor stability and resistance to piping.	Not needed----------	Not needed; porous sand; high intake rate.	Sand is highly erodible in cuts; droughty; difficult to establish vegetation.

heaving. If a highway subgrade is laid over glacial till, the subgrade material should contain a thick layer of material that is coarse enough to have no capillary potential, and is therefore not susceptible to damage by frost heaving when the water table is in close proximity.

There are large areas of organic soils in the county, comprising about 7 percent of the areas mapped. In many areas the organic material, Peaty muck, is more than 10 feet deep. The organic material has low bearing capacity and is not suitable for foundations of roads or other engineering structures. This material should be removed and replaced with suitable material.

About 30 percent of the county has a high seasonal water table. These areas generally have poorly drained or very poorly drained soils. The water table is close to the surface during wet seasons. Roads are generally built so that their surfaces are at least 4 feet above the highest point reached by the water table.

Use of the Soils for Town and Country Planning

Hennepin County lies within a region of rapid urban expansion. Suburbs and villages near Minneapolis are expanding into areas that a few years ago were farmland. The population increase in these areas has increased the demand for homes, schools, factories, shopping areas, churches, and other community developments.

The suitability or limitations of the soil must be considered before a site is selected for a home or factory. The main factors considered are slope, depth to water table, flooding, and those properties and qualities of undisturbed soils that affect the support of foundations of buildings less than 3 stories high. These properties are bearing capacity, volume change (shrink-swell potential), and frost heaving. Only the underlying material is evaluated.

The limitations of the soils for use as septic tank filter fields are important because many of the suburban developments are in areas beyond existing sewer lines. The limitations for this use are based on percolation tests and evaluation of texture, structure, and internal drainage. In general, filter fields (10) require soils in which the water table remains 4 feet below the drainfield trench in all seasons and soils that are not subject to flooding. Percolation rates should be less than 60 minutes per inch. Slower rates may cause effluent to rise to the surface and overflow, causing conditions dangerous to public health. High percolation rates may permit contamination of groundwater. Drainfield problems are common in the county because of installation in poorly drained or slowly permeable soils. In other places, in sandy soils, effluent travels long distances and has contaminated wells, lakes, and streams.

In selecting sites for drainfields, it is important to examine each site closely to determine the capacity of the soil to absorb and filter effluent. A percolation test is needed in some places to determine the drainfield size. Percolation design rates are suggested for the soils in each building site group where percolation tests are not available. These design rates are useful chiefly in calculating the drainfield size that is generally needed for a particular soil.

The soils of Hennepin County are generally not well suited to drainfields, because many of the soils are poorly drained, are sandy, or have slow percolation rates. Strong consideration should be given to installing public sewer systems in areas of intensive development.

Disposal of refuse becomes increasingly important as the population grows. One of the more successful methods of disposing of refuse is to utilize the soil. A sanitary landfill is a waste disposal area which is operated in such a way that problems with odors, smoke, rodents, insect pests, blowing paper, and water pollution are avoided.

Limitations for sanitary landfills are based on soil properties that affect the soil's ability to filter leachate and to serve as refuse cover. Leachate refers to the liquid product that results from the decomposition of organic refuse. The main properties are permeability, internal drainage, soil depth to coarse material, and shrink-swell potential (volume change). Slope and flood hazard are also considered.

The distance to streams and lakes was not considered in evaluating the use of soils for sanitary landfills, but this is an important factor. The best location for a sanitary landfill is one above flood levels, far removed from lakes, wells, or drainage channels, and having a substantial depth of relatively impervious surface soil above the water table. Undesirable locations for a sanitary landfill are river flood plains, areas that drain into lakes and streams, areas where the water table is high, and areas that are near water supplies.

Use of the Soils for Building Sites

The soils of Hennepin County have been placed into 13 building site groups on the basis of characteristics that affect their use for (1) residential, commercial, and industrial construction with public sewers, (2) septic tank filter fields, and (3) sanitary landfills. The soils were examined to a depth of 5 feet. Economic factors such as the distance to roads and streets were not considered.

Descriptions of the 13 building site groups follow. The limitations are expressed as slight, moderate, and severe. The limitation is slight if it is easy to overcome. The limitation is moderate if good management and careful design are needed. It is severe if the limitations are difficult to overcome, if special designs are generally needed to overcome the limitation, or if major reclamation work is required. Costs to overcome severe limitations are generally high.

Using the soil map to identify the soils, the interpretations described here can be useful in

selecting suitable locations for residences, stores, factories, schools, and similar facilities. It should be emphasized that these interpretations do not eliminate the need for detailed onsite investigation. Also, engineers and others should not apply specific values to the estimates given for bearing capacity of soils.

The names of soil series represented are mentioned in the description of each group, but this does not mean that all the soils of a given series are in the group. The names of soils in any group can be obtained by referring to the "Guide to Mapping Units" at the back of this survey.

Building Site Group 1

This group consists of soils of the Dakota and Kasota series and of the Burnsville series, thick solum variant. The Burnsville, thick solum variant, and Dakota soils are somewhat excessively drained and well drained. They have moderately rapid permeability and are underlain by sand and gravel at a depth of 24 to 36 inches. The Kasota soil is underlain by sand and gravel at a similar depth but has moderately slow permeability in the silty clay subsoil. The water table is at a depth below 5 feet throughout the season on all soils in this group. In most places it is below a depth of 10 feet. The Burnsville, thick solum variant, and the Dakota soils include small, 1-acre to 2-acre depressions in narrow drainageways that contain poorly drained soils. The Dakota and Kasota soils have slopes of 0 to 6 percent. The Burnsville soil, thick solum variant, has slopes of 2 to 12 percent.

Most soils in this group have only slight limitations for large residential developments, shopping centers, and industrial parks. Excavation and grading costs are generally low on slopes of 0 to 6 percent. The limitations are moderate where slopes are 6 to 12 percent because of the higher cost of site preparation. The design of buildings to fit the site can preserve the natural landscape. This reduces grading requirements, erosion, and sedimentation.

These soils have good bearing capacity for low buildings. They have only a low to moderate volume change with changes in moisture in the upper 2 to 3 feet of soil. The hazard of frost heaving is slight. Wetness is not a hazard. There is a hazard of trenches caving in during installation of utilities. The Kasota soil differs from the other soils in this group because it has high volume change with changes in moisture in the upper 2 to 4 feet. Therefore, foundations, driveways, and sidewalks are more apt to crack.

These soils have slight limitations for absorbing septic tank effluent. Percolation design rates are close to 20 minutes per inch in the loamy subsoil, except in the Kasota soil, and are less than 10 minutes per inch in the underlying material. The subsoil of the Kasota soil absorbs effluent slowly in the clayey material that is 2 to 4 feet thick, but the trench is generally placed below this material. The high percolation rates in the coarse underlying material of all the soils in this group create a severe hazard of pollution to the groundwater supply and to nearby lakes and streams. The hazard of pollution can be reduced by placing the drainfield tile on a bed of loamy material.

These soils have severe limitation for sanitary landfill because they are underlain by gravel and sand at a shallow depth. Leachate that is produced by decomposing refuse can easily travel long distances and contaminate the water table and nearby lakes and streams. Pollution may be prevented by covering the sand and gravel beds with 3 or 4 feet of impervious fill to prevent movement of the leachate through the coarse material below.

Lawns, trees, and shrubs are relatively easy to establish and maintain. Plant growth is limited slightly by drought on the Burnsville soil, thick subsoil variant.

Building Site Group 2

This group consists of moderately well drained to excessively drained, sandy soils of the Anoka, Burnsville, Dickman, Duelm, Estherville, Hubbard, Litchfield, Nymore, Rasset, Salida, and Zimmerman series. These soils are underlain by deep sand or gravel and sand at a depth of 12 to 24 inches. Except for Duelm and Litchfield, all the soils have a deep water table. In most places the water table is at a depth below 10 feet throughout the year. The Duelm and Litchfield soils have a high water table within 3 to 5 feet of the surface during periods of high or persistent rainfall. Slopes range from 0 to 35 percent but typically are 0 to 12 percent. The steeper slopes are associated mainly with the Burnsville, Salida, and Rasset soils, in the southern part of the county.

Where slopes are 0 to 6 percent, these soils have slight limitations for commercial development and residential development with public sewers. Where slopes are 6 to 12 percent, the limitations are moderate because of increased cost of grading and construction. The limitations are severe where slopes are more than 12 percent because of the generally high cost of building streets, installing utilities, and developing homesites. These soils are noncohesive, and gullies develop easily. Steep slopes and embankments are difficult to stabilize with vegetative practices. Increased runoff from roofs and streets can cause severe erosion. The resulting sedimentation can pollute nearby streams. Costly retaining walls and terraces are needed in many places to make desirable homesites.

These soils have good bearing capacity for foundations. They have low volume changes with changes in moisture and have a low susceptibility to frost heaving. Foundations are relatively easy to excavate, and where slopes are less than 6 percent, construction costs for roads and streets are relatively low. There is a hazard of trenches caving in during installation of utilities.

Wet basements occur in some years where foundations are built on the Duelm and Litchfield soils. Unless the water table is controlled or the foundation raised, in extremely wet years wet basements may occur in some areas of the Anoka and Hubbard soils in Brooklyn Park village and Champlin Township.

These soils have slight limitations for absorbing septic tank effluent. They absorb septic tank effluent very rapidly, and percolation rates are generally less than 10 minutes per inch. However, in areas of high population density the high percolation rate increases the hazard of pollution to wells, lakes, and streams. The severe hazard of pollution is reduced if the filter field is constructed in a thick bed of loamy fill. Downslope seepage of effluent is a severe hazard where slopes are more than 12 percent, and filter fields are difficult to lay out.

These soils have severe limitations for sanitary landfills because they are underlain by gravel and sand at a shallow depth. Leachate that is produced by decomposing refuse can easily travel long distances and contaminate the water table and nearby lakes and streams. Pollution may be prevented by covering the sand and gravel beds with 3 to 4 feet of impervious fill to prevent movement of the leachate through the coarse material below.

Vegetation is difficult to establish and maintain on these soils. Frequent watering and fertilizing are necessary to maintain a good vigorous sod. A topdressing of 12 to 18 inches of loamy material is desirable before seeding grass or laying sod.

The Burnsville, Estherville, and Salida soils are generally good sources of gravel and sand for construction purposes. Consideration should be given to developing this valuable resource before developing the soils for other uses.

Building Site Group 3

This group consists of soils of the Braham and Langola series and the Duelm series, loamy subsoil variant. These soils are moderately well drained to somewhat excessively drained and consist of 18 to 40 inches of sand over loam and sandy loam. The Braham and Langola soils that have slopes of 2 to 6 percent have a water table that is at a depth below 5 feet in all seasons and is generally at a depth below 10 feet. The nearly level Langola soils and the Duelm variant have a high seasonal water table at a depth of 3 to 5 feet.

The Braham and Langola soils that have slopes of 2 to 6 percent have slight limitations for residential and commercial development. Where slopes are 6 to 12 percent, limitations are moderate, and where slopes are more than 12 percent, limitations are severe because of the increased cost of development. The Braham soils that have a silty subsoil have moderate limitations for residential development because of poor to fair bearing capacity.

The Duelm variant and Langola soils that have slopes of 0 to 1 percent have moderate limitations for commercial and residential development because they have a high seasonal water table. Wet basements occur on these soils in some years unless the water table is lowered or foundations are raised above the water level. The steeper Braham soils have a hazard of side-slope seepage. For this reason, it is a good practice to install drain tile around the footings of basements. A good tile outlet is required. The Duelm variant has a perched water table that causes the upper 2 to 3 feet of the underlying material to be saturated during wet seasons. The saturated soil material should be removed before placing foundations for buildings on these soils.

Except for the Braham, the soils of this group have fair to good bearing capacity. Hazard of frost heaving is slight to moderate. The underlying material has moderate volume change with changes in moisture.

These soils have slight to moderate limitations for septic tank filter fields. Suggested percolation design rates for drainfields constructed in the sandy material are 20 minutes per inch. This rate is adjusted to the slower acceptance of effluent by the underlying material. If the drainfields are constructed in the loamy material, the suggested design rates for drainfields on the Braham and Duelm soils are near 60 minutes per inch. The percolation design rates on the Langola soils and the Braham soils that have a silty subsoil range from 30 to 60 minutes per inch. Lateral seepage is likely at the contact between the sandy and loamy material where slopes are more than 6 percent. Placing filter fields on the contour and in the loamy material reduces the hazard of side-slope seepage on these steeper slopes. Lots 1 acre or more in size are needed to allow for a sufficient absorption area.

These soils have moderate limitations for sanitary landfills, except for the Langola and the Duelm variant soils that have slopes of 0 to 1 percent, which have severe limitation for sanitary landfill because of their high seasonal water table. The ground water can be easily contaminated in these two soils by leachate percolating into the deep, loamy or sandy loam substratum. The sandy part of all of the soils, the upper 2 to 4 feet, is not well suited to refuse cover, because it is too porous to form a good seal over the refuse layers. The silty underlying material under the Braham soils that have a silty subsoil is very erodible if used to cover refuse. The Langola soils are also difficult to use as refuse cover because the reddish-brown sandy loam underlying material contains many cobblestones and stones.

Lawns are somewhat difficult to establish and maintain on these sandy soils, and they should be topdressed with 12 to 18 inches of loamy material that will hold more moisture. Lawns need to be fertilized and watered often during the dry summer months to maintain a good vigorous sod. Trees and shrubs that are resistant to drought are needed on these soils.

Building Site Group 4

This group consists of soils of the Heyder and Kingsley series. These soils range from shallow to deep, loamy to sandy, and moderately permeable to rapidly permeable. In many places the soil materials differ greatly within a distance of 5 to 10 feet. The soils mainly have slopes between 6 and 18 percent, but slopes range from 2 to 35 percent. The water table is at a depth below 5 feet in all seasons and is commonly below 10 feet. The Heyder soil includes depressions and drainageways that contain Nessel and Dundas soils. The Dundas soil is poorly drained and slowly permeable.

These soils have limitations for commercial or residential development using central sewerage systems. Limitations are slight to moderate where slopes are 2 to 6 percent, moderate where slopes are 6 to 12 percent, and severe where slopes are more than 12 percent (plate VII). As the slope increases, the cost of installing and maintaining utilities, grading roads, streets, and homesites increases. These soils generally are well suited to estate-type developments with large lots. Extensive grading, especially on steep slopes, increases erosion and can cause sedimentation in nearby lakes and streams. Where slopes are more than 18 percent, these soils are better suited to uses that enhance the natural beauty of the area than to most other uses.

The soils in this group have low to moderate volume change with changes in moisture content. The hazard of frost heaving is low to moderate. Wetness is not a hazard, except in a few drainageways included in the areas of Heyder soils. The bearing capacity is fair to good, although with large buildings differential settling because of wide differences in soil texture within a short distance may be a problem. In a few places, side-slope seepage occurs on the Heyder complex. For this reason it is good practice to install drain tile around footings of foundations. A good tile outlet is needed. It is a good practice to either compact the fill around foundations or to allow it to settle before seeding or sodding lawns. Soaking the fill with water hastens settling. When the fill is stabilized, the resulting low areas can be filled and the lawn established. The ease of establishing vegetation depends on the presence of sandy soils in the area. Except in the sandy and gravelly areas, vegetation such as lawns and trees is fairly easy to establish.

