SOIL SURVEY

Wells County, North Dakota

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

Issued June 1970

Major fieldwork for this soil survey was done in the period 1956–63. Soil names and descriptions were approved in 1966. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1963. This survey was made cooperatively by the Soil Conservation Service and the North Dakota Agricultural Experiment Station; it is part of the technical assistance furnished to the Wells County Soil 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, USDA, Washington, D.C. 20250.

HOW TO USE THIS SOIL SURVEY

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

Locating Soils

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

On each sheet of the detailed map, soil areas are outlined and are identified by symbol. 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 the survey. This guide lists all of the soils of the county in alphabetic order by map symbol. It shows the page where each kind of soil is described, and also the page for the capability unit and range site in which the soil has been placed.

Interpretations not given in this publication can be developed by grouping the soils according to their suitability or limitations for a particular use. Translucent material can be used as an overlay over the soil map and colored to show soils that have the same limitation or suitability. For example, soils that have a slight limitation for a given use can be colored green, those with a moderate limitation can be colored yellow, and those with a severe limitation can be colored red.

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

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

Ranchers and others interested in range can find, under "Range," groupings of the soils according to their suitability for range, and a description of the vegetation on each range site.

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

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

Newcomers in Wells County may be especially interested in the section "General Soil Map," where broad patterns of soils are described. They may also be interested in the section "General Nature of the County," which gives additional information about the county.

***Cover picture:* In foreground are soils of the LaDelle association used for growing corn, wheat, and hay. The windbreaks are used to control wind erosion. In background are the rolling and hilly soils of the Barnes-Buse association used as range.**

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Issued June 1970

SOIL SURVEY OF WELLS COUNTY, NORTH DAKOTA

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

WELLS COUNTY is in the center of the State (fig. 1). It has a total area of 832,000 acres. Fessenden is the county seat.

The county has a dry-subhumid, continental climate that is characterized by cold winters and warm summers. Its physiography consists of glacial landforms, mainly terminal moraines, ground moraines, and till plains. Although the Sheyenne River, the James River, and a few tributaries cross the county, most of the runoff collects in depressions and does not reach the rivers.

About 97 percent of the total land area is farmed, and about 75 percent is cultivated. Spring wheat is the principal crop. Flax and barley are other important crops. The livestock raised are mainly beef cattle.

How This Survey Was Made

Soil scientists made this survey to learn what kinds of soils are in Wells County, where they are located, and how they can be used.

They went into the county knowing they were likely to find many soils they had already seen, and perhaps some they had not. As they traveled over the county, they observed steepness, length, and shape of slopes; size and speed of streams; kinds of native plants or crops; 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.

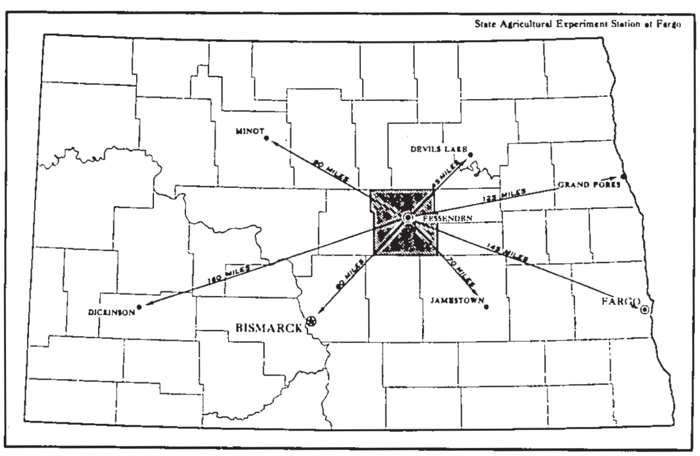

Figure 1.—**Location of Wells County in North Dakota.**

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. To use this publication efficiently, it is necessary to know the kinds of groupings most used in a local soil classification.

Soils that have profiles almost alike make up a soil series. Except for different texture in the surface layer, the major horizons of all the soils of one series 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. Arvilla and Colvin, 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 natural, undisturbed landscape.

A soil series may be subdivided on the basis of the texture of the surface layer, slope, stoniness, or some other characteristic that affects use of the soil. Each such subdivision is called a soil phase (*9*)[1] and is given a name that indicates one or more features that affect management. For example, Arvilla sandy loam, level, is one of the two phases of the Arvilla series mapped in this county.

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

The areas shown on a soil map are called mapping units. On most maps detailed enough to be useful in planning management of farms and fields, a mapping unit is nearly equivalent to a 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.

[1] Italicized numbers in parentheses refer to Literature Cited, page 82.

In preparing some detailed maps, the soil scientists have a problem of delineating areas where different kinds of soils are so intricately mixed or occur in such small individual tracts that it is not practical to show them separately on the map. Therefore, they show this mixture of soils as one mapping unit and call it a soil complex. Ordinarily, a soil complex is named for the major kinds of soil in it, for example, Colvin-Lamoure complex.

Another kind of mapping unit is the undifferentiated group, which consists of two or more soils that occur together without regularity in pattern or relative proportion. The individual tracts of the component soils could be shown separately on the map, but the differences are so slight that the separation is not important for the objectives of the survey. An example of an undifferentiated group is Colvin and LaPrairie soils.

Also, most surveys include areas where the soil material is so rocky, so shallow, or so frequently worked by wind and water that it cannot be classified by soil series. These areas are shown on the map like other mapping units, but they are given descriptive names, such as Eroded sandy land or Loamy lake beaches, and are called land types.

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 soils 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 soils. Yields under defined management are predicted 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 readers, among them farmers, ranchers, managers of woodland, engineers, and homeowners. Grouping soils that are similar in suitability for each specified use is the method of organization commonly used in soil surveys. On the basis of the 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 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 publication shows, in color, the soil associations in Wells 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 farming or other land use. Such a map is not suitable for planning the management of a farm or field, because the soils in any one association ordinarily differ in slope, depth, stoniness, drainage, and other characteristics that affect management.

The 10 soil associations in Wells County are described in this section. Terms for texture used in the descriptive heading of an association apply to the surface layer. For example, in the descriptive heading of association 1, the words "medium-textured" refer to texture of the surface layer. More detailed information about the individual soils in each association can be obtained by studying the detailed map and by reading the section "Descriptions of the Soils."

1. *Heimdal-Emrick-Fram association*

Level to undulating, well drained to moderately well drained, medium-textured soils on glaciofluvial materials

This soil association (fig. 2) consists of deep soils that formed in wind-sorted and water-sorted glacial till. Small shallow depressions are scattered across the landscape, and large ones are common east of Fessenden.

This association makes up about 38 percent of the county. Of the dominant soils, Heimdal soils make up about 43 percent of the association, Emrick soils about 25 percent, and Fram soils about 26 percent. Among the minor soils making up the rest are Tonka soils, which are in shallow depressions, and Borup soils, which surround the larger depressions.

Heimdal soils have a surface layer of black loam and a very dark grayish-brown subsoil, beneath which is light olive-brown limy material.

Emrick soils have a surface layer of black loam over very dark brown loam, a very dark grayish-brown subsoil, and olive-brown, limy underlying material. Emrick soils have a thicker surface layer than Heimdal soils, and they occupy a lower position in the landscape.

Fram soils are moderately well drained. They have a surface layer of black loam underlain by a lighter colored layer of lime accumulation.

Tonka soils are deep and poorly drained, and Borup soils are deep, limy, and somewhat poorly drained.

About 90 percent of this soil association is cultivated. Grain is the main crop. The main farming problems are controlling wind erosion and preventing the ponding of water in depressions.

2. *Barnes-Svea association*

Level to undulating, well drained and moderately well drained, medium-textured soils on glacial till plains

This soil association (fig. 3) consists of deep soils that formed in glacial till. The slopes are short and irregular. Small depressions number as many as 100 to a square mile. Most of the depressions are 10 to 100 feet across, but a few are more than 10 acres in area. Stones are numerous in some areas.

This association makes up about 19 percent of the county. Barnes soils make up about 60 percent of the association, and Svea soils about 30 percent. The rest is made up of Tonka soils, which are in shallow depressions; Parnell soils, which are in deeper depressions; Hamerly

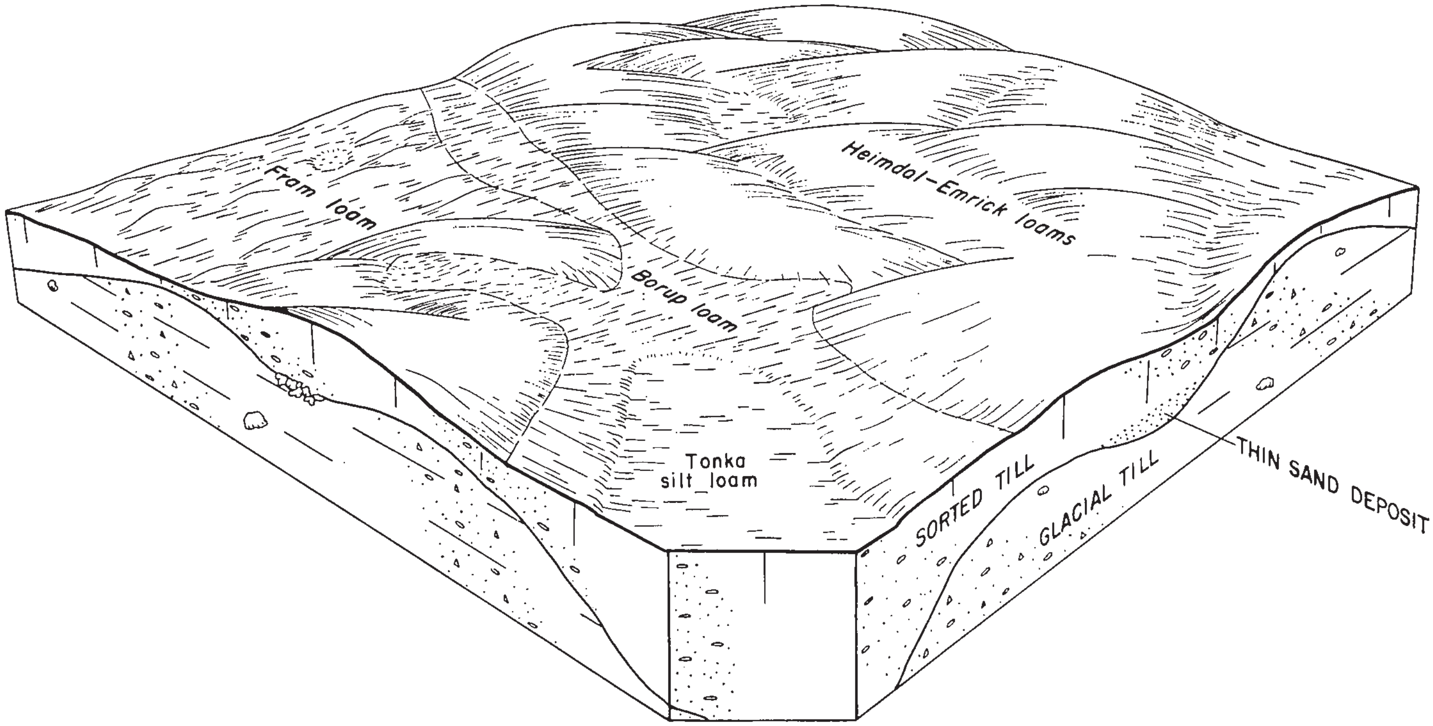

Figure 2.—Parent material and position of soils in association 1.

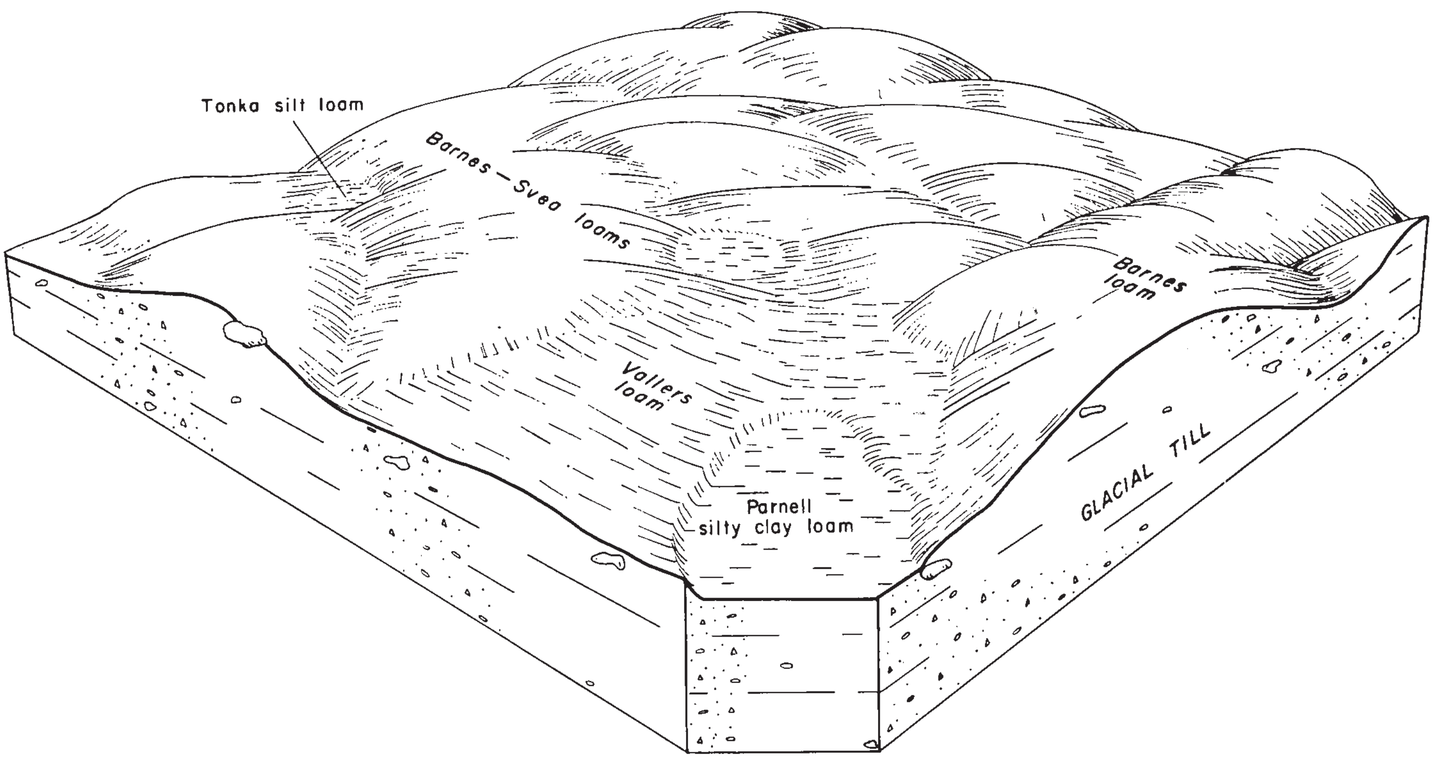

Figure 3.—Parent material and position of soils in association 2.

and Vallers soils, which occur as narrow rims surrounding the depressions; and other minor soils.

Barnes and Svea soils have a surface layer of black loam, beneath which is very dark grayish-brown loam. The underlying material contains lime. Barnes soils are better drained than Svea soils, and they have a thinner surface layer.

Parnell soils are very poorly drained; Vallers soils and Tonka soils are poorly drained; and Hamerly soils are moderately well drained. Vallers and Hamerly soils are limy.

About 80 percent of this association is cultivated. All the common crops are grown, and there are small herds of livestock on most of the farms. The main hazards are wind erosion and water erosion. The depressions and the stones create farming problems. Small tracts around farmsteads and areas where depressions are numerous are used as summer pasture.

3. Barnes association

Nearly level to rolling, well drained and moderately well drained, medium-textured soils on glacial till plains

This association consists of deep soils that formed in glacial till. The rolling areas have short, irregular slopes. Depressions occupy about 8 percent of this association; a few are 600 acres or more in area. Many of the larger depressions are flooded the year round. Stones are common in some areas.

This association makes up about 8 percent of the county. Barnes soils make up about 60 percent of the association. Svea soils make up about 15 percent, Buse soils about 10 percent; Vallers soils, which surround the depressions, about 10 percent; and Parnell soils, which are the most common soils in depressions, and others make up the rest.

Barnes and Svea soils have a surface layer of black loam, beneath which is very dark grayish-brown loam. The underlying material contains lime. Barnes soils occupy higher positions than Svea soils, and they are better drained and have a thinner surface layer.

Buse soils are somewhat excessively drained. They have a thin surface layer of black loam. The underlying material is limy glacial till. Parnell soils are very poorly drained, and Vallers soils are poorly drained.

About 60 percent of this association is cultivated. Small grain, corn, and alfalfa are grown. The main hazard is water erosion, but the rolling topography, the numerous depressions, and the stones create farming problems. Small herds of livestock are raised. The more strongly sloping areas, the areas where depressions are numerous, and small tracts around farmsteads are used as native grass pasture.

4. Barnes-Buse association

Rolling to hilly, somewhat excessively drained and well drained, medium-textured soils on glacial moraines

This association (fig. 4) consists mainly of deep soils that formed in glacial till. These soils are along the Sheyenne River and are characterized by short, irregular slopes. Depressions are common. Many are 20 acres or more in area, and many are intermittent lakes. Stones are common in some areas.

This association makes up about 8 percent of the county. Of the dominant soils, Barnes soils make up about 62 percent of the association, and Buse soils about 15 percent. Of the minor soils, Parnell soils, which are the most common soils in depressions, make up about 10

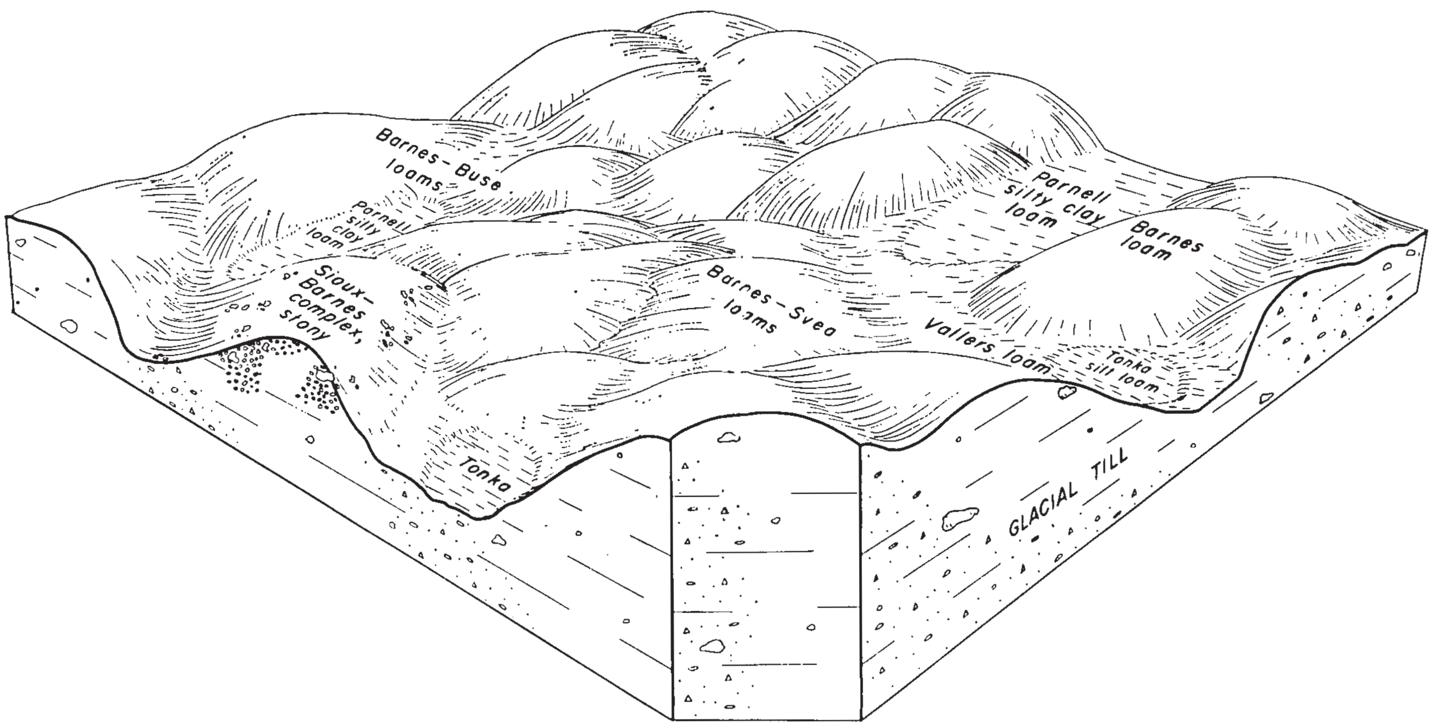

Figure 4.—**Parent material and position of soils in association 4.**

percent. Among the rest are Vallers soils, which surround the depressions; Sioux soils, which are on the knobs and ridges; and Colvin and Lamoure soils, which are most common on the bottom lands north and east of Harvey.

Barnes soils have a surface layer of black loam, a very dark grayish-brown subsoil, and limy underlying material. Buse soils have a surface layer of black loam, below which is limy material. Barnes soils occupy lower positions than Buse soils.

Parnell soils are very poorly drained; Vallers soils and Colvin soils are poorly drained; Lamoure soils are somewhat poorly drained; and Sioux soils are excessively drained. Vallers soils are limy, and Sioux soils are gravelly. On bottom lands south of Harvey are very shallow saline soils.

About 70 percent of this association is in grass, and beef cattle are the main source of farm income. Most of the cultivated acreage is on the milder slopes. The main hazard is water erosion. The topography, the numerous depressions, and the stones create farming problems.

5. Sioux-Barnes association

Hilly, excessively drained to well-drained, medium-textured soils on gravelly terminal moraines

This association (fig. 5) consists of soils that formed in the gravelly glacial till of terminal moraines. These soils have short, irregular slopes of as much as 15 percent. There are a few large depressions, and the larger ones dry up only after a series of dry years.

This association makes up less than 1 percent of the county. Of the dominant soils, Sioux soils make up about 50 percent of the association, and Barnes soils make up about 45 percent. Among the minor soils making up the rest are Renshaw and Arvilla soils.

Sioux soils have a surface layer of black loam, beneath which is a mixture of sand, gravel, and stones. Barnes soils have a surface layer of black loam, a very dark grayish-brown subsoil, and limy underlying material. The Barnes soils in this association generally contain numerous stones. Renshaw and Arvilla soils are moderately deep over gravel.

Most of this association is used for summer pasture.

6. Forman-Nutley association

Level to undulating, well drained and moderately well drained, moderately fine textured and fine textured soils on old glacial lakebeds

This association (fig. 6) consists of deep soils that formed in lacustrine deposits. A few depressions are scattered across the landscape.

This association makes up about 2 percent of the county. Of the dominant soils, Forman soils make up about 50 percent of the association, and Nutley soils make up about 17 percent. Of the minor soils, Fargo soils, which are in low, nearly level areas, make up about 9 percent; Dimmick soils, which are in a few large depressions,

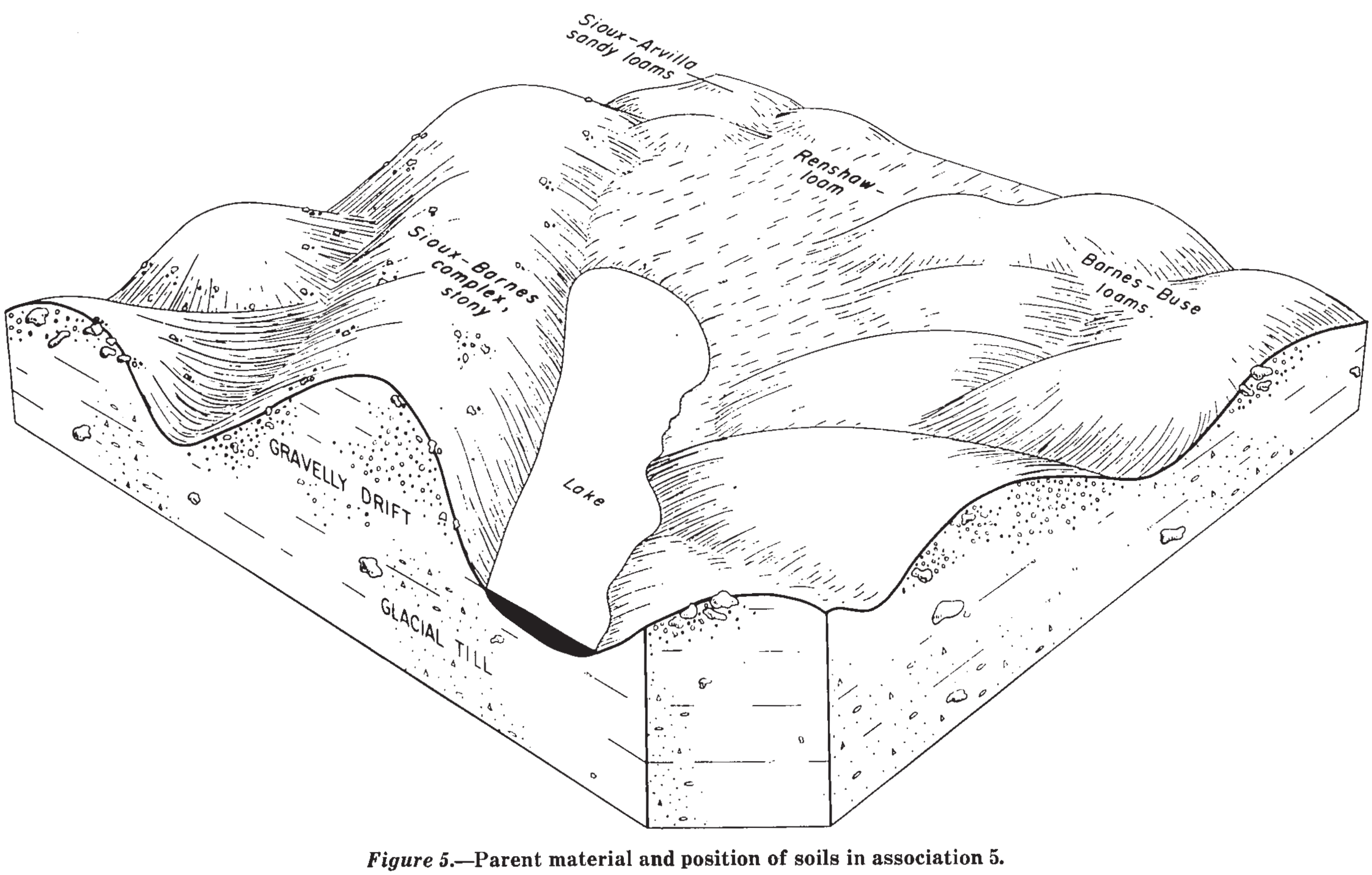

Figure 5.—**Parent material and position of soils in association 5.**

make up about 8 percent; and other soils make up the remaining 16 percent.

Forman soils are well drained. They have a surface layer of black clay loam and a very dark grayish-brown subsoil.

Nutley soils are moderately well drained. They have a surface layer of black silty clay, beneath which is very dark grayish-brown silty clay that contains lime.

Fargo and Dimmick soils are poorly drained. The other minor soils are mainly deep and medium textured.

About 80 percent of this association is cultivated. The main crops are small grain and alfalfa, and on most farms there are small herds of livestock. The main farming hazards are wind erosion and water erosion. The consistence of these soils makes them difficult to work.

7. Emrick-Larson association

Level to undulating, moderately well drained, medium-textured claypan soils on uplands

This association (fig. 7) consists of deep soils that have a claypan. Small shallow depressions are scattered across the landscape.

This association makes up about 13 percent of the county. Of the dominant soils, Emrick soils make up about 45 percent of the association, and Larson soils make up about 25 percent. Among the minor soils making up the rest are Miranda and Heimdal soils and, in the depressions, Tonka and Parnell soils.

Emrick soils are moderately well drained. They have a surface layer of black loam over very dark brown loam and a very dark grayish-brown subsoil.

Larson soils are moderately well drained. They have a surface layer of black loam and a very dark grayish-brown subsoil that has a claypan. Below this is limy material.

Heimdal soils are deep and well drained. Miranda soils have a thin surface layer and a claypan in the subsoil.

About 70 percent of this soil association is cultivated. The main crops are grain and other feed crops. There are small herds of livestock on most farms. The claypan in the Larson and Miranda soils creates a farming problem.

8. Egeland-Embden association

Level to undulating, well drained and moderately well drained, moderately coarse textured soils on sandy plains

This association (fig. 8) consists mainly of deep soils that formed in materials deposited by wind and water.

This association makes up about 7 percent of the county. Of the dominant soils, Egeland soils make up about 35 percent of the association and Embden soils make up about 35 percent. Among the minor soils making up the rest of this association are Letcher, Arvilla, Ulen, and Hamar soils.

Egeland soils have a surface layer of black fine sandy loam. Below this is very dark grayish-brown fine sandy loam.

Embden soils have a surface layer of black fine sandy loam over very dark gray fine sandy loam and a subsoil of very dark grayish-brown fine sandy loam. Embden soils are less well drained than Egeland soils, and they have a thicker surface layer.

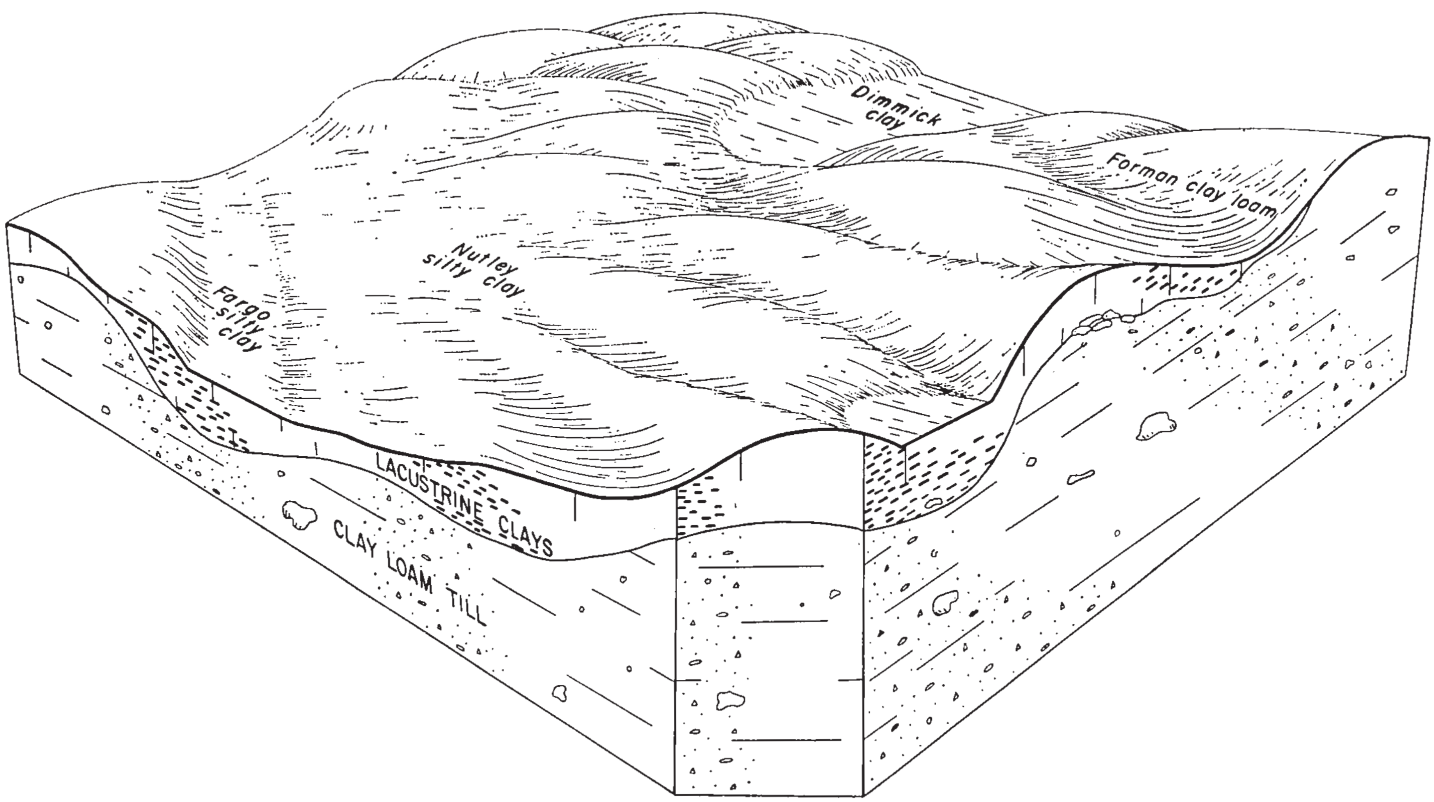

***Figure 6.*—Parent material and position of soils in association 6.**

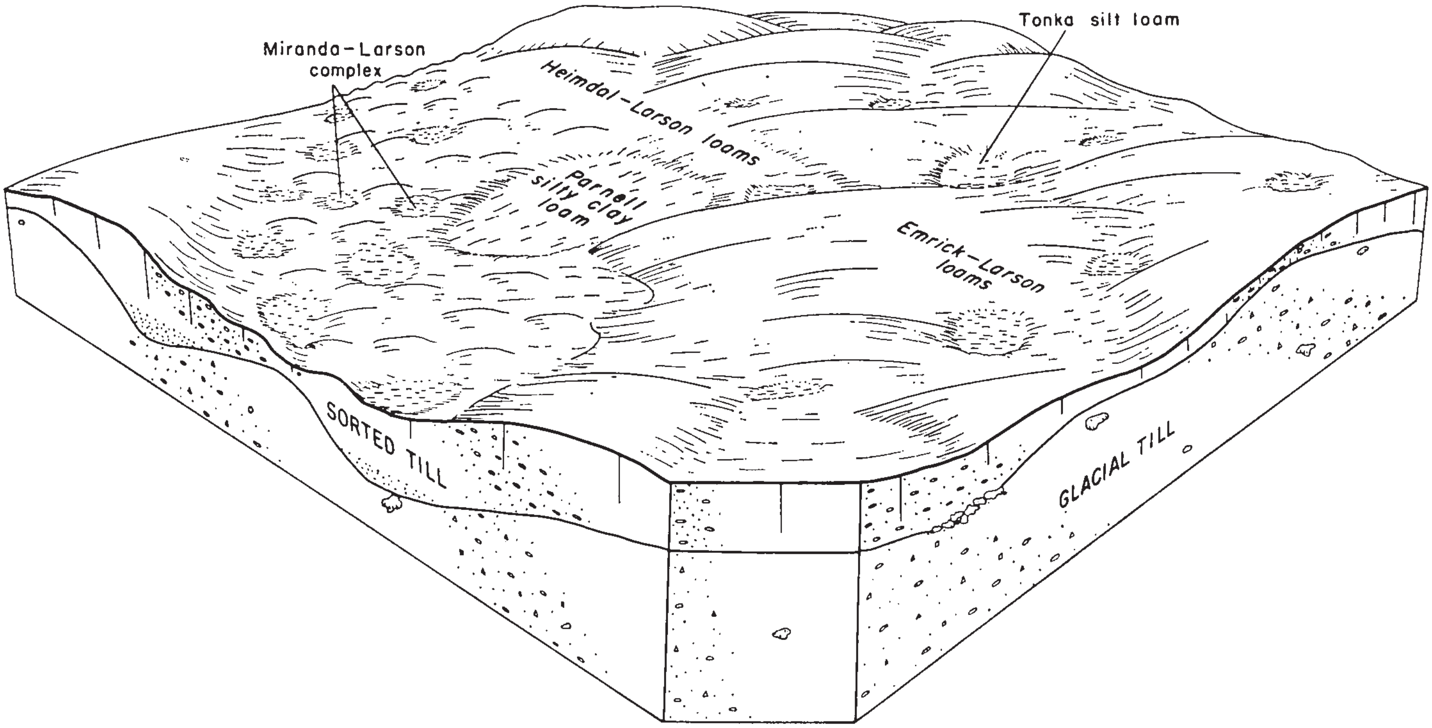

Figure 7.—Parent material and position of soils in association 7.

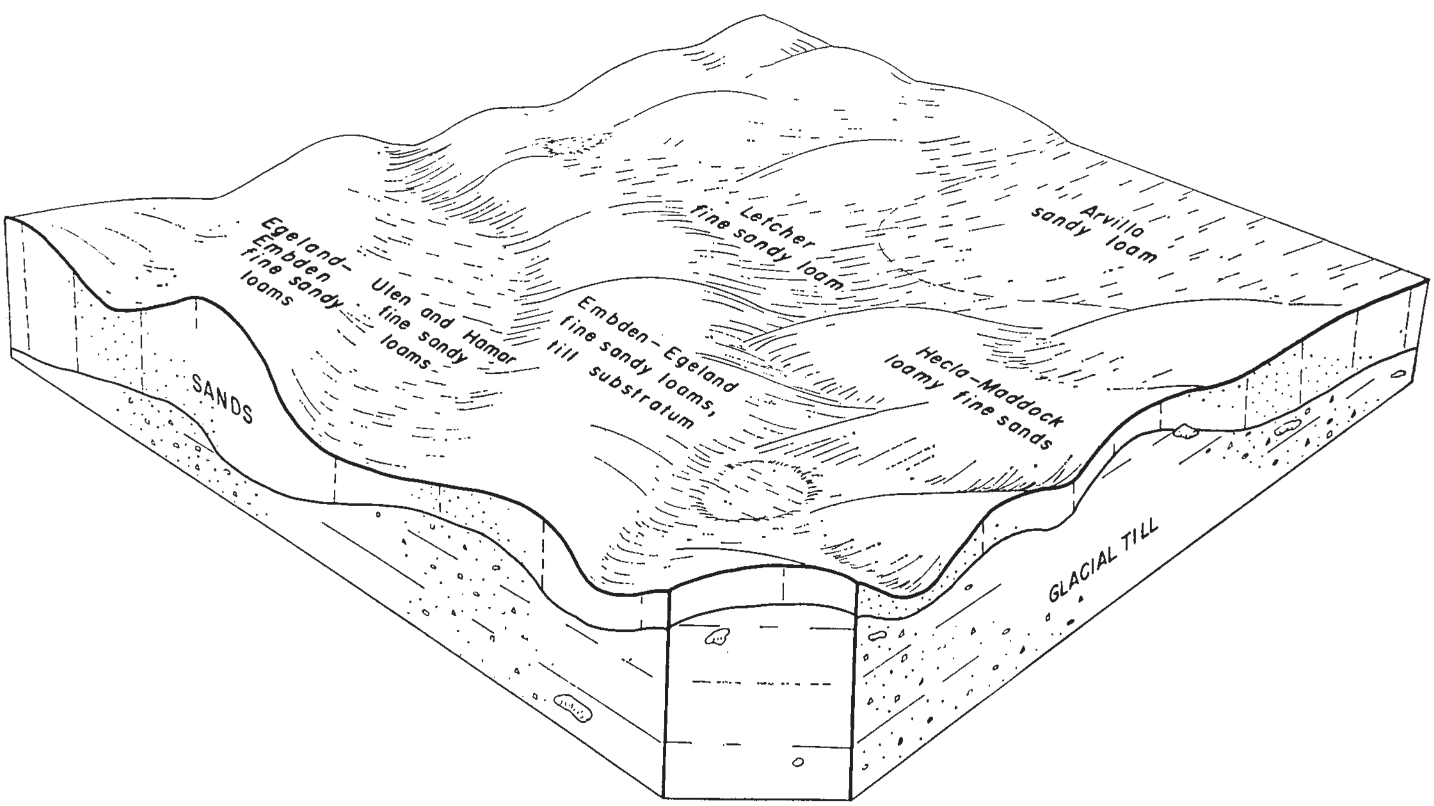

Figure 8.—Parent material and position of soils in association 8.

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Letcher soils have a thick surface layer and a claypan in the subsoil. Arvilla soils are moderately deep over sand and gravel. Ulen and Hamar soils are somewhat poorly drained.

About 75 percent of this soil association is cultivated. The main crops are grain and other feed crops, and there are small herds of livestock on most farms. Wind erosion is a serious hazard.

9. Renshaw-Arvilla-Lamoure association

Level, somewhat excessively drained to poorly drained, moderately coarse textured to moderately fine textured soils on gravelly terraces and in outwash channels

This association consists of gravelly terraces and outwash channels. It has the highest proportion of poorly drained and very poorly drained soils of any association in the county. Near the towns of Hamberg and Bremen are several large sloughs.

This association makes up about 2 percent of the county. Of the dominant soils, Renshaw soils make up about 45 percent of the association, Arvilla soils about 20 percent, and Lamoure soils about 15 percent. Among the minor soils are Colvin, Benoit, and Divide soils.

Renshaw soils are well drained. They have a surface layer of black loam and a subsoil of dark-brown loam.

Arvilla soils are somewhat excessively drained. They have a surface layer of black sandy loam. Below this is very dark grayish-brown sandy loam.

Lamoure soils are somewhat poorly drained and poorly drained. They have a surface layer and a subsoil of black silty clay loam.

Colvin soils are deep and calcareous. They have a surface layer of silty clay loam. Benoit soils are moderately deep over sand and gravel and are calcareous. They have a surface layer of loam. Divide soils are moderately well drained, calcareous, and moderately deep over gravel.

About 60 percent of this association is cultivated. Grain is the main crop. Renshaw, Arvilla, and Divide soils, although droughty, make up most of the cultivated areas. The poorly drained and very poorly drained soils are used for pasture and native hay.

10. LaDelle association

Level, well-drained, medium-textured soils on lacustrine plains

This association (fig. 9) consists mainly of deep soils that formed in colluvium and lacustrine sediments.

This association makes up about 2 percent of the county. LaDelle soils make up about 30 percent of the association. Of the minor soils, Emrick and Larson soils make up about 38 percent, and Overly soils about 7 percent. Among those that make up the remaining 25 percent are Exline, Renshaw, Aberdeen, Heimdal, Egeland, and Embden soils.

LaDelle soils are well drained. They have a thick surface layer of black loam over black silt loam. Beneath this is very dark grayish-brown silt loam.

Overly soils are deep and moderately well drained. They have a surface layer of silty clay loam. Exline soils are very shallow and have a claypan. Renshaw soils are moderately deep over gravel. Aberdeen soils have a surface layer of silty clay loam and a claypan in the sub-

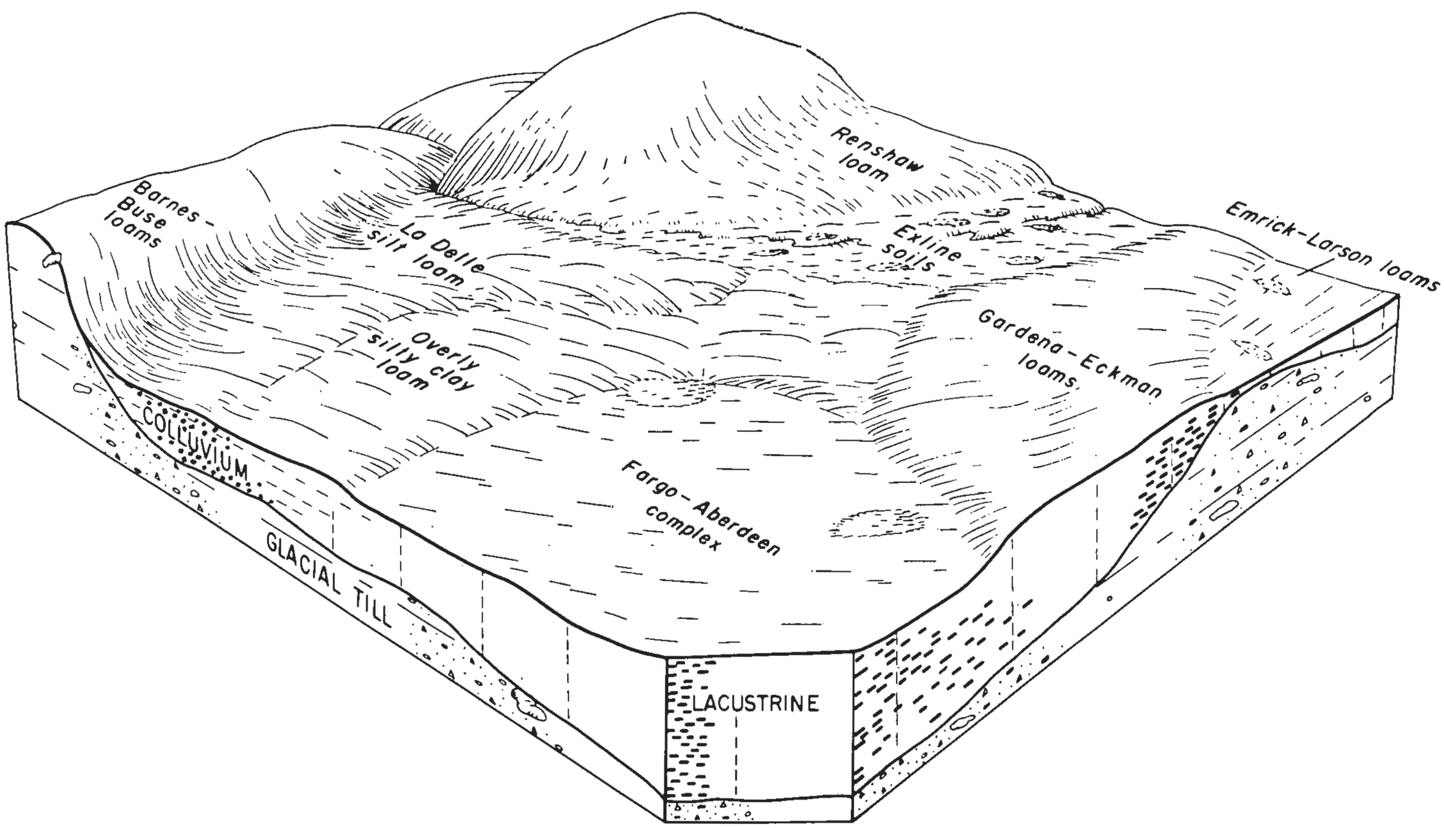

Figure 9.—**Parent material and position of soils in association 10.**

soil. Heimdal and Emrick soils are deep and medium textured, and Egeland and Embden soils are deep and sandy.

About 75 percent of this association is cultivated, mainly to small grain. Exline soils make up most of the grassland.

Descriptions of the Soils

In this section the soils of Wells County are described in detail. The procedure is to describe first the soil series and then the mapping units in that series. Thus, to get full information on any one mapping unit, it is necessary to read both the description of that unit and the description of the soil series to which the unit belongs.

Each series description contains a short description of a typical soil profile and a much more detailed description of the same profile that scientists, engineers, and others can use in making highly technical interpretations.

The detailed description of the profile is considered representative of all the soils in the series. If the profile of a given mapping unit differs from this typical profile, the differences are stated in the description of the mapping unit, unless they are apparent from the name of the mapping unit.

In the detailed descriptions of typical profiles, references to color apply to dry soil, except as otherwise noted. In all other places in the descriptions of the series and the mapping units, references to colors apply to moist soil, unless otherwise noted.

Many of the terms used in describing the soil series and mapping units are defined in the Glossary, and some are defined in the section "How This Survey Was Made."

The approximate acreage and proportionate extent of the soils are shown in table 1. At the back of this soil survey is the "Guide to Mapping Units," which lists the mapping units in the county and shows the capability unit and range site each mapping unit is in and the page where each of these groups is described.

Aberdeen Series

The Aberdeen series consists of level, somewhat poorly drained soils that have a claypan. These soils formed in water-sorted glacial deposits.

In a typical profile, the surface layer consists of 7 inches of black silty clay loam over 1 inch of very dark gray silty clay loam. The subsoil consists of 3 inches of black clay loam over 5 inches of very dark grayish-brown clay loam. This layer has a claypan. The underlying material consists of clay loam over silty clay. This material contains crystals of lime and gypsum.

Aberdeen soils have slow surface and internal drainage. The claypan restricts the growth of plant roots and the movement of air and water. Salinity of the underlying material limits the availability of moisture and plant nutrients.

