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Soil Survey

McKenzie County North Dakota

By
M. J. EDWARDS
United States Department of Agriculture, in Charge
J. K. ABLEITER
North Dakota Agricultural Experiment Station
and party

This number is the last Soil Survey Report for the Year 1933

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY
In cooperation with the
North Dakota Agricultural Experiment Station

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SOIL SURVEY OF McKENZIE COUNTY, NORTH DAKOTA

By M. J. EDWARDS, Soil Survey Division,[1] Bureau of Chemistry and Soils, United States Department of Agriculture, in Charge, J. K. ABLEITER, North Dakota Agricultural Experiment Station, and party [2]

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United States Department of Agriculture in cooperation with the North Dakota Agricultural Experiment Station

CONTENTS

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COUNTY SURVEYED

McKenzie County is in the extreme western part of North Dakota (fig. 1). Its southern boundary is about 100 miles north of the South Dakota State line, and its most northern point is approximately 60 miles south of the Canadian border. The central point of the county is approximately at the intersection of the north latitude parallel 47°45′ and the west longitude line 103°30′. The Missouri River forms the northern boundary and a part of the eastern boundary, and Montana borders the county on the west. The total area surveyed is 2,672 square miles, or 1,710,080 acres.[3]

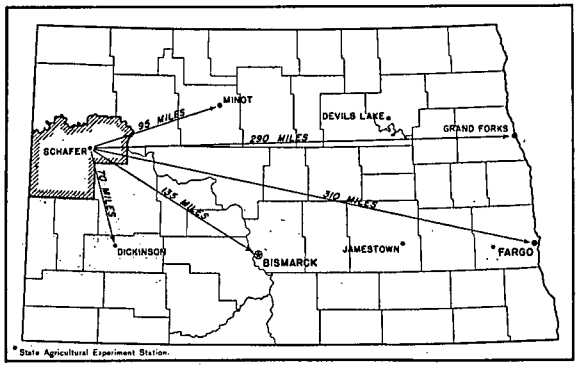


FIGURE 1.—Sketch map showing location of McKenzie County, N. Dak.

Physiographically, McKenzie County lies on the Missouri Plateau, a comparatively high plain sloping to the east and northeast. Within this county the plateau is underlain entirely by the Fort Union formation of the Tertiary period. Throughout the northern two-thirds of the county, the sedimentary rocks are covered by an uneven and comparatively thin layer of drift, presumably Kansan, that consists principally of olive-drab friable clayey till containing some pebbles and in places is distinctly stony or gravelly. In places in the extreme northwestern part of the county there is some evidence of a thin deposit of loess over the till. The Fort Union material is composed of stratified sand, silt, and clay, which are supposed to have been deposited in quiet fresh water. Numerous beds of lignite of various thicknesses and extent occur throughout this formation. Some of the sand strata are partly cemented, but otherwise little consolidation has taken place.

Land use is closely related to relief (fig. 2). McKenzie County has a few large areas of definite cropland; large areas that, because of their extreme relief, are suitable only for grazing; and extensive areas that consist of an intricate mixture of crop and grazing land. On the basis of relief the county can be divided into several sections. The most important agriculturally are the three fairly large smooth to gently rolling till plains in the northern part and the smooth to gently rolling plain of sedentary material in the southern part.

[3] This does not include about 175 square miles that lie within the Fort Berthold Indian Reservation. As the soil survey for this county was made at the request of the local county authorities, in order to provide accurate data for the classification and evaluation of rural lands for local taxation purposes, no soil survey was made of the land under the jurisdiction of the Bureau of Indian Affairs. The North Dakota Agricultural Experiment Station made up the land classification from the maps. On completion of their tabulation, these data were turned over to the county auditor's office for use as a basis for assessments. Funds were furnished by the county to pay for the State expense. An explanation of the land classification is given by Kellogg and Ableiter (4).[4]

[4] Italic numbers in parentheses refer to Literature Cited, p. 99.

As indicated in figure 2, the two till plains in the northwestern part of the county are the most extensive and together occupy about 300 square miles. The more northwestern area, lying principally in Charbon, Sioux, Elk, Poe, and Wilbur Townships, is a comparatively smooth tableland approximately 250 feet above the adjacent bottom land of the Yellowstone and Missouri Rivers. Because of proximity to these master streams, steep and abrupt slopes terminate the table on the north and west and form a very irregular fringe of badlands

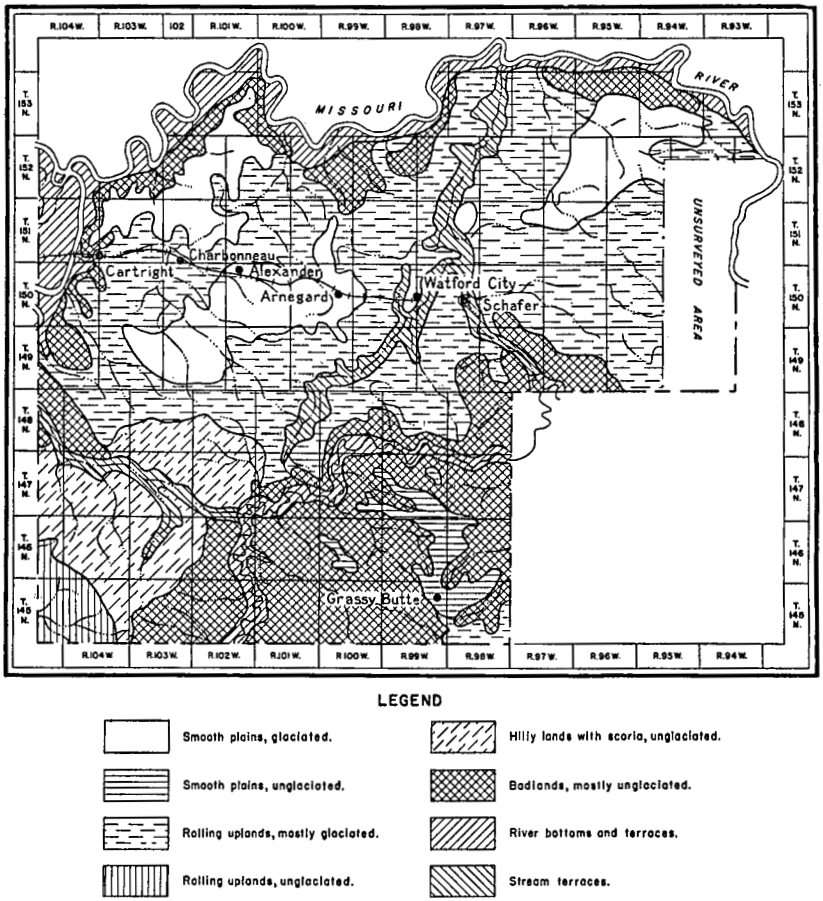


FIGURE 2.—Sketch map showing relief areas of McKenzie County, N. Dak.

between the smooth uplands and the bottom lands. An additional characteristic of this upland area is the tortuous pattern formed by the tributary V-shaped valleys that extend back into the tableland and break its continuity.

The second till plain, lying to the southeast, occupies the larger part of Arnegard and Alex Townships and extends more brokenly southwestward across Randolph and Moline Townships to T. 149 N., R. 103 W. The extremes of topography are less marked in this area, as the general relief of the upland plain is slightly more

undulating and the valleys less deeply incised than in the northwestern plain. Most of the run-off in the area is carried northwestward to the Yellowstone River by Charbonneau Creek and its tributaries. The more eastern part about Arnegard is drained northward to the Missouri River by Cottonwood Creek. Narrow alluvial benches, or terraces, have been formed along some of the principal upland drainageways, most of which are flanked on each side, except near their headwaters, by narrow strips of rolling to rough land. In the vicinity of Alexander and south of Rawson, knobs of Fort Union material capped by weakly cemented sand strata lie from 50 to 150 feet above the surrounding till plain.

The third important till plain is in Keene, Elm Tree, Riverview, and Hawkeye Valley Townships. The surface features in general are very similar to those of the Arnegard-Alexander plains. No isolated knobs occur, however, within the area, although the Blue Buttes can be seen to the south. The area adjacent to the upper part of Sand Creek in Elm Tree Township differs from similarly situated areas on other streams, in that it appears as a comparatively broad and shallow depression with gentle slopes that merge almost imperceptibly with the upland.

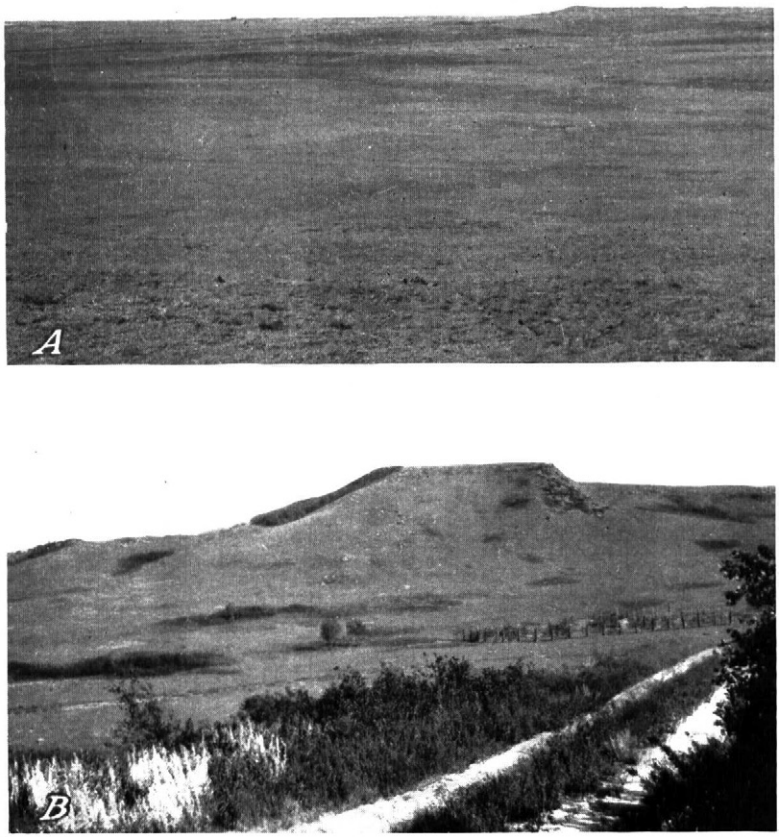
Numerous similar, but smaller, areas, such as the divide between Sand Creek and Tobacco Garden Creek, the upland area in Tobacco Garden Township, and the area to the north of Banks, are scattered throughout the glaciated parts of the county.

The smooth to gently rolling plain in the southern part near Grassy Butte had no covering of glacial drift. It occupies only a few square miles and is more encroached on by badlands areas than are the till plains. The relief is smooth to gently rolling, although much of the area consists of single broad ridges flanked on either side by deep badlands gorges. The elevation above the Little Missouri River is approximately 550 feet.

These smooth to gently rolling plains are occupied by zonal or climatically normally developed soils, which are dark brown and have a prismatic structure and a layer of lime accumulation about 16 inches below the surface. Prismatic structure in these soils refers to that arrangement of the soil particles whereby the aggregates appear in place as elongated prisms ranging from 4 to 8 or more inches in length. These prisms are firm but on removal readily fall into smaller nutlike aggregates that are held together by grass roots. When broken horizontally their outline is subangular or irregularly rounded. The common range in diameter is from ½ to 1½ inches. These soils are devoted extensively to the production of wheat, although some hay crops, flax, and other small grains are grown.

Bordering the valleys of the three main streams—the Yellowstone, Missouri, and Little Missouri Rivers—are belts of deeply dissected and extremely rough land. These areas are characterized by steep to precipitous slopes, extremely narrow uneven ridge tops, and narrow valleys having a marked stream gradient. The difference in relief throughout the Little Missouri Badlands is approximately 450 feet, throughout the Missouri River Badlands it is approximately 300 feet, and along the Yellowstone River it is a little less than 300 feet. Much of the surface of the Little Missouri River Badlands is entirely devoid of vegetation (pl. 1, *A* and *B*), whereas extensive areas of the

A, View overlooking the Badlands along the Little Missouri River; *B*, view looking southwest over the Little Missouri River Valley from a point near United States Highway No. 85.



A, View overlooking the undulating to rolling country of the till and intermixed till and sedentary belt in the vicinity of Watford City; *B*, grazing land and corral in the Blue Buttes district.

Yellowstone River and the Missouri River Badlands support good stands of grass and are devoted almost entirely to grazing. Along the greater part of their length the Badlands areas of the Missouri and the Yellowstone Rivers are from 1 to 2 miles wide, but in places the till-plain ridges extend to a distance of less than ½ mile from the river bottom lands, leaving a narrow strip of rough steep slopes intervening. The Badlands of the Little Missouri River range from 6 to 20 miles in width. The greater part is south and east of the stream, where the width ranges from 2 to 18 miles, whereas north and west of the stream the Badlands extend only 2 to 6 miles toward the interior of the county.

North of the Badlands of the Little Missouri River and extending to the glacial till plains, and in places to the Missouri River bottom land, is a belt of country marked by variations in parent material and topography. For convenience it is described as an area of till and intermixed till and sedentary material. Over much of the southern half of the belt, erosion has removed all or nearly all of the glacial till, except for remaining boulders, and the present dissection is being carried on in the Fort Union material. Dissection of the various strata of sandstone, silts, clays, and lignite in the Fort Union formation gives rise to various topographic forms and soils. The relief ranges from undulating to extremely rough, with numerous areas smooth enough to be well adapted to tillage (pl. 2, *A*) and others so rough as to be suited only to grazing. Most conspicuous of the rough areas are the Blue Buttes, a group of sandstone-capped outliers of the upper beds of the Fort Union formation. In the vicinity of Berg the buttes rise to an elevation of approximately 300 feet above the surrounding country. Much of the area is too rolling to be suited to tillage, nevertheless farmers have been growing crops on a large part of it. Most of this rolling part unquestionably would be best utilized as grazing land (pl. 2, *B*).

This till and intermixed till and sedentary area is, in general, well drained, but it embraces the two most poorly drained sections of the upland part of the county. The first is a morainic area of approximately 12 square miles west of Keene, which has not developed an efficient drainage system. The surface here is choppy to rolling and the lower parts are shallow, irregularly outlined depressions with no drainage outlets. These depressions are occupied by poorly drained soils and shallow ponds. The second section consists of a shallow lake with adjoining poorly drained land, approximately 10 miles southwest of Keene, which is about 2 miles long and ranges from ⅓ to nearly 1 mile in width. A part of it occupies what appears to be an abandoned stream valley. At present the lake includes but little open water, and the greater part of its surface is covered with reeds and sedges.

A belt of nearly level alluvial land, ranging from ½ mile to a little less than 2 miles in width, extends through the center of this area of intermixed rolling till and sedentary material from the Little Missouri River bottom land to the flood plain of the Missouri River. This alluvial lowland extends in an unbroken strip through the valleys of three independent streams—Redwing Creek, Cherry Creek, and Tobacco Garden Creek—and connects the valleys of the two larger streams. This indicates that the soil material was deposited by a stream—presumably the preglacial Little Missouri River—

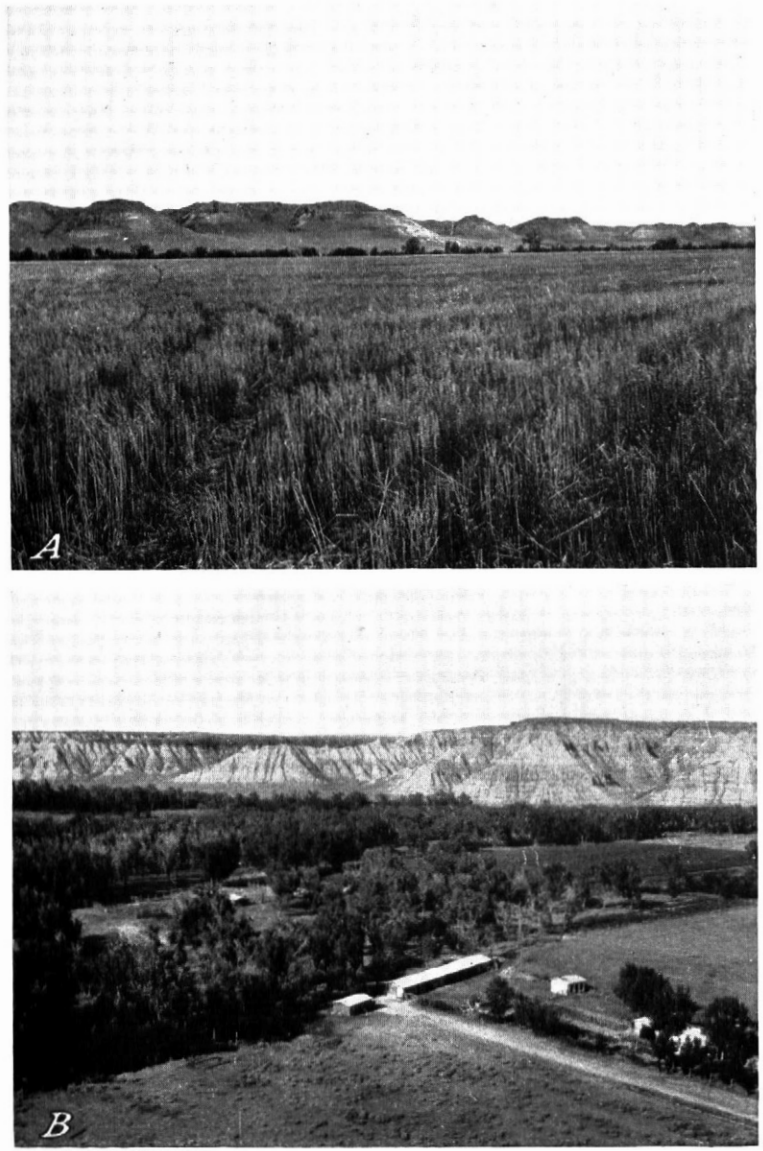
flowing into the Missouri River. Another less prominent abandoned valley is that in which Berg is located. Other examples of abandoned natural waterways are in the southwestern part of the county between the Little Missouri and Yellowstone Rivers, the largest of which is Hay Draw.

In the southwestern part of the county are two areas having distinctive surface features. One is a gently rolling comparatively low upland area, and the other is a mixed area of alluvium, buttes, and scoria. The lower lying area, embracing about 30 square miles in the extreme southwestern corner, slopes southwestward from the alluvium, butte, and scoria area to the north, and westward from the divide, beyond which, to the eastward, lie the Little Missouri Badlands. This area is an undulating to rolling upland dissected by two shallow valleys, the alluvial plains of which are approximately ½ mile wide and nearly level. Although the flow of water is intermittent, the stream channels in both valleys have cut to approximately 35 feet below the level of the alluvial flats. The area is topographically suited to dry farming, and wheat is the principal crop.

The area of mixed alluvium, buttes, and scoria lies immediately north of this lowland, south of the Arnegard-Alexander till plain, northwest of the Little Missouri Badlands, and west of the valley of Bowline Creek. In general, it embraces the watershed of Bennie Pierre Creek and has three distinct features of relief: (1) Nearly level alluvial plains along the larger drainageways; (2) very gently sloping relatively wide alluvial valley slopes; and (3) a hinterland of badland remnants consisting of rough, partly bare, and in many places narrow ridges and buttes. A large proportion of these remnants of the badlands are capped by a layer of scoria from 20 to 80 feet thick. Several old drainage or stream gaps connecting drainage systems occur in this area, the most important of which is Hay Draw, connecting the valley of Bennie Pierre Creek with the valley of the Little Missouri River. The broader areas of the valleys are used for the production of small-grain and hay crops (pl. 3, *A*), and the rest—more than 90 percent—is devoted to grazing, as the gentle slopes of the valleys provide some of the best grazing in the county.

The valleys of the Yellowstone and Missouri Rivers are mature. Their walls are steep, the valley floors are comparatively wide—approximately 3 miles—and stream meandering has developed to a marked degree. The land surface is nearly level, except for a few areas that have a gently to sharply billowy surface. The surface material over approximately three-fourths of the valley floors is silt and clay. The substrata, below a depth of 2½ feet, are mostly sands of various degrees of coarseness. Drainage ranges from very poor to good. The poorly drained areas are mainly old stream channels most of which are at or near the edge of the alluvial plain and next to the upland. Practically all of the valley floors are subject to occasional inundation.

A few terrace remnants border the flood plains. The most prominent, in the eastern part of Riverview Township, occupies part of secs. 5, 6, and 8, T. 152 N., R. 93 W., and secs. 29, 30, and 33, T. 153 N., R. 93 W. The terrace escarpment is abrupt, and the terrace plain is approximately 40 feet above the Missouri River bottom lands. The outer edge of this terrace is gravelly, but the inner part is composed of fine material, mainly silt and clay. The land is well drained, not



A, View of Farland silty clay loam with scoria buttes in the background. The trees border Bennie Pierre Creek. *B*, View of the Little Missouri River Valley near Lackey's ranch in the southwestern part of the county.

because of drainage channels but because of the coarse material composing the substrata. Another terrace, or bench remnant, that lies at approximately the same level is north of Charlson in T. 154 N., R. 95 W. It is not gravelly, but the substrata and some of the surface materials are sandy. Farther west, in secs. 33, 34, and 35, T. 154 N., R. 97 W., a third terrace remnant lies at an elevation of approximately 100 feet above the present valley floor of the Missouri River, and it is noticeably higher than the other two areas. With the exception of a few insufficiently drained areas, the soils on the terrace remnants are mature, and the heavier soils are well adapted to crops. All the soils of the valley floors of the Missouri and Yellowstone Rivers are immature, and the better drained soils are well adapted to crop production.

The valley of the Little Missouri River ranges from approximately ½ to 1 mile wide. The valley walls are more abrupt (pl. 3, *B*) than are those of the Missouri River Valley, and the stream gradient is greater than that of the Missouri River. There is no terrace land along this valley, but numerous alluvial fans, composed principally of sand and clay, extend out onto the valley floor from tributary valleys. Although some are adapted to tillage, most of the valley soils are better suited to grazing. The tillable parts are valuable for the production of forage crops as well as for grazing.

This county, as a whole, has a fairly good water supply. The most unsatisfactory supply is in those rough areas where springs are few or lacking, and streams with permanent water holes or continuous water flow are too far distant to be used by livestock. The area most destitute of water probably is the western part of T. 149 N., R. 96 W., which has no springs and is too far from the Little Missouri River to benefit from that source of water. In some areas, especially in the Little Missouri Badlands, the lack of water detracts from the value of the land for grazing.

Throughout the smoother parts of the county, sufficient water for farm use generally can be obtained by drilling wells from 50 to 150 feet deep, but the water differs widely in salt content and hardness. Water from some sources is too salty to be used, whereas that from other sources is surprisingly free of salt. A reliable and ample supply of water can be obtained throughout the valleys of the Missouri, Yellowstone, and Little Missouri Rivers from artesian wells, which average about 700 feet deep.

The Missouri, Yellowstone, and Little Missouri Rivers are the only streams having a continuous flow, although many of the creeks have permanent water holes and during favorable years maintain a constant flow. Although springs are not scarce, only a few have a heavy flow of water. Probably the largest are those south of Schafer in sec. 23, T. 150 N., R. 98 W.; at Alexander in sec. 5, T. 150 N., R. 101 W.; and in Randolph Township in sec. 29, T. 150 N., R. 102 W. Many small springs and seepage spots, when properly improved and protected, are capable of supplying the needs of 12 to 40 head of livestock. The sources of many of these springs are in lignite beds, and although the water has an unpleasant odor and taste, it seems to have no injurious properties. Brown colloidal materials from the lignite beds cause a brown color. The water from some seeps and springs is too salty to be used. The largest area containing such springs is in

sec. 21, T. 151 N., R. 98 W. (Tobacco Garden Township). This area occupies approximately 160 acres and slopes gently from the adjoining upland to the alluvial flat. It is perpetually wet and contains numerous mud-filled seep holes from which water slowly discharges. Salt has accumulated, especially in the proximity of the water holes, and very little vegetation grows within the area. Most of the other seepage areas occupy only a few square rods.

The lignite beds, which occur in the Fort Union geologic formation, are the source of a bountiful supply of fuel for local consumption. The mines, nearly all of which are open pits, are scattered throughout the county. Practically no lignite is mined for shipment to outside markets.

The county was organized in 1905, and Schafer was made the county seat. The Federal census for 1930 gives the total population as 9,709, all classed as rural. The average density of population in that year was 3.4 persons a square mile. The population is most dense in the vicinities of Alexander, Arnegard, Watford City, and Fairview. The most sparsely settled section is the Little Missouri Badlands, where the density of population is less than 1 person a square mile.

People of Scandinavian descent predominate among the foreign-born population in most sections. A few Russians and Czechs live in the vicinity of Grassy Butte, and German, English, Scotch, and Irish people are distributed throughout the county. The Federal census for 1930 gives the following figures for the foreign-born population, including the native-born with foreign or mixed parentage: Scandinavian, 3,505; German, 493; English, Irish, and Scotch, 293; Russian, 291; Czechoslovakian, 124; Canadian, 372. According to the same authority, the total number of foreign-born people was 1,471.

The county is fairly well supplied with marketing and trading facilities, although several sections are more than 30 miles from a trading and shipping point. The principal outlet for farm produce is over the Watford City branch of the Great Northern Railway, and all towns along this line have shipping facilities. Sanish, in Mountrail County, furnishes an outlet for the northeastern part over the Minneapolis, St. Paul & Sault Ste. Marie Railway; Killdeer, in Dunn County, served by the Northern Pacific Railway, affords an outlet for the southeastern part; and Beach, in Golden Valley County, and Sidney, Mont., afford shipping accommodations for the southwestern part. In addition, considerable freight shipments are carried by motortrucks.

Road conditions are fair. Two State highways and United States Highway No. 85 are well graded and maintained. Two of these highways cross the county from north to south, and one from east to west. Parts of them are surfaced with all-weather material. Those parts of the county devoted to farming are well supplied with graded roads, and some road improvement has been undertaken in the grazing sections.

School facilities are fairly good except in the sparsely settled sections.

CLIMATE

The climate of McKenzie County is typically semiarid and continental. It is characterized by long cold winters and short warm

summers. The data from the records of the United States Weather Bureau station at Watford City are fairly representative of climatic conditions throughout the county. These data are given in table 1.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Watford City, McKenzie County, N. Dak.*[1]

[Elevation, 2,084 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1934)	Total amount for the wettest year (1912)	Snow, average depth
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
December	13.0	56	−33	0.54	0.42	0.15	6.1
January	9.0	55	−45	.47	.33	.40	5.4
February	13.9	59	−44	.42	.05	(2)	4.1
Winter	12.0	59	−45	1.43	.80	.55	15.6
March	25.3	71	−32	.68	.40	.46	6.4
April	41.1	92	−9	1.16	.50	4.30	4.0
May	52.7	103	18	1.97	.28	5.79	1.5
Spring	39.7	103	−32	3.81	1.18	10.55	11.9
June	61.7	110	19	3.20	1.90	1.78	.0
July	69.3	112	32	1.83	1.52	2.33	.0
August	67.3	108	29	1.71	.56	2.87	.0
Summer	66.1	112	19	6.74	3.98	6.98	.0
September	56.3	103	10	1.32	.13	2.23	.2
October	42.9	90	−7	.87	.02	3.45	2.7
November	28.3	70	−22	.50	.03	.12	4.6
Fall	42.5	103	−22	2.69	.18	5.80	7.5
Year	40.1	112	−45	14.67	6.14	23.88	35.0

[1] The station was located at Arnegard prior to 1936.
[2] Trace.

The annual precipitation varies considerably from a mean of 14.67 inches, which is equal to about 75 percent of the mean precipitation at Fargo, N. Dak. Hot, dry winds from the south or southwest occasionally damage crops considerably during June or July. Temperatures as high as 112° and as low as −45° F. have been recorded. Such extremes are usually of short duration, although occasionally during the winter low temperatures may continue for several days. Summer days are long, warm, usually windy, and only rarely cloudy, but generally the nights are cool.

In winter the days are short and cold, although occasionally short periods of rather high temperature prevail. A temperature of 59° F. has been recorded during February. The spring season usually is short and erratic. From April 1 to September 30, the precipitation is nearly 11 inches, or about 70 percent of the mean annual amount; and almost half of the mean annual rainfall occurs during May, June, and July. The rainfall during this important growing period, however, varies considerably from one season to another. Seasons of severe drought are common.

The average frost-free season extends from May 17, the average date of the latest killing frost, to September 21, the average date of

the earliest, a period of 127 days. It is about the same at Fargo. Killing frosts have occurred as late as June 16 and as early as August 29. During the fairly long frost-free season the hours of sunshine reach a maximum in this section.

During the late spring and early summer, duststorms are a potential menace to crops. Cultivated fields are particularly susceptible to soil blowing when a comparatively dry period and strong winds come before the seedling plants are firmly established. Under such conditions, grain and potato seedlings may be destroyed and valuable surface soil removed. As more of the rolling and sandy land is cultivated and the coarser organic matter of the soil becomes depleted, the problem of soil blowing becomes more serious. Cultural practices, including less plowing and greater use of such tools as the duckfoot cultivator, are being directed toward the development of a cloddy and trashy surface so that the soil will be less susceptible to blowing.

Local hailstorms, especially during the hot periods of June and July, frequently damage crops severely. The State furnishes excellent protection against this hazard, in the form of insurance at cost. Frequent periods of rain interspersed with hot days favor black stem rust of wheat, and rust-resistant varieties of wheat have been introduced.

Although the transition from winter to summer is fairly rapid and not altogether pleasant as compared with the long spring season of the more eastern States, the autumn usually is dry and pleasant. Nights become cooler during September. Winter comes on gradually, and generally the ground freezes before much snow falls. The snowfall is irregular, and during many years the ground remains practically bare of snow throughout the season.

Much of the rainfall during the summer comes as short severe thundershowers, when run-off, especially in the hillier sections, is pronounced. Within a few minutes empty stream beds may become raging torrents, which subside and disappear shortly after the shower is over. A large percentage of the total rainfall in the Badlands runs off the surface. The great differences in the amount of moisture that penetrates the ground are reflected in the character of the soil, the native vegetation, and the adaptability of the soils to the various cultivated plants.