Limitations for septic tank drainfields are slight to moderate where slopes are 2 to 12 percent. Limitations for filter fields are severe where slopes are 12 to 35 percent. Filter fields are difficult to construct, and the hazard of side-slope seepage is severe. It is important to place the drainfield in undisturbed natural soils. Graded and filled areas generally absorb sewage very slowly and are, therefore, poor sites for filter fields. Percolation rates are variable because of differences in the texture of these soils. Percolation rate ranges from 75 minutes per inch to less than 10 minutes per inch at the depth at which tile trenches are generally constructed. The hazard of groundwater contamination is moderate. These soils contain pockets of sand and gravel that may allow effluent to travel long distances and contaminate nearby wells and lakes.

These soils have moderate limitations for sanitary landfills where slopes are less than 18 percent. They contain many pockets and veins of sand and gravel that may allow leachate to travel long distances and contaminate nearby wells and lakes. Where slopes are more than 18 percent, limitations for sanitary landfills are severe because of the hazard of operating machinery on the steep slopes.

In places these soils contain good quality gravel and sand suitable for construction purposes. In most places the larger veins and pockets of gravel and sand are at a depth of 5 to 20 feet or more. There are a number of gravel mining operations on these soils at present.

Building Site Group 5

This group consists of soils of the Dakota, Grays, Hayden, Heyder, and Lester series. These soils are deep, moderately permeable, and well drained. They generally are loamy. The water table is at a depth below 5 feet in all seasons and is usually at a depth below 10 feet. Slopes range from 0 to 35 percent. The Hayden and Lester soils are in convex positions intermingled with shallow, concave drainageways. These drainageways contain the poorly drained Cordova soils and poorly drained, slowly permeable Dundas soils. In places the Hayden and Lester soils contain a few patches of the clayey, slowly permeable Dalbo and Shorewood soils.

Soils of this group that have slopes of 2 to 12 percent have moderate limitations for urban and commercial developments with public sewers. Limitations are severe where slopes are more than 12 percent. Cost of installing utilities, grading, and leveling for homesites and streets is high. Extensive grading, especially on steep slopes, increases erosion and can cause sedimentation in nearby lakes and streams. Where slopes are more than 18 percent, these soils are better suited to uses that enhance the natural beauty of the area than to most other uses.

Except for the Grays soils, these soils have fair bearing capacity and fair shear strength. The Grays soils have poor to fair bearing capacity. Soils in this group have moderate volume change with change in moisture. Fairly wide footings are needed for foundations. Roads and driveways need careful design, especially on the Lester and Hayden soils, to prevent breakup of roads and other concrete structures because of volume changes in the soil.

If foundations are backfilled on these soils, air pockets are generally formed in the fill. As a result, the fill settles unevenly. It is a good practice to compact the fill or allow it to settle before establishing lawns. Soaking the fill with water during backfilling operations hastens settling. Low areas should be refilled before seeding or sodding the yard areas.

During unusually wet years, side-slope seepage occurs on these soils. Therefore, it is a good practice to place tile around foundation footings to intercept water that might seep into the basement. A tile outlet is needed.

The high hazard of frost heaving and the high seasonal water table need to be considered on the poorly drained soils in drainageways.

These soils have moderate limitations for absorbing septic tank effluent from private homes where slopes are 2 to 12 percent. Limitations for drainfields are severe where slopes are 12 to 35 percent. Side-slope seepage is a hazard, and filter fields are difficult to lay out. Design percolation rates for Hayden and Lester soils are near 60 minutes per inch, but percolation rates range from about 45 to 75 minutes per inch. The absorption capacity in the life of a drainfield can be increased by constructing deep trenches, 40 to 48 inches deep, and using large amounts of gravel under the tile. The Dakota, Grays, and Heyder soils have percolation design rates near 30 minutes per inch, but percolation rates range from about 20 to 60 minutes per inch. Large lots, one-half acre or more in size, are advisable on the Hayden and Lester soils to allow sufficient absorption area for drainfields. It is important to place the drainfield in undisturbed natural soils. Graded and filled areas of this soil material generally absorb sewage very slowly and are, therefore, poor sites for filter fields.

The Hayden and Lester soils, because they absorb sewage effluent somewhat slowly, are not well suited to absorbing effluent from large institutions such as schools and hospitals. A sewage lagoon or a central sewer system is needed for these facilities.

Because the water table is deep and the soils are moderately permeable, they are well suited to sanitary landfills. The pollution hazard is relatively low. However, the Lester and Hayden soils are sticky and plastic and, therefore, are somewhat difficult to use for refuse cover. The silty Grays soils are easily eroded. Care is needed to cover refuse properly to keep out flies and rodents and prevent the escape of gases.

It is easy to establish trees, shrubs, and sod on these soils. In many places the Hayden soils have poorer tilth, and seeded lawns are harder to establish.

Building Site Group 6

This group consists of soils of the Le Sueur and Nessel series. These are deep, loamy, moderately well drained soils that have slopes of 1 to 4 percent. They occupy nearly level to gently sloping, convex positions and are intermingled with shallow drainageways and depressions occupied by poorly drained soils. The Le Sueur and Nessel soils have a seasonally high water table that is at a depth of 3 to 5 feet for short periods of time during high or persistent rainfall.

Soils of this group have moderate limitations as locations for residential and commercial development because of foundation limitations. In areas where they are used for building sites, it is important to install drain tile around basement footings to control the water table. An adequate tile outlet is needed, or the foundation needs to be placed above the water level.

These soils have fair bearing capacity for foundations. Fairly wide footings are needed. The soils have moderate susceptibility to frost action and have moderate volume changes with changes in soil moisture. Streets, roads, and sidewalks tend to heave unless they are carefully designed with a thick sand subbase.

If foundations are backfilled on these soils, air pockets are usually formed in the fill. As a result, the fill settles unevenly. It is a good practice to compact the fill or allow it to settle before establishing lawns. Soaking the fill with water during backfilling operations hastens settling. The low areas should be refilled before seeding or sodding the yard areas.

These soils have moderate limitations for absorbing septic tank effluent. Percolation design rates are near 75 minutes per inch on the Nessel and Le Sueur soils, although percolation rates are mostly in the range of 45 to 75 minutes per inch. Deep absorption trenches are recommended on the Le Sueur and Nessel soils to increase the absorption area per lineal foot of drainfield. It is important to place the drainfields in undisturbed natural soils. Graded and filled areas of this soil material generally absorb sewage very slowly and are, therefore, poor sites for filter fields. Large lots, 1 acre or more in size, are needed to provide sufficient absorption areas for drainfields.

These soils have severe limitations for sanitary landfills because of the high water table that occurs at a depth of less than 5 feet during wet seasons for as much as a month or more during the year.

Sod, shrubs, and trees are easy to establish. Seeding lawns is fairly easy on the Le Sueur soils. The Nessel soils have poorer natural tilth, and seeded lawns are more slowly established on them.

Building Site Group 7

This group consists of soils of the Erin, Kilkenny, and Lerdal series. These soils are deep and have moderately slow permeability. The Erin and Kilkenny soils are well drained and have a water table that is generally at a depth below 5 feet in all seasons. The Erin and Kilkenny soils have convex slopes of 2 to 35 percent. They are intermingled with shallow, concave drainageways and depressions that are occupied by the poorly drained Cordova and Dundas soils. These poorly drained soils need to be considered when developing the soils in this group for urban uses. The Lerdal soils occur on slight rises and low knolls and are somewhat poorly drained. They have a seasonally high water table at a depth of 3 to 5 feet.

Soils in this group have moderate limitations for residential and commercial development with public sewer systems where slopes are less than 12 percent. In areas where slopes are more than 12 percent, these soils generally have severe limitations for commercial and residential development because of the high cost of installing utilities and grading streets and building sites. Proper design of buildings, site planning, and minimal grading reduce erosion and sedimentation. Where slopes are more than 18 percent, these soils are better suited to uses that enhance the natural beauty of the area than to most other uses.

The bearing capacity and shear strength of these soils are fair. The change in volume with changes in moisture content is moderate to moderately high. Fairly wide foundation footings are needed. Streets, roads, and concrete slabs, unless carefully designed, are subject to heaving and cracking.

If foundations are backfilled on these soils, air pockets are usually formed in the fill. As a result, the fill settles unevenly. It is good practice to compact the fill or allow it to settle before establishing lawns. Soaking the fill with water during backfilling operations hastens settling. Low areas should be refilled before seeding or sodding the yard areas.

These soils have severe limitations for residential or commercial developments without central sewer systems because they absorb septic tank effluent slowly (plate VII). Percolation design rates are near 120 minutes per inch. To keep drainfield failure to a minimum, it is best to construct large drainfields with deep, narrow trenches about 4 feet deep and to place 2 to 3 feet of gravel below the tile. This provides a large surface area for effluent absorption. It is important to place the drainfield in undisturbed natural soils. Graded and filled areas of this soil material generally absorb sewage very slowly and are therefore poor sites for filter fields. Large lots, 1 acre or more in size, are needed if these soils are to be used for filter fields.

Alternative methods for disposal of sewage effluent on these soils might be to construct drainfields in specified loamy fill or to use sand filters (10). Drainfields are difficult to construct on slopes of 12 to 35 percent. The hazard of side-slope seepage is severe. These soils are well suited to sewage lagoons where slopes are less than 6 percent.

These soils have moderate limitations for sanitary landfills. Leachate produced in landfills moves slowly through these soils. It may build up in the landfill, and anaerobic decompositon takes place. This results in the formation of compounds that may be hazardous to health. These soils are also sticky and plastic and are therefore somewhat difficult to use for refuse cover. Because of the moderate to high volume change with changes in moisture, cracks may develop on the surface, allowing the escape of gases and the entrance of flies and rodents.

It is fairly easy to establish sod and shrubs on these soils. Establishing lawns from seed is difficult, because these plastic, sticky soils are hard to work and erode easily.

Building Site Group 8

This group consists of soils of the Dalbo and Shorewood series. These are deep, moderately well drained soils that have moderately slow permeability. They consist of 24 to 72 inches of clay sediments, low in sand content, over loam. In many places silty material up to 4 feet thick occurs between the clay and loam. These soils have nearly level to rolling, convex slopes. They are intermingled with shallow, concave drainageways and depressions that are occupied by the slowly permeable Shields, Minnetonka, and other poorly drained soils. Slopes range from 0 to 6 percent. The water table is at a depth of 3 to 5 feet during high or persistent rainfall.

These soils have moderate limitations for residential and commercial development with public sewers. The main limitations are the high volume change with changes in moisture and the fair to poor bearing capacity of the clayey sediments and the underlying silty sediments. Foundations of low buildings may need to be reinforced to overcome these limitations. Fairly wide foundation footings are needed. To prevent wet basements, foundations need to be raised above the water level or drain tile installed around the footings and connected to a good outlet. Streets, sidewalks, parking lots, and driveways need to be carefully designed with extra subbase to prevent cracking and breakup of these structures.

If foundations are backfilled on these soils, air pockets are formed in the fill. As a result, uneven settling occurs unless the soils are compacted. It is a good practice to either compact the fill or allow it to settle. Soaking the fill with water during backfilling operations hastens settling. Low areas should be refilled before seeding or sodding the yard area.

These soils have severe limitations for septic tank drainfields. Predicted incidence of drainfield failure is high in areas where the clay is more than 3 feet thick. The thick clay layers have an estimated percolation rate of more than 120 minutes per inch. In areas where the clay is less than 3 feet thick, the lower part of the tile trench can be constructed in the silty or loamy material that lies below the clay. Deep trenches are recommended on these soils. Percolation rates should be near 60 minutes per inch in the loamy or silty material.

These soils have severe limitations for sanitary landfills because of the shallow depth to the seasonally high water table. In addition, the upper 2 to 5 feet of these soils is clayey and makes poor covering for refuse. Cracks form when the soil dries, allowing odors and gases to escape and flies and rodents to enter.

These soils are difficult to till and prepare for lawn seedbeds. Lawn sod, trees, and shrubs are easily established.

Building Site Group 9

In this group are the nearly level soils of the Biscay, Dassel, Isan, and Kennebec series and Lake beaches, sandy. Except for the Kennebec soil, these are poorly drained soils underlain by sand and gravel at a depth of 15 to 40 inches. The Kennebec soil is deep, silty, and moderately well drained, and is underlain by sand at a depth of more than 40 inches. Except for the Kennebec soil, all the soils in this group have a seasonally high water table, which is at a depth of 18 to 42 inches for 30 consecutive days or more during the year in periods of high or persistent rainfall. The water table is generally at a depth below 5 feet in the Kennebec soil, but this soil is subject to brief periods of ponding in some areas.

Because of wetness, these soils have moderate to severe limitations for residential and commercial development with central sewer systems. Wet basements occur on these soils unless the water table is lowered or the foundation is placed above the water level. The water table is relatively easy to lower in the Brooklyn Park and Brooklyn Center areas, where most of these soils occur. The regional water table has been lowered somewhat by deepening Shingle Creek and installing storm sewer systems.

Unless the water table is lowered, these soils have a high hazard of frost heaving. Streets, driveways, parking lots, and slabs at the entrances of shopping centers are subject to heaving and cracking unless carefully designed. The underlying material of these soils has good bearing capacity for buildings less than three stories high. The soils in this group have low volume change with changes in soil moisture, except for the upper 2 to 3 feet of the Biscay soil, which has moderate volume change.

These soils have severe limitations for drainfields because of the high water table and the pollution hazard to nearby wells, streams, and lakes. Drainfield performance is severely reduced during wet seasons unless the water table is controlled by regional drainage. Percolation rates on the soils underlain by sand and gravel are less than 10 minutes per inch. Biscay soil percolation rates range from 30 to 120 minutes per inch in the loamy layers to less than 5 minutes per inch in the coarse underlying material. The Dassel soil has variable percolation rates, but they are generally less than 30 minutes per inch. In areas where septic tank filter fields must be constructed in the soils of this group, placing the filter fields in a 3-foot to 5-foot bed of loamy material above the water level reduces the pollution hazard and overcomes the wetness hazard.

These soils have severe limitations for sanitary landfills, because of the high water table and the porous underlying material. Leachate from landfills can travel long distances in the sand and pollute nearby wells, lakes, and streams.

Building Site Group 10

This group consists of soils of the Canisteo, Cordova, Hamel, and Isan series. These generally are deep, nearly level, poorly drained, loamy to clayey soils. The Isan soil is sandy in the upper 2 to 4 feet. In undrained areas the water table is at a depth of 1 to 3 feet during wet seasons. The water table may be high for 90 or more consecutive days in a year. Small areas of the very poorly drained Glencoe soil are included.

Because of wetness, these soils have moderate to severe limitations for residential and commercial development with central sewer systems. If these soils are to be used for building sites, tile needs to be placed around foundation footings and connected to an adequate outlet to keep basements dry during wet seasons, or the foundations need to be placed above the water level (plate VII). In some places on the Isan soil, the water table has sufficient pressure during wet seasons to lift and crack basement floors.