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

Soil	Area	Extent	Soil	Area	Extent
	Acres	*Percent*		*Acres*	*Percent*
Arvilla sandy loam, level	4,798	0.6	Fram loam	84,800	10.2
Arvilla sandy loam, gently sloping	1,023	.1	Gardena-Eckman loams	5,658	.7
Barnes loam, rolling	34,292	4.1	Hamerly loam	1,853	.2
Barnes loam, rolling, eroded	35,151	4.2	Hecla-Maddock loamy fine sands	1,333	.2
Barnes-Buse loams, hilly	44,121	5.3	Heimdal-Emrick loams, level	162,919	19.7
Barnes stony loam	1,115	.1	Heimdal-Emrick loams, undulating	53,872	6.5
Barnes-Svea loams, level	32,460	4.0	Heimdal-Larson loams, gently sloping	2,588	.3
Barnes-Svea loams, undulating	87,324	10.5	LaDelle silt loam, level	3,048	.4
Bearden-Perella silt loams	1,791	.2	LaDelle silt loam, gently sloping	1,685	.2
Benoit loam	2,461	.3	Lamoure and Divide soils, channeled	4,183	.5
Benoit loam, very poorly drained	441	(1)	Lamoure-Exline complex	1,536	.2
Borup loam	16,203	1.9	Larson-Heimdal loams, gently sloping	347	1)
Buse-Barnes loams, steep	3,981	.5	Larson-Miranda complex	13,312	1.6
Colvin-Lamoure complex	5,754	.7	Letcher fine sandy loam	4,938	.6
Colvin and LaPrairie soils	1,460	.2	Loamy lake beaches	665	.1
Colvin soils, very poorly drained	4,095	.5	Miranda-Larson complex	19,556	2.3
Dimmick clay	2,559	.3	Nutley silty clay	3,788	.5
Divide loam	3,019	.4	Overly silty clay loam	1,171	.1
Egeland fine sandy loam, till substratum, rolling	1,917	.2	Parnell silty clay loam	14,866	1.8
Egeland-Embden fine sandy loams, undulating	3,982	.5	Pits and dumps	451	.1
Egeland-Embden fine sandy loams, till substratum, undulating	11,025	1.3	Renshaw loam, level	11,989	1.4
Embden-Egeland fine sandy loams, level	10,555	1.3	Renshaw loam, gently sloping	2,939	.4
Embden-Egeland fine sandy loams, till substratum, level	18,091	2.2	Saline land	2,786	.3
Emrick-Larson loams	52,735	6.3	Sioux-Arvilla sandy loams	2,814	.3
Eroded sandy land	304	(1)	Sioux-Barnes complex, stony	6,284	.8
Exline soils	3,155	.4	Stony alluvial land	611	.1
Fargo-Aberdeen complex	1,121	.1	Tonka silt loam	7,770	.9
Fargo silty clay	2,055	.2	Ulen and Hamar fine sandy loams	1,529	.2
Forman clay loam, nearly level	1,899	.2	Vallers loam	2,115	.3
Forman clay loam, undulating	11,789	1.4	Intermittent lakes	2,908	.3
			Water	7,020	.8
			Total	832,000	100.0

[1] Less than 0.05 percent.

These soils are suited to grass, legumes, and small grain, but they are poorly suited to trees.

The Aberdeen soils in this county are mapped only in a complex with Fargo soils.

Typical profile of Aberdeen silty clay loam, located 200 feet north and 65 feet west of the southeast corner of the SW¼ sec. 36, T. 148 N., R. 73 W.

Ap—0 to 7 inches, very dark gray (10YR 3/1) silty clay loam; black (10YR 2/1) when moist; cloddy; hard when dry, friable when moist, and slightly sticky and plastic when wet; abrupt boundary.

A2—7 to 8 inches, gray (10YR 5/1) silty clay loam; very dark gray (10YR 3/1) when moist; weak, fine, blocky structure; hard when dry, friable when moist, and sticky and plastic when wet; abrupt, irregular boundary.

B21t—8 to 11 inches, dark-gray (10YR 4/1) clay loam; black (10YR 2/1) when moist; moderate, medium, prismatic structure breaking to moderate, coarse, angular blocky; gray coatings on prisms and blocks; extremely hard when dry, very firm when moist, and sticky and plastic when wet; clear boundary.

B22t—11 to 16 inches, dark grayish-brown (10YR 4/2) clay loam; very dark grayish brown (10YR 3/2) when moist; black coatings and tongues; moderate, coarse, prismatic structure breaking to moderate, coarse, angular blocky; very hard when dry, firm when moist, and sticky and plastic when wet; gradual boundary.

C1—16 to 26 inches, light yellowish-brown (2.5Y 6/3) clay loam; light olive brown (2.5Y 5/4) when moist; weak, coarse, prismatic structure breaking to weak, coarse, blocky; hard when dry, friable when moist, and sticky and plastic when wet; weakly calcareous; gradual boundary.

C2cs—26 to 40 inches, grayish-brown (2.5Y 5/3) silty clay; dark grayish brown (2.5Y 4/2) when moist; weak blocky structure; extremely hard when dry, firm when moist, and very sticky and very plastic when wet; moderately calcareous; common nodules of segregated lime; common nests of salt crystals; gradual boundary.

C3cs—40 to 46 inches, silty clay; mixed very dark grayish brown and olive brown (2.5Y 3/2 and 4/3) when moist; weak blocky structure; very hard when dry, firm when moist, and very sticky and very plastic when wet; moderately calcareous; many nests of salt crystals; clear boundary.

IIAb—46 to 56 inches, very dark gray (10YR 3/1) clay loam; black (10YR 2/1) when moist; weak blocky structure; very hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; many small nests of salt crystals.

The A horizon ranges from 4 to 10 inches in thickness. In places the A2 horizon is lacking. In some places the B21t horizon has columnar structure that breaks readily into blocks. A buried soil occurs at a depth of more than 42 inches in some areas.

Aberdeen soils have a thicker surface layer and a more permeable subsoil than Exline soils.

Arvilla Series

The Arvilla series consists of somewhat excessively drained soils that are moderately deep over sand and gravel.

In a typical profile, the surface layer is black sandy loam about 8 inches thick, and the subsoil is very dark grayish-brown sandy loam over dark-brown sandy loam to a depth of about 19 inches. The underlying material is yellowish-brown gravelly sand.

Arvilla soils have slow surface drainage and moderately rapid permeability.

These soils are suited to grass and small grain.

Typical profile of Arvilla sandy loam, located 2,340 feet west and 80 feet south of the northeast corner of sec. 22, T. 147 N., R. 72 W.

Ap—0 to 8 inches, dark-gray (10YR 4/1) sandy loam; black (10YR 2/1) when moist; weak crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

B21—8 to 14 inches, dark grayish-brown (10YR 4/2) sandy loam; very dark grayish brown (10YR 3/2) when moist; tongues from the A horizon; moderate, coarse, prismatic structure; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual, irregular boundary.

B22—14 to 19 inches, grayish-brown (10YR 5/2) sandy loam; dark brown (10YR 3/3) when moist; weak, coarse, prismatic structure; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; clear boundary.

IIC—19 to 40 inches, yellowish-brown gravelly sand; moderately calcareous; loose.

The A horizon ranges from 4 to 10 inches in thickness. The depth to the IIC horizon ranges from 10 to 36 inches. The IIC horizon is medium or coarse sand in a few places. It ranges from noncalcareous to strongly calcareous.

Arvilla soils have a coarser textured solum than Renshaw soils. They are thicker over beds of loose sand than Sioux soils.

Arvilla sandy loam, level (0 to 3 percent slopes) (ArA).—This soil has the profile described as typical of the series. The depth to gravelly sand is ordinarily about 20 inches, but it ranges from only 15 inches to as much as 36 inches within a distance of 100 feet. Included in mapping were a few small areas of a similar soil that has more gravel than sand in the substratum.

This soil is droughty and is highly susceptible to wind erosion. It is cultivated in most places. Productivity is limited by droughtiness. A combination of several practices is required for control of wind erosion. (Capability unit IIIes-3; Sandy range site)

Arvilla sandy loam, gently sloping (3 to 6 percent slopes) (ArB).—This soil has a profile similar to the one described as typical of the series, but the depth to gravelly sand is commonly about 17 inches. Generally, the depth is less than this on the upper part of the slopes but more on the lower part. Included in mapping were a few small areas of Sioux sandy loam, on the upper part of slopes, and a few spots of a soil that is similar to Arvilla sandy loam except that it has more gravel than sand in the substratum.

This soil is droughty and is highly susceptible to wind erosion. A combination of practices is required for control of erosion on cropland, and close regulation of grazing is needed on range. (Capability unit IIIes-3; Sandy range site)

Barnes Series

The Barnes series consists of deep, level to hilly, well-drained soils that formed in glacial till.

In a typical profile, the surface layer is black loam about 6 inches thick, and the subsoil is very dark grayish-brown loam about 9 inches thick. The underlying material consists of light olive-brown loam that contains a large amount of lime over light olive-brown and gray loam that contains a moderate amount of lime.

Barnes soils have medium surface drainage and moderate permeability. These soils are well suited to crops, grass, and trees.

Typical profile of a Barnes loam, located 0.3 mile east and 100 feet north of the southwest corner of sec. 9, T. 145 N., R. 70 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

B2—6 to 15 inches, dark grayish-brown (10YR 4/2) loam; very dark grayish-brown (10YR 3/2) when moist; moderate, medium, prismatic structure breaking to weak, medium, blocky; slightly hard when dry, friable when moist, and slightly sticky and plastic when wet; tongues from the A1 horizon extend to a depth of 10 inches; clear, irregular boundary.

C1ca—15 to 32 inches, light-gray (2.5Y 7/2) loam; light olive-brown (2.5Y 5/4) when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and plastic when wet; strongly calcareous; gradual, irregular boundary.

C2—32 to 60 inches, light yellowish-brown and light brownish-gray (2.5Y 6/3 and 6/1) loam; light olive brown and gray (2.5Y 5/4 and 5/1) when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and plastic when wet; moderately calcareous.

The A horizon ranges from 4 to 8 inches in thickness. The B horizon ranges from 4 to 15 inches in thickness and commonly has a hue of 2.5Y instead of 10YR. Throughout the profile are pebbles, cobblestones, and other stones.

Barnes soils are better drained and have a thinner surface layer than Svea soils. They differ from the Buse soils in having a B horizon.

Barnes loam, rolling (6 to 9 percent slopes) (BaC).—This soil is characterized by short irregular slopes and, in the larger areas, by common potholes. It has a profile similar to one described as typical of the series, except for variations in the thickness of the surface layer and subsoil. The surface layer and subsoil are thickest on the lower, milder slopes and thinnest on the upper, stronger slopes. Where it is steepest this soil has a 5-inch surface layer, and here material from the subsoil has been mixed into the plow layer, which consequently is browner than the original surface layer. A few spots are eroded, and here part of the limy underlying material has been mixed into the plow layer. These spots are conspicuous because they are light olive brown. Included in mapping were a few small areas of Buse soil.

Surface runoff is medium, water-holding capacity is high, and natural fertility is high.

This soil is well suited to crops, and about 60 percent of the acreage is cultivated. Water erosion is the main hazard in cultivated areas. (Capability unit IIIe–6; Silty range site)

Barnes loam, rolling, eroded (6 to 9 percent slopes) (BaC2).—This soil is characterized by short, irregular slopes. It has a profile similar to the one described as typical of the series, except for the effects of erosion. The tops of most of the knobs and the steeper parts of the side slopes have lost so much soil material that limy material from the substratum has been brought up into the plow layer, which consequently is light gray. The middle parts of the slopes are less eroded, and here the plow layer is browner than the original surface layer because it is partly subsoil.

This soil is less fertile and less friable than uneroded soils of the same series, and it has a slower rate of water intake.

All of this soil is cultivated. Water erosion is the main hazard. (Capability unit IIIe–6; Silty range site)

Barnes-Buse loams, hilly (9 percent slopes or more) (BbD).—This complex is characterized by slopes that are 50 to 300 feet in length. Barnes loam generally is on the lower and less steep parts of the slopes, and Buse loam is on the tops of knobs and on the higher and steeper parts of the side slopes. About 70 percent of each area is the Barnes soil, and about 10 percent is the Buse soil. The rest consists of small areas of the Svea soils and of potholes occupied by the Tonka and Parnell soils.

Both the Barnes and the Buse soils in this complex have profiles similar to the ones described as typical of the respective series. The thickness of the surface layer and the subsoil varies, depending on the slope; these layers are thinnest where the slope is steepest. In most areas that have been cultivated, part of the limy underlying material has been mixed into the plow layer.

These soils have moderate permeability and high water-holding capacity. Surface runoff is medium to rapid, depending on the slope and the plant cover.

Most of the acreage is in grass. (Capability unit VIe–Si; Silty range site)

Barnes stony loam (5 to 10 percent slopes) (Be).—This soil is characterized by irregular rolling slopes that are rarely more than 200 feet long. In the larger areas, potholes are common. Stones make the use of farm machinery impractical. Generally, stones are more numerous on the tops of knobs and ridges than in other areas.

All of this soil is in grass. (Capability unit VIs–Si; Silty range site)

Barnes-Svea loams, level (0 to 3 percent slopes) (BnA).—This complex is characterized by level areas and irregular slopes generally no more than 75 feet long. Barnes loam is on the slopes and in the higher level areas, and Svea loam is in swales and the lower level areas. Figure 10 shows the relationship of soils and underlying material.

Although there is some variation in proportion, about 60 percent of most areas is the Barnes soil and about 25 percent the Svea soil. Included in mapping were Tonka and Parnell soils, which are in potholes, and Hamerly loam and Vallers loam, which generally rim the potholes. The areas of Hamerly loam are as much as 15 acres in size.

The Barnes and the Svea soils in this complex have profiles similar to the ones described for the respective series.

These soils are well suited to crops, and about 90 percent of the acreage is cultivated. The main limitation is lack of moisture. (Capability unit IIc–6; Silty range site)

Barnes-Svea loams, undulating (3 to 6 percent slopes) (BnB).—This complex is characterized by irregular slopes, generally not more than 100 feet long. Barnes loam is on the tops of knobs and on the stronger slopes, and Svea loam is in the less sloping areas. About 70 percent

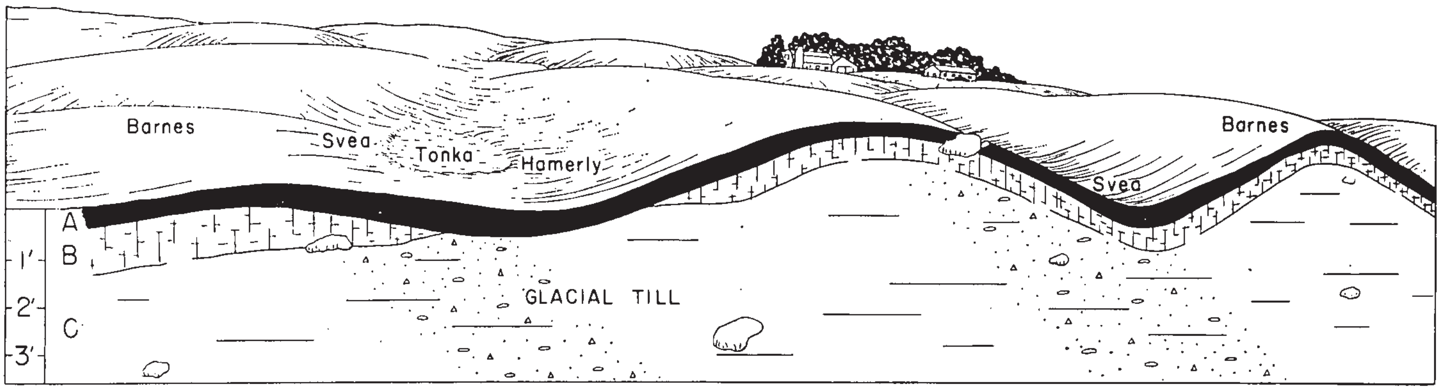

Figure 10.—**Barnes-Svea complexes: relationship of soils and underlying material. A is the surface layer, B is the subsoil, and C is the underlying material.**

of each area is the Barnes soil, and about 20 percent is the Svea soil. The rest consists of small areas of Tonka silt loam and Parnell silty clay loam and of Hamerly loam and Vallers loam, which occupy the rims of many potholes. Included in mapping were a few small areas of Barnes-Svea loams, level, and, in the southern part of the county, a few areas of Forman clay loam.

The Barnes soil has a profile similar to the one described as typical of the Barnes series, but the surface layer and subsoil are thinner. In eroded areas, part of the subsoil or the substratum has been mixed into the plow layer, which consequently is lighter colored than the original surface layer.

The Svea soil has the profile described as typical under "Svea Series." Areas of this complex in the southwestern part of the county have a finer texture than is typical in other parts. In these areas the soils are hard when dry and sticky when wet.

These soils are well suited to crops, and about 80 percent of the acreage is cultivated. The hazard of wind and water erosion is slight. (Capability unit IIe-6; Silty range site)

Bearden Series

The Bearden series consists of deep, somewhat poorly drained soils that are limy at or near the surface.

In a typical profile, the surface layer is black, limy silt loam about 8 inches thick. The underlying material consists of about 8 inches of dark-gray silty clay loam that contains a large amount of lime and, below that, light olive-brown, limy silty clay loam. The water table is commonly in the lower part of this layer in spring.

Bearden soils have slow to ponded surface drainage and slow permeability. These soils are suited to small grain, grass, legumes, and trees.

The Bearden soils in this county are mapped only with Perella soils.

Typical profile of Bearden silt loam, located in the northwest corner of sec. 24, T. 148 N., R. 71 W.

Ap—0 to 8 inches, dark-gray (10YR 4/1) silt loam; black (10YR 2/1) when moist; moderate, fine, crumb structure; friable; calcareous; abrupt boundary.

C1ca—8 to 16 inches, gray (10YR 6/1) silty clay loam; dark gray (10YR 4/1) when moist; moderate, fine, granular structure; friable; strongly calcareous; gradual boundary.

C2ca—16 to 28 inches, light yellowish-brown (2.5Y 6/3) silty clay loam; light olive brown (2.5Y 5/4) when moist; weak, medium, blocky structure; friable; strongly calcareous.

The A horizon ranges from 6 to 14 inches in thickness, and it is weakly to strongly calcareous.

Bearden-Perella silt loams (0 to 1 percent slopes) (Bp).—This complex is in large, shallow, flat-bottomed depressions. Runoff from adjoining areas ponds in these depressions, and the water disappears slowly because of moderately slow permeability.

If adequately drained, these soils are suited to flax and small grain. In undrained areas, farming operations have to be delayed, and in some seasons abandoned, because of the wetness. Growth of grass is best when shallow ponding lasts into midsummer and is curtailed drastically in years when there is no ponding. (Capability unit IIw-6; Wetland range site)

Benoit Series

The Benoit series consists of level, poorly drained to very poorly drained soils that are moderately deep over sand and gravel. These soils have a high water table that has contributed to the accumulation of lime near the surface.

In a typical profile, the 7-inch surface layer is black loam that contains a moderate amount of lime. The underlying material consists of about 9 inches of grayish-brown loam that contains a large amount of lime over about 14 inches of mottled gray and light olive-brown, stratified very fine sandy loam and silt loam that contain a large amount of lime. Below this is yellowish-brown sand and gravel.

Benoit soils have very slow to ponded surface drainage and moderate permeability.

Legumes, small grain, and flax can be grown in a few of the better drained areas, but generally these soils are better suited to grass.

Typical profile of Benoit loam, located 95 feet east and 95 feet north of the southwest corner of sec. 29, T. 147 N., R. 69 W.

A1—0 to 7 inches, very dark gray (10YR 3/1) loam; black (10YR 2/1) when moist; moderate, medium, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; clear, irregular boundary.

C1ca—7 to 16 inches, light-gray and gray (2.5Y 7/1 and 5/1) loam; grayish brown (2.5Y 5/2) when moist; weak, coarse, prismatic structure; dark grayish-brown (2.5Y 4/2) coatings on prisms; slightly hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual, irregular boundary.

C2—16 to 30 inches, gray, light yellowish-brown, and olive-yellow (2.5Y 6/1, 6/3, and 6/6) stratified very fine sandy loam and silt loam; gray and light olive brown (2.5Y 5/1 and 5/4) when moist; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; strongly calcareous; abrupt, wavy boundary.

IIC3—30 to 48 inches, yellowish-brown sand and gravel; single grain; loose; moderately calcareous.

The A horizon ranges from noncalcareous to strongly calcareous and from 4 to 10 inches in thickness. In a few places the C horizon has a color hue of N, and in the very poorly drained phase, it has fewer mixed colors and has mainly a hue of N or a chroma of 1 throughout. In places the IIC horizon has a greenish color or is mottled. The depth to this horizon ranges from 15 to 36 inches.

Benoit soils are more poorly drained than Divide soils.

Benoit loam (0 to 1 percent slopes) (Br).—This soil has the profile described as typical of the series. It is poorly drained. The water table is at the surface in spring and in wet seasons.

This soil is well suited to grass. Some areas are cultivated, but farming operations generally have to be delayed because of wetness. Grass and legumes should be included in the rotation, and summer fallow should be avoided. Drainage would eliminate the wetness, but most areas lack natural outlets. (Capability unit IIw–4L; Subirrigated range site)

Benoit loam, very poorly drained (0 to 1 percent slopes) (Bt).—This soil occurs in the northwestern part of the county. It has a water table near the surface almost the year round. Normally water is ponded on the surface in spring and early in summer, but it may remain ponded all through the growing season if rainfall is above normal.

This soil has a profile similar to the one described as typical of the series, but the underlying material is generally dark gray or gray, the depth to beds of sand and gravel ranges from 20 to 36 inches, and these beds have a greenish color.

This soil is not suited to cultivated crops, but it is well suited to grass and wetland vegetation. Cattails are the dominant vegetation in some years when the ponded water is deep enough to interfere with the growth of grasses. (Capability unit Vw–WL; Wetland range site)

Borup Series

The Borup series consists of deep, nearly level, somewhat poorly drained soils that formed in medium-textured material deposited by glacial melt water. These soils have a seasonal high water table that contributes to the accumulation of lime near the surface.

In a typical profile, the 7-inch surface layer is black loam that contains a moderate amount of lime. The underlying material, to a depth of 38 inches, consists of dark grayish-brown loam streaked with grayish brown over light olive-brown loam. Below this is light olive-brown, stratified sandy loam over light olive-brown sand and some fine gravel.

Borup soils have slow to ponded surface drainage and moderate permeability.

These soils are suited to small grain, flax, grass, legumes, and trees.

Typical profile of Borup loam, located 90 feet east and 120 feet south of the northwest corner of sec. 30, T. 149 N., R. 69 W.

Ap—0 to 7 inches, dark-gray (10YR 3/1) loam; black (10YR 2/1) when moist; moderate, fine, crumb structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; abrupt boundary.

C1ca—7 to 20 inches, gray and light-gray (N 6/0 and N 7/0) loam; dark grayish brown (2.5Y 4/2) streaked with grayish brown (2.5Y 5/2) when moist; weak prismatic structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; much tonguing of A1 horizon into this horizon; gradual, irregular boundary.

C2ca—20 to 32 inches, pale-yellow (2.5Y 7/4) loam; light olive brown (2.5Y 5/4) when moist; streaks and tongues of grayish brown (2.5Y 5/2) when moist; weak blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual boundary.

C3—32 to 38 inches, light yellowish-brown (2.5Y 6/4) loam; light olive brown (2.5Y 5/4) when moist; few, medium, distinct mottles of gray (2.5Y 5/1); weak blocky structure; hard when dry, very friable when moist, and slightly sticky and nonplastic when wet; moderately calcareous; clear boundary.

C4—38 to 46 inches, light yellowish-brown (2.5Y 6/4) stratified sandy loam; light olive brown (2.5Y 5/4) when moist; weak crumb structure; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; weakly calcareous; clear boundary.

IIC5—46 to 50 inches, light yellowish-brown (2.5Y 6/4) sand and some fine gravel; light olive brown (2.5Y 5/4) when moist; single grain; loose.

IIC6—50 inches +, stones and cobblestones.

The A horizon ranges from 4 to 12 inches in thickness. It is slightly calcareous to strongly calcareous. In places the C1ca horizon has platy instead of prismatic structure. At depths below 30 inches, the C horizon ranges from loamy sand to silt loam. The depth to the IIC horizon ranges from 18 to more than 60 inches. Where the IIC horizon is at a depth of less than 36 inches, it consists of loam-textured glacial till. Thin layers of sand, gravel, cobblestones, and stones commonly occur in contact with the glacial till where the till is at a depth of more than 40 inches.

Borup soils are more poorly drained than Fram soils.

Borup loam (0 to 1 percent slopes) (Bu).—This soil occurs around depressions and in narrow drainageways. The water table is near the surface in spring and in wet weather at other times of the year. Water ponds in the depressions and seeps from adjacent slopes.

Where it occurs in drainageways, this soil has a profile similar (fig. 11) to the one described as typical of the series. In other areas the surface layer is thicker, and in some places the texture is finer. In many areas surrounding depressions, the depth to loam-textured glacial till is less than 36 inches.

This soil is well suited to native grasses. Some trees can be grown, but wetness makes proper cultivation difficult. Many areas are cultivated, but farming operations have to be delayed because of the wetness, and in wet years either seeding or harvesting generally has to be abandoned. Drainage is needed before good yields can be expected every year, but most areas lack drainage

Figure 11.—**Profile of Borup loam.**

outlets. Summer fallow should be resorted to as little as possible, and grasses and legumes should be included in the cropping system. (Capability unit IIw-4L; Subirrigated range site)

Buse Series

The Buse series consists of deep, steep, somewhat excessively drained soils that formed in loam-textured glacial till.

In a typical profile (fig. 12), the surface layer is black loam about 5 inches thick. The underlying material consists of very dark grayish-brown loam over dark grayish-brown and gray loam. This material contains a large amount of lime. Below this is light olive-brown loam that contains a moderate amount of lime. Surface runoff is rapid.

Buse soils are suited to grass.

The Buse soils in this county are mapped only in complexes with Barnes soils.

Typical profile of Buse loam, located 100 feet north and 2,600 feet east of the southwest corner of sec. 16, T. 146 N., R. 72 W.

A1—0 to 5 inches, very dark gray (10YR 3/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; 1 percent cobblestones and stones; clear boundary.

C1ca—5 to 10 inches, grayish-brown (2.5Y 5/2) loam; very dark grayish brown (2.5Y 3/2) when moist; weak, medium, prismatic structure breaking to weak, medium, blocky; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual boundary.

C2—10 to 16 inches, grayish-brown (2.5Y 5/2) and gray (2.5Y 7/2) loam; dark grayish brown (2.5Y 4/2) and gray (2.5Y 6/1) when moist; weak blocky structure; slightly hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual boundary.

C3—16 to 48 inches, light brownish-gray (2.5Y 6/3) and light-gray (2.5Y 7/2) loam; light olive brown (2.5Y 5/4) when moist; weak blocky structure; slightly hard; moderately calcareous; common lime nodules.

The A horizon ranges from 4 to 8 inches in thickness and is noncalcareous or weakly calcareous. In some places in the southwestern corner of the county, varved material that more or less follows the curvature of the hills occurs at various depths. Throughout the profile are pebbles, cobblestones, and other stones.

Buse soils differ from Barnes soils in not having a B horizon.

Buse-Barnes loams, steep (12 to 30 percent slopes) (BvE).—This complex occurs along the Sheyenne River. Buse loam has convex slopes, and Barnes loam has smooth slopes. About 60 percent of each area is Buse loam, about 30 percent is Barnes loam, and the rest consists of small included areas of LaDelle and Embden soils, which are along the lower parts of the slopes. In a few places along the upper slopes or in drainageways that dissect the slopes are spots where only a thin smear of glacial deposit overlies shale and sandstone bedrock.

The Buse and Barnes soils in this complex have profiles similar to the ones described as typical of the respective series.

All of this complex is in grass. (Capability unit VIe-tSi; Thin Silty range site)

Colvin Series

The Colvin series consists of deep, nearly level, poorly drained and very poorly drained soils that are limy at or near the surface. These soils formed in glacial melt-water deposits. They have a seasonal high water table that contributes to the accumulation of lime near the surface.

In a typical profile, the 12-inch surface layer is black silty clay loam that contains lime and has a high organic-matter content. The underlying material, to a depth of 30 inches, consists of grayish-brown and light brownish-gray silty clay loam that contains a large amount of lime. Below this is gray and light yellowish-brown clay loam that contains soft spots of lime. The water table is commonly in this layer.

Colvin soils have poor to very poor surface drainage and moderately slow permeability.

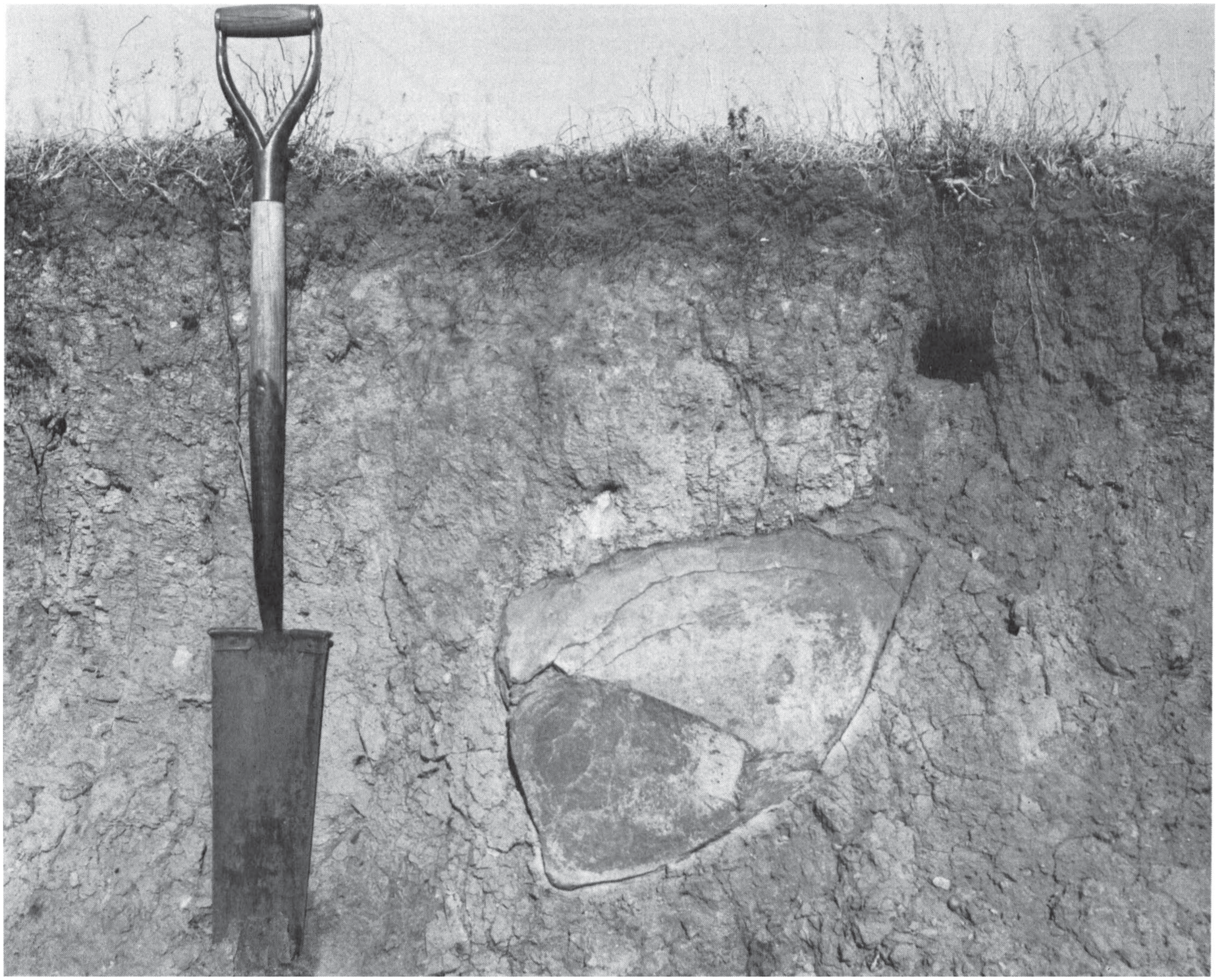

Figure 12.—**Profile of Buse loam, showing granitic stone and rodent hole.**

Small grain, flax, and legumes are grown in the better drained areas, but, in general, these soils are better suited to grass.

Typical profile of a Colvin silty clay loam, located 60 feet east and 460 feet south along driveway in the northwest corner of the NE¼ sec. 17, T. 147 N., R. 72 W.

A1—0 to 12 inches, very dark gray (10YR 3/1) silty clay loam; black (10YR 2/1) when moist; moderate, fine, granular structure; slightly hard when dry, friable when moist, and slightly sticky and plastic when wet; strongly calcareous; clear, irregular boundary.

C1ca—12 to 30 inches, gray and white (2.5Y 6/1 and 8/1) silty clay loam; grayish brown and light brownish gray (2.5Y 5/2 and 6/2) when moist; weak blocky structure; very hard when dry, friable when moist, and sticky and plastic when wet; strongly calcareous; gradual, irregular boundary.

C2ca—30 to 46 inches, light brownish-gray and white (2.5Y 6/2 and 8/1) clay loam; gray and light yellowish brown (2.5Y 5/1 and 6/4) when moist; weak blocky structure; very hard when dry, firm when moist, and sticky and plastic when wet; strongly calcareous; common nodules of lime; gradual, irregular boundary.

C3—46 to 60 inches, light brownish-gray (2.5Y 6/2) clay loam; olive gray (5Y 5/2) when moist; weak blocky structure; very hard when dry, friable when moist, and sticky and slightly plastic when wet; strongly calcareous; common nodules of segregated lime.

The A horizon ranges from 6 to 15 inches in thickness and in places is very dark gray instead of black. In a few areas the lower part of the A horizon and the C1ca horizon have moderate, very fine, blocky structure. The lower horizons are loam or coarser textured material in a few areas. In very poorly drained phases, the C horizon has a color hue of N or 5Y and a chroma of 1 throughout and has a few mottles.

Colvin soils are finer textured than Borup soils.

Colvin-Lamoure complex (0 to 2 percent slopes) (Ca).—These soils are poorly drained and receive surface runoff and seepage from adjacent areas. They are normally wet until early in summer and in wet seasons. Surface drainage is poor. In many places there are small spots of saline soil.

The proportion of the Colvin and Lamoure soils varies widely from area to area. In swales and on the edges of very poorly drained or ponded parts of the upland are areas made up entirely of the Colvin soils.

The Colvin soil in this unit has a profile like the one described as typical of the series except that in the drainageways the underlying material is darker gray. The Lamoure soil has a profile similar to the one described as typical under the heading "Lamoure Series," but in places the surface layer is clay loam instead of silty clay loam. In a few places, both of these soils have stratified sand below a depth of 40 inches.

These soils are well suited to grass. A few kinds of trees will grow, but cultivation is difficult because of the wetness, and consequently trees are generally crowded out by weeds and grass.

Because of wetness, tillage operations have to be delayed each year, and in some wet years either seeding or harvesting has to be abandoned. Drainage is necessary before good yields can be expected every year. (Capability unit IIw-4L; Subirrigated range site)

Colvin and LaPrairie soils (0 to 2 percent slopes) (Cp).—These soils receive extra moisture in the form of runoff from adjacent slopes and, in a few places, in the form of overflow. The water table is high during the spring thaw and in wet weather at other times of the year.

Some areas of this unit are part Colvin silty clay loam and part LaPrairie silt loam or loam. Other areas consist entirely of the LaPrairie soils. In the areas that contain soils of both series, the Colvin soils are on the higher parts of the landscape and the LaPrairie soils are in swales and other low places.

The Colvin soils in this mapping unit have a profile similar to the one described as typical of the series, except that each horizon has only the darker color. The LaPrairie soils have a profile similar to the one described as typical under the heading "LaPrairie Series," but the surface layer is loam instead of silt loam in some places.

These soils are well suited to grass, trees, small grain, and flax. Many areas are cultivated, but farming operations usually have to be delayed a few days in spring because of wetness. Wind erosion is a hazard in cultivated areas. (Capability unit IIw-4L; Overflow range site)

Colvin soils, very poorly drained (0 to 1 percent slopes) (Cs).—These soils commonly have a water table above the surface until midsummer and sometimes the year round.

The soils in this complex have a profile like the one described as typical of the Colvin series, but the surface layer is only 6 inches thick and the underlying material is darker gray. In places the surface layer is loam or silt loam instead of silty clay loam, and in a few drainageways, the surface layer is thicker than is typical and is only weakly calcareous. The organic-matter content of the surface layer is high. In a few places there is a thin layer of muck on the surface. Many areas, especially areas used as pasture, have hummocks 4 to 12 inches high and 6 to 18 inches across (fig. 13).

Cattails are the dominant vegetation in years when the ponded water is deep enough to limit the growth of native grasses and sedges. There are small areas where only bulrushes grow. (Capability unit Vw-WL; Wetland range site)

Dimmick Series

The Dimmick series consists of deep, poorly drained soils that formed in glacial depressions in which water ponds.

In a typical profile, the uppermost layer consists of a few inches of muck, and the surface layer is black clay about 14 inches thick and mottled below the first 2 inches. The underlying material is dark-gray clay that contains a moderate amount of lime.

Dimmick soils have very poor surface drainage and slow permeability.

The use of these soils depends upon the frequency of ponding and the depth of the water.

Typical profile of Dimmick clay, located 0.3 mile west and 250 feet south of the northeast corner of sec. 30, T. 146 N., R. 72 W.

O2—3 inches to 0, muck.

A1—0 to 2 inches, dark-gray (10YR 4/1) clay; black (10YR 2/1) when moist; weak, fine, crumb structure; firm when moist and very sticky and very plastic when wet; clear boundary.

A3—2 to 14 inches, gray (10YR 5/1) clay; black (10YR 2/1) when moist; fine distinct mottles of brown, dark yellowish brown, and olive brown; moderate, coarse, prismatic structure breaking to moderate, very fine, angular blocky; very firm when moist and very sticky and very plastic when wet; moderately calcareous; gradual boundary.

C1g—14 to 32 inches, gray (5Y 5/1) clay; dark gray (5Y 4/1) when moist; moderate, medium, blocky structure; very firm when moist and very sticky and very plastic when wet; moderately calcareous; few nodules and few threads of segregated lime; snail shell fragments; gradual boundary.

C2g—32 to 55 inches, gray (5Y 6/1 or 5/1) clay; gray and dark gray (5Y 5/1 and 4/1) when moist; moderate blocky structure; very firm when moist and very sticky and very plastic when wet; moderately calcareous; small shell fragments; gradual boundary.

C3g—55 to 60 inches, gray (5Y 6/1) clay; gray (5Y 5/1) when moist; many, medium, distinct mottles of light olive brown; very firm when moist and very sticky and very plastic when wet; snail shell fragments; moderately calcareous.

The O2 horizon is lacking in some places. The depth to lime ranges from 0 to 36 inches. Brownish mottles are common in all horizons except the A1. Snail shells are common in all horizons.

Dimmick soils are finer textured than Parnell soils, and they have lime nearer the surface.

Dimmick clay (0 to 1 percent slopes) (Dc).—This is a deep, fertile soil that has high water-holding capacity. It is in depressions in the southern part of the county. Unless drained, it is usually ponded until midsummer or later, and the year round in wet years. After a series of dry years, it dries out so much that it is ponded for only a few days after rain.

This soil is well suited to native grasses. It has to be drained of excess water before it can be cultivated successfully. (Capability unit IIIw-4; Wetland range site)

Divide Series

The Divide series consists of moderately well drained soils that are limy at or near the surface. These soils

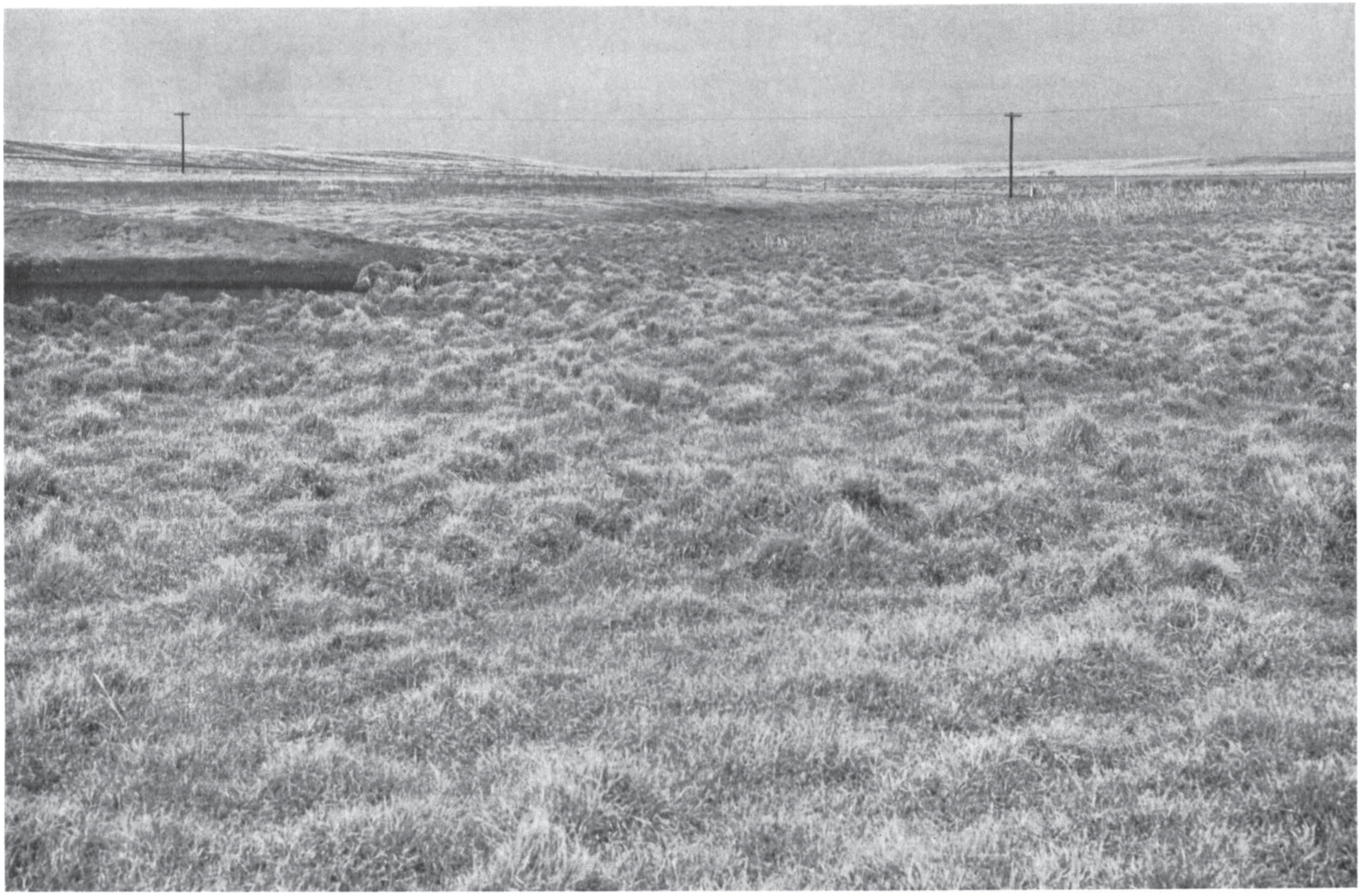

Figure 13.—**Small hummocks on the surface of Colvin soils, very poorly drained. At the left is a waterhole.**

formed in glacial outwash that is moderately deep over sand and gravel. A high water table during spring thaws and in wet seasons contributes to the accumulation of lime at or near the surface.

In a typical profile, the surface layer is black, moderately limy loam about 6 inches thick. The underlying material consists of very dark gray and grayish-brown loam about 13 inches thick over light brownish-gray loam that contains a large amount of lime. Below this is grayish-brown stratified sand and gravel that contains a small amount of lime.

These soils are well suited to small grain, flax, grass, legumes, and trees.

A typical profile of a Divide loam, located 0.3 mile north and 125 feet west of the southeast corner of sec. 29, T. 150 N., R. 73 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; abrupt boundary.

C1ca—6 to 19 inches, dark-gray and light-gray (2.5Y 4/1 and 7/2) loam; very dark gray and grayish brown (2.5Y 3/1, 5/2) when moist; weak, coarse, prismatic structure; tongues and coatings of black (10YR 2/1), when wet, on prisms; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous, but dark-colored tongues and coatings are weakly calcareous; clear, irregular boundary.

C2ca—19 to 25 inches, light-gray (2.5Y 7/2) loam and some gravel; light brownish gray (2.5Y 6/2) when moist; common prominent mottles of olive yellow and light olive brown (2.5Y 6/6 and 6/4); weak blocky structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; clear boundary.

IIC3—25 to 60 inches, light brownish-gray (10YR 6/2) stratified sand and gravel; grayish brown (10YR 5/2) when moist; single grain; loose; weakly calcareous.

The A horizon ranges from 5 to 12 inches in thickness and from noncalcareous to moderately calcareous. The C horizon has a color hue of 10YR instead of 2.5Y in places. In a few places layers of stone occur either at the contact with or in the lower part of the IIC horizon.

Divide soils are better drained than Benoit soils. They differ from Renshaw soils in having lime at or near the surface.

Divide loam (0 to 3 percent slopes) (Dd).—This soil has a profile similar to the one described as typical of the series but less deep. The depth to the underlying sand and gravel ranges from 15 to 30 inches and is greatest in small shallow swales. A few spots of this soil are somewhat saline. Small areas of Benoit loam occur in some of the swales and are included in the areas mapped.

Most areas are cultivated. The saline spots crust after rains, and they produce poor stands of crops, particularly in a dry year that follows one or more unusually wet years. Stripcropping and the use of crop residue are necessary for control of wind erosion in cultivated areas. In areas that are not cultivated, the saline spots have a cover of salt-tolerant grass. (Capability unit IIIs-4L; Silty range site)

Eckman Series

The Eckman series consists of deep, well-drained, medium-textured soils that formed in glacial melt-water deposits.

In a typical profile, the 6-inch surface layer is black loam, and the 13-inch subsoil consists of very dark grayish-brown loam over dark grayish-brown loam. The underlying material consists of a layer of light olive-brown loam, a layer of yellowish-brown and grayish-brown, stratified fine sandy loam and loam, and a layer of light olive-brown and gray sandy loam. All of this underlying material is limy.

Eckman soils have medium internal drainage and medium surface drainage.

These soils are suited to crops, grass, and trees.

The Eckman soils in this county are mapped only in a complex with the Gardena soils.

Typical profile of Eckman loam, located 500 feet north and 75 feet west of the southeast corner of sec. 24, T. 148 N., R. 71 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

B2—6 to 15 inches, dark grayish-brown (10YR 4/2) loam; very dark grayish brown (10YR 3/2) when moist; weak, medium, prismatic structure breaking to moderate, medium, blocky; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; clear, irregular boundary.

B3ca—15 to 19 inches, brown and white (10YR 5/3, 8/2) loam; dark grayish brown (10YR 4/2) when moist; weak, coarse, blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; few threads of lime; clear, irregular boundary.

C1ca—19 to 26 inches, light brownish-gray (2.5Y 6/3) loam; light olive brown (2.5Y 5/4) when moist; weak blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual boundary.

C2—26 to 48 inches, pale-brown, light brownish-gray, and light-gray (10YR 6/3 and 2.5Y 6/2 and 7/2) fine sandy loam that has many thin strata of loam; yellowish brown and grayish brown (10YR 5/4 and 2.5Y 5/3) when moist; weak crumb structure; strongly calcareous to moderately calcareous.

C3—48 to 60 inches, light yellowish-brown (2.5Y 6/3) sandy loam that has many thin strata of fine sand; light olive brown and gray (2.5Y 5/4 and 5/1) when moist; weakly calcareous.

The A horizon ranges from loam to silt loam in texture. In a few places the B horizon is lighter brown, and in some places there is no B3 horizon. The depth to a layer of lime accumulation ranges from 12 to 25 inches. The underlying material ranges from fine sand to loam in texture, and it is stratified in some places but not in others.

Eckman soils are associated with Gardena soils. They are better drained and have a thinner surface layer than Gardena soils.

Egeland Series

The Egeland series consists of deep, well-drained soils that formed in outwash and in eolian deposits.

In a typical profile, the 6-inch surface layer is black fine sandy loam, and the 13-inch subsoil consists of very dark grayish-brown fine sandy loam over dark grayish-brown fine sandy loam. The upper part of the underlying material is dark grayish-brown, generally limy fine sandy loam. Below this is light brownish-gray and light olive-brown loam.

Egeland soils have moderately rapid permeability, and little water runs off.