The influence of the variable, uncertain climate on crops is influenced by the type of soil. During seasons of high rainfall, differences in soils are not so pronounced, but the best plant growth is obtained on the loams, silt loams, and silty clay loams. Even on the sloping soils there may be sufficient moisture for abundant plant growth. The heavy soils on nearly flat land may have too much water. In extremely dry years the greatest growth is on the sandy soils, because they allow all the water that falls to enter the soil, they favor deep and extended root development, and they hold only a very little water in forms unavailable to plants. Good growth during dry years may be expected also on the loams and silt loams with good internal drainage, situated in depressions, like the Arnegard soils, where they receive extra water from surrounding slopes. The heavy clay soils hold so much water in forms unavailable to plants that plant growth is limited on them in very dry years. The naturally dry slopes become even drier during periods of drought. Thus, the char-

acter of the soil may either alleviate or intensify the effects of a harsh, variable climate.

VEGETATION [5]

The native vegetation of McKenzie County consists of mixed tall and short grasses, the latter by far predominating. The most common species growing on the well-drained fertile loam soils are blue grama, niggerwool (a sedge), and green porcupinegrass. Western wheatgrass and blue grama are the most common species growing on the fertile clay and clay loam upland and alluvial soils outside of the Missouri and the Little Missouri River bottoms. The dominant species growing on the sandy soils are niggerwool and sandgrass, and grama is common where the soil is a sandy loam or loam. Soils that are at all salty invariably support a high proportion of saltgrass. Low salty areas, such as those along draws from seeps, support a growth of sedges, small reeds, and arrowgrass, which is poisonous to livestock. The thin or infertile areas of the uplands support a vegetal cover largely of little bluestem and niggerwool. Redtop and foxtail barley commonly grow along the edges of poorly drained spots, and big bluestem is dominant in many of the small draws. Other grasses of the upland fertile soils, which are less common but nevertheless important, are western needlegrass, side-oats grama, slender wheatgrass, northern reedgrass, junegrass, buffalo grass, threeawn, Kentucky bluegrass, and Sandberg bluegrass.

The native vegetation of the Missouri and Little Missouri River bottoms is deciduous forest, with many open areas occupied by brush or grass. Originally cottonwood trees, ranging from 16 to 24 inches in diameter, were the predominant forest growth, but at present only a few areas of the original forest remain. Most of the present forest cover consists of second-growth ash, elm, cottonwood, water willow, and diamond willow. Large areas are covered by a dense growth of brush, consisting of mixed saplings, hawthorn, dogwood, wild rose, buckbrush, and buffaloberry.

Small trees, principally ash, elm, boxelder, and quaking aspen, and brush occupy many of the drains and gulches of the upland. In a few sections, as in the northern part of T. 153 N., R. 95 W., and the southern part of T. 149 N., R. 95 W., oaks are the dominant trees. Throughout the rougher parts of the Little Missouri Badlands, western redcedar was the dominant virgin tree growth, and well-established stands occupy many of the gulches. but most of the redcedar of merchantable size has been removed. Throughout the outer edges of this badlands area, ash, elm, and aspen predominate in the small groves.

Brush is more widely distributed than trees throughout the upland, but very little other than sagebrush grows where not favored by a shallow draw or ravine. The most common species of shrub and brush growth throughout the upland parts of the county are buckbrush, juneberry, buffaloberry, silver berry, pin cherry, and choke-

[5] The plants mentioned throughout this publication were identified by H. C. Hanson, botanist at the North Dakota Agricultural Experiment Station when this survey was made. Information relative to their occurrence, use, relative values, and their correlation with the important soil groups was obtained as the result of numerous field inspections made with him. The common and botanical names were verified, so far as possible, by C. O. Erlanson, ecologist, Division of Plant Exploration and Introduction, Bureau of Plant Industry, U. S. Department of Agriculture.

cherry. Less common shrubs are rabbitbrush, bittersweet, three-lobed sumac, and red-osier dogwood. It is worthy of note that the stand of trees and brush on southern slopes is more scant than the forest and brush cover on the slopes facing north.

Two herbs of importance for their grazing value, which are common but not abundant, are winterfat and saltbush. Winterfat particularly is readily exterminated by overgrazing.

Gray sagebrush is the most widespread of the sagebrushes, and false tarragon, or green sagebrush, and pasture sagebrush are common and widespread. The presence of the latter species on grazing sites is an indication of overgrazing. Desert sagebrush is scattered throughout the Little Missouri Badlands but is scarce in other parts of the county. Cacti, especially ball cactus, pricklypear, and small pricklypear, grow throughout the county, the last named commonly along the edges of Solonetz (scabby) spots.

Two poisonous plants are included in the native vegetation. Locoweed grows on the well-drained upland loam and clay loam soils and is widely scattered over the county. Arrowgrass grows on moist salty clay areas, especially salty areas of undifferentiated alluvial clay, where it forms from 10 to 80 percent of the vegetal cover, but only occasionally are livestock injured by these plants.

GLOSSARY OF PLANT NAMES FOR McKENZIE COUNTY, N. DAK.

GRASSES

Scientific name	*Common name*
Agropyron pauciflorum (*A. tenerum*)	Slender wheatgrass.
Agropyron repens	Quackgrass.
Agropyron smithii	Bluestem, or western wheatgrass.
Agrostis alba	Redtop.
Andropogon furcatus	Bluejoint turkeyfoot, or big bluestem.
Andropogon hallii	Turkeyfoot, or sand bluestem.
Andropogon scoparius	Prairie beardgrass, or little bluestem.
Aristida longiseta	Red three-awn, or triple-awn grass.
Beckmannia syzigachne (*B. erucaeformis*).	American sloughgrass.
Bouteloua curtipendula	Side-oats grama.
Bouteloua gracilis	Blue grama.
Bromus inermis	Smooth brome.
Buchloe dactyloides (*Bulbilis dactyloides*).	Buffalo grass.
Calamagrostis inexpansa (*C. americana*).	Northern reedgrass.
Calamovilfa longifolia	Prairie sandgrass.
Distichlis stricta (*D. spicata*)	Desert saltgrass.
Elymus canadensis	Canada wild-rye.
Elymus macounii	Macoun wild-rye.
Hordeum jubatum	Foxtail barley, wild barley, or squirreltail.
Koeleria cristata	Junegrass.
Muhlenbergia cuspidata	Plains muhly.
Poa palustris	Fowl bluegrass, or false-redtop.
Poa pratensis	Kentucky bluegrass.
Poa secunda (*P. buckleyana*)	Sandberg bluegrass.
Puccinellia nuttalliana (*P. airoides*)	Nuttall or Zawadke's alkali-grass.
Spartina pectinata (*S. michauxiana*)	Prairie cordgrass.
Sporobolus cryptandrus	Sand dropseed.
Stipa comata	Needle-and-thread, western needlegrass, or green porcupinegrass.
Stipa spartea	Porcupinegrass.
Stipa viridula	Green needlegrass, or feathergrass.

TREES

Scientific name	*Common name*
Acer negundo	Boxelder.
Fraxinus lanceolata	Green ash.
Juniperus scopulorum	Colorado juniper, or western redcedar.
Populus deltoides	Cottonwood.
Populus tremuloides	Quaking aspen.
Prunus pennsylvanica	Pin cherry.
Prunus virginiana	Chokecherry.
Prunus sp	Wild plum.
Quercus macrocarpa	Mossycup or bur oak.
Salix interior	Water willow.
Salix missouriensis	Diamond willow.
Ulmus americana	Elm.

OTHER PLANTS

Achillea millefolium	Common yarrow.
Agoseris glauca	Prairie dandelion.
Ambrosia psilostachya	Perennial ragweed.
Amelanchier alnifolia	Common serviceberry, or juneberry.
Artemisia cana	Gray sagebrush.
Artemisia caudata (*A. canadensis*)	Green sagebrush.
Artemisia dracunculoides	False tarragon, or green sagebrush.
Artemisia frigida	Pasture sagebrush, or little sagebrush.
Artemisia gnaphalodes	Cudweed, or white sagebrush.
Artemisia tridentata	Big sagebrush, or desert sagebrush.
Asclepias speciosa	Showy milkweed.
Aster multiflorus	Wreath aster, or white Prairie aster.
Aster oblongifolius	Aromatic aster.
Aster ptarmicoides	White upland aster.
Astragalus pectinatus	Narrow-leaved milkvetch.
Atriplex nuttallii	Nuttall saltbush.
Campanula rotundifolia	Harebell, or bluebell.
Carex filifolia	Threadleaf sedge, or niggerwool.
Carex stenophylla	Upland sedge.
Cerastium arvense	Starry cerastium, or prairie chickweed.
Chrysopsis villosa	Hairy golden-aster.
Chrysothamnus graveolens	Rabbitbrush.
Cirsium undulatum	Prairie thistle.
Cornus stolonifera	Red-osier dogwood.
Coryphantha vivipara	Ball cactus.
Crataegus chrysocarpa	Hawthorn.
Delphinium bicolor	Low larkspur.
Delphinium virescens	Tall larkspur.
Echinacea angustifolia	Purple coneflower.
Elaeagnus argentea	Silverberry.
Eriogonum flavum	Yellow eriogonum.
Eurotia lanata	Winterfat.
Gaillardia aristata	Common perennial gaillardia.
Glycyrrhiza lepidota	Wild licorice.
Grindelia squarrosa	Curlycup gumweed.
Gutierrezia sarothrae	Broom snakeweed.
Iva axillaris	Poverty weed.
Juncus balticus	Wire rush.
Juncus spp	Rush (several species).
Juniperus communis depressa	Dwarf juniper.
Juniperus horizontalis	Creeping juniper, or creeping cedar.
Lactuca ludoviciana	Western wild lettuce.
Lactuca pulchella	Blue wild lettuce.
Lappula occidentalis	Low stickseed.
Lepachys columnaris	Long-headed coneflower.
Leparggyrea argentea	Silver buffaloberry.
Lepidium densiflorum	Peppergrass.
Liatris punctata	Gayfeather, or blazing-star.
Liatris scariosa	Gayfeather, or blazing-star.

OTHER PLANTS—Continued

Scientific name	*Common name*
Linum lewisii	Prairie flax, or Lewis wild flax.
Linum rigidum	Stiffstem flax, or wild yellow flax.
Lomatium daucifolium	Wild parsley.
Lotus americana	Birdsfoot deervetch, or prairie birdsfoot trefoil.
Lygodesmia juncea	Skeletonweed.
Malvastrum coccineum	False-mallow.
Mentha canadensis	Wild mint.
Mertensia lanceolata	Bluebell, or wild forget-not.
Monarda fistulosa	Wildbergamot.
Musineon divaricatum	
Oenothera serrulata	Tooth-leaved evening-primrose.
Opuntia fragilis	Small pricklypear.
Opuntia polyacantha	Pricklypear.
Oxytropis lambertii	Crazyweed, or locoweed.
Pentstemon albidus	White beardtongue.
Pentstemon cristatus	Crested beardtongue.
Pentstemon gracilis	Slender beardtongue.
Petalostemum oligophyllum	White prairie clover.
Petalostemum purpureum	Purple prairie clover.
Phlox hoodii	Moss phlox.
Plantago purshii	Woolly Indianwheat, or prairie plantain.
Potentilla strigosa	Prairie cinquefoil.
Psoralea argophylla	Silverleaf scurfpea.
Psoralea esculenta	Indian breadroot, Indian turnip, or tipsin.
Rhus rydbergii	Western poison-ivy.
Rhus trilobata	Lemonade sumac, or three-lobed sumac.
Rosa woodsii	Woods rose, or wild rose.
Salicornia herbacea	Glasswort.
Salsola tragus	Russian-thistle.
Selaginella densa	Little clubmoss.
Senecio perplexus	Ragwort.
Solanum triflorum	Cut-leaved nightshade.
Solidago canadensis	Canada goldenrod.
Solidago missouriensis	Early goldenrod.
Solidago nemoralis	Oldfield goldenrod.
Solidago mollis	Soft goldenrod.
Solidago rigida	Stiff goldenrod.
Steironema ciliatum	Fringed loosestrife.
Symphoricarpos occidentalis	Wolfberry or buckbrush.
Teucrium occidentale	Wood sage.
Thermopsis rhombifolia	False lupine.
Triglochin maritima	Arrowgrass.
Verbena bracteosa	Bracted vervain.
Vicia sparsifolia	Wild vetch.
Viola nuttallii	Nuttall violet.
Yucca glauca	Soapweed yucca, or beargrass.
Zigadenus chloranthus	Deathcamas.

AGRICULTURE

Rapid settlement of McKenzie County started shortly after 1900, most of the homesteading taking place between 1904 and 1910, when a large proportion of the settlers migrated from eastern North Dakota, Minnesota, Iowa, and Wisconsin. Before 1900 almost all of the land in what is now this county was used as cattle range. Homesteaders came into the county to grow cash grain crops, especially wheat, and the first areas settled were those best adapted to growing grain, such as the gently rolling plains in the vicinities of Alexander, Arnegard, Charlson, and Grassy Butte.

A one-crop system of farming is practiced on some of the farms located on the extensive areas of good tillable land, but most farmers practice some diversification, at least to the extent of growing other small grains in addition to wheat. When other small grains (flax, oats, and barley) are grown, they are rotated with the wheat.

In addition to growing a cash grain crop, many farmers raise either beef or dairy cattle. Beef cattle are placed on range land during the greater part of the year, and dairy cattle are grazed either on range land or on pasture land producing crops such as sweetclover, wild oats, slender wheatgrass, or small grains, especially rye. This pasture feed is supplemented during part of the year by feed grown on the farms. General or mixed farming is practiced most commonly in parts of the county where range land and tillable land are in fairly close proximity, the range land providing economical summer feed and the tillable land winter feed and acreage for cash crops.

Throughout the rougher parts of the county, raising cattle and horses is the principal agricultural activity, and the crops grown are practically all used as feed to supplement the range. Some of the best land available on the ranches is selected for corn and for permanent hay land with either wild or introduced grasses. The breeding animals and calves are generally kept at ranch headquarters and fed during the winter, but the remainder of the herd runs on the range throughout the year except when grass is too scarce or during severe weather, when cattle are unable to graze. Range areas rough enough to afford good protection from storms are used for winter grazing purposes. Ranchers attempt to prevent these areas from being grazed during the summer, in order to preserve the grass for winter feed. Most cattlemen have a supply of forage available for feeding winter range cattle when the weather is bad or when there is a shortage of grass. Livestock losses are large during long periods of severe winter weather when cattlemen have a scant supply of forage.

According to the United States census reports, the acreage of land in farms expanded rapidly from 277,857 acres in 1910 to 1,231,370 acres in 1920, contracted to 894,252 acres in 1924, and again expanded to 1,210,957 acres in 1930 and to 1,340,093 acres in 1935. There were 309,068 acres of cropland in 1924, 442,105 acres in 1929, and 446,190 acres in 1934. Cropland represented 34.6 percent of the total land in farms in 1924, pasture land 48.4 percent, woodland not pastured 1 percent, and other land 16 percent. Comparable proportions of farm land in 1929 were 36.5 percent in cropland, 48.1 percent in pasture land, 0.5 percent in woodland not pastured, and 14.9 percent in other land. In 1934, 33.3 percent of the total land in farms was in cropland, 62.3 percent in pasture land, 0.4 percent in woodland not pastured, and 4 percent in other land Wheat occupied 41.8 percent of the total cropland in 1924 and 48.9 percent in 1929, based on the harvested acreages of wheat. The proportion of the cropland devoted to oats grown for grain was 9.9 percent in 1924 but declined to 2.9 percent in 1929. This decline in the acreage in oats is correlated with a more general use of mechanical power on the farms. Altogether, small grains occupied two-thirds of the total cropland in 1924 and 66.2 percent in 1929. Owing to drought, acreages of small grains in 1934 are not significant in tracing the trend of agriculture.

Actual acreages of the principal crops, as reported by the Federal census for the years 1909, 1919, 1924, 1929, and 1934, are given in table 2.

TABLE 2.—*Acreages of principal crops in McKenzie County, N. Dak., in stated years*

Crop	1909	1919	1924	1929	[1] 1934
	Acres	*Acres*	*Acres*	*Acres*	*Acres*
Wheat	25,613	99,841	129,060	216,317	31,921
Oats:					
Threshed	18,244	9,124	30,698	12,677	1,659
Cut and fed unthreshed			2,785	3,289	361
Barley	1,093	1,607	4,607	18,997	1,526
Rye	1	20,806	9,980	7,023	128
Flaxseed	12,696	6,457	23,995	29,820	581
Corn			14,152	4,284	11,577
For grain	1,343	496	1,631	518	106
For other purposes		[2] 2,202	12,521	3,766	11,471
Dry beans	2	18	511	702	413
Dry peas				273	43
Potatoes	456	804	690	1,469	1,609
Sugar beets			1,389	1,394	3,639
Hay	38,383	104,836	61,132	57,658	86,406
Alfalfa	322	9,906	9,283	7,598	1,184
Sweetclover			2,969	6,010	1,711
Grains cut green	996	40,017	13,691	14,710	13,480
Other tame hay	1,700	6,808	7,265	3,225	69,483
Wild hay	35,365	48,105	27,924	26,115	[3]

[1] Year of drought.
[2] Cut for forage only.
[3] Included with other tame hay.

A more accurate study of the trends in acreage of the different crops in the county is available through examining the annual reports of the Division of Crops and Livestock Estimates, Bureau of Agricultural Economics (now the Division of Agricultural Statistics, Agricultural Marketing Service), United States Department of Agriculture, from 1919 to 1933, inclusive. All these data are based on harvested acreages. During the period 1919–33, the harvested acreage of wheat rose from 51.3 percent of the total harvested acreage of all crops, including wheat, rye, flax, potatoes, corn, oats, barley, and tame hay, to 70.4 percent in 1933. There was a general trend upward in the percentage of land devoted to wheat as measured by the harvested acreages. The only exception to this was in the drought year of 1931, when, because of the drought, only a small proportion of the cropland was harvested. During approximately the same period, the percentage of land devoted to oats declined from a peak of 17.5 percent in 1921 to 6.2 percent in 1933. During the period 1919–33 there was a general downward trend of the percentage of land devoted to rye and a general upward trend of the percentage of land devoted to barley. The acreages of corn have not varied much from year to year. The percentage of land in flax has been highly variable. The percentage of land devoted to potatoes exceeded 1 percent in 1 year only, namely, 1922. Nevertheless, potatoes are a very important source of cash income in this county.

The toll taken by drought in the years 1931, 1934, 1936, and 1937 and by a black stem rust in 1935 can readily be seen from table 3.

TABLE 3.—*Acreages of the principal crops planted and harvested in McKenzie County, N. Dak., 1929–37* [1]

Crop	1929		1930		1931		1932		1933		1934		1935		1936		1937	
	Planted acres	*Harvested acres*	*Planted acres*	*Harvested acres*	*Planted acres*	*Harfested acres*	*Planted acres*	*Harvested acres*	*Planted acres*	*Harvested acres*	*Planted acres*	*Harvested acres*	*Planted acres*	*Harvested acres*	*Planted acres*	*Harvested acres*	*Planted acres*	*Harvested acres*
Corn	4,000	4,000	4,000	4,000	12,000	9,000	15,000	15,000	14,000	12,000	19,000	14,000	20,000	20,000	19,000	12,000	(2)	(2)
Durum wheat	8,000	5,000	4,000	4,000	2,000	(3)	4,000	4,000	3,000	2,000	1,000	(3)	3,000	2,000	3,000	(3)	3,000	(3)
Other spring wheat	237,000	221,000	226,000	223,000	222,000	11,000	231,000	229,000	242,000	238,000	195,000	44,000	249,000	199,000	245,000	17,000	214,000	9,000
Oats	20,000	17,000	20,000	17,000	20,000	3,000	36,000	34,000	22,000	21,000	27,000	2,000	37,000	34,000	37,000	3,000	(2)	(2)
Barley	21,000	19,000	20,000	18,000	26,000	3,000	25,000	24,000	22,000	18,000	18,000	2,000	23,000	21,000	20,000	2,000	(2)	(2)
Rye	(2)	7,000	(2)	8,000	8,000	1,000	5,000	3,000	2,000	1,000	5,000	(3)	4,000	3,000	6,000	(3)	(2)	(2)
Flax	34,000	32,000	52,000	37,000	30,000	2,000	30,000	23,000	21,000	15,000	7,000	1,000	25,000	22,000	17,000	(3)	(2)	(2)
Potatoes	1,600	1,500	1,600	1,300	1,400	500	2,200	1,800	2,200	1,900	2,100	1,600	1,900	1,800	2,300	1,300	(2)	(2)
Sugar beets	(2)	(2)	(2)	(2)	(2)	(3)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	3,915	(3)	3,220	3,125

[1] From North Dakota Crop Statistics by Counties, 1922-36, Bureau of Agricultural Economics, Office of the Agricultural Statistician, Fargo, N. Dak., May 1938 [Mimeographed.]

[2] No data given.

[3] Crop failure.

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Both fall and spring tillage are practiced in preparing land for crops. The heavier soils, such as clay loams, silty clay loams, and clays, are generally plowed in the fall so that freezing and thawing will improve the tilth, but the coarse-textured soils are generally plowed in the spring, although on some loam and sandy loam soils, grain is drilled in with no preparation of the seedbed. According to the Federal census, approximately 15 percent of the acreage in crops is summer-fallowed, and it is common practice to summer-fallow ground for 1 year out of 3 or 4. According to this policy, approximately 45 percent of the land in crops is farmed under a system including summer fallowing and 55 percent is farmed under a continuous-crop system.

Owing to the common use of moldboard plows, a plow sole has developed in many areas of the brown friable loam soils, especially Morton loam. This layer, which is about 3 inches thick, is about 5 inches below the surface and is characterized by a firm hard structure. When a spade is thrust into the soil, the material composing this hardened layer offers considerable resistance, and it comes out in comparatively large firm blocks, a condition very different from that in the normal virgin soils. This hardened layer interferes with normal root growth and the movement of soil moisture and may necessitate a change in tillage practices, in order to destroy it and prevent its further development.

Practically all seeding of small grains is done with a drill. Planting begins about April 1 and continues until after June 10. Wheat is the first crop sown and is followed by oats, barley, flax, and corn in the order given. Rye is the only crop sown in the fall, as very little winter wheat has been grown in McKenzie County. Most of the small grain is cut by tractor- or horse-drawn binders, and the greater part of the grain is threshed from the shock, although the use of combines is increasing on the smoother areas. Harvesting begins in the latter part of July and is completed about September 15, most of the wheat crop being cut during the latter part of August.

No definite system of rotation is practiced, and wheat may be grown on the same land for many years in succession, but part of the ground is summer-fallowed when cropped in this way. Where a system of general farming is followed, two or three cropping systems may be used. Part of the land may be rotated to a cultivated crop (corn or potatoes), wheat, and hay. This rotation may extend over 3 or 4 years; in fact, the hay-producing land generally is left as such as long as it yields fair crops. Summer fallowing is seldom practiced where a cultivated crop is included in the rotation. Any available manure is generally applied to the fields being farmed under a rotation of this sort, and as a rule it is applied to either the wheat or the corn. Inasmuch as only a small acreage is devoted to cultivated crops and tame hay, a different cropping system must be used on the rest of the tilled land. A grain rotation of wheat, oats, or barley followed by summer fallowing, is frequently practiced. Because flax cannot compete successfully with weeds, it generally follows a cultivated crop or summer fallow, and it also is usually the first crop grown when the land is broken for the first time.

The primary object of summer fallowing is to destroy weeds, and it is generally done either with moldboard plows or duckfoot culti-

vators. The ground is cultivated two or three times during the season, depending on the weed growth and the time at the disposal of the operator. The fallowed ground is left as rough or cloddy as possible, in order to minimize soil blowing, as the coarser textured soils, such as the very fine sandy loams, sandy loams, sands, and some silt loams, are especially susceptible to blowing. Areas having a bumpy or rolling surface are also particularly subject to soil blowing when summer-fallowed.

Wheat, the most important crop, ordinarily occupies almost one-half of the total cropland. The Division of Agricultural Statistics, Agricultural Marketing Service, United States Department of Agriculture, has made estimates of the wheat yields on the harvested acreage in McKenzie County since 1911. During the 26-year period 1911–36, the average yield per harvested acre was 9.9 bushels. Yields reached or exceeded 10 bushels an acre in 12 of the 26 years. Yields of 7.5 bushels or less were obtained in 11 of the 26 years. Relatively low yields were obtained between 1916 and 1920 and again between 1933 and 1936. The yield of wheat was also low in 1911. Black stem rust did serious damage in 1935, but all other low yields were due primarily to deficient seasonal precipitation plus above-normal seasonal temperatures. During the 10 years when yields were 7.5 bushels or less to the acre, the average maximum temperatures were above the 26-year average (1911–36) five times for May, five times for June, and eight times for July, and the average precipitation was below the 26-year average (1911–36) six times for May, seven times for June, and seven times for July. Wheat is grown primarily as a cash crop and is marketed through both independent and cooperative agencies. Grain elevators belonging to these agencies are located at all railroad shipping points.

Hard red spring wheats, including such varieties as Marquis, Ceres, and the more recently introduced Thatcher, are grown. The North Dakota Agricultural Experiment Station has conducted continuous comparative trials on a number of these hard red spring wheats at the Dickinson substation, in Stark County. During the period 1930–37, inclusive, 2 years—1935 and 1937—were years in which black stem rust did serious damage to susceptible varieties of wheat throughout the State. In these 2 years, Marquis returned an average yield at Dickinson of 8.9 bushels an acre, Ceres 11.3 bushels, Reward 9.4 bushels, and Thatcher 11.6 bushels, whereas Red Fife, the old standard hard red spring wheat of earlier years, returned only 4.6 bushels. The average test weight per bushel of the harvested crop at Dickinson for the several varieties in these 2 years was as follows: Red Fife 52.1 pounds, Marquis 54.5 pounds, Ceres 56.1 pounds, Reward 58 pounds, and Thatcher 55.5 pounds. During the years 1930–34, when wheat was not affected by the rust, Red Fife yielded 10 bushels an acre, Marquis 10.4 bushels, Ceres 12.6 bushels, Reward 9.7 bushels, and Thatcher 10.5 bushels. Average weights per bushel of the varieties for the 4 years excluding 1935 were as follows: Red Fife 55.6 pounds, Marquis 57.3 pounds, Ceres 57.5 pounds, Reward 58.9 pounds, and Thatcher 56.4 pounds.[6]

[6] STOA, T. E. THATCHER WHEAT. N. Dak. Agr. Expt. Sta. Agron. Cir. 64, 6 pp. 1937. [Mimeographed.]

Very small acreages are devoted to durum wheats. Consequently, some reference to comparative yields of durums and hard red spring wheats, where tests are made under comparable conditions, should be of interest. During the period 1923–37, inclusive, excluding 1936 because of total crop failure, the following comparable yields were obtained at the Dickinson substation: Durum wheats—Kubanka 14.5 bushels an acre, Mindum 13.1 bushels, and Pentad Red Durum, or D–5, 14.5 bushels; hard red spring wheats—Marquis 13.3 bushels, Ceres 15.9 bushels, Red Fife 12.2 bushels, and Haynes Bluestem 11.9 bushels.[7]

Flax grown for grain generally ranks next to wheat in acreage, being grown on 6.7 percent of the total cropland in 1929, according to the United States census. From 1911 to 1933, according to data from the Division of Agricultural Statistics, the yield ranged from a low of 2.1 bushels per acre to a high of 14.2 bushels. Flax yields were 5 bushels or less in 10 of the 23 years. Low yields of flax, like low yields of wheat, occur in years of abnormally low precipitation and abnormally high temperatures. Wilt-resistant varieties must be grown. Average acre yields of wilt-resistant varieties of flax at the Dickinson substation over the period 1928–39, inclusive (excluding 1934 and 1936 because of total failure, owing to drought, and 1938, owing to damage from grasshoppers), were as follows: Bison 4.4 bushels, Buda 3.2 bushels, Linota 3.9 bushels, N. D. R. 114 3.5 bushels, Redwing 4.1 bushels, and Rio (L–79) 4.3 bushels. Over the same period (excluding 1934 and 1936 because of crop failure, owing to drought) average acre yields at the Northern Great Plains Field Station, Mandan, N. Dak., were as follows: Bison 5.7 bushels, Buda 4.8 bushels, Linota 5.1 bushels, Redwing 4.7 bushels, and Rio (L–79) 5.2 bushels.[8] Flax generally is grown on land that produced an intertilled crop or was summer-fallowed the previous year. Flax fits in well with wheat farming because it is both sown and harvested a little later than wheat. The greatest difficulty experienced in growing flax is the control of weeds, especially Russian-thistle, in the drier seasons. Soil blowing on some soils causes serious damage during the early part of the growth period because of the lack of foliage and roots to protect the surface soil.

The production of potatoes has increased in recent years. Although the acreage is small, because the varieties grown are primarily for seed purposes and for export to the southern seed trade, this crop is an important source of farm income. An early strain of Triumph is produced for the southern market. Potatoes are grown throughout the county for home use, and they are grown commercially in the vicinity of Arnegard, and to less extent on the irrigated soils in the vicinity of Fairview. Potatoes are generally grown as a part of the general farming scheme in rotation with grain and hay crops. Yields under dry farming range from 30 to 125 bushels an acre, but larger yields are obtained under irrigation. Where grown commercially, this crop usually occupies about 10 acres of the farm. Most of the crop is planted and harvested by machinery and marketed cooperatively. Commercial fertilizer is not commonly used.

[7] STOA, T. E., and others. YIELDS FROM SMALL GRAIN VARIETY TESTS. N. Dak. Agr. Expt. Sta. Agron. Cir. 66, 32 pp. 1937. [Mimeographed.]