If foundations are backfilled on these soils, air pockets are usually formed in the fill. As a result, the fill settles unevenly. It is a good practice to compact the fill or allow it to settle before establishing lawns. Soaking the fill with water during backfilling operations hastens settling. Low areas should be refilled before seeding or sodding the yard areas.

The hazard of frost heaving is high on these soils. Streets, driveways, parking lots, and slabs at the entrance of large shopping centers are subject to heaving and cracking unless carefully designed (plate VIII). The bearing capacity and shear strength are fair to poor. The volume change with moisture change is moderate.

These soils have severe limitations for residential development with septic tank filter fields because of the high water table and moderate to moderately slow permeability. In areas where filter fields must be used, it is suggested that they be constructed in a thick bed of specified loamy material or that the water table in the filter field be controlled by installing drain tiles 3 1/2 to 4 feet deep and about 50 feet apart. A free-flowing outlet is needed. Drain tile can then be placed between the water table control tile. Trenches should be deep and narrow. These procedures should be approved by public health officials before adoption. Percolation rates are generally in the range of 45 to 90 minutes per inch. These soils are well suited to sewage lagoons.

Because of wetness, these soils have severe limitations for sanitary landfills. Placement of refuse below the water table results in anaerobic decomposition that produces undesirable odors and compounds hazardous to health. These soils can be used for landfills if the refuse is placed in loamy fill and is not placed below the water level.

Sod, trees, and shrubs are easy to establish on these soils.

Building Site Group 11

This group consists of soils of the Dundas, Minnetonka, and Shields series. These are deep, nearly

level, poorly drained to somewhat poorly drained soils. Permeability is moderately slow to slow. The Minnetonka and Shields soils consist of 30 to 72 inches of clay, low in sand content, overlying loam. In places, silty sediment up to 4 feet thick occurs between the clay and the loam. The Dundas soil is not quite so high in clay content as the Minnetonka and Shields soils. All of these soils occur in broad, level areas and in shallow drainageways. Included are small depressions that contain Glencoe soils. The water table is at a depth of 1 to 3 feet for as long as 90 consecutive days or more during wet seasons.

These soils have severe limitations as locations for residential and commmercial developments. If they are used as building sites, artificial drainage is needed to control the water table or the foundation needs to be built on fill to raise the foundation above the water level. These soils are sticky when wet and have poor trafficability if used for roads.

Foundations constructed on the Minnetonka and Shields soils need to be reinforced to prevent cracking caused by large changes in volume with changes in soil moisture. Roads, driveways, and parking lots are subject to cracking and heaving unless they are carefully designed. The bearing capacity, which ranges from fair to poor, needs to be carefully investigated before designing foundations on these soils.

If foundations are backfilled on these soils, air pockets are generally formed in the fill. As a result, the fill settles unevenly. It is a good practice to compact the fill or allow it to settle before establishing lawns. Soaking the fill with water during backfilling operations hastens settling. Low areas should be refilled before seeding or sodding the yard areas.

These soils have severe limitations for use as septic tank filter fields because of wetness and moderately slow and slow permeability. Percolation rates are generally more than 120 minutes per inch. In areas where filter fields must be constructed on these soils, it is suggested that they be placed in a 4-foot to 5-foot bed of loamy fill placed above the water level. The drainfield area needs to be protected from runoff from surrounding higher areas. These soils are well suited to sewage lagoons.

The soils in this group have severe limitations for sanitary landfills because of the high water table and the plastic, clayey soil material. Landfills need to be built above the water level to prevent anaerobic decomposition of refuse, which produces foul odors and compounds hazardous to health. The upper 3 to 6 feet of the Minnetonka and Shields soils is clayey, and the subsoil material of the Dundas soil makes poor covering for refuse. This material forms cracks on drying, allowing odors and gases to escape and flies and rodents to enter.

It is easy to establish sod, trees, and shrubs on these soils. Seedbeds for lawns are hard to prepare.

Building Site Group 12

This group consists of soils of the Biscay, Glencoe, and Isan series and of Lake beaches, loamy, Marsh, Peaty muck, Peaty muck over loam, and Peaty muck over sand. The soils in this group are very poorly drained, sandy to loamy, and organic, and are subject to ponding. Unless these soils are drained, the water table is near the surface much of the year.

These soils have severe limitations for community development because of the hazards of wetness and flooding. The limitations are not so great on the Biscay and Isan soils, which have fair to good bearing capacity for buildings less than 3 stories high. The hazard of frost heaving on these soils is high.

If these soils are used for building sites, drainage is needed or the foundations should be placed above the water level.

Peaty muck soils have severe limitations for foundations (plate VIII). Foundations in many places must be placed on pilings. Organic material should be completely removed before fill is added. In areas where the depth of organic material is such that it is impractical to remove all of it, there has been a fairly high incidence of waterline and sewerline breakage. If fill material is placed over organic material near foundations resting on pilings, sidewalks and entryways to shopping centers may settle and draw away from the foundations.

These soils have severe limitations for septic tank filter fields because of the very high water table. In addition, effluent can easily contaminate the water table and nearby lakes and streams.

These soils have severe limitations for sanitary landfills because of the hazard of polluting the ground water. In areas where these soils must be utilized, the landfill area needs to be protected from the entrance of surface water. The bottom of the landfill needs to be sealed with 3 to 4 feet of impervious material and diked to prevent leachate from escaping.

Many areas are suitable for wildlife habitat. Some areas are suitable for parks and recreational areas (plates VIII and IX), such as playgrounds and skating rinks.

Building Site Group 13

This group consists of soils of the Becker, Chaska, and Dorchester series and of Mixed alluvial land and Mixed alluvial land, frequently flooded. These are sandy to silty soils that occur on stream bottom lands. They are subject to flooding. The Chaska soils and Mixed alluvial land, frequently flooded, are poorly drained and have a high water table at a depth of 1 to 3 feet during periods of a month or more. The other soils in the group are moderately well drained to well drained and may have a water table at a depth of 3 to 5 feet during seasons when the river is high.

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TABLE 9.--DEGREE AND KIND OF SOIL

Borrow land (Bo), Borrow pits (Bp), Cut and fill land (Cu), and Fill land (Fd) are omitted from this table indicates that at least one mapping unit in this series is made up of two or more kinds of soil. The necessary to follow carefully the instructions for referring

Soil series and map symbols	Degree and kind of limitations for specified recreational uses	
	Intensive play areas	Extensive play areas
Anoka: AnB, AnC	Moderate where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Severe where slopes are 6 to 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer; vegetation difficult to maintain.
Becker:		
Ba	Moderate: occasional flooding	Moderate: occasional flooding
Bb	Moderate: occasional flooding	Moderate: occasional flooding
Biscay:		
Bc	Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: surface layer is sticky and soft when wet. Severe: high water table.
Bd	Moderate: surface layer is sticky and soft when wet. Severe: high water table; occasional ponding occurs.	Moderate: surface layer is sticky and soft when wet. Severe: high water table; occasional ponding occurs.
Braham:		
BsB, BsC	Moderate where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Severe where slopes are 6 to 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer; vegetation difficult to maintain.
BtB, BtC	Moderate where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Severe where slopes are more than 6 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer; vegetation difficult to maintain.
Burnsville: BuB, BuC, BuD, BuE	Moderate where slopes are 2 to 6 percent: vegetation difficult to maintain. Severe where slopes are more than 6 percent.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain. Severe where slopes are more than 12 percent.
Burnsville, thick solum variant: BxB, BxC.	Moderate where slopes are 2 to 6 percent. Severe where slopes are more than 6 percent.	Moderate where slopes are 6 to 12 percent.

LIMITATIONS FOR RECREATIONAL USES[1/]

because their properties are variable and onsite inspection is required. An asterisk in the first column soils in such mapping units may have different properties and limitations, and for this reason it is to other series that appear in the first column of this table]

Degree and kind of limitations for specified recreational uses--Continued			
Paths and trails	Golf fairways	Recreational buildings	Campsites
Moderate: sandy surface layer.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe; low natural fertility.	Slight where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Moderate where slopes are 6 to 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer.
Slight: occasional flooding--	Moderate: occasional flooding; medium natural fertility.	Severe: occasional flooding.	Moderate: occasional flooding.
Slight: occasional flooding--	Moderate: occasional flooding.	Severe: occasional flooding.	Moderate: occasional flooding.
Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: high water table.	Severe: high water table---	Moderate: surface layer is sticky and soft when wet. Severe: high water table.
Moderate: surface layer is sticky and soft when wet. Severe: high water table; occasional ponding occurs.	Severe: high water table; occasional ponding.	Severe: high water table; occasional ponding.	Moderate: surface layer is sticky and slippery when wet. Severe: high water table; occasional ponding.
Moderate: sandy surface layer.	Moderate where slopes are 6 to 12 percent; sandy surface layer. Severe: low natural fertility; vegetation difficult to maintain.	Slight where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain.	Moderate where slopes are 6 to 12 percent: sandy surface layer.
Moderate: sandy surface layer.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe: low fertility.	Slight where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain.	Moderate where slopes are 6 to 12 percent: sandy surface layer.
Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent. Severe where slopes are more than 18 percent.	Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.
Slight----------	Moderate where slopes are 6 to 12 percent: medium natural fertility; vegetation difficult to maintain.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent.

TABLE 9.--DEGREE AND KIND OF SOIL

Soil series and map symbols	Degree and kind of limitations for specified recreational uses	
	Intensive play areas	Extensive play areas
Canisteo: Ca	Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: surface layer is sticky and soft when wet. Severe: high water table.
Chaska: Ch	Severe: high water table; occasional flooding; surface layer is sticky and soft when wet.	Moderate: high water table; occasional flooding; surface layer sticky and soft when wet.
Cordova: Co	Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: surface layer is sticky and soft when wet. Severe: high water table.
Dakota:		
DaA, DaB	Slight on slopes of 0 to 2 percent. Moderate where slopes are 2 to 6 percent.	Slight
DbA	Slight	Slight
Dalbo: DlA, DlB, DlC	Moderate where slopes are 2 to 6 percent: surface layer is sticky and soft when wet. Severe where slopes are more than 6 percent.	Moderate where slopes are 6 to 12 percent: surface layer is sticky and soft when wet.
Dassel: Dm	Moderate: high water table	Moderate: high water table
Dickman: DnA, DnB, DnC	Moderate where slopes are 2 to 6 percent: vegetation difficult to maintain. Severe where slopes are 6 to 12 percent.	Slight on slopes of 0 to 6 percent. Moderate where slopes are 6 to 12 percent.
Dorchester: Do	Moderate: occasional flooding; surface layer is sticky and soft when wet.	Moderate: occasional flooding; surface layer is sticky and soft when wet.
Duelm: Dp	Moderate: sandy surface layer. Severe: vegetation difficult to maintain.	Moderate: sandy surface layer; vegetation difficult to maintain.
Duelm, loamy subsoil variant: Ds	Moderate: sandy surface layer. Severe: vegetation difficult to maintain.	Moderate: sandy surface layer; vegetation difficult to maintain.

LIMITATIONS FOR RECREATIONAL USES[1/]--Continued

Degree and kind of limitations for specified recreational uses--Continued			
Paths and trails	Golf fairways	Recreational buildings	Campsites
Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: high water table; surface layer is sticky and soft when wet.	Severe: high water table----	Moderate: surface layer is sticky and soft when wet; moderate permeability. Severe: high water table.
Moderate: high water table; occasional flooding; surface layer sticky and soft when wet.	Moderate: high water table; surface layer sticky and soft when wet; occasional flooding.	Severe: subject to occasional flooding.	Moderate: high water table; surface layer sticky and soft when wet. Severe: subject to occasional flooding.
Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: high water table; surface layer is sticky and soft when wet.	Severe: high water table---	Moderate: surface layer is sticky and soft when wet; slow permeability. Severe: high water table.
Slight----------	Slight----------	Slight----------	Slight.
Slight----------	Slight----------	Slight----------	Slight.
Moderate: surface layer is sticky and soft when wet.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent.	Slight where slopes are 2 to 6 percent. Moderate on slopes of 6 to 12 percent.	Moderate where slopes are 6 to 12 percent: surface layer is sticky and soft when wet.
Moderate: high water table--	Moderate: high water table; medium natural fertility.	Severe: high water table---	Severe: high water table.
Slight----------	Moderate where slopes are 6 to 12 percent: medium natural fertility.	Slight where slopes are 0 to 6 percent. Moderate where slopes are 6 to 12 percent.	Slight where slopes are 0 to 6 percent. Moderate where slopes are 6 to 12 percent.
Moderate: occasional flooding; surface layer is sticky and soft when wet.	Moderate: occasionally flooded.	Severe: occasionally flooded.	Severe: occasionally flooded.
Moderate: sandy surface layer.	Moderate: sandy surface layer. Severe: low natural fertility; vegetation difficult to maintain.	Slight: sandy surface layer; vegetation difficult to maintain.	Moderate: sandy surface layer.
Moderate: sandy surface layer.	Moderate: sandy surface layer. Severe: low natural fertility; vegetation difficult to maintain.	Slight: sandy surface layer; vegetation difficult to maintain.	Moderate: sandy surface layer.

TABLE 9.--DEGREE AND KIND OF SOIL

Soil series and map symbols	Degree and kind of limitations for specified recreational uses	
	Intensive play areas	Extensive play areas
Dundas; Du----------	Moderate: moderately slow permeability; surface layer is sticky and soft when wet. Severe: high water table.	Moderate: surface layer is sticky and soft when wet. Severe: high water table.
*Erin: EnB, EnC, EnD, EnE, ErB2, ErC2, ErD2, EsF. For Kilkenny part of EsF, see Kilkenny series.	Moderate where slopes are 2 to 6 percent: moderately slow permeability; surface layer in eroded areas is sticky when wet. Severe on slopes of more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 12 percent.
Estherville: EtA, EtB, EtC, EtD--	Moderate where slopes are 2 to 6 percent: vegetation difficult to maintain. Severe where slopes are more than 6 percent.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain. Severe on slopes of more than 12 percent.
Glencoe: Gc----------	Moderate: surface layer is sticky and soft when wet. Severe: high water table; frequently ponded.	Moderate: surface layer is sticky and soft when wet. Severe: high water table; frequently ponded.
Grays: GyB, GyC----------	Moderate where slopes are 2 to 6 percent. Severe where slopes are more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent.
Hamel: Ha----------	Moderate: moderately slow permeability; surface layer is sticky and soft when wet. Severe: high water table.	Moderate: surface layer is sticky and soft when wet. Severe: high water table.
Hayden: HbB, HbC, HbD, HbE, HcB2, HcC2, HcD2, HcE2, HdF. For Lester part of HdF, see Lester series.	Moderate where slopes are 2 to 6 percent: surface layer on eroded areas is sticky when wet. Severe where slopes are more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer on eroded areas is sticky when wet. Severe where slopes are more than 12 percent.
Heyder: HeB, HeC, HeD, HeE----------	Moderate where slopes are 2 to 6 percent. Severe where slopes are more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.