These soils are suited to crops, grass, and trees.

Typical profile of Egeland fine sandy loam, located in a cultivated field, 0.35 mile east and 100 feet north of the southwest corner of sec. 31, T. 149 N., R. 71 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) fine sandy loam; black (10YR 2/1) when moist; cloddy; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

B21—6 to 13 inches, dark grayish-brown (10YR 4/2) fine sandy loam; very dark grayish brown (10YR 3/2) when moist; moderate, coarse, prismatic structure breaking to moderate, coarse, subangular blocky; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; clear, irregular boundary.

B22—13 to 19 inches, brown (10YR 5/3) fine sandy loam; dark grayish brown (10YR 4/2) when moist; weak, coarse, prismatic structure breaking to weak, coarse to fine, blocky; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual, irregular boundary.

C1—19 to 32 inches, light olive-brown (2.5Y 5/4) fine sandy loam; dark grayish brown (10YR 4/2) when moist; weak crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; clear, wavy boundary.

IIC2—32 to 35 inches, light yellowish-brown and light-gray (2.5Y 6/3 and 7/2) loam; light brownish gray and light olive brown (2.5Y 6/2 and 5/4) when moist; weak blocky structure; slightly hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; clear, irregular boundary.

IIC3—35 to 60 inches, light yellowish-brown and light-gray (2.5Y 6/4 and 7/1) loam; light olive brown and grayish brown (2.5Y 5/4 and 5/2) when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; common nodules of segregated lime.

In places the B horizon is loamy sand instead of fine sandy loam. The C horizon ranges from fine sandy loam to sand in texture. This horizon is lacking in places. In some places there is a Cca horizon that ranges from fine sandy loam to fine sand in texture. The depth to the IIC horizon ranges from 14 to more than 60 inches. In a few places, free lime has been leached out of the uppermost few inches of this layer.

Egeland soils are better drained and have a thinner surface layer than Embden soils. They are finer textured than Maddock soils.

Egeland fine sandy loam, till substratum, rolling (6 to 9 percent slopes) (EdC).—This soil has a profile similar to the one described as typical of the series. The depth to the till substratum varies widely. Generally, it is less on ridgetops and knobs and on the upper parts of slopes than on the lower parts of slopes. The till is generally loam, but in a few places, mainly in the northwestern part of the county, it is loamy sand or sand and contains a little fine gravel.

This soil is highly susceptible to wind erosion. In many spots on the upper parts of slopes, so much erosion has taken place that the plow layer consists partly of material from the subsoil or even from the substratum.

Most areas of this soil are cultivated. (Capability unit IIIe–3; Sandy range site)

Egeland-Embden fine sandy loams, undulating (3 to 6 percent slopes) (EeB).—About 75 percent of each area of this complex is Egeland fine sandy loam, and about 25 percent is Embden fine sandy loam. The Egeland soil is in the higher positions, and the Embden soil is in the swales and other lower positions.

The Egeland soil in this unit has a profile similar to the one described as typical of the series, but the surface layer and subsoil, together, are only 15 inches thick over underlying material, and the depth to the loam-textured glacial till is more than 40 inches. The Embden soil has a profile similar to the one described for the Embden series, but in most places the depth to the loam-textured glacial till is more than 5 feet, and in a few swales, the surface layer is as much as 18 inches thick.

These soils are highly susceptible to wind erosion. Many cultivated areas have lost so much soil material through erosion that part of the subsoil has been mixed into the plow layer. The eroded spots have a brownish color. Windblown soil material has accumulated in ridges along field borders.

About 75 percent of this complex is cultivated. Yields are limited in most years by lack of moisture. (Capability unit IIIe–3; Sandy range site)

Egeland-Embden fine sandy loams, till substratum, undulating (3 to 6 percent slopes) (EfB).—This complex is characterized by short, irregular slopes, small depressions, and scattered surface stones that are most numerous on the upper parts of slopes. About 65 percent of each area is Egeland fine sandy loam, and about 35 percent is Embden fine sandy loam. The Egeland soil is on the higher parts of the landscape, and the Embden soil is at the base of slopes and in swales. Each of these soils has a profile like the one described as typical of the series.

The till substratum has a loam texture. It is most commonly at a depth of about 30 inches. Generally it is nearer the surface on the upper parts of the slopes than on the lower parts. In a few places it is at the surface.

These soils are highly susceptible to wind erosion. Many cultivated areas have lost so much soil material that part of the subsoil is mixed into the plow layer. Windblown soil material has accumulated in ridges along field borders.

Most areas of this complex are cultivated. (Capability unit IIIe–3; Sandy range site)

Embden Series

The Embden series consists of deep, moderately well drained soils that formed in outwash or eolian deposits.

In a typical profile, the 13-inch surface layer consists of black fine sandy loam over very dark gray fine sandy loam. The 23-inch subsoil is very dark grayish-brown fine sandy loam over very dark grayish-brown loamy fine sand. The underlying material consists of dark grayish-brown coarse sandy loam over loam-textured glacial till that contains a large amount of lime.

Embden soils have slow surface drainage and moderate to moderately rapid permeability.

These soils are well suited to crops, grass, and trees.

The Embden soils in this county are mapped only in four complexes with Egeland soils.

Typical profile of Embden fine sandy loam, located 230 feet west and 115 feet south of the northeast corner of sec. 12, T. 148 N., R. 72 W.

A11—0 to 4 inches, very dark gray (10YR 3/1) fine sandy loam; black (10YR 2/1) when moist; weak, fine and very fine, subangular blocky structure breaking to weak, fine, crumb; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; clear boundary.

A12—4 to 13 inches, dark-gray (10YR 4/1) fine sandy loam; very dark gray (10YR 3/1) when moist; moderate, coarse, prismatic structure breaking to moderate, coarse, angular blocky; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual, irregular boundary.

B2—13 to 27 inches, dark grayish-brown (10YR 4/2) fine sandy loam; very dark grayish brown (10YR 3/2) when moist; weak, coarse, prismatic structure breaking to weak, coarse, angular blocky; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual, irregular boundary.

B3—27 to 36 inches, dark grayish-brown (10YR 4/2) loamy fine sand; very dark grayish brown (10YR 3/2) when moist; weak, coarse and medium, subangular blocky structure; soft or loose when dry and nonsticky and nonplastic when wet; gradual boundary.

C1—36 to 42 inches, light olive-brown (2.5Y 5/4) coarse sandy loam; dark grayish brown (2.5Y 4/3) when moist; weak crumb structure; soft or loose when dry and nonsticky and nonplastic when wet; abrupt boundary.

IIC2ca—42 to 54 inches, pale-yellow (2.5Y 7/4) loam; mottled with dark grayish brown, light brownish gray, and olive brown (2.5Y 4/2, 6/2, and 4/4) when moist; weak blocky structure; friable when moist and slightly sticky and nonplastic when wet; strongly calcareous; stony contact layer at upper boundary or horizon; clear boundary.

IIC3—54 to 60 inches, light yellowish-brown and light-gray (2.5Y 6/3 and 7/2) loam; light olive brown and light brownish gray (2.5Y 5/4 and 6/2) when moist; weak blocky structure; slightly hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous.

The A and B horizons range from 15 to 40 inches in thickness. Mottling occurs below a depth of 20 inches. Either a C horizon or a Cca horizon is present in some places and not in others; where it is present, it ranges from sandy loam to fine sand in texture and from noncalcareous to strongly calcareous. The depth to the IIC horizon ranges from 15 to more than 60 inches. In some places free lime has been leached out of the uppermost few inches of this horizon. In places the lower part of the underlying material has a layer of loamy fine sand.

Embden soils are less well drained than Egeland soils, and they have a thicker surface layer.

Embden-Egeland fine sandy loams, level (0 to 3 percent slopes) (EgA).—Most commonly, the areas of this complex are about half Embden fine sandy loam and half Egeland fine sandy loam, but the proportion of either is as little as 25 percent in some areas and as much as 75 percent in some. The Embden soil has slightly concave slopes, and the Egeland soil has convex slopes.

Both of these soils have profiles similar to the ones described as typical of their respective series, but the underlying material, to a depth of 48 inches or more, consists of layers of fine sandy loam and loamy fine sand.

These soils are highly susceptible to wind erosion, and there are moderately eroded spots in many cultivated areas. In these spots, the plow layer has a brownish color, and along the field edges are ridges of accumulated windblown material. A few areas north of Bowdon, in which the subsoil is loamy fine sand, are somewhat more droughty than other areas.

About 80 percent of the acreage is cultivated. (Capability unit IIIe–3; Sandy range site)

Embden-Egeland fine sandy loams, till substratum, level (0 to 3 percent slopes) (EIA).—Most commonly, the areas of this complex are half Embden fine sandy loam and half Egeland fine sandy loam, but the proportions vary from place to place. The Egeland soil is on the slightly higher parts of the landscape. There are a few shallow depressions and scattered surface stones. Figure 14 shows the relationship of soils and underlying material in this complex.

Both of these soils have profiles similar to the ones described as typical of their respective series, but the substratum contains loam-textured glacial till. The depth to the till varies but is generally about 36 inches. The upper part of the substratum commonly has a sandy texture.

These soils are highly susceptible to erosion. In many cultivated areas there are spots where so much soil has been lost through erosion that part of the subsoil has been mixed into the plow layer, which consequently has a brownish color. Small ridges of windblown material along field borders are common.

Most of the acreage is cultivated. (Capability unit IIIe–3; Sandy range site)

Emrick Series

The Emrick series consists of deep, moderately well drained soils that formed in glacial deposits.

In a typical profile, the surface layer, 8 to 12 inches thick, is black loam over very dark brown loam. The subsoil is very dark grayish-brown loam about 9 inches thick. The underlying material is olive-brown, limy loam.

Emrick soils have slow surface drainage and moderate permeability.

These soils are well suited to crops, grass, and trees.

Typical profile of Emrick loam, located 115 feet east and 160 feet north of the southwest corner of sec. 9, T. 148 N., R. 69 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

A1—7 to 11 inches, dark grayish-brown (10YR 4/2) loam; very dark brown (10YR 2/2) when moist; weak, medium, blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; gradual boundary.

B2—11 to 20 inches, grayish-brown (10YR 5/2) loam; very dark grayish brown (10YR 3/2) when moist; moderate, medium, prismatic structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; irregular boundary.

C1ca—20 to 40 inches, light olive-brown (2.5Y 5/3) loam; olive brown (2.5Y 4/3) when moist; weak, medium to coarse, blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; common threads of lime; clear boundary.

IIC2ca—40 to 46 inches, light yellowish-brown (2.5Y 6/3) loam; light olive brown (2.5Y 5/4) when moist; weak, coarse, blocky structure; slightly hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual boundary.

IIC3—46 to 60 inches, olive-gray (5Y 5/2) loam; olive brown (2.5Y 4/3) when moist; weak blocky structure; slightly hard when dry, friable when moist, and sticky and plastic when wet; moderately calcareous.

The A and B2 horizons range from loam to silt loam in texture. The B2 and C1 horizons have a color hue of 10YR or 2.5Y. The C1 horizon ranges from silt loam to fine sandy loam in texture. Between the C1 and the IIC2 horizons in some places is a thin contact layer of loam to loamy sand that contains pebbles, cobblestones, and other stones. Coarse fragments are generally more numerous in the IIC horizon than in the other horizons. Salt crystals are common in the underlying glacial till.

Emrick soils have a thicker black surface layer than Heimdal soils.

Emrick loam is an extensive part of mapping units that make up about 32 percent of Wells County. Samples of this soil, taken at several locations, were tested by the laboratory methods described in Soil Survey Investigations Report No. 1, United States Department of Agriculture, 1967. The results of these tests are summarized, as follows:

The reaction of soil paste increases from a pH of 6.5 at the surface to a pH of 8.3 at a depth of 60 inches, and that of a 1–5 dilution in water increases from a pH of 7.0 at the surface to a pH of 9.0 at a depth of 60 inches. The content of organic carbon in the plow layer is 1.77 per-

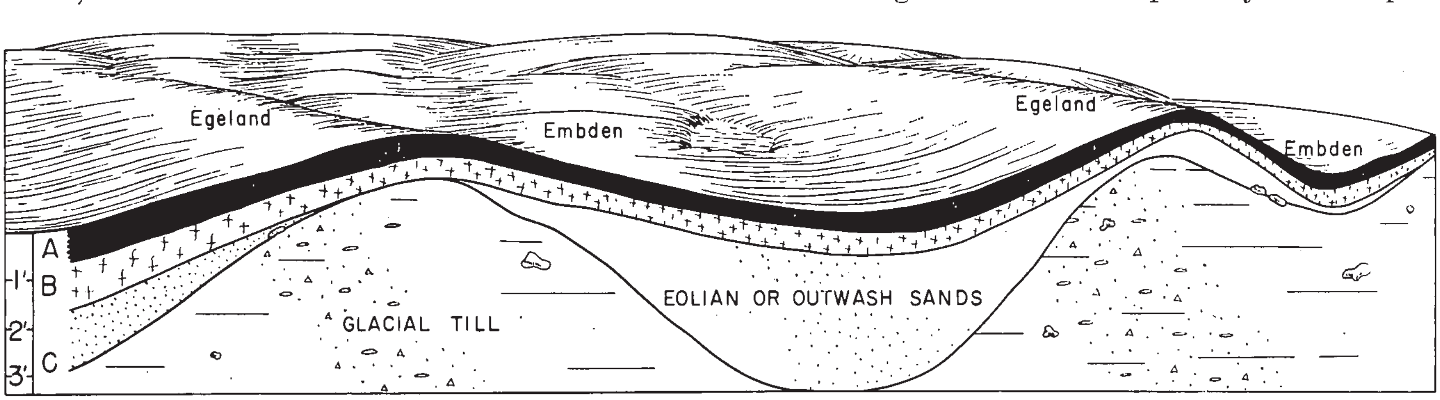

Figure 14.—**Embden-Egeland fine sandy loams, till substratum, level: relationship of soils and underlying material. A is the surface layer, B is the subsoil, and C is the underlying material.**

cent (3.2 percent organic matter) and, decreasing regularly with depth, is 0.92 percent at a depth of 17 inches and 0.12 percent at a depth of 60 inches.

The calcium carbonate equivalent is 1 percent at a depth of 13 to 17 inches, 12 percent at a depth of 17 to 32 inches, and 9 percent at a depth of 32 to 60 inches.

The content of pebbles in the various layers ranges from 0.1 to 2.5 percent; that of very coarse sand from 0.5 to 4.2 percent; that of coarse sand from 1.5 to 5 percent; that of medium sand from 2.2 to 5.8 percent; that of fine sand from 8.4 to 19.4 percent; that of very fine sand from 13.6 to 27.4 percent; that of silt from 31.1 to 41.3 percent; and that of clay from 13.2 to 23.4 percent. All the layers have a texture of loam or very fine sandy loam.

The content of moisture in dry samples of disturbed soil material ranges from 6.2 to 9.2 percent.

The apparent specific gravity or bulk density is 1.30 to 1.32 to a depth of 32 inches and is 1.45 in the 46- to 60-inch layer.

Pores too large to hold capillary water occupy 8.3 to 11.4 percent of the soil. The total pore space ranges from 51.0 percent in the plow layer to 45.1 percent at a depth of 60 inches. The permeability of the soil to water that has a ½-inch head in a core 3 inches long is 1.7 inches per hour in the plow layer, 2.6 inches per hour at a depth of 13 to 32 inches, and 0.5 inch per hour at a depth of 60 inches. When saturated, this Emrick soil has 32.5 to 43.7 percent water by weight.

The conductivity is 1.2 millimhos in the surface layer and ranges from 0.6 to 0.8 millimho in the lower layers.

The content of soluble salts is less than 0.2 percent. The milliequivalents of sodium per liter in the saturation extract range from 0.3 in the uppermost 13 inches to 4.9 at a depth of 46 to 60 inches, and those of potassium per liter in the saturation extract are 0.8 in the surface layer and 0.2 in the other layers.

The exchange capacity in the plow layer is 19.6 milliequivalents per 100 grams of soil and, decreasing with depth, is 8.7 at a depth of 32 to 45 inches and 14.6 in the 45- to 60-inch layer.

The exchangeable cations are mostly calcium and magnesium. The content of sodium and potassium is low except in the 45- to 60-inch layer where the exchangeable sodium is 6 percent.

Emrick-Larson loams (0 to 3 percent slopes) (Em).—This complex occurs as small, irregularly shaped areas. About 40 percent of each area is Emrick loam, about 25 percent is Larson loam, about 25 percent is Heimdal loam, and the rest consists of included soils. Included in mapping were small, scattered tracts of the Exline and Miranda soils and, in the potholes that dot the landscape, Tonka silt loam. Figure 15 shows the relationship of soils and underlying material in this complex.

The Emrick (fig. 16), Larson, and Heimdal soils in this unit have profiles similar to the ones described as typical of their respective series. The Larson soil has a claypan.

About 75 percent of the acreage is cultivated. In cultivated areas there are spots where part of the subsoil of the Exline, Miranda, and Larson soils has been mixed into the surface layer. These are called gumbo spots. They are a nuisance in farming. (Capability unit IIIs–P; Silty range site)

Eroded sandy land (Er).—This land type is characterized by hummocks that are generally less than 4 feet high. On knobs there are blowouts and eroded spots where the underlying material is exposed. Along fence lines and field borders and in many swales, as much as 2 feet of dark-colored material has been deposited on the surface of the soil. These areas of erosion and deposition make up 60 percent of the acreage.

The entire acreage has been cultivated, but most of it is now in grass. (Capability unit VIe–Sa; Sands range site)

Exline Series

The Exline series consists of poorly drained soils that formed in glacial melt-water deposits.

In a typical profile, the surface layer consists of about 3 inches of black loam over about 1 inch of dark-gray loam. The subsoil consists of about 4 inches of very dark grayish-brown clay over very dark grayish-brown, limy, saline clay loam. The underlying material is olive brown in the upper part and mottled light olive brown, gray, and pale yellow in the lower part. This layer contains a moderate amount of lime.

Exline soils have poor surface drainage and, because of the combination of a clayey subsoil and salinity, they have very slow permeability.

These soils are best suited to grass.

Typical profile of Exline loam.

A1—0 to 3 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

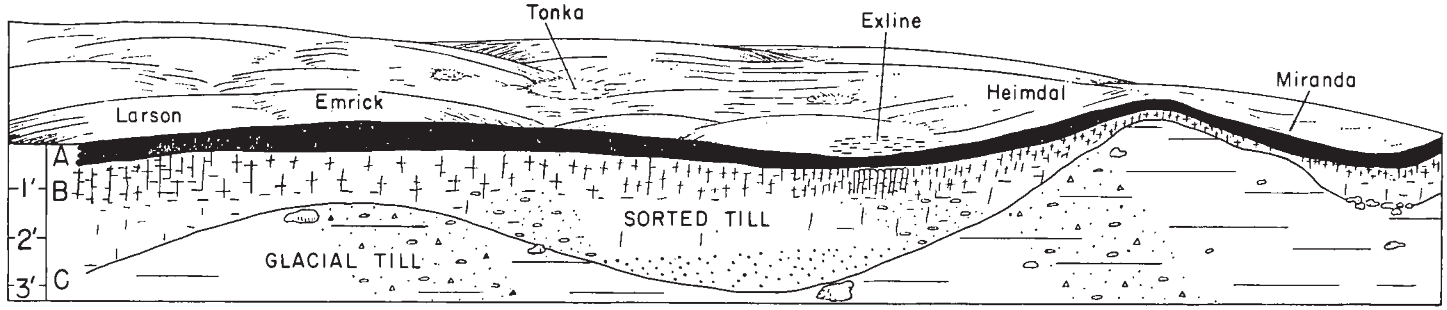

Figure 15.—Emrick-Larson loams: relationship of soils and underlying material. A is the surface layer, B is the subsoil, and C is the underlying material.

Figure 16.—**Profile of Emrick loam.**

A2—3 to 4 inches, light-gray (10YR 7/1) loam; dark gray (10YR 4/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

B21—4 to 8 inches, dark-gray (10YR 4/1) clay; very dark grayish brown (10YR 3/2) when moist; strong, coarse, columnar structure; coatings of black (10YR 2/1), when moist, on sides of columns; extremely hard when dry, very firm when moist, and sticky and plastic when wet; clear, irregular boundary.

B22—8 to 19 inches, dark grayish-brown (10YR 4/2) clay loam; very dark grayish brown (10YR 3/2) when moist; strong, coarse, prismatic structure breaking to moderate, medium, blocky; coatings of black (10YR 2/1), when moist, on prisms and blocks; extremely hard when dry, firm when moist, and sticky and plastic when wet; weakly calcareous; few small nests of gypsum crystals; gradual, irregular boundary.

C1—19 to 31 inches, light olive-brown (2.5Y 5/3) clay loam; olive brown (2.5Y 4/3) when moist; weak blocky structure; very hard when dry, firm when moist, and sticky and plastic when wet; moderately calcareous; clear, irregular boundary.

IIC2—31 to 60 inches, mottled light yellowish-brown, grayish-brown, and white (2.5Y 6/4, 5/2, and 8/2) clay loam (glacial till); light olive brown, gray, and pale yellow (2.5Y 5/4, 5/1, and 7/4) when moist; weak blocky structure; hard when dry, firm when moist, and sticky and plastic when wet; moderately calcareous.

The A horizon ranges from less than an inch to 8 inches in thickness. The B horizon may be black instead of very dark grayish brown in places. The depth to lime ranges from about 6 inches to 30 inches. The depth to visible gypsum crystals ranges from 4 to 60 inches. The C horizon ranges from sand to clay in texture, and in some places it has considerable stratification.

Exline soils are shallower to a strongly saline layer than Aberdeen soils.

Exline soils (0 to 1 percent slopes) (Ex).—These soils have an uneven surface; the microrelief is no more than a few inches. In the highest spots, the surface layer is less than an inch thick and in the lowest, it is about 2 inches thick. In cultivated areas the surface layer is loam, and in uncultivated areas it is clay loam. The underlying material is loamy sand or sand. The water table is within 5 feet of the surface, and extra moisture runs in from adjacent areas.

These soils are not suitable for cultivation. Almost all the acreage is in grass. (Capability unit VIIs–SS; Saline Subirrigated range site)

Fargo Series

The Fargo series consists of deep, poorly drained soils that formed in glacial-lake sediments. These soils receive runoff from adjacent areas.

In a typical profile, the surface layer is black silty clay and clay about 18 inches thick. Beneath this is a 10-inch transitional layer of very dark gray clay, into which tongues of black soil material from the surface layer extend. In the lower part of this transitional layer are spots and threads of lime. Below a depth of 28 inches the underlying material is dark grayish-brown clay that has nests of gypsum crystals in the lower part.

Fargo soils have slow to ponded surface drainage and slow permeability.

These soils are suited to small grain, grass, legumes, and trees.

Typical profile of Fargo silty clay, located in a cultivated field, 0.2 mile east and 120 feet south of the northwest corner of sec. 34, T. 145 N., R. 70 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) silty clay; black (10YR 2/1) when moist; moderate, medium, crumb and granular structure; hard when dry, friable when moist, and sticky and plastic when wet; abrupt boundary.

A1—6 to 18 inches, dark-gray (N 4/0) clay; black (10YR 2/1) when moist; strong, very fine, angular blocky structure; very hard when dry, firm when moist, and very sticky and very plastic when wet; clear, irregular boundary.

AC1ca—18 to 28 inches, dark-gray (N 4/0) clay; very dark gray (2.5Y 3/1) when moist; tongues of black (10YR 2/1) and spots of dark gray (5Y 4/1); moderate, very fine, angular blocky structure; very hard when dry, firm when moist, and very sticky and very plastic when wet; moderately calcareous; common nodules of lime; clear, irregular boundary.

C2g—28 to 42 inches, grayish-brown (2.5Y 5/1) clay; dark grayish brown (2.5Y 4/2) when moist; weak blocky structure; extremely hard when dry, firm when moist, and very sticky and very plastic when wet; moderately calcareous; gradual, irregular boundary.

C3cs—42 to 60 inches, grayish-brown (2.5Y 5/2) clay; dark grayish brown (2.5Y 4/2) when moist; many fine mottles of light olive brown (2.5Y 5/3); weak blocky structure; very hard when dry, firm when moist, and very plastic and very sticky when wet; moderately calcareous; few small nests of gypsum crystals.

The A horizon ranges from silty clay to clay in texture and from 8 to 30 inches in thickness. In a few places the lower part of the A horizon has prismatic instead of angular blocky structure. Tongues from the A horizon occasionally extend to a depth of as much as 50 inches. In a few places there is a very thin discontinuous A2 horizon on the top and sides of large prisms at a depth of 8 to 18 inches. The depth to lime ranges from 8 to 40 inches. Gypsum occurs at depths ranging from 36 to 52 inches.

Fargo soils are more poorly drained than Nutley soils and they have a thicker surface layer. They are better drained than Dimmick soils.

Fargo-Aberdeen complex (0 to 1 percent slopes) (Fa).—Fargo silt loam is the dominant soil in this complex. Aberdeen silty clay loam makes up about 25 percent of the acreage; it generally occurs on the lower parts of the landscape, as circular areas, 10 to 100 feet across, encircled by Fargo silt loam. The areas in the west-central part of the county include some Overly silty clay loam and some moderately saline soils that do not have a claypan. Those in the southwestern part include some Forman clay loam. The Overly and Forman soils are on the slightly higher parts of the landscape.

The Fargo soil in this unit has a profile similar to the one described as typical of the series, but the surface layer is silty clay loam instead of silty clay. The Aberdeen soil has a profile similar to the one described as typical of the Aberdeen series. Spots of the Aberdeen soil where the original surface layer was thin are now gumbo spots.

Most areas of this complex are cultivated. Stripcropping and good use of crop residue are necessary, because of a moderate hazard of wind erosion. Including grasses and legumes in the cropping system helps to improve tilth and maintain fertility. (Capability unit IIIs–P; Clayey range site)

Fargo silty clay (0 to 1 percent slopes) (Fc).—This soil is in the southern part of the county. Water ponds on the smooth surface for a few days after rain. Some areas are in shallow depressions. Areas in native grass have hexagonal mounds 2 to 6 feet across separated by depressed rings 3 to 8 inches deep.

This soil swells when wet and shrinks when dry. Consequently, cracks form in the surface layer as it dries. Wind erosion is a severe hazard on summer-fallow land late in winter and early in spring.

Most of the acreage is cultivated. (Capability unit IIwe–4; Clayey range site)

Forman Series

The Forman series consists of deep, well-drained soils that formed in glacial deposits.

In a typical profile, the surface layer is black clay loam about 6 inches thick, and the subsoil is very dark grayish-brown clay loam about 10 inches thick. The underlying material consists of light olive-brown and light brownish-gray clay loam over dark grayish-brown and light olive-brown loam.

Forman soils have good surface drainage and moderately slow permeability.

These soils are suited to crops, grass, and trees.

Typical profile of Forman clay loam, located 240 feet south and 105 feet west of the northeast corner of the SE¼ sec. 31, T. 145 N., R. 70 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) clay loam; black (10YR 2/1) when moist; cloddy; slightly hard when dry, friable when moist, and sticky and plastic when wet; abrupt boundary.

B2t—6 to 16 inches, olive-brown (2.5Y 4/3) clay loam; very dark grayish brown (2.5Y 3/2) when moist; coatings of very dark gray on prisms; moderate, medium, prismatic structure; hard when dry, friable when moist, and sticky and plastic when wet; clear, irregular boundary.

C1ca—16 to 25 inches, light yellowish-brown and light-gray (2.5Y 6/3 and 7/2) clay loam; light olive brown and light brownish gray (2.5Y 5/4 and 6/2) when moist; weak blocky structure; slightly hard when dry, friable when moist, and sticky and plastic when wet; strongly calcareous; clear, wavy boundary.

IIC2—25 to 60 inches, light brownish-gray (2.5Y 6/2) and yellowish-brown (10YR 5/6) loam; dark grayish brown and light olive brown (2.5Y 4/2 and 5/6) when moist; weak blocky structure; slightly hard when dry, friable when moist, and sticky and plastic when wet; moderately calcareous.

The solum ranges from 12 to 24 inches in thickness. The B2 horizon has a color hue of 10YR or 2.5Y. In places there is a B3ca horizon. The C and IIC horizons range from loamy sand to silty clay loam in texture and in many places are stratified. In the places where these horizons have a texture of loamy sand or sandy loam, they are below a depth of 40 inches. Pebbles and cobblestones are common throughout the profile.

Forman soils are coarser textured than Nutley soils.

Forman clay loam, nearly level (0 to 3 percent slopes) (FoA).—This soil generally occurs on the lower part of slopes and in swales. There are scattered small depressions. Included in mapping were Nutley silty clay and Fargo silty clay.

This soil has high water-holding capacity and high natural fertility. It is moderately susceptible to wind erosion and water erosion.

This soil is well suited to the crops commonly grown in the county. About 80 percent of the acreage is cultivated. (Capability unit IIe–4; Clayey range site)

Forman clay loam, undulating (3 to 6 percent slopes) (FoB).—This soil is generally on the lower part of slopes and in swales. Small potholes are common. The profile is similar to the one described as typical of the series, but on the higher and steeper parts of slopes the surface layer and subsoil are generally thinner. Included in mapping were small areas of Nutley silty clay and Fargo silty clay.

The water-holding capacity is high. Cultivated areas are moderately susceptible to wind erosion and water erosion. In places so much erosion has taken place that the plow layer consists partly of light-colored material from the subsoil and, in a few spots, from the substratum.

This soil is well suited to the commonly grown crops. About 80 percent of the acreage is cultivated. (Capability unit IIe–4; Clayey range site)

Fram Series

The Fram series consists of deep, moderately well drained soils that have lime at or near the surface. These soils formed in medium-textured glacial deposits. A seasonal high water table contributes to the accumulation of lime at or near the surface.

In a typical profile, the 7-inch surface layer is black loam that contains a small amount of lime. The underlying material consists of 11 inches of dark grayish-brown and light brownish-gray loam over light olive-brown to olive-brown loam. The upper part of the underlying material contains a large amount of lime.

Fram soils have slow surface drainage and moderate permeability.

These soils are suited to crops, grass, and trees.

Typical profile of Fram loam, located 45 feet north and 385 feet west of the southeast corner of sec. 13, T. 148 N., R. 70 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

C1ca—7 to 18 inches, grayish-brown and light-gray (2.5Y 5/2 and 7/2) loam; dark grayish brown and light brownish gray (2.5Y 4/2 and 6/2) when moist; weak, coarse, blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; few tongues from the A horizon; gradual, irregular boundary.

C2—18 to 38 inches, light yellowish-brown (2.5Y 6/3) loam; light olive brown (2.5Y 5/3) when moist; weak, coarse, blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; clear, wavy boundary.

IIC3—38 to 46 inches, light olive-brown (2.5Y 5/4) loam (glacial till); olive brown (2.5Y 4/4) when moist; weak blocky structure; hard when dry, friable when moist, and sticky and plastic when wet; moderately calcareous; few small nests of gypsum crystals; gradual, irregular boundary.

IIC4—46 to 60 inches, light olive-brown (2.5Y 5/4) loam (glacial till); olive brown (2.5Y 4/4) when moist; weak blocky structure; hard when dry, friable when moist, and sticky and plastic when wet; moderately calcareous; few rust mottles; common nests of gypsum crystals.

The A horizon ranges from loam to silt loam in texture and from 5 to 12 inches in thickness. It is noncalcareous to moderately calcareous. The C1 horizon has a color hue of 2.5Y or 10YR and a chroma ranging from 2 to 4. The depth to the loam-textured glacial till ranges from 15 to more than 60 inches. In places where the depth to glacial till is more than 30 inches, the C horizon ranges from silt loam to loamy fine sand in texture. In a few places a contact layer of sand, gravel, and stones is between the C horizon and the underlying till (IIC horizon).

Fram soils are better drained than Borup soils.

Fram loam (0 to 3 percent slopes) (Fr).—This soil has the profile (fig. 17) described as typical of the series. It has a high water table for short periods, usually during spring thaws and in wet seasons, but the surface layer is rarely saturated for more than a few days. In many areas there are a few scattered stones. In a few areas there are saline spots, 5 to 20 feet across. Such spots are more numerous after one or more unusually wet years.

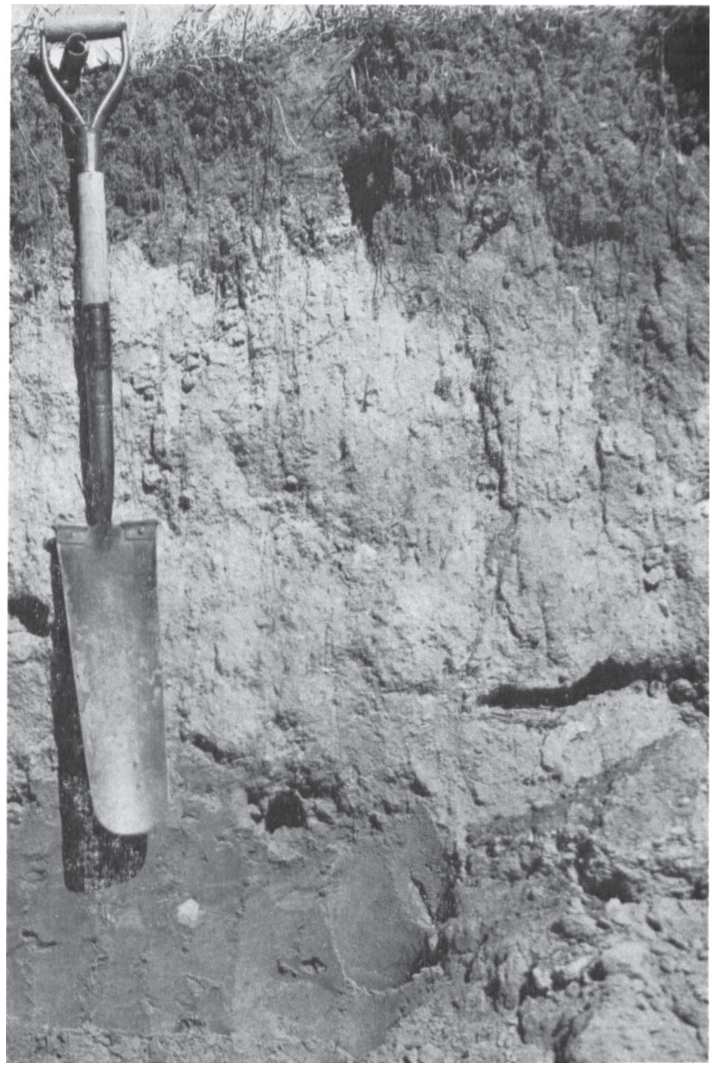

Figure 17.—**Profile of Fram loam.**

Included in mapping were areas of Emrick loam, which makes up about 15 percent of the acreage; of Borup silt loam, which makes up about 10 percent; and of Tonka silt loam, which makes up about 10 percent. Also included were a few areas that have slopes of 3 to 6 percent.

Wind erosion is a hazard. In places so much erosion has taken place that the plow layer consists partly of limy material from the subsoil. The plow layer is grayer in these places than in others.

Most of the acreage is cultivated. The saline spots produce poor stands of crops, particularly in a dry year that follows one or more unusually wet years. Good use of crop residue is necessary for control of wind erosion. (Capability unit IIe-4L; Silty range site)

Gardena Series

The Gardena series consists of deep, moderately well drained soils that formed in medium-textured glacial melt-water deposits.

In a typical profile, the 9-inch surface layer is black loam, and the 12-inch subsoil consists of very dark grayish-brown loam over dark grayish-brown loam. The underlying material consists of a layer of grayish-brown loam over a layer of light olive-brown fine sandy loam.

Gardena soils have slow surface drainage and moderate permeability.

These soils are well suited to crops, grass, and trees.

The Gardena soils in this county are mapped only in a complex with Eckman soils.

Typical profile of Gardena loam, located in a cultivated area, 1,200 feet east and 150 feet north of the southwest corner of sec. 8, T. 148 N., R. 71 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

A1—6 to 9 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; clear, irregular boundary.

B21—9 to 17 inches, dark grayish-brown (10YR 5/2) loam; very dark grayish brown (10YR 3/2) when moist; moderate, medium, prismatic structure; coatings of very dark brown on sides of prisms; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; gradual, irregular boundary.

B22—17 to 21 inches, grayish-brown (10YR 5/2) loam; dark grayish brown (10YR 4/2) when moist; weak, coarse, prismatic structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; clear, irregular boundary.

C1ca—21 to 29 inches, light-gray (2.5Y 7/2) loam; grayish brown (2.5Y 5/3) when moist; weak, medium, blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual, wavy boundary.

C2—29 to 42 inches, light yellowish-brown (2.5Y 6/3) fine sandy loam; light olive brown (2.5Y 5/4) when moist; weak, medium, crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; moderately calcareous; gradual boundary.

C3—42 to 60 inches, grayish-brown (2.5Y 5/3) stratified very fine sandy loam and fine sandy loam; olive brown (2.5Y 4/3) when moist; very friable; weakly calcareous.

The A horizon ranges from loam to silt loam in texture and from 8 to 18 inches in thickness. The B horizon ranges from loam to silt loam in texture, and in places the B21 horizon is very dark brown instead of very dark grayish brown. Below a depth of 24 inches, the C horizon ranges from silt loam to fine sand in texture, but the fine sand occurs at depths of more than 36 inches. In places the C horizon is loam-textured glacial till.

Gardena soils are associated with Eckman soils. They are less well drained and have a thicker surface layer than Eckman soils. Gardena soils differ from Fram soils in that they have a B horizon.

Gardena-Eckman loams (0 to 3 percent slopes) (Ge).—About half of each area of this complex is Gardena loam, and about half is Eckman loam. The Gardena soil is in the lower areas and has concave slopes; the Eckman soil is in the higher areas and has convex slopes.

The Gardena soil in this complex has the profile described as typical of the series. The Eckman soil has a profile similar to the one described for the Eckman series.

These soils are well suited to the commonly grown crops. About 90 percent of the acreage is cultivated. Wind erosion is a hazard, particularly in a few spots where the surface layer is a coarse loam. (Capability unit IIe–5; Silty range site)

Hamar Series

The Hamar series consists of deep, somewhat poorly drained soils that formed in outwash or eolian sand. These soils have a seasonal high water table.

In a typical profile, the surface layer is black fine sandy loam about 13 inches thick. The underlying material consists of very dark grayish-brown loamy fine sand over dark grayish-brown loamy fine sand mottled with dark yellowish brown. Below this is a layer of very dark gray and dark gray, limy fine sandy loam mottled with brown.

Hamar soils have very slow surface drainage.

These soils are suited to small grain, flax, grass, legumes, and trees.

The Hamar soils in this county are mapped only in an undifferentiated unit with Ulen soils.

Typical profile of Hamar fine sandy loam, located 35 feet west and 80 feet north of the southeast corner of the SE¼ sec. 18, T. 147 N., R. 70 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) fine sandy loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

A1—6 to 13 inches, dark-gray (10YR 4/1) fine sandy loam; black (10YR 2/1) when moist; weak, coarse, prismatic structure; soft when dry, friable when moist, and nonsticky and nonplastic when wet; clear, irregular boundary.

C1g—13 to 24 inches, dark grayish-brown (10YR 4/2) loamy fine sand; very dark grayish brown (10YR 3/2) when moist; common medium mottles of dark yellowish brown (10YR 4/4) when moist; weak, coarse, blocky structure; soft or loose when dry and nonsticky and nonplastic when wet; gradual, wavy boundary.

C2g—24 to 45 inches, light brownish-gray (10YR 6/2) loamy fine sand; dark grayish brown (10YR 4/2) when moist; common medium mottles of dark yellowish brown (10YR 4/4) when moist; weak crumb structure; loose when dry and nonsticky and nonplastic when wet; gradual, wavy boundary.

IIC3g—45 to 52 inches, gray (10YR 5/1) fine sandy loam; very dark gray and dark gray (10YR 3/1 and 4/1) when moist; common, medium, prominent mottles of brown (10YR 5/3) when moist; weak crumb structure; hard when dry, very friable when moist, and nonsticky and nonplastic when wet; strongly calcareous; clear boundary.

IIC4g—52 to 60 inches, pale-brown (10YR 6/3) loamy fine sand; dark grayish brown (10YR 4/2) when moist; common, medium, distinct mottles of brownish yellow (10YR 6/6) when dry; weak crumb structure; slightly hard to loose when dry and nonsticky and nonplastic when wet; weakly calcareous.

The A horizon ranges from 8 to 24 inches in thickness. The depth to lime ranges from 30 to 60 inches. In a few places gypsum crystals are evident in the calcareous lower horizons. In a few places there are strata of medium-textured material below a depth of 50 inches.

Hamar soils are more poorly drained than Embden and Hecla soils.

Hamerly Series

The Hamerly series consists of deep, moderately well drained soils that are limy at or near the surface. These soils formed in loam-textured glacial till.

In a typical profile, the 5-inch surface layer is very dark gray loam that contains a moderate amount of lime. The underlying material consists of about 11 inches of light olive-brown, very limy loam over olive-brown, moderately limy loam. Below a depth of 32 inches is a layer of olive-brown and gray, moderately limy loam mottled with black and rust brown.

The Hamerly soils have medium surface drainage and moderate permeability.

These soils are suited to crops, grass, and trees.

A typical profile of Hamerly loam, located 700 feet north and 100 feet east of the southwest corner of sec. 20, T. 146 N., R. 70 W.

Ap—0 to 5 inches, gray (10YR 5/1) loam; very dark gray (10YR 3/1) when moist; many fine spots of white (10YR 8/1) lime segregation; weak, fine, crumb structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; few pebbles, cobblestones, and stones; abrupt boundary.

C1ca—5 to 16 inches, light brownish-gray (2.5Y 6/3) loam; light olive brown (2.5Y 5/4) when moist; weak, very coarse, prismatic structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; few pebbles, cobblestones, and stones; gradual, irregular boundary.

C2—16 to 32 inches, light olive-brown (2.5Y 5/4) loam; olive brown (2.5Y 4/4) when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; few nodules and threads of lime; few nests of gypsum crystals; few pebbles, cobblestones, and stones; gradual, irregular boundary.

C3—32 to 60 inches, light yellowish-brown and gray (2.5Y 6/3 and 6/1) loam; olive brown and gray (2.5Y 4/4 and 5/1) when moist; black and rust-brown mottles; weak blocky structure; very hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; few threads and nodules of lime; few large nests of gypsum crystals; few pebbles, cobblestones, and stones.

The A horizon ranges from 4 to 12 inches in thickness and from noncalcareous to strongly calcareous. In a few places tongues from the A horizon extend into the underlying C horizon. In most places there are gypsum crystals. Throughout the profile are pebbles, cobblestones, and other stones.

Hamerly soils are better drained than Vallers soils.

Hamerly loam (0 to 3 percent slopes) (Ha).—This soil has the profile described as typical of the series. It is characterized by short choppy slopes, smooth level areas, and many potholes. The surface layer is thickest in the level areas, and it is not more than 5 inches thick in convex sloping areas. The potholes, although numerous, make up only about 5 percent of the acreage. In many areas, there are scattered saline spots, 5 to 20 feet across. Included in mapping were areas of Tonka silt loam, which is in the potholes.

This soil is highly susceptible to wind erosion. In places where there are slopes in cultivated areas, so much erosion has taken place that the plow layer consists partly of material from the subsoil. The plow layer is grayer in these places than in others.

Most of the acreage is cultivated. The potholes do not create a farming problem, but the saline spots produce poor stands of crops. (Capability unit IIe-4L; Silty range site)

Hecla Series

The Hecla series consists of deep, moderately well drained soils that formed in outwash or eolian sand.

In a typical profile, the surface layer is black loamy fine sand about 15 inches thick. Below this is a transitional layer of very dark grayish-brown loamy fine sand about 13 inches thick. The underlying material consists of about 8 inches of brown loamy fine sand over a layer of brown fine sand. These layers have a few mottles of dark yellowish brown and dark brown.

Hecla soils have very slow surface drainage and rapid permeability.

Small grain, corn, grass, legumes, and trees are grown.

The Hecla soils in this county are mapped only in a complex with Maddock soils.

Typical profile of Hecla loamy fine sand, located 0.2 mile south and 140 feet west of the northeast corner of sec. 28, T. 147 N., R. 71 W.

Ap—0 to 8 inches, dark-gray (10YR 4/1) loamy fine sand; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

A1—8 to 15 inches, dark-gray (10YR 4/1) loamy fine sand; black (10YR 2/1) when moist; weak, coarse and medium, blocky structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual, wavy boundary.

AC1—15 to 28 inches, grayish-brown (10YR 5/2) loamy fine sand; very dark grayish brown (10YR 3/2) when moist; few, fine, faint mottles of dark brown (10YR 4/3) when moist; very weak, coarse, prismatic structure; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual, irregular boundary.

C2—28 to 36 inches, pale-brown (10YR 6/3) loamy fine sand; brown (10YR 5/3) when moist; common, medium, prominent mottles of dark yellowish brown (10YR 4/4) when moist, and few, medium, prominent mottles of dark brown (7.5YR 3/2) when moist; weak crumb structure; loose; gradual, wavy boundary.

C3--36 to 52 inches, pale-brown (10YR 6/3) fine sand; brown (10YR 5/3) when moist; few, fine, prominent mottles of dark yellowish brown (10YR 4/4) and dark brown (7.5YR 3/2) when moist; single grain; loose; clear boundary.

C4—52 to 60 inches, light brownish-gray (2.5Y 6/2) fine sand; grayish brown (2.5Y 5/2) when moist; single grain; loose.

The A horizon ranges from 12 to 24 inches in thickness. Below the A horizon there may be a color hue of 2.5Y. Lime occurs below a depth of 24 inches in a few places. The C horizon is loam-textured glacial till in some places.

Hecla soils have better drainage and a thicker surface layer than Maddock soils, which are excessively drained. They are coarser textured than Embden soils.

Hecla-Maddock loamy fine sands (0 to 3 percent slopes) (Hd).—Most areas of this complex are about 60 percent Hecla loamy fine sand and about 40 percent Maddock loamy fine sand. The Hecla soil is level or has concave slopes, and the Maddock soil has convex slopes. Some areas in the northwestern part of the county have a larger proportion of the Maddock soil and a coarser textured substratum than the areas in the central part. Also, the areas where the substratum consists of glacial till have a larger proportion of the Maddock soil. There is little correlation between the surface topography and the depth to the till. Included in mapping were areas of Embden fine sandy loam, which is in swales.

Both of these soils have profiles similar to the ones described as typical of their respective series.

These soils are somewhat droughty and are highly susceptible to wind erosion. Most cultivated areas have small blowout spots where the surface layer and part or all of the subsoil has been lost through erosion. The windblown material has accumulated in small hummocks and ridges.

These soils are poorly suited to crops. A combination of practices is needed to control erosion. (Capability unit IVe–2; Sandy range site)

Heimdal Series

The Heimdal series consists of deep, well-drained, loamy soils that formed in glacial deposits.

In a typical profile, the surface layer is black loam 5 inches thick, and the subsoil is very dark grayish-brown and brown loam. Below the subsoil is a layer of light olive-brown loam that is limy and has gypsum crystals in the lower part.

Heimdal soils have good surface drainage and moderate permeability.

These soils are well suited to crops, grass, and trees.

The Heimdal soils in this county are mapped only in complexes with Emrick and Larson soils.

Typical profile of a Heimdal loam, located 1,340 feet west and 150 feet south of the northeast corner of sec. 14, T. 148 N., R. 70 W.

Ap—0 to 5 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; about 1 percent pebbles, cobblestones, and stones; abrupt boundary.

B21—5 to 14 inches, grayish-brown (10YR 5/2) loam; very dark grayish brown (10YR 3/2) when moist; moderate, coarse and medium, prismatic structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; about 1 percent pebbles, cobblestones, and stones; clear, wavy boundary.

B22—14 to 19 inches, pale-brown (10YR 6/3) loam; brown (10YR 4/3) when moist; moderate, coarse and medium, prismatic structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; about 1 percent pebbles, cobblestones, and stones; clear, wavy boundary.

C1ca—19 to 34 inches, light yellowish-brown (2.5Y 6/3) loam; light olive brown (2.5Y 5/4) when moist; weak, medium, blocky structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; common fine threads of lime; about 1 percent pebbles, cobblestones, and stones; clear boundary.

IIC2—34 to 60 inches, light olive-brown (2.5Y 5/4) loam (glacial till); olive brown (2.5Y 4/4) when moist; weak blocky structure; friable; moderately calcareous; about 1 percent pebbles, cobblestones, and stones.