[8] STOA, T. E., and others. YIELDS FROM SMALL GRAIN VARIETY TRIALS IN NORTH DAKOTA. N. Dak. Agr. Expt. Sta. Agron. Cir. 70, 30 pp. 1939. [Mimeographed.]

Sugar beets rank third in the total acreage of cash crops. According to the Federal census, the average yield for 1929 was 10.8 tons an acre. This crop is grown on the irrigated soils of the Yellowstone River Valley. The beets are marketed at Sidney, Mont., where a beet-sugar refinery is located. According to the United States Department of Agriculture Yearbook for 1932, the percentage of sucrose of the beets grown in this county ranges from 14.8 to 17.2 percent. Most of the sugar beets are grown as a cash crop by farmers practicing general farming. The crop is rotated with grain and hay, and from 100 to 125 pounds of 45-percent phosphate fertilizer is applied at the time of sowing. Some beets are grown as a special crop independent of other farming activities. In past years Mexican labor has been utilized in the beet fields, but during recent years much of the labor has come from local sources.

During the last 15 years the acreage in rye has steadily declined, so that rye now occupies a relatively unimportant place in the agriculture of the county. In 1919 rye occupied 9.2 percent of the harvested crop acreage. By 1932 it had declined to 1.4 percent of the harvested acreage. During the period 1911–33, inclusive, yields ranged from a total failure to a high of 17½ bushels an acre. Yields were less than 10 bushels an acre in 13 of the 23 years, according to data from the Division of Agricultural Statistics. Rye is sown in the fall and is frequently used for grazing in early spring. Occasionally the entire crop is grazed rather than being allowed to mature as a grain crop.

Barley is an important feed crop (*9*). During the last 15 years there has been a rather marked increase in the relative proportion of land devoted to barley. Some of this increase, however, is probably due to a direct substitution of barley for wheat as a cash crop. Yields of barley during the period 1911–33, inclusive, ranged from a low of 2 bushels to the acre to a high of 36.2 bushels. Yields were less than 15 bushels per acre in 10 of the 23 years. Usually barley follows wheat or oats in the small-grain rotation. Barley fits in well with the small-grain enterprise, because it is ready for early harvest and also can be seeded relatively late, although yields are better if the crop is seeded early. Barley is extensively used as a feed grain for hogs, cattle, and poultry.

The production of oats has declined steadily during the last 15 years, owing largely to the introduction of mechanical power and curtailment of yields during drought years. During the period 1911–33, inclusive, according to data from the Division of Agricultural Statistics, yields of oats in McKenzie County ranged from a low of 2½ bushels an acre to a high of 51.2 bushels. Yields have been less than 20 bushels an acre in 11 of the 23 years of the period. Oats are sown after wheat and usually are harvested at about the same time. A considerable proportion of the oats acreage is used as a supplementary hay crop or is cut when ripe and fed unthreshed. Much of the oat straw is cut as roughage for cattle and horses. The crop is grown primarily as a feed crop.

Although the acreage in corn varies greatly, the trend is upward. Yields of corn, according to data from the Division of Agricultural Statistics, ranged during the period 1911–33, inclusive, from almost total failure to 31.7 bushels an acre. Yields were less than 20 bushels

an acre in 10 of the 23 years. The production of corn tends to add stability to farming. This has been especially true during the series of hot dry years, such as those during the last decade.

The most common practice is to cut and shock the corn when it has reached a fair stage of maturity and afterwards feed it to livestock from the shock as mixed grain and forage. Another common practice is to husk the corn for grain feed and either cut the fodder and stack it or turn cattle into the field to graze on the standing forage. A small quantity of corn, mainly that grown on the irrigated area in the vicinity of Fairview, is placed in silos. According to the 1930 Federal census, 10 farms reported harvesting corn for silage in 1929. Most of the corn forage and silage is fed to horses and cattle, and the grain is used as feed for practically all kinds of livestock.

Corn is planted from about May 10 to June 15 and is harvested in September. Early-maturing (110-day) varieties are used almost entirely. Falconer Semi-dent is the most common variety, the stalks of which are short, but the yield of grain is comparatively high. A small acreage is devoted to flint varieties and varieties especially suitable for fodder. A variety of corn, locally called Four X, is the principal variety grown for fodder. Falconer Semi-dent and Wisconsin 25 are varieties commonly grown on the irrigated soils.

Corn is a desirable crop to rotate with hay and small-grain crops. It is planted later than the small grains, its harvesting is not so urgent as that of most of the small grains, and its cultivation keeps the ground free from weeds. Many farmers state that it is more profitable to use a corn and grain rotation than to use a summer-fallow and grain rotation. Corn is planted with machine planters and harvested by both machine and hand methods (*9*).

Some emmer is grown for grain feed. It yields less than oats or barley but has the advantage of greater resistance to drought and rust and consequently greater certainty of producing at least a fair yield. Emmer can be sown later in the season than either oats or barley and consequently serves as a supplementary grain crop. The total acreage, although small, varies considerably from year to year.

A larger area was devoted to hay in 1934 than in 1909, although it was not so large as in 1919. In 1909, however, hay occupied 39 percent of the cropland, whereas in 1934 it occupied about 20 percent. Formerly almost all of the hay was cut from the wild-hay land, but at present less than half the hay is so-called wild hay. Grains cut for hay, alfalfa, and sweetclover are the principal tame-hay crops. In 1929, 72 farms reported a total of 1,755 acres of sweetclover pasture. Most of the alfalfa and sweetclover are grown by farmers who practice mixed or general farming, although some ranchers have attempted to develop alfalfa and sweetclover meadows. These crops are the most desirable types of forage for both dairy and beef cattle.

Both alfalfa and sweetclover are seeded with small-grain nurse crops and are not grazed or cut the first year. It is probable that stands of these two crops would be established more successfully, especially on the upland soils, if they were seeded without a nurse crop on land freed from weeds by summer fallowing or by the clean cultivation of a crop. As sweetclover is primarily a biennial plant, it yields for but one full season. Frequently two crops are harvested a year, or the second crop may be grazed. If some seed is allowed to

mature each year, this crop will practically perpetuate itself by reseeding, provided moisture conditions are suitable. If seed is desired for harvesting, the second crop is used for this purpose. Two varieties, yellow and white, are grown. The former is preferred, principally because of its greater palatability, but also because it is better adapted to grazing, as cattle are able to eat practically all of the plant. Undoubtedly it is the most desirable crop grown for tame-grass pasture. Its nutritive value is high, and it is palatable to cattle after they become accustomed to it. It produces green foliage more persistently through dry periods than any other grazing crop.

Alfalfa is probably the most desirable hay crop grown, but it has a higher water requirement than sweetclover, and great care must be taken in the choice of areas on which it is to be grown. The largest acreage is on the irrigated lands in the vicinity of Fairview. It is also grown to some extent on the nonirrigated soils of the Missouri River Valley. The acreage devoted to alfalfa under dry-farming methods is distributed over the northern part of the county, especially along streams and in other fertile well-drained lowland areas. A few fields are on the more fertile upland soils where the land does not lose part of its rainfall through run-off. Alfalfa fields generally are maintained as long as they produce profitable yields. Some farmers harrow their fields every few years to control the encroachment of grass and to split the alfalfa crowns, thereby increasing stalk production. Alfalfa fields that have produced for more than 10 years are not uncommon in areas having the most favorable water supply. This crop is more difficult to establish than is sweetclover, and occasionally it is killed by freezing and thawing. Under dry-farming methods, sweetclover appears to do better than alfalfa on most of the soils. Acre yields of sweetclover average about 1 ton. Alfalfa produces about 1.5 tons on the average and, on irrigated land, from 2 to 4 tons. Phosphate fertilizer having a 45-percent phosphoric acid content is commonly applied at the time of seeding alfalfa, at the rate of 100 to 125 pounds an acre. Grimm is the most common of the several varieties grown.

The 1930 Federal census reports 768 bushels of alfalfa seed from 284 acres and 836 bushels of clover seed (practically all sweetclover) from 391 acres in 1929.

Other crops used for tame hay are the small grains, particularly oats and millet, cowpeas, and soybeans. Volunteer wild oats and Russian-thistle are commonly cut for hay. In some localities wild oats grow readily on idle fields where the seed has at some time been distributed. Russian-thistle, although ordinarily considered a weed, affords an important source of forage in years when moisture is too scarce to develop other crops for hay. The thistles spring up in fields seeded to crops and, during dry years, generally develop a fair stand of vegetation, which is cut for hay about midsummer. Summer seasons must be extremely dry to prevent at least a fair growth of this volunteer weed, and during seasons with sufficient moisture to develop the seeded crops, the thistles are thoroughly suppressed.

Small grains are commonly grown for hay and are of special value when other crops fail. During dry years it is more profitable to cut the small grain for hay than to leave it for a scant grain crop. When sowing small grain for hay, oats or wheat and oats mixed are pre-

ferred. Millet is a desirable annual grass for hay, as it grows rapidly and ordinarily yields well. It is sown in late spring and is cut some time between the latter part of August and the latter part of September. Siberian and German millets are the two common varieties. According to farmers, the yield of millet averages a little more than 1 ton an acre on such soils as Bainville loam.

Crested wheatgrass (*Agropyron cristatum*) is recommended as a forage crop for the western part of North Dakota. It produces good yields and appears to be less subject to injury from drought than are many other grasses. It is also desirable because of its ability to establish itself permanently.

The acreage devoted to wild hay has diminished considerably since 1919. The grass mixture of this hay varies considerably. The most desirable wild hay is cut from a pure stand of western wheatgrass, but very little of this type of meadow remains in the county. It grows most commonly on well-drained alluvial clay loam soils. A mixture of western wheatgrass, western needlegrass, blue grama, and junegrass is more common and makes desirable hay if cut after the needles have fallen from the needlegrass. Blue grama furnishes but a very small part of the hay crop, as only the seedstalks are high enough to be cut by a mower. This grass mixture grows on heavy loams of the uplands. A common mixture that grows on the coarser textured soils (sandy loams and sands) includes western needlegrass, junegrass, grama, and two upland sedges. Although the grama and sedges comprise a large percentage of the cover, they yield but a small part of the hay because they are short. Undesirable grasses, generally growing in patches in meadows, are sandgrass and little bluestem, the latter growing on the more exposed or barren spots. Most farmers do not cut meadows of this type more than once every 2 or 3 years. The grass is clipped as close to the ground as possible and collected with a buncher attached to the mower. Wild hay is cut in the fall after it has matured. Generally it is stacked either in the meadow or in a place convenient for winter feeding.

The grasses here discussed as the important meadow grasses are likewise the important grazing grasses. Blue grama is of little value as a hay crop, but in many ways it equals or even surpasses western wheatgrass for grazing. The most desirable natural grazing cover is a mixture of western wheatgrass and blue grama. Side-oats grama, buffalo grass, junegrass, reedgrass, and Kentucky bluegrass are also good grazing grasses, but they are less common than blue grama. The needlegrasses are valuable, but they are objectionable, especially to sheep, during the period when the needles are mature but have not yet dropped from the seedstalks. Although the upland sedges are less palatable than the above-mentioned grasses, they are important as pasture forage because they grow on sandier soils than do the other species. Other important but less common grazing grasses and shrubs are big bluestem, Sandberg bluegrass, quackgrass, winterfat, and saltbush. The most common grasses having little or no grazing value are little bluestem, sandgrass, plains muhly, foxtail barley, and three-awn.

The natural stands of grass are radically altered by overgrazing and tillage. These changes are nearly always detrimental to the quality and carrying capacity of the range, as many of the grasses, when destroyed, are very hard to reestablish. Tillage, for example, even

though practiced for only 1 year, destroys the grama and buffalo grasses. Western wheatgrass and quackgrass, however, reestablish themselves after tillage, provided it is not continued for several consecutive years.

Overgrazing is particularly injurious to western wheatgrass, and much of it has been eradicated by this practice. As blue grama can stand considerable overgrazing, areas once occupied almost entirely by western wheatgrass now are occupied almost wholly by blue grama. Most of the injurious grazing of western wheatgrass is done by cattle and horses, as sheep prefer most other grasses and even some weeds. Excessive and continuous overgrazing of blue grama, especially by sheep, will injure the stand severely. The grass is then replaced by weeds and pasture sage. Ruthless overgrazing can destroy the well-established sod to such an extent that the soil is exposed to ruinous wind and water erosion. Grazing should be intelligently supervised and so regulated as to avoid destroying the virgin or natural grass cover.

The large areas of rough broken land, on which there is still a high proportion of native-grass vegetation, make the grazing of beef cattle an important livestock enterprise. The numbers of livestock have fluctuated widely, being seriously depleted in the severe drought years and built up again during periods of greater rainfall. Recently, grazing associations have been organized to control the maintenance of a good grazing cover.

A total of 39,075 head of cattle was reported on farms on January 1, 1935, which was a greater number than any reported since 1920. The raising of beef cattle is the most important branch of livestock farming. Beef cattle, including breeding animals, comprise about 60 percent of all the cattle in the county. Apparently the raising of beef cattle has diminished since 1920, when beef cattle numbered 34,927 and represented over 75 percent of all cattle. Hereford is the most common breed, although a few Shorthorn and Aberdeen-Angus cattle are raised. Beef cattle were the main product on the 104 ranches reported in the county in 1930. Many of the farmers practicing general farming raise a few cattle for beef. The most extensive production is in the southern half of the county and throughout the Missouri River Badlands. No cash grain is grown on most of these ranches, only forage crops being produced.

Beef cattle are sold at ages ranging from 1½ to nearly 4 years, depending partly on market conditions. Probably most of them are sold when about 3 years old. They are marketed from the middle of August to the latter part of October, the date of shipment depending on range and market conditions.

Dairying is practiced as a specialty on only a small number of farms. A few farmers devote most of their attention to it and supply the towns with whole milk. Small herds of dairy cattle, however, are kept throughout the county outside of the range areas. Guernsey and Holstein-Friesian are the most common breeds. The combination of grain farming and dairying is common and has increased during recent years. The number of cows and heifers kept for milk was 5,920 on January 1, 1920. The number of cows and heifers milked was 6,235 in 1929 and 7,571 in 1934. Less milk was produced, however, in 1934 than in 1929—1,955,158 gallons compared with 2,561,217

gallons. The average number of milk cows on the mixed grain and dairy farms is probably about 8. Cream is the main product, and practically all of it is shipped to centralized creameries farther east.

Horses are raised both for use on the farm and for sale. Those raised for market are produced principally in the grazing areas of the southern part of the county. When 2 or 3 years old they are shipped by truck or railroad to Minneapolis, St. Louis, and other markets of the Middle West. Farmers throughout the county raise horses for their own use. According to the Federal census, 285 farms reported colts born during 1929, but the number of horses raised in the county in recent years has diminished. On January 1, 1920, the census reported 6,530 colts less than 2 years old; on January 1, 1925, 1,749; and on April 1, 1930, only 885, although on January 1, 1935, the number had increased to 1,894. The total number of horses likewise dropped from 26,924 on January 1, 1920, to 13,376 on January 1, 1935. During this period tractors displaced many horses.

Sheep raising is less important than the raising of beef cattle, but it has increased considerably since 1920, whereas the number of beef cattle has decreased. There were 24,138 sheep on farms on January 1, 1935, a larger number than any reported since 1910. Of the total of 19,753 sheep, excluding lambs, on farms on April 1, 1930, 7,593 were raised on ranches and the rest were raised on general farms. Dual-purpose breeds predominate, many of the sheep being a cross between well-bred Merino or Rambouillet rams and grade Shropshire ewes.

According to the 1930 Federal census, in 1929, 121 of the 169 farms raising sheep sheared their flocks, 116,859 pounds of wool being produced by 13,689 sheep. In 1934, 193 farms sheared 15,766 sheep, producing 135,814 pounds of wool. Shearing is done mostly during May. Sheep for mutton, which are sold during the late fall, are shipped directly from the range, no feeding or finishing being done in preparation for market, except on the irrigated area in the vicinity of Fairview. Here, feeder sheep are purchased in the fall and fed for the winter market. Sheep must have readier access to watering places than is usually possible in the Badlands areas. Whereas horses will graze as far as 5 miles, and cattle at least 1¼ miles, from a watering place, sheep, during the summer months, must be within ½ or ¾ of a mile of a water supply.

Hogs are raised on about one-third of the farms. The total number of hogs in the county on January 1, 1935, was 2,451. This represents a marked decline from the number reported in 1924, which was 9,676. A few hogs are shipped to outside markets, but a large part of the pork produced is for home and local consumption. The greatest obstacles to hog raising are poor pasture, great distance to market, and low and unreliable yields of corn. Barley, corn, emmer, and skim milk are commonly used as feed for hogs, and rape, alfalfa, and sweetclover are grown for hog pasture.

The raising of chickens and turkeys is important. In 1929, 1,426 farms reported raising 99,944 chickens, of which 30,066 were sold, and 701 farms reported raising 27,039 turkeys. In the same year, 403,531 dozens of chicken eggs were produced. In 1934, 91,629 chickens were raised and 373,799 dozens of eggs were produced. The number of turkeys raised was not reported. Most of the poultry is

raised in small farm flocks. The dual-purpose breeds, Barred Plymouth Rock, Wyandotte, and Rhode Island Red, are the most common breeds of chickens. Most of the few farmers who make chicken raising a specialty raise White Leghorns. A few large flocks of turkeys are raised, but most flocks include less than 100 birds. Only a few ducks and geese are raised. Most of the poultry is marketed in the fall through poultry dealers and agents for packing houses. Eggs are marketed through these organizations and the local merchants.

In 1910 there were 1,406 farms in McKenzie County having an average size of 198 acres; in 1920 there were 2,033 farms having an average size of 605.7 acres; in 1925 there were 1,721 farms with an average size of 519.6 acres; in 1930 there were 1,738 farms with an average size of 696.8 acres; and in 1935 there were 1,931 farms having an average size of 694 acres. The average size of farms increased steadily from 1910 to 1930 and declined very slightly in 1935.

According to the Federal census of agriculture, the proportion of farms operated by tenants was 1.9 percent in 1910, 7.9 percent in 1920, 18.1 percent in 1925, 20.7 percent in 1930, and 23.4 percent in 1935. Only one other North Dakota county, namely, Bowman County, had a lower rate of tenancy in 1935 (22.2 percent). The North Dakota Agricultural Experiment Station made a survey of the types of tenancy on all rented farms covered by the 1933–35 Agricultural Adjustment Administration wheat contracts. Of a total of 391,428 acres of rented land covered by those contracts, 91,342 acres, or 23.4 percent, were operated under a 50–50 or ½–½ contract; 238,316 acres, or 60.8 percent, under a ¼–¾ contract; 13,466 acres, or 3.4 percent, under a ⅓–⅔ contract; 5,744 acres, or 1.5 percent, under a ⅕–⅘ contract; 440 acres, or 0.1 percent, under a ⅖–⅗ contract; 320 acres, or 0.1 percent, under a ⅔–⅓ contract; and 41,800 acres, or 10.7 percent, were rented for cash (*5*). In recent years the Federal Government has acquired a considerable acreage of the land that is suitable only for grazing. These areas are leased to livestock producers at a stipulated rate per head of cattle during the grazing season.

According to the Federal census for 1930, the value of farm implements and machinery amounted to $2,847,584, which was 15.7 percent of the value of all farm property, or an average investment in implements and machinery of $1,638 a farm. All farms on which grain crops are produced are fairly well equipped with tillage and harvesting machinery. During recent years, combine harvesters have become fairly common on farms devoting large acreages to wheat. Grain cut with binders is threshed by separators owned either by individuals or by cooperative groups. The use of tractors for tilling the land, for threshing, and to less extent for harvesting is common. Most of the grain is hauled to market by trucks. The Federal census for 1930 reports 974 tractors and 540 motortrucks in the county at that time. A few farms are equipped with electric power and light, telephones, and water piped to the house.

SOIL-SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field. The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures,

such as those in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers, or horizons, called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail; and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil [9] and its content of lime and salts are determined by simple tests.[10] Drainage, both internal and external, and other external features, such as relief, or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics soils are grouped into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. Areas of land, such as riverwash, or bare rocky hillsides that have no true soil, are called (4) miscellaneous land types. Where two or more soil series, types, or phases occur in small areas so intimately associated with one another that they cannot be mapped separately, they are mapped as (5) complexes.

The most important group is the series, which includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics or the same natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first recognized. Thus, Williams, Patent, and Morton are names of important soils series in this county.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Morton loam and Morton clay loam are soil types within the Morton series. Except for the texture of the surface soil, these soil types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within a type, which differs from the type in some minor soil characteristic that may have practical significance. Differences in relief, stoniness, and the degree of accelerated erosion frequently are shown as phases. For example, within the normal range of relief for a soil type there may be areas that are adapted to the use of machinery and the growth of cultivated crops and others that are not. Even though there may be no important difference in the soil itself or in its capability for the

[9] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality, higher values indicate alkalinity, and lower values indicate acidity.

[10] The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction.

growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such an instance the more sloping parts of the soil type may be segregated on the map as a sloping or a hilly phase. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS AND CROPS

The soils of McKenzie County differ widely in appearance and composition and in their capacity to produce crops. The differences in the character and distribution of the different soils are the results of several factors. The most important of these are the composition of the parent rocks from which the soils were derived, the character and density of the vegetation, and the relief, or lay of the land. As a result of these factors, in the well-drained areas there are many gradations between the deep dark soils of the nearly level or gently rolling uplands and benches and the grayish-brown or light-brown soils of the eroded areas and Badlands. Every soil described has its particular relationship to agriculture. Among the factors that affect production, it is difficult to assign the exact influence of the soil, but in this county the quality and yield of pasture grass and crops bear a close relationship to the character of the soil. Climatic and economic conditions make the profitable production of crops uncertain, even on the best soils, but a knowledge of the character of any particular soil is necessary in determining its usefulness. Variations in climatic conditions influence crops on the several soils differently. Hence, in nearly every locality in this county, the type of farming practiced and the crops grown are determined by particular types of soil.

The agriculture of this county is centered principally around the production of small grains, the raising of livestock, or a combination of the two. The smooth areas of friable soils are used extensively for the production of wheat and other small grains. These soils are especially adapted to such a system of agriculture, and the surface features allow the use of machinery for sowing and harvesting. Rough, stony, salty, poorly drained, and extremely sandy areas are not suited to grain farming and, consequently, are used almost exclusively for grazing. Most of the farms comprised largely of land suitable for crops are devoted to the production of cash grain crops, particularly wheat; those ranches composed largely of areas suitable only for grazing are devoted to the raising of livestock, principally beef cattle; and on most farms or ranches that include both tillable and nontillable land, a system of mixed grain and livestock farming is practiced. On such farms, grain, livestock, and livestock products may be sold or only livestock and livestock products may be sold, and the tillable land is used for the production of feed to supplement the range. On any particular farm, the kinds of crops grown and the relative pro-

portion of each, whether wheat alone, wheat and other cash crops, or cash crops and subsistence crops, depend to a large extent on the character of the soil and the proportion of the different types of soil. Likewise the usefulness of those soils suitable only as range land for grazing depends to a great extent on their character, particularly in regard to texture, degree or absence of salts or alkali, and lay of the land.

The soils of McKenzie County have been classified in 21 series, which include 27 types, 20 phases, 8 complexes, and 4 miscellaneous land types, including Patent clay. All stoniness, extreme saltiness, small or unmappable areas of soils with claypans, scoria, and wet tracts are indicated by symbols.

The Williams series includes the dark grayish-brown soils developed from olive-drab gravelly clay till. The Morton series includes the dark grayish-brown soils developed from the beds of the Fort Union geologic formation, consisting chiefly of fine sand, silt, and clay. The Searing series includes the dark reddish-brown soils developed primarily from scoria beds of the Fort Union geologic formation. The Flasher series includes the grayish-brown soils developed from the sandy beds of the Fort Union geologic formation. The Bainville series includes the grayish-brown and brownish-gray soils developed from the silt and clay beds of the Fort Union formation. The Arnegard series includes the very dark grayish-brown soils developed in the well-drained depressions commonly associated with the Williams and Morton soils. The Grail series includes the dark grayish-brown soils developed on the gentle valley slopes, which are comprised principally of fine-textured local alluvium. The Patent series includes the brownish-gray soils developed on the gentle valley slopes, which are comprised principally of fine-textured local alluvium. The Farland series includes the friable dark grayish-brown soils developed on the well-drained alluvial silt and clay benches, or terraces, of the stream valleys. The Cheyenne series includes the friable dark grayish-brown soils developed on the well-drained alluvial sandy and gravelly benches, or terraces. The Cherry series includes the fine-textured brownish-gray soils developed on olive-drab alluvial benches, or terraces, of the stream valleys. The Huff series includes the light grayish-brown loamy fine sands developed on natural levees and alluvial fans.

The Moline series includes the brownish-gray alkali-claypan soils developed on the gentle alluvial valley slopes. The Rhoades series includes the grayish-brown and dark grayish-brown alkali-claypan soils developed from the silt and clay beds of the Fort Union geologic formation. The Wade series includes the dark grayish-brown alkali-claypan soil developed on the alluvial terraces and benches of the valleys. The McKenzie series includes the very dark dense hard clay soils developed on old lake or pond sites. The Sage series includes the light-colored clay soils having a high content of carbonates developed on alluvial material, which generally lies in a position to acquire salty material by either flooding or seepage. The Havre series includes the light-colored friable soils of the first bottoms, which are comprised of clayey material to a depth of more than 12 inches. The Banks series includes the light-colored friable soils of the first bottoms, which are underlain by sand to within a few inches of the surface. The Bowdoin series includes soils of the first bottoms that

are similar to the Havre soils in color but are more clayey and somewhat firmer structured. The clay material extends to a depth of several feet. The Dimmick series includes mottled poorly drained clayey soils developed on moist pond sites and abandoned river channels.

In the following pages the soils of McKenzie County are described in detail, and their agricultural relationships are discussed; their location and distribution are shown on the accompanying soil map; and table 4 gives their acreage and proportionate extent.

TABLE 4.—*Acreage and proportionate extent of the soils mapped in McKenzie County, N. Dak.*

Soil type	Acres	Percent	Soil type	Acres	Percent
Williams loam	139,584	8.2	Flasher loamy fine sand, smooth phase	3,648	.2
Williams clay loam	60,544	3.5	Huff loamy very fine sand	3,008	.2
Morton loam	26,816	1.6	Banks loamy fine sand	8,128	.5
Morton clay loam	21,056	1.2	Alluvial loam soils, undifferentiated	20,352	1.2
Arnegard silt loam	20,992	1.2	Alluvial clay soils, undifferentiated	8,384	.5
Grail silty clay loam	37,888	2.2	Havre silty clay, poorly drained phase	7,808	.5
Grail silt loam	13,120	.8	Cherry silty clay loam, poorly drained phase	1,984	.1
Farland silt loam	38,720	2.3	Banks very fine sandy loam, poorly drained phase	1,792	.1
Farland silty clay loam	47,872	2.8	Dimmick clay	3,648	.2
Cheyenne loam	4,736	.3	Rhoades loam (complex with Morton, Bainville, or Williams loams)	6,208	.4
Searing loam	3,072	.2	Rhoades clay loam (complex with Morton, Bainville, or Williams clay loams)	12,224	.7
Patent clay loam	52,480	3.1	Rhoades clay loam, rolling phase (complex with Morton, Bainville, or Williams loams and clay loams, rolling phases)	8,448	.5
Patent silt loam	4,544	.3	Moline clay loam (complex with Patent or Grail soils)	55,872	3.3
Bainville loam, smooth phase	5,440	.3	Moline clay loam, slope phase (complex with Patent or Grail soils, slope phases)	17,536	1.0
Bainville clay loam, smooth phase	5,888	.3	Wade-Farland silty clay loams	17,088	1.0
Cherry silty clay loam	7,616	.4	McKenzie clay	2,496	.1
Havre silty clay	29,120	1.7	McKenzie clay, light-colored phase	6,592	.4
Bowdoin clay	4,160	.2	Sage clay	3,200	.2
Flasher fine sandy loam	40,064	2.3	Rough broken land	204,352	11.9
Cheyenne fine sandy loam	22,400	1.3	Scoria	62,208	3.6
Banks very fine sandy loam	22,976	1.3	Patent clay	3,008	.2
Williams loam, rolling phase	61,952	3.6	Riverwash	6,528	.4
Williams clay loam, rolling phase	67,456	4.0			
Williams clay loam, steep phase	77,696	4.5			
Morton loam, rolling phase	13,376	.8			
Morton clay loam, rolling phase	7,424	.4			
Flasher fine sandy loam, rolling phase	35,072	2.1			
Grail silty clay loam, slope phase	2,240	.1			
Patent clay loam, slope phase	31,680	1.9			
Bainville loam	21,376	1.3			
Bainville loam, steep phase	57,408	3.4			
Bainville clay loam	23,744	1.4			
Bainville clay loam, steep phase	131,840	7.7			
Flasher loamy fine sand	30,080	1.8			
Flasher loamy fine sand, steep phase	64,000	3.7			
Searing loam, rolling phase	7,296	.4			
Cheyenne gravelly loam, steep phase	3,840	.2			
			Total	1,710,080	

SOILS USED PRINCIPALLY FOR CROPS

The broad group of soils used principally for crops includes those soils that, according to common practice, are suitable for crops demanding tillage of the soil. In general, they are friable, range in texture from fine sandy loam to silty clay, are well drained, are free of excessive quantities of alkali or other salts, have nearly level to gently rolling surfaces, and, except where so indicated by symbols on the map, are comparatively free of boulders and other stones. Areas of these soils indicated as having numerous stones on and in the soil are suitable only for grazing.

The soils of this group differ widely in general productivity and usefulness. Their major characteristics are emphasized by the several

subgroups, and the important characteristics of each separation are described in the soil type and phase descriptions.

DARK GRAYISH-BROWN SOILS OF THE SMOOTH TO UNDULATING UPLANDS AND TERRACES

The subgroup of dark grayish-brown soils of the smooth to undulating uplands and terraces includes the most desirable soils of the county for producing crops under dry-farming conditions. Their comparatively dark color indicates a good content of organic matter, and they are in a comparatively high natural state of fertility. They have nearly level to gently rolling surfaces, are well drained and are friable throughout their entire depth. Consequently they are easily worked and are suitable for good crop growth under a comparatively wide range of moisture conditions. A very large proportion of the acreage of these soils is tilled. Wheat is the dominant crop, although the soils are well suited to the production of all crops commonly grown in the county. Average yields are higher on these soils than on those of any other group.