LIMITATIONS FOR RECREATIONAL USES[1/]--Continued

Degree and kind of limitations for specified recreational uses--Continued			
Paths and trails	Golf fairways	Recreational buildings	Campsites
Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: high water table.	Severe: high water table--	Moderate: surface layer is sticky and soft when wet; moderately slow permeability. Severe: high water table.
Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 18 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 18 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 12 percent.
Slight where slopes are 0 to 12 percent. Moderate where slopes are 12 to 18 percent.	Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent: low natural fertility; vegetation difficult to maintain.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.
Moderate: surface layer is sticky and soft when wet. Severe: high water table; frequently ponded.	Severe: high water table; frequently ponded; surface layer is sticky and soft when wet.	Severe: high water table; frequently ponded.	Severe: high water table; frequently ponded.
Slight where slopes are 2 to 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent.
Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: high water table; surface layer is sticky and soft when wet.	Severe: high water table--	Moderate: surface layer is sticky and soft when wet; slow permeability. Severe: high water table.
Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 18 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer on eroded areas is sticky when wet. Severe where slopes are more than 12 percent.
Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent. Severe where slopes are more than 18 percent.	Moderate where slopes are 6 to 12 percent: medium natural fertility. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.

Soil series and map symbols	Degree and kind of limitations for specified recreational uses	
	Intensive play areas	Extensive play areas
Heyder: (Continued) HlB, HlC, HlD, HlE	Moderate where slopes are 2 to 6 percent: vegetation difficult to maintain in some places. Severe where slopes are more than 6 percent.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain in some places. Severe where slopes are more than 12 percent.
Hubbard: HuA, HuB, HuC, HuD, HuE	Moderate where slopes are 2 to 6 percent: sandy surface layer. Severe where slopes are more than 6 percent: vegetation difficult to maintain.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain; sandy surface layer. Severe where slopes are more than 12 percent.
Isan:		
Is	Moderate: high water table	Moderate: high water table
It	Severe: high water table; occasional ponding.	Severe: high water table; occasional ponding.
Iv	Moderate: some surface stones. Severe: high water table.	Severe: high water table
Kasota: KaB	Moderate where slopes are 2 to 6 percent: surface layer is sticky and soft when wet.	Moderate: surface layer is sticky and soft when wet.
Kennebec: Ke	Moderate: occasional ponding after heavy rains.	Moderate: occasional ponding after heavy rains.
Kilkenny: KkB, KkC, KkD, KkE, K1C2, K1D2.	Moderate where slopes are 2 to 6 percent: moderately slow permeability; surface layer in eroded areas is sticky when wet. Severe where slopes are more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 12 percent.
Kingsley: KnB, KnC, KnD, KnE, KnF	Moderate where slopes are 2 to 6 percent: few surface stones; vegetation difficult to maintain in some places. Severe where slopes are more than 6 percent.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain in some places. Severe where slopes are more than 12 percent.

LIMITATIONS FOR RECREATIONAL USES[1/]--Continued

Degree and kind of limitations for specified recreational uses--Continued			
Paths and trails	Golf fairways	Recreational buildings	Campsites
Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent. Severe where slopes are more than 18 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: vegetation may be difficult to maintain. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.
Moderate where slopes are 12 to 18 percent: sandy surface layer. Severe where slopes are more than 18 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe where slopes are more than 12 percent: vegetation difficult to maintain; low natural fertility.	Slight where slopes are 0 to 6 percent: sandy surface layer; vegetation difficult to maintain. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe where slopes are more than 12 percent.
Moderate: high water table---	Moderate: high water table. Severe: low natural fertility.	Severe: high water table----	Severe: high water table.
Severe: high water table; occasional ponding.	Moderate: occasional ponding. Severe: high water table; low natural fertility.	Severe: high water table; occasional ponding.	Severe: high water table; occasional ponding.
Severe: high water table-----	Moderate: high water table; some surface stones. Severe: low natural fertility.	Severe: high water table----	Moderate: some surface stones. Severe: high water table.
Moderate: surface layer is sticky and soft when wet.	Moderate: surface layer is sticky and soft when wet.	Slight----------	Moderate: surface layer is sticky and soft when wet.
Moderate: occasional ponding after heavy rains.	Moderate: occasional ponding after heavy rains.	Moderate: occasional ponding after heavy rains.	Severe: occasional ponding after heavy rains.
Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 18 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer on eroded areas is sticky when wet. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 12 percent.
Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent. Severe where slopes are more than 18 percent.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain in some places. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.

TABLE 9.--DEGREE AND KIND OF SOIL

Soil series and map symbols	Degree and kind of limitations for specified recreational uses	
	Intensive play areas	Extensive play areas
Lake beaches:		
Lc	Moderate: sandy surface layer. Severe: high water table; occasionally submerged by water.	Moderate: sandy surface layer. Severe: high water table; occasionally submerged by water.
Ld	Severe: high water table	Severe: high water table
Langola:		
LgA, LgB	Moderate where slopes are 2 to 6 percent: sandy surface layer; stony layer at depth of 15 to 36 inches. Severe where slopes are 6 to 12 percent: vegetation difficult to maintain.	Moderate where slopes are 6 to 12 percent: sandy surface layer; vegetation difficult to maintain.
Lh	Moderate: sandy surface layer; stony layer at depth of 15 to 36 inches. Severe: vegetation difficult to maintain.	Moderate: sandy surface layer; vegetation difficult to maintain.
Lerdal: LmB	Moderate where slopes are 2 to 6 percent: moderately slow permeability.	Slight
Lester: LrB, LrC, LrD, LrE, LsB2, LsC2, LsD2.	Moderate where slopes are 2 to 6 percent. Severe where slopes are more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 12 percent.
Le Sueur: LtB	Moderate where slopes are 2 to 6 percent.	Slight
Litchfield: Lu	Moderate: sandy surface layer. Severe: vegetation difficult to maintain.	Moderate: sandy surface layer; vegetation difficult to maintain.
Marsh: Ma	Severe: high water table; ponded most of the year.	Severe: high water table; ponded most of the year.
Minnetonka: Mt	Moderate: surface layer is sticky and soft when wet. Severe: high water table; slow permeability.	Moderate: surface layer is sticky and soft when wet. Severe: high water table.
Mixed alluvial land:		
Mu	Moderate: occasionally flooded	Moderate: occasionally flooded
Mx	Severe: frequently flooded	Severe: frequently flooded

LIMITATIONS FOR RECREATIONAL USES[1/]--Continued

Degree and kind of limitations for specified recreational uses--Continued			
Paths and trails	Golf fairways	Recreational buildings	Campsites
Moderate: sandy surface layer. Severe: high water table; occasionally submerged by water.	Moderate: sandy surface layer. Severe: high water table; occasionally submerged by water; low natural fertility.	Severe: high water table; occasionally submerged by water.	Moderate: sandy surface layer. Severe: high water table; occasionally submerged by water.
Severe: high water table----	Severe: high water table---	Severe: high water table---	Severe: high water table.
Moderate: sandy surface layer.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe: low natural fertility.	Slight where slopes are 0 to 6 percent: sandy surface layer; vegetation difficult to maintain. Moderate where slopes are 6 to 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer.
Moderate: sandy surface layer.	Moderate: sandy surface layer. Severe: low natural fertility.	Slight: sandy surface layer; vegetation difficult to maintain.	Moderate: sandy surface layer.
Slight----------	Slight----------	Slight----------	Moderate: moderately slow permeability.
Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 18 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 18 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent: surface layer in eroded areas is sticky when wet. Severe where slopes are more than 12 percent.
Slight----------	Slight----------	Slight----------	Slight.
Moderate: sandy surface layer.	Severe: sandy surface layer; low natural fertility.	Slight: sandy surface layer; vegetation difficult to maintain.	Moderate: sandy surface layer.
Severe: high water table; ponded most of the year.	Severe: high water table; ponded most of the year.	Severe: high water table; ponded most of the year.	Severe: high water table; ponded most of the year.
Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: high water table; surface layer is sticky and soft when wet.	Severe: high water table--	Moderate: surface layer is sticky and soft when wet. Severe: high water table; slow permeability.
Moderate: occasionally flooded.	Moderate: occasionally flooded.	Severe: occasionally flooded.	Moderate: occasionally flooded.
Severe: frequently flooded--	Severe: frequently flooded-	Severe: frequently flooded-	Severe: frequently flooded.

TABLE 9.--DEGREE AND KIND OF SOIL

Soil series and map symbols	Degree and kind of limitations for specified recreational uses	
	Intensive play areas	Extensive play areas
Nessel: NeB----------	Moderate where slopes are 2 to 6 percent.	Slight----------
Nymore: NyB, NyC----------	Moderate where slopes are 2 to 6 percent: sandy surface layer. Severe where slopes are more than 6 percent; vegetation difficult to maintain.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain.
Peaty muck: Pa----------	Severe: high water table; seasonally ponded; soft organic surface layer; peat and muck 10 feet thick or more in places.	Severe: high water table; seasonally ponded; soft organic surface layer.
Pb, Pm----------	Severe: high water table; seasonally ponded; soft organic surface layer.	Severe: high water table; seasonally ponded; soft organic surface layer.
Rasset: RsB, RsC, RsD----------	Moderate where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Severe where slopes are more than 6 percent.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain. Severe where slopes are more than 12 percent.
Salida: SaB, SaC, SaD, SaE--------	Severe where slopes are more than 6 percent: sandy surface layer; vegetation difficult to maintain; gravel near surface.	Moderate where slopes are 6 to 12 percent: coarse sandy surface layer; vegetation difficult to maintain. Severe where slopes are more than 12 percent.
Shields: Sh----------	Moderate: surface layer is sticky and soft when wet. Severe: high water table; slow permeability.	Moderate: surface layer is sticky and soft when wet. Severe: high water table.
Shorewood: SwA, SwB----------	Moderate where slopes are 2 to 6 percent: surface layer is sticky and soft when wet; moderately slow permeability.	Moderate: surface layer is sticky and soft when wet.
Zimmerman: ZmB, ZmC----------	Moderate: sandy surface layer. Severe on slopes of more than 6 percent: vegetation difficult to maintain.	Moderate where slopes are 6 to 12 percent: vegetation difficult to maintain. Severe where slopes are more than 12 percent.

1/ Some soils on which the severe limitations for a particular use have been overcome may continue to have some

LIMITATIONS FOR RECREATIONAL USES[1/]--Continued

Degree and kind of limitations for specified recreational uses--Continued			
Paths and trails	Golf fairways	Recreational buildings	Campsites
Slight----------	Slight----------	Slight----------	Slight.
Moderate: sandy surface layer.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe: low natural fertility.	Slight where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Moderate where slopes are 6 to 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer.
Severe: high water table; seasonally ponded; soft organic surface layer.	Severe: high water table; seasonally ponded; soft organic surface layer.	Severe: high water table; seasonally ponded; soft organic surface layer; peat and muck 10 feet thick or more in places.	Severe: high water table; seasonally ponded; soft organic surface layer; peat and muck 10 feet thick or more in places.
Severe: high water table; seasonally ponded; soft organic surface layer.	Severe: high water table; seasonally ponded; soft organic surface layer.	Severe: high water table; seasonally ponded; soft organic surface layer.	Severe: high water table; seasonally ponded; soft organic surface layer.
Moderate where slopes are 12 to 18 percent: sandy surface layer. Severe where slopes are more than 18 percent.	Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent: sandy surface layer; low natural fertility.	Slight where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe where slopes are more than 12 percent.
Moderate where slopes are 12 to 18 percent: sandy surface layer. Severe on slopes of more than 18 percent.	Severe where slopes are more than 12 percent: coarse sandy surface layer; low natural fertility.	Slight where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe where slopes are more than 12 percent.
Moderate: surface layer is sticky and soft when wet. Severe: high water table.	Moderate: high water table; surface layer is sticky and soft when wet.	Severe: high water table---	Moderate: surface layer is sticky and soft when wet. Severe: high water table; slow permeability.
Moderate: surface layer is sticky and soft when wet.	Moderate: surface layer is sticky and soft when wet.	Slight----------	Moderate: surface layer is sticky and soft when wet; slow permeability.
Moderate: sandy surface layer.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe where slopes are more than 12 percent: low natural fertility.	Slight where slopes are 2 to 6 percent: sandy surface layer; vegetation difficult to maintain. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Moderate where slopes are 6 to 12 percent: sandy surface layer. Severe where slopes are more than 12 percent.

moderate limitations. For this reason, both the moderate and the severe limitations of some soils are shown.

The hazard of flooding is a severe limitation to the use of these soils for residential and commercial development.

Limitations for sanitary landfills are severe because of the hazard of flooding. During floods, refuse pollutes nearby rivers and streams.

These soils can be used for parks, recreation areas, and wildlife sanctuaries. Areas that are seldom flooded are suitable for campsites and picnic areas. Flooding is not so severe a limitation to these uses, because the period of peak use generally occurs after flood waters have receded.

Use of the Soils for Recreation

Hennepin County abounds in lakes and streams, which provide ample opportunities for fishing, swimming, and boating. Ideal picnic areas, campsites, and sites for paths and trails occur along the major rivers in the county. Lake Minnetonka has many bays and arms and is used heavily for boating and fishing (plate IX). Morris Baker Park on the eastern shore of Lake Independence is a popular swimming and picnicking area. Some of the rolling hills in the southern part of the county are well suited to development of ski and toboggan runs (plate IX). Information in the following paragraphs can be used as a guide in determining the suitability of sites in Hennepin County for recreational development. (See also table 8.)

The degree and kind of limitations of the soils for specified recreational uses are given in table 9. The degree of limitation is expressed as slight, moderate, or severe. The limitation is slight if the soil is suitable for a specified use. The limitation is moderate if the soil can be used, but good management and careful design are needed to overcome the limitations. The limitation is severe if use is severely limited or is impractical.

Soils having a wide range in slope may have all three degrees of limitation given in an evaluation, depending upon the slope. Steep slopes may be a severe limitation for a particular use, even though other features may be favorable. For example, some soils may have slight limitations for picnic areas where slopes are 2 to 6 percent. Soils having slopes of 6 to 12 percent, however, are less desirable, and the limitations are moderate. Limitations for picnic areas are severe where slopes are more than 12 percent, because the soils would have to be leveled for this purpose.

Some soils on which the severe limitations for a particular use have been overcome may continue to have some moderate limitations. For this reason, both the moderate and the severe limitations of some soils are shown.

This table can serve as a general guide for selecting recreational sites and to assist in the design of recreational developments. Evaluations are based on soil features only and serve as preliminary information to be used in further onsite investigation.

In table 9 all mapping units were treated as having suitable width, depth, and uniformity. However, on many landscapes the size, shape, or pattern in which they occur with other soils may change a unit's limitations greatly. The planner will have to consider these relationships in making his final decision.

All soils have been treated as being in their natural condition. Intensive drainage, effective diking, and other practices can greatly alter limitations, and such manmade alterations need to be considered during onsite evaluations.

Recreational uses and the factors evaluated for each use are discussed in the paragraphs that follow.