The A horizon ranges from loam to silt loam in texture, and the B2 and C1 horizons range from loam to fine sandy loam. In places a stone line consisting of fragments the size of pebbles or cobblestones rests on the IIC horizon. Salt crystals are common in the glacial till. Scattered throughout the profile are pebbles, cobblestones, and, in a few places, stones.

Heimdal soils are better drained and have a thinner surface layer than Emrick soils.

Heimdal-Emrick loams, level (0 to 3 percent slopes) (HeA).—This complex occurs as small areas characterized by common, generally shallow depressions and by stones scattered on the surface. The Heimdal soil occupies the more sloping parts of these areas and also occurs in an intricate pattern with the Emrick soil in the level parts. Figure 18 shows the relationship of soils and underlying material in this complex.

About 65 percent of each area is Heimdal loam, about 25 percent is Emrick loam, and the rest consists of small inclusions of Fram loam and Tonka silt loam.

The Heimdal soil has a profile similar to the one described as typical of the series, but in places the surface layer is silt loam instead of loam. The Emrick soil has a profile similar to the one described for the Emrick series, but in places the surface layer is silt loam instead of loam. The depth to the underlying glacial till averages about 32 inches but varies greatly in both soils. The till generally is nearer the surface on knobs and small ridges than in nearly level areas. In some nearly level areas, the depth to till varies widely within short distances. On long, smooth slopes in the northeastern part of the county, the till is at a uniform depth of about 24 inches.

These soils are moderately susceptible to wind erosion. In some areas a layer of stones is close enough to the surface to be a nuisance in cultivating.

These soils are well suited to the common crops, and most of the acreage is cultivated. (Capability unit IIe–5; Silty range site)

Heimdal-Emrick loams, undulating (3 to 6 percent slopes) (HeB).—Heimdal loam occupies undulating areas, and Emrick loam occurs in swales. Slopes are short and irregular. Few are more than 50 feet in length, even

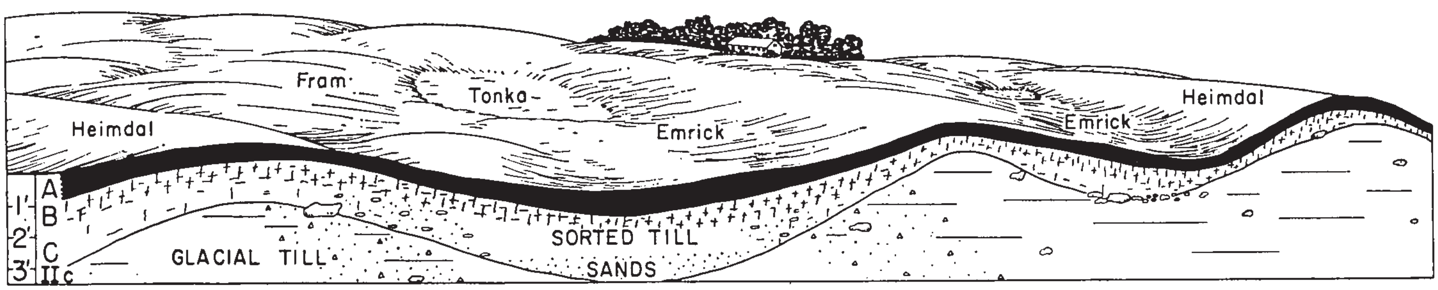

Figure 18.—**Heimdal-Emrick loams, level: relationship of soils and underlying material. A is the surface layer, B is the subsoil, and C is the underlying material.**

where the gradient is more than 4 percent. Stones are scattered on the surface and are generally more numerous on the top of knobs and ridges than in other areas.

About 70 percent of each area consists of the Heimdal soil, about 20 percent of the Emrick soil, and 10 percent of other soils, mainly Tonka silt loam, which is in small depressions, and Fram loam, which surrounds the depressions.

The Heimdal soil in this unit has a profile similar to the one described as typical of the series, but in places the surface layer is silt loam instead of loam. The Emrick soil has a profile similar to the one described for the Emrick series, but in places the surface layer is silt loam instead of loam.

These soils are moderately susceptible to wind erosion. They are well suited to the common crops, and most areas are cultivated. (Capability unit IIe–5; Silty range site)

Heimdal-Larson loams, gently sloping (3 to 6 percent slopes) (HlB).—This complex occurs as scattered, small, irregularly shaped areas, in which circular spots of Larson loam, 10 to 100 feet in diameter, are surrounded by Heimdal loam. The Heimdal soil is on the convex slopes in these areas, and the Larson soil is commonly in the low-lying areas, although in a few places it occurs on higher slopes. Emrick loam is commonly intermixed with the Larson soil in the low-lying areas.

About 40 percent of each area is Heimdal loam; about 15 to 40 percent (averaging 20 percent) is Larson loam; about 25 percent is Emrick loam; and the remaining 15 percent consists of small areas of Fram loam, Miranda loam, Exline loam, and Tonka loam.

These soils are moderately susceptible to water and wind erosion. About 85 percent of the acreage is cultivated. The claypan in the Larson soil creates farming problems. (Capability unit IIIse–P; Silty range site)

LaDelle Series

The LaDelle series consists of deep, well-drained, medium-textured soils that formed in local alluvium.

In a typical profile, the 11-inch surface layer consists of black silt loam, and the subsoil consists of about 13 inches of very dark grayish-brown silt loam over about 14 inches of very dark grayish-brown loam. The underlying material is dark grayish-brown loam that contains a moderate amount of lime. Below a depth of 52 inches in many places is a buried soil.

LaDelle soils have good surface drainage and moderate permeability.

These soils are suited to crops, grass, and trees.

Typical profile of LaDelle silt loam, located 125 feet west and 100 feet south of the northeast corner of the NW¼ sec. 12, T. 147 N., R. 73 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) silt loam; black (10YR 2/1) when moist; weak crumb structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

A1—7 to 11 inches, dark-gray (10YR 4/1) silt loam; black (10YR 2/1) when moist; weak crumb structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; gradual, irregular boundary.

B21—11 to 24 inches, dark grayish-brown (10YR 4/2) silt loam; very dark grayish brown (10YR 3/2) when moist; tongues and coatings of black (10YR 2/1) when moist; weak, coarse, prismatic structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; gradual, irregular boundary.

B22—24 to 38 inches, grayish-brown (10YR 5/2) loam; very dark grayish brown (10YR 3/2) when moist; weak, coarse, prismatic structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; clear, irregular boundary.

Cca—38 to 52 inches, grayish-brown and light-gray (2.5Y 5/2 and 7/2) loam; dark grayish brown (2.5Y 4/2) when moist; weak blocky structure; very hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; common threads and few nodules of lime; clear boundary.

IIAb—52 to 58 inches, dark-gray (10YR 4/1) silt loam; black (10YR 2/1) when moist; weak blocky structure; very hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; common threads of lime; clear boundary.

IIBb—58 to 63 inches, dark grayish-brown and grayish-brown (10YR 4/2 and 5/2) loam; very dark grayish brown and brown (10YR 3/2 and 4/3) when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous.

The A horizon ranges from loam to silt loam in texture and from 6 to 24 inches in thickness. The depth to lime ranges from 16 to 50 inches, and the limy horizons range from weakly calcareous to strongly calcareous. The underlying material ranges from fine sand to clay loam in texture. This material is commonly underlain by a buried soil.

LaDelle soils differ from Gardena soils in that they formed in local alluvium instead of glacial melt-water deposits.

LeDelle silt loam, level (0 to 3 percent slopes) (LaA).—This soil is at the base of steep slopes. Small knobs are scattered over the surface. During periods of heavy runoff from the adjoining slopes, small washout channels are cut and fresh alluvium is deposited.

This soil has a profile similar to the one described as typical of the series. In swales and on fresh alluvial fans, the surface layer is as much as 24 inches thick, but on the small knobs it is generally only about 6 inches thick. In a few areas the underlying material contains layers of sandy material.

About 85 percent of the acreage is cultivated. (Capability unit IIe–5; Silty range site)

LaDelle silt loam, gently sloping (3 to 6 percent slopes) (LaB).—Most areas of this soil occur along the base of steep slopes. They receive runoff from these adjoining slopes, and erosion is a hazard.

The surface layer of this soil is only 6 inches thick, and the depth to calcareous material is only 16 inches.

Most of the acreage is cultivated. Both wind erosion and water erosion are moderate hazards. (Capability unit IIe–5; Silty range site)

Lamoure Series

The Lamoure series consists of deep, somewhat poorly drained to poorly drained soils that formed in alluvium. These soils have a seasonal high water table and receive surface runoff from adjacent uplands.

In a typical profile, the surface layer and subsoil consist of black silty clay loam to a depth of 22 inches. These layers contain a small amount of lime. The underlying material is very dark gray, moderately limy silty clay.

Lamoure soils have slow surface drainage and moderate permeability.

These soils are well suited to grass, and if drained, can be used for cultivated crops and trees.

The Lamoure soils in this county are mapped only with Colvin, Divide, and Exline soils.

Typical profile of a Lamoure silty clay loam, located 2,400 feet west and 130 feet north of the southeast corner of sec. 14, T. 146 N., R. 69 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) silty clay loam; black (10YR 2/1) when moist; moderate, fine, crumb structure; hard when dry, friable when moist, and sticky and plastic when wet; weakly calcareous; abrupt boundary.

B2g—7 to 22 inches, very dark gray (10YR 3/1) silty clay loam; black (N 2/0) when moist; moderate, fine, blocky structure; hard when dry, friable when moist, and very sticky and plastic when wet; weakly calcareous; gradual, irregular boundary.

Cg—22 to 43 inches, dark-gray (2.5Y 4/1) silty clay; very dark gray (2.5Y 3/1) when moist; few prominent mottles of light olive brown; weak, medium, blocky structure; very hard when dry, firm when moist, and very sticky and very plastic when wet; moderately calcareous.

The surface layer and subsoil range from loam to silty clay loam in texture. In places, there are strata of silt loam, silty clay loam, and silty clay, and here and there thin strata of fine sandy loam at depths of 7 to 36 inches. In some areas beds of either coarse sand or gravel occur below a depth of 36 inches. Buried soils are common.

Lamoure soils are less calcareous near the surface than Colvin soils.

Lamoure and Divide soils, channeled (0 to 2 percent slopes) (Ld).—These soils are crisscrossed by entrenched drainage channels (fig. 19), which cause wide variations in drainage within short distances. The areas are flooded occasionally, mainly in spring.

The Lamoure soil in this unit has a profile similar to the one described for the series. In many places there is gravelly material below a depth of 40 inches. The Divide soil has a profile similar to the one described for the Divide series.

These soils are not suitable for cultivation, because of the entrenched channels. They are in native grass. They are susceptible to water erosion unless a good cover is maintained. (Capability unit VIw–Ov; Overflow range site)

Lamoure-Exline complex (0 to 3 percent slopes) (Le).—The soils in this complex have a seasonal high water table and are flooded occasionally. Most areas are about 85 percent Lamoure soil and about 15 percent Exline soil, but a few areas are as much as 30 percent Exline soil.

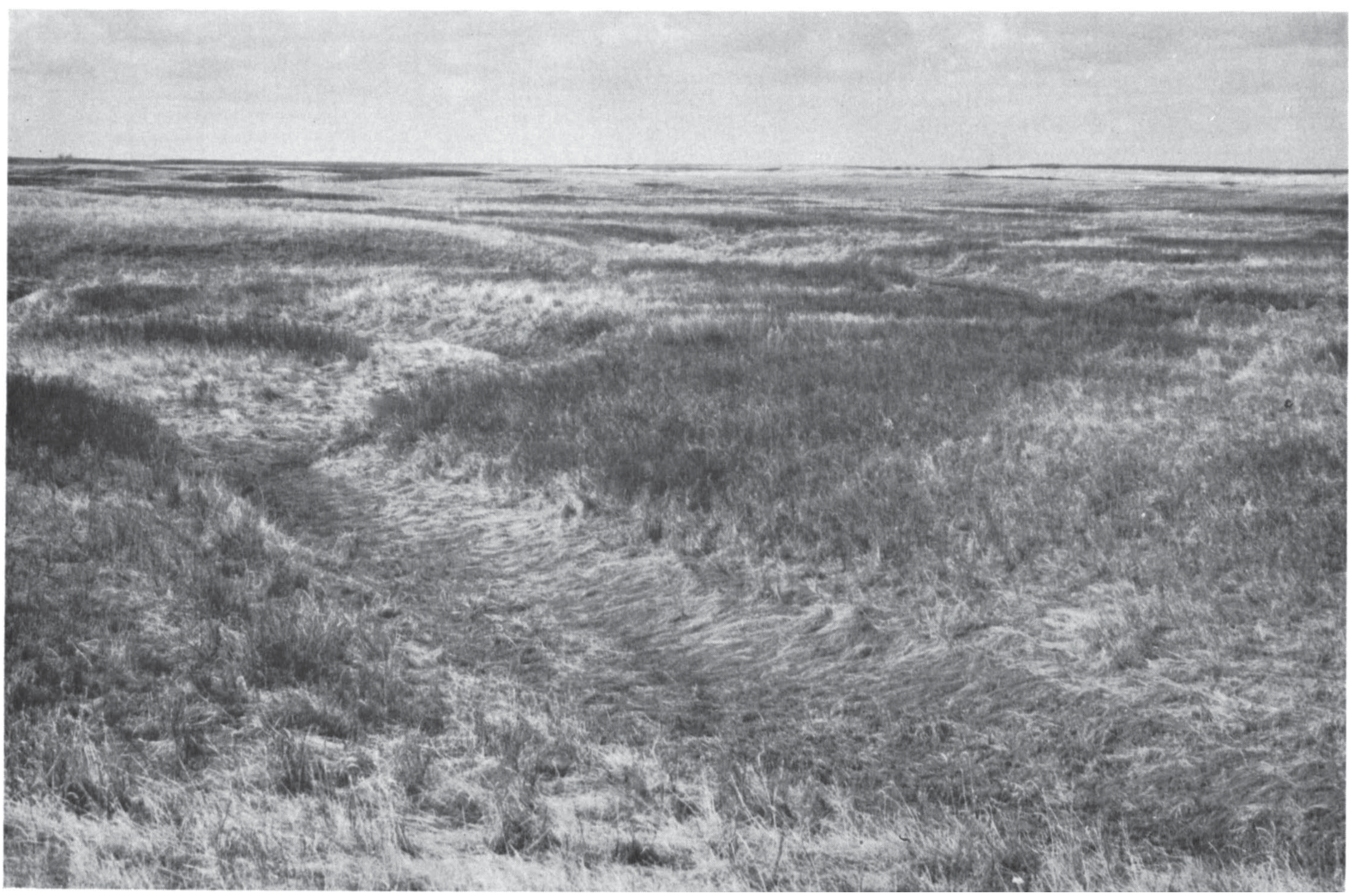

Figure 19.—**Drainage channels in an area of Lamoure and Divide soils, channeled.**

The Lamoure soil in this unit has the profile described as typical of the series, but in some spots, the underlying material contains salt crystals.

The Exline soil has a profile similar to the one described as typical of the Exline series, but the subsoil has weak columnar structure and the underlying material has grayer colors.

Most of the acreage is cultivated. In cultivated areas most spots of the Exline soil have a plow layer of silty clay loam that crusts after a heavy rain. (Capability unit IIIws-4; Overflow range site)

LaPrairie Series

The LaPrairie series consists of deep, moderately well drained soils that formed in alluvium. These soils receive runoff from adjacent uplands, and in spring they have a high water table.

In a typical profile the surface layer consists of about 7 inches of black silt loam over about 11 inches of black clay loam. The underlying material consists of grayish-brown clay loam over dark grayish-brown, strongly calcareous clay loam. Tongues of black material from the surface layer extend into the upper part of the clay loam.

LaPrairie soils have slow surface drainage and moderate permeability.

These soils are well suited to grass, and if drained, they can be used for crops and trees.

The LaPrairie soils in this county are mapped only in an undifferentiated unit with Colvin soils.

Typical profile of LaPrairie silt loam, located 0.2 mile east and 100 feet north of the southwest corner of sec. 20, T. 146 N., R. 69 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) silt loam; black (10YR 2/1) when moist; cloddy; slightly hard when dry, very friable when moist and nonsticky and nonplastic when wet; abrupt boundary.

A1—7 to 18 inches, very dark gray (10YR 3/1) clay loam; black (10YR 2/1) when moist; strong, fine, blocky structure; slightly hard when dry, friable when moist, and sticky and plastic when wet; weakly calcareous; clear, irregular boundary.

C1ca—18 to 30 inches, light brownish-gray (2.5Y 6/2) clay loam; grayish brown (2.5Y 5/2) when moist; many tongues and coatings of dark gray (2.5Y 4/1) and black (10YR 2/1) when moist; weak, coarse, prismatic structure breaking to moderate, fine, blocky; hard when dry, friable when moist, and sticky and plastic when wet; strongly calcareous; gradual, irregular boundary.

C2—30 to 50 inches, grayish-brown (2.5Y 5/2) clay loam; dark grayish brown (2.5Y 4/2) when moist; weak blocky structure; hard when dry, friable when moist, and sticky and plastic when wet; strongly calcareous; gradual boundary.

C3—50 to 60 inches, dark-gray (2.5Y 4/1) loam; very dark grayish brown (2.5Y 3/2) when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; common gypsum crystals.

The A horizon ranges from silt loam to loam in texture and from 16 to 30 inches in thickness. The C horizon has a wide range in texture and in some places is only moderately or weakly calcareous. In many places there is a buried soil below a depth of 24 inches, and in a few places there are beds of sand and gravel below a depth of 36 inches.

Larson Series

The Larson series consists of moderately well drained soils that have a claypan. These soils formed in glacial deposits.

In a typical profile, the 6-inch surface layer is black loam, and the 13-inch subsoil is very dark grayish-brown clay loam. The lower part of the subsoil has gypsum crystals. The uppermost layer of underlying material is light olive-brown, limy clay loam that contains gypsum crystals. Below this is light olive-brown and pale-yellow silt loam and light olive-brown, dark grayish-brown, and gray silty clay loam and loam.

Larson soils have slow surface drainage and slow permeability. The claypan subsoil limits the downward movement of water and air and the growth of plant roots. The salinity of the underlying material limits the root zone.

Larson soils are suited to small grain, grass, and legumes, but they are poorly suited to trees.

The Larson soils in this county are mapped only in complexes with Emrick, Heimdal, and Miranda soils.

Typical profile of Larson loam, located 195 feet south and 210 feet west of the northeast corner of the NW¼ sec. 18, T. 148 N., R. 72 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; cloddy; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and plastic when wet; abrupt boundary.

B2t—6 to 14 inches, dark grayish-brown (10YR 4/2) clay loam; very dark grayish brown (10YR 3/2) when moist; moderate, coarse, prismatic structure breaking to strong, medium, blocky; clay coatings of very dark gray (10YR 3/1), when moist, on prisms and blocks; very hard when dry, friable when moist, and sticky and plastic when wet; clear, irregular boundary.

B3cs—14 to 19 inches, dark grayish-brown (10YR 4/2) clay loam; very dark grayish-brown (10YR 3/2) when moist; moderate, coarse, prismatic structure breaking to moderate, coarse and medium, blocky; clay coatings of very dark gray (10YR 3/1), when moist, on prisms and blocks; hard when dry, friable when moist, and sticky and plastic when wet; common, medium-sized nests of gypsum crystals; gradual, irregular boundary.

C1cs—19 to 25 inches, light yellowish-brown (2.5Y 6/4) clay loam; light olive brown (2.5Y 5/4) when moist; weak blocky structure; hard when dry, friable when moist, and sticky and plastic when wet; common small nests of gypsum; strongly calcareous; gradual, irregular boundary.

C2ca—25 to 35 inches, light yellowish-brown and pale-yellow (2.5Y 6/3 and 7/3) silt loam; light olive brown and pale yellow (2.5Y 5/4 and 7/4) when moist; weak blocky structure; hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual boundary.

C3—35 to 44 inches, light yellowish-brown and pale-yellow (2.5Y 6/4 and 7/3) silty clay loam; light olive brown, dark grayish brown, and gray (2.5Y 5/4, 4/2, and 5/1) when moist; weak blocky structure; hard when dry, friable when moist, and sticky and slightly plastic when wet; moderately calcareous; clear, wavy boundary.

IIC4—44 to 60 inches, light olive-brown and light yellowish-brown (2.5Y 5/4 and 6/3) loam; light olive brown and gray (2.5Y 5/4 and 5/1) when moist; weak blocky structure; slightly hard when dry, friable when moist, and slightly sticky and plastic when wet; moderately calcareous; few gypsum crystals.

The A horizon ranges from 6 to 10 inches in thickness. An A2 horizon can be recognized in a few places when the soil is dry, but not when the soil is moist. The A2 horizon is generally less than 1 inch thick and has weak to moderate platy or very fine blocky structure. The B2 horizon commonly is very dark brown (10YR 2/2) when moist and has strong blocky structure, and the blocks have patchy coatings of material from the A2 horizon. In some places the B horizon has relict, round-topped columns that break to blocks. The lower part of the B horizon may have threads or nodules of lime in a noncalcareous soil mass. Generally there is visible gypsum in some part of the profile. Glacial till occurs at various depths in the profile, and in places a layer of sandy material is in contact with the till.

Larson soils have a thicker surface layer, have a more permeable subsoil, and are finer textured than Miranda and Exline soils.

Larson-Heimdal loams, gently sloping (3 to 6 percent slopes) (LhB).—All areas of this complex are near Sykeston. About 60 percent of each area is Larson loam, about 25 percent is Heimdal loam, and about 15 percent is Emrick loam. The higher, steeper parts of the complex consist of the Larson and Heimdal soils, and the lower, less steep parts of the Larson and Emrick soils. Included in mapping were areas of Miranda loam and Exline loam, mostly in swales.

Both the Larson and the Heimdal soils have profiles that are similar to the ones described for their respective series, but the underlying material is coarser textured.

About 85 percent of the acreage is cultivated. The Larson and Heimdal soils are moderately susceptible to erosion by wind and water. The Larson soil has a claypan that creates a farming problem. (Capability unit IIIse-P; Silty range site)

Larson-Miranda complex (0 to 3 percent slopes) (Lm).—All areas of this complex are near the town of Sykeston. About 50 percent of each area is Larson loam, about 25 percent is Miranda loam, and the remaining 25 percent consists of Emrick loam and Heimdal loam. Included in mapping were areas of Tonka silt loam, in scattered potholes. Also included were a few areas of Larson loam and Miranda loam that are underlain by sand and gravel below a depth of 30 inches.

Both the Larson and Heimdal soils have profiles that are similar to the ones described for their respective series, but the underlying material is coarser textured.

About three-fourths of the acreage is cultivated. Cultivated areas have gumbo spots, which create a problem in farming. The hazard of wind erosion is moderate. (Capability unit IVs-5; Panspots range site)

Letcher Series

The Letcher series consists of soils that have a claypan.

In a typical profile, the 15-inch surface layer consists of fine sandy loam that is black in the uppermost part, very dark grayish brown in the middle part, and dark grayish brown in the lowermost part. The 15-inch subsoil consists of very dark brown clay loam or sandy loam over very dark grayish-brown sandy loam. The underlying material is light olive-brown and light-gray loam (glacial till) that contains a large amount of lime.

Letcher soils have slow surface drainage. Permeability is moderately rapid in the surface layer and very slow in the subsoil and underlying material.

These soils are suited to small grain, flax, corn, grass, and legumes.

Typical profile of Letcher fine sandy loam, located 100 feet east and 100 feet south of the northwest corner of the NE¼ sec. 9, T. 146 N., R. 70 W.

Ap—0 to 8 inches, dark-gray (10YR 4/1) fine sandy loam; black (10YR 2/1) when moist; cloddy; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

A21—8 to 12 inches, dark grayish-brown (10YR 4/2) fine sandy loam; very dark grayish brown (10YR 3/2) when moist; tongues of black (10YR 2/1) when moist; weak, coarse, prismatic structure breaking to weak, coarse, subangular blocky; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; clear, wavy boundary.

A22—12 to 15 inches, grayish-brown (10YR 5/2) fine sandy loam; dark grayish brown (10YR 4/2) when moist; weak, coarse, blocky structure; coatings of grayish brown (10YR 5/2), when moist, on sides of blocks; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

B21t—15 to 20 inches, dark grayish-brown (10YR 4/2) clay loam or sandy loam; very dark brown (10YR 2/2) when moist; strong, very coarse, columnar structure breaking to moderate, very coarse, blocky; continuous clay films on all faces of columns and blocks; very hard when dry, firm when moist, and sticky and plastic when wet; gradual boundary.

B22t—20 to 30 inches, light olive-brown (2.5Y 5/4) sandy loam; very dark grayish brown (2.5Y 3/2) when moist; moderate, coarse, prismatic structure breaking to moderate, coarse, blocky; hard when dry, firm when moist, and sticky and plastic when wet; clear boundary.

IIC—30 to 60 inches, light yellowish-brown and white (2.5Y 6/3 and 8/2) loam (glacial till); light olive brown and light gray (2.5Y 5/4 and 7/2) when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous.

The A horizon ranges from 6 to 24 inches in thickness. In a few places the B21 horizon has strong prismatic structure. Below this horizon, in places, are nests of gypsum crystals. The underlying material ranges from loam (glacial till) to fine sand.

Letcher soils have a finer textured subsoil than Embden and Egeland soils, and their subsoil has moderate structure instead of the weak structure that is characteristic of Embden soils.

Letcher fine sandy loam (0 to 3 percent slopes) (Ln).—Most areas of this soil have smooth topography and a slope of less than 1 percent. A few small areas are crossed by low ridges that have slopes of about 2 percent. In these areas there are inclusions of Larson loam and Exline loam, which are in swales, and of Egeland fine sandy loam, which is on the ridges.

This soil is suited to crops, and most of the areas are cultivated. The hazard of wind erosion is severe. (Capability unit IIIe-3P; Sandy range site)

Loamy Lake Beaches

This land type consists of somewhat excessively drained soils that surround the deeper, larger depressions in the county. It is flooded only about once in 50 years.

In a typical profile, the surface layer is black sandy loam about 3 inches thick. The underlying material consists of 4 inches of grayish-brown gravelly sand over gray and olive-brown loam that extends to a depth of 60 inches.

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This land type is highly susceptible to erosion by wave action when the depressions are flooded. It is low in organic-matter content. The loamy underlying material is slowly permeable to water, air, and plant roots.

Profile of a sandy loam typical of Loamy lake beaches, located 0.4 mile east and 125 feet south of the northwest corner of sec. 29, T. 146 N., R. 72 W.

A—0 to 3 inches, dark-gray (10YR 4/1) sandy loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

IIC1—3 to 7 inches, grayish-brown gravelly sand; single grain; loose; abrupt boundary.

IIC2—7 to 32 inches, gray and light olive-brown (2.5Y 6/1 and 5/4) loam; gray and olive brown (2.5Y 5/1 and 4/4) when moist; massive; firm; strongly calcareous; clear boundary.

IIC3—32 to 60 inches, gray and light olive-brown (2.5Y 6/1 and 5/4) clay loam; gray and olive brown (2.5Y 5/1 and 4/4) when moist; common large mottles of red; massive; firm; moderately calcareous; few nests of salt crystals.

The A horizon ranges from 1 inch to 5 inches in thickness and from 2 to 4 in moist color value. It is sandy loam or loam in texture. There may be one, two, or three coarse-textured layers, each 1 inch to 12 inches thick. Cobblestones and pebbles are common in the upper part of the profile.

Loamy lake beaches (1 to 9 percent slopes) (Lo).—This land type surrounds the larger, deeper depressions. It is suited to grass. (Capability unit VIs–Si; Silty range site)

Maddock Series

The Maddock series consists of deep, somewhat excessively drained soils that formed in outwash or eolian deposits.

In a typical profile, the 13-inch surface layer is very dark brown loamy fine sand over black loamy fine sand. The 17-inch subsoil is very dark grayish-brown loamy fine sand over brown loamy fine sand. The underlying material consists of brown loamy fine sand over yellowish-brown loamy fine sand. Below this is a layer of brown loamy fine sand. The lower part of the underlying material is generally limy.

Maddock soils have good surface drainage and moderately rapid permeability.

These soils are suited to small grain, corn, grass, legumes, and trees.

The Maddock soils in this county are mapped only in a complex with Hecla soils.

Typical profile of Maddock loamy fine sand, located 140 feet west and 0.18 mile south of the northeast corner of sec. 28, T. 147 N., R. 71 W. The profile is overlain with a 6-inch deposit of windblown material.

Ap1—0 to 6 inches, very dark gray (10YR 3/1) loamy fine sand; very dark brown (10YR 2/2) when moist; single grain; soft or loose; abrupt boundary.

Ap2—6 to 13 inches, very dark gray (10YR 3/1) loamy fine sand; black (10YR 2/1) when moist; weak, medium, blocky structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; clear boundary.

B21—13 to 22 inches, dark grayish-brown (10YR 4/2) loamy fine sand; very dark grayish brown (10YR 3/2) crushing to dark brown (10YR 3/3) when moist; very weak, medium, prismatic structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual boundary.

B22—22 to 30 inches, grayish-brown (10YR 5/2) loamy fine sand; brown (10YR 4/3) when moist; very weak, medium, prismatic structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual boundary.

C1—30 to 38 inches, brown (10YR 5/3) loamy fine sand; brown (10YR 4/3) when moist; very weak, medium, prismatic structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; gradual boundary.

C2—38 to 45 inches, pale-brown (10YR 6/3) loamy fine sand; yellowish brown (10YR 5/4) when moist; single grain; loose; gradual boundary.

C3ca—45 to 54 inches, brown (10YR 5/3) loamy fine sand; brown (10YR 4/3) when moist; common, medium, distinct mottles of pale brown (10YR 6/3); weak crumb structure; loose; strongly calcareous; gradual boundary.

C4ca—54 to 60 inches, pale-brown (10YR 6/3) sandy loam; yellowish brown (10YR 5/4) when moist; weak crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; strongly calcareous; common threads and few nodules of segregated lime.

The depth to lime ranges from 18 to 60 inches. In some places small amounts of gravel or lenses of gravel are common throughout the profile. The C horizon has strata of sandy loam to fine sand. In places loam-textured glacial till occurs at depths of 18 to 60 inches.

Maddock soils are coarser textured than Egeland soils. They have a thinner surface layer than Hecla soils, and they are excesssively drained instead of moderately well drained.

Miranda Series

The Miranda series consists of poorly drained soils that have a claypan. These soils formed in glacial till.

In a typical profile, the surface layer is very dark gray loam, and the subsoil consists of 2½ inches of black clay over 16 inches of very dark gray clay loam that contains lime and gypsum crystals. The underlying material consists of grayish-brown and gray loam over gray and yellowish-brown loam. The upper part of this material contains a large amount of lime, and the lower part contains a moderate amount.

Miranda soils have very slow surface drainage and very slow permeability.

These soils are suited only to grass.

The Miranda soils in this county are mapped only in two complexes with Larson soils.

Typical profile of Miranda loam, located 225 feet south and 70 feet west of the northeast corner of the SE¼ sec. 28, T. 148 N., R. 71 W.

A2—0 to 1½ inches, gray (10YR 6/1) loam; very dark gray (10YR 3/1) when moist; weak, fine, crumb structure; soft when dry, friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

B2t—1½ to 4 inches, dark-gray (10YR 4/1) clay; black (10YR 2/1) when moist; strong, medium, columnar structure; extremely hard when dry, very firm when moist, and sticky and plastic when wet; few cobblestones and stones; clear, wavy boundary.

B3cs—4 to 20 inches, dark-gray (10YR 4/1) clay loam; very dark gray (10YR 3/1) when moist; moderate, coarse, prismatic structure; very hard when dry, friable when moist, and slightly sticky and plastic when wet; strongly calcareous; common small nests of gypsum crystals; few cobblestones and stones; gradual, irregular boundary.

C1—20 to 40 inches, light brownish-gray (2.5Y 6/2) loam; grayish brown and gray (2.5Y 5/2 and 5/1) when moist; common mottles of light olive brown; weak blocky structure; very hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; few cobblestones and stones; gradual, irregular boundary.

C2—40 to 60 inches, gray (5Y 5/1 or 6/1) and yellowish-brown (10YR 5/6) loam; same colors when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; few cobblestones and stones; moderately calcareous.

The A horizon ranges from less than 1 inch to 6 inches in thickness, and in the places where it is at least 3 inches thick there is a thin, black, moist A1 horizon in addition to the A2 horizon. The B2t horizon ranges from black to very dark grayish brown in color and from 2 to 8 inches in thickness. In most areas, coarse fragments are common throughout the profile.

Miranda soils have a thinner surface layer than Larson soils, and they have strong instead of moderate structure in the upper part of the subsoil. They resemble thin-surfaced Exline soils, but they formed in glacial till instead of glacial melt-water deposits.

Miranda-Larson complex (0 to 3 percent slopes) (Mr).—From 10 to 60 percent of each area of this complex consists of irregularly shaped depressions a few inches deep and generally 3 to 20 feet across. The soils in these depressions are Miranda loam and a thin-surfaced Exline loam. Extending out from the depressions are Larson loam and Miranda loam and a thick-surfaced Exline loam. Potholes in the landscape are occupied by Tonka silt loam and Parnell silty clay loam. Scattered small areas of Fram loam and Emrick loam are also included in the areas mapped.

Both Miranda and Larson soils have profiles similar to the ones described as typical of their respective series. Cultivated areas have many spots where part of the clayey subsoil has been mixed into the plow layer, which consequently is very soft and sticky when wet and extremely hard when dry.

Most areas are in grass. (Capability unit VIs-Ps; Panspots range site)

Nutley Series

The Nutley series consists of deep, moderately well drained soils that formed in glacial lake sediments.

In a typical profile, the 6-inch surface layer is black silty clay, and the 20-inch subsoil consists of very dark grayish-brown silty clay over dark grayish-brown silty clay. The underlying material consists of olive-gray and olive silty clay over olive-gray and gray clay loam. The clay loam contains a moderate amount of lime.

Nutley soils have moderate surface drainage and slow permeability.

These soils are suited to small grain, grass, legumes, and trees.

Typical profile of Nutley silty clay, located 350 feet north and 105 feet west of the southeast corner of sec. 30, T. 145 N., R. 70 W.

Ap—0 to 6 inches, very dark gray (10YR 3/1) silty clay; black (10YR 2/1) when moist; moderate, very fine, crumb structure; soft when dry, friable when moist, and very sticky and very plastic when wet; abrupt boundary.

B2—6 to 11 inches, dark grayish-brown (2.5Y 4/2) silty clay; very dark grayish brown (2.5Y 3/2) when moist; tongues of black (10YR 2/1) when moist; weak, coarse, prismatic structure breaking to strong, very fine, blocky; patchy clay coatings on prisms and blocks; hard when dry, firm when moist, and very sticky and very plastic when wet; vertical streaks of weakly calcareous material; gradual, irregular boundary.

B3ca—11 to 26 inches, light olive-gray (5YR 6/2) silty clay; dark grayish brown (2.5Y 4/2) when moist; weak, coarse, prismatic structure breaking to moderate, medium and fine, blocky; hard when dry, firm when moist, and very sticky and very plastic when wet; moderately calcareous; gradual, irregular boundary.

C1—26 to 44 inches, olive-gray and light olive-gray (5Y 5/2 and 6/2) silty clay; olive gray and olive (5Y 4/2 and 4/3) when moist; weak blocky structure; very hard when dry, firm when moist, and very sticky and very plastic when wet; clear boundary.

IIC2—44 to 60 inches, light olive-gray (5Y 6/2) clay loam; olive gray and gray (5Y 4/2 and 5/1) when moist; few, medium, distinct mottles of olive, red, and black; weak blocky structure; hard when dry, firm when moist, and sticky and plastic when wet; moderately calcareous.

The A horizon ranges from 4 to 8 inches in thickness. The B2 horizon ranges from 4 to 20 inches in thickness and in a few places is weakly calcareous. In the underlying material are varved deposits, pockets of clay, and either pockets or a layer of till-like material.

Nutley soils have better drainage and a thinner surface layer than Fargo soils.

Nutley silty clay (0 to 3 percent slopes) (Nu).—This soil is in the southern and western parts of the county. It has longer and smoother slopes than any other soil in the county. Included in mapping were small areas of Fargo silty clay, which occurs in swales and in low, level areas.

This soil has very high water-holding capacity and good natural fertility. It is suited to crops, and most areas are cultivated. (Capability unit IIe-4; Clayey range site)

Overly Series

The Overly series consists of deep, moderately well drained soils that formed in glacial melt-water deposits.

In a typical profile, the 8-inch surface layer is black silty clay loam, and the 29-inch subsoil consists of very dark grayish-brown silty clay loam over brown silty clay loam. The underlying material consists of very dark gray and very dark grayish-brown, limy silty clay loam over light brownish-gray, limy loam.

Surface drainage is slow in most places and very slow in swales and a few other places. Permeability is moderately slow.

Overly soils are suited to crops, grass, and trees.

Typical profile of Overly silty clay loam, located 85 feet north and 60 feet west of the southeast corner of the NE¼ sec. 28, T. 148 N., R. 73 W.

Ap—0 to 8 inches, dark-gray (10YR 4/1) silty clay loam; black (10YR 2/1) when moist; moderate, fine, granular structure; slightly hard when dry, friable when moist, and sticky and plastic when wet; abrupt boundary.

B2—8 to 21 inches, grayish-brown (10YR 5/2) silty clay loam; very dark grayish brown (10YR 3/2) when moist; tongues from the A horizon and coatings are very dark grayish brown (2.5Y 3/2); moderate, medium, prismatic structure breaking to strong, very fine, blocky; hard when dry, firm when moist, and very sticky and plastic when wet; clear boundary.

B3ca—21 to 37 inches, light yellowish-brown (2.5Y 6/3) silty clay loam; brown (10YR 4/3) when moist; moderate, medium, prismatic structure breaking to moderate, medium, blocky; hard when dry, firm when moist, and sticky and plastic when wet; moderately calcareous; gradual boundary.

IIC1—37 to 42 inches, dark-gray and dark grayish-brown (2.5Y 4/1 and 4/2) silty clay loam; very dark gray and very dark grayish brown (2.5Y 3/1 and 3/2) when moist; weak prismatic structure; extremely hard when dry, very firm when moist, and sticky and plastic when wet; strongly calcareous; clear boundary.

IIC2—42 to 48 inches, white (2.5Y 8/2) loam; light brownish gray (2.5Y 6/2) when moist; weak blocky structure; slightly hard when dry, friable when moist, and sticky and slightly plastic when wet; strongly calcareous; abrupt boundary.

IIIC3—48 to 60 inches, grayish-brown gravelly sandy loam; weak crumb structure; loose.

The A horizon ranges from 6 to 12 inches in thickness. The layer of lime accumulation ranges from faint to prominent. The depth to this layer ranges from 15 to 30 inches. The depth to the gravelly layer ranges from 36 inches to more than 60 inches. In a few places there is a buried soil.

Overly soils are finer textured than Eckman soils. They are coarser textured than Nutley soils.

Overly silty clay loam (0 to 1 percent slopes) (Ov).—Generally, this soil has a profile similar to the one described for the series, but in swales and in a few entire areas the surface layer is thicker than that in the typical profile. The slopes are long and smooth.

This soil is suited to the commonly grown crops. About 90 percent of the acreage is cultivated. (Capability unit IIc–6; Clayey range site)

Parnell Series

The Parnell series consists of deep, poorly drained soils that formed in glacial depressions. These soils are frequently ponded with water received from the adjacent slopes. Consequently, lime and other salts have been leached out of the upper part of the profile and have accumulated in the lower part.

In a typical profile, the 10-inch surface layer is black silty clay loam that contains a large amount of organic matter. The subsoil is black clay loam about 9 inches thick. The underlying material consists of dark-gray clay loam over gray clay loam that is mottled with yellowish brown. Below a depth of 36 inches, the underlying material contains a moderate amount of lime.

Parnell soils have very poor surface drainage and slow permeability.

The use of these soils depends upon the frequency of ponding and the depth of the water.

Typical profile of Parnell silty clay loam, located 0.15 mile south and 75 feet east of the northwest corner of sec. 18, T. 146 N., R. 71 W.

A1—0 to 10 inches, dark-gray (10YR 4/1) silty clay loam; black (10YR 2/1) when moist; moderate, medium, crumb structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; gradual, irregular boundary.

B2tg—10 to 19 inches, dark-gray (10YR 4/1) clay loam; black (10YR 2/1) when moist; moderate, medium, blocky structure; hard when dry, friable when moist, and sticky and plastic when wet; gradual, irregular boundary.

C1g—19 to 27 inches, gray (5Y 5/1) clay loam; dark gray (5Y 4/1) when moist; weak blocky structure; hard when dry, friable when moist, and sticky and plastic when wet; gradual, irregular boundary.

C2g—27 to 36 inches, gray (5Y 6/1) clay loam; gray (5Y 5/1) when moist; many, coarse, prominent mottles of yellowish brown (10YR 5/6) when moist; weak blocky structure; very hard when dry, friable when moist, and sticky and plastic when wet; gradual boundary.

C3g—36 to 45 inches, gray (5Y 6/1) clay loam; gray (5Y 5/1) when moist; common medium mottles of yellowish brown (10YR 5/6) when moist; moderately calcareous; common threads of segregated lime.

C4g—45 to 60 inches, gray and light yellowish-brown (5Y 6/1 and 2.5Y 6/4) loam; gray and light olive brown (2.5Y 5/1 and 5/4) when moist; massive; very hard when dry, friable when moist, and slightly sticky and plastic when wet; moderately calcareous; common nodules and few threads of segregated lime.

The A horizon ranges from silty clay loam to loam in texture and from 6 to 28 inches in thickness. Generally, the depth to a calcareous layer is no less than 30 inches. In places in the larger sloughs, these soils are weakly calcareous near the surface, but there is no prominent layer of lime accumulation at a depth of less than 24 inches.

Parnell soils are coarser textured than Dimmick soils. They differ from Colvin soils in being leached of lime in the upper part of the profile.

Parnell silty clay loam (0 to 1 percent slopes) (Pa).—This soil is in depressions. Unless drained, it is usually ponded until midsummer or later. It is sometimes ponded the year round after a series of wet seasons or wet years, but after a series of dry years, it is ponded for only a few days following heavy rain.

Undrained areas of this soil are well suited to native grass. Drained areas can be cultivated and are well suited to small grain, flax, and legumes. (Capability unit IIIw–6; Wetland range site)

Perella Series

The Perella series consists of deep, somewhat poorly drained soils that formed in glacial melt-water deposits. These soils are in shallow depressions.

In a typical profile, the surface layer consists of 6 inches of black silt loam over 5 inches of black silty clay loam. The 5-inch subsoil is dark-gray silty clay loam that contains a small amount of lime. The underlying material is grayish-brown silt loam to loam that contains a moderate amount of lime. Below a depth of 22 inches are brownish-yellow mottles.

Perella soils have very slow surface drainage and slow permeability. Because of their location in depressions, they are subject to flooding.

These soils are suited to grass. Flooding makes it impossible to grow crops every year.

The Perella soils in this county are mapped only in a complex with Bearden soils.

Typical profile of Perella silt loam, located 0.1 mile south and 125 feet east of the northwest corner of sec. 24, T. 148 N., R. 71 W.

Ap—0 to 6 inches, very dark gray (10YR 3/1) silt loam; black (10YR 2/1) when moist; weak, fine, crumb structure; slightly hard when dry, friable when moist, and sticky and plastic when wet; abrupt boundary.

A3—6 to 11 inches, dark-gray (10YR 4/1) silty clay loam; black (N 2/0) when moist; weak, coarse, prismatic structure breaking to moderate, coarse, blocky; slightly hard when dry, very firm when moist, and sticky and plastic when wet; clear, irregular boundary.

B2—11 to 16 inches, gray (10YR 6/1) silty clay loam; dark gray (10YR 4/1) when moist; weak, coarse, prismatic structure breaking to strong, very fine, blocky; hard when dry, firm when moist, and sticky and plastic when wet; weakly calcareous; clear, irregular boundary.

C1—16 to 22 inches, light-gray (2.5Y 7/1) silt loam; grayish brown (2.5Y 5/2) when moist; weak blocky structure; slightly hard when dry, firm when moist, and sticky and plastic when wet; moderately calcareous; gradual boundary.

C2—22 to 28 inches, gray (2.5Y 6/1) loam; grayish brown (2.5Y 5/2) when moist; mottles of brownish yellow (10YR 6/6); weak blocky structure; slightly hard when dry, very friable when moist, and sticky and plastic when wet; moderately calcareous; gradual boundary.

C3—28 to 48 inches, gray and light olive-brown (5Y 6/1 and 2.5Y 5/6) loam; olive gray and light olive brown (5Y 5/2 and 2.5Y 5/4) when moist; weak blocky structure; hard when dry, friable when moist, and sticky and plastic when wet; moderately calcareous; many nodules of segregated lime; gradual boundary.

C4—48 to 60 inches, gray and brownish-yellow (2.5Y 6/1 and 10YR 6/6) loam; grayish brown and brownish yellow (2.5Y 5/2 and 10YR 6/6) when moist; massive; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; moderately calcareous.

The A horizon ranges from loam to silty clay loam in texture and from 6 to 18 inches in thickness. In some places the B horizon is mottled. The depth to lime ranges from 0 to 30 inches. In places the lower part of the C horizon is fine sandy loam instead of loam. There is much tonguing of the first four horizons, and consequently there are wide variations in the thickness and the sequence of horizons.

Perella soils contain less lime than Borup and Colvin soils, and they are flooded more frequently than Colvin soils. They contain lime at a lesser depth than Tonka soils.

Pits and dumps (Pd).—This unit is made up of borrow pits, gravel pits, and refuse dumps. Grass can be grown if gravel pits are smoothed and covered with topsoil. Cottonwood trees can be grown if the water table is close to the bottom of the pit. (Not placed in a capability unit; not placed in a range site)

Renshaw Series

The Renshaw series consists of well-drained, moderately deep soils that formed in a mantle of glacial outwash underlain by sand and gravel outwash.

In a typical profile, the surface layer is black loam about 6 inches thick, and the subsoil is dark-brown loam about 11 inches thick. The underlying material is pale-brown sand and gravel that contains a small amount of lime.

Renshaw soils have good surface drainage. They have moderate permeability in the surface layer and subsoil and rapid permeability in the underlying material. Water is stored only in the layers above the beds of sand and gravel.

These soils are suited to small grain, flax, grass, legumes, and trees.

Typical profile of Renshaw loam, located 75 feet east and 75 feet south of the northwest corner of sec. 4, T. 146 N., R. 69 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

B21—6 to 11 inches, brown (10YR 4/3) loam; dark brown (10YR 3/3) when moist; moderate, medium, prismatic structure; coatings of very dark grayish brown (10YR 3/2), when moist, on prisms; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; gradual, irregular boundary.

B22—11 to 17 inches, brown (10YR 4/3) loam; dark brown (10YR 3/3) when moist; moderate, medium, prismatic structure; hard when dry, friable when moist, and slightly sticky and slightly plastic when wet; clear, wavy boundary.

IIC—17 to 60 inches, pale-brown sand and gravel; weakly calcareous; single grain; loose.

The depth to the IIC horizon ranges from 12 to 28 inches. In places there is a layer of lime accumulation immediately above the IIC horizon. The upper part of the IIC horizon ranges from noncalcareous to strongly calcareous.

Renshaw soils differ from Sioux soils in having a B horizon and in being deeper over sand and gravel. They have a finer textured solum than Arvilla soils.

Renshaw loam, level (0 to 3 percent slopes) (ReA).—This soil has a profile similar to the one described as typical of the series. The depth to sand and gravel varies. It is generally greatest in swales and least in small areas that have slopes of more than 1 percent.

This soil is suited to crops. Most areas are cultivated. (Capability unit IIIs–5; Silty range site)

Renshaw loam, gently sloping (3 to 6 percent slopes) (ReB).—This soil has a profile similar to the one described as typical of the series. The depth to sand and gravel is generally greatest on the lower, milder part of slopes and least on the upper, stronger part. Included in mapping were areas of Divide loam, which occupies low areas.