Williams loam.—The surface soil of Williams loam is dark grayish-brown mellow loam or silt loam. It is underlain by a layer of dark-brown clay loam or sandy clay loam to a depth of approximately 16 inches, which has a prismatic structure, and, when dug out, falls apart in blocky prismatic fragments about the size of hulled walnuts. These are easily crushed to a soft fine mealy mass. Below this layer the material is olive-drab friable clay, the upper 3 or 4 inches of which shows an abundance of white flecks of lime carbonate. Lime carbonate in sufficient quantity to effervesce with acid occurs at a depth of approximately 15 inches. A few pebbles invariably occur through this soil, and boulders are scattered over the surface. In some places they are so numerous as to interfere with or even prohibit tillage and cultivation and thereby lower the value of the land. The stony areas are indicated on the soil map by appropriate symbols. Much of Williams loam in the vicinity of Charlson is noticeably darker brown to a depth of about 14 inches than is normal for this soil, and the productivity here is probably slightly higher than that of the typical soil. Areas of Williams loam occupying the narrow ridges bordering the Yellowstone River Valley and part of the Missouri River Valley in the northwestern part of the county are somewhat more silty below a depth of 20 inches than is Williams loam elsewhere. These areas are free of both boulders and pebbles.

Williams loam is one of the most uniform soils in the county. It occurs throughout most of that part of the county that was subjected to glaciation. Very few areas are mapped south of a line drawn from the northern edge of the Little Missouri Badlands at the western edge of Norstog Township, northwest through the northern part of Elsworth Township, thence west along the northern edge of Antelope Creek Township and through the northern half of Moline Township, and thence northwest to the Yellowstone River. This is the predominant soil on the smooth to gently rolling till plains in the vicinities of Alexander, Arnegard, and Charlson. Throughout the remainder of the northern half of the county, the areas of this soil are irregular in size and shape, and they are separated by more rolling areas of soils of the Morton and Bainville series.

Most areas are undulating to gently rolling, but a few small areas are nearly level. As a rule, this soil occupies gently rolling ridge tops and high plains, but where the till is thin many areas occupy isolated valley slopes or ridge tops. Both surface drainage and internal drainage are good, and erosion is not serious.

The native vegetation consists of mixed blue grama, western wheatgrass, and western needlegrass. As a result of overgrazing, the western wheatgrass has been largely replaced by blue grama. Severe overgrazing leads to supplanting of the grasses by pasture sage and other weeds.

Williams loam is one of the most desirable soils of the county, and more than 90 percent of it is cultivated. Wheat is the dominant crop grown; probably 65 percent of the acreage is devoted to this crop. Other small grains, particularly oats and barley, are commonly grown, especially by farmers who practice general farming. Many farmers who raise cattle grow some sweetclover or alfalfa, and a large proportion of the total acreage of sweetclover is produced on this soil. Other hay crops commonly grown successfully are millet, sorghum, and small grains cut green. Crested wheatgrass, although not commonly grown, appears to be adapted to this soil. A small acreage of Williams loam is devoted to corn, potatoes, and flax. A large proportion of the acreage devoted to potatoes grown for commercial purposes in the vicinity of Arnegard is on this soil.

A considerable acreage is planted to small grains continuously, and on many farms wheat is grown for several consecutive years, although crop rotation is practiced to some extent to good advantage. A desirable rotation for general farming, which is practiced by a very few farmers, is a 3- or 4-year rotation that includes a cultivated crop, a small-grain crop, and a leguminous-hay crop. Where no cultivated crop is grown, the ground is summer-fallowed 1 year out of 3 or 4. When a leguminous-hay crop is grown, it generally is seeded with a small grain. Sweetclover is more commonly grown than alfalfa. When hay land of this kind is plowed under, the hay is generally followed by flax, wheat, or a cultivated crop.

Owing to the preponderance of the small grains, the comparatively small acreage of cultivated crops, and the difficulties and hazards involved in growing leguminous-hay crops, crop rotation is not practical for the entire acreage of such soils as Williams loam. A common and recommended system is to summer-fallow the ground for 1 year out of 3 or 4, then plant it to wheat followed by other small grains as often as is feasible. It is considered good practice to rotate crops, even though cultivated and leguminous crops cannot be included regularly.

Owing to the wide variation in seasons and the small amount of data available on yields, it is only possible to give estimates of the yields of various crops on the several agricultural soils of the county. Yields under favorable conditions [11] are from 14 to 17 bushels of wheat an acre, but yields of more than 30 bushels have been obtained. Barley in favorable seasons yields from 20 to 25 bushels an acre, oats 30 to 35 bushels, corn 25 to 30 bushels, flax about 12

[11] Average yields, including seasons of partial and total crop failures, are probably not more than 60 percent of the yields here given as being obtained under favorable conditions.

bushels, and potatoes about 80 bushels. Under like weather conditions, sweetclover and alfalfa yield from 1.5 to 1.7 tons an acre, alfalfa yielding a little more than sweetclover when there is sufficient moisture for its growth. Those areas of Williams loam having a lighter color and a less well defined structure, which occur on the narrow ridges, particularly in the extreme western and northwestern parts of the county, are considered a little less productive than typical Williams loam.

Land values in terms of dollars are difficult to estimate, as very little of this land has been sold during recent years except under unusual circumstances. The most productive soil for the most part is Arnegard silt loam, and the value of Williams loam as agricultural land is about 90 percent of that of Arnegard silt loam. Areas that include gravelly, stony, or scabby patches or that are too small or isolated have a correspondingly lower value.

Virgin areas of Williams loam are desirable for grazing and have a comparatively high carrying capacity. On the basis of a grazing experiment conducted on Williams loam and Arnegard silt loam over a period of several years at the Northern Great Plains Field Station (*6*), it requires about 7½ acres of Williams loam to carry a 2-year-old steer satisfactorily through a 5-month grazing season.

Williams clay loam.—Williams clay loam is similar to Williams loam, except that the texture, particularly of the 6-inch surface layer, is more nearly clay loam than loam, and the soil is more distinctly dark gray. The surface layer is dark grayish-brown or dark-gray clay loam that breaks into irregular fragments that can be crushed fairly easily to a crumbly mass. It is underlain, to a depth of about 16 inches, by dark grayish-brown or dark-gray clay loam with prismatic structure, which breaks to nut-sized fragments that are somewhat brittle and crush to a crumbly mass. Below this, the color is lighter and nearly white specks of lime carbonate are abundant. At a depth of about 26 inches is olive-drab mellow clay containing numerous nearly white specks of lime carbonate.

This soil, like Williams loam, is developed from glacial till. The surface is undulating to gently rolling, and drainage is satisfactory for good crop growth. The native vegetation is similar to that on Williams loam. The aggregate area of this soil is 94.6 square miles. The greater part of it and the most extensive areas are south and southwest of Alexander.

Practically all of the sizable areas of Williams clay loam are tilled. Owing to its finer texture, this soil is a little harder to till than Williams loam and is not quite so well adapted to cultivated crops, especially potatoes. The crops grown and the relative acreage of each approximate those common to Williams loam. Yields, particularly of small grains and hay, are very nearly equal to those on Williams loam, and the value of the clay loam, as either crop or grazing land, is about 80 percent of that of the most desirable land in the county.

Morton loam.—Morton loam is the dark grayish-brown loam soil that lies on the unglaciated upland areas. The 5-inch surface layer is dark-brown friable loam or silt loam, which normally contains more very fine sand and fine sand than does the corresponding layer of Williams loam, although many areas have a surface layer as fine in texture as that of typical Williams loam. Below this layer and

continuing to a depth of about 16 inches, the material is brown friable loam with prismatic structure. With depth this structure gradually becomes less well defined and the color becomes lighter. Below a depth of about 24 inches the material is variable in both color and texture, ranging from yellowish-brown very fine sand to yellowish-gray silt. In a few places the texture is even more clayey. Lime carbonate sufficient to cause effervescence with acid is present at a depth ranging from 14 to 20 inches, and in some places a visible accumulation, in the form of nearly white specks, lies at a depth of about 18 inches. Numerous areas of this soil, particularly those underlain by sandy material, have an abundance of brown hardened sandstone or indurated fragments, ranging from one-fourth to one-half inch in diameter, through the surface soil and upper subsoil layers. Such areas are most common on the smooth to gently rolling ridge land in the vicinity of Grassy Butte.

Morton loam is developed from material of the Fort Union geologic formation. The surface of this soil is undulating to gently rolling, and both surface and internal drainage are good. This soil is not subject to significant erosion by water, but many areas are somewhat subject to wind erosion when the surface is not protected by vegetation.

The aggregate area of Morton loam is 41.9 square miles. The most extensive areas are in the vicinity and north of Grassy Butte, but the individual areas are not so large as those common to Williams loam. Scattered areas are throughout most of the upland part of the county, except within the three larger gently rolling till plains. Numerous areas, ranging in size from 20 to 300 acres, are in the townships of Loyal, Blue Butte, Pershing, Northfork, Grail, Bear Den, and T. 151 N., R. 95 W. In some places it is closely associated with the Bainville soils, which occupy the higher parts of the land, whereas Morton loam occupies the lower parts.

The native vegetation is similar to that on Williams loam, although the sandier areas support less western wheatgrass and more nigger-wool, mixed with blue grama and western needlegrass.

Most of the acreage of this soil is tilled. Yields of crops are comparatively good, although the yields of small grains average slightly lower than those obtained on Williams loam. The value of this soil, as either crop or grazing land, is from 80 to 85 percent of that of the best soil in the county. The crops grown, the methods of handling the soil, and the crop yields are similar to those described for Williams loam, except that few potatoes are grown on this soil for commercial purposes—owing to location rather than to any difference in the productive characteristics of the soil—and that many small tracts of Morton loam are in those parts of the county where cattle grazing predominates. Much of the acreage of this soil in these localities is devoted to the production of subsistence crops, such as corn and hay. Small grains, millet, and wild oats are the most common hay crops.

Morton clay loam.—Morton clay loam is similar to Morton loam, except that the texture throughout its entire profile averages more nearly clay loam. The 5-inch surface layer is dark grayish-brown friable heavy silt loam or clay loam. Below this, to a depth of about 16 inches, is dark grayish-brown clay loam with prismatic structure,

which breaks readily into firm nut-sized fragments that crush easily to a crumbly mass. Below this layer the color is lighter, and nearly white salt specks are abundant at a depth of about 18 inches. Gray and yellow clay underlies this soil at a depth of about 24 inches.

Morton clay loam is developed from clayey beds of the Fort Union geologic formation. Its surface is undulating to gently rolling, and surface drainage is good. Internal drainage, though slower than that of Morton loam, is sufficient for good plant growth. The native vegetation is similar to that on Williams loam, with blue grama as the most abundant grass.

The aggregate area of this soil is 32.9 square miles. It is widely distributed over the county, but there are no large areas.

A large proportion of this soil is tilled. It is devoted to the same crops as are grown on Williams loam, with wheat as the most extensively grown crop. Yields of all crops very nearly equal those obtained on Williams loam. Because of its heavier texture, the Morton soil is somewhat less easily tilled and makes less efficient use of light showers during the growing season than those soils having a somewhat coarser texture. As either crop or grazing land, the value of this soil is about 80 percent of that of the best soil in the county.

Arnegard silt loam.—Arnegard silt loam is the comparatively dark colored soil that occupies the better drained depressions and drainageways of the uplands. The 5-inch surface layer is dark grayish-brown or very dark grayish-brown mellow silt loam. Below this, to a depth of about 16 inches, is slightly darker material with a prismatic structure, which breaks into somewhat brittle nut-sized fragments that crush to a crumbly mass. Below this depth the color fades and the structure becomes less well defined. Olive-drab fairly mellow clay underlies this soil at a depth ranging from 24 to 30 inches. Lime carbonate sufficient to cause effervescence when the mass is treated with acid is present at a depth ranging from 16 to 20 inches below the surface, and some white salt specks are within a few inches below the depth at which effervescence takes place.

This soil is developed on local alluvial deposits, especially along the gentle well-drained drainageways and shallow depressions of the uplands. The surface is nearly level in depressions or on broad alluvial flats, and along upland drainageways it is gently sloping. Most of the soil occurs in areas of less than 80 acres, and 80 percent of the aggregate acreage is within areas of soil on gently rolling glacial till. The remaining acreage is distributed widely over the smoother parts of the unglaciated section of the county.

The native vegetation consists chiefly of western wheatgrass and blue grama, and several other species are less abundant. Native vegetation grows more abundantly on this soil than on any other soil in the county, and this characteristic, combined with the high quality of the grass for grazing, gives this soil the highest carrying capacity of any range land in the county. Based on the grazing experiments at the Northern Great Plains Field Station (*6*), it requires about 6½ acres of this soil to carry a 2-year-old steer through a 5-month grazing season.

Arnegard silt loam is the most desirable soil in the county for either crop production or grazing, and more than 90 percent of it is cultivated. It is fertile, has good tilth, and its position and relief

make its water relations for crop production superior to those of other soils. It is cultivated in the same manner as such soils as Williams loam, with which it is commonly associated. Difficulty in preparing the seedbed in the spring occasionally is experienced because of the slower drainage. Fall plowing obviates part of this difficulty and also improves the tilth, especially of the finer textured areas.

Wheat occupies the greater part of the tilled acreage, and flax, barley, and oats are commonly grown and yield well, although barley and oats are apt to lodge in especially wet seasons. Corn and potatoes are grown to some extent, and on many farms this soil is chosen for gardens because of its good tilth and moisture conditions. As the soil occurs in depressions, late-season crops, such as corn and potatoes, are somewhat more subject to frost hazard than when grown on higher lying soils, such as Morton loam and Williams loam. Because of its fertility and especially because of its favorable position for receiving moisture from the surrounding uplands, this is the best soil for alfalfa in the county, excepting some of the soils on the first bottoms.

Yields of all crops are comparatively high. During good years wheat averages about 20 bushels an acre and corn about 32 bushels. Alfalfa, during favorable years, probably yields from 1½ to 2 tons an acre. During dry years, crops may be produced on this soil when they may fail on the Morton or Williams soils.

Grail silty clay loam.—Grail silty clay loam is the dark grayish-brown silty clay loam that occupies some of the gentle alluvial valley slopes. The 5-inch surface layer is dark grayish-brown or very dark grayish-brown mellow silty clay loam. Below this, to a depth of about 14 inches, the material is dark grayish-brown silty clay loam with a prismatic structure, which breaks into firm nut-sized fragments that are easily crushed to a crumbly mass. Below this layer the structure is less distinct, and at a depth of about 24 inches the material consists of olive-drab clay that is firm and compact in place. Lime carbonate sufficient to cause effervescence occurs at a depth of about 15 inches below this layer, and white carbonate specks are common within a very few inches of the depth at which effervescence takes place. A few small areas are underlain by an alkali claypan. They are indicated on the map by appropriate symbols.

The aggregate area of this soil is 59.2 square miles. It is developed on the local alluvium of the gentle valley slopes and is associated with the Patent soils. A few areas lie in a position similar to that of Arnegard silt loam, but because of the heavier texture and somewhat less friable character of the soil these areas are included with Grail silty clay loam. Grail silty clay loam is widely distributed over the county, the most extensive areas being in Tobacco Garden, Antelope Creek, Randolph, and Elsworth Townships. The surface is gently sloping, and drainage is sufficient for good crop growth. Some areas that lie in shallow drainageways have a nearly level to gently sloping surface. Surface drainage of the nearly level areas is slow, but, except during unusually wet periods, drainage is sufficient for satisfactory crop growth. Because of the position of this soil immediately below adjoining higher lying areas, much of Grail silty clay loam is in a position to benefit somewhat from run-off.

The native vegetation is chiefly western wheatgrass and blue grama. Where subjected to overgrazing, the western wheatgrass has been almost entirely displaced by blue grama, and where severely overgrazed, pasture sagebrush and other undesirable vegetation have developed.

This is one of the most productive soils in the county, and at least 70 percent of it is tilled. It is well suited to the production of most general farm crops, such as wheat, oats, barley, corn, hay, and flax, and yields approximate those obtained on Williams loam. Because of its heavy texture it is somewhat less desirable for potatoes, but corn usually does well. Few farmers practice a consistent rotation of crops on this soil, and much of the acreage is devoted to small grains, particularly wheat. The land commonly is fall plowed when moisture conditions are favorable, and summer fallowing is practiced on most farms. These two practices are well suited to this soil because its position, relief, and structure make it less subject to soil blowing, and the tilth of clayey soils generally is improved by fall plowing.

Average crop yields are slightly less than those obtained on Williams loam. Wheat is somewhat more readily affected by rust, and flax may have greater competition from weeds than on the higher lying loam soils. As cropland this soil is considered from 75 to 85 percent as valuable as Arnegard silt loam, and as grazing land its carrying capacity is from 80 to 90 percent of that of Arnegard silt loam.

Grail silt loam.—Grail silt loam differs from Grail silty clay loam principally in having a silt loam texture to a depth of 5 or 6 inches. The slope, position, drainage, and native vegetation of the two soils are similar, but owing to its more mellow surface soil, Grail silt loam is preferable for cropping. Its productivity is probably a little higher, but it is cropped and managed in nearly the same manner as Grail silty clay loam.

Though widely distributed over much of the county, in association with the Patent soils and the other Grail soils, the total acreage of this soil is less than that of Grail silty clay loam. It occurs in nearly all of the townships where there is a considerable acreage of the Patent soils and Grail soils. Representative areas are in secs. 28, 31, and 32, T. 150 N., R. 98 W., and secs. 3, 21, 22, and 31, T. 149 N., R. 100 W.

Farland silt loam.—In profile, Farland silt loam resembles Williams loam, but it occupies a different topographic position. It lies on alluvial terraces, or benches, in the valleys of the larger streams, such as those of Tobacco Garden and North Fork Creeks. The surface is nearly level to undulating, and, although surface drainage is slow, internal drainage is good. The 5- or 6-inch surface layer is dark grayish-brown or brown mellow loam or silt loam, below which is dark grayish-brown heavy silt loam with prismatic structure, which breaks into nut-sized fragments that are easily crushed to a mellow crumbly mass. Below a depth of about 16 inches the color becomes lighter and the prismatic structure gradually disappears. Below a depth of 20 inches the color of the material is olive drab or olive gray and the texture ranges from loam to clay. Lime carbonate sufficient to cause effervescence when the soil is treated with acid is at a depth of about 17 inches, and nearly white carbonate specks are common below a depth ranging from 17 to 20 inches. Some small areas having an alkali claypan are shown on the map by appropriate symbols.

The native vegetation is similar to that on Williams loam, blue grama predominating with a smaller amount of western wheatgrass and western needlegrass intermixed. As with most of the other dark grayish-brown soils, little clubmoss commonly occupies much of the surface not covered by grasses and shrubs. Virgin areas of this soil afford good grazing. The carrying capacity of the pastures is about 90 percent of that of Arnegard silt loam.

Very nearly 90 percent of the acreage of Farland silt loam is cropped. Wheat occupies more than 50 percent of the cultivated acreage, and the rest is devoted to other small grains, corn, and hay crops including some alfalfa. This is considered a very desirable soil, is easily worked, free of stone, and equally as or more productive than Williams loam. Owing to its nearly level surface and silt loam texture, this soil loses very little water either from run-off or from percolation. Its value as cropland is approximately 90 percent of that of Arnegard silt loam.

Because of the uniformity of texture and lack of stones and small pebbles, this soil, where poorly managed, is somewhat more susceptible to blowing than the Williams soil.

Farland silty clay loam.—The 5-inch surface layer of Farland silty clay loam is dark grayish-brown or very dark grayish-brown fairly mellow silty clay loam. Below this is dark grayish-brown or very dark grayish-brown silty clay loam with prismatic structure, that breaks into nut-sized fragments, which, though fairly friable, are noticeably less so than the material of the corresponding layer in such soils as Williams loam or Farland silt loam. A few areas have a fairly hard consistence, and in such areas the color is more nearly very dark gray than very dark grayish brown. Below a depth of about 16 inches the color becomes gradually lighter until, at a depth of about 24 inches, it is olive drab. The prismatic structure rapidly becomes less pronounced below a depth of 16 inches. Carbonates sufficient to cause effervescence when the soil is treated with acid are reached at a depth ranging from 12 to 18 inches, and nearly white carbonate specks are abundant below a depth of 16 to 18 inches. The numerous small areas with an alkali claypan are indicated on the soil map.

Farland silty clay loam is developed on the broader terraces, or benches, of the stream valleys, such as those of Cherry Creek, Bennie Pierre Creek, and Yellowstone River. Several of the areas along the creeks and their tributaries have a fairly hard consistence, especially below the 5-inch surface layer, but most of the extensive acreage in the Yellowstone Valley is of a more friable character. The color of this soil in the Yellowstone Valley is slightly darker in the surface soil and more yellowish brown in its subsurface layer than in the more representative areas. In addition, carbonates sufficient to cause effervescence with acid are near the surface. The surface of Farland silty clay loam is nearly level, and both surface drainage and subdrainage, although slow, are sufficient under ordinary conditions to maintain a condition in the soil satisfactory for good root development.

The native vegetation is predominantly western wheatgrass and blue grama, together with other grasses, such as prairie junegrass and feathergrass, intermixed. Such plants as gray sagebrush, green sagebrush, and pricklypear are common but ordinarily not abundant. This soil affords good grazing. Virgin areas have a carrying capacity of about 90 percent of that of Arnegard silt loam.

Approximately 80 percent of this soil is tilled, and the rest is used as virgin grazing land. The acreage within the Lower Yellowstone irrigation project is almost entirely under cultivation and irrigation. This is one of the most desirable soils of the county for cultivation under irrigation, although its silty clay loam texture is somewhat heavier than is most desirable for this purpose. The acreage within this project is devoted principally to sugar beets, oats, barley, wheat, alfalfa, and corn. Other crops, such as beans, sorghum cane, potatoes, melons, and garden crops are commonly and successfully grown and are of good quality. Sugar beets occupy the largest acreage, and the average yield is about 10½ tons[12] an acre. Somewhat higher yields are obtained under superior farm practices. The average acre yield of wheat is between 25 and 30 bushels, with yields ranging from 35 to 40 bushels commonly reported. Yields of alfalfa range from 3 to 5 tons an acre, of potatoes about 135 bushels, and of Great Northern beans from 25 to 30 bushels, with occasional yields of 40 bushels reported.

A 4-year crop rotation is commonly practiced on the nonirrigated areas. Manure from dairy herds and from the fattening pens where sheep and cattle are fed the beet-sugar factory byproduct is applied to this soil, and some phosphate fertilizer, particularly for sugar beets and alfalfa, is used.

The dry-farmed part of Farland silty clay loam is devoted principally to wheat, which occupies from 50 to 60 percent of the acreage. Oats, barley, flax, corn, and hay crops occupy most of the remainder. Yields are comparatively good, particularly of the small grains, and approximate those obtained on Williams loam. This soil is not so well adapted to this wide range of crops as are some of the loams. Because of its heavy texture, crops are not capable of making as good use of light summer showers as they are on more sandy soils, and this soil is somewhat more difficult to manage than the loams or sandy soils. Observations and local opinion, however, indicate that, on the average, crops on this soil and other fertile clay loam and silty clay loam soils do not suffer from drought any sooner than, or, in fact, as soon as, do crops on the coarser textured commonly tilled soils. When moisture conditions are favorable, fall plowing improves the tilth of this soil for planting the following spring. Because of its comparatively slow surface and internal drainage, difficulty at planting time, because of wetness, is more frequent on this soil than on such soils as Williams loam or Morton loam. Its general productivity is from 80 to 90 percent of that of Arnegard silt loam.

Cheyenne loam.—Cheyenne loam consists of dark grayish-brown loam underlain by alluvial gravel beds. The 5-inch surface layer is dark grayish-brown mellow loam. Below this, to a depth of about 17 inches, is dark grayish-brown loam or gritty clay loam of prismatic structure, which breaks into nut-sized fragments that are easily crushed to a crumbly mass. Here and there, pebbles occur in these upper layers, but in few places are they sufficiently abundant to interfere seriously with cultivation. The more gravelly areas are indicated on the map. Below this is stratified gravelly material, in the upper 4- or 5-inch layer of which the pebbles are coated with lime, and effer-

[12] These are average yields, whereas yields approximated for soils operated only under dry farming are for favorable years.

vescence with an acid generally takes place in the lower inch or two of the overlying soil layer. Except for the gravel beds beneath this soil, it resembles Williams loam and Farland silt loam.

The surface of Cheyenne loam is nearly level or gently rolling, and drainage is good. Probably this soil is developed on gravelly alluvial terraces, most of which were laid down during the glacial period.

The largest areas of this soil are in the northeastern part of the county, and other areas are widely distributed throughout that part where glacial outwash may occur. Several gently rolling areas are on ancient terraces in the Badlands. These terraces lie adjacent to and from 140 to 260 feet above the valley of the Little Missouri River.

Cheyenne loam is a fairly productive soil and is adapted to the same crops as are commonly produced on Williams loam and Morton loam. Wheat is the principal crop, and other small grains, hay, and corn occupy the rest of the cultivated land. Yields average a little lower than those obtained on Williams loam, owing to the droughty character of the underlying gravel layer and to the occasional patches that are gravelly to the surface. The native vegetation is predominantly blue grama, with considerable western needlegrass intermixed. Green sagebrush and pasture sagebrush are common. The value of this soil as cropland is about 80 percent of that of Arnegard silt loam and as grazing land is slightly less than 80 percent.

Searing loam.—Searing loam is the reddish-brown soil developed from scoria. The 7-inch surface layer is dark reddish-brown loam that crumbles easily into soft fragments when crushed. Below this layer and continuing to a depth of about 16 inches the material is light reddish-brown friable heavy loam that breaks easily into soft fragments. Below a depth of 16 inches the color fades and in many places is splotched or spotted with gray. The soil material below a depth of 20 inches is variable. Its color generally is grayish brown with a red cast, and the texture ranges from loam to clay. Scoria fragments, ranging from one-sixteenth to one-half inch in diameter, occur throughout all the soil layers. In most places a bed of scoria underlies this soil at a depth of about 28 inches. In many places small patches of scoria, ranging in size from a few square rods to one-half acre, particularly free of overlying fine soil material, are exposed throughout areas of this soil. Where numerous they are indicated on the soil map by symbols. Lime, indicated by effervescence when the mass is treated with an acid, generally occurs at a depth of about 15 inches, and abundant effervescence takes place below a depth of 18 or 20 inches.

The surface of Searing loam ranges from gently rolling to gently sloping, and both internal and external drainage are good. Areas of this soil are few and small, very few occupying more than 50 acres, and they are confined almost entirely to the unglaciated part of the county. Owing to their small total area, the tracts of Searing loam in which an alkali claypan has developed are included with the typical soil. The presence of the claypan is indicated on the soil map by symbols.

The native vegetation varies to some extent on this soil, depending on the quantity of scoria fragments it contains. Where the quantity is comparatively small, blue grama and western needlegrass predom-

inate, with some prairie junegrass, side-oats grama, and western wheatgrass intermixed; where the soil is stony or sandy, niggerwool comprises a good proportion of the cover; and, where an alkali claypan is developed, the grass cover on the clay spots varies considerably in density, but it is thinner than on the normally developed soil, generally consisting of western wheatgrass with some blue grama intermixed.

Probably one-third of the total acreage of this soil is tilled, as practically all of it in which the claypan and clay spots are not developed is arable; but many areas are too isolated to be profitably utilized as cropland. Where it is tilled, it is managed in practically the same way as are the small tracts of Williams loam and Morton loam; but most of it occurs either in irregular-shaped areas of arable land or in association with areas of rolling land, which are not suitable to farming with heavy machinery. A rather large proportion of the tilled acreage is used for the production of subsistence crops, such as hay, oats, and corn, because most of it lies in those parts of the county where livestock farming predominates. Crop yields on this soil are about 70 percent of those obtained on Arnegard silt loam.

Practically all of the alkali-claypan areas are grazed. The carrying capacity of the part free from the claypan and clay spots is probably about 75 percent of that of Arnegard silt loam, and those areas on which clay spots are developed have a carrying capacity of about 65 percent of that of the normally developed soil.

BROWNISH-GRAY AND GRAYISH-BROWN LOAMS TO SILTY CLAYS ON SMOOTH TO UNDULATING UPLANDS AND ALLUVIAL LANDS

The subgroup of brownish-gray and grayish-brown loams to silty clays on smooth to undulating uplands and alluvial lands includes the comparatively light colored heavy-textured soils having a smooth surface. The brownish-gray or grayish-brown surface layers extend to less depth than does the dark grayish-brown surface layer of the soils of the first subgroup, the soil structure is only weakly developed, and abundant carbonates are at or within a few inches of the surface. The natural fertility of these soils is lower, and with the exception of Havre silty clay their productivity is notably less than for the soils of the first subgroup. As with the soils of the first subgroup, however, wheat is the main crop, and the rest of the acreage is devoted to a comparatively wide range of crops including other small grains, hay, and corn.

Patent clay loam.—The 7-inch surface layer of Patent clay loam is light-brown or brownish-gray friable clay loam, which, when plowed, dries to a distinctly gray color. Below this layer is brownish-gray or light grayish-brown clay loam that has a fair to weak prismatic structure. The nut-sized fragments are readily crushed to a fine-grained mass. Below a depth of approximately 15 inches the soil mass is less friable and less easily removed from place with a spade. Here, the color approaches olive drab and the texture ranges from clay loam to clay. In many places the upper part of the subsoil contains flecks of lime carbonate. Effervescence with an acid takes place at a depth ranging from 6 to 14 inches below the surface. A few small included areas have an alkali claypan and clay spots developed in them, and although in few places are they extensive enough

to prohibit use of the land for crops, they diminish the value of the land somewhat.