Intensive play areas are used for playgrounds and athletic fields. They are used frequently and are subject to intensive foot traffic. Areas selected for this use generally have a nearly level surface, good drainage, and a soil consistence that assures a firm surface. The most desirable soils are also free of rock outcrops and coarse fragments. Wetness, flooding, permeability, slope, surface texture, depth to hard bedrock, and classes of stoniness and rockiness were the specific items evaluated.

Extensive play areas refer to picnic areas and parks. These sites are subject to a moderate amount of foot traffic and can use somewhat less desirable sites than those needed for intensive play areas. Specific items evaluated were the same for both uses.

Paths and trails are used for cross-country hiking, bridle paths, and intensive uses that allow for random movement of people. It is assumed that these areas are to be used as they occur in nature and that little soil will be excavated or moved. Specific items evaluated were wetness, flooding, slope, surface texture, and surface stones or rocks.

The ratings of soils for golf fairways refer only to the fairways, because the traps and greens are manmade. Fairways require soils with good trafficability, a minimum of coarse fragments or stones, and slopes that are not too steep. Specific items evaluated were slopes, depth to water table, surface texture, surface stones or rocks, flooding, and natural fertility.

Recreational buildings are those used as seasonal and year-round cottages, washrooms, bathhouses, golf shelters, and service buildings. Specific items evaluated were wetness, flooding, slope, rockiness or stoniness, and depth to bedrock. Such items as frost heaving, shrink-swell potential, waste disposal and other engineering considerations are not given in table 9. Soil ratings for use of onsite sewage disposal systems are discussed in the subsection "Use of the Soils for Town and Country Planning." These ratings are useful in planning the locations of cottages and service buildings in recreational areas.

Campsites refer to areas suitable as sites for tents and small trailers and the accompanying activities of outdoor living. Tents and trailers are used frequently during the season, and the sites require little preparation. Specific items evaluated were wetness, flooding, permeability, slope, surface texture, amount of coarse fragments, and percentage of stones or rocks.

This section tells how the factors of soil formation have affected the development of soils in Hennepin County. It also explains the system of soil classification currently used and places each soil series in the classes of that system.

Factors of Soil Formation

Soil is produced by soil-forming processes acting on materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by (1) the physical and mineralogical composition of the parent material, (2) the climate under which the soil material has accumulated and existed since accumulation, (3) the plant and animal life on and in the soil, (4) the relief, or lay of the land, and (5) the length of time the forces of soil formation have acted on the soil material.

Climate and plant and animal life, chiefly plants, are active factors of soil formation. They act on the parent material that has accumulated through the weathering of rocks and slowly change it to a natural body that has genetically related horizons. The effects of climate and plant and animal life are conditioned by relief. The parent material also affects the kind of soil profile that is formed and, in extreme cases, determines it almost entirely. Finally, time is needed for changing the parent material into a soil profile. It may be much or little, but some time is always required for differentiation of soil horizons. Generally, a long time is required for the development of distinct horizons.

The factors of soil formation are so closely interrelated in their effects on the soil that few generalizations can be made regarding the effect of any one factor unless conditions are specified for the other four. Many of the processes of soil development are unknown.

The five factors of soil formation as they occur in Hennepin County are described in the pages that follow.

Parent Material

Hennepin County was covered by drift of the Grantsberg sublobe of the Lake Mankato Glaciation (11). The drift is composed of relatively recent material derived through the reworking of older deposits. The thickness of the drift ranges from a few feet, in the southeastern corner of the county near Fort Snelling, to 450 feet, in preglacial valleys. In most places the drift is 100 to 200 feet deep. The most extensive sources of parent material are glacial till and glacial outwash. Smaller areas consist of alluvium, glaciolacustrine deposits, and organic material.

The differences among these parent materials account for many of the differences in the soils. Parent material is a mixture of clay, unweathered minerals, and rock fragments that vary widely in their composition and density.

Glacial till.--Glacial till refers to drift that is not stratified. A number of continental glaciers are believed to have covered all of Hennepin County. The material deposited by these glaciers lies deeply buried under the more recent Wisconsin glacial deposits. The uppermost deposits were laid down during the late stages of what geologists refer to as the Wisconsin Glaciation. This glacial age deposited different types of glacial material and provided the parent material from which the soils in Hennepin County were formed.

The oldest drift was deposited by the ice of the Superior lobe, which flowed into the area from the north and covered the entire county. This glacier deposited till that is reddish brown in color, generally sandy in texture, and noncalcareous. This material is commonly known as red till (plate IX). Pebbles of basalt, felsite, and red sandstone are common. Kingsley soils developed in red till.

Somewhat later the Grantsberg sublobe, a protrusion of the Des Moines lobe, advanced into the area. This lobe moved in a northeasterly direction across the county and followed the lowland across the east-central part of the State. The till deposited by the Des Moines lobe is commonly referred to as gray till. The gray till covers nearly all of the red till, except for small areas in the eastern part of the county. In some places the Grantsberg sublobe picked up till previously deposited by the Superior lobe; consequently, complex mixtures of reddish-brown and light olive-brown drift were deposited in some areas.

The till of this last glaciation is grayish brown or light olive brown in areas where drainage is good and the material had access to air. In poorly drained areas the till is olive gray. The gray till is derived mostly from limestone and shale particles, but it contains enough granite and sandstone to provide an abundance of minerals. This material is calcareous and contains many limestone pebbles. The content of carbonates is high (15 to 25 percent), and the material effervesces strongly with hydrochloric acid.

In most places this till is friable loam that contains 18 to 24 percent clay, 30 to 40 percent silt, and 35 to 50 percent sand. Hayden, Lester, and Nessel soils developed in gray till. In the eastern part of Maple Grove and Plymouth villages and in scattered patches elsewhere, the gray till is more sandy and contains common pockets of sand. Red drift underlies this till at a depth of 5 to 20 feet in many places. Heyder soils are an example of soils that formed in the more sandy gray till.

In the western part of Medina, the eastern two-thirds of Independence, the eastern half of Minnetrist, and the western part of Orono villages, along with small, scattered tracts elsewhere, the loam till is mantled with a veneer of till, 3 to 20 feet thick, that is higher in content of silt and clay than the loam till. Texture is typically heavy

loam or light clay loam. This material appears to be more dense than the loam till, generally contains more shale, and has a greater concentration of lime carbonates along fracture planes.

Glaciolacustrine deposits.--During the retreat of the Grantsberg sublobe, it appears that ice stagnated in many parts of the county. Lakes were probably formed in depressions in the ice in the late stages of melting, and the bottoms of the lakes or ponds rested on gray till and the walls formed by the melting ice. Lacustrine sediments, 2 to 10 feet or more in thickness, were deposited in these glacial lakes. These sediments occupy irregular tracts 2 acres to about 160 acres in size, mostly in the central and southwestern parts of the county. The sediments have a rather abrupt margin, and the depth of sediment varies greatly within short distances. Most of the sediments are silty clay in the upper 2 to 5 feet and silt loam below that depth. Dalbo and Minnetonka are examples of soils that formed in silty clay sediments. In some places, only a silt loam mantle 3 to 10 feet thick overlaps the gray till and the clay sediments are absent. Grays soils formed in areas where the sediments are silty.

Glacial outwash or collapsed alluvium.--As the stagnant ice melted, alluvium consisting of sand and gravel was deposited in places on lower lying stagnant ice. When the ice below finally melted, an undulating to hilly landscape resulted.

The largest area of glacial outwash or collapsed alluvium occurs in the southern part of the county near the Minnesota River. Here the landscape is undulating to hilly. The parent material includes sand, stratified sand and loamy material, and stratified sand and gravel with a 1/2-foot to 3-foot veneer of loamy material.

A number of smaller areas of glacial outwash or collapsed alluvium also occur in the county. A gently undulating to rolling area occurs in a belt 1/4 mile to 2 miles wide between Delano and Dayton. The parent material here consists mainly of sand and of sand with a thin mantle of loamy alluvium. Two small areas of outwash or collapsed alluvium that consists mainly of stratified sand and gravel with a thin mantle of loamy alluvium lie in the east-central part of the county. One area lies just north of Gleason Lake and extends in a belt, 1/4 mile to 1 1/2 miles wide to the western shore of Medicine Lake. The other area occurs just off the eastern side of Lake Minnetonka.

In places in the eastern part of the county, the coarse alluvium probably filled crevasses in the stagnant ice. When the icefield melted, the coarse alluvium remained as an elevated ridge. Crevasse ridges range in height from 50 to 125 feet, in width from 200 to 500 feet, and in length from 500 feet to 1 1/2 miles 5/.

Finally, the Grantsberg sublobe retreated westward, which uncovered the Mississippi Valley. Melt water from the wasting Des Moines lobe filled the valley in Hennepin County with coarse alluvium. This coarse alluvium, referred to by some as stream outwash, occupies an extensive area in the northeastern part of the county. This material is mainly sand, but there are small areas of stratified calcareous sand and gravel near Osseo. A thin veneer of more loamy alluvium, up to 36 inches thick, covers much of the coarser material. Hubbard is an example of a soil that formed in sandy alluvium. Estherville soils formed in a thin, loamy veneer over stratified sand and gravel. The gravel and sand deposits are mainly more than 20 feet in thickness, but in a few places they are only a few feet thick over gray or red till. Braham is an example of a soil that formed in thin alluvium over gray till.

In the extreme southeastern corner of the county, the coarse alluvium is underlain by limestone and sandstone bedrock within a depth of 5 feet. Only a very small acreage, about 20 acres, occurs.

As the glacier retreated, large blocks of ice were left in the till and outwash. The melting of the ice blocks produced depressions in all of the glacial deposits, and most of these depressions are now lakes or swamps. Organic soils developed in the depressions where water stood for part of the year and along drainageways that were frequently flooded. The organic material is 1 foot to more than 10 feet in thickness.

Recent alluvium.--Recent alluvium refers to alluvium that has been deposited by streams during past glacial times. Recent alluvium was deposited on the flood plains of all the streams in the county. The largest areas of alluvium are on the broad flood plains along the Minnesota River. The material varies widely in color, texture, and reaction. In most places the material is too recent for a profile to have formed. Chaska soils are an example of soils that formed in alluvium.

Climate

Climate is an important factor in soil formation because it determines the kind of vegetation and the rate and intensity of chemical and physical processes in the soil. The effects of climate are in turn modified by the topography and the length of time the parent material has been in place.

Hennepin County has a subhumid climate. Summers are hot and winters are cold. In winter the soils are frozen to a depth of 2 to 4 feet for 4 or 5 months. During winter soil-forming processes are largely dormant. The depth of frost penetration depends mainly on the amount of snowfall late in fall or early in winter.

The climate is essentially uniform throughout the county. Variations in soils result from differences in parent material, relief, and vegetation.

Relief

Relief, or topography, is an important factor in the formation of soils because it modifies climate and vegetation.

5/ From Proceedings of Fourth Forum on Geology of Industrial Minerals, March 14-15, 1968. Austin, Tex.

The topography of Hennepin County is the result of a melting glacier. The glacial drift that was deposited was so thick that the underlying bedrock had little effect on the landscape pattern. The topography of Hennepin County ranges from nearly level on the outwash plain near Osseo to hilly in the southeastern part of the county, where end moraines form a complex pattern.

The main drainage channels were developed during the melting of the glacier. They occur as abrupt gorges.

Soil development varies widely as a result of differences in topography. Topography affects the natural drainage and color of many soils. Gray till parent material in nearly level areas has a water table that is near the surface during wet seasons. The content of air in poorly drained soils is relatively low. Consequently, iron oxides that are being released from minerals by various processes are reduced. The reduced iron and aluminum oxides are easily carried by percolating water to lower depths, where they accumulate as strong-brown mottles. The soil material above remains gray. Cordova is an example of a poorly drained soil, as indicated by its gray subsoil.

In relief positions where the water table is deep, a much greater amount of air enters the soils. Here, the iron oxides being released in the soil are oxidized, and they coat the relatively unweathered minerals. The subsoil, to the depth of carbonate leaching, takes on the characteristic brownish color of rusted iron. Hayden is an example of a soil that has good natural drainage, as indicated by its dark yellowish-brown subsoil.

Topography affects the depth of carbonate leaching. Lime carbonates must be removed from the upper part of the parent material before clay can be moved from the surface soil into the subsoil. On steep slopes, where runoff is high, little water percolates down through the soils. Consequently, on steep slopes carbonates are not generally removed to so great a depth as on more gentle slopes. In places on the more convex knolls, lime carbonates occur at the surface after rainfall has fallen on the surface for hundreds of years. Here, rainfall has probably eroded the soils as quickly as carbonates were removed. In areas of gray till in Hennepin County, where the water table is at a depth below 3 feet all year, the lime carbonates are leached to a depth of 26 to 48 inches.

In wet, poorly drained areas on level sites, removal of lime carbonates has been slowed by the upward evaporation of moisture that carries carbonates during dry seasons. This counteracts the forces of carbonate removal, namely rainfall.

Carbonate removal and soil development are greatest on nearly level and gently sloping soils where the water table is at a depth below 3 feet in all seasons.

Vegetation

Vegetation was an important factor in soil formation in Hennepin County. The two types of vegetation that influenced soil development were mainly tall prairie grass and mixed northern hardwoods.

Most of Hennepin County was wooded at the time of settlement. Oak, elm, basswood, maple, and ash were the main species. The only areas that were prairie were the broad, level outwash plains along the Mississippi River and the rolling plain of collapsed alluvium in the southern part of the county. In these areas the soils were too droughty to grow good stands of trees. The vegetation here consisted of tall grasses and scattered patches of aspen and scrub oak. The wet, very poorly drained soils were covered with marsh grass, reeds, and sedges.

In the soils that formed in similar positions and have similar parent material, drainage, and development time, the surface layer that formed under prairie is thicker and darker than that of soils that formed under forest. In forest soils, movement of clay and organic material into the subsoil is greater and the subsoil generally is less permeable. Large areas of forest soils, such as those of the Hayden series, are in the northern and eastern parts of the county. Soils that formed under prairie, such as those of the Hubbard series, are mainly on sandy outwash plains. At one time the entire county may have been covered with grass. Grass produces an abundance of fine roots that easily break down into humus after the plants die. In time a thick, dark surface layer is formed. A thicker and darker surface layer occurs in areas where the water table is high. Here, the air supply necessary to decomposition is low, and decay of plant remains proceeds slowly. In addition, the cool temperatures associated with wet soils slow decay.

Hennepin County is near the western edge of the Big Woods, and small shifts in climate can influence the vegetation. Broad, level plains in this part of the country generally are prairie. Timber probably first developed on the till soils where the topography was rolling to hilly. Here, many north-facing slopes occur that provide a more moist, cool climate than level areas and protect trees from hot, dry summer winds. The timber spread from these rolling to hilly areas of gray till and from other moist areas, such as ravines and gullies along streams.