Most areas of this soil are cultivated. The moisture supply is usually inadequate during part of the growing season. (Capability unit IIIse–5; Silty range site)

Saline land (Sa).—This land type occurs in drainageways and in and around depressions. It is flooded during periods when runoff is above normal. The soil material is saline enough that only a few kinds of plants can grow. In drainageways the water table is near the surface in spring and in wet seasons but drops to a depth of more than 3 feet late in summer. The texture is silty clay loam or silty clay throughout. At the surface is an 11-inch, black, nonlimy layer, and below that is a very dark gray to light brownish-gray, limy layer. Areas in and around depressions are flooded occasionally for periods long enough to drown out the perennial vegetation. These areas have a 7-inch layer of limy loam or sandy loam at the surface and below that layers of olive-brown and gray, limy loam or clay loam. The underlying material is commonly gravelly in the upper part. Annual grasses and weeds are the first to grow back when these areas dry out. (Capability unit VIIs–SS; Saline Subirrigated range site)

Sioux Series

The Sioux series consists of excessively drained soils that are shallow over sand and gravel.

In a typical profile, the surface layer is black loam about 8 inches thick. The underlying material consists of grayish-brown, very limy gravelly loamy sand over pale-brown, slightly limy gravelly sand.

Sioux soils have good surface drainage and rapid permeability.

These soils are suited to grass.

The Sioux soils in this county are mapped only in two complexes, one with Arvilla soils and one with Barnes soils.

Typical profile of Sioux loam, located at the northwest corner of sec. 17, T. 147 N., R. 72 W.

Ap—0 to 8 inches, very dark gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; clear, wavy boundary.

IIC1ca—8 to 30 inches, grayish-brown (10YR 5/2) gravelly loamy sand; single grain; loose; strongly calcareous; much segregation of lime; sand grains are cemented with lime; thick coatings of lime on underside of pebbles; gradual, irregular boundary.

IIC2—30 to 45 inches, pale-brown (10YR 6/3) gravelly sand; single grain; loose; weakly calcareous.

The A horizon ranges from 4 to 12 inches in thickness, and it is sandy loam instead of loam in places. In places the upper part of the IIC horizon lacks an accumulation of lime. In some places the underlying material is stratified sand and gravel, and in others it is a mixture of sand and gravel.

Sioux soils are shallower over sand and gravel than Renshaw and Arvilla soils, and they lack a B horizon.

Sioux-Arvilla sandy loams (1 to 9 percent slopes) (So).—Sioux sandy loam makes up the higher, steeper parts of this complex, and Arvilla sandy loam makes up the lower parts. Included in mapping were areas of Renshaw loam, on the lower part of slopes.

The Sioux soil in this unit has a profile (fig. 20) like the one described as typical of the series, except that the surface layer is sandy loam instead of loam. The Arvilla soil has a profile similar to the one described as typical of the Arvilla series, but in most areas the depth to sand and gravel is less than 15 inches.

These soils are suited to grass. (Capability unit VIIs–SwG; Shallow to Gravel range site)

Sioux-Barnes complex, stony (4 to 15 percent slopes) (Sr).—In some areas of this complex, Sioux loam occurs as small pockets within areas of Barnes loam; in other areas, Sioux loam occupies entire hills or knobs.

The Sioux soil in this complex has a profile similar to the one described as typical of the series, but the substratum is finer textured and stones are more numerous. The thickness of the substratum ranges from less than 1 foot to more than 20 feet and commonly varies considerably within short distances. The Barnes soil has a profile similar to the one described as typical of the series, except for coarser texture and content of about 5 percent cobblestones and stones throughout.

This complex is not suited to crops, because of stoniness and the shallowness of the Sioux soil, but it is suited to grass. Forage production is good if grazing is so regulated as to maintain the desirable grasses. (Capability unit VIs–Si; Silty range site)

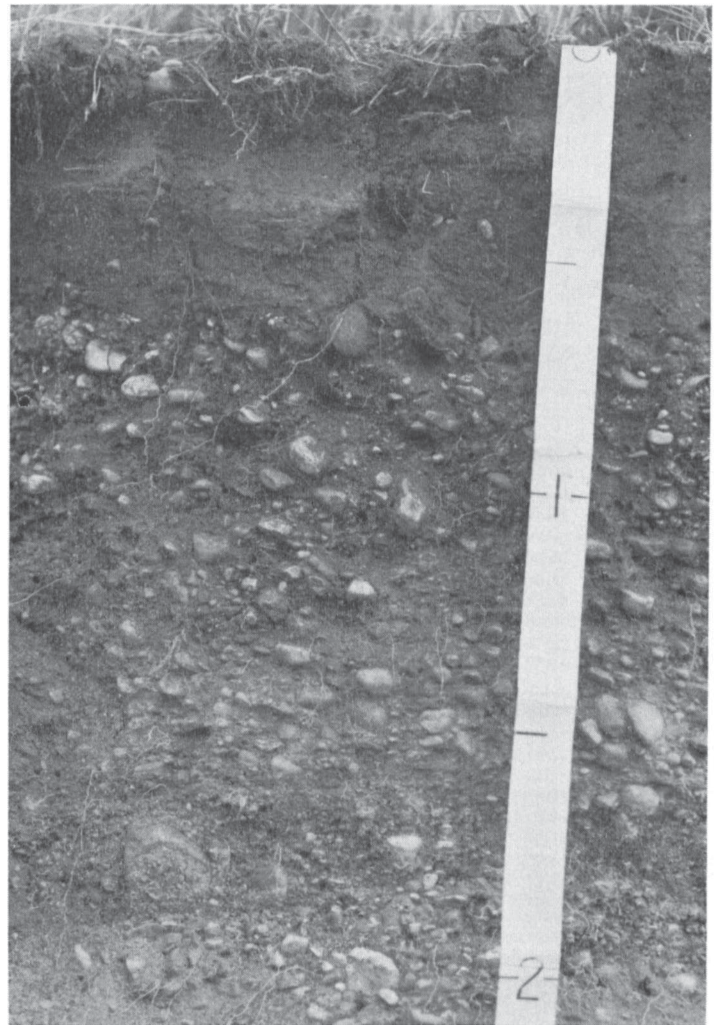

Figure 20.—**Profile of a Sioux soil.**

Stony alluvial land (St).—This is a level, somewhat poorly drained land type that is limy at or near the surface. In most places this land type is made up of layers of loam or clay loam, and in a few places it has gravel below a depth of 20 inches. Most areas are stony to a depth of at least 12 inches, but a few areas are stony only at the surface.

Included in mapping were a few areas of moderately wet, noncalcareous to moderately calcareous soils, generally loams or sandy loams, that contain a few large boulders.

All areas of this land type are in native vegetation. They are not likely to be overgrazed by livestock and so are easily managed. (Capability unit VIs–Sb; Subirrigated range site)

Svea Series

The Svea series consists of deep, moderately well drained, nearly level, medium-textured soils that formed in glacial till.

In a typical profile, the 9-inch surface layer is black loam, and the 11-inch subsoil consists of very dark grayish-brown loam over olive-brown loam. The underlying material consists of grayish-brown, very limy loam over olive-brown, moderately limy loam.

Svea soils have slow surface drainage and moderate permeability. They receive runoff from adjacent slopes, but the water does not pond on the surface.

These soils are well suited to crops, grass, and trees.

The Svea soils in this county are mapped only in complexes with Barnes soils.

Typical profile of Svea loam, located in a cultivated field, 95 feet north and 210 feet east of the southwest corner of sec. 11, T. 146 N., R. 72 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; abrupt boundary.

A1—6 to 9 inches, dark-gray (10YR 4/1) loam; black (10YR 2/1) when moist; weak, medium, blocky structure; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; gradual boundary.

B21—9 to 15 inches, dark grayish-brown (10YR 4/2) loam; very dark grayish brown (10YR 3/2) when moist; weak, medium, prismatic structure breaking to moderate, medium, blocky; soft when dry, very friable when moist, and slightly sticky and slightly plastic when wet; gradual boundary.

B22—15 to 20 inches, light olive-brown (2.5Y 5/4) loam; olive brown (2.5Y 3/3) when moist; weak, coarse, prismatic structure breaking to moderate, medium, blocky; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; clear boundary.

C1ca—20 to 34 inches, light yellowish-brown (2.5Y 6/3) loam; grayish brown (2.5Y 5/2) when moist; weak prismatic structure; slightly hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; strongly calcareous; gradual boundary.

C2—34 to 60 inches, light yellowish-brown (2.5Y 6/3) loam; olive brown (2.5Y 4/3) when moist; weak blocky structure; hard when dry, friable when moist, and slightly sticky and plastic when wet; moderately calcareous; common nodules of segregated lime.

The A horizon ranges from 8 to 18 inches in thickness. The B horizon ranges from 6 to 15 inches in thickness. Where this horizon has a hue of 10YR or 2.5Y, the color value is 3 or less. The texture of the B horizon is commonly clay loam instead of loam in the southwestern part of the county. In a few places, the lower part of the B horizon has a few mottles. The depth to lime ranges from 12 to 30 inches. Throughout the profile are pebbles, cobblestones, and other stones.

Svea soils are associated with Barnes soils, but they are less well drained and have a thicker surface layer than Barnes soils. They differ from Hamerly soils in having a B horizon.

Tonka Series

The Tonka series consists of deep, poorly drained soils that formed in shallow depressions. These soils receive runoff from adjacent areas.

In a typical profile, the surface layer, about 9 inches thick, consists of black silt loam over very dark gray silt loam, and the subsoil is dark-gray and yellowish-brown silty clay loam about 6 inches thick. The underlying material consists of dark-gray and light olive-brown clay loam over gray and light olive-brown loam that contains a moderate amount of lime. Below this is olive-brown and gray loam that contains a moderate amount of lime.

Tonka soils have slow to ponded surface drainage and moderately slow permeability.

These soils are well suited to grass. The frequency of ponding governs their use for crops.

Typical profile of Tonka silt loam, located 0.35 mile west and 90 feet north of the southeast corner of sec. 21, T. 148 N., R. 69 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) silt loam; black (10YR 2/1) when moist; weak, fine, crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt boundary.

A2—7 to 9 inches, gray (10YR 5/1) silt loam; very dark gray (10YR 3/1) when moist; few mottles of brown (10YR 5/3); moderate, thin, platy structure; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; abrupt, irregular boundary.

B2—9 to 15 inches, gray and yellowish-brown (10YR 5/1 and 5/4) silty clay loam; dark gray and yellowish brown (10YR 4/1 and 5/4) when moist; moderate, coarse and medium, blocky structure breaking to strong, fine, blocky; hard when dry, firm when moist, and sticky and plastic when wet; tongues from the A2 horizon extend to a depth of 12 inches; gradual, irregular boundary.

C1g—15 to 38 inches, gray and light yellowish-brown (5Y 6/1 and 2.5Y 6/3) clay loam; dark gray and light olive brown (5Y 4/1 and 2.5Y 5/4) when moist; weak, coarse, prismatic structure breaking to moderate, fine, blocky; hard when dry, friable when moist, and sticky and plastic when wet; clear, irregular boundary.

C2g—38 to 54 inches, gray and light yellowish-brown (5Y 6/1 and 2.5Y 6/3) loam; gray and light olive brown (5Y 5/1 and 2.5Y 5/4) when moist; weak blocky structure; hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous; nodules of segregated lime; gradual, irregular boundary.

C3g—54 to 60 inches, light yellowish-brown and gray (2.5Y 6/3 and 7/1) loam; olive brown and gray (2.5Y 4/4 and 7/1) when moist; weak blocky structure; hard when dry, very friable when moist, and slightly sticky and slightly plastic when wet; moderately calcareous.

The A horizon ranges from 6 to 25 inches in thickness. The structure of the A2 horizon ranges from weak thin platy to strong thick (12 inches) platy. Mottles in the A2 and B2 horizons range from common to few in abundance. The depth to lime ranges from 15 to more than 60 inches. In a few places the underlying material is stratified with clay loam to loamy sand.

Tonka soils are ponded more frequently than Borup soils and are deeper over lime. They are less wet than Parnell soils.

Tonka silt loam (0 to 1 percent slopes) (To).—This soil is in shallow depressions. It is flooded by runoff from adjacent areas during spring thaws and in unusually wet seasons, for periods ranging from only a day or two to an entire growing season. Included in mapping were areas of Borup loam, Fram loam, and Vallers loam. Most of the depressions are rimmed with these included soils. In the east-central part of the county, inclusions of Borup loam make up parts of the mapping unit where water ponds to a depth of only a few inches and remains for only a short time.

If drained and fertilized, this soil is suited to the commonly grown crops. Most of it is cultivated, but ponding makes it impossible to grow crops in some years. (Capability unit IIw–6; Overflow range site)

Ulen Series

The Ulen series consists of deep, somewhat poorly drained soils that are limy at or near the surface. These soils have a seasonal high water table that contributes to the accumulation of lime at or near the surface.

In a typical profile, the surface layer consists of 7 inches of black, moderately limy fine sandy loam over 7 inches of dark-gray, very limy fine sandy loam. The underlying material consists of a 22-inch layer of grayish-brown fine sandy loam over a layer of light brownish-gray loamy fine sand. Below this are stratified, strong-brown sand and sandy loam. The underlying material contains a large amount of lime.

Ulen soils have slow surface drainage.

These soils are suited to small grain, flax, grass, legumes, and trees.

The Ulen soils in this county are mapped only in an undifferentiated group with Hamar soils.

Typical profile of Ulen fine sandy loam, located 265 feet east and 135 feet south of the northwest corner of sec. 28, T. 147 N., R. 71 W.

A11—0 to 7 inches, very dark gray (10YR 3/1) fine sandy loam; black (10YR 2/1) when moist; moderate, fine, crumb structure; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; moderately calcareous; clear, irregular boundary.

A12cs—7 to 14 inches, gray (10YR 5/1) fine sandy loam; dark gray (10YR 4/1) when moist; weak prismatic structure; slightly hard when dry, very friable when moist, and slightly sticky and nonplastic when wet; strongly calcareous; common very small salt crystals; clear, irregular boundary.

C1ca—14 to 36 inches, light brownish-gray (2.5Y 6/2) fine sandy loam; grayish brown (2.5Y 5/2) when moist; weak blocky structure; slightly hard when dry, very friable when moist, and nonsticky and nonplastic when wet; strongly calcareous; gradual, irregular boundary.

C2ca—36 to 52 inches, light-gray (2.5Y 7/2) loamy fine sand; light brownish gray (2.5Y 6/2) when moist; weak crumb structure; soft when dry, very friable when moist, and nonsticky and nonplastic when wet; strongly calcareous; gradual, wavy boundary.

C3—52 to 60 inches, reddish-yellow (7.5YR 6/6), stratified sand and sandy loam; strong brown (7.5YR 5/6) when moist; loose; strongly calcareous.

The A horizon ranges from 6 to 18 inches in thickness and is slightly calcareous to strongly calcareous. In some places the C horizon is less gray in color and is reddish in the lower part.

Ulen soils differ from Hamar soils in having lime at or near the surface.

Ulen and Hamar fine sandy loams (0 to 1 percent slopes) (Uh).—Some areas of this undifferentiated group consist of Ulen fine sandy loam, some consist of Hamar fine sandy loam, and some contain both. The Ulen soil is the more extensive and is dominant in the areas that contain both soils. The areas that consist of Hamar fine sandy loam are small. Both soils have the profile described for their respective series. The water table is at or near the surface during spring thaws and in unusually wet seasons. In some low and concave areas, the Ulen soil is moderately saline.

These soils are well suited to native grass. About half of the acreage is cultivated. Wind erosion is a severe hazard, and controlling wetness is a problem. (Capability unit IIIe–3; Subirrigated range site)

Vallers Series

The Vallers series consists of deep, poorly drained soils that are limy near the surface. These soils formed in glacial till. They have a seasonal high water table that has contributed to the accumulation of lime near the surface. Slightly to moderately saline spots are common.

In a typical profile, the surface layer is very dark gray loam about 7 inches thick. The underlying material consists of 9 inches of light brownish-gray and light-gray loam over 8 inches of olive-brown, light brownish-gray, and olive-gray clay loam mottled with light gray. Below this is olive-gray, dark-gray, and light yellowish-brown clay loam mottled with light gray. Throughout the profile are large amounts of lime.

Vallers soils have slow surface drainage and moderate permeability.

These soils are suited to grass. If drained, they are suited to small grain, flax, and alfalfa. Wetness and salinity make them generally unsuitable for trees.

Typical profile of Vallers loam, located 100 feet south and 80 feet east of the northwest corner of sec. 15, T. 145 N., R. 70 W.

Ap—0 to 7 inches, grayish-brown (2.5Y 5/1) loam; very dark gray (10YR 3/1) when moist; weak, fine, crumb structure; slightly hard when dry, friable when moist, and sticky and plastic when wet; strongly calcareous; abrupt boundary.

C1ca—7 to 16 inches, light-gray and white (2.5Y 7/1 and 8/2) loam; light brownish gray and light gray (2.5Y 6/2 and 7/2) when moist; grayish-brown coatings; weak, coarse, prismatic structure breaking to moderate, very fine, angular blocky; slightly hard when dry, friable when moist, and sticky and plastic when wet; strongly calcareous; clear boundary.

C2—16 to 24 inches, light olive-brown, white, and pale-olive (2.5Y 5/6, 8/2, and 5Y 6/3) clay loam; olive brown (2.5Y 4/4), light brownish gray (2.5Y 6/2), and olive gray (5Y 5/2) when moist; few, medium, distinct mottles of light gray (5Y 7/2) when moist; massive; very hard when dry, friable when moist, and sticky and plastic when wet; strongly calcareous; few nodules of segregated lime; gradual boundary.

C3—24 to 60 inches, light yellowish-brown and light-gray (2.5Y 6/4 and 7/1) clay loam; olive gray (5Y 5/2), dark gray (N 4/0), and light yellowish brown (2.5Y 6/4) when moist; few, fine, distinct mottles of light gray (2.5Y 7/2) when moist; massive; very hard when dry, friable when moist, and sticky and plastic when wet; strongly calcareous; few nodules of segregated lime.

The A horizon ranges from loam to clay loam in texture and from 5 to 12 inches in thickness. Below the A horizon pockets of gypsum crystals are common. Throughout the profile are pebbles, cobblestones, and other stones.

Vallers soils are more poorly drained than Hamerly soils.

Vallers loam (0 to 1 percent slopes) (Va).—This soil occurs around large depressions and in areas that have several small depressions. Seepage from adjacent slopes ponds in these depressions. The water table is at or near the surface during spring thaws and in wet seasons.

Slightly saline to moderately saline spots, a few feet across, are common.

Many areas of this soil are cultivated, although tillage operations usually have to be delayed because of the wetness and crops do not grow well in the saline spots. Subsurface drainage that would lower the water table is not generally feasible. (Capability unit IIw-4L; Subirrigated range site)

Use and Management of the Soils

This section discusses the use and management of the soils as cropland, as range, as wildlife habitat, and as sites for windbreaks. It describes the relative suitability of soils for highway construction and other engineering works. A table showing predicted yields under two levels of management is provided.

General Management of Cropland [2]

The main considerations in managing cultivated soils in Wells County are conserving moisture, controlling wind erosion and water erosion, and maintaining fertility.

In dryfarmed areas conserving moisture generally means reducing evaporation, limiting runoff, increasing infiltration, and controlling weeds. Among the effective measures are stubble mulching, contour farming, stripcropping, field windbreaks, buffer strips, timely tillage, minimum tillage, use of crop residue, and application of fertilizer. Fallow helps to control weeds and to build up the moisture content.

Among the measures that help to control erosion are cover crops, stripcropping, buffer strips, windbreaks, contour farming, diversions, waterways, minimum tillage, timely tillage, emergency tillage, and the use of crop residue. Generally, a combination of several measures is used.

Among the measures that help to maintain fertility are the application of chemical fertilizer, green manure, and barnyard manure and the inclusion in the cropping system of cover crops, grasses, and legumes, as well as the use of summer fallow. Control of erosion also helps to conserve fertility.

Drainage, removal of stones, and reduction of salinity may be needed to offset the effects of unfavorable soil characteristics.

Capability Groups of Soils

Capability classification is the grouping of soils to show, in a general way, their suitability for most kinds of farming. It is a practical classification based on the limitations of the soils, the risk of damage when they are used, and the way they respond to treatment. The classification does not apply to most horticultural crops or to rice and other crops that have special requirements. The soils are classified according to degree and kind of permanent limitation, without considering major and generally expensive alterations in the slope, depth, or other characteristics of the soils, and without considering possible but unlikely major reclamation projects.

In the capability system, soils are grouped at three levels: the capability class, the subclass, and the unit.

Capability Classes, the broadest grouping, 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 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 restrict the choice of plants, require very careful management, or both.

Class V. Soils are subject to little or no erosion but have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife food and cover.

Class VI. Soils have severe limitations that make them generally unsuitable for cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover.

Class VII. Soils have very severe limitations that make them unsuitable for cultivation and that restrict their use largely to pasture, range, woodland, or wildlife.

Class VIII. Soils and landforms have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, or water supply, or to esthetic purposes.

Capability Subclasses are soil groups within one class; they are designated by adding a small letter, *e*, *w*, *s*, or *c*, to the class numeral, for example, IIe. The *e* shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; *w* shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c*, used in only some parts of the United States, shows that the chief limitation is climate that is too cold or too dry. For some soils, erosion or wetness and one of the other kinds of limitation have about equal importance, and the subclass symbol shows both kinds; IIIes is an example.

In class I there are no subclasses, because the soils of this class have few limitations. Class V can contain, at the most, only the subclasses indicated by *w*, *s*, and *c*, because the soils in it are subject to little or no erosion, though they have other limitations that restrict their use largely to pasture, range, woodland, wildlife, or recreation.

Capability Units are soil groups within the subclasses. The soils in one capability unit are enough alike to be suited to the same crops and pasture plants, to require similar management, and to be similar in productivity and other responses to management. Thus, the

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capability unit is a convenient grouping for making many statements about the management of soils. Capability units are generally designated by adding an Arabic numeral to the subclass symbol, for example, IIe–6 or IIIw–6. Thus, in one symbol, the Roman numeral designates the capability class, or degree of limitation; the small letter indicates the subclass, or kind of limitation, as defined in the foregoing paragraphs; and the Arabic numeral identifies the capability unit within the subclass. Arabic numerals are also used to indicate the susceptibility to wind erosion, ranging from 2, which is very high, to 6, which is slight. The letter P indicates the presence of a sodic claypan in the subsoil, and the letter L indicates that the soil is calcareous. Following the subclass designation in capability units in classes V, VI, and VII is an abbreviation of the name of the range site into which the soils of this unit have been placed.

Management by Capability Units

In the following pages each of the capability units in Wells County is described, and suggestions for the use and management of the soils in each unit are given. The units are not numbered consecutively, because not all of the units in the statewide system are represented in this county. The names of the soil series represented are mentioned in the description of each unit, but this does not mean that all the soils in a given series are in the unit. The capability classification of each individual soil is given in the "Guide to Mapping Units." The mapping unit called Pits and dumps was not placed in a capability unit.

Capability unit IIe–4

This unit consists of deep, level to undulating soils that have a surface layer of clay loam or silty clay. These soils are members of the Forman and Nutley series. They absorb water readily, but when wet, they have moderately slow permeability. They have very high water-holding capacity. These soils are slow to warm up in spring. They have high fertility. The undulating soils are susceptible to water erosion during high-intensity rain in summer. Cropland is susceptible to wind erosion in spring, because freezing and thawing break the larger clods into granules that are easily blown away.

The common cropping system is a 3-year rotation of wheat, barley, and fallow. Flax, corn, and potatoes are not well suited. Grass and legumes added to the rotation are beneficial. If the supply of moisture is good at seeding time, sweetclover can be seeded with small grain and plowed down in fall as green manure.

Careful management of crop residue is important in control of erosion. If fall plowing is necessary, it should be done in such a way as to leave as much residue as possible on the surface and to leave the surface rough. It should be done early enough to allow some regrowth of plants. Other measures needed to control erosion are wind stripcropping, cover crops, and windbreaks. Special attention to spring tilling is necessary because working the soils when they are too wet or too dry results in a poor seedbed. Response to nitrogen and phosphate is good. In a few places the drainage of potholes would facilitate farming operations and conservation practices.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Deferment of grazing and distribution of water and salt are beneficial.

Most areas of these soils are favorable for wildlife.

Capability unit IIe–4L

This unit consists of deep loamy soils that are limy at or near the surface. These soils are members of the Fram and Hamerly series. The natural fertility of these soils is medium, and the water-holding capacity is high. The lime content causes granulation of the surface layer and thus makes it susceptible to wind erosion. A seasonal high water table contributes to the accumulation of lime. Small depressions are common.

These soils are suited to all locally grown crops. The common cropping system is a 3- or 4-year rotation of wheat, barley, flax, and summer fallow. On farms where livestock is raised, corn generally is substituted for fallow. Where grass and legumes are included in the cropping system, they are used for hay or pasture. Sweetclover seeded with small grain helps to remove excess water from the soil. The sweetclover can be plowed down in fall as green manure.

Careful management of crop residue is needed for control of erosion. Stripcropping, windbreaks, cover crops, and buffer strips are other measures that should be considered in planning a program of erosion control. Timely and minimum tillage, combined with the use of the plow and pony press drill for seeding, helps to overcome the effects of granulation. Drainage of the small depressions, if feasible, lowers the temporary high water table and thus retards accumulation of lime in the surface layer. The response to phosphate is good.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Deferment of grazing and distribution of salt and water are beneficial.

Some areas of these soils are favorable for wildlife.

Capability unit IIe–5

This unit consists of deep, mostly well-drained soils that have a surface layer of loam or silt loam. These soils are members of the Eckman, Emrick, Gardena, Heimdal, and LaDelle series. Potholes are common in many areas. These soils are moderately permeable to water, air, and plant roots. They have high water-holding capacity. Natural fertility is high, and the organic-matter content is adequate. Wind erosion is a moderate hazard in cultivated areas.

The soils in this unit are suited to all locally grown crops. The common cropping system is a 3- or 4-year rotation of wheat, barley, flax, and summer fallow. On farms where livestock is raised, corn replaces fallow part of the time.

Stubble mulching and crop-residue use are the principal measures used to control wind erosion. Stripcropping and windbreaks are alternative measures. Buffer strips are needed to protect fallow land that has little crop residue on the surface. In a few areas of Heimdal-Emrick loams, undulating, contour strip farming for control of erosion (fig. 21) is feasible. In a few areas grassed waterways are needed as outlets for excess surface runoff.

Figure 21.—**Contour farming on Heimdal-Emrick loams, undulating, which are in capability unit IIe-5. In the right foreground are two grassed waterways.**

Drainage of the potholes, where feasible, would facilitate farming operations. Fertilizer is beneficial to grain crops.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Deferment of grazing helps to maintain or improve range condition. Proper location of water and salt helps in the distribution of grazing.

Some areas are favorable for wildlife.

Capability unit IIe-6

This unit consists of Barnes-Svea loams, undulating, which are deep soils characterized by small potholes. These soils have moderate permeability and high water-holding capacity. Natural fertility is high. Erosion by wind and water is a moderate hazard.

The soils in this unit are suited to all locally grown crops. The common cropping system is a 3- or 4-year rotation of wheat, barley, flax, and fallow. On farms where livestock is raised, brome and alfalfa for hay and pasture are commonly included in the rotation.

Good use of crop residue provides protection against wind and water erosion. Stripcropping and windbreaks are effective also, but they are not feasible unless the potholes are drained. Buffer strips are needed to protect fallow land that has little crop residue on the surface. Grassed waterways are beneficial in a few areas. Fertilizer benefits grain and other crops.

Grazing of range should be regulated so that only about half the annual growth of desirable plants is consumed. Deferment of grazing helps to maintain and improve range condition. Proper location of water and salt helps in distributing grazing. Treatment for control of brush is necessary occasionally.

Some areas of these soils are favorable for wildlife.

Capability unit IIwe-4

This unit consists of Fargo silty clay, a deep soil that receives runoff from adjacent uplands and is ponded for short periods when runoff is excessive. Permeability is slow, and the water-holding capacity is very high. Natural fertility is high. The hazard of wind erosion is severe in spring if the surface layer is dry.

This soil is suited to small grain. The common cropping system is 6 years of wheat, barley, and summer fallow and 4 years of grass and legumes in 10 years. In wet areas sweetclover should be seeded with the small grain. It uses up excess moisture, and it can be plowed down in fall as green manure.

Farming operations usually have to be delayed in spring because the extra moisture keeps the soil too cool for seeds to germinate. Many of the small shallow depressions where water ponds could be eliminated by land shaping and leveling, but the larger and deeper ones need to be drained. Wind erosion has to be controlled in areas adjacent to drainage ditches, because windblown material can plug the ditches. Important in the control of erosion is careful management of crop residue. Other effective measures are stripcropping, windbreaks, and cover crops.

This soil is difficult to work because it is very sticky when wet and hard when dry. Working it when it is either too dry or too wet results in a poor seedbed, and consequently the proper timing of spring tillage is of great importance. The surface should be left rough after fall tillage. The response to nitrogen fertilizer is good.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed.

Capability unit IIw-4L

This unit consists of soils that have a surface layer of silt loam or loam and are calcareous throughout the profile. These soils are members of the Benoit, Borup, Colvin, Lamoure, LaPrairie, and Vallers series. They have a seasonal high water table, and they are intermittently flooded. In most years they are moderately wet and, consequently, are slow to warm up in spring. These soils are fertile and are high in organic-matter content. Because of their lime content, they are highly susceptible to wind erosion.

If drained, these soils are well suited to small grain and flax. Undrained areas are suitable for late-planted crops of barley and flax or for sweetclover and grass. Some of the larger, more uniformly shaped areas are in native hay.

Some areas have been drained to remove surface water. Sweetclover and grass use large amounts of water. Thus, these plants can be grown to help lower the water table, as well as to improve tilth and permeability. Summer fallow tends to intensify the drainage problem and should be used only to control weeds. Land smoothing removes some of the small wet spots on the Colvin, LaPrairie, and Lamoure soils, which are generally adjacent to low-gradient streams. Native hay should be mowed early to allow time for some regrowth before the ground freezes. The mowing should leave several inches of stubble in the field.

Generally, these soils make up only a small proportion of the pasture in Wells County. Grazing should be regulated so that only about half the annual growth of plants is consumed. Proper location of water and salt helps in the distribution of grazing.

Cover for wildlife is available in places.

Capability unit IIw-6

This unit consists of deep silt loams that are in depressions where runoff water collects (fig. 22). These soils are in the Bearden, Perella, and Tonka series. The natural fertility is high, and the organic-matter content is high. Permeability is moderately slow.

The soils in this unit are suited to small grain, flax, grass, and legumes. Sweetclover grown with the small grain helps to control wetness.

These soils are farmed with the surrounding cropland. Because they dry out slowly, this practice causes delay in planting. Some areas of these depressional soils are artificially drained. The rest are ponded intermittently. Even in drained areas, excess wetness remains a limitation. Water is removed slowly because drainage ditches can have only a slight gradient, and soil material blown from adjoining areas sometimes plugs the ditches. Appropriate management practices can help reduce wetness in undrained areas. Sweetclover grown with a small grain removes moisture from the subsoil, and other legumes and grass use large amounts of water. Fall tillage reduces the amount of snow trapped and thus permits more rapid drying and warming in spring. Grass and legumes in the rotation help to improve permeability.

Only a few areas are in range. Grazing needs to be regulated so that only about half the annual growth of desirable plants is consumed.

Cover for wildlife is available in places.

Capability unit IIc-6

This unit consists of deep soils that have a surface layer of loam or silty clay loam. These soils are members of the Barnes, Overly, and Svea series. They have high natural fertility and very high water-holding capacity. The hazard of erosion by wind or water is only slight.

These soils are well suited to all locally grown crops. The common cropping system is a 3- or 4-year rotation of wheat, barley, flax, and either fallow or corn. On farms where livestock is raised, brome and alfalfa are grown for hay or pasture.

Lack of available moisture is the main limitation. For cropland, the main management measures are stubble mulching, crop-residue use, and application of commercial fertilizer. Drainage of the common small depressions, where feasible, and removal of stones from the Barnes and Svea soils would facilitate farming operations and conservation practices.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Proper use of the range is accomplished by deferment of grazing and distribution of water and salt. Treatment for control of brush is necessary occasionally. The range recovers quickly after short periods of overuse, but continued abuse reduces production.

Most areas of these soils are favorable for wildlife.

Capability unit IIIe-3

This unit consists of deep soils that have a surface layer of fine sandy loam. These soils are members of the Egeland, Embden, Hamar, and Ulen series. They have moderately rapid to rapid permeability and medium to low water-holding capacity. Except in eroded spots, they are fertile and are high in organic-matter content. Wind erosion is a serious hazard.

The soils of this unit are suited to all locally grown crops. Generally, the cropping sequence used is wheat, barley, flax, and corn or summer fallow. Flax produces only a small amount of residue and is easily damaged by windblown sand. Legumes should not be grown alone, because they cause excessive loosening of the soil, which results in the loss of moisture.

These soils warm up rapidly in spring and are the first to be ready for planting. The use of early maturing crops lessens the risk of drought damage. In some years the planting of wheat on Hamar and Ulen soils has to be delayed because of a seasonal high water table.

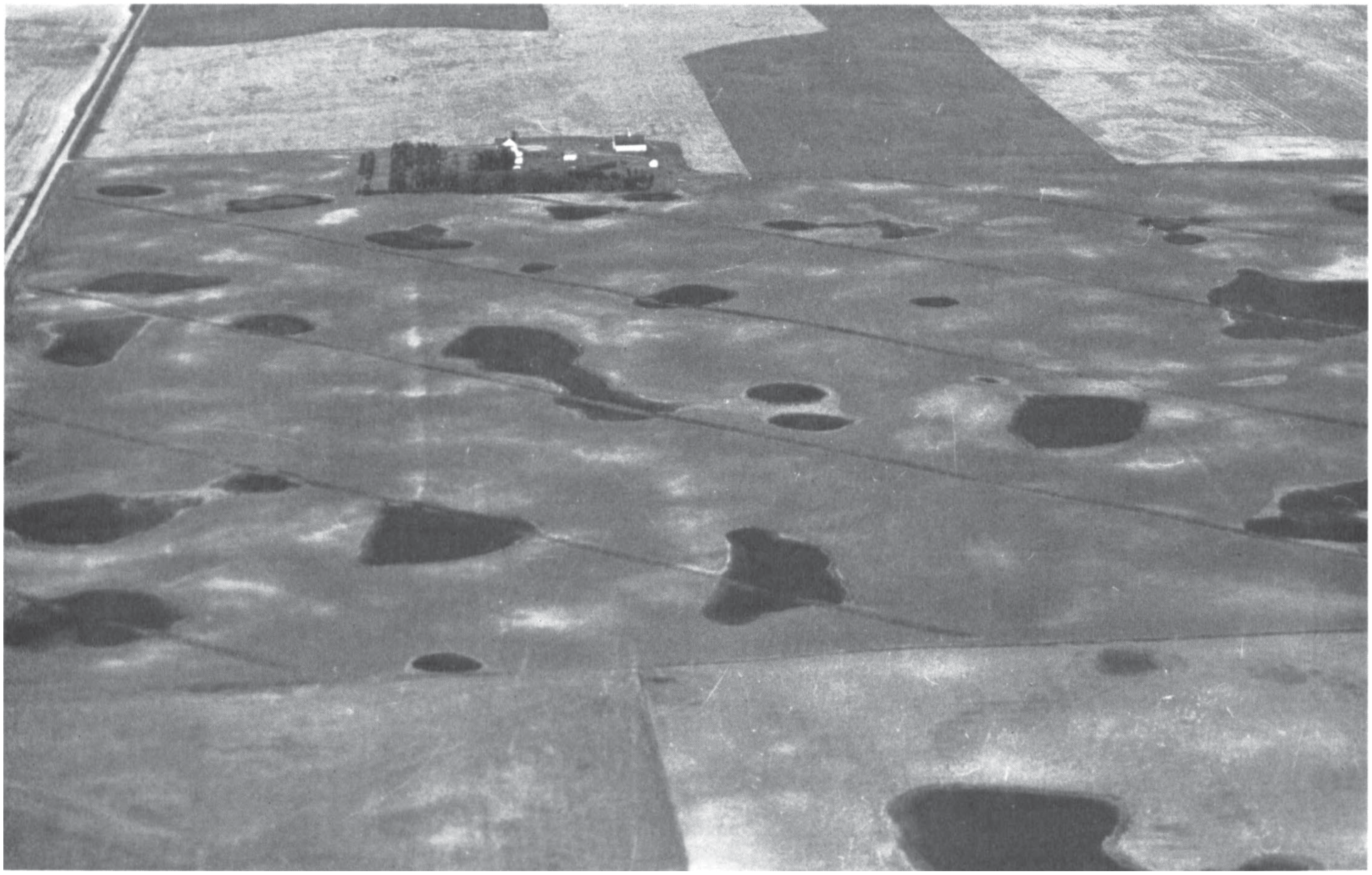

Figure 22.—**Depressions filled with runoff water after an intense rain in summer. The soil in the depressions is Tonka silt loam, which is in capability unit IIw-6. The dark diagonal lines are buffer strips of corn, which help to control erosion.**

A combination of practices is required to control erosion. Crop residue and stubble mulching, combined with either stripcropping or patterned windbreak planting, are needed to control wind erosion. The inclusion of cover crops, buffer strips, and grass in the cropping system also helps to control erosion. Occasionally, emergency tillage, which roughens the surface, is required to control erosion. Summer fallow should be used only to control weeds, because the amount of moisture that can be stored is limited. Generally, tillage should be kept to the minimum needed to control weeds and to prepare a seedbed. The rates for application of fertilizer need to be closely governed by the moisture content at the time of seeding.

Management that helps to keep an adequate cover of grass on the range is needed. Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Pastures benefit from deferred grazing. In many places tame pasture is used for grazing in rotation with range. Proper location of water and salt helps in the distribution of grazing.

Cover for wildlife is available in places.

Capability unit IIIe-3P

This unit consists of Letcher fine sandy loam, a soil that has a claypan in the subsoil. Erosion is a serious hazard. The natural fertility is medium, and the organic-matter content is adequate. The surface layer has moderately rapid permeability. The claypan has very slow permeability, and it limits the water-holding capacity.

This soil is suited to small grain, flax, grass, and legumes. Corn can be grown, but it is usually damaged late in summer by lack of moisture.

This soil is easily worked. It can be protected from erosion by wind stripcropping, in combination with the use of cover crops and the inclusion of grass and legumes in the cropping system. Buffer strips can also be used. Extreme care is needed in managing crop residue.

Grazing should be regulated so that only half the annual growth of desirable plants is consumed. Deferment of grazing is beneficial.

Capability unit IIIes-3

This unit consists of soils of the Arvilla series. These soils have a surface layer of sandy loam and are only moderately deep over sand and gravel, and consequently are droughty. Wind erosion is a severe hazard. Water infiltration is moderately rapid.

The common cropping system consists of 3 or 4 years of small grain followed by a few years of grass or grass-legume mixtures, and then by corn or summer fallow. Occasionally, flax is included.

These soils are easily worked, but a combination of practices is needed to control erosion. Narrow stripcropping and use of crop residue are essential. It is necessary that grass either be included in the cropping system every 4 or 5 years or be grown in permanent buffer strips. Tree windbreaks also help to control erosion, but the number of suitable species is limited and the height of the trees at maturity is limited. Only early maturing crop varieties should be seeded.

Capability unit IIIe-6

This unit consists of deep, rolling, medium-textured soils of the Barnes series. These soils have high water-holding capacity. The natural fertility is high, and the organic-matter content is medium.

The soils in this unit are suited to all locally grown crops. The common cropping system consists of wheat, barley, flax, and either summer fallow or corn. Brome and alfalfa are grown for hay or pasture on farms where livestock is raised.

Good use of crop residue is necessary for control of erosion. The amount of residue is not adequate for protection of fallow land, and stripcropping or the use of windbreaks, cover crops, or buffer strips is essential. The potholes may have to be drained before stripcropping or planting of windbreaks is feasible. Tillage should be on the contour. Grassed waterways are needed in places where water concentrates. Grass and legumes in the cropping system also help to check erosion.

Regulating grazing so that only about half the annual growth of desirable plants is consumed helps to maintain and improve range condition. Deferring grazing during part or all of the growing season increases the vigor of desirable plants. Proper location of water and salt helps in the distribution of grazing.

Some areas of these soils are favorable for wildlife.

Capability unit IIIw-4

This unit consists of Dimmick clay. This soil is subject to ponding. It is slowly permeable, sticky when wet, and slow to warm up in spring. The natural fertility is high, and the organic-matter content is high. Wind erosion is a serious hazard early in spring, before the soil is tilled.

Drained areas of this soil can be cultivated. Small grain and flax are suitable crops. Undrained areas are well suited to water-tolerant grasses.

Special care should be taken to make sure that this soil is not worked when it is wet. Grass and legumes in the rotation help to use up excess moisture, as well as to maintain tilth. Plowing down the fall growth of sweetclover grown with a small grain is beneficial. Fall tillage is necessary for the preparation of a good seedbed, but it should be done early enough to permit a growth of volunteer vegetation sufficient to protect the soil from wind erosion. In some of the larger areas, stripcropping can also be used. Hay should be mowed early enough to allow time for some regrowth before the ground freezes. The mowing should leave several inches of stubble.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Some of the larger areas can be fenced and thus can be managed more easily.

Capability unit IIIw-6

This unit consists of Parnell silty clay loam. This soil is wet, slowly permeable, and slow to warm up in spring. It is not easily eroded. The natural fertility is high, and the organic-matter content is high.

Drained areas of this soil are well suited to grasses, legumes, small grain, and flax. Undrained areas are well suited only to water-tolerant grasses.

Grasses and legumes are needed in the crop rotation to use up excess moisture and to maintain permeability and tilth. Sweetclover, seeded with small grain or flax, is also beneficial. Summer fallow should be used as little as possible. Fall plowing of drained areas reduces the amount of snow trapped and allows the soil to warm up more rapidly in spring. Hay should be mowed early so there will be time for some regrowth before the ground freezes. The mowing should leave several inches of stubble in the field.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Some of the larger areas can be fenced and thus can be managed more easily.

Capability unit IIIws-4

This unit consists only of Lamoure-Exline complex. Both soils have a seasonal high water table, and the Exline soil contains salts that are harmful to plants. Wind erosion is a hazard. In the Lamoure soil, natural fertility is high, the organic-matter content is very high, and permeability is moderate. In the Exline soil, natural fertility is low, and permeability is very slow.

These soils are suited to grass, legumes, small grain, and flax. Generally small grain and flax are grown continuously for 4 or 5 years, then grass and legumes for 4 or 5 years.

The excess wetness can be eliminated by land shaping and drainage. Sweetclover can be grown with small grain as a green-manure crop. It uses up excess moisture, adds nitrogen, and improves both permeability and tilth. Management of small-grain residue, combined with tillage that roughens the surface, is usually sufficient to control wind erosion, but cover crops should be grown after flax has been harvested or land has been fallowed. Summer fallow should be used as little as possible.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed.

Some areas of these soils are favorable for wildlife.

Capability unit IIIs-P

This unit consists of two soil complexes, each made up of one deep soil and one claypan soil. The deep soils are members of the Emrick and Fargo series, and the claypan soils are members of the Aberdeen and Larson series. The natural fertility is high, and the organic-matter content is high. The claypan is very slowly permeable to water, air, and plant roots, but once saturated, it becomes very soft and is slow to dry out. Where subsoil material has been mixed into the plow layer, the surface tends to crust as it dries.

These soils are suited to grass and legumes. The common cropping system consists of 3 to 4 years of wheat, barley, flax, and either fallow or corn. Stands of flax and corn are generally spotty because of the crusting of the surface.

Tillage and other farming operations are complicated by the fact that the moisture content is not optimum at the same time in all the soils. Grass and legumes in the rotation help to maintain the tilth. The roots of legumes loosen the soil by opening temporary channels through the claypan. Where crops are grown every year, wind erosion can generally be controlled by leaving crop residue undisturbed, but seldom is there residue enough to protect fallowed land. Consequently, stripcropping or the use of cover crops or of other means of erosion control is essential. Grass and legumes in the cropping system also help to control erosion. Field windbreaks are generally unsatisfactory, because of poor growth of trees on the Aberdeen and Larson soils. Applications of barnyard manure benefit crops grown on Aberdeen and Larson soils. Growing early maturing crop varieties lessens the chance of drought damage.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Range benefits from deferment of grazing

Some areas of these soils are favorable for wildlife.

Capability unit IIIse-P

This unit consists of two complexes of Heimdal and Larson soils. These soils have good natural fertility and adequate organic-matter content. Water erosion is a moderate hazard. The Larson soils have a claypan that is very slowly permeable to water, air, and plant roots but, once saturated, becomes very soft and is slow to dry out. Where subsoil material has been mixed into the plow layer, the surface tends to crust as it dries.

These soils are suited to grass and legumes. The common cropping system consists of 3 or 4 years of wheat, barley, flax, and either summer fallow or corn. Stands of flax and corn are generally spotty because of the crusting of the surface layer.

Tillage and other farming operations are complicated by the fact that the moisture content is not optimum in both soils at the same time. Grass and legumes in the rotation help to maintain the tilth. The roots of legumes open temporary channels through the claypan in the Larson soils. Where crops are grown every year, wind erosion can generally be controlled by leaving crop residue undisturbed, but seldom is there residue enough to protect fallowed land. Consequently, stripcropping or the use of cover crops or of other means of erosion control is essential. Grass and legumes in the cropping system also help to control erosion. Field windbreaks are generally unsatisfactory, because of poor growth of trees on the Larson soils. Barnyard manure greatly benefits crops grown on Larson soils. Growing early maturing crop varieties lessens the chance of drought damage.

Grazing should be regulated so that not more than half the annual growth of desirable plants is consumed. A system of deferred grazing is highly desirable. Range recovers slowly from overuse.

Capability unit IIIs-4L

This unit consists of Divide loam, a limy soil that is moderately deep over sand and gravel. This soil has medium natural fertility and high organic-matter content. It has a high water table in spring but is droughty after the water table recedes, because the space for storage of water is limited. The lime content makes the soil susceptible to wind erosion.

All of the local crops are grown. A 3- or 4-year rotation is usual. Barley and flax are the crops best suited.

Careful management of crop residue is needed for control of erosion. Stripcropping and windbreaks are needed also, because in some years the amount of residue is inadequate for protection. Grass in the crop rotation helps to check erosion. Summer fallow should be resorted to only when necessary for control of weeds, and fallow land needs to be protected with buffer strips. The response to phosphate is good.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed.

Some areas of this soil are favorable for wildlife.

Capability unit IIIs-5

This unit consists only of Renshaw loam, level, a soil that is moderately deep over sand and gravel. This soil is droughty because of the limited space for storage of moisture. Natural fertility is medium, and the organic-matter content is medium. Wind erosion is a hazard in cultivated areas.

This soil is suited to grass, legumes, and all locally grown crops. The common cropping system is a 3- or 4-year rotation of wheat, barley, flax, and corn.

Stripcropping is needed for control of wind erosion because the amount of crop residue is so small in dry years. Summer fallow does little good because the moisture storage capacity is so limited. Early maturing crops are best suited. Grass and legumes in the rotation improve the moisture relationship.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Forage production is readily affected by weather. The range recovers slowly once its condition has deteriorated.

Capability unit IIIse-5

This unit consists only of Renshaw loam, gently sloping. This soil is droughty because it is only moderately deep over sand and gravel. Natural fertility is medium, and the organic-matter content is medium. Wind erosion and water erosion are hazards in cultivated areas.

This soil is suited to grass, legumes, and all locally grown crops. The common cropping system is a 3- to 4-year rotation of wheat, barley, flax, and corn. Grass could be included also.

Stripcropping and good use of crop residue are essential for control of erosion. Cover crops help also. Except for control of noxious weeds, summer fallow is of little benefit, because the soil has low water-holding capacity.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed.

Capability unit IVe-2

This unit consists only of Hecla-Maddock loamy fine sands, which are deep soils that are extremely susceptible to wind erosion. These soils have rapid permeability and low water-holding capacity. The natural fertility is low, and the organic-matter content is low.

Small grain, corn, grass, and legumes are grown. The common cropping sequence is 4 to 6 years of summer fallow or corn, wheat, and barley and 4 to 6 years of grass and legumes in 10 years.

For control of erosion, crop residue should be left undisturbed between harvest and seeding; in years when there is not enough residue, cover crops are needed. It is helpful to use tillage and seeding implements that leave as much residue as possible on the surface. In stripcropping, the strips ought to be extremely narrow, and grass should be grown at least half the time. If corn is grown, a few rows should be left unharvested to serve as buffer strips. Windbreaks are useful in erosion control, but they are hard to establish. Only early maturing crop varieties should be seeded.