Patent clay loam occupies gentle valley slopes and is developed from local alluvium from the adjoining uplands. Many areas lie as aprons that extend out from the upland bordering the valleys and occupy a position parallel with the direction of the valleys. The average gradient is about 2 degrees, whereas the gradient of the smooth areas of the Williams and Morton soils ranges from 1 to 4 degrees. Surface drainage of this soil is good, but subsurface drainage is only fair. Because of its sloping position immediately below the upland, areas of this soil include many small sharp ditches cut by run-off water from the bordering upland.

Patent clay loam is widely distributed, except on the gently rolling till plains and the rougher parts of the Badlands. Throughout much of the watershed of Bennie Pierre Creek the areas are fairly extensive and occupy the larger part of many of the small valleys, or coulees, and the larger part of the valley slopes of some of the larger valleys. In Blue Butte, Grail, and other townships the areas are smaller and more irregular in shape.

Probably half of the area of Patent clay loam is tilled. Most of it is adapted to tillage, but many areas are so far from shipping points or so closely associated with soils adapted only to grazing that they are more economically used as grassland. Probably 85 percent of Patent clay loam occurring in such localities as Cherry and Elsworth Townships is tilled, and the tilled areas within reasonable distances of shipping points are devoted largely to wheat and flax. Diversification is practiced to about the same extent on this soil as it is on the less extensive areas of Williams loam, but potatoes and rye are not commonly grown and the acreage of alfalfa is comparatively small. The tilled areas are used extensively for the production of hay and to less extent for corn. Millet, sorghum cane, sweetclover, and small grains are the most common hay crops. Crop yields on Patent clay loam are about 60 percent of those obtained on Arnegard silt loam. Under continuous grain cropping this soil will show a diminution in yields sooner than will the darker colored well-drained loams.

Fall plowing is commonly practiced in preparing the seedbed, as freezing and thawing during the winter season improves the tilth of clay and clay loam soils. Owing to their position, numerous areas of Patent clay loam are subject to erosion by run-off from the adjoining upland, and many such areas are used to best advantage as grazing land.

Patent clay loam furnishes nearly ideal grazing. The grass cover, where it has not been overgrazed, is a mixture of western wheatgrass, blue grama, and side-oats grama. Western wheatgrass predominates in some places almost to the exclusion of the other grasses. Those areas that have been subjected to overgrazing at some time generally have a grass cover composed almost wholly of the grama grasses. Some areas of this soil are subject to sheet deposition of soil material by run-off from the adjoining higher lying upland, and in such places the grass cover is thinner and more irregular and affords less grazing than on areas less affected by run-off.

Patent silt loam.—Patent silt loam differs from Patent clay loam principally in having a silt loam or very fine sandy loam surface soil.

The soil material below a depth of 10 inches is generally clay loam or clay. The gradient, position, and drainage of this soil are similar to those features of Patent clay loam.

The acreage of Patent silt loam is much smaller than that of Patent clay loam. Most of this soil, in fact all the more extensive areas, is in the southwestern part of the county. As most of this soil is in a grazing section, practically all of it is devoted to grazing. The type of grass cover is similar to that on Patent clay loam, and the carrying capacity of the two soils is about equal. Most of the areas in the farming sections of the county are tilled, and crops and crop yields approximate those on Patent clay loam. These areas are cropped and managed in much the same way as is Patent clay loam, except that fall plowing is not so commonly practiced on the silt loam as on the clay loam.

Bainville loam, smooth phase.—Bainville loam, smooth phase, is a light-colored loam of the gently rolling upland. The 5-inch surface layer is light-brown or grayish-brown loam, below which the color fades rapidly to brownish yellow. The material of this layer is friable but has no well-defined prismatic structure, such as that common to Williams loam or Morton loam. The mass breaks into comparatively soft fragments that are easily crushed. Below a depth of about 12 inches is the comparatively unaltered laminated gray and yellow silt and clay of the Fort Union geologic formation. Carbonates sufficient to cause effervescence when the soil is treated with an acid are within a few inches of the surface, and white carbonate specks are numerous below a depth of 10 inches.

The surface of most of this soil is gently rolling, and both surface drainage and internal drainage are good. The soil is widely distributed over the county, being most extensive in the southwestern part, but the areas are small and their aggregate acreage is not large. It is associated with the Morton soils and the steeper areas of the Bainville soils. Where associated with the Morton soils it occupies the knolls or higher part of the land, and where associated with steeper Bainville soils it occupies the more smoothly rounded parts of the ridge tops.

The native vegetation on Bainville loam, smooth phase, is predominantly blue grama, with western needlegrass, niggerwool, and little bluestem intermixed. The grass cover is not so uniform and in many places does not so completely cover the ground as does that on areas of Williams loam, and for this reason and because of the somewhat less desirable type of vegetal cover, the carrying capacity of this soil is only from 65 to 75 percent of that of Arnegard silt loam.

Possibly 70 percent of the aggregate area of this soil is tilled, and much of the remaining acreage occupies irregular areas associated with land suitable only for grazing. Wheat is the most extensive crop grown. The rest of the acreage is devoted to other small grains, corn, and hay crops, such as small grains cut green and millet. Yields are notably less than on such soils as Williams loam, wheat during favorable years yielding from 10 to 14 bushels an acre and millet about 1 ton of hay. Because of the relatively high position and somewhat rolling surface, farmers are of the general opinion that wheat is somewhat less subject to rust on the Bainville soils than on such soils as Williams loam and Grail silty clay loam. Its exposed posi-

tion, however, combined with its general lack of structure, make this soil noticeably more subject to soil blowing than are the dark grayish-brown soils of the first group. For this reason, those areas most subject to soil blowing probably should be returned to permanent pasture, and those areas that are continued as cropland should be occupied by a cultivated crop rather than summer-fallowed, in order to avoid exposing the soil to the wind. The value of this soil as cropland is about 55 percent of that of Arnegard silt loam.

Bainville clay loam, smooth phase.—Bainville clay loam, smooth phase, is similar to Bainville loam, smooth phase, except that the texture throughout is clay loam rather than loam, the underlying material is almost everywhere clay of the Fort Union geologic formation, and the color of the surface layer is more nearly gray. The surface is gently rolling, and drainage is good.

There are only 9.2 square miles of this soil. It is widely distributed, but the individual areas are small and scattered. The most extensive acreage is in the west-central and southwestern parts of the county.

The native vegetation is similar to that on Bainville loam, smooth phase, except that weedy and shrubby growth is more common and patches of thinly covered ground are more numerous.

From 60 to 70 percent of the acreage of this soil is tilled, and the remainder is used as permanent grassland. Approximately the same crops are grown on it as are grown on Bainville loam, smooth phase, and yields are about the same. Because of a more cloddy structure due to its finer texture, it is less subject to soil blowing than the loam.

Cherry silty clay loam.—Cherry silty clay loam is a comparatively light colored heavy-textured soil developed on the terraces, or second bottoms, particularly along the Little Missouri River and to some extent along the Missouri River. The 5-inch surface layer is brownish-gray mellow silty clay loam, below which, to a depth of about 16 inches, is olive-drab, splotched with dark gray, silty clay. This layer has fair structure, resembling the prismatic structure common to Williams loam, and the nut-sized fragments that break out crush easily to a crumblike condition. Below this layer the structure is less distinct and the material consists of olive-drab silty clay or clay somewhat mottled with gray, which breaks into large but easily crushed blocks or chunks. Carbonates sufficient to cause effervescence when the soil material is treated with acid are at or within a very few inches of the surface, and almost white flecks or splotches of carbonates are plentiful below a depth ranging from 12 to 16 inches.

Areas of this soil lie at slightly higher elevations than the Havre and Banks soils but generally at not so great an elevation as the Farland soils. The land surface is nearly level to gently sloping, and drainage is sufficient for good crop growth.

The native vegetation is predominately blue grama, with western wheatgrass intermixed. Where overgrazing has not taken place or where areas have been preserved as wild meadowland, western wheatgrass predominates. This soil affords very good grazing and where used for this purpose has a value approximating that of Arnegard silt loam.

Approximately 50 percent of the acreage of this soil is tilled, and, owing to its occurrence in extensive grazing areas, a large proportion

of the cultivated acreage is devoted to subsistence crops, particularly small grains for both grain and hay, other hay crops such as millet, and corn. Some alfalfa is grown but the acreage is small, and the acreage of wheat and flax is comparatively small.

Yields are fairly good. Oats in normally good years yield from 15 to 30 bushels an acre; small grains cut green for hay about 1 ton; and wild hay, most of which is western wheatgrass, from ½ to 1 ton. As cropland, the general productivity of this soil is about 65 percent of that of Arnegard silt loam.

Havre silty clay.—Havre silty clay is the brownish-gray well-drained silty clay soil on the first bottoms along the rivers. The 6-inch surface layer of this soil is brownish-gray or light grayish-brown friable silty clay, which breaks easily into fine granular fragments that are easily crushed. Below this layer the material has a well-defined laminated structure. When removed with a spade the material breaks readily into small flat angular fragments that are very resistant to crushing. The material in some areas where the surface soil has not been disturbed shows this structure within a very few inches of the surface. The color of the material in this layer ranges from dark grayish brown to olive gray and the texture from silty clay loam to silty clay. When the soil is crushed and moistened the color becomes medium gray. Varves, or very thin laminations, of lighter colored very fine sand occur in a few places in this layer. Below a depth of approximately 24 inches the material consists of alternate layers of silty clay loam and yellowish-gray very fine sand. This soil, throughout its entire depth, contains sufficient carbonates to cause effervescence when the soil is treated with acid.

In a few areas included with this soil, the surface soil material is silt loam in texture rather than silty clay, and in such areas the lenses and laminations of sandy material are more prominent and occur nearer the surface.

Havre silty clay occupies areas on the first bottoms of the Yellowstone, Missouri, and Little Missouri Rivers, being most extensive along the Yellowstone and Missouri Rivers. The land surface of most areas is nearly level, and surface drainage is slow. Because of the friable character of the soil material and general presence of coarser laminations below a depth of 24 inches, internal drainage is sufficient to maintain good conditions for plant growth.

The native vegetation on part of this soil evidently was cottonwood trees that ranged in size from about 20 to about 36 inches in diameter, but many open patches, or prairies, were occupied mostly by grasses and shrubby growth. At present the greater part of the untilled land is occupied by a dense growth of brush composed of ash and elm saplings, buckbrush, wild rose, some buffaloberry, and other shrubby growth. Probably 25 percent of the uncleared land supports a medium to fairly dense stand of cottonwood ranging in diameter from 9 to 24 inches, and a few areas support a fair stand of elm and ash ranging in diameter from 2 to 20 inches. Uncultivated land grows up readily to forest and brush.

Probably 90 percent of this soil in the Yellowstone Valley is cultivated and irrigated, and about 35 percent of the acreage in the Missouri Valley and possibly 10 percent of the acreage in Little Missouri Valley are tilled. Dry-farmed areas are productive and yield

as well as the best areas of Williams loam, although the natural fertility of Havre silty clay is lower than that of such soils as Williams loam and Grail silty clay loam. About the same crops are grown on it as are grown on Williams loam, but a larger acreage is devoted to hay crops. Wheat is an important crop and in favorable seasons yields are nearly as large as those obtained on Williams loam and are somewhat more reliable. Other crops commonly grown are oats, barley, flax, and corn. The principal hay crops are small grains cut green and millet. A small acreage is devoted to alfalfa and sweetclover, and some wild hay, principally western wheatgrass, quackgrass, and Canada wild-rye, is cut. Sedges and wild blue lettuce are common on the lower areas. Acre yields of wild hay range from a fraction of a ton to a little more than a ton. Unlike many of the upland wild meadows, the crop is cut annually rather than in alternate years.

Havre silty clay is well adapted to irrigation, and a considerable acreage is farmed under irrigation along the Yellowstone River. Its natural state of fertility is not so high as that of the irrigated Farland silty clay loam, but because of its particularly friable and workable surface soil and generally fairly open subsoil it is the preferred irrigable soil of many farmers practicing irrigation.

The principal crops grown on Havre silty clay within the Lower Yellowstone irrigation project are sugar beets, beans, oats, barley, wheat, alfalfa, and corn. Other crops such as sorghum cane, potatoes, melons, and garden crops are common and are successfully grown. Sugar beets occupy the largest acreage of the cash crops, and the average yield is about 10.5 tons an acre, although somewhat higher yields are obtained under the best farm practices. The average yield of wheat is about 25 bushels an acre, with yields ranging from 30 to 40 bushels commonly reported. Alfalfa yields range from 3 to 5 tons an acre, and the average yield of potatoes is about 135 bushels. Where this soil is well managed, corn yields from 35 to 40 bushels an acre, and yields as high as 65 bushels have been reported.

Crop rotation is commonly practiced, and manure from the dairy herds and from the fattening pens where sheep and cattle are fed byproducts from the beet-sugar factories is applied to this soil. The manure generally is applied and plowed under for either the sugar beets or the corn crop. Some phosphate fertilizer, particularly for sugar beets and alfalfa, is used. The common acre rate of application is from 100 to 125 pounds of 45-percent superphosphate applied at the time of sowing. A suitable rotation recommended by one successful farmer is sugar beets followed by a small grain seeded to alfalfa. The alfalfa is retained for a period of years, depending on the stand and the demand for the land for other crops. Corn follows the alfalfa, which, in turn, is followed by a small grain.

A few small areas elsewhere in the Yellowstone and Missouri Valleys are irrigated by centrifugal pumps operated by tractors. These tracts lie adjacent to the river channels, and few of them occupy more than a few acres. Most of them are devoted to truck crops, such as potatoes, melons, cabbage, and tomatoes, which are sold to local markets. Yields of all these crops are satisfactory.

Areas of Havre silty clay that are not cropped or used for wild meadow are devoted to grazing. Where the brush and tree growth

is heavy, the value of the land for grazing is not high, but open areas and areas where the tree and brush growth is not so thick as to prevent the growth of sweetclover are valuable as range land. The carrying capacity of open areas is equal to that of Arnegard silt loam, and where sweetclover has become established on such areas it is probably higher.

The value of this soil for dry farming is from 80 to 90 percent of that of Arnegard silt loam, and where the land is irrigated its productivity is several times that of dry-farmed areas.

Table 5 gives the results of mechanical analyses of samples of the surface soil, subsurface soil, and subsoil of Havre silty clay.

TABLE 5.—*Mechanical analyses of Havre silty clay*

Sample No.	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
352032	Surface soil, 0 to 1 inch	1.3	0.4	0.3	1.0	2.8	34.6	59.7
352033	Subsurface soil, 1 to 12 inches	.1	.1	.0	.2	.6	38.6	60.3
352034	Subsoil, 12 to 15 inches	0	0	.1	.2	.3	19.7	79.7
352035	Subsoil, 15 to 16 inches	0	.2	1.4	33.4	33.7	17.1	14.2
352036	Subsoil, 16 inches+	0	.1	.2	1.0	.8	17.6	80.3

Bowdoin clay.—Bowdoin clay differs from Havre silty clay primarily in having a higher content of clay in the upper layer and in that the underlying material extends to a greater depth. Consequently the Bowdoin soil is less well drained and less easily worked. The surface layer, which is a few inches thick, consists of brownish-gray friable clay. Below this is olive-gray fairly friable clay similar to the upper subsurface layers of Havre silty clay, except that the material is free of the coarser sandy lenses and everywhere extends to a depth of several feet before sandier material is reached. Carbonates sufficient to cause effervescence when the material is treated with acid are present throughout this soil.

About 1 square mile of this soil immediately northeast of Dore is very salty and consequently is unsuitable for crop production. Throughout most of this area white salt flecks are abundant within a few inches of the surface.

Bowdoin clay occurs only in the Yellowstone River Valley, where it is associated with Havre silty clay. It lies at or slightly below the elevation of the Havre soil. The surface of Bowdoin clay is nearly level. Internal drainage and surface drainage are very slow. Consequently, when thoroughly moistened, the soil retains the excess moisture for a longer time than does Havre silty clay, and considerable difficulty attends the use of irrigation water and tillage. With the exception of the salty area near Dore, however, more than 90 percent of the land is successfully irrigated and cropped. Practically all crops common to the county are grown, and average yields approach those obtained on Havre silty clay. Good stands, particularly of wheat, alfalfa, beets, and beans, have been observed. The value of Bowdoin clay as irrigable land is probably from 75 to 85 percent of that of Havre silty clay.

SANDY LOAM SOILS OF THE SMOOTH TO UNDULATING UPLANDS AND ALLUVIAL LANDS

The subgroup of sandy loam soils of the smooth to undulating uplands and alluvial lands comprises grayish-brown or dark grayish-brown sandy loams underlain by sandy material. The prismatic structure is lacking, and the only evident structure is a weakly developed blocky condition of the topmost layer, which ranges from 8 to 14 inches in thickness.

These soils differ considerably in regard to their physiographic position and depth to carbonates, but they have several characteristics that make them different from the soils of the first two subgroups. They are decidedly more subject to soil blowing, and their water-holding capacity is lower, but they are capable of converting the light summer showers to better use for the crops growing on them, they are more easily tilled and can be worked under a wider range of moisture conditions, and the deeper rooted row crops are particularly suited to them. The natural supply of plant nutrients is markedly less than is common to the soils of the subgroup of dark grayish-brown loam and clay loam soils, and the native vegetation is less desirable for grazing.

Flasher fine sandy loam.—Flasher fine sandy loam is a grayish-brown sandy loam soil of the uplands. The 5-inch surface soil is grayish-brown or dark grayish-brown crumbly fine sandy loam. Below this layer and continuing to a depth of about 16 inches, the material is brown and is a little finer, the texture ranging from heavy fine sandy loam to loam. It breaks into irregular chunks that are easily crushed. Below this layer the color becomes lighter and the texture sandier, and below a depth of 22 inches the soil material is yellow or brownish-yellow fine sand. Effervescence with acid usually takes place at a depth ranging from 10 to 25 inches below the surface, but on the more exposed parts, or knobs, the surface-soil material effervesces. In some places the material below a depth of 20 inches is olive-drab clay till.

Several areas in the vicinity of Grassy Butte have brown relatively hard sandstone fragments throughout the soil and on the surface. A few areas of very fine sandy loam, which appear to be wind-blown or loessial material, are in T. 150 N., R. 104 W. The surface soil of these areas, to a depth of approximately 7 inches, is light-brown very fine sandy loam. The material immediately below this layer is brown very fine sandy loam, which breaks to fragments that are easily crushed. White flecks of carbonates are at a depth of about 24 inches. At a depth of about 28 inches is light-brown soft very fine sandy loam or silt loam. This soil is noticeably free from pebbles or boulders. A few areas of Flasher fine sandy loam, particularly in secs. 2, 3, 10, and 11, T. 145 N., R. 98 W., have a noticeably darker surface layer, the organic part appearing black rather than dark brown. Below a depth of 5 or 6 inches the material grades rapidly into light-colored fine sand.

Flasher fine sandy loam includes an aggregate area of 62.6 square miles. The largest areas are in T. 145 N., R. 98 W.; T. 146 N., R. 98 W.; and T. 146 N., R. 99 W.; several areas of approximately one-half square mile each are in Bear Den Township; and less extensive areas

are elsewhere, particularly in North Fork, Schafer, Ideal, and Arnegard Townships. The very fine sandy loam variation occupies several of the gently rolling ridge tops bordering the Yellowstone Valley. Practically all of it lies within 1½ miles of the edge of the valley.

Flasher fine sandy loam is especially susceptible to soil blowing when unprotected by vegetation. The exposed areas frequently lose a large part of the surface soil, and the lighter colored subsoil is exposed. When the land is first cleared, the tenacious roots of the native grasses and upland sedges hold the soil together and prevent erosion, but the roots serve in this capacity for only 2 or 3 years after tillage is begun.

The native vegetation on this soil is somewhat less desirable for grazing than that on Morton loam. Blue grama and niggerwool are the dominant species, and upland sedge and western needlegrass are common. The last three are much more abundant on this soil than on Morton loam or Williams loam. The vegetation on most of the sandier areas includes patches of sandgrass. Because this soil is drier and supports a less desirable type of vegetation, it will support only from 40 to 60 percent of the number of cattle as will Morton loam or Williams loam. In very dry years, however, vegetation thrives better on this soil than on the loams and silt loams.

Much of this soil is devoted to the production of crops. Small grains, especially wheat, occupy much of the cultivated land, and many farmers prefer it for potato growing. Where general farming is practiced, corn is commonly grown on it. Sweetclover and millet, as well as small grains, are commonly grown for hay, and fair yields of alfalfa are produced on areas that receive run-off from adjoining higher lying soils. Yields of small grain and hay range from 50 to 60 percent of those obtained on Arnegard silt loam.

The greatest handicap, other than lack of moisture, experienced in cultivating this soil is soil blowing, as much soil material is removed when the tilled surface soil is unprotected by growing vegetation, and the blowing sand frequently ruins young crops. Owing partly to the danger of blowing, fall plowing and summer fallowing are not commonly practiced on the fine sandy loam soils. As in the coarser textured areas of the loam soils, the heavier textured areas of Flasher fine sandy loam commonly develop a hardened layer, or plow sole, as a result, evidently, of continuous tillage with moldboard plows. This hardened layer interferes with the development of plant roots and the movement of soil moisture. The most practical means of remedying this condition is to use a subsoiling implement for the purpose of breaking up the hardened layer.

This soil, as well as other fine sandy loam soils, has one marked advantage over the finer textured soils, namely, crop response to light summer showers, which is considerably more marked because a greater proportion of the moisture that falls is absorbed and is made available to the plants.

Cheyenne fine sandy loam.—Cheyenne fine sandy loam resembles Flasher fine sandy loam, except for its more nearly level surface and its position on alluvial terraces. The surface soil is dark grayish-brown friable fine sandy loam or very fine sandy loam that breaks easily into soft fragments. From a depth of about 6 inches to approximately 15 inches the material has slightly finer texture and somewhat

firmer structure than the surface soil, and it digs out in fragments that crush easily to a friable mass. Below this layer the material becomes light brown, and the texture grades into fine sand or gravelly sand. The depth at which carbonates are sufficient to cause effervescence is variable, ranging from 14 to 25 inches below the surface in the smoother areas, but bordering the streams and on exposed swells or knolls, carbonates occur at or within a few inches of the surface.

A few areas that consist of very dark grayish-brown soil material to a depth of 18 or 20 inches are included with Cheyenne fine sandy loam. These are Arnegard fine sandy loam, but, owing to their small extent, they are not indicated separately on the soil map. Another variation includes areas having a light grayish-brown or grayish-brown very fine sandy loam surface soil underlain at a depth ranging from 18 to 30 inches by dark-brown clay. The sandy material in many places grades into light grayish-brown very fine sand before the clay is reached. Most of these areas are natural levees along streams.

The native vegetation on Cheyenne fine sandy loam is similar to that on Flasher fine sandy loam, blue grama and niggerwool predominating. The carrying capacity of this soil as range land is about 40 percent of that of Arnegard silt loam.

Cheyenne fine sandy loam lies on the older benches of the larger stream valleys. Where it is associated with finer textured soils in the valleys of the larger creeks, it occupies the areas nearer the streams. It is not of widely distributed as Farland silt loam, with which it is commonly associated. The most extensive areas are along Tobacco Garden Creek and in the irrigated section of Yellowstone Valley. Most of the areas along Tobacco Garden Creek are fine sandy loam in texture, whereas most of the areas in Yellowstone Valley are more nearly very fine sandy loam. The surface of most areas of this soil is gently billowy or very gently undulating. Drainage is good, and for the sandier areas it is somewhat excessive.

From 80 to 90 percent of the acreage of this soil in Yellowstone Valley is irrigated and tilled, and about 60 percent of that outside the valley is tilled. Wheat occupies a large part of the dry-farmed land, and corn is a common crop, although the acreage is considerably less than that of wheat. Rye, though well adapted to this soil, is not commonly grown, but barley, oats, and flax are common crops, and some hay is produced. The areas of more loamy soil are fairly productive. Yields on them range from 60 to 70 percent of those obtained on Arnegard silt loam, but yields on the areas of more sandy soil are not more than 40 percent of those obtained on Arnegard silt loam. Corn, rye, and potatoes are well adapted to the Cheyenne soil, and the few areas that are favorably located in regard to soil moisture are capable of producing good yields of alfalfa. Because of their great susceptibility to soil blowing, the areas of more sandy soil are probably best used as grassland. Summer fallowing and fall plowing are not practiced. Because of the danger of severe soil blowing, farmers should keep this soil occupied by crop residue and grass as much of the time as possible.

The irrigated areas of Cheyenne fine sandy loam are productive, and all crops common to the irrigation district are successfully grown on it. Yields approximate those obtained on such soils as Havre silty

clay and Farland silty clay loam. The natural fertility is somewhat lower than that of Farland silty clay loam, but the greater ease with which the Cheyenne soil is managed under irrigation at least partly offsets this disadvantage.

Banks very fine sandy loam.—The characteristics of Banks very fine sandy loam vary considerably. This soil includes the well-drained soils of the river bottoms, which have a texture coarser than that of the silt loam areas included with Havre silty clay and finer than that of Banks loamy fine sand. The surface soil is light-brown very fine sandy loam that breaks into weakly brittle chunks. In most places the material, below a depth of approximately 7 inches, is yellow fine sand, although many areas have a subsoil composed of alternate lenses of sand and clay. The surface soil of several areas is fine sand or fine sandy loam, which is underlain by silty clay or lenses of sand and clay; and a few areas have a thin brownish-gray friable silty clay surface layer, ranging from 4 to 10 inches in thickness, underlain by pale-yellow fine sand. Carbonates sufficient to cause effervescence when the soil is treated with an acid are at or within a few inches of the surface.

Banks very fine sandy loam is widely distributed throughout the valleys of the Missouri, Yellowstone, and Little Missouri Rivers. In general, the areas are larger and more continuous in the Missouri and Yellowstone Valleys than in the Little Missouri Valley.

The surface of this soil is slightly hummocky to billowy, especially in the more sandy areas, where the range in relief is from 2 to 10 feet. Many of the more billowy areas consist of narrow ridges or swells, ranging from 20 to 200 feet in width, of Banks loamy fine sand separated by shallow troughs of heavier soil material. The lower lying soil consists of 6 or 8 inches of soil material, ranging in texture from very fine sandy loam to silty clay, underlain by fine sand. Owing to the impracticability of separating the soils of the swells and troughs, they are all included with Banks very fine sandy loam in mapping.

Surface drainage of this soil is not established, but because of the sandy character of the subsoil, most of the areas are inclined to be excessively drained and consequently droughty.

The native vegetation probably was cottonwood. At present much of the land is covered by a medium to dense growth of cottonwood, ash saplings, and brush. Possibly 50 percent of the land is cleared, and a large proportion of the cleared land is cropped, mainly to corn. A small acreage is devoted to sweetclover and alfalfa. A few cleared areas are used as wild meadowland, although yields of the natural grasses are low and many of the grasses are not so palatable as those on the more loamy soils. Yields of crops grown on this soil are fair to good. Corn and rye probably are the crops best adapted to it.

The agricultural value of Banks very fine sandy loam varies considerably. The more sandy areas are less productive and support a less palatable type of native grass, but many of the more loamy areas produce yields approaching those obtained on Havre silty clay. The most productive areas are those having a very fine sandy loam surface layer underlain at a depth of 8 or 10 inches by silty clay. The value of Banks very fine sandy loam when cleared is from one-third to two-thirds that of Havre silty clay. Banks very fine sandy loam is the

principal soil used for crops in the Little Missouri River Valley. Cleared areas of this soil are particularly desirable throughout this part of the county because of the comparative scarcity of soils capable of producing forage crops. The grazing value of the uncleared areas is relatively low because of the small amount of desirable grass growth. A few areas have a volunteer cover of yellow sweetclover, which enhances the grazing value considerably. The average value of cleared areas for grazing is about 30 percent of that of Arnegard silt loam.

Very little if any of this soil is irrigated. The areas underlain by silty clay should be suitable for irrigation, provided the surface is not too uneven, but the areas underlain by fine sand are very porous and probably not suitable for irrigation unless water can be obtained at a moderate cost.

SOILS USED PRINCIPALLY FOR GRAZING

The broad group of soils used principally for grazing includes those that, for one or more reasons, are not commonly considered suitable for crops requiring tillage. The principal factors that prevent these soils from being suitable for tillage are stoniness, steepness of slope, extremely fine or coarse textures, poor drainage, the presence of an alkali claypan and clay spots, and excessive quantities of salts. As previously explained, all stoniness is indicated on the map by stone symbols and is not a characteristic used in the soil designation; consequently areas of soils described as suitable for crops are actually suitable only for grazing in those places where stone symbols indicate an abundance of stones. The other characteristics that limit the use of soils to grazing, such as steepness of slope, poor drainage, and other unfavorable features, are recognized in the following subgroups and determine, to a marked degree, the value or usefulness of these soils for grazing.

DARK GRAYISH-BROWN SOILS OF THE ROLLING UPLANDS AND SLOPES

The subgroup of dark grayish-brown soils of the rolling uplands and slopes includes those that primarily, because of their steep slope, are not suitable for crops requiring tillage, although a considerable proportion of the acreage of some of them is devoted to such crops. Soils and other agronomic factors related to the steepness of slope are a greatly variable depth of the more fertile soil layers, great susceptibility to water erosion, considerable loss of soil moisture through run-off to the detriment of the crops to be grown on them, and the great difficulty or impossibility of using machinery on them.

Williams loam, rolling phase.—Williams loam, rolling phase, differs from typical Williams loam in having a noticeably steeper slope. Although this soil, in general, resembles the typical soil, the character of the soil layers is markedly variable, particularly as to the thickness of the brown layer. The very small acreage that lies on the smoothest parts of the ridge tops and slopes and many of the narrow strips along the drainageways is like the typical soil, but that on the steeper slopes is considerably more shallow over the gray layer, the depth ranging from 5 to 10 inches. Much of the soil contains considerable gravel throughout, and on the knobs, with an area of

one-fourth to one-half acre, the olive-gray gravelly clay subsoil outcrops at the surface. In such places carbonates are abundant throughout. Many areas of Williams loam, rolling phase, are so stony as practically to prevent tillage even where the slope is not too steep. Such areas are indicated on the map by stone symbols.