Timber produces only a small amount of fine roots. Tree roots are mainly large and decompose slowly. The organic matter produced by leaves remains mainly on the surface. The organic matter produced by timber vegetation is lower in bases than that produced by grasses. Organic acid produced by water acting on decaying leaves is a strong weathering agent. In time, organic matter and clay particles weathered from minerals in the surface layer are moved down and deposited in cracks and pores in the subsoil. Timber soils are characterized by a thin, dark surface layer, a thin, ashy-gray subsurface layer (zone of clay removal), and a structurally developed subsoil that has waxy clay coatings (zone of clay accumulation). The subsoil has a marked increase over the surface layer in clay content. In most places, cultivation has mixed the dark surface layer and the gray subsurface layer, but the original surface layer can be observed in

467-556 O - 74 - 11

undisturbed wooded areas. The Hayden series is an example of soils that formed under forest vegetation.

Soils that formed under grassland typically lack the gray subsurface layer and the marked increase in clay content in the subsoil.

Some soils in the county reflect the effect of both prairie and forest vegetation. These soils, the Lester series for example, have a dark-colored surface layer and typically lack the gray subsurface layer of forest soils. The subsoil, however, is similar to that of the forest soils because it has a marked increase in content of clay and accumulation of organic matter.

Forest soils in Hennepin County are mainly in positions where the water table is at a depth below 3 feet throughout the year. These soils are well drained and moderately well drained. Trees do not establish themselves so easily, nor do they grow so well, on poorly drained and very poorly drained soils. In addition, a high water table slows the movement of lime carbonates from the surface and subsurface layers, which is necessary before clay and organic matter can be moved into the subsoil. Consequently, in most parts of the county, the poorly drained soils have a thicker, darker surface layer and less accumulation of clay in the subsoil than the nearby, well-drained soils on the slopes. Cordova and Hayden are examples of closely associated soils. They formed in similar parent material but differ because of the influences of vegetation and wetness as controlled by topography (plate X).

Peaty muck soils formed in sites where abundant water encourages the luxuriant growth of reeds and sedges. The organic matter from these plants decays slowly in areas where the water table is at the surface much of the year. The plant remains accumulate faster than they decay, and organic material known as peat accumulates.

Time

The length of time the parent material has been in place and exposed to the active forces of climate and vegetation is an important factor in soil formation. The soils in Hennepin County are considered young soils. With the exception of the alluvial soils, time has had similar influence on all the soils in the county.

It should be noted, however, that the age of a soil is influenced by other factors as well as by time. Because of differences in parent material, climate, relief, and vegetation, soils that have been developing for about the same length of time have not necessarily reached the same degree of profile development. If the parent material weathers slowly, profile development is slow. If the slope is steep, soil is eroded almost as soon as it forms and, therefore, there are no well-developed layers. On flood plains the frequent deposition of fresh alluvium delays the development of a distinct profile.

Classification of Soils

Soils are classified so that we can more easily remember their significant characteristics. Classification enables us to assemble knowledge about the soils, to see their relationship to one another and to the whole environment, and to develop principles that help us understand their behavior and their response to manipulation.

Two systems of classifying soils have been used in the United States in recent years. The older system was adopted in 1938 and later revised (5). The system currently used was adopted for general use by the National Cooperative Soil Survey in 1965 (7). The current system is under continual study. Therefore, readers interested in developments of the current system should search the latest literature available (4). In table 10 the soil series of Hennepin County are placed in some categories of the current system.

The current system of classification has six categories. Beginning with the most inclusive, these categories are the order, the suborder, the great group, the subgroup, the family, and the series. The criteria for classification are soil properties that are observable or measurable, but the properties are selected so that soils of similar genesis are grouped together. The placement of some soil series in the current system of classification, particularly in families, may change as more precise information becomes available. Some of the categories of the current system are briefly defined in the following paragraphs.

ORDER: Ten soil orders are recognized. They are Entisols, Vertisols, Inceptisols, Aridisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, and Histosols. The properties used to differentiate these soil orders are those that tend to give broad climatic groupings of soils. The two exceptions to this are the Entisols and Histosols, which occur in many different kinds of climate. Table 10 shows that the soil orders represented in Hennepin County are Entisols, Inceptisols, Mollisols, Alfisols, and Histosols.

Entisols are light-colored soils that do not have natural genetic horizons or that have only very weakly expressed beginnings of such horizons. These soils do not have traits that reflect soil mixing caused by shrinking and swelling.

Inceptisols are light-colored mineral soils that are weakly expressed. The only development is leaching of bases. The soil material in these soils has not been mixed by shrinking and swelling.

Mollisols are soils that formed under grass and have a thick, dark-colored surface horizon that contains colloids dominated by bivalent cations. The soil material in these soils has not been mixed by shrinking and swelling.

Alfisols are mineral soils that contain horizons of clay accumulation. Unlike the Mollisols, they lack a thick, dark-colored surface layer that contains colloids dominated by bivalent cations, but

TABLE 10.--SOILS CLASSIFIED ACCORDING TO THE CURRENT SYSTEM OF CLASSIFICATION

Series	Family 1/	Subgroup	Order
Anoka 2/	Coarse-loamy, mixed, frigid	Arenic Glossoboralfs	Alfisols.
Becker	Coarse-loamy, mixed, mesic	Typic Haplaquolls	Mollisols.
Biscay	Fine-loamy over sandy-skeletal, mixed, noncalcareous, mesic.	Typic Haplaquolls	Mollisols.
Braham	Sandy over loamy, mixed, frigid	Arenic Eutrochrepts	Inceptisols.
Burnsville	Coarse-loamy, mixed, mesic	Typic Hapludalfs	Alfisols.
Burnsville, thick solum variant.	Coarse-loamy, mixed, mesic	Typic Argiudolls	Mollisols.
Canisteo	Fine-loamy, mixed, calcareous, mesic.	Typic Haplaquolls	Mollisols.
Chaska 3/	Fine-loamy, mixed, calcareous, mesic.	Cumulic Haplaquolls	Mollisols.
Cordova	Fine-loamy, mixed, noncalcareous, mesic.	Typic Argiaquolls	Mollisols.
Dakota 4/	Fine-loamy over sandy, mixed, mesic-	Typic Argiudolls	Mollisols.
Dalbo	Fine, montmorillonitic, frigid	Aquic Eutroboralfs	Alfisols.
Dassel	Coarse-loamy, mixed, noncalcareous, mesic.	Typic Haplaquolls	Mollisols.
Dickman	Sandy, mixed, mesic	Typic Hapludolls	Mollisols.
Dorchester 5/	Fine-silty, mixed, mesic	Typic Udifluvents	Entisols.
Duelm	Sandy, mixed, frigid	Aquic Haploborolls	Mollisols.
Duelm, loamy subsoil variant.	Sandy over loamy, mixed, frigid	Aquic Haploborolls	Mollisols.
Dundas	Fine-loamy, mixed, mesic	Udollic Ochraqualfs	Alfisols.
Erin	Fine, montmorillonitic, mesic	Glossoboric Hapludalfs	Alfisols.
Estherville	Coarse-loamy over sandy or sandy-skeletal, mixed, mesic.	Typic Hapludolls	Mollisols.
Glencoe	Fine-loamy, mixed, noncalcareous, mesic.	Cumulic Haplaquolls	Mollisols.
Grays	Fine-silty, mixed, mesic	Mollic Hapludalfs	Alfisols.
Hamel	Fine-loamy, mixed, noncalcareous, mesic.	Typic Argiaquolls	Mollisols.
Hayden	Fine-loamy, mixed, mesic	Typic Hapludalfs	Alfisols.
Heyder	Fine-loamy, mixed, mesic	Glossoboric Hapludalfs	Alfisols.
Hubbard	Sandy, mixed, frigid	Udic Haploborolls	Mollisols.
Isan 6/	Sandy, mixed, noncalcareous, frigid-	Typic Haplaquolls	Mollisols.
Kasota	Clayey over sandy or sandy-skeletal, mixed, mesic.	Typic Argiudolls	Mollisols.
Kennebec	Fine-silty, mixed, mesic	Cumulic Hapludolls	Mollisols.
Kilkenny	Fine, montmorillonitic, mesic	Mollic Hapludalfs	Mollisols.
Kingsley	Coarse-loamy, mixed, mesic	Mollic Hapludalfs	Alfisols.
Langola 7/	Coarse-loamy, mixed, frigid	Udic Haploborolls	Mollisols.
Lerdal 8/	Fine, montmorillonitic, mesic	Udollic Ochraqualfs	Alfisols.
Lester	Fine-loamy, mixed, mesic	Mollic Hapludalfs	Alfisols.
Le Sueur	Fine-loamy, mixed, mesic	Aquic Argiudolls	Mollisols.
Litchfield 9/	Coarse-loamy, mixed, mesic	Aquic Hapludolls	Mollisols.
Minnetonka	Fine, montmorillonitic, mesic	Typic Argiaquolls	Mollisols.
Nessel	Fine-loamy, mixed, mesic	Glossaquic Hapludalfs	Alfisols.
Nymore	Sandy, mixed, frigid	Typic Udipsamments	Entisols.
Peaty muck 10/	Euic, mesic	Typic Medihemists	Histosols.
Peaty muck over sand 10/	Sandy, mixed, euic, mesic	Hemic Terric Medisaprists or Terric Medisaprists.	Histosols.
Peaty muck over loam 10/	Loamy, mixed, euic, mesic	Hemic Terric Medisaprists or Terric Medisaprists.	Histosols.

TABLE 10.--SOILS CLASSIFIED ACCORDING TO THE CURRENT SYSTEM OF CLASSIFICATION--Continued

Series	Family 1/	Subgroup	Order
Rasset	Coarse-loamy, mixed, mesic	Typic Argiudolls	Mollisols.
Salida	Sandy-skeletal, mixed, mesic	Entic Hapludolls	Mollisols.
Shields 11/	Fine, montmorillonitic, mesic	Mollic Albaqualfs	Mollisols.
Shorewood	Fine, montmorillonitic, mesic	Aquic Argiudolls	Mollisols.
Zimmerman	Sandy, mixed, frigid	Alfic Udipsamments	Entisols.

1/ Hennepin County has soil temperatures on the border between the mesic and frigid soil temperature classes; therefore, soils in both classes occur in the county. However, these temperature differences are minor and are usually not significant to growing crops in the county.

2/ These soils are taxadjuncts of the Anoka series because the surface layer is thicker and darker and the sand fraction is dominantly fine sand.

3/ These soils are taxadjuncts of the Chaska series because they contain less fine sand than the defined range for the series.

4/ These soils are taxadjuncts of the Dakota series because they have less translocated clay in the B horizon than the defined range for the series.

5/ These soils are taxadjuncts of the Dorchester series because they have darker colored upper horizons and contain more sand than the defined range for the series.

6/ Some of these soils are taxadjuncts of the Isan series because the C horizon is loam or heavy sandy loam.

7/ These soils are taxadjuncts of the Langola series because they have more silt and clay in the solum and some have grayer colors than the defined range for the series.

8/ These soils are taxadjuncts of the Lerdal series because the A horizon is thicker than the defined range for the series.

9/ These soils are taxadjuncts of the Litchfield series because they have a thinner, darker colored A horizon and contain more medium and coarse sand than the defined range for the series.

10/ Organic soils that have not been classified at the series level.

11/ These soils are taxadjuncts of the Shields series because the upper part of the B horizon is darker than the defined range for the series.

the base status of the lower horizons is not extremely low.

Histosols are organic soils that are wet much of the year.

SUBORDER: Each order has been subdivided into suborders, primarily on the basis of the characteristics that seem to produce classes that have the greatest genetic similarity. The suborders narrow the broad climatic range permitted in the orders. The soil properties used to separate suborders are mainly those that reflect either the presence or absence of waterlogging or soil differences resulting from the climate or vegetation.

GREAT GROUPS: Suborders are separated into great groups on the basis of uniformity in the kind and sequence of major soil horizons and features. The horizons used to make separations are those in which clay, iron, or humus has accumulated or those that contain a pan that interferes with the growth of roots or movement of water. The features used are the self-mulching properties of clays, soil temperature, major differences in chemical composition (mainly calcium, magnesium, sodium, and potassium), and the like. The great group is not shown separately in table 10, because it is the last word in the name of the subgroup.

SUBGROUP: Great groups are subdivided into subgroups, one representing the central (typic) segment of the group, and 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.

FAMILY: Families are separated within a subgroup primarily on the basis of properties important to the growth of plants or behavior of soils when used for engineering. Among the properties considered are texture, mineralogy, reaction, soil temperature, permeability, thickness of horizons, and consistence.

ADDITIONAL FACTS ABOUT THE COUNTY

This section gives some information about the settlement and development of Hennepin County. It also discusses the climate, physiography, lakes and streams, and farming in the county. Statistics used in the discussion about farming are mainly from reports of the U.S. Bureau of the Census.

Hennepin County was established in 1852. It was named for Louis Hennepin, a Franciscan priest who went up the Mississippi River as far as the Falls of St. Anthony in 1680. He is believed to have been the first white man to enter the county. Settlement did not begin, however, until 1819, when a garrison of Federal troops took command of the fort that was located on the site now occupied by Fort Snelling.

Farming began in about 1823 with the arrival of a small band of Swiss colonists, who settled near Fort Snelling and grew vegetables and grains for the garrison. Farming did not begin to develop to any extent, however, until the 1870's, when a large number of settlers entered the county.

Hennepin County has a population of about one million. About half of the population resides in Minneapolis, the county seat and the largest city in the State. It is located in the east-central part of the county and developed around the site of St. Anthony Falls on the Mississippi River. Minneapolis, a city known for its lakes and natural beauty, is an important railroad and manufacturing center. It is the principal distributing center for the Northwest and is the largest flour-producing center in the world. It is also the center of the computer industry in the United States.

Dairying is the most important farm enterprise. Potato growing is important near Osseo but is rapidly declining because of urban expansion. There are a few farms in the county where cattle feeding is the main enterprise.

There are nine cities and 37 villages in the county, and three unincorporated townships are in the northern part of the county. Most of these are suburbs of Minneapolis or villages along the shores of Lake Minnetonka.

Climate [6/]

The climate of Hennepin County is predominantly continental. There are wide variations in temperature. Precipitation in summer is ample, but it is scanty in winter. Disturbances that originate in the northwestern part of the United States, and many that originate in the southwestern part, migrate eastward through this area and are followed by cooler, sometimes much colder, polar airmasses from the northwest and north. This cyclonic control of climate gives the county changeable weather, which is stimulating.

The temperature variation from season to season is quite large, as is shown in table 11. It is very warm, though comfortable, in summer, because of low daytime humidity, and very cold in winter. The mean temperature for the winter months of December, January, and February is about 15° F., and for the summer months of June, July, and August, about 70°. Recorded temperature extremes cover a range of 142°,

6/ By DONALD A. HAINES, climatologist for Minnesota, National Weather Service, U.S. Department of Commerce.

from 34° below zero in January 1936 to 108° in July of that same year. There were 36 consecutive days during January and February 1936 when the temperature was below zero and 11 straight days in July 1948 when it was 90° or higher.

Although the total precipitation is important, its distribution during the growing season is even more significant. For the most part, vegetation is dormant for 7 months. During the remaining 5 months, May through September, the major area crops are produced. During this period the normal rainfall is 16.07 inches, which is approximately 65 percent of the normal annual precipitation. Snowfall in winter can be heavy, and it averages more than 40 inches a season. The heaviest snowfall observed in any single month was 40 inches, in March 1951. Snow has occurred in all months except June, July, and August.