On range it is necessary to maintain a vegetative cover adequate to control wind erosion. Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Proper location of water and salt helps in the distribution of grazing. Deferment of grazing is beneficial. Sheep create more of an erosion hazard than cattle.

Capability unit IVs–5

This unit consists of Larson-Miranda complex. The soils in this complex have a claypan in the subsoil that is very slowly permeable to water, air, and plant roots but, when saturated, becomes very soft and is slow to dry out. In places where part of the subsoil has been mixed into the plow layer, the surface tends to crust over as it dries.

The common cropping system is a 3- or 4-year rotation of wheat, barley, and either flax or summer fallow.

The legumes open temporary channels through the claypan. Small-grain residue left undisturbed generally controls erosion until seeding time in spring but is not sufficient for protection through a season of fallow. Seldom does a flax crop leave enough residue for control of erosion. Consequently, stripcropping, cover crops, inclusion of grass and legumes in the rotation, and other measures are required. Grass and legumes help to maintain tilth also. Trees do not grow satisfactorily on these soils. Barnyard manure benefits plants.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed.

Capability unit Vw–WL

This unit consists of very poorly drained soils that have excess water on or at the surface during much of the growing season. These soils are members of the Benoit and Colvin series. They contain a large amount of organic matter. The natural fertility is very high.

These soils are not suitable for cultivation, but they are well suited to grass. In some years ponded water is deep enough that cattails and bulrushes grow instead of grass. Areas surrounded by cropland and too small to fence for use as pasture are used for hay or for fall grazing.

Grass production is not readily affected by periods of drought, nor is the grass likely to be overgrazed. Hay should be mowed early enough to allow time for some regrowth before the ground freezes. The mowing should leave several inches of stubble in the field.

Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Some of the larger areas can be fenced as a complete pasture and thus can be managed more easily. Proper location of water and salt helps in the distribution of grazing.

These soils are favorable for wildlife.

Capability unit VIe–Sa

This unit consists only of Eroded sandy land, a land type that absorbs water rapidly but, in most places, has low water-holding capacity. In the places where all the original surface layer and subsoil have been removed by erosion, natural fertility is low and the organic-matter content is low.

Areas now cultivated need to be seeded to grass. Grazing and haying have to be delayed until the grass is well established. For best results, these areas should be managed separately from surrounding areas.

Careful management of areas already covered with grass is needed because rapid deterioration results from even a short period of overuse. Special attention should be paid to the establishment of grass in blowouts. Barnyard manure or a straw mulch helps to get the grass started. Grazing should be regulated so that not more than half the annual growth of desirable plants is consumed, and it should be properly distributed. The range benefits from deferment of grazing, especially through the early part of the growing season and the period of seed production. Grazing is easier to manage if the livestock are cattle, rather than sheep.

Only a few areas are favorable for wildlife.

Capability unit VIe–Si

This unit consists of Barnes-Buse loams, hilly. These are deep soils that are somewhat droughty because of excessive surface drainage. They are highly susceptible to erosion. The water-holding capacity and the natural fertility are high.

These soils are not suitable for cultivation. Areas still cultivated ought to be seeded to grass. Areas that cannot be included in larger acreages of range can be used for fall grazing. Grazing should be regulated so that not more than half the annual growth of desirable plants is consumed. The range benefits from deferment of grazing, which is made possible by using several pastures in rotation. Proper location of salt and water, particularly in the steeper areas that are likely to be undergrazed, promotes distribution of grazing. Favorable sites for water developments are available. Brush control is necessary in a few places. The range recovers slowly from overuse.

Some areas of these soils are favorable for wildlife.

Capability unit VIe–tSi

This unit consists only of Buse-Barnes loams, steep. These are deep soils that are droughty because of excessive surface drainage. They are highly susceptible to erosion. The water-holding capacity and natural fertility are high.

A good protective cover is needed on these soils for control of runoff and maintenance of productivity. Proper range use is needed for maintenance or improvement of the range. Grazing should be regulated so that not more than half the annual growth of desirable plants is consumed. Pastures benefit from deferred grazing, which is made possible by using several pastures in rotation. Fences that separate these soils from soils in other range sites are feasible in most areas, and they help in the proper distribution of grazing. Range recovers slowly from overuse.

Capability unit VIs-Ps

This unit consists only of Miranda-Larson complex. The soils in this complex have a thin surface layer, a very slowly permeable claypan in the subsoil, and a saline substratum.

These soils are not suitable for cultivation, and any areas still cultivated ought to be seeded to grass. Areas that cannot be included in a larger acreage of range can be used for hay, for fall grazing, or as wildlife habitat. Even when the range is in excellent condition, grass production is low because of lack of moisture in midsummer and because grass tends to mature early. Grazing and mowing need to be regulated so that not more than half the annual growth of desirable plants is removed. Proper location of water and salt and fencing where practical help to keep grazing distributed. Sites suitable for dugout ponds are available.

Capability unit VIs-Sb

This unit consists of Stony alluvial land. This land type is moderately wet. It is not suitable for cultivation, because of its stoniness, but is easily managed as range. The moderate wetness improves productivity, and the productivity is not affected by lowering the water table, because plant roots penetrate deep into the soil. The chief management need is the regulation of grazing so that only about half the annual growth of desirable plants is consumed. Range condition is improved by deferment of grazing. Range recovers readily from short-term overuse.

Capability unit VIs-Si

This unit consists of soils of the Barnes and Sioux series and Loamy lake beaches. These soils are too stony to be cultivated, but they can be used for range. Grazing should be regulated so that only about half the annual growth of desirable plants is consumed. Deferment of grazing is beneficial. Proper location of salt and water helps in the distribution of grazing. Salt should not be placed on the Sioux soils, because the range deteriorates rapidly if overused. Favorable sites for water developments are few, except on Loamy lake beaches. Overuse of the Barnes and Sioux soils is not likely, because they are so stony.

These areas are favorable for wildlife.

Capability unit VIw-Ov

This unit consists only of Lamoure and Divide soils, channeled. These soils receive extra moisture in the form of seepage from adjacent areas. They have moderate permeability and high to medium water-holding capacity.

Production of forage is very good on these soils, and it is reduced only slightly by short periods of drought. Grazing needs to be regulated so that only about half the annual growth of desirable grass is consumed. Deferment of grazing helps to maintain and improve range condition. The range recovers readily from short periods of overuse.

Some areas of these soils are favorable for wildlife.

Capability unit VIIs-SS

This unit consists of Exline soils and Saline land. These soils have a fluctuating water table and contain large amounts of salts. The salts limit the depth to which roots can penetrate and restrict the availability of plant nutrients. The soils have to be wet before plant nutrients are available. Plants grow well in spring and during wet seasons, but usually they do not mature, because the water table drops as the growing season progresses and rainfall is inadequate to sustain growth.

These soils are best suited to grass. Range that is overused even for short periods deteriorates rapidly. Grazing should be regulated, if possible, so that not more than half the annual growth of desirable plants is consumed.

Capability unit VIIs-SwG

This unit consists only of Sioux-Arvilla sandy loams. These soils are shallow over gravel and have low water-holding capacity. The organic-matter content is low. The soils can be used for range, but careful management is needed because, at best, the production of grass is low, and once abused, the range is slow to recover.

Predicted Yields

Predicted yields of the principal crops grown in Wells County, under two levels of management, are shown in table 2. These predictions are based on information obtained from farmers and other agricultural workers in the county. They are averages for a period long enough to include years of both favorable and unfavorable temperatures and moisture supply during the growing season. The predictions represent the acreage planted, rather than only the acreage harvested.

Woodland and Windbreaks

Only about 200 acres in Wells County consists of native woodland. Most of this acreage consists of north-facing slopes. A large part is in the vicinity of Hawks Nest, which is in the southeastern corner of the county, and in the vicinity of Pony Gulch, which is in the west-central part. The trees are principally American elm, aspen, boxelder, and green ash, and the understory is made up of chokecherry, plum, juneberry, and wolfberry. These shrubs also grow in clumps on the fringes of wooded areas and in areas of brush where there are no trees. The native woodland and brushy areas are used mainly for watershed protection and as wildlife habitat.

In the rest of the county, the native vegetation was mainly prairie grass. A few stunted aspens and cottonwoods and some clumps of willow were scattered throughout the county, but these trees did not amount to much, because they were damaged so often by prairie fires.

Trees and shrubs have been planted in this county mainly to make windbreaks. The windbreaks protect crops, livestock, wildlife, and farm buildings, and they

TABLE 2.—*Predicted average acre yields of principal crops*

[Yields in columns A can be expected under prevailing management; those in columns B can be expected under improved management. Dashed lines indicate that the crop is not suited to the soil]

Soil	Hard spring wheat		Durum wheat		Flax		Barley		Oats		Corn	
	A	B	A	B	A	B	A	B	A	B	A	B
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Tons*	*Tons*
Arvilla sandy loam, level	13	17	8	13	4	6	18	24	27	35	3	4
Arvilla sandy loam, gently sloping	11	16	7	11	3	5	15	22	24	33	2	4
Barnes loam, rolling	18	23	18	23	5	7	24	30	34	45	3	4
Barnes loam, rolling, eroded	15	20	15	20	4	6	21	27	30	40	2	3
Barnes-Buse loams, hilly	----	----	----	----	----	----	----	----	----	----	----	----
Barnes stony loam	----	----	----	----	----	----	----	----	----	----	----	----
Barnes-Svea loams, level	28	32	28	32	8	11	35	40	45	55	5	6
Barnes-Svea loams, undulating	26	30	26	30	7	10	32	38	42	50	5	6
Bearden-Perella silt loams	15	35	12	30	5	11	35	50	40	60	2	6
Benoit loam	8	15	8	15	3	8	12	25	18	30	2	4
Benoit loam, very poorly drained	----	----	----	----	----	----	----	----	----	----	----	----
Borup loam	15	22	12	20	5	9	25	35	30	38	2	5
Buse-Barnes loams, steep	----	----	----	----	----	----	----	----	----	----	----	----
Colvin-Lamoure complex	6	14	4	10	4	6	12	18	15	20	----	----
Colvin and LaPrairie soils	20	28	16	26	8	12	25	35	35	50	5	6
Colvin soils, very poorly drained	----	16	----	10	----	7	----	25	----	28	----	----
Dimmick clay	----	35	----	22	----	5	----	45	----	45	----	----
Divide loam	16	20	13	18	5	8	22	28	30	36	3	4
Egeland fine sandy loam, till substratum, rolling	12	18	9	16	2	5	20	26	30	40	3	5
Egeland-Embden fine sandy loams, undulating	17	24	15	21	5	8	25	32	37	45	4	6
Egeland-Embden fine sandy loams, till substratum, undulating	18	25	15	21	5	8	28	34	38	46	4	6
Emden-Egeland fine sandy loams, level	21	26	18	24	6	9	30	36	39	48	5	6
Embden-Egeland fine sandy loams, till substratum, level	22	28	20	26	6	9	32	38	40	50	5	6
Emrick-Larson loams	17	22	16	20	5	7	25	32	35	44	4	5
Eroded sandy land	----	----	----	----	----	----	----	----	----	----	----	----
Exline soils	----	----	----	----	----	----	----	----	----	----	----	----
Fargo-Aberdeen complex	17	20	17	20	2	5	28	34	32	46	3	5
Fargo silty clay	16	25	14	24	4	7	30	40	35	50	----	----
Forman clay loam, nearly level	25	30	25	32	7	10	36	42	42	50	3	5
Forman clay loam, undulating	25	30	25	32	6	10	35	40	40	48	3	5
Fram loam	25	30	27	32	8	11	30	40	45	55	5	6
Gardena-Eckman loams	28	32	28	32	8	11	35	40	45	55	5	6
Hamerly loam	24	30	25	32	8	11	33	40	45	55	5	6
Hecla-Maddock loamy fine sands	9	13	6	11	3	5	20	25	24	30	2	4
Heimdal-Emrick loams, level	28	32	28	32	8	11	35	40	45	55	5	6
Heimdal-Emrick loams, undulating	26	30	26	30	8	11	34	38	43	53	5	6
Heimdal-Larson loams, gently sloping	17	22	16	20	5	7	26	32	36	44	4	5
LaDelle silt loam, level	28	32	28	32	8	11	35	40	45	55	5	6
LaDelle silt loam, gently gloping	26	31	25	31	7	11	30	38	42	53	4	6
Lamoure and Divide soils, channeled	----	----	----	----	----	----	----	----	----	----	----	----
Lamoure-Exline complex	12	18	10	14	5	8	18	28	20	30	2	4
Larson-Heimdal loams, gently sloping	15	20	14	18	3	6	25	30	35	42	2	4
Larson-Miranda complex	14	18	12	18	3	6	20	30	35	40	1	4
Letcher fine sandy loam	16	20	13	18	5	8	24	30	32	40	4	5
Loamy lake beaches	----	----	----	----	----	----	----	----	----	----	----	----
Miranda-Larson complex	----	----	----	----	----	----	----	----	----	----	----	----
Nutley silty clay	25	30	27	34	6	8	35	50	40	55	2	4
Overly silty clay loam	26	30	27	32	8	11	38	45	50	60	4	5
Parnell silty clay loam	----	35	----	30	----	10	----	50	----	60	----	----
Pits and dumps	----	----	----	----	----	----	----	----	----	----	----	----
Renshaw loam, level	16	20	12	16	5	7	20	25	28	35	3	4
Renshaw loam, gently sloping	12	15	9	12	4	6	18	23	26	32	2	3
Saline land	----	----	----	----	----	----	----	----	----	----	----	----
Sioux-Arvilla sandy loams	----	----	----	----	----	----	----	----	----	----	----	----
Sioux-Barnes complex, stony	----	----	----	----	----	----	----	----	----	----	----	----
Stony alluvial land	----	----	----	----	----	----	----	----	----	----	----	----
Tonka silt loam	18	35	10	35	8	12	30	50	40	60	----	5
Ulen and Hamar fine sandy loams	12	19	10	17	4	7	15	30	20	35	2	5
Vallers loam	12	20	8	16	4	8	20	35	25	40	2	5

TABLE 3.—*Predicted mature height of trees and shrubs*

[Dashes indicate soil is marginal or not suited to the tree or shrub]

Soil	Ash	Box-elder	Cotton-wood	American elm	Siberian elm	White and golden willow	Cedar	Colorado blue spruce	Ponderosa pine	Siberian crab	Russian-olive	Lilac	Choke-cherry	Plum	Honey-suckle	Caragana
	Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*
Arvilla sandy loam	30	26	-----	35	32	-----	12	-----	32	16	16	6	11	-----	8	10
Barnes loam	38	33	-----	45	45	-----	16	-----	40	20	20	8	14	-----	10	12
Bearden silt loam	44	36	-----	50	42	35	16	38	40	17	22	8	10	8	10	10
Borup loam	-----	-----	60	35	-----	30	-----	35	-----	-----	18	-----	-----	10	-----	-----
Dimmick clay	-----	-----	60	-----	-----	30	-----	-----	-----	-----	20	-----	-----	-----	-----	-----
Divide loam	38	33	65	44	40	-----	16	-----	34	16	18	8	10	-----	8	10
Eckman loam	38	33	-----	45	42	-----	16	-----	40	20	20	8	14	-----	10	12
Egeland fine sandy loam	36	33	-----	45	44	-----	16	-----	40	20	20	8	14	-----	10	12
Embden fine sandy loam	42	37	65	50	48	32	18	44	44	22	22	10	15	8	12	14
Emrick loam	42	38	70	50	48	26	20	46	46	24	24	11	15	8	14	16
Exline soils	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Fargo silty clay	36	33	-----	45	42	-----	16	-----	40	16	16	8	14	-----	10	12
Forman clay loam	38	33	-----	45	42	-----	16	-----	40	20	20	8	14	-----	10	12
Fram loam	44	36	70	53	45	36	18	40	42	18	24	8	12	8	12	12
Gardena loam	42	38	70	50	48	36	20	46	46	24	24	11	15	8	14	16
Hamar fine sandy loam	42	37	75	50	-----	32	18	44	-----	22	22	9	15	10	-----	-----
Hamerly loam	42	35	60	50	42	35	16	38	40	17	22	8	10	8	10	10
Hecla loamy fine sand	42	37	60	50	48	32	18	42	44	22	22	9	15	8	12	14
Heimdal loam	38	33	-----	45	44	-----	16	-----	40	20	20	8	14	-----	10	12
LaDelle silt loam	45	40	68	55	50	35	19	46	46	24	24	11	16	8	14	16
LaPrairie silt loam	44	35	70	55	45	36	12	40	35	15	24	6	10	10	10	-----
Maddock loamy fine sand	34	32	-----	42	40	-----	14	-----	38	18	18	7	12	-----	10	10
Nutley silty clay	36	32	-----	42	40	-----	14	-----	38	18	18	7	12	-----	10	10
Overly silty clay loam	40	35	-----	47	45	-----	16	40	42	20	20	8	14	-----	10	12
Parnell silty clay loam [1]	-----	-----	60	-----	-----	30	-----	-----	-----	-----	20	-----	-----	-----	-----	-----
Perella silt loam [1]	-----	-----	60	-----	-----	30	-----	-----	-----	-----	20	-----	-----	-----	-----	-----
Svea loam	45	40	70	55	50	35	20	46	46	24	24	11	16	8	14	16
Tonka silt loam [1]	35	-----	60	45	-----	30	-----	40	-----	16	20	7	-----	10	-----	-----
Ulen fine sandy loam	35	-----	70	45	-----	30	-----	40	38	14	20	7	12	7	-----	-----

[1] Suitable for the trees indicated if drained.

help to control erosion, to conserve moisture, and to control the drifting of snow. They are important in the Northern Great Plains, and many have been established during the history of Wells County. Early settlers planted trees on the north and west sides of their farmsteads. Among the agencies that have planted windbreaks or cooperated with farmers in planting windbreaks are the following: The Great Northern Railway Company, in the early 1900's; the Northern Great Plains Field Station, from 1924 to 1947; the Prairie States Forestry Project, from 1938 to 1942; the Soil Conservation Service, since 1939; and, in recent years, the North Dakota State Game and Fish Department. Remnants of the plantings of the early 1900's are still to be seen along the tracks of the Great Northern Railway Company. Nearly all the later plantings are still in good condition. A few windbreaks have been damaged by heavy grazing, and the two or three center rows of cottonwoods in many of the older windbreaks have died out, except in low areas that receive extra moisture.

Most of the soils of the county have no native trees or shrubs, and some are so ill suited to trees that planting of windbreaks should not be attempted. Table 3 lists the soils that are suitable for windbreak plantings and shows the kinds of trees and shrubs best suited and the height to which each kind can be expected to grow. (Although the Aberdeen and Larson soils are not suitable for trees and are not listed in the table, windbreaks can be established in some areas where these soils are mapped in complexes with Fargo, Emrick, and Heimdal soils.) The information in the table is based on field measurements and on the judgment of agricultural workers.

A farmstead windbreak in Wells County ordinarily occupies about 2.5 acres and protects only the north and west sides of the farmstead. In recent years snow-trap plantings have been established on the south and east sides of some homesteads. The trend in field windbreaks has been toward narrower plantings. Plantings of 10 to 23 rows were popular in 1942, and of 1 to 3 rows since 1959.

Establishment of a windbreak and continued growth of the trees depend upon careful selection of the site, suitable preparation, and adequate maintenance. Grass and weeds have to be eliminated before the trees are planted, and the regrowth of the ground cover has to be controlled for the entire life of the windbreak. Some replanting is likely to be needed in the first and second years.

Cottonwood, Siberian elm, and willow all grow rapidly, perhaps 2 feet a year, in the first years after planting. Ash, American elm, and boxelder grow more slowly, perhaps 1 foot a year, in the first years. Ponderosa pine and Colorado blue spruce grow 6 to 9 inches a year for the first 10 years and then 1 foot to 1½ feet a year until maturity. Most of the suitable shrubs grow 1½ to 2 feet a year for the first 15 years and then more slowly.

Four types of windbreak plantings are common. The most important are field windbreaks that consist of a series of narrow 1- to 3-row strips, planted at intervals across cropped fields for control of wind erosion. Next in importance is the multiple-row (generally 5- to 10-row) farmstead windbreak (fig. 23) that protects buildings and livestock from winter wind and drifting snow, shelters wildlife, and beautifies the homestead. Another type is generally 15 or more rows wide and is planted near the farmstead and in or adjacent to fields to provide food and cover for wildlife. A fourth type is planted to screen unsightly areas, add color and contrast in areas of open fields, and otherwise beautify the landscape. Windbreaks of this type vary in size and shape.

Range [3]

The original vegetation in Wells County consisted mainly of mid grasses, but there were also short and tall grasses, broad-leaved plants (forbs), and numerous kinds of legumes. The short grasses were prevalent on the droughtier soils, and the tall grasses were common in places where the moisture supply was favorable, generally in areas subject to flooding, subirrigation, or drifting snow. Cool-season grasses predominated, but warm-season grasses also grew in most areas.

At present, about 19 percent of the county is in range. Most of this acreage consists of hilly glacial moraines, stream breaks, and ponded or saline soils. Most of the grassland has been depleted as a result of overuse. Some has been damaged by silt washed from cultivated fields.

Range sites and condition classes

Soils are grouped into range sites on the basis of similarity in the characteristics that affect their capacity for producing native forage plants. Eleven range sites are recognized in Wells County. Each site has a distinctive climax vegetation, the composition of which depends upon a combination of environmental conditions, mainly the combined effect of soil and climate. The climax vegetation reproduces itself as long as the environmental conditions remain the same.

Range condition is rated by comparing the composition of the existing vegetation with that of the climax vegetation. An estimate of the deterioration that has taken place indicates the degree of improvement possible.

Four range condition classes are recognized: excellent, good, fair, and poor. A range is in excellent condition if 76 to 100 percent of the existing vegetation is of the same composition as that of the potential stand. It

[3] By HUGH E. COSBY, range conservationist, Soil Conservation Service.

Figure 23.—**A good farmstead windbreak that provides protection for buildings and livestock. The soils are Embden-Egeland fine sandy loams.**

is in good condition if the percentage is between 51 and 75, in fair condition if the percentage is between 26 and 50, and in poor condition if the percentage is less than 26.

The plants on any given range site are grouped, according to their response to grazing, as decreasers, increasers, and invaders. Decreasers are plants in the climax vegetation that tend to die out if heavily grazed. Increasers are plants in the climax vegetation that become more abundant as the decreasers decline, and then start to die out if heavy grazing continues. Invader plants are not a part of the climax vegetation, but they generally take over under heavy grazing.

In the following pages each of the 11 range sites in Wells County is described, and estimates of average yields are given. These are estimates of the entire annual growth above ground, not what would be removed by grazing or haying.

The names of the soil series represented are mentioned in the description of each site, but this does not mean that all the soils in a given series are in the range site. The range site classification of each soil is given in the "Guide to Mapping Units." The mapping unit called Pits and dumps was not placed in a range site.

CLAYEY RANGE SITE

This site consists of soils in the Aberdeen, Fargo, Forman, Nutley, and Overly series. These soils have a surface layer of silty clay loam, clay loam, or silty clay. They take in about 3 inches of water an hour if there is a good cover of grass and mulch, but there is a rapid decline in water intake with the loss of cover. More water per foot of soil is stored in these soils than in those on the other range sites in this county.

Green needlegrass and western wheatgrass produce most of the forage on this site. A decline in range condition results first in a decrease of green needlegrass and an increase of western wheatgrass. A continued decline results in a decrease of western wheatgrass and an increase of blue grama and needleleaf sedge. Fringed sagewort is the most prominent increaser forb. Curlycup gumweed is a common invader where the range condition has declined.

If this range site is in excellent condition, the estimated average yield per acre is 2,600 pounds, air-dry weight, in years of favorable moisture supply and 1,000 pounds in years of unfavorable supply.

OVERFLOW RANGE SITE

This site consists of soils in the Colvin, Divide, Exline, Lamoure, LaPrairie, and Tonka series. These soils regularly receive more than a normal amount of moisture because they are flooded or because water runs in from higher areas. Since much of the water that runs in is stored in the soils, the production of forage in these soils is greater than in other soils on uplands.

The principal decreaser grasses on this site are needlegrass and porcupinegrass. Other common decreaser grasses are bearded wheatgrass, slender wheatgrass, big bluestem, and prairie dropseed. Among the decreaser forbs are purple prairie-clover, silverleaf scurf-pea, and stiff sunflower.

A decline in range condition results first in a temporary increase of western wheatgrass. Continued decline results in an increase of bluegrass, Penn sedge, needleleaf sedge, fringed sagewort, western snowberry, and western yarrow. Kentucky bluegrass and curlycup gumweed are common invaders.

If this range site is in excellent condition, the estimated average yield per acre is 3,200 pounds, air-dry weight, in years of favorable moisture supply and 1,200 pounds in years of unfavorable moisture supply.

PANSPOTS RANGE SITE

This site consists of soils in areas where shallow depressions make up 20 to 50 percent of the acreage. These soils are members of the Larson and Miranda series. Little moisture penetrates the hard, impervious, clayey soil material that is close to or at the surface in the depressions, but the penetration of moisture is fair to good in the areas between the depressions.

Western wheatgrass and green needlegrass are the main decreasers. When the site is in excellent condition, they make up most of the forage. When the site is in poor condition, most of the cover is made up of blue grama, needleleaf sedge, and inland saltgrass, which are increasers, and curlycup gumweed, which is an invader.

If this range site is in excellent condition, the estimated average yield per acre is 2,000 pounds, air-dry weight, in years of favorable moisture supply and 600 pounds in years of unfavorable moisture supply.

SALINE SUBIRRIGATED RANGE SITE

This site consists of Saline land and soils in the Exline series. These soils have accumulations of salts and alkali. The Exline soils have a permanent high water table that is beneficial to forage plants through most of the growing season. Saline land has a fluctuating water table that is beneficial to plants only in spring or in seasons when rainfall is above normal. The cover on this site consists mostly of salt-tolerant plants.

Nuttall alkaligrass, alkali cordgrass, slender wheatgrass, western wheatgrass, and plains bluegrass are among the principal decreasers. A decline in range condition results first in an increase of inland saltgrass, alkali muhly, and mat muhly. Continued decline results in an increase in Baltic rush and spike sedge. Pursh seepweed is a common invader. This site deteriorates rapidly if overused.

When this site is in excellent condition, the estimated average yield per acre is 3,200 pounds, air-dry weight, in years of favorable moisture supply and 1,200 pounds in years of unfavorable moisture supply.

SANDS RANGE SITE

This site consists only of Eroded sandy land, a land type that consists of deep, loose, excessively drained loamy fine sand. Water is taken in rapidly and penetrates deeply. The climax plants are deep rooted and obtain water from deep in the soil, but a decline in range condition limits the development of the root system and thus makes less moisture available to plants.

Among the decreaser grasses, prairie sandreed is the most prevalent; big bluestem, little bluestem, and switchgrass are common in swales and slight depressions; and sand bluestem is common on ridges. Among the decreaser legumes are leadplant amorpha, purple prairie-clover, and silky prairie-clover. The increasers include needle-and-thread, sand dropseed, sun sedge, field sagewort, and hairy goldaster. Numerous kinds of brush and scrubby trees invade if the range condition declines. Of the common invaders, Kentucky bluegrass has the most forage value.

If this range site is in excellent condition, the estimated average yield per acre is 2,600 pounds, air-dry weight, in years of favorable moisture supply and 1,000 pounds in years of unfavorable moisture supply.

SANDY RANGE SITE

This site consists of soils in the Arvilla, Egeland, Embden, Hecla, Letcher, and Maddock series. These soils have a surface layer of sandy loam, fine sandy loam, or loamy fine sand. They hold more moisture than soils of the Sands range site. Water intake generally is moderately rapid, but it is affected by range cover.

The climax vegetation on this site consists of many different kinds of plants. The common decreasers are prairie sandreed, Canada wildrye, big bluestem, little bluestem, prairie dropseed, silverleaf scurf-pea, purple prairie-clover, and leadplant amorpha. Among the increasers are needle-and-thread, western wheatgrass, bluegrass, sun sedge, sand dropseed, prairie junegrass, fringed sagewort, stiff goldenrod, and western snowberry.

If this range site is in excellent condition, the estimated average yield per acre is 2,600 pounds, air-dry weight, in years of favorable moisture supply and 1,000 pounds in years of unfavorable moisture supply.

SHALLOW TO GRAVEL RANGE SITE

This site consists of Sioux-Arvilla sandy loams, which are shallow over clean gravelly material. These soils are more droughty than any of the soils in the other range sites. Very little moisture is stored below a depth of about 20 inches, and consequently plant growth depends on the weather.

Among the decreaser grasses, needle-and-thread is the most important, but western wheatgrass, prairie sandreed, and plains muhly may be present. Dotted gayfeather is a prominent decreaser forb. The most common increasers are blue grama, needleleaf sedge, and fringed sagewort.

If this range site is in excellent condition, the estimated average yield per acre is 1,600 pounds, air-dry weight, in years of favorable moisture supply and 600 pounds in years of unfavorable moisture supply.

SILTY RANGE SITE

This site consists of soils of the Barnes, Buse, Divide, Eckman, Emrick, Fram, Gardena, Hamerly, Heimdal, LaDelle, Larson, Renshaw, Sioux, and Svea series and Loamy lake beaches. These soils have a surface layer of loam or silt loam. They take in more than 3 inches of water an hour when the site is in excellent condition (*3*), but they often take in less than 1 inch an hour when the condition is only fair.

The climax vegetation on this site consists of many grasses, forbs, and legumes. Among the important decreasers are green needlegrass and porcupinegrass. Other decreasers of considerable importance are little bluestem, big bluestem, prairie dropseed, and bearded wheatgrass. Among the decreaser forbs and legumes are black sampson, dotted gayfeather, silverleaf scurf-pea, breadroot scurf-pea, purple prairie-clover, and stiff sunflower.

A decline in range condition results first in an increase of western wheatgrass and needle-and-thread and then in a decrease of western wheatgrass and needle-and-thread and a rapid increase in blue grama, threadleaf sedge, sun sedge, prairie junegrass, and other shorter grasses and sedges. Fringed sagewort, stiff goldenrod, and western snowberry invade when the range condition has declined. Kentucky bluegrass has invaded much of this range site.

If this range site is in excellent condition, the estimated average yield per acre is 2,600 pounds, air-dry weight, in years of favorable moisture supply and 1,000 pounds in years of unfavorable moisture supply.

SUBIRRIGATED RANGE SITE

This site consists of soils in the Benoit, Borup, Colvin, Hamar, Lamoure, Ulen, and Vallers series and Stony alluvial land. The water table is high, but it is rarely at the surface during the growing season. Moisture is usually within reach of deep-rooted plants. Production of forage is not much affected by dry weather, but it is affected by a drop in the water table and by overuse, which limits the development of roots.

The climax vegetation on this site consists of many kinds of grasses and forbs. The main decreaser grasses are big bluestem, little bluestem, switchgrass, prairie dropseed, and indiangrass. A decline in range condition results in a decrease of maximilian sunflower, Rydberg sunflower, and other forbs and an increase of mat muhly, Baltic rush, and pussytoes.

If this range site is in excellent condition, the estimated average yield per acre is 4,500 pounds, air-dry weight, in years of favorable moisture supply and 1,500 pounds in years of unfavorable moisture supply.

THIN SILTY RANGE SITE

This site consists only of Buse-Barnes loams, steep, which are thin soils on convex hilltops along the Sheyenne River. These soils take in less water than do those of the Silty range site and lose more as runoff. When the range is in excellent condition, the erosion hazard is only slight, but a decline in range condition results in a greater erosion hazard as well as more runoff and greater droughtiness.

Important grasses in the climax vegetation are little bluestem, side-oats grama, plains muhly, and needle-and-thread. Stiff sunflower is one of the most important broad-leaved plants. A decline in range condition results in a decrease in the size and amount of more desirable forage plants and an increase in blue grama, needleleaf sedge, and other short plants and of fringed sagewort and other invaders.

If this range site is in excellent condition, the estimated average yield per acre is 2,000 pounds, air-dry weight, in years of favorable moisture supply and 600 pounds in years of unfavorable moisture supply.

WETLAND RANGE SITE

This site consists of soils in the Bearden, Benoit, Colvin, Dimmick, Parnell, and Perella series. These soils are ponded part of the growing season. Benoit and Colvin soils are ponded because they have a high water table, and the other soils because they are in potholes and depressions. All of the soils on this site are too wet for cultivation. Usually, they are not too wet for a good stand of grass and sedges, but in some years they are ponded deeply enough to limit the growth of grass and promote the growth of cattails and bulrush.

The natural vegetation on Benoit and Colvin soils consists predominantly of northern reedgrass and woolly sedge and other tall and mid sedges. In these areas the range condition remains excellent even through short periods of drought, and it is not likely to deteriorate, because cattle prefer the grass in other areas.

In areas of Bearden, Dimmick, Parnell, and Perella soils, the dominant vegetation is rivergrass, sloughsedge, and American mannagrass. These areas produce more forage plants when shallow ponding lasts well into the growing season. Range condition often deteriorates rapidly because cattle seek out rivergrass and sloughsedge.

American sloughgrass, spike sedge, Baltic rush, and foxtail appear when the condition of this range site has declined. Areas where reeds, cattails, rushes, or true aquatics are common are not considered in determining the carrying capacity of this site.

If this range site is in excellent condition, the estimated average yield per acre is 7,500 pounds, air-dry weight, in years of favorable moisture supply and 2,000 pounds in years of unfavorable moisture supply.

Range management

The acreage in range in Wells County is small compared with that under cultivation, but range is an important resource and should be managed in a way that permits the best possible sustained forage yields. Basic to all successful management is proper stocking of the range in relation to the forage-producing capacity of the site. Proper stocking in this county means that about only half the annual growth on upland sites can be consumed. Uniform distribution of grazing throughout all parts of the range is commonly obtained by fencing and by distribution of water and salt. In a well-balanced grazing program that provides ample high-quality forage for the longest period possible, supplemental pasture is provided by seeding annual crops, expanding areas of native range, or seeding tame grasses in permanent pasture. Areas of range should be rested occasionally so that the cover of desirable plants will remain vigorous. This can be accomplished by using a system of deferred grazing. Both chemical and mechanical means of suppressing brush or weeds are effective in this county.

Wildlife [4]

About 20,200 acres in Wells County has been planted or is being protected primarily for wildlife habitat. This acreage includes 280 acres that has been planted to trees and shrubs with the cooperation of the Soil Conservation Service and the North Dakota Game and Fish Department. This and other changes in land use since the county was settled have affected the quality and distribution of wildlife habitat and thus the kinds and numbers of wildlife. For example, conversion of grassland to farms has eliminated the once-common bison, elk, antelopes, and bears and greatly reduced the number of sharptail grouse but has created a habitat suitable for introducing pheasant and partridge. Since the distribution of wildlife is closely related to use and management of the soils, it is discussed in relationship to the 10 soil associations, which are described in the section "General Soil Map."

Wells County has a fair potential for ringneck pheasants, which have been introduced. Pheasants are associated with cropland because they depend upon waste grain and the associated weed seeds for food. The best habitat for pheasants is in soil associations 1, 7, and 8, but there are areas that have some potential in soil association 2. The main limitation, especially in soil association 1, is lack of adequate cover. Cover for nesting areas can be provided by grass, weeds, and legumes that are not disturbed during the nesting season, which lasts through May and June. Cover for roosting areas can be provided by the kind of tall herbaceous vegetation that is native to wetland. Winter cover can be provided by tracts of tall herbaceous vegetation and shrubs, or combinations of shrubs and trees that are large enough and are arranged to control the drifting of snow.

Gray (Hungarian) partridge, which also is an introduced species, prefer somewhat more open sites than pheasants and are less demanding in their requirements for winter cover and protection of roosting areas. They need a large number of well-distributed shrub thickets. Otherwise, their requirements and range are quite similar to those of the pheasant. The best habitat for partridge is in soil associations 1, 7, and 8.

Sharptail grouse, a native game bird, need native grassland, shrub thickets, and scattered tracts of woodland. The best habitat for grouse is in soil associations 3 and 4 and along the James River and the Sheyenne River. The habitat can be maintained or improved by using conservative grazing practices, providing well-distributed shrub thickets on breeding range in summer, and planting or protecting the shrubs or combinations of shrubs and trees that can be used for winter cover.

Prairie chickens need both mid and tall grasses, but big bluestem and little bluestem appear to be the key grasses. Only a remnant of the prairie chicken population remains, because generally the tall grasses are grazed heavily by livestock or are used for hay. Soil associations 2, 3, and 7 have potential for prairie chickens. Protecting small, well-distributed areas of tall grasses from overgrazing is the best way to improve the habitat.

Among the furbearing animals in the county, the most important are minks, muskrats, and jackrabbits. Of lesser importance are badgers, foxes, skunks, weasels, and raccoons. There are a few beavers along the James River and the Sheyenne River. The streams and wetlands in soil associations 3 and 4 provide the best potential for minks and muskrats, although streams in other areas also have a good potential for minks. Habitat for minks and muskrats can be created or improved by constructing level ditches, impoundments, or facilities for controlling the water level. They can also be improved by protecting the vegetation on the margins of wetlands, on streambanks, and along the edges of the facilities used for watering livestock.

[4] By ERLING B. PODOLL, biologist, U.S. Conservation Service.

Ducks are numerous in Wells County. Among the species are mallards, pintails, bluewing teals, gadwalls, redheads, ruddy ducks, shovelers, American widgeons, canvasbacks, and scaups. The James River and the sloughs near the towns of Heimdal, Hamburg, and Bremen provide an excellent habitat. Soil associations 3 and 4 support good to excellent numbers of ducks, and the potential of soil association 1 could be increased substantially by creating permanent bodies of water at least an acre in size. Parnell, Colvin, Benoit, and Dimmick soils are wetland soils that can be developed as habitat for ducks by creating small ponds and by protecting the margins of wetland from trampling by cattle.

Geese live in the county only during migration. They prefer the food and the nearly level to undulating relief of the uplands of associations 1 and 7, but they also use the undulating areas of association 2 to a limited extent. More geese could be attracted to associations 1 and 7 by creating extensive impoundments of shallow water.

White-tailed deer are to be found in all parts of the county, but they are most numerous in areas that provide a woody cover and in areas where tall wetland vegetation is fairly extensive. Soil associations 3 and 4 have the best potential as deer habitat. Protecting woods, wooded draws, wetlands, and the margins of shrubby wetlands from damage by livestock is essential in maintaining the habitat. Proper use of grassland is also important.

Among the small birds and mammals in the county are mourning doves, seed-eating and insect-eating songbirds, cottontail rabbits, and tree squirrels. The most common insect-eating songbirds are western meadowlarks, sparrows, kingbirds, lark buntings, robins, horned larks, upland plovers, swallows, Franklin's gulls, and several kinds of woodpeckers.

Most of the fishing opportunities in Wells County are provided by artificial impoundments at Harvey and Sykeston, but in years when runoff is heavy there is fishing in the Sheyenne River and the James River. Perch, bullhead, and northern pike are the most common fish. Associations 3 and 4 have a fair potential for the construction of ponds, most of which would be suitable for bass and bluegill.

Engineering Uses of the Soils [5]

Some soil properties are of interest to engineers because they affect construction and maintenance of roads, airports, pipelines, building foundations, facilities for water storage, erosion control structures, irrigation and drainage systems, and sewage disposal systems. Among the properties most important to engineers are permeability to water, shear strength, compaction characteristics, drainage, shrink-swell properties, texture, plasticity, and reaction. Other important properties are depth to water table, depth to bedrock, water-holding capacity, and topography. Estimates of the soil properties significant in engineering are given in table 4, interpretations relating to engineering uses of the soils in table 5, page 60, test data in table 6, page 70, and the location and quantity of aggregate deposits in table 7, page 74.

The information in this section 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 soil properties that are significant in the planning of agricultural drainage systems, farm ponds, irrigation systems, and diversion terraces.
3. Make preliminary evaluations of soil and ground conditions that will aid in selecting locations for highways, airports, pipelines, and cables and in

[5] By EDWIN KUBLER, agricultural engineer, and WAYNE D. WAVRIN, State conservation engineer, Soil Conservation Service.

TABLE 4.—*Estimated engineering*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	Classification		
			USDA	Unified	AASHO
	Feet	*Inches*			
Aberdeen.	4–5	0–8	Silty clay loam	CL	A–6
		8–26	Clay loam	CL	A–7
		26–60	Silty clay and clay loam	CL	A–6
Arvilla: ArA, ArB.	5+	0–19	Sandy loam	SM	A–4
		19–60	Sand and gravel	SM, SP	A–2 or A–3
Barnes: BaC, BaC2, BbD, Be, BnA, BnB. For Buse part of BbD, see Buse series. For Svea part of BnA and BnB, see Svea series.	5+	0–60	Loam	CL or ML	A–6 or A–4
Bearden: Bp. For Perella part of this unit, see Perella series.	0–3	0–28	Silty clay loam	CL	A–6
Benoit: Br, Bt.	0–5	0–30	Loam	ML	A–4
		30–60	Sand and gravel	SW–SM	A–1 or A–2
Borup: Bu.	0–5	0–38	Loam or silt loam	ML	A–4
		38–50	Loamy fine sand	SM	A–2
Buse: BvE. For Barnes part of BvE, see Barnes series.	5+	0–60	Loam	CL or ML	A–6 or A–4

planning detailed investigations at the selected locations.

4. Locate probable sources of gravel, sand, and other construction materials.
5. Correlate performance of engineering structures with soil mapping units to develop information for overall planning useful in designing and maintaining engineering structures.
6. Determine the suitability of soils for cross-country movement of vehicles and construction equipment.
7. Supplement the information obtained from other published maps and reports and aerial photographs for the purpose of making soil maps and reports that can be used readily by engineers.
8. Develop other preliminary estimates for construction purposes pertinent to the particular area.

With the use of the soil map for identification, the engineering interpretations reported here can be useful for many purposes. It should be emphasized that they do not eliminate the need for sampling and testing at the site of specific engineering works involving heavy loads and excavations deeper than the depths of layers here reported. Even in these situations, the soil map is useful for planning more detailed field investigations and for suggesting the kinds of problems that may be expected.

Some of the terms used in soil science—for example, clay, silt, and sand—differ in meaning from the same terms used in engineering. These terms and others are defined in the Glossary.

Engineering classification systems

The system of classifying soils used by the American Association of State Highway Officials (AASHO) (*1*) is based on field performance of the soils in highways. It groups together soils that have about the same general load-carrying capacity. In this system the soils are placed in seven principal groups. The groups range from A–1, which consists of gravelly soils of high bearing capacity, to A–7, which consists of clayey soils that have low strength when wet. The relative engineering values of the soils within each group are indicated by group index numbers, which range from 0 for the best material to 20 for the poorest. The group index of a soil can be established only by laboratory tests. The AASHO classifications in table 6, engineering test data, include group index numbers for the soils tested.

The Unified soil classification system developed by the U.S. Army Corps of Engineers (*11*) is based on texture, plasticity, and liquid limit, and performance as engineering construction material. In this system, soil materials are identified as coarse grained (eight classes), fine grained (six classes), or highly organic (one class). The coarse-grained soils (less than half the material, by weight, passes the No. 200 sieve) are identified by the following symbols: GC, GW, GP, GM, SW, SP, SM, and SC. The fine-grained soils (more than half the material, by weight, passes the No. 200 sieve) are identified by the following symbols: ML, CL, OL, MH, CH, and OH.

Estimated engineering properties

Table 4 shows estimates of soil properties that affect engineering significantly. Depth to bedrock is not shown because, in this county, depth to bedrock is far enough below the surface to be no problem for engineering purposes. Some of the column headings in table 4 are discussed briefly in the following paragraphs.

Permeability indicates the rate at which water moves through undisturbed soil material. The estimates are based on structure and porosity and on the results of permeability and infiltration tests on undisturbed cores of similar soil material.

properties of the soils

Percentage passing sieve—			Permeability	Available water capacity	Reaction	Salinity	Dispersion	Shrink-swell potential
No. 4	No. 10	No. 200						
			In./hr.	*In./in. of soil*	*pH*			
100	100	75–85	0.63–2.0	0.20	6.1–7.3	None	Low	Moderate.
100	100	75–85	0.20–0.63	.20	7.4–8.4	None	High	High.
95–100	90–100	70–80	<0.06	.18	7.4–8.4	Severe [1]	High	Moderate.
100	95–100	35–45	2.0–6.3	.14	6.6–7.8	None	Low	Low.
80–100	40–60	5–15	6.3–20.0	.02	6.6–8.4	None	Low	None.
95–100	85–95	60–70	0.63–2.0	.17	6.6–8.4	None	Low	Moderate.
100	100	75–90	0.2–0.63	.20	7.4–9.0	None	Low	Moderate.
100	100	65–75	0.6–2.0	.20	7.4–8.4	None [2]	Low	Low.
60–70	25–35	5–15	6.3–20.0	.02	7.4–8.4	None	Low	None.
100	95–100	65–75	0.63–2.0	.17	7.4–8.4	None [2]	Low	Low.
100	95–100	20–30	2.0–6.3	.08	7.4–8.4	None	Low	Low.
90–100	85–95	65–75	0.63–2.0	.17	6.6–8.4	None	Low	Moderate.