This soil is extensive throughout the northern part of the county, that is, that part having a covering of glacial till. Where the areas are extensive the relief may be described as rolling, the degree of slope ranging from 8 to 20 percent. Some small areas occur as rather steeply sloping strips between areas of level soils. Surface drainage in all places is excessive, and the sloping areas are subject to water erosion.

The native vegetation is variable. That on the smoother areas is similar to that on typical Williams loam, and here blue grama and western needlegrass predominate, with numerous other desirable grasses, such as junegrass and western wheatgrass. The more sloping areas support a less desirable type of vegetation for grazing. Blue grama dominates, but niggerwool and, on the steeper knobs, little bluestem are common.

Although this soil is designated as being used principally for grazing, between 20 and 30 percent of the acreage is tilled. Wheat is the dominant crop, and the rest of the cultivated land is devoted to oats and barley (for both grain and hay), millet, corn, and flax. Yields range from 40 to 60 percent of those obtained on typical Williams loam. Many farmers state, however, that during years of heavy infestation of rust the best yields of wheat are obtained on areas of the more rolling soils, such as Williams loam, rolling phase, but this soil and the rolling phases of other soils are too variable in natural fertility and too subject to erosion, lose too much moisture as a result of run-off, and offer too much difficulty in the use of farm machinery to justify the use of any but the smoothest parts for crops requiring tillage.

This soil is considered desirable grazing land and as such has a carrying capacity ranging from 50 to 60 percent of that of Arnegard silt loam.

Williams clay loam, rolling phase.—Williams clay loam, rolling phase, is similar to Williams loam, rolling phase, except that the texture of the 5- or 6-inch surface layer is clay loam rather that loam; a greater proportion of Williams clay loam, rolling phase, is gravelly; and boulders are very abundant in places, such areas being indicated on the map by symbols. The relief is rolling, the land is excessively drained, and the soil is subject to water erosion.

This soil is more widely distributed and more extensive than Williams loam, rolling phase. The largest areas are in a belt just south of the Missouri River Badlands, especially in Riverview and Elm Tree Townships and in T. 153 N., R. 96 W.

Possibly 25 percent of this soil is tilled, but only a small acreage is considered suitable for this purpose, because of its low productivity, susceptibility to erosion, general stoniness, and the difficulty it offers to the use of farm machinery. Wheat is the most widely grown crop. The rest of the tilled acreage is devoted to other small grains, hay crops, and corn. This is considered desirable grazing land and as such has a carrying capacity ranging from 50 to 60 percent of that of Arnegard silt loam.

Williams clay loam, steep phase.—Williams clay loam, steep phase, includes all steep areas of soils of the Williams series. The gradient or slope of this soil is 20 percent or more. The surface soil is thin, in few places being more than 4 inches thick. It consists of heavy loam or clay loam that is fairly friable and almost everywhere contains gravel, many areas containing so much gravel as to make difficult the removal of the surface soil from place with a spade. Carbonates are abundant from the surface to a depth ranging from 10 to 12 inches. Olive-drab till is reached at a depth ranging from 3 inches to 2 feet. In most places the till is thin, the stratified clay beds of the Fort Union formation lying at a depth of a few feet, and in places they are exposed at the surface. Bare clay spots occur throughout some of the steeper areas, and boulders in variable numbers are on the surface, in places being so numerous as to diminish the carrying capacity of the land as grazing land.

This soil occurs only in the northern part of the county where a layer of glacial till is on the surface. It occupies steeply rolling areas ramified by deep drainageways that extend from the uplands across the Missouri Badlands to the river bottoms.

Owing to the thin surface soil and the great abundance of gravel, the grass cover is thin and contains some less desirable species than those growing on the less steep areas of Williams loam and Williams clay loam. The carrying capacity of this soil for grazing is from 20 to 30 percent less than that of Williams loam, rolling phase. It is devoted entirely to grazing and should be kept in such use.

Morton loam, rolling phase.—Morton loam, rolling phase, differs from Morton loam primarily in having a more rolling surface and a more variable depth to which the dark grayish-brown material extends. In the more level areas this material extends to a depth comparable to that in the typical soil, but on the slopes it forms only a very thin layer. On a few knobs none of the dark grayish-brown material occurs and the olive-gray silt and clay of the underlying layers are exposed at the surface. Carbonates are abundant at a correspondingly slight depth. A few areas of this rolling soil have an alkali claypan, and in a few small areas hard dense angular rocks, ranging from a few inches to 3 feet in diameter, are on the surface. These two variations are indicated on the soil map by appropriate symbols. The relief of this soil is rolling or markedly sloping; drainage is excessive, and the land is subject to erosion.

This is not an extensive soil. It occupies small areas associated with areas of typical Morton loam. Most of the acreage is in the southeastern part of the county, where several areas are in the vicinity of Grassy Butte, especially west of the village; numerous areas are in Northfork and Bear Den Townships; and some occur throughout the rolling sections, where the soil material is not derived from glacial till.

The native vegetation on the more level areas is similar to that on typical Morton loam, but the more sloping and exposed areas, which comprise a great part of the total acreage of this soil, support several of the less desirable species of grasses, principally niggerwool, little bluestem, and plains muhly.

From 20 to 30 percent of the acreage of this soil is tilled, but parts of this are not suitable for tillage. It is the common opinion of farm-

ers that tillage has been extended over the rolling lands to a greater extent than long-time profitable returns will justify. Wheat is the most extensively grown crop, and the rest of the cultivated acreage is devoted to other small grains (for grain and hay), flax, corn, and millet for forage. Yields are extremely variable, ranging, according to the slope and corresponding soil condition, from a small percentage to 70 percent of those obtained on typical Morton loam. As grazing land, this soil has a carrying capacity ranging from 50 to 60 percent of that of Arnegard silt loam.

Morton clay loam, rolling phase.—Morton clay loam, rolling phase, is similar to Morton loam, rolling phase, except that the texture of the surface layer is clay loam rather than loam. The surface is rolling, drainage is excessive, and the soil is subject to erosion. This is not an extensive soil. It occurs only in that part of the county having no covering of glacial till. Most of the areas are associated with typical Morton clay loam, and very few of them are within the Little Missouri River Badlands.

Between 20 and 30 percent of the acreage is tilled. The soil, in general, is not desirable cropland because of its variable and low productivity, the difficulty experienced in the use of farm machinery, and its droughty and erosive character; but the more level areas are fairly productive and, according to some farmers, are satisfactory for crop production. Wheat is the main crop, although other small grains and hay crops are commonly grown. Yields are variable and, as previously indicated, average markedly lower than those obtained on Morton loam and Morton clay loam. This soil, with few exceptions, is most profitably used as grazing land, and as such it has a carrying capacity ranging from 50 to 60 percent of that of Arnegard silt loam.

Flasher fine sandy loam, rolling phase.—Flasher fine sandy loam, rolling phase, includes areas of Flasher fine sandy loam having a rolling relief. Because of the more rolling surface, much of the browner surface material has been removed by the wind, especially where the land has been cultivated. The surface soil on the less rolling areas is similar to that of Flasher fine sandy loam, but many of the steeper and more exposed areas have little or no surface soil and the brownish-yellow fine sand is exposed. Where soil of this phase is associated with Williams loam, a considerable quantity of gravel occurs throughout the surface soil and subsoil, and in places the material below a depth of 2 feet is olive-drab gravelly clay till.

Flasher fine sandy loam, rolling phase, is widely distributed, mostly in small scattered areas, much of it being associated with Flasher fine sandy loam. The most extensive areas are in Patent Gate, Arnegard, and Ideal Townships and in the southeastern part of the county. The total area is 54.8 square miles.

The grass cover is similar to that on typical Flasher fine sandy loam, blue grama and niggerwool predominating. Little bluestem and sandgrass comprise a large proportion of the cover on the more sloping areas.

Only a very small acreage of this soil is tilled. Wheat, other small grains, corn, and flax are the most commonly grown crops. Because of the droughty character of this soil, its susceptibility to wind erosion, and its naturally low state of fertility, yields are particularly

low and variable. Very little if any of the soil is suitable for tillage, consequently it should be devoted to grazing. Although the quality of the grass vegetation is less desirable than that on such soils as Morton loam, this is considered desirable grazing land, with a carrying capacity about 30 percent of that of Arnegard silt loam.

Grail silty clay loam, slope phase.—Grail silty clay loam, slope phase, differs from typical Grail silty clay loam principally in having a more sloping relief, with gradient ranging from about 6 to 18 percent. Surface drainage of the slope phase is more rapid and somewhat excessive, eroded tracts are more common, and the surface soil is thinner.

The total acreage of Grail silty clay loam, slope phase, is small, and the areas are few and scattered. A fairly large area is in secs. 29, 32, and 33 of Schafer Township.

The native vegetation is similar to that on typical Grail silty clay loam, blue grama and western wheatgrass predominating. The grass cover in many places is thin, particularly adjoining the upland, where the surface slope, in general, is steepest and where the land is more subject to surface wash by run-off from the higher lying land.

Approximately 35 percent of the acreage of this soil is tilled. Wheat is the principal crop, but other small grains, corn, and hay crops are commonly grown. The less sloping areas are fairly satisfactory as cropland, as the average gradient is less and the natural fertility is somewhat greater than for the rolling soils previously described. Crop yields are somewhat more variable and probably range from 15 to 30 percent less than those obtained on Williams loam. This land is farmed about as is typical Grail silty clay loam, but more care must be taken to avoid erosion during periods of comparatively heavy precipitation. The steeper areas are best used as grazing land or wild meadowland. In areas protected from overgrazing, western wheatgrass generally becomes dominant and will produce fair yields of hay. As grazing land, this soil has a carrying capacity ranging from 60 to 70 percent of that of Arnegard silt loam.

GRAYISH-BROWN AND BROWNISH-GRAY SOILS OF THE ROLLING UPLANDS AND SLOPES

This subgroup of grayish-brown and brownish-gray soils of the rolling uplands and slopes includes immature soils developed on rolling upland areas and on steep slopes. The steepness of the slopes, at least in part, has prevented the formation and accumulation of a dark humus layer over the greater part of the soil. One reason for the thinness of the dark-colored layer is that the greater part of the scant rainfall runs off the slopes and leaves the soil immediately below the surface in a dry condition. Vegetation is sparse over such soil, and very little organic matter is incorporated into the surface layer. The processes of weathering and soil formation go on very slowly, and only a very thin soil overlies the parent rock. A second reason for the thin soil is that erosion is more rapid on these slopes than on smoother land, and the dark-colored layer is removed almost as rapidly as it forms and in places is entirely removed. As a result of these conditions, a dark thick surface soil, comparable to that of the smooth uplands, has developed only in small areas, and over the greater part of the land the surface soil either is thin and only

moderately dark or is absent, and light grayish-yellow or light-brown material is exposed. The general effect in looking across these areas is that the soils are markedly light colored.

Because of their comparatively droughty character, low natural fertility, susceptibility to both wind and water erosion, and the difficulty they offer to the use of farm machinery, a large proportion of the area of these soils is not suitable for crops requiring tillage, and it is commonly conceded that a large part of the tilled acreage, as evidenced by low yields and soil deterioration, would be more profitably utilized as grazing land. A large proportion of the grazing land of the county is included in the soils of this subgroup, but their carrying capacity is considerably less than that of the more level dark-brown soils, such as Grail silty clay loam and Morton loam.

Patent clay loam, slope phase.—Patent clay loam, slope phase, differs from typical Patent clay loam essentially in having a greater slope, the gradient ranging from 7 to about 18 percent. Because of this greater slope, the soil is more variable and the depth to the underlying olive-gray clay is less, but the variation in the character of the soil on the slopes, in general, is not so great as that of soils of the rolling land.

The surface layer of Patent clay loam, slope phase, is brownish-gray clay loam, very thin or lacking on the more exposed knobs and slopes. The underlying material grades into light brownish-gray or olive-gray material, the topmost 5- or 6-inch layer breaking easily, if disturbed, into nut-sized mellow fragments. Below this is olive-gray clay similar to that underlying typical Patent clay loam. Carbonates sufficient to cause effervescence when the soil is treated with acid are within a depth of 12 inches from the surface.

This soil is less extensive than typical Patent clay loam. It is associated with the typical soil distributed widely over the county. The largest areas are in T. 146 N., R. 102 W.; T. 147 N., R. 102 W.; and T. 146 N., R. 104 W. Many smaller areas are in Blue Butte Township and the immediately surrounding townships and in the southwestern part of the county.

The grass cover is similar to that on typical Patent clay loam, the dominant species being blue grama, with smaller quantities of western wheatgrass. Less desirable species and a thinner stand are on the most exposed patches or knobs.

Probably 30 percent of this soil is tilled. Wheat is by far the dominant crop, with other small grains and hay crops occupying most of the remaining tilled acreage. Yields are markedly less and are more variable than those obtained on typical Patent clay loam and range from 35 to 50 percent of the yields on Williams loam. Because of its greater susceptibility to erosion and lower natural fertility, only the smoothest areas of this soil are suitable for tillage, and the rest of the land is best utilized as grazing land. Although the carrying capacity of this soil is only about 60 percent of that of Arnegard silt loam, it is considered desirable grazing land, principally because of the good type of grasses forming the cover.

Bainville loam.—Bainville loam is a rolling light-colored loam soil of the upland part of the county. The more level areas are similar to Bainville loam, smooth phase, but, as a large proportion of the land is more sloping, the thickness of the grayish-brown surface layer

is considerably more variable. Whereas on the more level areas the grayish-brown loam surface soil is about 5 inches thick, on the more exposed places, which include a large proportion of the area of this soil, it is only a few inches thick, and in places it is entirely lacking and the highly calcareous olive-gray silt or clay parent material is exposed at the surface. The depth at which carbonates are sufficiently abundant to cause effervescence when the soil is treated with acid ranges from the surface to 5 inches beneath.

Bainville loam is developed from very fine sand, silt, and clay beds of the Fort Union geologic formation. The surface is rolling, much of the soil occupying narrow rounded ridge tops, extensive slopes ranging in gradient from 8 to 20 percent, and narrow but fairly smooth drainageways. Surface drainage is excessive, except for the narrow strips along the drainageways. The native vegetation differs with the slope. On the more level parts of the ridge tops and along the drains, blue grama and western needlegrass predominate, but on the slopes little bluestem and niggerwool are commonly intermixed with it. The coarser or more sandy areas are covered principally by niggerwool and little bluestem.

Bainville loam is fairly extensive, but few of the individual areas cover more than 150 or 200 acres. Much of this soil occurs throughout the southwestern part of the county, the most extensive areas being in T. 148 N., R. 104 W., and numerous areas are widely distributed over much of the remainder.

Between 20 and 30 percent of this soil is tilled, and most of the cultivated land is devoted to wheat, other small grains, and hay crops. Yields are comparatively low and variable, owing to the low natural fertility and the droughty character of the soil. Because of its low productivity, its marked susceptibility to soil blowing and water erosion, and the difficulty of handling machinery on much of it, by far the larger part is best utilized as grazing land. As such, its carrying capacity is about 50 percent of that of Arnegard silt loam.

Bainville loam, steep phase.—Bainville loam, steep phase, differs primarily from typical Bainville loam in having a steeper slope. The gradient ranges from 20 to as much as 60 percent. This soil includes all steep areas of upland soil developed from material of the Fort Union formation that average a loam in texture. The surface soil varies more than does that of the typical soil. Very small included areas having a gentle slope are not subject to erosion and have a 10- or 12-inch surface layer that is as dark as that of Morton loam. Those areas having steeper slopes, which include a large proportion of the total acreage, have very little brown material on the surface, and the color is predominantly brownish yellow or gray.

Bainville loam, steep phase, is more extensive than the typical soil, and the two soils are closely associated in many places. Soil of the steep phase is extensive throughout the Badlands part of the county, but very few areas are associated with the gently rolling till plains. The most extensive areas are in T. 148 N., R. 104 and 105 W., and T. 149 N., R. 104 W.

None of this soil is suitable for tillage. The grass cover is similar to that on typical Bainville loam, except that such grasses as little bluestem and niggerwool are more common, and in places, creeping cedar occupies the steepest slopes. A small amount of brush, such as

buckbrush, juneberry, and buffaloberry, grows on the north-facing slopes and in the deeply cut drain heads. In places, particularly on the south-facing slopes, steep or nearly precipitous bare spots, ranging from 1/10 to 1 acre in size, are numerous, in some places occupying 20 percent of the land. The carrying capacity of this soil as grazing land is about 25 percent of that of Arnegard silt loam. Because of the steeply rolling relief of the more extensive areas, they afford some protection from winds and storms and consequently are preferred for winter grazing.

Bainville clay loam.—Bainville clay loam is a rolling light-colored clay loam of the upland part of the county. It is similar to Bainville loam except that its texture is clay loam rather than loam and the surface layer is grayer. The surface is rolling. The land consists of narrow ridges and drainageways with intervening slopes that range in gradient from about 8 to 20 percent, the slopes occupying a large proportion of the acreage. The surface layer on the slopes consists of brownish-gray or grayish-brown friable clay loam only 2 or 3 inches thick. This is underlain by olive-gray friable clay. Carbonates sufficient to cause effervescence when the soil is treated with acid are general throughout this soil, especially on the slopes.

The native vegetation consists principally of blue grama and little bluestem with numerous other plants, such as skeletonweed and purple coneflower, intermixed, especially on the steeper slopes. Little bluestem dominates the vegetation on the steeper areas, and blue grama dominates along the draws and on the more level parts of the ridge tops.

Only a small part of this soil is tilled, and in general it is poorly suited to crops because of its low state of fertility, droughtiness, susceptibility to water erosion, and the difficulty involved in working the land. Wheat and other small grains are the most commonly grown crops, and yields are low and variable. As grazing land, its carrying capacity is about 50 percent of that of Arnegard silt loam.

Bainville clay loam, steep phase.—Bainville clay loam, steep phase, is similar to Bainville loam, steep phase, except that the average texture is clay loam rather than loam. It differs from typical Bainville clay loam primarily in having a steeper slope, the gradient ranging from 20 to about 60 percent. The surface layer is very thin and in places is lacking, but where it exists it is 2 or 3 inches thick and consists of grayish-brown or brownish-gray friable clay. Below this is olive-gray clay of the Fort Union geologic formation. Lime nearly everywhere is abundant from the surface downward. Included with this soil as mapped are a few small areas of Morton loam and Morton clay loam, most of which are on the smoother parts of the narrow ridge tops.

The native vegetation is largely little bluestem, with some nigger-wool and grama intermixed. Creeping cedar, shrubs, and brush grow on some of the north-facing slopes, and, because of less favorable temperature and moisture conditions for plant growth, many bare spots occur on the south-facing slopes.

This soil is widely distributed. Extensive areas occur throughout the Badlands, especially in the less broken areas, and smaller areas, ranging from 50 to 400 acres, are in other parts of the county. The total area is 206 square miles.

This soil is devoted entirely to grazing and has a carrying capacity about 25 percent of that of Arnegard silt loam. The value of the more extensive areas is enhanced somewhat by the protection from winter storms afforded to livestock by the steep slopes.

Flasher loamy fine sand.—Flasher loamy fine sand is a brown or grayish-brown sand soil in the rolling sandy upland parts of the county. It is developed from the sandy layers of the Fort Union geologic formation. As is true of the Bainville soils, the relief of this soil is rolling and the soil character varies widely. The smoother parts, which comprise a comparatively small proportion of the total area, have a 6-inch surface layer of brown or grayish-brown loamy fine sand that readily falls apart to weak structural lumps or soft fragments. Below this the color gradually becomes lighter and the structure weaker to a depth ranging from 15 to 20 inches, where the material is olive-gray or olive-drab loose fine sand. The soil contains no visible accumulation of carbonates and does not effervesce with acid above a depth of 14 inches. A large part of the area of this soil has a marked slope, the gradient ranging from 8 to 20 percent. Within the steeper areas the brown color extends to only a slight depth and carbonates sufficient to cause effervescence are at or within a few inches of the surface.

This soil is fairly extensive and is widely distributed over the county. Several areas are east and south of Alexander, throughout the eastern half of Schafer Township, and throughout much of Loyal Township.

Because of the rolling relief and sandy character of this soil, it is excessively drained and markedly subject to soil blowing when tilled; and because of these characteristics and its low natural fertility, it is not suitable for crops requiring tillage. This is commonly recognized by farmers, as evidenced by the fact that very little of it has been plowed.

The native vegetation on the more level areas is a mixture of niggerwool, western needlegrass, and blue grama. The more sloping areas, which include by far the greater part of the acreage, support a cover principally of niggerwool, with some blue grama, western needlegrass, and numerous dense patches of sandgrass. Although this type of vegetation is much less desirable than that growing on Patent clay loam or Williams loam, this soil is considered desirable grazing land. Its carrying capacity is about 20 percent of that of Arnegard silt loam.

Flasher loamy fine sand, steep phase.—Flasher loamy fine sand, steep phase, is differentiated from the typical soil by its steeper slope. The gradient is more than 20 percent, and the relief ranges from steeply rolling to broken. Because of the steeper slope, the surface layer is more variable in color and thickness, and barren sand spots and outcrops of soft sandstone are numerous.

This soil is more extensive and occurs in larger bodies than either the typical soil or the smooth phase. The largest areas are southeast and south of Schafer, and smaller bodies occur throughout much of the county, especially east and northeast of Grassy Butte and in the southwestern part.

The native vegetation is similar to that on the typical soil, but it includes a larger proportion of less palatable grasses. The lower

yield and poorer quality of the vegetation, in addition to the barren patches, reduces the carrying capacity of this soil below that of the typical soil. Its value as grazing land is about 15 percent of that of Arnegard silt loam. Because of its steep slope, droughtiness, and great susceptibility to soil blowing, none of the land is tilled.

Searing loam, rolling phase.—The characteristics of Searing loam, rolling phase, vary widely, but all areas are rolling. Some are similar to those of typical Searing loam, except that they contain more numerous spots where the surface soil is thin, and bare patches of red scoria. Other areas are comprised of mixtures of several different soils. The higher parts are largely Searing loam, the slopes are mostly either scoria or clay, and the lower parts or draws are occupied principally by soils of the Patent and Grail series. Alkali claypan and clay spots are numerous in many areas, especially in the southwestern part of the county.

Soil of this phase is somewhat more extensive than is typical Searing loam, but the individual areas are small, and most of them are in the southwestern part of the county. Scattered areas are associated with typical Searing loam or with areas of scoria in other parts.

Principally because of the large number of bare patches composed of scoria fragments, this soil is not suitable for tillage. The native vegetation is varied. The patches consisting of scoria fragments are bare except for a growth of low shrubs, such as sagebrush, skeletonweed, and creeping cedar. The vegetation on the intervening soil approaches that common to Patent clay loam, but in few places is it as luxuriant. The carrying capacity of this soil as range land is about 30 percent of that of Arnegard silt loam.

Cheyenne gravelly loam, steep phase.—Cheyenne gravelly loam, steep phase, occupies extremely gravelly or cobbly ridges and alluvial terrace escarpments. The surface material, to a depth of a few inches, consists of brown very gravelly loam. This is underlain by assorted gravel similar to that underlying the surface soil of Cheyenne loam.

This soil has steeply sloping or sharply bumpy relief. It is not an extensive soil. The individual areas are few, and most of them are small. Much of the soil occupies steep terrace slopes at the edges of areas of Cheyenne loam. A very few areas appear to be eskers. In the valley of Cherry Creek several bodies occupy steep moundlike remnants of glacial gravelly outwash, which cover only a few acres, are sharply rounded, and rise to elevations ranging from 10 to 30 feet.

Because of its generally steep slope and gravelly character, this soil is excessively drained and vegetation is sparse and composed for the most part of the less desirable grasses; consequently, the grazing value of this soil is low and its carrying capacity as grazing land is about 20 percent of that of Arnegard silt loam. Some of the gravel deposits underlying this soil are satisfactory sources for road-surfacing material.

SANDY SOILS ON SMOOTH TO GENTLY ROLLING UPLANDS AND ALLUVIAL LANDS

The subgroup of sandy soils on smooth to gently rolling uplands and alluvial lands includes three very sandy soils that have several features in common but occupy different topographic positions. The smooth phase of Flasher loamy fine sand has developed from sand-

stone and sandy shales on the upland, Huff loamy very fine sand from sandy alluvial fan and terrace materials, and Banks loamy fine sand from sandy stream deposits of the first bottoms. All the soils of this subgroup are light in color and are deficient in organic matter. They are very subject to soil blowing, and their surfaces are billowy as a result of wind action. Excessive drainage is a common characteristic of these soils, and their value for the production of farm crops is low. A scant grass cover furnishes grazing of inferior quality.

Flasher loamy fine sand, smooth phase.—Flasher loamy fine sand, smooth phase, includes smooth areas of brown sandy soil of the upland. The surface soil, to a depth of about 6 inches, in general, is light-brown loose loamy fine sand, although some areas have a loamy very fine sand surface soil. The soil mass in both kinds of soil falls apart readily to very weak structured or soft fragments. Below the surface layer the color gradually becomes lighter and the slight cohesion of the surface material practically disappears. Below a depth of about 15 inches the material is olive-gray fine sand. No visible accumulation of carbonates has occurred, but effervescence with acid takes place at a depth ranging from 10 to 44 inches.

The relief of this soil is gently sloping or gently rolling, and most of the areas occupy low gently sloping swells or hills. Surface drainage is good, but internal drainage is excessive, owing to the sandy character of the subsoil.

This soil is widely distributed, but the total area is small. Few of the individual bodies cover more than 160 acres. The most extensive areas are in T. 150 N., R. 101 W., and isolated areas are scattered throughout the less hilly parts of the county outside of the roughest sections. Areas of sandy soil in the hilly areas are included with typical Flasher loamy fine sand and with its steep phase.

The native vegetation is not so palatable or so desirable as that which grows on the finer textured Morton and Williams soils. Two upland sedges, the more common of which is niggerwool, predominate and are uniformly distributed over all areas. Blue grama and western needlegrass are intermixed with the sedges on the more loamy parts and areas that receive some run-off water. Sandgrass grows in dense patches in places, to the exclusion of all other vegetation.

This soil is not well adapted to tillage, as it is extremely susceptible to soil blowing when cultivated, although approximately 40 percent of it is tilled. The crops most commonly grown are rye, corn, potatoes, and wheat. Except under most favorable weather conditions, yields are low. This soil is most efficiently used as grazing land, and its carrying capacity as such is from 25 to 30 percent of that of Arnegard silt loam.

Huff loamy very fine sand.—The characteristics of Huff loamy very fine sand differ considerably from place to place, but those similar throughout all areas are (1) a light-colored sand subsoil; (2) a surface soil that, though differing in color, is in all places relatively light colored; and (3) a soil material consisting of alluvium deposited by streams originating within the county. Most of the areas of this soil border on the large inland streams as natural levees or occupy alluvial fans deposited by inland streams, where their valleys join the valleys of the Missouri and Little Missouri Rivers.

The surface soil of those areas bordering the streams is light brown or light grayish brown, and the texture in general is loamy very fine

sand. In a few areas, as in the northern half of sec. 23, T. 150 N., R. 98 W., the surface soil has a distinct brown color and the texture ranges from fine sand to loamy fine sand. Below a depth of about 8 inches the loaminess disappears and the color is light grayish brown or yellowish gray. Huff loamy very fine sand on the alluvial fans is more or less mixed. It is composed largely of light-colored laminations of very fine sand and silt. The relative amounts of very fine sand and silt differ considerably within a short distance. Lime carbonate is at or within a few inches of the surface.

The surface of the areas along the streams is nearly level or very gently billowy, but the areas on the alluvial fans are gently sloping. Drainage is excessive because of the extremely sandy character of the subsoil. This soil is not extensive. The largest areas in the inland valleys are in the vicinity of Schafer, along Cherry Creek, and in T. 148 N., R. 105 W., along Bennie Pierre Creek. Areas on alluvial fans are in the valley of the Little Missouri River, and to less extent along the edge of the Missouri River bottom lands.

A few areas of this soil are tilled, but yields are low, probably being equal to about 30 percent of the yields obtained on Williams loam. Rye and corn are the two crops best adapted to this soil. Probably 75 percent of the land is used for grazing. The finer textured parts support a growth comprised largely of western needlegrass and blue grama, but some of the more sandy areas are of little value for grazing, owing to their droughtiness and to the less palatable grasses that grow on them. The average carrying capacity of this soil as grazing land is about 25 percent of that of Arnegard silt loam.

Banks loamy fine sand.—Banks loamy fine sand is the most sandy soil of the river bottoms. The 3- or 4-inch surface soil is brown or grayish-brown loose loamy very fine sand or loamy fine sand. Below this the color fades gradually to light yellow or grayish yellow, and the texture grades into fine sand. Lenses of clay may be at various depths below the surface covering of 20 to 30 inches of sand. The characteristics of this clay are similar to those of the clay comprising the upper few feet of Havre silty clay, and the lenses range in thickness from a fraction of an inch to 4 or 5 inches, but sand layers comprise the greater part of the subsoil material. Carbonates sufficient to cause effervescence when the soil materials are treated with acid are abundant in most places throughout the soil.

Most of this soil occupies gently billowy areas, although some areas have a sharply billowy relief, with ridges rising above the immediately surrounding land to a height ranging from 8 to 10 feet. Such relief suggests that these areas have been affected by wind action. Other areas are in close proximity to old or present river channels and lie at only slightly higher elevations than the surrounding soils. Owing to its sandy texture, this soil is excessively drained, except for a few areas that have narrow strips of poorly drained soil running through them.

A large acreage of Banks loamy fine sand is in the valley of the Missouri River, and this is also one of the dominant soils in the valley of the Little Missouri River.