The probability of certain temperatures occurring in spring and fall are shown in table 12 (2, 3). The average last date of occurrence of a temperature of 32° F. or lower in spring is April 29. The latest date recorded was May 24, in 1925. The average date of the first occurrence of a temperature of 32° or lower in autumn is October 13. The earliest date recorded was September 18, in 1929. The shortest growing season was 124 days, in 1929, and the longest was 207 days, in 1894 and 1900. The average growing season is 166 days. Because of the favorable growing season, all plants generally mature before the fall freeze occurs.

Occurrence of tornadoes, freezing rain, and hail is not especially frequent. The county lies along the northern edge of the region of maximum tornado frequency in the United States. During the period 1916-67, 18 tornadoes were reported within its boundaries. Thunderstorms are the principal source of precipitation during the growing season. Although some damage results from the more severe thunderstorms, losses are largely offset by the benefits gained from the rain that falls during the average of 36 days per year when thunderstorms occur.

Windspeed ranges from an average of 9.1 miles per hour in August to 12.6 miles per hour in April. The prevailing direction is from the south to southeast from May through October and from the northwest during the other months. Noontime relative humidity ranges from 55 percent in June to 70 percent in December. During a typical year, 102 clear days, 102 partly cloudy days, and 161 cloudy days can be expected. Heavy fog is not frequent, and 12 days of heavy fog are expected during the average year.

Physiography

Glacial drift covers all of Hennepin County and in most places is more than 100 feet thick.

Most of the county is rolling to hilly, but fairly large areas of undulating topography occur near Rogers and Burschville in the northwestern part of the county. The only large, nearly level area in the county occurs on outwash plains along the Mississippi River.

The valley of the Minnesota River is bordered by bluffs that rise 150 to 200 feet above the flood plains. The flood plains are up to 3 miles wide.

The highest elevation in the county is 1,160 feet. The highest elevations are in the west-central and southern parts of the county. The lowest elevations, about 700 feet, are along the Minnesota River.

Lakes and Streams

More than 100 lakes occur within the county borders. The largest, Lake Minnetonka, is a lake of rare scenic beauty, with many bays and arms. Along its shores are located many beautiful homes and summer cottages. The lake extends about 23 miles from east to west and about 12 miles from north to south. Other important lakes are Independence, Medicine, and Sarah.

All the streams in Hennepin County eventually empty into the Mississippi River, which borders the northeastern part of the county. The Crow River enters the county on the west side, a few miles south of Rockford, and meanders northwesterly to the Mississippi River. It drains a belt 3 to 7 miles wide in the western part of the county.

The south-central part of the county drains into Lake Minnetonka, which outlets eastward through Minnehaha Creek into the Mississippi River at the famous Minnehaha Falls. The northern part of the county is drained mainly by the Mississippi River. Shingle, Elm, Rush, and Bassett Creeks drain areas of the northern and central parts of the county.

Farming

Farming has been important in Hennepin County since the time of earliest settlement. The sandy soils east of Osseo and near the Minnesota River have been under cultivation for more than 100 years. These soils were the first to be cultivated because they were easy to clear and till. Farming developed more slowly in the more thickly wooded areas because the dense hardwood forests were more difficult to clear. Since the early years general farming, including the production of small grain, corn, potatoes, and hay, together with the raising of dairy cattle and hogs, has been practiced.

Wheat was the most important crop in the 1880's, but by the 1920's and 1930's corn had become the leading crop in the county. Corn and hay, mostly alfalfa, are now the two most important crops. A small acreage of winter wheat is grown.

The principal crop on the sandier soils near Osseo was potatoes. Potato production reached its peak in the late 1940's, when about 14,000 to 15,000 acres was in production. The sandy potato soils are easy to develop for residences. The growing suburbs have been rapidly expanding into the potato areas in recent years. In 1968 only about 12 major potato growers remained in the area.

TABLE 11.--TEMPERATURE AND PRECIPITATION

[All data from weather station at airport, Minneapolis-St. Paul; period of record, 1931-60]

Month	Temperature				Precipitation				
	Average daily maximum	Average daily minimum	Two years in 10 will have at least 4 days with--		Average total	One year in 10 will have--		Days with snow cover 1.0 inch or more	Average depth of snow on days with snow cover
			Maximum temperature equal to or higher than--	Minimum temperature equal to or lower than--		Less than--	More than--		
	° F.	° F.	° F.	° F.	Inches	Inches	Inches	Number	Inches
January----	22	2	42	-17	0.7	0.2	1.3	24	5
February---	26	5	44	-13	.8	.2	1.5	22	6
March------	37	18	59	-1	1.5	.6	2.7	13	5
April------	56	33	76	23	1.9	.7	3.0	1	3
May--------	69	45	86	35	3.2	.9	6.2	(1/)	-
June-------	78	56	91	47	4.0	1.6	6.7	0	-
July-------	84	61	98	54	3.3	1.1	6.0	0	-
August-----	81	59	94	51	3.2	1.8	4.5	0	-
September--	72	49	90	39	2.4	.8	4.9	(1/)	-
October----	61	37	79	26	1.6	.3	2.5	(1/)	-
November---	41	22	60	6	1.4	.5	2.4	6	3
December---	27	9	43	-9	.9	.2	1.5	18	5
Year-----	55	33	2/ 99	3/ -21	4.9	21.1	29.1	84	5

1/ Less than one-half day.

2/ Average annual highest maximum.

3/ Average annual lowest minimum.

TABLE 12.--PROBABILITIES OF LAST FREEZING TEMPERATURE IN SPRING AND FIRST IN FALL

[Add data from weather station at airport, Minneapolis-St. Paul]

Probability	Dates for given probability and temperature						
	16° F. or lower	20° F. or lower	24° F. or lower	28° F. or lower	32° F. or lower	36° F. or lower	40° F. or lower
Spring:							
1 year in 10 later than----	April 6	April 13	April 19	May 3	May 13	May 23	May 30
2 years in 10 later than----	March 31	April 8	April 14	April 28	May 8	May 19	May 26
5 years in 10 later than----	March 22	March 29	April 5	April 19	April 29	May 10	May 17
Fall:							
1 year in 10 earlier than--	November 3	October 28	October 18	October 9	September 28	September 16	September 7
2 years in 10 earlier than--	November 8	November 2	October 23	October 14	October 3	September 22	September 12
5 years in 10 earlier than--	November 17	November 11	November 2	October 25	October 13	October 2	September 21

At one time commercial fruit growing was carried on extensively in the southeastern part of the county and around Lake Minnetonka. However, in the last 15 years fruit growing has declined because of urban expansion into these parts of the county.

Hennepin County was at one time one of the most important dairy counties in the State. Dairying reached its peak around 1950, when there were about 23,000 cows and heifers in the county. Since 1950 the number of cattle has declined because of urban expansion in the county. By 1968 the number of cattle and heifers had declined to 15,200.

The average size of farms in 1930 was about 64 acres; by 1964 it had increased to about 105 acres. The total area in farms in 1968 was 116,595 acres, or roughly 35 percent of the land area in the county.

Since about 1950 the towns and suburbs in the Minneapolis area have expanded westward across the eastern part of the county. All the townships except Hassan, Champlin, and Dayton in the northern part of the county are incorporated villages. In 1968 only about one-third of the county remained as dominantly farmland. Many farmers operate small acreages and work in Minneapolis or nearby communities.

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Alluvium. Soil material, such as sand, silt, or clay, that has been deposited on land by streams.

Available water capacity (also termed available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil.

Calcareous soil. A soil containing enough calcium carbonate (often with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid.

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.

Colluvium. Soil material, rock fragments, or both, moved by creep, slide, or local wash and deposited at the base of steep slopes.

Concretions. Grains, pellets, or nodules of various sizes, shapes, and colors consisting of concentrations of compounds, or of soil grains cemented together. The composition of some concretions is unlike that of the surrounding soil. Calcium carbonate and iron oxide are examples of material commonly found 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 can be pressed together into a lump.

Firm.--When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.--When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger.

Sticky.--When wet, adheres to other material, and tends to stretch somewhat and pull apart, rather than to pull free from other material.

Hard.--When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Soft.--When dry, breaks into powder or individual grains under very slight pressure.

Cemented.--Hard and brittle; little affected by moistening.

Deep soil. In this county, a soil more than 42 inches deep to rock or other strongly contrasting material. Also, a soil with a deep, black surface layer; a soil more than about 42 inches deep to the parent material or to other unconsolidated rock material not modified by soil-forming processes; or a soil in which the total depth of unconsolidated material, whether true soil or not, is 42 inches or more.

Drainage class (natural). Refers to the conditions of frequency and duration of periods of saturation or partial saturation that existed during the development of the soil, as opposed to altered drainage, which is commonly the result of artificial drainage or irrigation but may be caused by the sudden deepening of channels or the blocking of drainage outlets. Seven different classes of natural soil drainage are recognized.

Excessively drained soils are commonly very porous and rapidly permeable and have a low water-holding capacity.

Somewhat excessively drained soils are also very permeable and are free from mottling throughout their profile.

Well-drained soils are nearly free from mottling and are commonly of intermediate texture.

Moderately well drained soils commonly have a slowly permeable layer in or immediately beneath the solum. They have uniform color in the A and upper B horizons and have mottling in the lower B and the C horizons.

Somewhat poorly drained soils are wet for significant periods but not all the time, and some soils commonly have mottling at a depth below 6 to 16 inches.

Poorly drained soils are wet for long periods and are light gray and generally mottled from the surface downward, although mottling may be absent or nearly so in some soils.

Very poorly drained soils are wet nearly all the time. They have a dark-gray or black surface layer and are gray or light gray, with or without mottling, in the deeper parts of the profile.

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 wind (sandblast), running water, and other geological agents.

Horizon, soil. A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. These are the major horizons:

O horizon.--The layer of organic matter on the surface of a mineral soil. This layer consists of decaying plant residues.

A horizon.--The mineral horizon at the surface or just below an O horizon. This horizon is the one in which living organisms are most active and therefore is marked by the accumulation of humus. The horizon may have have lost one or more of soluble salts, sesquioxides (iron and aluminum oxides).

B horizon.--The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or some combination of these; (2) by prismatic or blocky structure; (3) by redder or stronger colors than the A horizon; or (4) by some combination of these. Combined A and B horizons are usually called the solum, or true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

C horizon.--The weathered rock material immediately beneath the solum. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a Roman numeral precedes the letter C.

R layer.--Consolidated rock beneath the soil. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

Internal soil drainage. The downward movement of water through the soil profile. The rate of movement is determined by the texture, structure, and other characteristics of the soil profile and underlying layers, and by height of the water table, either permanent or perched. Relative terms for expressing internal drainage are none, very slow, slow, medium, rapid, and very rapid.

Mineral soil. Soil composed mainly of inorganic (mineral) material and low in content of organic matter. Its bulk density is greater than that of organic soil.

Moderately deep soil. In this county, a soil that has 24 to 42 inches of moderately coarse or finer textured material over bedrock, sand, or gravel.

Morphology, soil. The physical makeup of the soil, including the texture, structure, porosity, consistence, color, and other physical mineralogical, and biological properties of the various horizons, and their thickness and arrangement in the soil profile.

Muck. An organic soil consisting of fairly well decomposed organic material that is relatively high in mineral content, finely divided, and dark in color.

Mulch tillage. Tillage or preparation of soil in such a way that plant residue is left on the surface.

Nutrient, plant. Any element taken in by a plant, essential to its growth, and used by it in the production of food and tissue. Nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, boron, zinc, and perhaps other elements obtained from the soil and carbon, hydrogen, and oxygen obtained largely from the air and water, are plant nutrients.

Organic soil. A general term applied to a soil or to a soil horizon that consists primarily of organic matter, such as peat soils, muck soils, and peaty soil layers. In chemistry, organic refers to the compounds of carbon.

Outwash, glacial (geology). Rock material transported by glacial ice and then deposited; also includes the assorted and unassorted materials deposited by streams flowing from glaciers.

Parent material. Disintegrated and partly weathered rock from which soil has formed.

Peat. Unconsolidated soil material, largely undecomposed organic matter, that has accumulated where there has been excess moisture.

Ped. An individual natural soil aggregate, such as a crumb, a prism, or a block, in contrast to a clod.

Permeability. The quality that enables the soil to transmit water or air. Terms used to describe permeability are as follows: very slow, slow, moderately slow, moderate, moderately rapid, rapid, and very rapid.

pH value. A numerical means for designating acidity and alkalinity in soils. A pH value of 7.0 indicates precise neutrality; a higher value, alkalinity; and a lower value, acidity.

Profile, soil. A vertical section of the soil through all its horizons and extending into the parent material.

Reaction, soil. The degree of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is precisely neutral in reaction because it is neither acid nor alkaline. An acid, or "sour" soil is one that gives an acid reaction; an alkaline soil is one that is alkaline in reaction. In words, the degrees of acidity or alkalinity are expressed thus:

	pH
Extremely acid	Below 4.5
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	9.1 and higher

Relief. The elevations or inequalities of a land surface, considered collectively.

Sand. Individual rock or mineral fragments in a soil that range in diameter from 0.05 to 2.0 millimeters. Most sand grains consists of quartz, but they may be of any mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.

Shallow soil. In this county, a soil that has 12 to 24 inches of moderately coarse textured or medium-textured material over bedrock, sand, or gravel.

Silt. Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

Soil. A natural, three-dimensional body on the earth's surface that supports plants and that has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

Solum. The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soil includes the A and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the underlying material. The living roots and other plant and animal life characteristic of the soil are largely confined to the solum.

Stratified. Composed of, or arranged in, strata, or layers, such as stratified alluvium. The term is confined to geological material. Layers in soils that result from the processes of soil formation are called horizons; those inherited from the parent material are called strata.

Structure, soil. The arrangement of primary soil particles into compound particles or clusters that are separated from adjoining aggregates and have properties unlike those of an equal mass of unaggregated primary soil particles. The principal forms of soil structure are--platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular), and granular. Structureless soils are either single grain (each grain by itself, as in dune sand) or massive (the particles adhering together without any regular cleavage, as in many claypans and hardpans).

Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.

Substratum. Technically, the part of the soil below the solum.

Subsurface layer. Technically, that part of the A horizon below the surface layer. In soils of weak profile development, the term "subsurface layer" (subsurface soil) can be defined only in terms of arbitrary depths.

Surface soil. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, about 5 to 8 inches in thickness. The plowed layer.

Terrace. An embankment, or ridge, constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surface runoff so that it may soak into the soil or flow slowly to a prepared outlet without harm. Terraces in fields are generally built so they can be farmed. Terraces intended mainly for drainage have a deep channel that is maintained in permanent sod.

Terrace (geological). An old alluvial plain, ordinarily flat or undulating, bordering a river, lake, or the sea. Stream terraces are frequently called second bottoms, as contrasted to flood plains, and are seldom subject to overflow. Marine terraces were deposited by the sea and are generally wide.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

Till plain. A nearly level or undulating land surface covered by glacial till.