TABLE 4.—*Estimated engineering*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	Classification		
			USDA	Unified	AASHO
	Feet	*Inches*			
Colvin: Ca, Cp, Cs. For Lamoure part of Ca, see Lamoure series; for LaPrairie part of Cp, see LaPrairie series.	0–3	0–60	Silty clay loam or clay loam	CL	A–6
Dimmick: Dc.	0–3	0–60	Clay	CH	A–7
Divide: Dd.	2–5	0–25	Loam	ML	A–4
		25–60	Sand and gravel	SW–SM	A–1 or A–2
Eckman.	5+	0–48	Loam or silt loam	ML or CL	A–4
		48–60	Sandy loam and loamy fine sand	SM	A–2
Egeland:					
EeB. For Embden part of this unit, see Embden series, unit EgA.	5+	0–40	Fine sandy loam	SM	A–4
		40–60	Loamy fine sand	SM	A–2
EdC, EfB. For Embden part of EfB, see Embden series, unit ElA.	5+	0–32	Fine sandy loam	SM	A–4
		32–60	Loam	CL or ML	A–6 or A–4
Embden:					
EgA. For Egeland part of this unit, see Egeland series, unit EeB.	5+	0–45	Fine sandy loam	SM	A–4
		45–60	Loamy fine sand	SM	A–2
ElA. For Egeland part of this unit, see Egeland series, units EdC, EfB.	5+	0–42	Fine sandy loam	SM	A–4
		42–60	Loam	CL or ML	A–6 or A–4
Emrick: Em. For Larson part of this unit, see Larson series.	5+	0–40	Loam or silt loam	CL–ML	A–4
		40–60	Loam	CL–ML	A–4
Eroded sandy land: Er.	5+	0–60	Sandy loam and loamy sand	SM	A–4 or A–2
Exline: Ex.	1–4	0–60	Clay loam	CL	A–6
Fargo: Fa, Fc. For Aberdeen part of Fa, see Aberdeen series.	1–4	0–6	Silty clay	MH	A–7
		6–60	Clay	CH	A–7
Forman: FoA, FoB.	5+	0–60	Clay loam or loam	CL	A–6
Fram: Fr.	2–5	0–60	Loam or silt loam	CL–ML	A–4
Gardena: Ge. For Eckman part of this unit, see Eckman series.	5+	0–56	Loam	CL–ML	A–4
		56–60	Sand	SM	A–2
Hamar.	1–4	0–13	Fine sandy loam	SM	A–4
		13–60	Loamy fine sand	SM	A–2
Hamerly: Ha.	2–5	0–60	Loam	CL	A–6
Hecla: Hd. For Maddock part of this unit, see Maddock series.	4–5	0–36	Loamy fine sand	SM	A–2
		36–60	Fine sand	SP–SM	A–2 or A–3
Heimdal: HeA, HeB, HlB. For Emrick part of HeA and HeB, see Emrick series; for Larson part of HlB, see Larson series.	5+	0–34	Loam or silt loam	ML–CL	A–4
		34–60	Loam	ML, CL	A–4
LaDelle: LaA, LaB.	5+	0–60	Loam or silt loam	ML–CL	A–4
Lamoure: Ld, Le. For Divide part of Ld. see Divide series; for Exline part of Le, see Exline series.	0–4	0–60	Silty clay loam or silty clay	CL	A–6

See footnotes at end of table.

properties of the soils—Continued

Percentage passing sieve— No. 4	Percentage passing sieve— No. 10	Percentage passing sieve— No. 200	Permeability	Available water capacity	Reaction	Salinity	Dispersion	Shrink-swell potential
			In./hr.	*In./in. of soil*	*pH*			
100	100	80–90	0.20–0.63	.19	7.4–9.0	Slight [2]	Low	Moderate.
100	100	90–100	0.06–0.20	.20	6.6–8.4	None	Low	High.
100	100	65–75	2.0–6.3	.17	6.6–8.4	None to slight [2]	Low	Low.
60–70	25–35	5–15	6.3–20.0	.02	6.6–8.4	None	Low	None.
98–100	95–100	70–80	0.63–2.0	.16	6.6–8.4	None	Low	Low.
100	95–100	20–30	2.0–6.3	.08	6.6–8.4	None	Low	Low.
100	100	35–45	2.0–6.3	.14	6.6–7.8	None	Low	Low.
100	100	20–30	6.3–20.0	.08	6.6–8.4	None	Low	Low.
100	100	35–45	2.0–6.3	.14	6.1–7.3	None	Low	Low.
95–100	90–100	60–75	0.63–2.0	.17	6.6–8.4	None	Low	Moderate.
100	100	35–45	2.0–6.3	.14	6.6–7.8	None	Low	Low.
100	100	20–30	6.3–20.0	.08	6.6–8.4	None	Low	Low.
100	100	35–45	2.0–6.3	.14	6.1–7.8	None	Low	Low.
95–100	90–100	60–75	0.63–2.0	.17	6.6–8.4	None	Low	Moderate.
100	95–100	65–75	0.63–2.0	.16	6.6–7.8	None	Low	Low.
98–100	90–100	65–75	0.2–0.63	.16	7.4–8.4	None	Low	Low.
100	90–100	20–45	2.0–6.3	.10	6.6–8.4	None	Low	Low.
100	95–100	80–90	<0.06	.17	6.6–9.0	Slight to severe [1]	High	High.
100	100	85–95	0.20–0.63	.20	6.6–8.4	None	None	High.
100	100	85–95	0.06–0.20	.19	6.6–8.4	None	None	High.
95–100	85–95	70–90	0.20–0.63	.19	6.6–8.4	None	Low	Moderate.
100	95–100	65–75	0.63–2.0	.16	6.6–8.4	None	Low	Low.
100	95–100	70–80	0.63–2.0	.16	6.6–8.4	None	Low	Low.
100	100	5–15	6.3–20.0	.02	6.6–8.4	None	Low	Low.
100	100	35–45	2.0–6.3	.14	6.6–8.4	None	Low	Low.
100	100	20–35	2.0–6.3	.08	6.6–8.4	None	Low	Low.
95–100	85–95	60–75	0.63–2.0	.17	6.6–8.4	None to moderate [2]	Low	Moderate.
100	100	15–25	6.3–20.0	.10	6.6–7.8	None	Low	Low.
100	100	5–15	6.3–20.0	.02	6.6–8.4	None	Low	Low.
98–100	95–100	65–75	0.63–2.0	.16	6.6–7.8	None	Low	Low.
95–100	90–100	65–75	0.63–2.0	.16	7.0–8.4	None	Low	Low.
98–100	95–100	70–80	0.63–2.0	.16	6.6–7.8	None	Low	Low.
100	100	70–80	0.63–2.0	.18	6.6–8.4	None to moderate	Low	Moderate.

TABLE 4.—*Estimated engineering*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	Classification		
			USDA	Unified	AASHO
	Feet	*Inches*			
LaPrairie.	4–5	0–7	Silt loam	ML–CL	A–4
		7–50	Clay loam	CL	A–6
		50–60	Loam	ML	A–4
Larson: LhB, Lm.	5+	0–6	Loam	ML	A–4
		6–60	Clay loam	CL	A–6
For Heimdal part of LhB, see Heimdal series; for Miranda part of Lm, see Miranda series.					
Letcher: Ln.	5+	0–15	Fine sandy loam	SM	A–4
		15–60	Clay loam or loam	CL	A–6 or A–7
Loamy lake beaches: Lo.	0–5	0–3	Loam	ML	A–4
		3–7	Sand and gravel	SM	A–2
		7–60	Loam or clay loam	SW–CL	A–6
Maddock.	5+	0–60	Loamy fine sand	SM	A–2
Miranda: Mr. For Larson part of this unit, see Larson series.	2–5	0–20	Clay loam	CL	A–6 or A–7
		20–60	Loam	CL	A–6
Nutley: Nu.	5+	0–60	Silty clay or clay loam	CH or CL	A–7
Overly: Ov.	5+	0–48	Silty clay loam	CL	A–6
		48–60	Gravelly sandy loam	SM	A–4
Parnell: Pa.	0–4	0–10	Silty clay loam	ML	A–4
		10–60	Clay loam	CL	A–6
Perella.	0–4	0–60	Silt loam, silty clay loam, or loam.	CL	A–6
Pits and dumps: Pd.	5+	(3)	(3)	(3)	(3)
Renshaw: ReA, ReB.	5+	0–17	Loam	ML	A–4
		17–60	Sand and gravel	SW–SM	A–1–b
Saline land: Sa.	0–5	(3)	(3)	(3)	(3)
Sioux: So, Sr. For Arvilla part of So, see Arvilla series; for Barnes part of Sr, see Barnes series.	5+	0–8	Loam	ML	A–4
		8–60	Sand and gravel	SW–SM	A–1–b
Stony alluvial land: St.	0–5	(3)	(3)	(3)	(3)
Svea.	5+	0–9	Loam	ML	A–4
		9–60	Loam	CL or ML	A–6
Tonka: To.	0–4	0–15	Silt loam or silty clay loam	ML	A–4
		15–38	Clay loam	CL	A–6
		38–60	Loam	CL	A–4
Ulen: Uh. For Hamar part of Uh, see Hamar series.	2–5	0–36	Fine sandy loam	SM	A–4
		36–60	Loamy sand	SM	A–2
Vallers: Va.	0–5	0–60	Loam or clay loam	CL	A–6

[1] Nests of gypsum are common below the upper part of the subsoil.
[2] Gypsum crystals are scattered through any or all soil layers.

properties of the soils—Continued

Percentage passing sieve— No. 4	No. 10	No. 200	Permeability	Available water capacity	Reaction	Salinity	Dispersion	Shrink-swell potential
			In./hr.	*In./in. of soil*	*pH*			
95–100	95–100	70–80	0. 63–2. 0	. 18	6. 6–8. 4	None	Low	Low.
95–100	95–100	65–75	0. 2–0. 63	. 18	7. 4–9. 0	None	Low	Moderate.
95–100	95–100	60–75	0. 63–2. 0	. 16	7. 4–9. 0	None or slight	Low	Low.
100	95–100	65–75	0. 63–2. 0	. 16	6. 1–7. 3	None	Low	Low.
100	95–100	70–80	<0. 06	. 18	7. 4–8. 4	None	High	High.
100	100	35–45	2. 0–6. 3	. 14	6. 1–7. 4	None	Low	Low.
100	95–100	70–80	<0. 06	. 18	7. 4–9. 0	None to severe [2]	High	High.
90–100	90–100	65–75	0. 63–2. 0	. 17	6. 6–8. 4	None	Low	Low.
50–70	25–45	5–15	6. 3–20. 0	. 02	6. 6–8. 4	None	Low	Low.
98–100	90–100	65–75	0. 06–0. 20	. 17	7. 4–9. 0	None	Low	Moderate.
100	100	20–30	6. 3–20. 0	. 08	6. 6–8. 4	None	Low	Low.
96–100	90–100	75–95	<0. 06	. 17	6. 6–9. 0	Moderate to severe	High	High.
96–100	85–95	70–90	0. 20–0. 63	. 17	7. 4–9. 0	Severe	High	Moderate.
100	100	85–95	0. 20–0. 63	. 20	6. 1–7. 8	None	Low	High.
100	100	75–85	0. 2–0. 63	. 19	6. 6–8. 4	None	Low	Moderate.
95–100	85–95	35–45	6. 3–20. 0	. 08	6. 6–8. 4	None	Low	Low.
100	95–100	75–85	0. 63–2. 0	. 19	6. 6–8. 4	None	Low	Low.
100	95–100	65–75	0. 2–0. 63	. 18	6. 6–8. 4	None	Low	Moderate.
100	100	75–85	0. 06–0. 20	. 18	6. 6–8. 4	None	Low	Moderate.
(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3).
98–100	90–100	65–75	0. 63–2. 0	. 17	6. 1–7. 8	None	Low	Low.
50–70	25–45	5–15	6. 3–20. 0	. 02	6. 6–8. 4	None	Low	None.
(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3).
90–100	90–100	60–70	0. 63–2. 0	. 16	6. 6–7. 8	None	Low	Low.
50–70	25–45	5–15	6. 3–20. 0	. 02	6. 6–8. 4	None	Low	None.
(3)	(3).	(3)	(3)	(3)	(3)	(3)	(3)	(3).
95–100	90–100	65–75	2. 0–6. 3	. 20	6. 6–7. 3	None	Low	Low.
95–100	90–100	65–75	0. 63–2. 0	. 17	6. 6–8. 4	None	Low	Moderate.
100	98–100	75–85	0. 2–0. 63	. 16	6. 1–7. 3	None	Low	Low.
100	100	80–90	0. 2–0. 63	. 19	6. 6–7. 8	None	Low	Moderate.
98–100	95–100	65–75	0. 2–0. 63	. 17	6. 6–8. 4	None	Low	Low.
100	100	35–45	2. 0–6. 3	. 14	7. 4–9. 0	Low [2]	Low	Low.
100	100	20–30	6. 3–20. 0	. 08	7. 4–9. 0	Low to moderate	Low	Low.
95–100	85–95	60–75	0. 63–2. 0	. 17	6. 6–8. 4	Slight to moderate [2]	Low	Moderate.

[3] Properties variable; onsite investigation necessary.

TABLE 5.—*Engineering*

Soil series and map symbols	Suitability as a source of—			Highway location	Susceptibility to frost action
	Topsoil	Sand and gravel	Road fill		
Aberdeen	Fair	Not suitable	Poor to very poor; subject to volume change.	Seasonal high water table.	Moderate
Arvilla: ArA, ArB	Good	Good for road subbase; medium to coarse sand.	Good in uppermost 1½ feet; material in substratum is hard to compact unless clay binder is added; not subject to volume change.	Vibratory compaction required to obtain high density; very good under bituminous surface.	Low
Barnes: BaC, BaC2, BbD, Be, BnA, BnB. For Buse part of BbD, see Buse series; for Svea part of BnA and BnB, see Svea series.	Good	Not suitable	Fair	Fair density; fair shear strength when compacted; not suitable under thin flexible base course or bituminous surface.	Low
Bearden: Bp. For Perella part of Bp, see Perella series.	Good	Not suitable	Poor; subject to volume change.	Not suitable under flexible base course or bituminous surface.	Moderate
Benoit: Br, Bt	Good in uppermost 6 inches; poor below a depth of 6 inches.	Excellent for gravel surfacing; good for road subbase and asphalt; may require washing for concrete.	Fair in uppermost 28 inches; material in substratum may be hard to compact.	Ordinary drainage installations of little value; high water table.	High
Borup: Bu	Good	Not suitable	Poor	Seasonal high water table; not suitable under thin flexible base course or bituminous surface.	High
Buse: BvE. For Barnes part of this unit, see Barnes series.	Fair	Not suitable	Fair	Not suitable under thin flexible base course or bituminous surface.	Low
Colvin: Ca, Cp, Cs. For Lamoure part of Ca, see Lamoure series; for LaPrairie part of Cp, see LaPrairie series.	Fair	Not suitable	Poor	Seasonal high water table; not suitable under thin flexible base course or bituminous surface.	High
Dimmick: Dc	Poor	Not suitable	Very poor	Low density; not suitable under thin flexible base course or bituminous surface.	Moderate
Divide: Dd	Fair	Good for gravel surfacing; good for road subbase; fair for asphalt; poor for concrete.	Fair in uppermost 2½ feet; material in substratum may be hard to compact.	Seasonal high water table; not suitable under thin flexible base course or bituminous surface.	Moderate

interpretations of the soils

Farm ponds		Agricultural drainage	Irrigation	Waterways
Reservoir	Embankments, dikes, and levees			
Holds water well if kept wet.	Impervious when compacted; poor shear strength; high dispersion; fair for homogeneous embankment or core material; subject to cracking.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Slow permeability; large amount of salts.	Erodibility.
Rapid permeability in substratum.	Not suitable, unless core can cut off gravel; mixing with clay required if used for embankment.	Not applicable	Rapid permeability in substratum; poor water-holding capacity; sprinkler method more suitable than gravity method.	Not applicable.
Soil features favorable.	Impervious when compacted; good for homogeneous embankment; excellent for core material; fair shear strength.	Not applicable	Irregular topography; moderate permeability in subsurface.	Features favorable.
Soil features favorable.	Moderately slow permeability; good for embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Moderately slow permeability; drainage problems.	Soil features favorable.
Rapid permeability; fluctuating water table.	Low density; hard to compact because of moisture content.	High water table	Generally not suitable because of drainage problems.	Not applicable.
Moderately rapid permeability in substratum; fluctuating water table.	Semipervious to impervious when compacted; surface material fair; can be used for core material; substratum can be used for outer shell, but is subject to wave action.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Not suitable because of drainage problems.	Soil features favorable.
Soil features favorable.	Impervious when compacted; fair shear strength; good for homogeneous embankment; excellent for core material.	Not applicable	Generally not suitable because of slope.	Erodibility.
Soil features favorable.	Impervious when compacted; good for core material; fair for homogeneous embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Drainage problems; slight salinity.	Soil features favorable.
Soil features favorable.	Impervious when compacted; volume change critical; subject to cracking when dry; poor shear strength; poor for homogeneous embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Slow permeability; drainage problems.	Not applicable.
Rapid permeability in substratum.	Low density; uppermost 2½ feet semipervious to impervious when compacted; fair shear strength.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Slight salinity; drainage problems.	Soil features favorable.

TABLE 5.—*Engineering*

Soil series and map symbols	Suitability as a source of—			Highway location	Susceptibility to frost action
	Topsoil	Sand and gravel	Road fill		
Eckman	Excellent	Not suitable	Poor in surface layer; good in substratum.	Uppermost 3½ feet not suitable under thin flexible base course or bituminous surface; substratum is good.	Moderate
Egeland: EeB. For Embden part of this unit, see EgA of Embden series.	Good	Not suitable	Very good; not subject to volume change.	Suitable for base course under bituminous surface when compacted.	Low
EdC, EfB. For Embden part of EfB, see ElA of Embden series.	Good	Not suitable	Very good in surface layer; fair in substratum.	Uppermost 2½ feet good; substratum not suitable under thin flexible base course or bituminous surface.	Low
Embden: EgA. For Egeland part of this unit, see EeB of Egeland series.	Excellent	Not suitable	Very good	Suitable for base course under bituminous surface if compacted.	Low
ElA. For Egeland part of this unit, see EdC and EfB of Egeland series.	Excellent	Not suitable	Very good in uppermost 3½ feet; fair in substratum.	Uppermost 3½ feet not subject to volume change. Below a depth of 3½ feet, subject to volume change.	Low
Emrick: Em. For Larson part of this unit, see Larson series.	Excellent	Not suitable	Fair to poor	Not suitable under thin flexible base course or bituminous surface.	Moderate
Eroded sandy land: Er	Fair to poor	Good; fine sand with silt and clay; not suitable for gravel.	Good	Suitable for base course under bituminous surface when compacted.	Low
Exline: Ex	Very poor	Not suitable	Poor; subject to critical volume change.	Poor workability; not suitable for base course.	High
Fargo: Fa, Fc. For Aberdeen part of Fa, see Aberdeen series.	Excellent	Not suitable	Poor; subject to critical volume change.	Poor workability; not suitable under thin flexible base course or bituminous surface.	Moderate
Forman: FoA, FoB	Good	Not suitable	Fair; subject to volume change.	Poor workability	Low

interpretations of the soils—Continued

Farm ponds: Reservoir	Farm ponds: Embankments, dikes, and levees	Agricultural drainage	Irrigation	Waterways
Moderately rapid permeability in substratum.	Uppermost 3½ feet semipervious to impervious when compacted; can be used for core material. Substratum pervious and subject to wave action.	Not applicable	Moderate permeability; good water-holding capacity.	Soil features favorable.
Rapid permeability in substratum.	Good density; clay core required; subject to wave and wind action.	Not applicable	Irregular topography on steeper slopes.	Erodibility under concentrated flow.
Core trench needed to tie into substratum; low runoff potential.	Uppermost 2½ feet semipervious; substratum impervious when compacted; fair for homogeneous embankment; good for core material.	Not applicable	Generally irregular topography; slower permeability in substratum than in surface layer.	Soil features favorable.
Rapid permeability in substratum; sealing of pond area required.	Good density; clay core required for dam; subject to wave and wind action.	Not applicable	Moderately rapid permeability.	Erodibility under concentrated flow.
Core trench needed to tie into substratum; low runoff potential.	Uppermost 3½ feet semipervious when compacted; fair for homogeneous embankment. Substratum impervious when compacted; good for core material.	Not applicable	Good water-holding capacity; moderate permeability in substratum.	Soil features favorable.
Soil features favorable; may have layers of sand.	Semipervious to impervious when compacted; fair shear strength; fair for homogeneous embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Moderate permeability; good water-holding capacity.	Soil features favorable.
Rapid permeability; sealing of pond areas required.	Clay core required; good density; subject to wave action.	Not applicable	Rapid permeability; rapid intake rate; irregular topography; low organic-matter content.	Erodibility under concentrated flow; low organic-matter content; very susceptible to wind erosion; hard to establish vegetation.
Soil features favorable.	Impervious when compacted; volume change critical; subject to cracking; poor for homogeneous embankment and for core material; not suitable for shell material because of high dispersion.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Very slow permeability; sodium accumulation.	Erodibility; hard to establish vegetation.
Soil features favorable.	Impervious when compacted; volume change critical; subject to cracking; poor shear strength; poor for homogeneous embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Slow permeability and slow intake.	Soil features favorable.
Soil features favorable.	Impervious when compacted; good for homogeneous embankment; excellent as core material; fair shear strength.	Not applicable	Irregular topography; moderate permeability.	Soil features favorable.

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TABLE 5.—*Engineering*

Soil series and map symbols	Suitability as a source of—			Highway location	Susceptibility to frost action
	Topsoil	Sand and gravel	Road fill		
Fram: Fr	Fair	Not suitable	Fair	Not suitable under thin flexible base course or bituminous surface; poor shear strength.	Moderate
Gardena: Ge For Eckman part of this unit, see Eckman series.	Excellent	Not suitable	Fair in uppermost 4½ feet; good in substratum.	Uppermost 4½ feet not suitable under thin flexible base course or bituminous surface; poor bearing capacity.	Moderate
Hamar	Good	Good; fine sand with silt and clay; not suitable for gravel.	Good	Fair shear strength; seasonal high water table.	Low
Hamerly: Ha	Fair	Not suitable	Fair; subject to volume change.	Not suitable under thin flexible base course or bituminous surface.	Moderate
Hecla: Hd For Maddock part of this unit, see Maddock series.	Good	Good; fine sand with silt and clay; not suitable for gravel.	Good; not subject to volume change.	Suitable as base course under bituminous surface if compacted and drained.	Low
Heimdal: HeA, HeB, HIB For Emrick part of HeA and HeB, see Emrick series; for Larson part of HIB, see Larson series.	Good	Not suitable	Fair to poor	Not suitable under thin flexible base course and bituminous surface; fair shear strength.	Moderate
LaDelle: LaA, LaB	Good	Not suitable	Fair to poor	Not suitable under thin flexible base course and bituminous surface; fair shear strength.	Moderate
Lamoure: Ld, Le For Divide part of Ld, see Divide series; for Exline part of Le, see Exline series.	Good	Good substratum; good for road surfacing in some places.	Very poor; subject to volume change.	Not suitable under thin flexible base course or bituminous surface; high water table.	Moderate
LaPrairie	Good	Not suitable	Poor	Not suitable under thin flexible base course or bituminous surface; temporary water table; occasional flooding.	Moderate
Larson: LhB, Lm For Heimdal part of LhB, see Heimdal series; for Miranda part of Lm, see Miranda series.	Fair	Not suitable	Poor to very poor; subject to volume change.	Not suitable under thin flexible base course or bituminous surface.	Moderate
Letcher: Ln	Good	Not suitable	Poor to very poor; subject to volume change.	Not suitable under thin flexible base course or bituminous surface.	Low
Loamy lake beaches: Lo	Very poor	Not suitable	Fair in substratum; subject to volume change.	Occasional flooding	Low

interpretations of the soils—Continued

Farm ponds		Agricultural drainage	Irrigation	Waterways
Reservoir	Embankments, dikes, and levees			
Moderate permeability; considerable fluctuation of water table.	Uppermost 4½ feet fair for center core. Substratum can be used for outer shell but is subject to wave action.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Good water-holding capacity; needs drainage.	Soil features favorable.
Rapid permeability in substratum.	Uppermost 4½ feet fair for center core. Substratum can be used for outer shell but is subject to wave action.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Good water-holding capacity; needs drainage.	Soil features favorable.
Moderately rapid permeability; fluctuating water table.	Good as homogeneous embankment; semipervious when compacted; subject to wave action.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Needs drainage	Soil features favorable.
Soil features favorable.	Impervious when compacted; good for homogeneous embankment and for core material.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Needs drainage	Soil features favorable.
Rapid permeability; sealing of pond area required.	Clay core required; good density; subject to wave action.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Poor water-holding capacity; rapid intake rate.	Erodibility under concentrated flow.
Soil features favorable.	Semipervious to impervious when compacted; good for homogeneous embankment; little volume change.	Not applicable	Good water-holding capacity; irregular topography.	Soil features favorable.
Soil features favorable.	Semipervious to impervious when compacted; good for homogeneous embankment; low volume change.	Not applicable	Good water-holding capacity; irregular topography.	Soil features favorable.
Soil features favorable; seepage possible in sand layers.	Fair density; acceptable for embankment; difficult to compact when wet.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Seasonal flooding; high water table; moderate permeability.	Soil features favorable.
Soil features favorable.	Impervious when compacted, but difficult to compact when wet; acceptable for embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Occasional flooding; high water table; moderate permeability.	Soil features favorable.
Soil features favorable; may have sand layers that allow seepage unless sealed.	Impervious when compacted; poor shear strength; subject to cracking; fair for homogeneous embankment and for core material.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Very slow permeability; large amount of salts.	Erodibility.
Soil features favorable.	Impervious when compacted; poor shear strength; subject to cracking; fair for homogeneous embankment and for core material.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Very slow permeability; large amount of salts.	Not applicable.
Soil features favorable.	Substratum semipervious to impervious when compacted; fair for core material; fair for homogeneous embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Occasional flooding	Soil features favorable.

TABLE 5.—*Engineering*

Soil series and map symbols	Suitability as a source of—			Highway location	Susceptibility to frost action
	Topsoil	Sand and gravel	Road fill		
Maddock	Good	Good; fine sand with silt and clay; not suitable for gravel.	Good	Suitable for base course under bituminous surface when compacted.	Low
Miranda: Mr For Larson part of this unit, see Larson series.	Very poor	Not suitable	Very poor; subject to volume change.	Not suitable under thin flexible base course or bituminous surface.	High
Nutley: Nu	Good	Not suitable	Poor; subject to critical volume change.	Poor workability; not suitable under thin flexible base course or bituminous surface.	Moderate
Overly: Ov	Good	Good substratum; good for road subbase and surfacing; layers may be thin.	Poor to a depth of 4 feet; subject to volume change.	Uppermost 4 feet not suitable under thin flexible base course or bituminous surface; substratum material requires vibratory compaction to acquire high density.	Moderate
Parnell: Pa	Poor	Not suitable	Very poor; subject to volume change.	Not suitable under thin flexible base course or bituminous surface.	Moderate
Perella	Fair	Not suitable	Poor; subject to volume change.	Not suitable under thin flexible base course or bituminous surface.	Moderate
Pits and dumps: Pd	([1])	([1])	([1])	([1])	([1])
Renshaw: ReA, ReB	Good	Good; good for road subbase, gravel surfacing, and asphalt.	Good in uppermost 1½ feet; substratum hard to compact unless clay binder is added; not subject to volume change.	Requires vibratory compaction to obtain high density; very good under bituminous surface.	Low
Saline land: Sa	([1])	([1])	([1])	([1])	([1])
Sioux: So, Sr For Arvilla part of So, see Arvilla series; for Barnes part of Sr, see Barnes series.	Fair	Good; good for road subbase, gravel surfacing, and asphalt.	Good in surface layer; substratum difficult to compact unless clay binder is added; not subject to volume change.	Vibratory compaction required for high density; very good under bituminous surface.	Low
Stony alluvial land: St	([1])	([1])	([1])	([1])	([1])
Svea	Excellent in surface layer.	Not suitable	Fair	Fair density; fair shear strength when compacted; fair workability; not suitable under thin flexible base course.	Moderate

interpretations of the soils—Continued

Farm ponds		Agricultural drainage	Irrigation	Waterways
Reservoir	Embankments, dikes, and levees			
Rapid permeability; sealing of pond areas required.	Clay core required; good density; subject to wave action.	Not applicable	Poor water-holding capacity; high intake rate; irregular slopes.	Erodibility under concentrated flow.
Soil features favorable.	Impervious when compacted; subject to cracking; poor shear strength; fair for homogeneous embankment or core material.	Needs surface or subsurface drainage if cultivated; outlets may be difficult to establish.	Very slow permeability; thin surface layer.	Not applicable.
Soil features favorable.	Impervious when compacted; volume change critical; subject to cracking; poor shear strength; poor as homogeneous embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Moderately slow permeability and intake rate.	Soil features favorable.
Rapid permeability in substratum; sealing of pond areas required.	Uppermost 4 feet impervious when compacted; subject to volume change and to cracking.	Not applicable	Moderately slow permeability; needs drainage.	Soil features favorable.
Soil features favorable.	Low density; hard to compact because of moisture content; subject to volume change and to cracking.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Not applicable	Soil features favorable.
Soil features favorable.	Low density; hard to compact because of moisture content; subject to volume change and to cracking.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Slow permeability; needs drainage.	Soil features favorable.
(1)	(1)	(1)	(1)	(1).
Rapid permeability in substratum.	Not suitable unless core can cut off gravel; mixing with clay required if used for embankment.	Not applicable	Rapid permeability in substratum; sprinkler method more suitable than gravity method.	Soil features favorable.
(1)	(1)	(1)	(1)	(1).
Rapid permeability in substratum.	Not suitable unless core can cut off gravel; mixing with clay required if used for embankment.	Not applicable	Poor water-holding capacity; rapid permeability.	Not applicable.
(1)	(1)	(1)	(1)	(1).
Soil features favorable.	Impervious when compacted; fair shear strength; good as homogeneous embankment; excellent as core material; good to fair workability.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Needs drainage	Soil features favorable.

TABLE 5.—*Engineering*

Soil series and map symbols	Suitability as a source of—			Highway location	Susceptibility to frost action
	Topsoil	Sand and gravel	Road fil		
Tonka: To	Fair	Not suitable	Poor; subject to volume change.	Not suitable under thin flexible base course or bituminous surface.	Moderate
Ulen: Uh For Hamar part of this unit, see Hamar series.	Fair	Poor	Good	Suitable under thin flexible base course or bituminous course; seasonal high water table.	Moderate
Vallers: Va	Fair	Not suitable	Poor; subject to volume change.	Seasonal high water table; not suitable under thin flexible base course or bituminous surface.	Moderate

[1] Variable properties; onsite investigation is necessary.

Available water capacity refers to the amount of water held in a form that plants can use readily. The figures in the table show the amount of water that will wet air-dry soil material to a depth of 1 inch without deeper percolation.

Reaction (pH) refers to the degree of acidity or alkalinity of a soil. The degrees of acidity or alkalinity are defined under "Reaction" in the Glossary. Soils that have a pH of less than 8.5 are likely to have a higher consolidation potential and better shear strength than other soils, and a high degree of alkalinity, particularly a pH of more than 8.5, promotes dispersion.

Control of salinity is not a problem in most soils of this county. The soils that are shown in table 4 as having moderate to severe salinity contain gypsum. Gypsum is not harmful if the soil material is to be used as borrow material but is critical if it is to be used in foundations, because abnormal porosity may result when the crystals dissolve.

Dispersion, as used in this publication, refers to the degree to which particles smaller than 0.005 millimeter are separate or dispersed. It should be distinguished from the single-grain or unaggregated condition of clean sand. Dispersed soils often become slick when wet, and a crust of clay forms as the surface dries. Soil particles affected by calcium carbonate tend to aggregate rather than disperse, but soils that contain a large amount of sodium are likely to disperse, as are acid, silty soils that formed under poor drainage conditions. Critically dispersed soils are dangerous in dams and other embankments, especially if used in the foundation or embankment without special preparation. They are made up of unstable aggregates that slake down in water and go into suspension easily. They have low shear strength and high piping potential and are easily eroded.

Shrink-swell potential indicates the volume change to be expected when the moisture content changes. It is based on the liquid limit and plasticity index of the soil. Shrink-swell potential is low if the liquid limit is 30 or less and the plasticity index is 10 or less; it is moderate if the liquid limit is 31 to 40 and the plasticity index is 11 to 20; it is high if the liquid limit is 41 to 60 and the plasticity index is 21 to 40. Coarse sand and gravel have such a very low shrink-swell potential that they are designated as having none.

Engineering interpretations

Table 5 shows, for each soil series and each land type, suitability as a source of road construction materials and susceptibility to frost action. It also provides interpretations for highway location, farm ponds, agricultural drainage, irrigation, and waterways. These interpretations are based on the estimates in table 4 and the data in table 6.

Normally, only the surface layer of a soil is rated for topsoil. Suitability for this use depends largely on texture and depth. Topsoil material must be capable of being worked into a good seedbed for seeding or sodding yet be clayey enough to resist erosion on steep slopes.

The suitability of soil material for road fill depends mainly on texture and water content. Clay and organic material are poorest because they are highly plastic and contain a large amount of water. Silt and fine sand are fair to poor because they are erodible, are difficult to compact, and require moderately gentle slopes and rapid establishment of vegetation for control of erosion. In general, a sandy material that contains adequate binder is best because it is least affected by adverse weather conditions and can be worked during a greater number of months of the year.

In determining the soil features that affect highway location, the entire profile of an undisturbed soil is evaluated. Some of the features considered are depth to bedrock, depth to water table, stability, erodibility, and flood hazard.

interpretations of the soils—Continued

Farm ponds		Agricultural drainage	Irrigation	Waterways
Reservoir	Embankments, dikes, and levees			
Soil features favorable.	Semipervious to impervious when compacted; difficult to compact when wet; subject to cracking; good as core material; fair as homogeneous embankment; fair shear strength.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Moderately slow permeability; drainage difficult.	Soil features favorable.
Rapid permeability in substratum.	Semipervious to impervious when compacted; good shear strength; good as homogeneous embankment.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to establish.	Suitable if good drainage is provided.	Soil features favorable.
Soil features favorable.	Impervious when compacted; good as homogeneous embankment and as core material.	Needs surface and subsurface drainage if cultivated; outlets may be difficult to obtain.	Moderately slow permeability; drainage difficult.	Soil features favorable.

Susceptibility to frost action depends on the texture of the soil and on the position of the water table at the time of freezing. Susceptibility is high if the texture is silt and fine sand and the water table is high.

Engineering test data

To help evaluate the soils in Wells County for engineering purposes, samples from 20 profiles were tested according to standard procedures. The results are given in table 6.

Moisture-density data are obtained by compacting soil material at a successively higher moisture content. Assuming that the compactive effort remains constant, the density of the compacted material increases until the optimum moisture content is reached. After that, the density decreases with increase in moisture content. The highest dry density obtained in the compaction test is termed "maximum dry density." Moisture-density data are important in earthwork because, as a rule, optimum stability is obtained if the soil is compacted to about the maximum dry density when it is at approximately the optimum moisture content.

The tests for plastic limit and liquid limit measure the effect of water on the consistency of soil material. As the moisture content of a clayey soil increases from a very dry state, the material changes from a semisolid to a plastic; the moisture content at which this change occurs is the liquid limit. The plasticity index is the numerical difference between the liquid limit and the plastic limit. It indicates the range of moisture content within which a soil material is plastic.

Deposits of aggregates

Few of the soils in Wells County are suitable as a source of sand and gravel. Those that are suitable should be explored extensively to find material that meets gradation requirements for specific uses. Table 7, prepared from data furnished by the North Dakota State Highway Department, shows the approximate amount of sand and gravel in known deposits in the county and gives other characteristics of these deposits. Several other deposits are in the county but are not shown in the table, because the sand or gravel is of limited or of poor quality or the supply has not been tested.

The quality of the gravel is not adequate for most concrete requirements, because of the content of shale and soft rock. Removal of the shale from the gravel is not economically feasible at this time.

The bank-run aggregates have been successfully used for roads that have a gravel surface and as a base for asphalt and concrete surfacing. The proportion of sand to gravel is high, and some deposits contain a high percentage of clay and colloids.

The locations given in this table are not specifically tied to any one kind of soil. Generally, the sand and gravel underlie two or more kinds of soil, chiefly those that formed in glacial outwash.

Formation and Classification of the Soils

This section discusses the factors of soil formation and the classification of the soils in Wells County by higher categories.

Factors of Soil Formation

The factors that determine the characteristics of a soil are the composition of the parent material, the climate under which the soil material accumulated and weathered, the plant and animal life on and in the soil, the relief, and time. Each of these factors modifies the effect of the other four.

TABLE 6.—*Engineering*

[Tests performed by the North Dakota State University in cooperation with the North Dakota in accordance with standard procedures of the American

Soil name and location	Parent material	North Dakota report No. SCS–	Depth from surface	Moisture-density data [1]	
				Maximum dry density	Optimum moisture
			In.	*Lb. per cu. ft.*	*Pct.*
Barnes loam:					
0.2 mile W. and 100 feet N. of S¼ corner, sec. 9, T. 145 N., R. 69 W. (modal).	Glacial till.	107 131 132	0–6 6–15 32–60	105 111 114	18 16 15
485 feet E. and 450 feet N. of SW. corner, sec. 36, T. 147 N., R. 73 W. (clay loam subsoil).	Glacial till.	127 128 94	0–6 6–13 36–60	83 100 109	29 22 17
0.25 mile W. of SE. corner, sec. 28, T. 150 N., R. 68 W. (friable till substratum).	Glacial till.	129 106 130	0–6 6–16 25–60	90 113 121	24 14 12
Egeland fine sandy loam:					
400 feet S. and 150 feet W. of NE. corner, sec. 6, T. 148 N., R. 71 W. (modal).	Outwash or eolian sands over glacial till.	103 140 104	0–6 6–13 35–60	115 116 121	12 12 12
Embden fine sandy loam:					
150 feet E. and 900 feet N. of NW¼ sec. 21, T. 147 N., R. 70 W. (loamy sand B horizon).	Outwash or eolian sands over glacial till.	101 138 139	0–6 8–24 42–60	108 119 114	15 11 15
120 feet W. and 0.1 mile S. of E¼ corner, sec. 5, T. 148 N., R. 73 W. (higher in very fine sand).	Lacustrine sands over till.	23 141 142	0–5 5–15 42–60	113 118 115	11 12 14
Heimdal loam:					
0.2 mile N. of SW. corner, sec. 12, T. 148 N., R. 70 W. (modal).	Glacial lacustrine material or loess over glacial till.	133 134 135	0–7 7–14 34–60	101 109 113	18 16 14
260 feet E. and 110 feet S. of NW. corner, sec. 23, T. 148 N., R. 73 W. (coarser textured).	Reworked glacial till.	136 137 92	0–5 5–14 45–60	112 118 122	13 13 11
Larson loam:					
110 feet S. and 200 feet E. of NW. corner, sec. 26, T. 148 N., R. 72 W. (modal).	Reworked glacial till.	149 99 150	0–7 7–12 34–60	104 111 117	16 15 12
135 feet S. and 185 feet E. of N¼ corner, sec. 26, T. 148 N., R. 71 W. (thinner A horizon).	Lacustrine material over glacial till.	143 144 95	3–8 17–30 42–60	116 118 124	12 13 11
95 feet S. and 210 feet W. of N¼ corner, sec. 18, T. 148 N., R. 72 W. (prismatic B horizon).	Glacial melt-water deposits over glacial till.	145 146 147 148	0–6 6–14 25–35 44–60	105 115 118 116	15 13 12 14
Nutley silty clay:					
350 feet N. and 105 feet W. of SE. corner, sec. 30, T. 145 N., R. 70 W. (modal).	Lacustrine material over glacial till.	125 90 126	0–6 11–26 44–60	93 96 102	23 22 20
300 feet N. and 0.05 mile W. of S¼ corner, sec. 19, T. 146 N., R. 72 W. (clay solum and shallow).	Lacustrine material over glacial till.	122 123 124	0–6 6–15 28–60	91 92 106	24 25 18

test data

State Highway Department and the U.S. Department of Commerce, Bureau of Public Roads, Association of State Highway Officials (AASHO) (*1*)]

Mechanical analysis [2]									Liquid limit	Plasticity index	Classification	
Percentage passing sieve—					Percentage smaller than—							
¾-in.	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	0.05 mm.	0.02 mm.	0.005 mm.	0.002 mm.			AASHO	Unified [3]
									Pct.			
100	99	98	93	71	57	34	14	8	30	3	A-4(7)	ML
100	99	98	95	75	67	45	24	15	28	8	A-4(8)	CL
100	99	98	94	75	68	47	24	16	27	8	A-4(8)	CL
100	99	99	97	80	69	42	18	11	(4)	(4)	A-4(8)	ML
---------	100	99	96	79	70	53	34	23	36	12	A-6(9)	ML-CL
---------	100	98	94	71	63	49	34	25	38	20	A-6(11)	CL
100	99	99	92	65	49	24	9	6	(4)	(4)	A-4(6)	ML
[5] 99	96	93	84	55	47	30	17	12	28	4	A-4(4)	ML-CL
100	95	91	80	54	46	31	16	11	25	5	A-4(4)	ML-CL
---------	---------	100	96	35	26	15	8	5	(4)	(4)	A-2-4(0)	SM
---------	---------	100	98	36	28	15	10	7	(4)	(4)	A-4(0)	SM
100	99	96	91	61	51	36	19	13	22	5	A-4(5)	ML-CL
---------	---------	100	95	41	31	15	7	4	(4)	(4)	A-4(1)	SM
---------	---------	100	96	36	25	13	8	5	(4)	(4)	A-4(0)	SM
100	99	98	95	78	70	53	36	27	27	10	A-4(8)	CL
---------	100	98	94	46	35	19	11	8	(4)	(4)	A-4(2)	SM
100	99	99	97	41	30	16	10	6	(4)	(4)	A-4(1)	SM
100	99	98	91	66	60	49	35	27	33	18	A-6(9)	CL
100	99	99	98	79	64	38	18	11	(4)	(4)	A-4(8)	ML
---------	---------	100	99	82	66	39	19	13	28	7	A-4(8)	ML-CL
---------	---------	---------	100	87	74	49	25	19	26	7	A-4(8)	ML-CL
---------	100	99	94	56	45	28	14	9	(4)	(4)	A-4(4)	ML
100	99	98	94	54	45	28	18	14	24	6	A-4(4)	ML-CL
100	97	95	88	48	38	23	12	8	(4)	(4)	A-4(3)	SM
---------	---------	100	95	67	57	37	17	9	(4)	(4)	A-4(6)	ML
100	99	99	94	69	61	43	27	20	28	11	A-6(7)	CL
100	99	97	88	64	55	41	24	17	27	12	A-6(7)	CL
---------	---------	100	96	56	46	31	13	8	19	3	A-4(4)	ML
---------	100	98	84	46	45	41	33	25	34	22	A-6(6)	SC
[5] 98	97	94	85	52	44	33	17	12	21	3	A-4(3)	ML
---------	---------	100	96	70	55	33	13	8	(4)	(4)	A-4(7)	ML
---------	100	99	96	73	60	31	17	12	23	5	A-4(8)	ML-CL
---------	---------	100	98	85	70	44	28	21	24	7	A-4(8)	ML-CL
100	99	97	93	72	66	51	32	23	29	14	A-6(9)	CL
100	99	99	97	87	79	61	35	22	40	10	A-4(8)	ML
---------	100	98	98	96	93	86	65	50	59	32	A-7-6(20)	CH
---------	100	98	96	88	84	74	52	40	48	29	A-7-6(17)	CL
---------	---------	100	97	77	66	48	30	19	38	6	A-4(8)	ML
---------	---------	100	95	75	66	55	38	27	38	11	A-6(8)	ML
---------	---------	100	97	73	69	63	51	39	41	24	A-7-6(14)	CL

TABLE 6.—*Engineering*

[Tests performed by the North Dakota State University in cooperation with the North Dakota in accordance with standard procedures of the American

Soil name and location	Parent material	North Dakota report No. SCS–	Depth from surface	Moisture-density data [1]	
				Maximum dry density	Optimum moisture
			In.	*Lb. per cu. ft.*	*Pct.*
Nutley silty clay:–Continued					
650 feet S. and 100 feet W. of NE. corner, sec. 33, T. 145 N., R. 70 W. (varved C horizon).	Lacustrine clays.	100	0–7	92	28
		121	7–21	92	24
		108	42–60	98	22
Parnell silty clay loam:					
0.15 mile S. and 75 feet E. of NW. corner, sec. 18, T. 146 N., R. 71 W. (modal).	Alluvium over glacial till.	118	0–10	91	24
		93	45–60	116	12
180 feet E. and 105 feet S. of NW¼ corner, sec. 12, T. 145 N., R. 69 W. (dark-colored A horizon).	Alluvium over glacial till.	105	0–12	87	26
		119	22–42	106	18
		96	42–60	111	16
350 feet N. and 0.1 mile E. of SW. corner, sec. 18, T. 146 N., R. 69 W. (coarse texture).	Melt-water deposits over glacial till.	102	0–8	87	25
		120	25–37	117	17
		91	37–60	121	12
Tonka silt loam:					
180 feet S. and 70 feet E. of NW. corner, sec. 3, T. 147 N., R. 69 W. (modal).	Glacial melt-water deposits over glacial till.	114	0–8	91	24
		115	8–16	104	18
		116	16–21	109	16
		117	27–60	116	13
0.05 mile W. of S¼ corner, sec. 21, T. 148 N., R. 69 W. (stratified C horizon).	Alluvium over stratified glacial till.	109	0–8	92	24
		110	18–23	108	18
		111	52–60	116	14
70 feet S. and 0.1 mile W. of SE. corner, sec. 33, T. 148 N., R. 72 W. (sandy A2 variant).	Lacustrine material over glacial till.	98	0–8	103	18
		112	19–32	116	13
		97	32–40	109	15
		113	40–60	114	16

[1] Based on AASHO Designation: T 99–57, Methods A and C (*1*).

[2] Mechanical analysis according to AASHO Designation: T 88 (*1*). Results by this procedure may differ somewhat from results obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHO procedure, the fine material is analyzed by the hydrometer method and the various grain-size fractions are calculated on the basis of all the material, including that coarser than 2 millimeters in diameter. In the SCS soil survey procedure, the fine material is analyzed by the pipette method, and the material coarser than 2 millimeters in diameter is excluded from calculations of grain-size fractions. The mechanical analysis data used in this table are not suitable for use in determining the textural class of a soil.

test data—Continued

State Highway Department and the U.S. Department of Commerce, Bureau of Public Roads, Association of State Highway Officials (AASHO) (*1*)]

Mechanical analysis [2]									Liquid limit	Plasticity index	Classification	
Percentage passing sieve—					Percentage smaller than—							
¾-in.	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	0.05 mm.	0.02 mm.	0.005 mm.	0.002 mm.			AASHO	Unified [3]
									Pct.			
--------	--------	--------	100	96	90	79	50	32	46	16	A-7-5(12)	ML
--------	--------	--------	100	99	96	87	66	54	57	31	A-7-6(19)	CH
--------	--------	--------	100	98	96	87	59	43	52	29	A-7-6(18)	CH
--------	--------	100	98	85	72	46	22	13	(4)	(4)	A-4(8)	ML
--------	100	97	91	63	53	38	22	16	30	13	A-6(7)	CL
--------	--------	100	99	82	67	44	20	11	42	1	A-5(8)	ML
--------	--------	100	99	94	85	64	41	29	35	17	A-6(11)	CL
--------	--------	100	99	97	80	47	24	20	29	6	A-4(8)	ML-CL
--------	--------	100	97	69	55	30	15	9	(4)	(4)	A-4(7)	ML
--------	--------	100	98	77	67	45	29	23	25	8	A-4(8)	CL
[5] 98	96	93	88	63	57	43	28	19	24	5	A-4(6)	ML-CL
--------	--------	100	99	89	76	48	24	14	41	7	A-5(8)	ML
--------	100	99	97	85	72	46	24	16	35	10	A-4(8)	ML-CL
--------	--------	100	99	88	75	51	35	30	31	14	A-6(10)	CL
--------	99	97	92	63	55	42	26	19	26	10	A-4(6)	CL
--------	--------	100	98	82	70	47	19	10	39	4	A-4(8)	ML
--------	--------	100	98	88	80	59	32	22	27	7	A-4(8)	ML-CL
--------	99	97	93	69	62	47	30	22	30	12	A-6(8)	CL
--------	--------	100	99	60	48	33	16	2	(4)	(4)	A-4(5)	ML
--------	--------	100	98	49	35	21	16	14	(4)	(4)	A-4(3)	SM
--------	100	99	94	63	55	42	31	26	30	13	A-6(7)	CL
--------	98	96	89	63	57	43	28	21	29	12	A-6(6)	CL

[3] SCS and BPR have agreed that all soils having plasticity indexes within 2 points of the A-line are to be given borderline classifications. An example of the borderline classifications obtained by this use is ML-CL.

[4] Nonplastic.

[5] 100 percent passed the 1-inch sieve.

TABLE 7.—*Deposits of aggregate in Wells County*

[Data furnished by the North Dakota State Highway Department]

Location	Quantity available	Content of soft rock	Content of clay and colloids	Plasticity index	Liquid limit	Weight per cubic foot	Percentage retained on ¼-inch seive	Quality	Suitable for—
	Tons	*Percent*	*Percent*		*Percent*	*Pounds*			
NW¼ sec. 14, T. 147 N., R. 69 W.	3, 502	8. 1	3. 4	0	--------	109	12	Fairly poor: rather fine.	Pit-run base; gravel surfacing.
NE¼ sec. 15, T. 147 N., R. 69. W.	(1)	--------	--------	--------	--------	112	27	Unknown-----	Gravel surfacing.
SW¼ sec. 33, T. 147 N., R. 69 W.	6, 781	4. 2	5. 4	0	--------	109	15	Fair---------	Base material; gravel surfacing.
SE¼SE¼ sec. 15, T. 146 N., R. 70 W.	2, 000	--------	--------	--------	--------	--------	28	Unknown----	Gravel surfacing.
NW¼ sec. 23, T. 146 N., R. 70 W.	16, 000	2. 9	6. 8	0	--------	112	27	Fair: rather fine.	Pit-run base; gravel surfacing.
NW¼ sec. 23, T. 147 N., R. 70 W.	(1)	--------	--------	--------	--------	--------	45	Unknown----	Pit-run base; gravel surfacing.
SW¼ sec. 25, T. 147 N., R. 70 W.	58, 300	4. 4	8. 4	5. 3	19. 8	122	35	Fairly good---	All road purposes.
SW¼ sec. 32, T. 148 N., R. 70 W.	(1)	3. 7	5. 3	0	--------	116	12	Fairly poor: quite fine.	Pit-run base; gravel surfacing.
NE¼ sec. 4, T. 146 N., R. 71 W.	(1)	2. 8	10. 8	3. 5	22. 0	113	31	Good--------	All road purposes except concrete aggregate.
SE¼ sec. 22, T. 147 N., R. 71 W.	(1)	5. 1	8. 3	0	--------	117	24	Fairly good---	All road purposes except concrete aggregate.
E½NW¼ sec. 13, T. 150 N., R. 71 W.	(1)	. 2	8. 3	6. 0	19. 3	118	38	Fairly good---	All road purposes except concrete aggregate.
Sec. 6, T. 145 N., R. 72 W.--	90, 000	2. 8	7. 4	0	--------	117	42	Good--------	All road purposes except concrete aggregate.
SW¼ sec. 31, T. 146 N., R. 72 W.	(1)	3. 2	7. 4	0	--------	113	26	Fairly good---	All road purposes except concrete aggregate.
SW¼ sec. 17, T. 147 N., R. 72 W.	40, 000	3. 2	5. 3	0	--------	119	22	Good--------	All road purposes except concrete aggregate.
SE¼ sec. 35, T. 147 N., R. 72 W.	50, 000	1. 4	6. 8	0	--------	119	30	Good--------	All road purposes except concrete aggregate.
NE¼NE¼ sec. 4, T. 148 N., R. 72 W.	66, 200	7. 4	4. 3	0	--------	113	13	Fair: rather fine.	Pit-run base; gravel surfacing.
NW¼ sec. 35, T. 149 N., R. 72 W.	(2)	4. 4	4. 3	0	--------	116	22	Fair---------	Base material; gravel surfacing.
NW¼ sec. 28, T. 150 N., R. 72 W.	(1)	. 7	6. 3	0	--------	107	22	Fair: fine-----	Pit-run base; gravel surfacing.
NW¼ sec. 14, T. 145 N., R. 73 W.	26, 800	3. 4	9. 2	0	--------	114	38	Good--------	All road purposes except concrete aggregate.
NW¼ sec. 17, T. 148 N., R. 73 W.	30, 780	. 3	7. 3	2. 6	18. 5	120	39	Good--------	All road purposes except concrete aggregate.
NE¼ sec. 18, T. 148 N., R. 73 W.	60, 292	. 8	12. 8	3. 5	22. 6	108	31	Fairly good---	All road purposes except concrete aggregate.
SW¼ sec. 24, T. 149 N., R. 73 W.	1, 300	. 8	2. 8	--------	--------	--------	14	Fairly poor: rather fine.	Only base material.
N½ sec. 8, T. 150 N., R. 73 W.	(1)	3. 6	2. 4	0	--------	118	41	Good--------	All road purposes except concrete aggregate.
SW¼ sec. 10, T. 150 N., R. 73 W.	(1)	1. 7	2. 4	0	--------	118	19	Fair: somewhat fine.	Base material; gravel surfacing.