Practically none of this soil is tilled, and most of the land is not cleared. The vegetation consists principally of brush and second-growth cottonwood, boxelder, and ash. The cleared areas support

a thin cover of grass, but because of the small amount of available moisture, the growth is very scant. A few areas support a fair stand of volunteer sweetclover. As a whole, this soil is poorly adapted to crop production, and its carrying capacity as grazing land is low. The areas on which sweetclover has become established afford good grazing for a short period, but during prolonged dry periods growth ceases at an early date.

POORLY DRAINED SOILS OF THE STREAM BOTTOMS AND DEPRESSIONS

Several soils of different composition have remained out of cultivation because of excessive moisture during a part of or all the year. With the exception of Dimmick clay, which occupies depressions, these soils occur on stream bottoms and are developed over recently deposited alluvial materials. A small part of Havre silty clay, poorly drained phase, is cultivated, but the other soils of this subgroup are used only for grazing or for growing native hay.

Alluvial loam soils, undifferentiated.—Alluvial loam soils, undifferentiated, include mixed areas of alluvium of recent deposition along the streams and drainageways of the interior of the county in which the soil texture averages that of a loam. The texture, however, is not uniform and in places ranges from loamy fine sand to silt loam. The color ranges from yellowish gray to very dark brown. Many small areas of Farland soils, too small to be indicated on the soil map, are included in areas of this material.

The drainage differs considerably but in most places is fairly good, although the drainage of the lower lying areas is insufficient, especially in places where the subsoil is clay. Practically all areas are subject to occasional inundation.

Very little of this soil is tilled, owing largely to the fact that it is badly cut by stream channels and ditches. Most of this land affords fair to good grazing. The grasses, except in the lower parts, are similar to those on Farland silt loam, but saltgrass is intermixed with the other grasses in many places, and a few areas especially subject to accumulation of salts are devoid of all grasses except saltgrass. Patches of buckbrush, buffaloberry, chokecherry, and juneberry grow on this soil. The grazing value of the land where no accumulation of salt has taken place is about 75 percent of that of the most desirable range land, but salt accumulation reduces the value considerably, some very salty areas being nearly worthless because of the lack of palatable grasses.

Alluvial clay soils, undifferentiated.—Alluvial clay soils, undifferentiated, include clay and clay loam soils of variable character developed over recent alluvium along the streams and drainageways of the interior of the county. Most of the acreage of this land is composed of poorly drained heavy clay where some salt accumulation has taken place, most of which occupies strips ranging from 5 to 15 rods in width along drainageways. The drainage channels are shallow and fairly well developed, although much of the adjacent surface soil is usually moist, and any small depressions, such as hoof marks, are filled with water. A few areas include small spots of Farland soils.

162010—42——5

Practically none of this land is tilled, but a few of the better drained areas afford good grazing. The dominant grasses on these areas are blue grama and western wheatgrass, with saltgrass more or less intermixed. The more common poorly drained salty areas are useless; in fact, many of them are detrimental owing to the common occurrence on these areas of the poisonous arrowgrass. The dominant vegetation on the salty areas is saltgrass, and arrowgrass, sedges, and a few reeds grow on the wetter parts.

Havre silty clay, poorly drained phase.—This mapping separation includes those areas of Havre silty clay that are too poorly drained to allow tillage or the successful production of crops requiring tillage of the soil. The color varies widely, but the texture is uniformly silty clay or clay to a depth of 2½ or more feet. The color in general is dark gray and in many places is mottled with yellow and reddish-brown specks. Particularly on the bottom land of the Missouri River, the fragmentary structure common to Havre silty clay is plainly evident in many areas. In several areas the soil material is very dark grayish-brown or nearly black silty clay specked with rust brown to a depth of about 10 inches. Below this is dark-gray, mottled with yellow, silty clay or clay.

Havre silty clay, poorly drained phase, occupies slight depressions within areas of typical Havre silty clay or on lower lying bottom land adjoining the present river channels or abandoned river channels. Most of the areas are in the valleys of the Yellowstone and Missouri Rivers, and smaller areas border an intermittent lake, approximately 10 miles southwest of Keene, in T. 151 N., R. 96 W., and locally known as Dimmick Lake.

Except where drainage has been artifically improved, very little of this soil is tilled, and probably 70 percent of the untilled part is covered with brush and small trees. Most of the cleared or open land is in secs. 5, 6, 7, and 8, T. 152 N., R. 100 W. These areas are devoted to the production of wild hay. The vegetation is composed principally of sedges and blue wild lettuce which make hay of fair quality, with yields ranging from ½ to 1½ tons an acre. Because of the moist condition of the land, it is practically certain to produce some hay even during the driest years. The carrying capacity of this soil as grazing land ranges from 10 percent of that of Arnegard silt loam on areas occupied by dense unedible brush to as much as 50 percent on some of the cleared or open areas. As on the uncleared areas of Havre silty clay, some areas support a dense stand of yellow sweetclover intermixed with the brush. As a whole the uncleared areas have a low value for grazing, except where sweetclover is established.

Cherry silty clay loam, poorly drained phase.—This soil includes those areas of Cherry silty clay loam that are so low as to be poorly drained and as a consequence are nontillable. The entire soil shows marked mottling. This soil material, as a whole, is of more recent deposition than is the material of the typical soil and is subject to occasional inundation, whereas most areas of typical Cherry silty clay loam are subject to very infrequent overflow.

Most of this soil is in the valley of the Little Missouri River, especially in T. 147 N., R. 100 W. and T. 149 N., R. 96 W. Many of the areas are alluvial fans formed by tributaries at their junction

with the Little Missouri River. Practically none of the land is tilled, and most of it is covered with brush and a growth of elm, ash, willow, and cottonwood saplings. Grasses grow on the higher ground of the small open spaces, and sedges occupy the lower part. Where grazed, the carrying capacity of this land is very low, owing to the poor type of vegetation it supports.

Banks very fine sandy loam, poorly drained phase.—This soil includes those areas of Banks very fine sandy loam that are poorly drained, the water table in most places being within a few feet of the surface. It also includes areas of sandy soil that are cut by many shallow troughs occupied by wet soil. Much of this soil is covered by brush, and practically none of it is cleared, as it is not adapted to tillage, but it is devoted entirely to grazing, which ranges from fair to poor. Some areas on the bottom land of the Missouri River support a good stand of volunteer yellow sweetclover, and this increases the carrying capacity of the areas considerably. Because of the great variation in the character of the soil material and the vegetation, the carrying capacity ranges from about 10 to as much as 25 percent of that of Arnegard silt loam.

Dimmick clay.—Dimmick clay includes dark-colored or mottled wet clay soil in old river channels and pond sites. The 5-inch surface layer of this soil is grayish-black silty material intermixed with an abundance of grass roots. The content of organic matter in this layer is very high. Below it and extending to a depth of approximately 18 inches, the material is grayish-black fairly plastic clay. When moist, which is its normal condition, the material breaks fairly easily into definite but easily kneaded fragments. Only a few roots extend into this layer. Below it the soil material is grayish-black dense clay, which grades below into lighter gray clay more or less mottled with rust brown. In the wetter areas, especially in old stream channels such as the so-called Dimmick Lake, the soil is not so dark-colored and is more mottled. In places the material is olive-gray plastic clay mottled with rust brown and yellow. In most places lime is plentiful at all depths.

The typical and most extensive areas of this soil occupy nearly level depressions in the rolling gravelly morainic area in the northwestern part of Keene Township, in Blue Butte Township, and in the immediately bordering township to the west. The depressions that this soil occupies have no drainage outlets, and they are practically waterlogged, some of them having as much as 8 inches of water over a part of their area at all times. A few areas of Dimmick clay occur throughout the river bottoms. Most of these are in abandoned river channels and, though poorly drained, generally have a dry surface, at least during a part of the summer season.

In those areas where water stands during the greater part of the year, the native vegetation is mostly reeds and rushes with some sedges intermixed along the drier edges of the areas. The parts that are above the water table during a considerable part of the growing season support a cover composed mainly of lowland sedges, smartweed, and foxtail. Redtop grows in places along the outer edges and on the best drained parts. Those areas in abandoned stream channels and in some of the dried pond sites are bare except for a growth of weeds, which spring up rapidly when moisture conditions are suitable.

A few of the abandoned stream channel areas are occupied by a dense growth of willow.

None of this soil is tilled. Its grazing value is low, owing principally to the unpalatable type of vegetation or to a total lack of vegetation. The sedges and the small amount of redtop are the only plants that have any value for forage.

ALKALI CLAYPAN AND SALTY SOILS

The subgroup of alkali claypan and salty soils includes those soils that have been markedly influenced by an excess of salts. The alkali claypan soils are characterized by a spotted landscape. The spots are irregular depressions, which range from 2 to 15 feet in diameter and lie from 4 to 12 inches below the interspot parts. The spots consist of comparatively intractable clay and generally support a scant vegetation. The so-called interspot parts are more variable and range in character from alkali claypan soils (Rhoades, Moline, or Wade) to the zonal soils of the region (Williams, Morton, and Farland). Many of the claypan parts of the interspot areas are characterized by a grayish-brown friable surface layer, about 5 inches thick, below which is darker colored claypan. Most of the interspot parts support a good stand of grass. Primarily because of the intractable character of the clay spots and the alkali claypan, a great part of the acreage of these soils is not suitable for tillage. Those areas most suitable for this purpose are where the clay spots are less numerous and less strongly developed.

The McKenzie and Sage soils are more uniform in character but for the most part are composed of intractable clay. They are considerably less extensive than the alkali claypan soils and do not lend themselves well to cultivation.

The small acreage of the alkali claypan and salty soils that is suitable for tillage is best adapted to small grains and hay crops, the remaining acreage being most advantageously used as permanent grassland.

Rhoades loam (complex with Morton, Bainville, or Williams loams).—This soil complex occurs in the upland part of the county, largely in that part not covered by glacial till. As indicated in the general description of the group of alkali claypan soils, the areas of this soil complex appear to comprise two distinct but intricately mixed component parts—the interspot parts and the clay spots. The former occupy from 50 to 85 percent of the soil area and consequently represent the main body of this soil. As stated above, neither the clay spots nor the interspot areas are uniform in respect to soil conditions. This soil complex is characterized by the alkali claypan condition, and because of differential erosion of its surface, parts of it are in grass and other parts are nearly bare and form what are locally known as "scab" or " gumbo clay" spots.

Because of the impossibility of showing on the published soil map all the various soil conditions, these areas are recognized as complexes. Thus, the soil of any particular interspot area may be either Rhoades loam, Morton loam, Bainville loam, Williams loam, or some intermediate condition. The most common variations are in the thickness, color, and texture of the surface layer, the thickness of the clayplan layer, and the abruptness of the change from the comparatively friable surface layer to the hard intractable claypan. Although the

changes are generally abrupt, in some places there is a gradation from the one to the other, which extends through a transitional layer 2 or 3 inches thick.

The 5-inch surface layer of an interspot part representative of Rhoades loam is dark grayish-brown very fine sandy loam or silt loam that crumbles easily to a fine crumbly mass. Abruptly below this is a very dark grayish-brown hard dense layer of sandy clay or clay, which breaks, when removed from place, into hard angular fragments that are very resistant to further crushing. At a depth of about 10 inches the color becomes lighter and the hardness becomes less pronounced, and at a depth of about 15 inches is olive-drab or olive-gray clay with numerous white carbonate flecks. Carbonates sufficient to cause effervescence with an acid are generally less than 3 inches below the claypan layer.

The clay spots of Rhoades loam complex, which lie from 4 to 12 inches below the adjoining interspot parts, have a gray semicrust of very fine sand a fraction of an inch thick. Below this and extending to a depth of about 1½ inches is grayish-brown or dark grayish-brown fairly friable silty clay loam. Below this is a 2-inch layer of very dark grayish-brown fairly hard dense clay, which resembles somewhat the claypan layer as described. In many places this material lies somewhat nearer the surface. Below a depth of about 4 inches the material grades rapidly into olive-drab silty clay, which below a depth of 6 or 8 inches contains an abundance of white salt flecks—most of them carbonates. This material is hard in place but crushes fairly easily when subjected to firm pressure.

Rhoades loam complex is distributed widely over the upland part of the county, except that few areas occur on the largest glacial till plains of the northern part. The most extensive areas are in the vicinity of Grassy Butte. Except for the areas where the complex contains Williams loam, it is developed from clay material of the Fort Union geological formation, and the surface is sloping or undulating. Internal drainage is slow, but surface drainage is good.

The native vegetation on the clay spots differs markedly from that on the interspot parts. Where the clay spots are most numerous and the claypan well developed, the clay spots are very nearly bare except for a scattered growth of saltgrass, western wheatgrass, and small pricklypear. Where the clay spots are less developed and have a somewhat more fertile surface layer, the soil supports a fair to good stand of buffalo grass and blue grama. The native vegetation on the interspot parts is similar to that on Morton loam, and here blue grama dominates, with such grasses as western needlegrass, western wheatgrass, and junegrass intermixed. Little clubmoss is common on the interspot areas, where it occupies that part of the ground not covered by grasses. The carrying capacity of this soil naturally differs according to the number and productivity of the clay spots. Those areas where the bare clay spots are most numerous are of low value as grazing land and will support only 20 to 30 percent of the number of cattle that Arnegard silt loam will carry; but where the clay spots are least numerous and are at least partly covered with grass, the carrying capacity is from 40 to 60 percent of that of Arnegard silt loam.

The usefulness of this soil differs considerably according to the abundance and productivity of the clay spots and the depth to and

thickness of the alkali claypan. The areas commonly tilled are those where the clay spots occupy but a small part of the surface and where the claypan is but mildly developed. The tilled acreage is about 25 percent of the total area, and most of it is in the more accessible parts of the county. Wheat is the dominant crop and probably occupies more than half of the tilled acreage. Oats, barley, flax, and, to less extent, corn occupy the remaining acreage. Yields differ considerably according to the character of the claypan and clay spots. Acre yields of wheat on the tilled part, which represents the most desirable areas of this soil, range from 10 to 13 bushels during favorable years. Acre yields of oats under similar conditions range from 20 to 25 bushels, and of barley about 17 bushels. Small grains are frequently cut for hay and yield from ¾ ton to 1½ tons an acre during good years.

The clay spots are particularly unproductive, as the clay has a poor structure, inhibiting root development, and holding much of its moisture unavailable to plants. At the approach of dry periods, plants invariably die first in the clay spots, leaving the crops on this soil in a spotted condition. The claypan and clay spots offer marked hindrances to cultivation. If plowed when too dry they offer considerable resistance to turning, the plow soil coming up as hard fragments or clods that are pulverized only with great difficulty. It is practically impossible to plow the clay spots when very dry. If the land is plowed when too wet, the claypan and clay spot materials turn up as plastic masses that harden to very resistant clods when dried. The tilth of these soils is improved considerably by fall plowing, such practice being common when moisture conditions are favorable at that season of the year. The intermittent freezing and thawing of the following winter and early spring crumbles the hard clods to a more mellow consistence.

It is a common opinion that areas of alkali claypan soils improve in tilth and productiveness as a result of repeated tillage and cropping. After several years of such practice the claypan structure is at least partly destroyed and the more friable material of the surface layer of the interspot parts is mixed with the more intractable material of the claypan and clay spots, resulting in a more desirable soil condition for growing plants.

Rhoades clay loam (complex with Morton, Bainville, or Williams clay loam).—Rhoades clay loam complex is similar to Rhoades loam complex, except that the texture of the surface layer of the interspot part averages clay loam rather than loam. The 4- or 5-inch surface layer of the Rhoades clay loam part of the interspot areas is grayish-brown or dark grayish-brown friable clay loam that is easily crushed to a crumbly mass. Below this is the dark grayish-brown or very dark grayish-brown claypan. As in Rhoades loam complex, the clay spots differ considerably in regard to size, number, and vegetative cover.

Except for those few areas containing Williams clay loam, this soil is developed from clay of the Fort Union geologic formation. The surface is undulating or sloping, and surface drainage is good, but, because of the clayey character of the subsurface layers, internal drainage is slow. This soil is widely distributed over the county except on the smooth till plains of the northern part and in the Badlands areas. The most extensive areas are southeast of Grassy Butte and in T. 149 N., R. 103 W.

The native vegetation is similar to that growing on Rhoades loam complex, and its carrying capacity has a similarly wide range. It is from 25 to 50 percent of that of Arnegard silt loam.

As with Rhoades loam complex, about 25 percent of this soil is considered suitable cropland. Wheat is the main crop. Other small grains and corn occupy the remainder of the tilled land. Yields differ widely, according to the number and productivity of the clay spots. The average yields approximate those on Rhoades loam complex. Difficulties of tillage and methods of handling common to Rhoades loam complex apply to this soil complex.

Rhoades clay loam, rolling phase (complex with Morton, Bainville, or Williams loams and clay loams, rolling phases).—Rhoades clay loam, rolling phase, complex includes all areas of Rhoades loam complex and Rhoades clay loam complex that have a rolling rather than level or undulating surface, the slope or gradient ranging from about 8 to 18 percent. As a consequence of the greater slope, this soil complex is more variable, and in a few places, especially on the steeper slopes and exposed knobs, the extent of the Bainville loam and Bainville clay loam component parts is greater than normal for the complex.

As with the other Rhoades soils complexes, soil of this phase, except the areas containing Williams clay loam, is developed from silts and clays of the Fort Union geologic formation. The surface is rolling, and consequently the land is somewhat excessively drained. The native vegetation is similar to that on the typical soil, although some little bluestem grows on the more exposed knobs where the claypan is lacking.

Practically none of this soil is considered suitable for tillage, and only a very small part of it is under cultivation. It is best suited to grazing and has a carrying capacity ranging from 20 to 40 percent of that of Arnegard silt loam.

Moline clay loam (complex with Patent or Grail soils).—Moline clay loam complex is a complex of soils similar to the Rhoades soils complexes in general characteristics, but it differs in its location and in the color of the surface soils. The Rhoades soils complexes are on the uplands, whereas the Moline soil complex is on the gentle valley slopes of local alluvium. These areas, similarly to the Rhoades soils complexes, have been outlined on the soil map to cover a wide variation in soil characteristics. The outstanding and common feature of the complexes is the claypan development. Parts of the areas are bare, or nearly so, because of differential erosion of the surface soil above the claypan. A particular interspot area may represent a Moline soil, a Patent soil, a Grail soil, or some intermediate condition.

The color of the surface layer of the interspot part representative of Moline clay loam is grayish brown or brownish gray rather than dark grayish brown, although a few areas with dark grayish-brown or very dark grayish-brown color are included in mapping. The clay spots are similar to those of the Rhoades soils. The alkali claypan in general is well developed in this soil, as the position of the Moline clay loam complex seems to be more nearly normal for this condition than the position of the Rhoades soils complexes. As with the Rhoades soils complexes, the number and relative unproductiveness of the clay spots differ widely.

Several areas of Moline clay loam complex in the southwestern part of the county, particularly in T. 146 N., R. 103 W., include numerous bare clay spots, but the heavy claypan has not developed. The bare spots are the result, for the most part, of steplike erosion of the slopes. The interspot parts consist of Patent clay and support the common type of vegetation.

The surface of Moline clay loam complex is similar to that of the Patent soils, as this soil complex occurs on gentle valley slopes immediately below adjoining higher lying soils. Surface drainage is good, but internal drainage is slow.

The native vegetation on the interspot parts is mostly blue grama, with some western wheatgrass and other desirable grasses intermixed. In many places little clubmoss occupies the ground not covered by the grass vegetation. Pasture sagebrush, green sagebrush, and prairie plantain grow on this soil, and in many places the latter is very abundant. The vegetation on the clay spots is extremely variable. Where such spots are most pronounced, they are very nearly bare, and such areas support some pricklypear and a scant growth of saltgrass and western wheatgrass. Where they are less pronounced or less productive, they are occupied by a fair to very good cover of buffalo grass, with some blue grama along the edges. The areas supporting the best grass cover provide good grazing and have a carrying capacity ranging from 50 to 70 percent of that of Arnegard silt loam, but the poorer areas have a carrying capacity ranging from only 20 to 30 percent of that of the Arnegard soil.

Approximately 25 percent of this soil complex is considered suitable for tillage. Wheat, the main crop, occupies more than half the tilled acreage, and other small grains, hay, and corn occupy most of the rest. Yields approximate those obtained on Rhoades loam complex, that of wheat during favorable years being about 11 bushels an acre. As with the Rhoades soils complexes, Moline clay loam complex responds to fall plowing and improves in tilth as it is tilled from year to year.

Moline clay loam, slope phase (complex with Patent or Grail soils, slope phases).—Moline clay loam, slope phase, complex is similar to Moline clay loam complex, except that the surface is more sloping and consequently the soil areas are still more variable. The soils of a few of the knobs resemble soils of the Bainville series. The gradient ranges from 8 to 18 percent, consequently surface drainage is rapid. The native vegetation is similar to that on Moline clay loam complex, but the growth is not so heavy or so uniform.

This soil complex is considerably less extensive than Moline clay loam complex, the areas are smaller, and, although commonly associated with Moline clay loam complex, it occurs mainly in the rougher parts of the county.

Very little of this soil complex is tilled, as it is best adapted to grazing. As grazing land, it has a carrying capacity ranging from 20 to 40 percent of that of Arnegard silt loam.

Wade-Farland silty clay loams.—The areas of this soil complex have a distribution of clay spots and interclay spots similar to that of the Moline and Rhoades soils complexes. The areas occur on the nearly level heavy-textured alluvial benches or terraces.

The alkali-claypan member of the complex is Wade silty clay loam and includes the clay spots and parts of the interspot areas. The

grassed areas may be either Farland silty clay loam or some condition intermediate between that soil and Wade silty clay loam.

The surface soil of many of the interspot parts is dark grayish-brown fairly friable silty clay loam that crumbles easily. The dark-brown or very dark grayish-brown hard dense alkali claypan begins abruptly at a depth of about 5 inches below the surface. This layer, when removed from place, breaks easily into hard angular fragments that are very resistant to further crushing. At a depth of about 12 inches, the hardness gradually disappears and the color grades toward olive drab. Below a depth of about 16 inches is olive-drab clay containing numerous white carbonate flecks. This material is fairly hard in place but crushes fairly easily under firm pressure to a fine-grained mass. Carbonates sufficient to cause effervescence with acid are at a depth of only a few inches below the claypan layer.

The clay spots are similar to those in Rhoades clay loam complex. Most of them have a thin white siliceous crust on the surface, below which is hard rather dark clay. At a depth ranging from 1½ to 3 feet is olive-drab clay containing an abundance of white carbonate flecks. As with the clay spots in the Rhoades and Moline soils complexes, these clay spots occupy depressions from 4 to 12 inches below the level of the surrounding interspot parts.

Wade-Farland silty clay loams complex includes a variation that is characterized by a great excess of salts. This condition is indicated on the map by the addition of symbols representing excessive saltiness. The land has a hummocky or billowy relief somewhat similar to that of the Wade-Farland silty clay loams complex. The hummocks have no developed claypan but are composed of friable clayey material. They are rounded or slightly domelike, rise from 4 to 12 inches above the interspot parts, and are commonly known as "puff spots." The surface soil of the puff spots has a white siliceous crust about one-fourth inch thick, underlain by an 8- or 9-inch layer of friable grayish-brown or dark grayish-brown very fine sandy clay. Below this layer, the color fades to light brown with an olive tinge. All the soil layers except the thin surface crust are moist at practically all times, and a spade can be forced its full length into the soil with ease. Below the thin surface crust, white salt flecks and crystals are abundant throughout these puff spots. Carbonates are generally abundant, but in some places other salts predominate, as evidenced by their failure to effervesce when the soil is treated with acid. The parts between the puff spots generally have a moderately developed alkali claypan at a depth of 3 or 4 inches below the surface.

Wade-Farland silty clay loams complex is developed on clayey alluvium that forms the nearly level benches of the stream valleys. About three-quarters of the total acreage is in the valleys of Tobacco Garden Creek and Cherry Creek, south, east, and northeast of Watford City.

Drainage of this soil complex is slow, owing to the nearly level surface and impervious character of the subsoil. Some of the areas in which large accumulations of salts have developed are subject to seepage from the adjoining uplands.

The native vegetation on the areas more typical of this complex is similar to that on Moline clay loam complex, blue grama dominating on the interclay-spot parts and the vegetation on the clay

spots ranging from very scant to a fairly good stand of buffalo grass or blue grama. The puff spots support an inedible growth consisting almost wholly of *Dondia* sp. and saltgrass.

Approximately 20 percent of the acreage of this soil complex is considered suitable for crops requiring tillage, including those parts in which the clay spots are neither so pronounced nor so numerous, but no areas having excess salt accumulations or puff spots are considered suitable for tillage. Wheat is the most common crop grown, and the remaining acreage is devoted principally to other small grains and hay crops. Yields are variable, according to the character and number of the clay spots. Wheat, during good years, on the areas considered suitable for crops, yields about 12 bushels an acre and other small grains yield accordingly. As with the other alkali-claypan soils, Wade-Farland silty clay loams complex improves with added years of tillage, and its tilth is improved by fall plowing. The values of the individual soil areas for grazing differ greatly. The most desirable parts support a fairly good grass cover and have a carrying capacity ranging from 50 to 70 percent of that of Arnegard silt loam; but those areas in which the clay spots are numerous and, for the most part bare, and where the puff-spot condition prevails, have a grazing value of only 10 to 20 percent of that of the Arnegard soil. A few of the puff-spot areas, owing to the preponderance of saltgrass and *Dondia* sp., are practically worthless.

McKenzie clay.—McKenzie clay is a very dark colored hard dense clay soil occupying old pond and lake sites. The 16- or 18-inch surface layer is very dark grayish-brown or grayish-black clay. When dry this material is very hard and impenetrable and cracks from 1 to 3 inches wide develop, breaking the mass into blocks ranging from 8 to 20 inches in diameter. These blocks are broken to smaller pieces only by considerable force, and the resultant mass breaks only to smaller equally resistant hard angular fragments. Below a depth of about 16 inches, the color grades into dark olive drab, and the mass is not so hard and intractable. Small white carbonate flecks occur throughout this soil in some areas, but in most places there are no carbonates above a depth of 15 inches.

In a few areas of McKenzie clay the material is not so dark, and the dark color does not extend to so great a depth. The material in these areas is also hard and intractable, and large cracks develop when it is drying.

The surface is nearly level, and drainage is very poor. The aggregate area is very small, but the soil is scattered widely over all parts of the county, except in the Badlands. The areas are not numerous, and only a few are larger than a few acres. One of the largest is about 1½ miles west of Watford City.

The native vegetation on much of this soil is western wheatgrass, but on a few areas sedges predominate. The character and quantity of the vegetation differs from one season to another, depending on the amount and distribution of the precipitation. During excessively dry years, the vegetation consists of a very scant growth of western wheatgrass and weeds; during normal seasons, western wheatgrass, together with some sedges and weeds, develops a fair cover; and during seasons of excessive moisture, sedges and, in some places, rushes and weeds produce a luxuriant vegetal cover.

Practically none of this soil is suitable for crops. It is a most difficult soil to till, and because of its physical character, optimum moisture conditions do not continue over any great length of time, consequently crops almost invariably suffer. When moisture conditions are right, which condition comes possibly once in 10 or 15 years, wheat has been known to yield approximately 40 bushels an acre. Some areas of this soil are utilized as wild-hay meadows, which produce from a fair to good quality of hay, but the yields are extremely variable. The rest of the soil is used as grazing land, which has a carrying capacity ranging from 15 to 30 percent of that of Arnegard silt loam.

McKenzie clay, light-colored phase.—McKenzie clay, light-colored phase, differs from typical McKenzie clay mainly in having a lighter colored and more mellow surface soil. To an average depth of 6 inches, the surface soil, when moist, is dark gray or grayish brown. It ranges in texture from silt loam to clay loam, the heavier texture being more common. When this surface layer is thoroughly dry, it is strikingly lighter colored than the surface soil of typical McKenzie clay. It is abruptly underlain by dark grayish-brown or grayish-black hard dense clay similar to that of typical McKenzie clay. When dry, this material cracks into the large blocks so characteristic of it. Below a depth of about 18 inches, the material grades into dark olive-drab clay, and the cracks are less pronounced or are absent. The light-colored surface layer is free of carbonates, but they occur at a depth of 10 or 12 inches below the surface, as indicated by effervescence when the soil is treated with acid.

Included with this soil are several areas that are somewhat lighter colored than typical McKenzie clay but not so strikingly so as that described as the light-colored phase. In these included areas the surface soil to a depth of 10 or 12 inches is very dark gray or dark grayish-brown silty clay loam or clay. The material in this layer is somewhat friable, at least more so than in typical McKenzie clay and does not develop such large cracks on drying as does the typical soil. Below this layer the color gradually becomes lighter until, at a depth ranging from 16 to 20 inches, the material is dark olive-drab clay. Carbonates sufficient to cause effervescence when the soil is treated with acid are lacking in the upper part of the surface layer, but they are generally present at a depth ranging from 10 to 18 inches below the surface, and a few fine white flecks are present at this depth.

This soil is developed from alluvium occupying dried pond and lake sites. Its total acreage is small, and most of the areas are small. It is widely distributed over the county and in many places is associated with typical McKenzie clay and other soils developed from alluvium. The surface is nearly level, and both surface and internal drainage are slow, but the soil is slightly better drained than typical McKenzie clay.

The native vegetation is predominantly western wheatgrass, but the stand is not everywhere good, especially on the lower lying areas.

About 25 percent of this soil is tilled, and a very large part of the cultivated land is devoted to wheat. Other small grains (for grain and hay) occupy the remainder. Although this is a fairly fertile soil, its physical character and slow drainage severely limit its produc-

tivity, and crops are adversely affected by comparatively slight excesses or deficiencies of moisture. Crop yields differ widely from year to year, and failures are more frequent than on the coarser textured, more mellow, and better drained soils. The value of this land as cropland is about 40 percent of that of Arnegard silt loam. Some of the land that is not tilled is devoted to growing wild hay, western wheatgrass being the most common grass on these areas. The remaining acreage is used as grazing land and has a carrying capacity ranging from 35 to 60 percent of that of Arnegard silt loam.