Tilth, soil. The condition of the soil in relation to the growth of plants, especially soil structure. Good tilth refers to the friable state and is associated with high noncapillary porosity and stable, granular structure. A soil in poor tilth is nonfriable, hard, nonaggregated, and difficult to till.

Topsoil. A presumed fertile soil or soil material, or one that responds to fertilization, ordinarily rich in organic matter, used to topdress roadbanks, lawns, and gardens.

Variant soil. A soil having properties sufficiently different from those of other known soils to suggest establishing a new soil series, but a soil of such limited known area that creation of a new series is not believed to be justified.

Water table. The highest part of the soil or underlying rock material that is wholly saturated with water. In some places an upper, or perched, water table may be separated from a lower one by a dry zone.

GUIDE TO MAPPING UNITS

For a full description of a mapping unit, read both the description of the mapping unit and the description of the soil series to which the mapping unit belongs. In referring to a capability unit, a woodland suitability group, or any other group, read the introduction to the section it is in for general information about its management. Other information is given in tables as follows:

Acreage and extent of soils, table 1, p. 8.
Estimated yields, table 2, p. 79.
Woodland interpretations, table 4, p. 85.
Engineering uses of the soils, tables 6, 7, and 8, pp. 90 through 125.
Recreational uses, table 9, p. 134.

Map symbol	Mapping unit	Described on page	Capability unit		Woodland suitability group		Building site group	
			Symbol	Page	No.	Page	No.	Page
AnB	Anoka loamy fine sand, 2 to 6 percent slopes	10	IIIs-2	75	3	84	2	127
AnC	Anoka loamy fine sand, 6 to 12 percent slopes	11	IVs-1	77	3	84	2	127
Ba	Becker fine sandy loam	12	IIw-3	71	5	87	13	133
Bb	Becker loam	12	IIw-3	71	5	87	13	133
Bc	Biscay clay loam	13	IIw-1	70	6	87	9	132
Bd	Biscay clay loam, depressional	13	IIIw-1	73	7	87	12	133
Bo	Borrow land	13	-------	--	--	--	--	---
Bp	Borrow pits	13	-------	--	--	--	--	---
BsB	Braham loamy sand, silty subsoil, 2 to 6 percent slopes	14	IIIs-2	75	2	84	3	128
BsC	Braham loamy sand, silty subsoil, 6 to 12 percent slopes	14	IVs-1	77	2	84	3	128
BtB	Braham loamy fine sand, 2 to 6 percent slopes	14	IIIs-2	75	2	84	3	128
BtC	Braham loamy fine sand, 6 to 12 percent slopes	15	IVs-1	77	2	84	3	128
BuB	Burnsville sandy loam, 2 to 6 percent slopes	16	IIIe-3	73	3	84	2	127
BuC	Burnsville sandy loam, 6 to 12 percent slopes	16	IVe-4	76	3	84	2	127
BuD	Burnsville sandy loam, 12 to 18 percent slopes	16	VIs-1	78	3	84	2	127
BuE	Burnsville sandy loam, 18 to 35 percent slopes	16	VIIs-1	78	3	84	2	127
BxB	Burnsville sandy loam, thick solum variant, 2 to 6 percent slopes	17	IIIe-3	73	2	84	1	127
BxC	Burnsville sandy loam, thick solum variant, 6 to 12 percent slopes	17	IVe-4	76	2	84	1	127
Ca	Canisteo clay loam	18	IIw-1	70	6	87	10	132
Ch	Chaska clay loam	19	IIw-1	70	6	87	13	133
Co	Cordova silty clay loam	20	IIw-1	70	6	87	10	132
Cu	Cut and fill land	20	--------	--	--	--	--	---
DaA	Dakota loam, 0 to 2 percent slopes	21	IIs-2	72	2	84	1	127
DaB	Dakota loam, 2 to 6 percent slopes	21	IIe-4	70	2	84	1	127
DbA	Dakota loam, loamy substratum, 0 to 2 percent slopes	21	I-1	69	1	84	5	129
DlA	Dalbo silt loam, 0 to 2 percent slopes	23	IIs-1	71	1	84	8	131
DlB	Dalbo silt loam, 2 to 6 percent slopes	23	IIe-2	70	1	84	8	131
DlC	Dalbo silt loam, 6 to 12 percent slopes	23	IIIe-2	73	1	84	8	131
Dm	Dassel sandy loam	24	IIIw-2	74	6	87	9	132
DnA	Dickman sandy loam, 0 to 2 percent slopes	25	IIIs-1	74	3	84	2	127
DnB	Dickman sandy loam, 2 to 6 percent slopes	25	IIIe-3	73	3	84	2	127
DnC	Dickman sandy loam, 6 to 12 percent slopes	25	IVe-4	76	3	84	2	127
Do	Dorchester loam	26	IIw-3	71	5	87	13	133
Dp	Duelm loamy sand	27	IVs-2	77	4	87	2	127
Ds	Duelm loamy sand, loamy subsoil variant	28	IIIs-2	75	2	84	3	128
Du	Dundas silt loam	29	IIw-2	71	6	87	11	132
EnB	Erin loam, 2 to 6 percent slopes	30	IIe-2	70	1	84	7	130
EnC	Erin loam, 6 to 12 percent slopes	30	IIIe-2	73	1	84	7	130
EnD	Erin loam, 12 to 18 percent slopes	30	IVe-2	75	1	84	7	130
EnE	Erin loam, 18 to 24 percent slopes	30	VIe-1	77	1	84	7	130
ErB2	Erin clay loam, 2 to 6 percent slopes, eroded	30	IIe-2	70	1	84	7	130
ErC2	Erin clay loam, 6 to 12 percent slopes, eroded	31	IIIe-2	73	1	84	7	130
ErD2	Erin clay loam, 12 to 18 percent slopes, eroded	31	IVe-2	75	1	84	7	130
EsF	Erin and Kilkenny loams, 24 to 35 percent slopes	31	VIIe-1	78	1	84	7	130
EtA	Estherville sandy loam, 0 to 2 percent slopes	32	IIIs-1	74	3	84	2	127
EtB	Estherville sandy loam, 2 to 6 percent slopes	32	IIIe-3	73	3	84	2	127

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GUIDE TO MAPPING UNITS--Continued

Map symbol	Mapping unit	Described on page	Capability unit		Woodland suitability group		Building site group	
			Symbol	Page	No.	Page	No.	Page
EtC	Estherville sandy loam, 6 to 12 percent slopes	32	IVe-4	76	3	84	2	127
EtD	Estherville sandy loam, 12 to 18 percent slopes	32	VIs-1	78	3	84	2	127
Fd	Fill land	32	-------	--	--	--	--	---
Gc	Glencoe silty clay loam	33	IIIw-1	73	7	87	12	133
GyB	Grays very fine sandy loam, 2 to 6 percent slopes	34	IIe-1	69	1	84	5	129
GyC	Grays very fine sandy loam, 6 to 12 percent slopes	35	IIIe-1	72	1	84	5	129
Ha	Hamel loam	36	IIw-1	70	5	87	10	132
HbB	Hayden loam, 2 to 6 percent slopes	37	IIe-1	69	1	84	5	129
HbC	Hayden loam, 6 to 12 percent slopes	37	IIIe-1	72	1	84	5	129
HbD	Hayden loam, 12 to 18 percent slopes	37	IVe-1	75	1	84	5	129
HbE	Hayden loam, 18 to 24 percent slopes	37	VIe-1	77	1	84	5	129
HcB2	Hayden clay loam, 2 to 6 percent slopes, eroded	37	IIe-1	69	1	84	5	129
HcC2	Hayden clay loam, 6 to 12 percent slopes, eroded	38	IIIe-1	72	1	84	5	129
HcD2	Hayden clay loam, 12 to 18 percent slopes, eroded	38	IVe-1	75	1	84	5	129
HcE2	Hayden clay loam, 18 to 24 percent slopes, eroded	38	VIe-1	77	1	84	5	129
HdF	Hayden and Lester loams, 24 to 35 percent slopes	38	VIIe-1	78	1	84	5	129
HeB	Heyder sandy loam, 2 to 6 percent slopes	39	IIe-1	69	1	84	5	129
HeC	Heyder sandy loam, 6 to 12 percent slopes	39	IIIe-1	72	1	84	5	129
HeD	Heyder sandy loam, 12 to 18 percent slopes	40	IVe-1	75	1	84	5	129
HeE	Heyder sandy loam, 18 to 24 percent slopes	40	VIe-1	77	1	84	5	129
H1B	Heyder complex, 2 to 6 percent slopes	40	IIe-3	70	2	84	4	129
H1C	Heyder complex, 6 to 12 percent slopes	40	IVe-3	76	2	84	4	129
H1D	Heyder complex, 12 to 18 percent slopes	40	VIe-1	77	2	84	4	129
H1E	Heyder complex, 18 to 35 percent slopes	41	VIIe-1	78	2	84	4	129
HuA	Hubbard loamy sand, 0 to 2 percent slopes	42	IVs-2	77	4	87	2	127
HuB	Hubbard loamy sand, 2 to 6 percent slopes	42	IVs-2	77	4	87	2	127
HuC	Hubbard loamy sand, 6 to 12 percent slopes	42	VIs-1	78	4	87	2	127
HuD	Hubbard loamy sand, 12 to 18 percent slopes	42	VIIs-1	78	4	87	2	127
HuE	Hubbard loamy sand, 18 to 35 percent slopes	42	VIIs-1	78	4	87	2	127
Is	Isan sandy loam	43	IIIw-2	74	6	87	9	132
It	Isan sandy loam, depressional	43	IVw-1	76	7	87	12	133
Iv	Isan sandy loam, loamy subsoil	44	IIIw-2	74	5	87	10	132
KaB	Kasota silty clay loam, 1 to 5 percent slopes	45	IIe-4	70	1	84	1	127
Ke	Kennebec silt loam	45	I-1	69	5	87	9	132
KkB	Kilkenny loam, 2 to 6 percent slopes	46	IIe-2	70	1	84	7	130
KkC	Kilkenny loam, 6 to 12 percent slopes	46	IIIe-2	73	1	84	7	130
KkD	Kilkenny loam, 12 to 18 percent slopes	47	IVe-2	75	1	84	7	130
KkE	Kilkenny loam, 18 to 24 percent slopes	47	VIe-1	77	1	84	7	130
K1C2	Kilkenny clay loam, 6 to 12 percent slopes, eroded	47	IIIe-2	73	1	84	7	130
K1D2	Kilkenny clay loam, 12 to 18 percent slopes, eroded	47	IVe-2	75	1	84	7	130
KnB	Kingsley complex, 2 to 6 percent slopes	48	IIe-3	70	2	84	4	129
KnC	Kingsley complex, 6 to 12 percent slopes	48	IVe-3	76	2	84	4	129
KnD	Kingsley complex, 12 to 18 percent slopes	49	VIe-1	77	2	84	4	129
KnE	Kingsley complex, 18 to 24 percent slopes	49	VIIe-1	78	2	84	4	129
KnF	Kingsley complex, 24 to 35 percent slopes	49	VIIe-1	78	2	84	4	129
Lc	Lake beaches, sandy	49	VIw-1	77	6	87	9	132
Ld	Lake beaches, loamy	49	IIIw-1	73	6	87	12	133
LgA	Langola loamy sand, 1 to 2 percent slopes	50	IIIs-2	75	2	84	3	128
LgB	Langola loamy sand, 2 to 12 percent slopes	51	IIIs-2	75	2	84	3	128
Lh	Langola loamy sand, moderately well drained, 0 to 2 percent slopes	51	IIIs-2	75	2	84	3	128
LmB	Lerdal loam, 1 to 4 percent slopes	52	IIs-1	71	1	84	7	130
LrB	Lester loam, 2 to 6 percent slopes	53	IIe-1	69	1	84	5	129
LrC	Lester loam, 6 to 12 percent slopes	53	IIIe-1	72	1	84	5	129
LrD	Lester loam, 12 to 18 percent slopes	53	IVe-1	75	1	84	5	129
LrE	Lester loam, 18 to 24 percent slopes	54	VIe-1	77	1	84	5	129
LsB2	Lester clay loam, 2 to 6 percent slopes, eroded	54	IIe-1	69	1	84	5	129
LsC2	Lester clay loam, 6 to 12 percent slopes, eroded	54	IIIe-1	72	1	84	5	129
LsD2	Lester clay loam, 12 to 18 percent slopes, eroded	54	IVe-1	75	1	84	5	129

GUIDE TO MAPPING UNITS--Continued

Map symbol	Mapping unit	Described on page	Capability unit		Woodland suitability group		Building site group	
			Symbol	Page	No.	Page	No.	Page
LtB	Le Sueur loam, 1 to 4 percent slopes	55	I-1	69	1	84	6	130
Lu	Litchfield loamy fine sand	56	IIIs-1	74	3	84	2	127
Ma	Marsh	56	VIIIw-1	78	7	87	12	133
Mt	Minnetonka silty clay loam	57	IIw-2	71	6	87	11	132
Mu	Mixed alluvial land	58	IIw-3	71	5	87	13	133
Mx	Mixed alluvial land, frequently flooded	58	VIw-1	77	5	87	13	133
NeB	Nessel loam, 1 to 4 percent slopes	59	I-1	69	1	84	6	130
NyB	Nymore loamy sand, 2 to 6 percent slopes	60	IVs-2	77	4	87	2	127
NyC	Nymore loamy sand, 6 to 12 percent slopes	60	VIs-1	78	4	87	2	127
Pa	Peaty muck	60	IIIw-3	74	7	87	12	133
Pb	Peaty muck over sand	61	IVw-1	76	7	87	12	133
Pm	Peaty muck over loam	61	IIIw-3	74	7	87	12	133
RsB	Rasset loamy sand, 2 to 6 percent slopes	62	IIIs-2	75	3	84	2	127
RsC	Rasset loamy sand, 6 to 12 percent slopes	62	IVs-1	77	3	84	2	127
RsD	Rasset loamy sand, 12 to 25 percent slopes	62	VIIs-1	78	3	84	2	127
SaB	Salida coarse sandy loam, 2 to 6 percent slopes	63	IVs-2	77	4	87	2	127
SaC	Salida coarse sandy loam, 6 to 12 percent slopes	63	VIs-1	78	4	87	2	127
SaD	Salida coarse sandy loam, 12 to 18 percent slopes	63	VIIs-1	78	4	87	2	127
SaE	Salida coarse sandy loam, 18 to 35 percent slopes	64	VIIs-1	78	4	87	2	127
Sh	Shields silty clay loam	65	IIw-2	71	6	87	11	132
SwA	Shorewood silty clay loam, 0 to 2 percent slopes	66	IIs-1	71	1	84	8	131
SwB	Shorewood silty clay loam, 2 to 6 percent slopes	66	IIe-2	70	1	84	8	131
ZmB	Zimmerman loamy fine sand, 2 to 6 percent slopes	67	IVs-2	77	4	87	2	127
ZmC	Zimmerman loamy fine sand, 6 to 18 percent slopes	67	VIs-1	78	4	87	2	127

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