1 Unknown. 2 Large.

Climate and vegetation are the active factors of soil formation. They act on the accumulated parent material and slowly change it into a soil that has genetically related horizons. Relief, mainly by its influence on temperature and runoff, modifies the effects of climate and vegetation. The parent material also affects the kind of profile that can be formed and, in extreme cases, determines it almost entirely. Finally, time is needed for the changing of the parent material into a soil profile. Usually, a long time is required for the development of distinct horizons.

Parent material

All the soils in Wells County formed in glacial material derived from preglacial granite, gneiss, sandstone, shale, limestone, and basalt. The glacier picked up these materials, ground and mixed them as it transported them across country, and then deposited them as it melted. Some deposits consist of unsorted material, or glacial till; others consist of material sorted either by water when it was being deposited or by wind and water afterward.

The parent material of the soils in each of the 10 associations is described in the following paragraphs. The soil associations are described in the section "General Soil Map."

The dominant soils of the Heimdal-Emrick-Fram association formed in glacial material high in content of silt and very fine sand. This material is 1 foot to 20 feet thick over glacial till. The depth to bedrock is 50 to 100 feet. Indications are that this material resulted mainly from the sorting of glacial till by shallow, slow-moving water. Some was probably wind sorted. Possibly some of it accumulated in lakes on the glacier and was deposited on the land when the ice melted. The lower horizons of the Gardena, Eckman, Fram, and Borup soils appear to have formed in sandy material. In many places the lower horizons of the Emrick, Heimdal, and Fram soils formed in glacial till. In a few areas a pebble line or a stone line separates the silty upper part of the parent material from the unsorted till.

The dominant soils of the Barnes-Svea association and the Barnes association formed in glacial till. The Heimdal and Emrick soils, which are minor soils in the Barnes-Svea association, formed in material sorted by water that flowed into small lakes on the surface of the ice sheet. The water-sorted material is siltier than the underlying glacial till. The total thickness of the till ranges from 100 to 500 feet.

The dominant soils of the Barnes-Buse association formed in friable, loam-textured glacial till. This till is 100 to 500 feet thick over preglacial sediments, except along the Sheyenne River, where glacial melt water washed away all but a trace of it.

The dominant soils of the Sioux-Barnes association formed in coarse outwash materials deposited over loamy glacial till. These coarse materials were sorted by the action of glacial melt water that deposited beds of clean sand and gravel in some places and washed away varying amounts of silt and clay from other places.

The dominant soils of the Forman-Nutley association formed in glacial lake sediments. These sediments are rarely more than 10 feet thick, and they are underlain by 100 to 400 feet of glacial till. They contain more clay than the other glacial material deposited in the county.

The dominant soils of the Emrick-Larson association formed in silty glacial material that, except for the content of sodium, is similar to the material in which the dominant soils of the Heimdal-Emrick-Fram association formed. The sodium probably originated in underlying till or bedrock. The depth to bedrock ranges from 6 to an estimated 100 feet.

The dominant soils of the Egeland-Embden association formed in moderately coarse textured material sorted by glacial melt water and wind. In many places the material sorted by melt water was later reworked by wind. These deposits are 1 foot to 3 feet thick, and all of them are probably underlain by loam-textured glacial till. The depth to bedrock ranges from 50 to 100 feet.

The dominant soils of the Renshaw-Arvilla-Lamoure association formed in material deposited by glacial melt water. The materials deposited near Little Pipestem Creek consist only of beds of sand and gravel 3 to 20 feet thick. Those along the Sheyenne River are as much as 100 feet thick and consist of loamy material over sand and gravel. The deposits in the northwestern part of the county consist of loamy material over sand and gravel. There are few areas where the loamy material is more than 4 feet thick over the sand and gravel, and few where the entire deposit is more than 20 feet thick.

The dominant soils of the LaDelle association formed in alluvium and colluvium derived from glacial materials. Of the minor soils in this association, the Nutley and Overly soils formed in fine-textured material deposited in glacial lakes, and the others formed in silty material deposited by glacial melt water.

Climate

Wells County has a cool, dry-subhumid, continental climate characterized by long cold winters and a short growing season, during which the distribution of rainfall is erratic. The climate does not vary much from place to place in the county and probably has not changed much during the period of soil formation. It has not been too severe for the growth of a prairie vegetation.

Temperature and moisture affect the growth of plants, the activity of micro-organisms, and the speed of chemical reactions, particularly during the growing season. Rainfall has not been sufficient for the deep leaching of the soils, nor has it caused more than a minor amount of erosion. Freezing and thawing help to disintegrate parts of the glacial debris, and frost heaving helps mix soil materials, thus affecting soil structure. The cool temperatures slow the decay of plant and animal materials, thus promoting the accumulation of organic matter. This process is responsible for the large amount of organic matter in Svea, Emrick, and Hecla soils. In these ways climate has had an effect on soil formation in this county.

Plant and animal life

Soil formation started in Wells County when plants began to grow in the unconsolidated materials deposited by the glacier. Well-drained soils have formed under predominantly cool-season, drought-resistant grasses. Tall, warm-season grasses grow where the soils receive extra moisture.

Plant roots loosen the soil material and bring minerals from the parent material upward toward the surface. As the plants die and decay, they contribute organic matter, which bacteria and other micro-organisms help to decompose. Thus, nutrients leached out of the surface layer are replaced, and a good supply is maintained for the growth of other plants.

The activity of animals seems to be of less importance to soil formation in this county than the growth of plants. Earthworms and burrowing animals help to mix the soil materials from various horizons and bring some fresh parent material to the surface layer. Man's activities, particularly in altering drainage conditions, maintaining fertility, and changing the kinds of vegetation, will have an important effect upon both the rate and the direction of soil formation in the future.

Relief

Relief influences the formation of soils through its effect on runoff and drainage. If other soil-forming factors are equal, relief largely determines the degree of profile development, mainly because it controls the amount of moisture in the soil. Because of excessive drainage, only a little water is in the more sloping and coarser textured soils, and vegetation is sparse; consequently, profile development is slow. Among the soils affected in this way are Buse and Sioux. On the other hand, excessive water in areas that have poor drainage also disturbs the process of soil formation. Affected in this way are Parnell, Dimmick, and Benoit soils and Loamy lake beaches and Saline land.

Time

Time is necessary for the factors of soil formation to act on parent material. Generally, length of time determines whether the soil has reached an equilibrium with its environment.

The degree of profile development in most of the soils in Wells County has been affected more by differences in the other soil-forming factors than by differences in the length of time, because, except for the Lamoure, LaPrairie, and LaDelle soils, the length of time has been about the same. In terms of geologic time, the soils are young because they formed from materials deposited in late Pleistocene time, which ended about 11,000 years ago.

Classification of the Soils

Soils are classified so that we can more easily remember their significant characteristics, assemble knowledge about them, see their relationships to one another, and understand their behavior and their response to the whole environment. Through classification and the use of soil maps, we can apply our knowledge of soils to specific fields and other tracts of land.

Two systems of classifying soils above the series level have been used in the United States in recent years. The older system was adopted in 1938 (*2*) and revised later (*8*). The system currently used by the National Cooperative Soil Survey was adopted in 1965 and is under continual study. Readers interested in the development of the system should refer to the latest literature available (*6*, *10*).

The current system consists of 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 measurable or observable, but the properties are selected so that soils of similar genesis are grouped together. Placement of some series in the current system of classification, particularly in families, may change as more precise information becomes available.

Table 8 shows the classification of the soil series in Wells County according to the current system and according to the great soil group of the 1938 system. The categories of the current system are defined briefly in the following paragraphs.

ORDER.—Soils are grouped into orders according to properties that seem to have resulted from the same processes acting to about the same degree on the parent material. Ten soil orders are recognized in the current system: Entisols, Vertisols, Inceptisols, Aridisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, and Histosols. Only the Mollisols are represented in Wells County.

Mollisols have a thick, dark-colored surface layer, moderate to strong structure, and base saturation of more than 50 percent.

SUBORDER.—Each order is divided into suborders, primarily on the basis of soil characteristics that indicate genetic similarity. The suborders have a narrower climatic range than the order. The criteria for suborders reflect either the presence or absence of waterlogging or differences in climate or vegetation.

GREAT GROUP.—Each suborder is divided into great groups, on the basis of uniformity in kind and sequence of genetic horizons. The great group is not shown in table 8, because the name of the great group is the same as the last word in the name of the subgroup.

SUBGROUP.—Each great group is divided into subgroups, one representing the central (typic) concept of the group, and the other subgroups, called intergrades, made up of soils that have mostly the properties of one great group but also one or more properties of another great group.

FAMILIES.—Families are established within subgroups, primarily on the basis of properties important to plant growth. Some of these properties are texture, mineralogy, reaction, soil temperature, permeability, consistence, and thickness of horizons.

SERIES.—The series has the narrowest range of characteristics of the categories in the classification system. It is explained in the section "How This Survey Was Made."

General Nature of the County

Wells County was first inhabited by Sioux Indians, and it was visited by the early French and English traders and hunters. It was formally opened to settlement in the 1880's, and the first cropland furrow was turned by an ox-drawn plow near Sykeston in 1883.

The population increased rapidly, particularly between 1890 and 1900, reached a peak in 1930, and then gradually declined. In 1960 the county population was 9,237,

TABLE 8.—*Soil series in Wells County classified into higher categories*

Series	Current classification				Great group, 1938 classification
	Family	Subgroup	Suborder	Order	
Aberdeen	Fine, mixed, frigid	Glossic Udic Natriborolls	Borolls	Mollisols	Degraded Solodized-Solonetz soils.
Arvilla	Coarse-loamy, mixed, frigid	Udic Haploborolls	Borolls	Mollisols	Chernozems.
Barnes	Fine-loamy, mixed, frigid	Udic Haploborolls	Borolls	Mollisols	Chernozems.
Bearden	Fine-silty, mixed, frigid	Aeric Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.
Benoit	Fine-loamy over sandy or sandy-skeletal, mixed, frigid.	Typic Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.
Borup	Coarse-silty, mixed, frigid	Typic Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.
Buse	Fine-loamy, mixed, frigid	Udorthentic Haploborolls	Borolls	Mollisols	Regosols.
Colvin	Fine-silty, mixed, frigid	Typic Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.
Dimmick	Fine, montmorillonitic, noncalcareous, frigid.	Vertic Haplaquolls	Aquolls	Mollisols	Humic Gley soils.
Divide	Fine-loamy over sandy or sandy-skeletal, mixed, frigid.	Aeric Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.
Eckman	Coarse-silty, mixed, frigid	Udic Haploborolls	Borolls	Mollisols	Chernozems.
Egeland	Coarse-loamy, mixed, frigid	Udic Haploborolls	Borolls	Mollisols	Chernozems.
Embden	Coarse-loamy, mixed, frigid	Pachic Udic Haploborolls.	Borolls	Mollisols	Chernozems.
Emrick	Coarse-loamy, mixed, frigid	Pachic Udic Haploborolls.	Borolls	Mollisols	Chernozems.
Exline	Fine, mixed, frigid	Leptic Natriborolls	Borolls	Mollisols	Solodized-Solonetz soils.
Fargo	Fine, montmorillonitic, noncalcareous, frigid.	Vertic Haplaquolls	Aquolls	Mollisols	Grumusols.
Forman	Fine-loamy, mixed, frigid	Udic Argiborolls	Borolls	Mollisols	Chernozems.
Fram	Coarse-loamy, mixed, frigid	Aeric Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.
Gardena	Coarse-silty, mixed, frigid	Pachic Udic Haploborolls.	Borolls	Mollisols	Chernozems.
Hamar	Sandy, mixed, noncalcareous, frigid.	Typic Haplaquolls	Aquolls	Mollisols	Humic Gley soils.
Hamerly	Fine-loamy, mixed, frigid	Aeric Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.
Hecla	Sandy, mixed, frigid	Pachic Udic Haploborolls.	Borolls	Mollisols	Regosols.
Heimdal	Coarse-loamy, mixed, frigid	Udic Haploborolls	Borolls	Mollisols	Chernozems.
LaDelle	Fine-silty, mixed, frigid	Cumulic Udic Haploborolls.	Borolls	Mollisols	Alluvial soils.
Lamoure	Fine-silty, mixed, calcareous, frigid.	Cumulic Haplaquolls	Aquolls	Mollisols	Humic Gley soils intergrading to Alluvial soils.
LaPrairie	Fine-loamy, mixed, frigid	Cumulic Udic Haploborolls.	Borolls	Mollisols	Alluvial soils.
Larson	Fine-loamy, mixed, frigid	Udic Natriborolls	Borolls	Mollisols	Solodized-Solenetz soils.
Letcher	Coarse-loamy, mixed, frigid	Udic Natriborolls	Borolls	Mollisols	Solodized-Solonetz soils.
Maddock	Sandy, mixed, frigid	Udorthentic Haploborolls	Borolls	Mollisols	Regosols.
Miranda	Fine, mixed, frigid	Leptic Natriborolls	Borolls	Mollisols	Solodized-Solonetz soils.
Nutley	Fine, montmorillonitic, frigid.	Udertic Haploborolls	Borolls	Mollisols	Grumusols.
Overly	Fine-silty, mixed, frigid	Pachic Udic Haploborolls.	Borolls	Mollisols	Chernozems.
Parnell	Fine, montmorillonitic, noncalcareous, frigid.	Pachic Argiaquolls	Aquolls	Mollisols	Humic Gley soils.
Perella	Fine-silty, mixed, noncalcareous, frigid.	Typic Haplaquolls	Aquolls	Mollisols	Humic Gley soils.
Renshaw	Fine-loamy over sandy or sandy-skeletal, mixed, frigid.	Udic Haploborolls	Borolls	Mollisols	Chernozems.
Sioux	Sandy-skeletal, mixed, frigid	Udorthentic Haploborolls	Borolls	Mollisols	Regosols.
Svea	Fine-loamy, mixed, frigid	Pachic Udic Haploborolls.	Borolls	Mollisols	Chernozems.
Tonka	Fine, montmorillonitic, frigid.	Argiaquic Argialbolls	Albolls	Mollisols	Planosols.
Ulen	Coarse-loamy, mixed, frigid	Aeric Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.
Vallers	Fine-loamy, mixed, frigid	Typic Calciaquolls	Aquolls	Mollisols	Calcium Carbonate Solonchaks.

which included 2,365 at Harvey and 920 at Fessenden, the county seat. Only about half the population lived on farms.

At present, about 1,076 farms are operated in the county. They range from less than 100 acres to more than 1,000 acres in size and average 751 acres. Cash-grain farms number 824 (77 percent), livestock or livestock product farms number 135 (12.5 percent), and the rest are general or miscellaneous farms. Full owners operate 368, part owners operate 499, tenants 205, and managers or others 4. Most of the farms are mechanized. The equipment used includes tractors, motortrucks, grain swathers and combines, and grain elevators or blowers.

The main field crops are durum and other spring wheat, flax, barley, oats, and corn. Spring wheat is grown most extensively. Rye is also grown. The raising of livestock, mostly beef cattle, is the second most important farming enterprise. Most of the herds are small and of the cow-calf type. Hereford, Aberdeen Angus, and Shorthorn are the most common breeds. Several herds are registered. The beef is either sold at auction in Harvey or shipped outside the county. Holstein-Freisian is the most popular dairy breed, particularly on the few farms that sell whole milk. Dairy cows of other breeds are raised on farms that have only a few milk cows and that sell only cream. The milk is sold either to the creamery in Harvey or to cheese factories, outside the county, that have established truck routes in Wells County.

Providing transportation and access to markets, both within and outside the county, are three transcontinental railway systems, one U.S. highway, four major State highways, and numerous county roads. The towns served by the railroads are Sykeston, Heaton, Bowdon, Chaseley, Hurdsfield, Cathay, Emrick, Fessenden, Manfred, Harvey, Bremen, Hamberg, Heimdal, and Wellsburg. Most of the county roads are graded, graveled, and otherwise well maintained. About 92 percent of the farms are adjacent to either a graveled road or a paved road.

Climate [6]

The climate of Wells County is typical of the northern Great Plains. Wide variations in precipitation, temperature, and humidity are characteristic. Summer days are warm, and nights are cool. Winters are cold, and snow covers the ground from the end of November to the middle of March. Northwesterly winds predominate, particularly in the period October through April, but southerly winds may blow for 60 or more hours in the period June through September and in December. In summer the relative humidity ranges from an average of 85 percent in early morning to an average of 50 percent in late afternoon; in winter, it averages 75 percent for day and night. About 220 days a year are either clear or partly cloudy, and the percentage of time that the sun shines ranges from 45 in winter to 70 in summer, or an average of 60 the year round.

Temperature and precipitation data based on records kept at Fessenden are given in table 9. The probability of receiving specified amounts of precipitation during 1-week, 2-week, and 3-week periods is shown in table 10. Table 11 gives the probability of freezing temperatures after specified dates in spring and before specified dates in fall. The average hours of stated wind velocity, by months, based on data kept at Jamestown in Stutsman County, are shown in table 12. Except for minor differences caused by variations in local topography, these data are generally representative of Wells County.

[6] By Alfred A. Skrede, State climatologist, U.S. Weather Bureau.

TABLE 9.—*Temperature and precipitation data*

[All data from the U.S. Weather Bureau Station at Fessenden, elevation 1,620 feet, for the period 1911 through 1961]

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	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.	In.	In.	In.	No.	In.
January	17	−5	40	−28	0.52	0.2	1.0	27	5
February	22	0	45	−24	.50	.1	1.0	25	5
March	35	13	56	−12	.70	.2	1.3	17	4
April	53	29	75	15	1.36	.4	2.5	4	1
May	67	40	85	27	2.29	.8	4.3	(1)	
June	76	50	90	37	3.46	1.2	5.3		
July	84	55	96	45	2.55	1.0	3.6		
August	83	52	96	40	2.29	.7	3.7		
September	71	42	90	28	1.62	.3	3.5		
October	58	31	79	18	1.05	.2	2.4	2	(2)
November	37	16	59	−7	.74	.1	1.6	11	2
December	23	3	43	−23	.56	.2	1.2	21	3
Year	52	27	[3] 100	[4] −32	17.44	13	22	107	

[1] Less than 1 day. [2] Less than 1 inch. [3] Average annual highest temperature. [4] Average annual lowest temperature.

TABLE 10.—*Probability of receiving the stated amounts of precipitation during 1-week, 2-week, and 3-week periods*

[Adapted from data prepared under the North-Central Regional Project NC–26 (*5*)]

1-week period	Probability of receiving at least—				
	Trace or none	0.2 inch	0.6 inch	1 inch	2 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
March 29–April 4	32.0	39.5	12.2	4.7	0.3
April 5–April 11	36.5	37.5	11.0	4.0	.4
April 12–April 18	30.0	41.5	16.2	7.0	.9
April 19–April 25	25.4	48.3	22.0	10.3	1.5
April 26–May 2	21.8	53.3	26.2	13.2	2.4
May 3–May 9	22.3	53.2	27.0	14.0	2.8
May 10–May 16	22.2	53.2	26.7	13.2	2.7
May 17–May 23	20.2	56.5	29.3	15.0	3.0
May 24–May 30	24.0	63.3	34.2	19.5	4.3
May 31–June 6	10.2	67.2	39.0	23.3	6.4
June 7–June 13	6.7	72.5	44.5	27.4	8.2
June 14–June 20	6.2	75.1	47.4	30.0	9.1
June 21–June 27	8.4	73.3	45.9	38.0	8.5
June 28–July 4	8.5	72.7	43.5	35.0	7.0
July 5–July 11	10.4	67.3	37.6	21.6	4.6
July 12–July 18	12.3	65.0	34.9	18.2	3.8
July 19–July 25	14.3	60.6	31.8	17.0	3.7
July 26–August 1	15.2	60.0	31.9	17.4	4.1
August 2–August 8	15.8	60.2	32.4	27.7	4.1
August 9–August 15	17.3	58.3	31.1	16.6	4.0
August 16–August 22	17.8	56.7	28.6	14.8	3.0
August 23–August 29	21.2	52.7	26.5	13.8	3.0
August 30–September 5	20.9	53.0	26.0	13.4	2.8
September 6–September 12	23.1	51.5	25.5	13.1	2.8
September 13–September 19	23.8	51.0	24.3	11.8	2.1
September 20–September 26	28.5	45.0	19.5	9.0	1.2

2-week period	Probability of receiving at least—				
	Trace or none	0.2 inch	0.6 inch	1 inch	2 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
March 29–April 11	11.2	56.2	25.1	11.2	1.6
April 12–April 25	8.3	70.3	38.5	22.2	4.6
April 26–May 9	3.5	80.0	52.3	33.4	11.2
May 10–May 23	7.5	80.5	53.1	33.4	10.0
May 24–June 6	.9	88.6	66.7	48.1	20.0
June 7–June 20	.2	93.6	75.5	58.5	28.2
June 21–July 4	2.0	94.0	77.1	59.1	26.7
July 5–July 18	1.5	93.0	70.6	49.0	15.8
July 19–August 1	4.6	85.0	60.0	40.5	14.1
August 2–August 15	2.6	85.7	60.4	41.0	15.2
August 16–August 29	.8	83.8	54.7	33.8	9.7
August 30–September 12	3.5	80.4	52.5	33.1	10.5
September 13–September 26	8.0	76.3	47.2	28.1	7.8
September 27–October 11	19.5	60.0	33.2	19.7	4.5
3-week period					
March 22–April 11	8.0	74.5	43.5	24.8	6.0
April 12–May 2	2.9	88.0	63.6	43.4	15.0
May 3–May 23	1.8	89.0	68.0	49.5	21.4
May 24–June 13	0	98.0	88.0	74.4	40.1
June 14–July 4	0	98.5	91.5	81.2	50.4
July 5–July 25	.5	98.0	87.8	71.3	32.1
July 26–August 15	.5	94.5	78.4	61.7	30.0
August 16–September 5	.6	91.5	71.5	52.5	22.3
September 6–September 26	.8	88.0	64.2	45.0	18.4
September 27–October 11	10.0	72.0	43.0	26.5	7.5

TABLE 11.—*Probability of freezing temperatures later than specified dates in spring and earlier than specified dates in fall*

Probability	Dates for given probability and temperature				
	32° F. or lower	28° F. or lower	24° F. or lower	20° F. or lower	16° F. or lower
Spring:					
10 percent	June 3	May 23	May 18	May 6	April 24
25 percent	May 27	May 16	May 10	April 29	April 16
50 percent	May 20	May 9	May 2	April 20	April 7
75 percent	May 13	May 2	April 24	April 12	March 29
90 percent	May 6	April 25	April 16	April 4	March 21
Fall:					
10 percent	September 3	September 12	September 23	September 30	October 12
25 percent	September 9	September 18	October 1	October 8	October 20
50 percent	September 15	September 25	October 9	October 17	October 29
75 percent	September 21	October 2	October 17	October 26	November 7
90 percent	September 27	October 8	October 25	November 3	November 15

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TABLE 12.—*Average hours, by months, of specified wind velocities*

[All data from Jamestown, Stutsman County, for the period 1936 through 1938]

Month	Wind velocity of—			Calm
	4 to 15 miles an hour	16 to 31 miles an hour	32 to 47 miles an hour	
	Number of hours	*Number of hours*	*Number of hours*	*Number of hours*
January	472	175	3	94
February	395	192	17	68
March	476	222	13	33
April	449	224	24	23
May	447	257	12	28
June	488	176	13	43
July	546	147	2	49
August	519	169	3	53
September	515	160	2	43
October	487	217	2	38
November	477	195	7	41
December	521	184	6	33
Year	5,792	2,318	104	546
Percent of year [1]	66	27	1	6

[1] Computed on actual total, or 8,760 hours.

Precipitation in Wells County averages a little more than 17 inches a year. Most of it falls during the growing season, and about half in the period June through August. In the period 1953 through 1963, precipitation ranged from a low of slightly less than 14 inches for the year and about 9 inches for the growing season, in 1959, to a high of more than 22 inches for the year and about 18 inches for the growing season, in 1957. The lowest annual precipitation recorded in Wells County was 9 inches, in 1934, and the highest was more than 25 inches, in 1941.

Precipitation of 0.1 inch in 1 day can be expected on 44 days each year, and 1 inch or more in 1 day can be expected about twice each year. Table 10 shows the probability of receiving at least a given amount of precipitation in 1-week, 2-week, and 3-week periods during the growing season (*5*). For example, the table shows that the probability of receiving 0.2 inch or more in a 1-week period is greatest in the week of June 14 through June 20, when the probability is about 75 percent, or about 3 years out of 4 years. The probability of receiving 0.2 inch in a 2-week period is greatest in the period June 21 through July 4, when the probability is 94 percent. About once in 2 years, rainfall of the following intensities can be expected: 0.85 inch in 30 minutes, 1.10 inches in 1 hour, 1.20 inches in 2 hours, 1.35 inches in 3 hours, 1.65 inches in 6 hours, 1.75 inches in 12 hours, and 2 inches in 24 hours.

In summer most of the rain falls during thunderstorms. An average of 30 thunderstorms is reported each year, and normally about 7 of these storms occur in each month during the period June through August.

Hail accompanies two or three thunderstorms each year, but it does only a moderate amount of damage. Figure 24 shows, by years, the insured acreage in Wells County reported as at least 5 percent damaged by hail. These data are based on records kept by the State Hail Insurance Department of North Dakota. The figure shows that the damaged acreage ranged from a low of 1 percent in 1951 to a high of 41 percent in 1952. Ac-

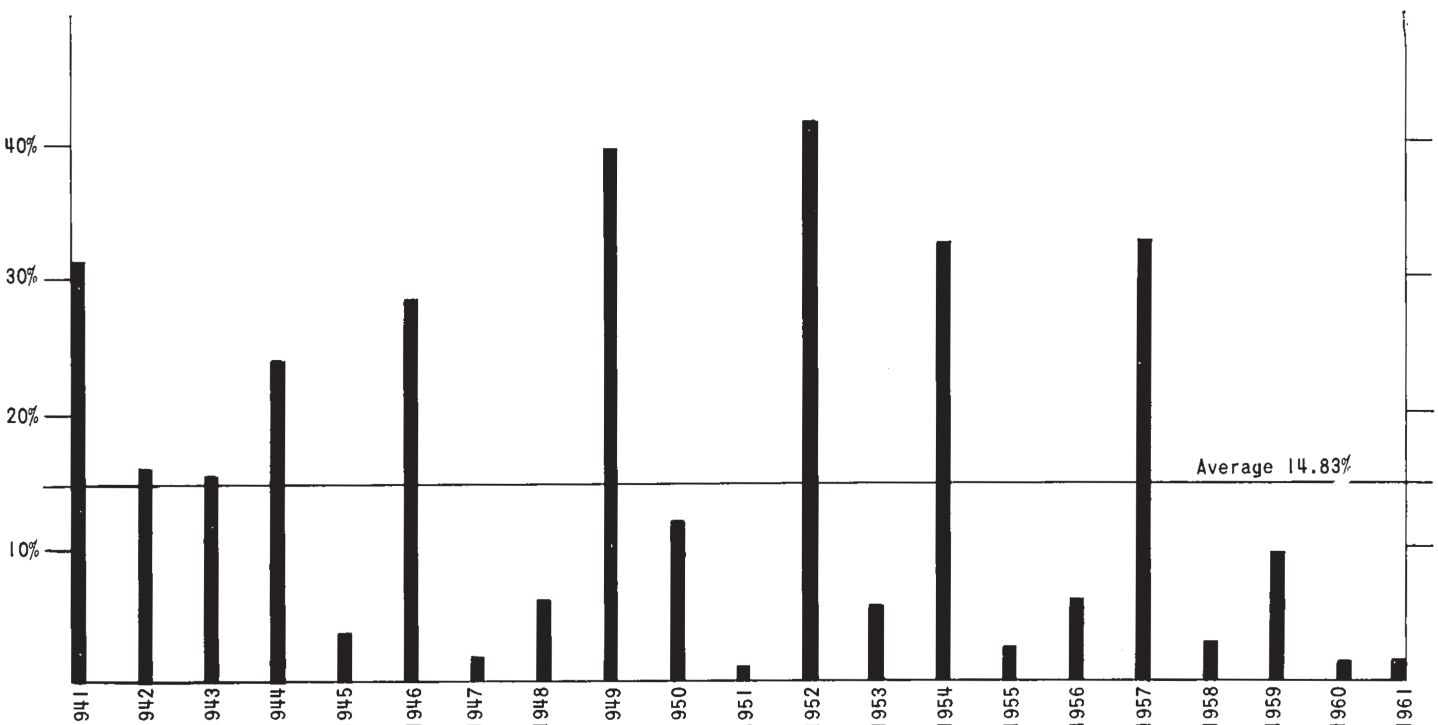

Figure 24.—Percentage of insured acreage in Wells County reported as damaged by hail, for the period 1941 through 1961.

cording to records kept at the U.S. Weather Bureau Station in Bismarck, Burleigh County, about 17 percent of the days on which hail falls occur in May, 33 percent in June, 20 percent in July, 18 percent in August, 7 percent in September, and 5 percent in March, April, and October, combined.

Yearly snowfall ranges from a low of 8 inches to a high of 64 inches, but the average is 32 inches a year. In most years, snow covers the ground from the end of November to the middle of March. A measurable amount of snow can be expected to fall during October in 1 year out of 2 years, during April in 3 years out of 5 years, and during May in 1 year out of 10 years. Table 9 shows the average number of days with snow cover in each month.

Pan evaporation data were obtained for the period 1951 to 1962 through the use of a Class A evaporation pan at the U.S. Weather Bureau Office at Devils Lake in Ramsey County. These data show that for the growing season, April through September, precipitation averaged 13.57 inches and pan evaporation averaged 31.75 inches. Based on these figures and estimated by the Thornthwaite method, the potential evapotranspiration is 21.51 inches (*7*). The true potential is probably between 21.51 and 31.75, and probably closer to 31.75.

In the period June through August, the maximum temperature averages 81° F., but a temperature of 90° or more can be expected on 19 days. In the period December through February, the maximum temperature averages 10°, but a maximum temperature of 32° or more can be expected on 21 days and a minimum temperature below zero can be expected on about 57 days.

The average length of the growing season is 119 days. The average date of the last freezing temperature (32°) in spring is May 20, and the date of the first in fall is September 15 (*4*). Table 11 shows the probability of a temperature of 32° or lower after May 27 is 25 percent, or once in 4 years. The data in this table are based on instrument readings taken above ground level, and consequently, frost may occur at ground level when these data indicate temperatures above 32°.

The wind velocity is between 16 and 47 miles an hour about 34 percent of the time in April, 36 percent in May, and 26 percent in June. These are the months when fields have little protective cover. Table 12 shows the average number of hours that winds of specified velocities can be expected in each month. The data in this table are based on a 3-year record kept by the U.S. Weather Bureau Station at Jamestown, in Stutsman County. Jamestown is about 72 miles southeast of Fessenden, and it has about the same elevation and topography.

Physiography, Relief, and Drainage

Wells County is made up of undulating prairies that slope gently northward. Short irregular slopes characterize the relief in areas of hilly glacial deposits in the southwestern corner and the west-central part of the county, the southeastern tip, and the area north of Bremen. In these areas the slope is as much as 20 percent. Short choppy slopes characterize the relief in the rolling and undulating areas or moraines, which are in the southern part of the county, the northwestern part, and the area north of Heimdal. In these areas the slope range is generally 1 to 8 percent. Except for a few isolated knobs and breaks to drainageways, short slopes characterize the low relief in areas of wind- and water-sorted glacial materials. In these areas the slope is rarely more than 4 percent.

The elevation ranges from 2,000 feet above sea level in the southwestern part of the county to 1,425 feet on bottom lands in the northeastern corner. The difference in maximum and minimum elevation ranges from about 100 feet in areas of hilly glacial deposits to less than 10 feet in areas of low, wind- and water-sorted glacial deposits.

The Sheyenne River is in the watershed of the Red River of the North. It is entrenched 60 feet where it enters the county on the western edge and 150 feet in the northern part of the county. The James River is in the watershed of the Missouri River. It is entrenched to a maximum of about 35 feet in a few places for a short distance, south of Bremen. The Sheyenne River and the James River drop less than 3 feet a mile, and the water flows very slowly. Rocky Run, Little Pipestem Creek, and Pipestem Creek, which are tributaries of the James River, drop less than 5 feet a mile. Rocky Run is entrenched as much as 35 feet in the areas south of Fessenden, and Pipestem Creek about 40 feet in the area south of Heaton (fig. 25).

The streams of the county flow in channels formed by the melt water of the retreating glacier. Limited amounts of drainage are provided by a well-marked channel that runs between the Sheyenne River and the James River in the area near Heimdal and Bremen, a channel that runs between Pipestem Creek and Little Pipestem Creek in the areas south of Sykeston, and several small, shallow channels that run in a southeasterly direction and are scattered throughout the county. The channel that runs between the Sheyenne River and the James River is half a mile wide, and it is marshy in most places because of the backwater from the James River. Water flows in these channels only during wet seasons. Most of the runoff collects in upland depressions.

Water Supply

Wells are the main source of water for domestic use on farms in Wells County. The wells range from less than 20 feet to more than 200 feet in depth. The water in these wells comes mainly from lenses or beds of sand and gravel in the glacial till, and the supply is limited because many of the beds are small and isolated. Although usually adequate for domestic use, the supply may not be adequate for livestock; consequently, dugouts and natural sloughs are used to water livestock on many farms. The well water generally is hard and contains varying and objectionable amounts of salts, mainly sulfates and iron. Water softener is used by many families.

Wells also supply the water used in Fessenden and Harvey, and at present the supply is adequate. One aquifer supplying Fessenden is about 4 miles wide and extends in an east-west direction across the northern part of the county, generally south of the Great Northern Railroad tracks. Water from the valley of the Sheyenne River supplies the city of Harvey, which softens

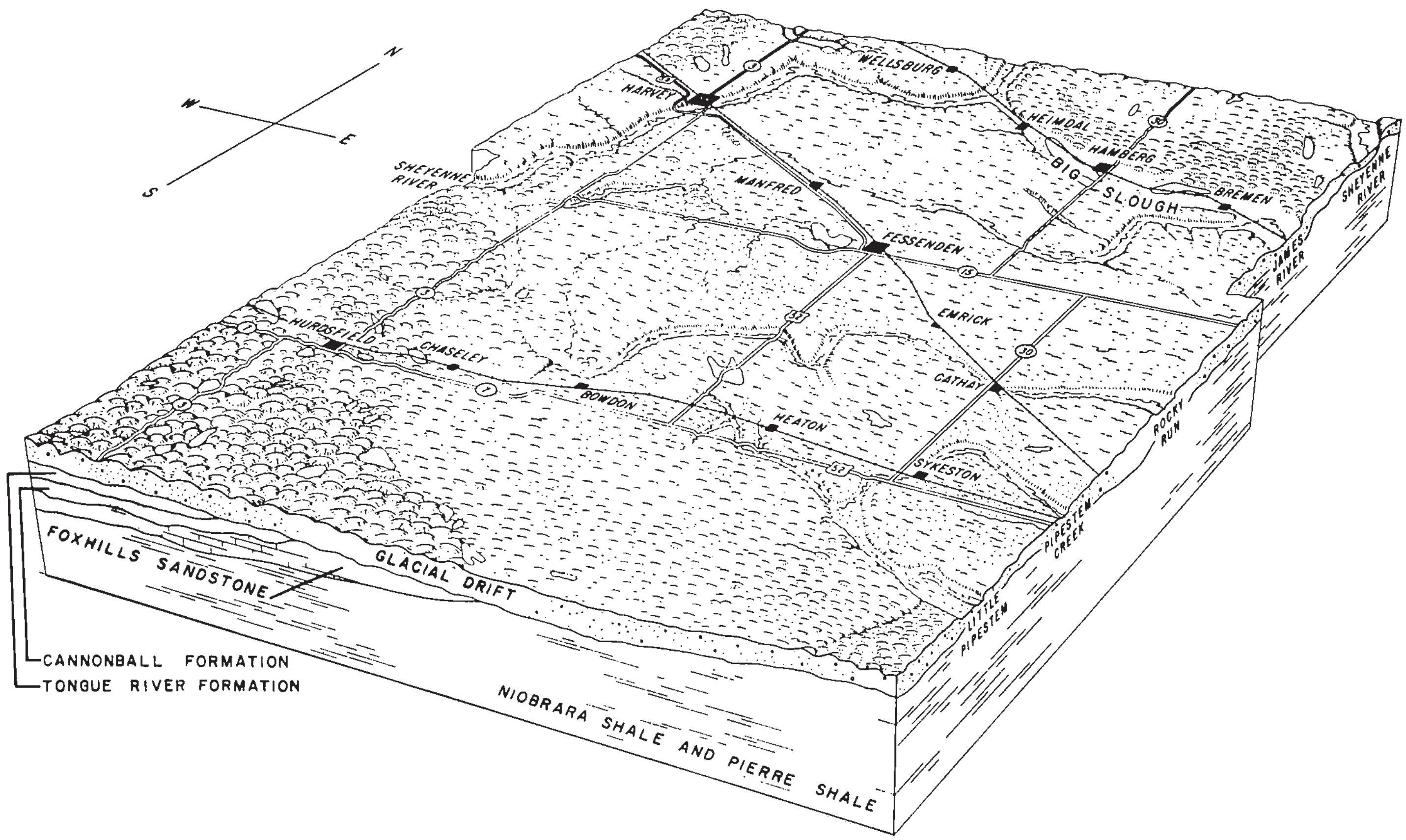

***Figure 25.*—Relief and drainage in Wells County.**

the water in its plant. A 2,235-foot well drilled into the Dakota Formation at Harvey yields soft water, but the water contains a total of 3,400 ppm. dissolved salts, mainly sodium bicarbonate and sulfates. At a depth of about 2,000 feet in most of the county, water can be obtained from the Dakota Formation, but this water is not considered suitable for domestic use.

Literature Cited

(*1*) American Association of State Highway Officials.
1961. Standard specifications for highway materials and methods of sampling and testing. Ed. 8, 2 v., illus.

(*2*) Baldwin, Mark, Kellogg, Charles E., and Thorp, James.
1938. Soil classification. U.S. Dept. Agr. Ybk.: 978–1001.

(*3*) Rauzi, Frank.
1960. Water intake studies on range sites at three locations in the northern plains. Jour. Range Management, v. 13, No. 4, pp. 180, 181.

(*4*) Sanderson, C. J.
1963. The probability of freezing temperatures in spring and fall in North Dakota. N. Dak. Exp. Sta. Bul. 443.

(*5*) Shaw, Robert W., Barger, Gerald L., and Dale, Robert F.
1960. Precipitation probabilities in the north central states. N. Cent. Region. Pub. No. 1115, 72 pp., illus.

(*6*) Simonson, Roy W.
1962. Soil classification in the United States. Science 137: 1027–1034, illus.

(*7*) Thornthwaite, C. W., and Mather, J. R.
1955. The water balance. In Climatology. Drexel Institute of Technology, v. 8, No. 1.

(*8*) Thorp, James, and Smith, Guy D.
1949. Higher categories of soil classification: order, suborder, and great soil groups. Soil Sci. 67: 117–122.

(*9*) United States Department of Agriculture.
1951. Soil survey manual. U.S. Dept. Agr. Handbook 18, 503 pp., illus.

(*10*) ———
1960. Soil classification, a comprehensive system, 7th approximation. 264 pp., illus. [Supplement issued in March 1967].

(*11*) Waterways Experiment Station, Corps of Engineers.
1953. The unified soil classification system. Tech. Memo. 3-357, 2 v., and appendix. 48 pp., and charts, illus.

Glossary

Aggregate, soil. Many fine particles held in a single mass or cluster, such as a clod, crumb, block, or prism.

Alluvium. Soil material, such as sand, silt, or clay, that has been deposited on land by streams.

Base saturation. The degree to which material that has base-exchange properties is saturated with exchangeable cations other than hydrogen, expressed as a percentage of the cation-exchange capacity.

Buried soil. A developed soil, once exposed but now overlain by more recently formed 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.

Clay coating. A thin coating of clay on the surface of a soil aggregate.

Claypan. A compact, slowly permeable soil horizon that contains more clay than the horizon above and below it. A claypan is commonly hard when dry and plastic or stiff when wet.

Colluvium. Soil material, rock fragments, or both, moved by creep, slide, or local wash and deposited at the base of steep slopes.

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; will not hold together in a mass.

Friable.—When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

Firm.—When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.—When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger.

Sticky.—When wet, adheres to other material, and tends to stretch somewhat and pull apart, rather than to pull free from other material.

Hard.—When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Soft.—When dry, breaks into powder or individual grains under very slight pressure.

Cemented.—Hard and brittle; little affected by moistening.

Contour farming. Plowing, cultivating, planting, and harvesting in rows that are at right angles to the natural direction of the slope or parallel to the terrace grade.

Cover crop. A close-growing crop grown primarily to improve and to protect the soil between periods of regular crop production; or a crop grown between trees and vines in orchards and vineyards.

Gleyed soil. A soil in which waterlogging and lack of oxygen have caused the material in one or more horizons to be neutral gray in color. The term "gleyed" is applied to soil horizons with yellow and gray mottling caused by intermittent waterlogging.

Grassed waterway. A natural or constructed waterway, typically broad and shallow, and covered by grass for protection against erosion; used to conduct surface water away from cropland.

Gumbo spots. Small areas where the plow layer is soft and sticky when wet and very hard or extremely hard when dry because fine-textured saline material from the subsoil has been mixed into the plow layer.

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 lost one or more of the following: soluble salts, clay, and sesquioxides (iron and aluminum oxides).

B horizon. The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused by (*1*) accumulation of clay, sesquioxides, humus, or some combination of these; (2) prismatic or blocky structure; (3) redder or stronger colors than the A horizon; or (4) 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 texture, structure, and other characteristics of the soil profile and underlying layers, and by the 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.*

Mottled. Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage. Descriptive terms are as follows: Abundance—*few, common,* and *many;* size—*fine, medium,* and *coarse;* and contrast—*faint, distinct,* and *prominent.* The size measurements are these: *fine,* less than 5 millimeters (about 0.2 inch) in diameter along the greatest dimension; *medium,* ranging from 5 millimeters to 15 millimeters (about 0.2 to 0.6 inch) in diameter along the greatest dimension; and *coarse,* more than 15 millimeters (about 0.6 inch) in diameter along the greatest dimension.

Muck. An organic soil consisting of fairly well decomposed organic material that is relatively high in mineral content, finely divided, and dark in color.

Natural drainage. Drainage 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 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 are uniform in color in the A and upper B horizons and have mottling in the lower B and C horizons.

Somewhat poorly drained soils are wet for significant periods but not all the time. If podzolic, they commonly have mottling below 6 to 16 inches in the lower part of the A horizon and in the B and C horizons.

Poorly drained soils are wet for long periods; they are light gray and generally mottled from the surface downward; but some may have few or no mottles.

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.

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 are nutrients obtained from the soil. Carbon, hydrogen, and oxygen are nutrients obtained largely from the air and water.

Parent material, soil. The disintegrated and partly weathered rock from which soil has formed.

Ped. An individual natural soil aggregate, such as a crumb, a prism, or a block, in contrast to a clod.

Permeability, soil. The quality that enables a soil horizon 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.*

Profile, soil. A vertical section of the soil through all its horizons and extending into the parent material.

Phase, soil. A subdivision of a soil type, series, or other unit in the soil classification system, made because of differences that affect management but do not affect classification. A soil type, for example, may be divided into phases because of differences in slope, stoniness, thickness, or some other characteristic that affects management.

Reaction, soil. The degree of acidity of 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. In words, the degrees of acidity or alkalinity are expressed thus:

	pH		*pH*
Extremely acid	Below 4.5	Mildly alkaline	7.4 to 7.8
Very strongly acid	4.5 to 5.0	Moderately alkaline.	7.9 to 8.4
Strongly acid	5.1 to 5.5	Strongly alkaline	8.5 to 9.0
Medium acid	5.6 to 6.0	Very strongly alkaline.	9.1 and higher
Slightly acid	6.1 to 6.5		
Neutral	6.6 to 7.3		

Runoff (hydrology). The part of the precipitation upon a drainage area that is discharged from the area in stream channels. The water that flows off the land surface without sinking in is called surface runoff; that which enters the ground before reaching surface streams is called ground-water runoff or seepage flow from ground water.

Sand. As a soil separate, individual rock or mineral fragments ranging from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz, but sand may be of any mineral composition. As a textural class, soil that is 85 percent or more sand and not more than 10 percent clay.

Series, soil. A group of soils developed from a particular type of parent material and having genetic horizons that, except for texture of the surface layer, are similar in differentiating characteristics and in arrangement in the profile.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.005 millimeter). As a textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Stone line. A concentration of coarse rock fragments in soils. In a cross section, the line may be one stone or more thick. The line generally overlies material that weathered in place, and it is ordinarily overlain by sediment of variable thickness.

Stripcropping. Growing crops in a systematic arrangement of strips, or bands, to serve as vegetative barriers to wind and water erosion.

Structure, soil. The arrangement of primary soil particles into compound particles or clusters that are separated from adjoining aggregates and have properties unlike those of an equal mass of unaggregated primary soil particles. The principal forms of soil structure are—*platy* (laminated), *prismatic* (vertical axis of aggregates longer than horizontal), *columnar* (prisms with rounded tops), *blocky* (angular or subangular), and *granular*. *Structureless* soils are (1) *single grain* (each grain by itself, as in dune sand) or (2) *massive* (the particles adhering together without any regular cleavage, as in many claypans and hardpans).

Stubble mulch. Stubble or other crop residues left on the soil, or partly worked into the soil, to provide protection from wind and water erosion after harvest, during preparation of a seedbed for the next crop, and during the early growing period of the new crop.

Summer fallow. The tillage of uncropped land during the summer to control weeds and allow storage of moisture in the soil for the growth of a later crop. A practice common in semiarid regions, where annual precipitation is not enough to produce a crop every year. Summer fallow is frequently practiced before planting of winter grains.

Surface layer. A nontechnical term for one or more layers above the subsoil. Includes A horizon and part of B horizon; has no depth limit.

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."

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.

Varved material. Distinctly marked annual deposits of sediment, regardless of their origin.

Water-holding capacity. The capacity of a soil to hold water in a form available to plants. Amount of moisture held in soil between field capacity, or about one-third atmosphere of tension, and the wilting coefficient, or about 15 atmospheres of tension.

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 is separated from a lower one by a dry zone.

Accessibility Statement