Sage clay.—The surface soil of Sage clay is dark olive-drab clay. Over the greater part of the area the soil is firm and hard to penetrate with a spade. In some places, a thin gray siliceous crust covers the surface during dry periods and salt crusts form in patches, but other areas, especially those associated with Farland silty clay loam are free of an accumulation of salts on the surface. White specks or flecks of carbonates and other salts are distributed throughout the soil below the thin surface crust. The soil does not crumble easily but breaks under pressure to angular chunks, and in many places the soil mass is moist to within a very few inches of the surface at all times.

This soil occupies positions favoring the accumulation of salts. The most common locations are (1) slight depressions in comparatively narrow strips of Farland silty clay loam that extend into rolling or steep areas of upland, (2) very gentle slopes at the openings or mouths of small valleys, and (3) narrow strips on alluvial flats along the borders of upland areas. The surface of this soil is nearly level, and drainage is poor. On some areas small puddles or muddy spots remain even during dry periods.

This soil is widely scattered in small areas, but the total acreage is not large. The range in size of the individual bodies is from 4 to 40 acres. Typical areas are in sec. 11, T. 152 N., R. 100 W.; sec. 34, T. 148 N., R. 99 W.; and sec. 24, T. 146 N., R. 103 W.

The native vegetation is sparse, and some areas are nearly barren. Some support a fair growth of sagebrush, and others have a fair cover of brome snakeweed and some saltgrass. In places a thin patchy cover of blue grama and western wheatgrass has established itself. None of this soil is tilled, as it is incapable of crop production and very difficult to plow. Its grazing value is extremely low, in fact, most areas are practically worthless either as tilled or grazing land.

MISCELLANEOUS LAND TYPES

The separations included in the group of miscellaneous land types are properly designated land types rather than soil types because their dominating characteristics are the result of erosion and geologic conditions rather than of soil-forming factors. They all are the comparatively recent result of either removal or deposition of geologic materials by water. No one of them is suitable for tillage, and they are of comparatively little value as grazing land.

Rough broken land.—Rough broken land includes all steep areas that have a slope of more than 20 percent and a surface of which more than 25 percent is bare. The areas partly covered with grass or other vegetation are similar to the steep phases of the Williams, Morton, and Bainville soils. The comparatively bare parts occupy from 26 to nearly 100 percent of the areas and have a surface expo-

sure of olive-drab and gray clay, occasional outcropping lignite beds, and on a few areas outcrops of olive-drab fine sand. Most of these latter areas have irregular outcropping ledges of weakly cemented sandstones.

On parts of the rough broken land, the grass vegetation is similar to that on the steep phases of Williams loam and Williams clay loam and on the steep phases of Bainville loam and Bainville clay loam. Some nearly bare areas support a very scant shrubby growth of sagebrush, cacti, creeping juniper, rabbitbrush, buckbrush, and buffaloberry. In many gulches and short steep ravines, especially those facing northward, there is a fairly dense growth of western redcedar, and in some such places thickets of ash and elm form the predominant growth.

The most extensive areas of rough broken land occur in the Little Missouri Badlands. Less extensive areas border the valleys of the Missouri and Yellowstone Rivers, and isolated tracts, ranging from 5 to 500 acres in size, are scattered over all parts of the county where geologic erosion has been active.

Owing to the great proportion of bare ground and the poor type of vegetation on much of the grassed part, the grazing value of this land is low, in most places ranging from one-thirtieth to one-tenth of the grazing value of Arnegard silt loam. One of the few advantages of the rough broken land is that, because of its extreme roughness, characterized in most places by deep ravines, it offers protection for grazing animals during the winter.

Scoria.—Scoria is a term applied to areas where most of the surface material consists of angular hard fragments of light-red shale. The material presumably has been formed by the baking of the clay overlying burning lignite beds. The greater part of this material is made up of fragments ranging from 1 to 4 inches in diameter, but a small part consists of very dark reddish-brown hard clinkerlike masses ranging from 6 inches to several feet in diameter.

Nearly all of the areas of this land have a sharply rolling or rough surface, the range in relief being from 50 to about 150 feet. The most extensive areas are in the southern and southwestern parts of the county. Smaller areas are throughout most of the county, where erosion has been active.

The vegetation is sparse and is composed mostly of plants of low palatability. A thin cover of grass, including some niggerwool and blue grama is on many areas. The draws or drainageways, where moisture conditions are better and where some soil material has accumulated, have a good grass cover. The grasses here are mostly big bluestem, an upland sedge, and some blue grama. The percentage of the total acreage of the land occupied by this desirable grass cover ranges from about 2 to 8 percent. None of this land is tillable, and its grazing value is about equal to that of rough broken land. Scoria is commonly used for road-surfacing material, and conveniently situated exposures of the beds are of value as sources of this material.

Patent clay.—Patent clay includes areas of slope alluvium so recent in deposition that no soil layers have developed, and the material from the surface downward is olive-drab silt or clay. It generally lies immediately below or at the foot of buttes or other upland areas that are subject to active erosion. The surface is gently to steeply

sloping and is cut by many ditches ranging from a foot to 4 feet in depth.

Patent clay is devoid of vegetation, except for a few patches of blue grama and western wheatgrass and some sagebrush and cacti. Where the drainageways through these areas are wet most of the year, sedges, a few reeds, and arrowgrass occupy them. The total acreage of this land is small, and few areas occupy more than 30 acres each. One area of approximately 180 acres is in sec. 19 of Red Wing Township.

None of the land is tillable, and it has practically no value as grazing land.

Riverwash.—Riverwash includes sandy material of very recent deposition, lying immediately along the channels of the rivers and generally opposite their cutting sides. The areas lie but a few feet above the surface of the water and are partly or wholly subject to overflow whenever the river is at flood stage. The material is pale-yellow sand or fine sand, showing no accumulation of organic matter since deposition. The surface of the areas is slightly billowy. Most of the land is devoid of vegetation, although a few areas support a fair to thick stand of willow saplings. Riverwash has no value either as tillable or grazing land.

PRODUCTIVITY RATINGS AND LAND CLASSIFICATION

In table 6 estimates are given, by means of indexes, of the approximate yields obtained for the crops commonly grown on each soil type in McKenzie County, under the common farming practices. Estimates are given for average yields over a period of years and also for the average of the better years.

F O O T N O T E S — Bowdoin

Column A refers to average yield; column B to average yield in better years. In general, yields in column A are assumed to be about 60 percent of those in column B. Absence of indexes indicates crop not commonly grown on soil.

Based upon yields when alfalfa first grown in the rotation; do not take into account the detrimental effect that alfalfa has in the Great Plains through the depletion of soil moisture for succeeding crops — including alfalfa.

6/ Single estimates of crop yields cannot be expected to be equally applicable to all areas — or to all parts of same area -- of these mapping units that are a complex of soil conditions. Double ratings given to cover range of productivity for pasture, lower figure being for more scabby (alkali) areas.

TABLE 6.—*Productivity ratings of soils in McKenzie County, N. Dak.*

UNDER DRY FARMING

Soil [1]	Crop-productivity index [2] for—																						General productivity grade [4]		Land classification [5]
	Corn (grain) 50 B		Corn (fodder) 12 T		Wheat 20 B		Barley 40 B		Oats 50 B		Flax 15 B		Alfalfa [3] 4 T		Sweet-clover 2 T		Potatoes 200 B		Millet 3 T		Wild hay 1 T		Permanent pasture				
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	
Arnegard silt loam ✓	40	60	30	40	50	80	45	70	45	70	50	80	30	40	55	90	30	50	50	70	70	90	23	40	5	3	Good cropland.
Farland silt loam ✓	35	55	25	35	40	65	35	55	40	65	45	70	25	35	50	80	25	40	40	70	60	80	21	35			
Havre silty clay	35	55	20	30	40	65	35	55	40	65	45	70	30	40	60	80	25	40	40	65	50	70	21	35			
Grail silt loam	35	55	20	30	40	65	35	55	40	65	45	70	20	35	50	80	25	40	40	70	60	80	21	35			
Williams loam	35	55	20	30	40	65	35	55	40	65	45	70	20	35	50	80	25	40	40	65	50	70	20	33			
Farland silty clay loam	35	55	20	30	40	65	35	55	40	65	45	70	25	35	50	80	25	40	40	70	60	80	21	35			
Grail silty clay loam	35	55	20	30	40	65	35	55	40	65	45	70	20	35	50	80	20	35	40	70	60	80	21	35	9	4	
Williams clay loam ✓	30	45	15	25	40	65	35	55	40	65	45	70	20	35	50	80	20	35	35	60	50	70	20	33			
Morton loam	35	55	20	30	35	60	30	50	35	60	40	65	15	30	40	70	20	40	40	65	50	70	20	33			
Cheyenne loam	35	55	20	30	35	60	30	50	35	60	40	65	15	30	40	70	20	40	35	60	40	60	18	30			
Morton clay loam	30	45	15	25	35	60	30	50	35	60	40	65	15	30	40	70	20	35	35	60	50	70	20	33			
Searing loam	35	55	20	30	30	55	25	45	30	55	35	60	----	----	40	70	20	30	35	60	40	60	17	30			
Banks very fine sandy loam ✓	30	50	15	25	30	55	20	35	20	30	25	40	15	25	35	60	25	40	25	40	20	35	9	15			
Cheyenne fine sandy loam	30	50	15	25	30	55	20	35	20	30	25	40	----	----	30	55	20	30	25	40	25	40	10	16			
Flasher fine sandy loam	30	50	15	25	30	55	20	35	20	30	25	40	----	----	30	55	20	30	25	40	25	40	10	16			
Patent silt loam	30	45	20	30	30	55	25	45	30	55	35	60	15	25	35	60	20	30	35	60	50	70	20	35	7	5	Fair cropland.
Cherry silty clay loam	25	45	15	25	30	55	25	40	30	55	35	55	15	25	35	60	15	25	35	60	50	70	21	35			
Grail silty clay loam, slope phase	25	45	15	25	30	55	25	40	30	55	35	55	15	25	40	70	15	25	30	50	40	60	15	26			
Patent clay loam	25	40	15	25	30	55	25	40	25	40	30	50	15	25	35	60	20	30	35	60	50	70	20	35			
Bainville loam, smooth phase ✓	25	40	15	25	25	45	20	35	25	40	30	50	----	----	30	55	20	30	20	30	30	50	16	27			
Wade-Farland silty clay loams [6]	20	35	10	20	25	45	20	35	25	45	25	40	----	----	10	20	----	----	20	35	35	55	{14 / 4	25 / 6			
Rhoades loam (complex) [6]	20	35	10	20	25	45	20	35	25	45	25	40	----	----	10	20	----	----	20	35	35	55	{14 / 6	25 / 10			
Moline clay loam (complex) [6]	20	35	10	20	25	45	20	35	25	45	25	40	----	----	10	20	----	----	20	35	{35 / 20	55 / 30	14 / 6	25 / 10		6	
Bainville clay loam, smooth phase ✓	20	35	10	20	25	45	20	35	25	40	30	50	----	----	30	55	15	25	20	30	30	50	15	----			
Rhoades clay loam (complex) [6]	20	30	10	20	25	45	20	35	25	45	25	40	----	----	10	20	----	----	20	35	{35 / 20	55 / 30	14 / 6	25 / 10	8		
McKenzie clay, light-colored phase [6]	15	25	10	20	20	30	20	35	20	35	25	40	----	----	10	20	----	----	15	25	25	40	{14 / 8	25 / 13			

See footnotes at end of table.

TABLE 6.—*Productivity ratings of soils in McKenzie County, N. Dak.*—Continued

UNDER DRY FARMING—Continued

Soil [1]	Crop-productivity index [2] for—																						General productivity grade [4]		Land classification [5]
	Corn (grain) 50 B		Corn (fodder) 12 T		Wheat 25 R		Barley 40 B		Oats 50 B		Flax 15 B		Alfalfa [3] 4 T		Sweet-clover 2 T		Potatoes 200 R		Millet 3 T		Wild hay 1 T		Permanent pasture 100 cal				
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b		
Patent clay loam, slope phase	15	25	10	20	20	30	15	25	20	30	25	30	10	30	25	40	10	20	25	40	30	50	14	24			
Williams loam, rolling phase	15	25	10	20	20	30	15	25	20	30	20	30	----	----	25	40	10	20	20	30	30	50	14	23			
Morton loam, rolling phase	15	25	10	20	20	30	15	25	20	30	20	30	----	----	25	40	10	20	20	30	30	50	14	23			
Williams clay loam, rolling phase	15	25	10	20	20	30	15	25	20	30	20	30	----	----	25	40	10	20	20	30	30	50	14	23			
Morton clay loam, rolling phase	15	25	10	20	20	30	15	25	20	30	20	30	----	----	25	40	10	20	20	30	30	50	14	23			
Bainville loam	15	25	10	20	20	30	15	25	20	30	25	30	----	----	30	55	15	25	25	40	25	40	11	20		7	Generally unsuited for permanent cropland. Best suited for grazing.
Bainville clay loam	10	20	10	20	15	25	10	20	15	25	25	30	----	----	30	55	10	20	25	40	25	40	11	20			
Flasher loamy fine sand, smooth phase	15	20	10	15	15	20	15	20	15	20	15	20	----	----	15	20	25	35	10	15	15	20	6	11			
Flasher fine sandy loam, rolling phase	15	25	10	20	10	15	10	15	10	15	10	15	----	----	20	30	10	20	10	20	10	20	7	12			
Banks loamy fine sand	15	----	10	----	10	----	10	----	10	----	10	----	10	----	15	----	10	----	10	----	5	----	5	8			
Huff loamy very fine sand	15	20	10	15	10	15	10	15	10	15	10	15	10	15	15	20	15	20	10	15	10	15	6	10			
Flasher loamy fine sand	10	15	10	15	10	15	10	15	10	15	----	----	----	----	10	15	20	30	5	10	10	15	5	8			
Havre silty clay, poorly drained phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	50	100	20	35			
Alluvial loam soils, undifferentiated	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	17	30			
Alluvial clay soils, undifferentiated	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	12	20			
Dimmick clay	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	12	20			
Williams clay loam, steep phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	11	18			
Cherry silty clay loam, poorly drained phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	10	20	9		
Bowdoin clay	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	10	20		9	
Banks very fine sandy loam, poorly drained phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	10	16			
Searing loam, rolling phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	8	13			
Rhoades clay loam, rolling phase (complex) [6]	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	30	50	9	16			
																					15	25	5	8			
Moline clay loam, slope phase (complex) [6]	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	30	50	9	16			
																					15	25	5	8			
Bainville loam, steep phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	7	12			Grazing land.
Bainville clay loam, steep phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	7	12			
McKenzie clay [6]	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	15	25	7	12			
																							3	6			

Cheyenne gravelly loam, steep phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	5	8			
Flasher loamy fine sand, steep phase	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	3	6			
Rough broken land	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2	3			
Sage clay	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	2			
Scoria	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	2	10	10	
Patent clay	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----					
Riverwash	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----			

UNDER IRRIGATION

Soil [1]	Crop productivity index [2] for—									General productivity grade [4]	Land classification [5]
	Corn (grain) 50 B	Corn (fodder) 12 T	Wheat 25 B	Barley 40 B	Oats 50 B	Alfalfa [3] 4 T	Sugar beets 12 T	Beans 25 B	Potatoes 200 B		
Farland silt loam	70	75	120	100	110	90	120	100	100	1	Excellent cropland.
Farland silty clay loam	70	75	120	100	110	90	120	100	100		
Havre silty clay	70	70	100	90	100	100	100	100	80		
Cheyenne fine sandy loam	55	60	90	80	60	85	80	90	75	2	Good cropland.
Bowdoin clay	60	60	85	75	80	80	80	85	60		
Banks very fine sandy loam	55	60	85	75	55	80	75	90	70		
Cherry silty clay loam	50	60	90	80	85	80	80	80	50		

[1] Soils are listed in the approximate order of their general productivity under the prevailing current practices.

[2] Soils inherently most productive for the specified crop in the United States are given the index 100. The soils in McKenzie County are assigned indexes that give the approximate production in percent of the standard. It should be realized that these indexes are largely estimates of judgment, as yield data by soil types are yet too fragmental to be adequate. Indexes in column "a" represent the average yield, whereas those in column "b" represent the average yield in the better years. In general, yields in column "a" are assumed to be about 60 percent of those in column "b".

[3] These indexes are based upon yields when alfalfa is first grown in the rotation. They do not take into account the detrimental effect that alfalfa has in the Great Plains through the depletion of soil moisture for succeeding crops—including alfalfa.

[4] This classification indicates the comparative general productivity of the soils under prevailing practices of management on a national basis.

[5] This is a general classification to show comparative productivity and use adaptation in simple terms of local application. The delineation on a map of areas of land classes in a given county is a distinct and supplemental step to this type of classification of soil types and is influenced also by the pattern of soil-type distribution.

[6] Single estimates of crop yields cannot be expected to be equally applicable to all areas—or to all parts of the same area—of these mapping units that are a complex of soil conditions. Double ratings are given to cover the range of productivity for pasture, the lower figure being for the more scabby (alkali) areas.

Absence of indexes indicates that the crop is not commonly grown on the soil.

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The indexes compare the productivity of each of the soils for each crop to a standard, namely, 100. This standard index represents the productivity without the use of amendments of the more productive soils of the region in which the crop is commonly grown. An index of 50 indicates that the soil is about half as productive for the specified crop as is the soil with the standard index. Soils given amendments, such as lime or commercial fertilizers, or unusually productive soils of small extent, may have productivity indexes of more than 100 for some crops. The following tabulation sets forth some of the acre yields that have been set up as standards of 100. They represent long-time average yields of crops of satisfactory quality on the better soils without the use of amendments.

Crop:		
Corn	bushels	50
Wheat	do	25
Barley	do	40
Oats	do	50
Flax	do	15
Potatoes	do	200
Beans	do	25
Corn (fodder)	tons	12
Alfalfa hay	do	4
Sweetclover hay	do	2
Millet	do	3
Wild hay	do	1
Sugar beets	do	12
Pasture	cow-acre-days [1]	100

[1] Cow-acre-days is a term used to express the carrying capacity of pasture land. As used here it is the product of the number of animal units carried per acre multiplied by the number of days the animals are grazed without injury to the pasture. For example, a soil type able to support 1 animal unit per acre for 360 days of the year rates 360, whereas another soil able to support 1 animal unit per 2 acres for 180 days of the year rates 90. Again, if 4 acres of pasture support 1 animal unit for 100 days, the rating is 25.

The principal factors determining the productivity of land are climate, soil, and management. Under the term "soil" as used here, conditions of slope and drainage are included. Climate as a factor in crop production cannot be isolated from the soil factor, inasmuch as climate determines in part the type of soil. In McKenzie County, however, variations of the seasonal climate from year to year are very pronounced in their effect on crop production, and they overshadow the soil condition. As a result, the productivity of the land is rather definitely associated in the experience of the farmer with climate, particularly the amount and time of precipitation, and the presence or absence of hot winds. Other elements that contribute to determine actual yields obtained by the farmers in McKenzie County are the infestation of insects, such as grasshoppers, and the prevalence of fungi, such as black-stem rust. Two soil conditions of particular importance to productivity in this county are the content of soluble salts and the degree of saturation by sodium. Since these conditions are commonly associated and result in a series of bare circular spots locally known as scab spots, distinctly scabby areas are mapped separately (see descriptions for alkali claypan and salty soils). A range in scabbiness naturally occurs in the areas designated as scabby, and so the table gives two indexes for pasture on the alkali claypan and salty soils. These factors of soil, climate, and management do not operate independently of one another, and the productivity of

all soils cannot be measured directly by any one of them. Crop yields over a long period of time furnish the best available summation of the combined effect of the factors, and they are used as a basis for the indexes wherever they are available. A lack of substantial data concerning yields on individual soil types in McKenzie County has resulted in the indexes in table 6 being largely estimates based on the experience and judgment of local farmers, county agents, other agricultural workers, and members of the soil-survey party.

In table 6 the indexes in column "a" indicate the estimated average yield, whereas those in column "b" refer to the estimated average for the better years. Average yields, including those in seasons of partial and total crop failures, probably are not more than 60 percent of the yields obtained in average favorable years. Estimates of crop yields are given also for the soils under irrigation. The soils are listed in the order of their general productivity under dominant current practices, and productivity grade numbers are assigned in the column, "General productivity grade." The general productivity grade is based largely on the indexes for wheat in this spring-wheat section of the country, although the actual placements recognized also the indexes for the other crops. Since it is difficult to measure mathematically either the exact significance of a crop in local agriculture or the importance and suitability of certain soils for particular crops, the placements are a result of inspection of the indexes and personal judgment rather than of precise mathematical computation. If the apparent average of the crop indexes for a soil type comes between 90 and 100, the soil type is assigned a grade of 1; if it comes between 80 and 90 a grade of 2 is given, etc.

The column "Land classification" summarizes in a simple way the productivity and use capabilities of the various soils by placing them in a few groups on the basis of their relative suitability for dry farming, grazing, and farming under irrigation.

Productivity tables do not present the relative roles which soil types, because of their extent and pattern of their distribution, play in the agriculture of the county. The tables give a characterization to the productivity of individual types. They cannot picture the total quantitative production of crops by soil areas without the additional knowledge of the acreage of the individual soil types devoted to each of the specified crops.

Inasmuch as these ratings are based only on the characteristics of the soils and their productivity, they cannot be interpreted directly into land values except in a very general way. Distance to market, relative prices of farm products, and other factors influence the value of the land.

In connection with the use of the soil map as a basis for rural assessment for taxation, it may be stated that several of the units shown on the published soil map represent, for purposes of simplification, combinations of rather similar units shown on the field sheets, which were used in arriving at the rating of each tract of land. In addition to comparative productivity, distance to market, location in relation to other tracts, size, and present use were factors that determined the relative rating of each unit area considered in the evaluation of land for assessment. This productivity table, although similar to those set up for the assessment classification, cannot be considered identical.

LAND USES AND AGRICULTURAL METHODS

A planned agricultural program for McKenzie County will involve the production of feed crops for livestock, the extensive grazing of meat animals, and the limited production of cash crops. Because of the numerous crop hazards, only the most productive soils can be tilled profitably, and in order to maintain sufficient reserves of feed, much of their acreage must be devoted to feed crops, and the remaining acreage may be considered as available for cash crops. The kinds of cash crops, however, are limited by both climatic conditions and the comparatively long distance to markets.

The production of feed crops deserves the more serious attention of the farmers because of the hazards in crop production and the serious consequences to livestock farming if there is a shortage of feed. The development of irrigation projects, particularly in the valley of the Missouri River, for the purpose of having a more reliable source of feed crops, should be a contribution to a more stable agriculture for at least a part of this county.

During the period of settlement by homesteaders and the subsequent continued expansion brought about by the World War and mechanized agriculture, tillage of soils spread rapidly to all except the roughest sections. Experience of recent years has shown that crops cannot be successfully produced on the less productive soils, and, based on the general welfare of the county, isolated areas of even more productive soils should be abandoned to a meadow or grazing status. Since about 1935 the Land Utilization Division of the Resettlement Administration (and more recently transferred from the Bureau of Agricultural Economics to the Soil Conservation Service) has been acquiring those extensive areas that are best utilized as grazing land, where grazing districts will be set up and grazing rights leased to livestock producers. The expected consequence of this program will be to return unproductive tilled areas to a grazing status, to eliminate isolated farmed areas that are expensive to the community, and to improve the status and stability of the grazing areas by eliminating overcrowding and consequent overgrazing of the range.

Even under the best plan of operation, land operators in this section will be confronted by crop and range hazards. Successive years during which cash crops will fail, feed reserves become seriously reduced, and grazing sharply curtailed will occur occasionally. Such a regional condition makes a demand on credit not experienced in more uniformly productive sections, and calls for an elastic, low-cost though conservative plan of credit that will bridge these occasional unproductive periods and spread the financial burden over the more prosperous years.

Most of the soils of McKenzie County that are otherwise suitable for crop production are in a fairly high natural state of fertility compared to those of the more humid sections of eastern United States. They are well supplied with nitrogen and are sufficiently calcareous for the satisfactory growth of plants, such as alfalfa, which require relatively large quantities of lime. The natural fertility of these soils has decreased only slightly during the cropping history of the county, in spite of the fact that cash grain crops are the main source of income, and very little effort has been made to return plant nutrients

to the soil either through legume crops, barnyard manure, or commercial fertilizers. This relatively slow diminution is due, at least in part, to low average yields and slow loss of plant nutrients through oxidation of plant residues. At some time in the future, however, the effect of continual tillage and removal of crops, accompanied in places by erosion, and other physical difficulties intensified by drought conditions, and with no appreciable compensating return of plant nutrients to the soil, will be reflected in a diminution of yields. Lower yields will be noticed first on the less fertile soils; in fact, such a trend has already been experienced.

Phosphorus is probably the most nearly deficient of the plant nutrients. It has been definitely determined that the regular application of phosphate fertilizer is advantageous to most crops produced on irrigated areas. Its use on dry-farmed areas is as yet questionable, because a lack of available moisture limits yields to such a low figure as to make the probable return on money invested in fertilizer of this sort extremely low. Barnyard manure, however, can be utilized to good advantage even on the dry-farmed areas. The usual practice is to spread the comparatively small available supply of manure to the stubble land in winter or early spring. Some farmers assert that light applications worked into summer-fallowed land, or otherwise thoroughly incorporated with the soil, give justifiable returns, and experiments conducted at the Northern Great Plains Field Station indicate increased yields where barnyard manure was used (*7*).

Operators on dry-farmed areas probably influence productivity of their soils more through their treatment of soil structure and tilth than through their treatment of soil fertility, drainage, or any of the other soil-productivity factors. The natural structure of the more productive soils of this county is very suitable for plant growth, much better in fact than in soils of more humid sections, and it is conceded that the productivity of these soils is jeopardized by the destruction of this natural structure. Continuous tillage breaks the natural fragments or clods to a fine or nearly single grained condition, making the soil mass considerably more subject to wind and water erosion and, as a result of the destruction of the natural vesicles or air channels, making the soil less well aerated. Another detrimental effect of tillage is the development, in certain soils, of a hardened layer or plow sole directly below the plow layer. Observations, particularly of fine sandy loam and loam soils, indicate that the use of moldboard plows for a long time develops this hard, dense plow sole ranging from 1½ to 3 inches in thickness. This condition interferes with the movement of soil moisture and the growth of plant roots. The productivity of these soils very probably would be enhanced by subsoil tillage that would break up the plow sole. The cost of such an operation, however, will be an important item in determining its practicability.

The farmer, recognizing the general desirability of maintaining natural soil structure, however, is faced by the unavoidable necessity of seedbed preparation and crop cultivation. The nearest approach to the most desirable condition is to follow a cultural system that gives sufficient tillage for satisfactory crop growth with implements designed to least disturb the natural structure (*1*) and to cover or turn under only partly the surface sod or stubble. Leaving a rough-

ened surface containing bits of stubble, etc., tends to check soil blowing and in fall-plowed areas tends to act as catchment basins for snow.

Most of the silty clay loam and clay soils have their tilth improved by fall plowing, as the natural weather conditions of the winter season slake or soften the hard chunks and clods; but fall tillage may be detrimental even to these soils because of increased soil blowing. On the other hand, the retention of snow is an advantage not to be entirely overlooked. In general, silty clay loams and clays are much less subject to damage by soil blowing in winter as a result of fall plowing than are loams and sandy loams. The so-called alkali-claypan soils have their productivity improved by tillage over a period of years. Improvement here is due to the breaking up of the claypan and the distribution and incorporation of the more loamy surface layer of the interclay-spot areas with the less productive clay of the clay spots, but tillage of these soils should be moderate and only sufficient for the accomplishment of this purpose.

The presence of excessive amounts of salts (so-called white alkali) in soils practically eliminates them from consideration for crops demanding tillage of the soil under present agricultural conditions in the dry-farming section of the county. The safeguarding against the accumulation of salts deserves especial attention on the irrigated areas and areas where irrigation is contemplated. The entire area of the Lower Yellowstone irrigation project has a complete ditch drainage system designed to remove excess water and thereby afford a means of removal of undesirable quantities of salts that might otherwise accumulate. The matter of possible salt intrusion and accumulation deserves particular attention on those areas that may be irrigated from the creeks and drains whose sources of water are local. Almost invariably the water of these streams is more salt laden than that of either the Missouri or the Yellowstone River, and, because of their more limited flow, removal of salts by flushing the soil will be possible in few places. Limited experience with irrigation from creeks within the county indicates that, with few exceptions, accumulation of salts will be difficult to avoid.

Although a great many of the soils inherently have many characteristics favorable to a high productivity under dry farming, many of the characteristics of the environment are distinctly undesirable and seriously discount the otherwise high productivity of the soils. These are principally lack of sufficient moisture during the growing season, hot periods during midsummer, winds of high velocity, hail, black stem rust, and insect pests. Lack of sufficient moisture is considered the primary limiting factor in crop production in this county. Selection and diversification of crops, selection of improved varieties, and cultural and rotation methods are the most effective means of coping with the above-mentioned hazards. Diversification of crops reduces the chances of total crop losses. For example, a season that may result in a total loss of the wheat crop, may be comparatively favorable for corn or millet. Selection of crops involves the choosing of those crops which have a comparatively low water requirement and are either drought-resistant or early maturing. Thus, the small grains—rye, wheat, and barley—are early maturing, and corn, sorghum, flax, and millet are at least moderately tolerant

of dry periods. Most of these crops have been improved by the development of new varieties and by varietal research conducted by the North Dakota Agricultural Experiment Station and other stations, in regard to weather, disease, and insect hazards. Thus, Ceres and later developed varieties of wheat are rust-resistant and more tolerant of drought and grasshopper attacks than the commonly grown Marquis wheat. Bison and Buda are wilt-resistant varieties of flax, and early maturing varieties of corn are very largely responsible for the good yields of this crop obtained by many farmers in this county.

The hazards of crop production in counties such as McKenzie have been called to the attention of the public in recent years by the occurrence and recurrence of drought, duststorms, grasshoppers, rust, and low prices. Weather data indicate that the recent drought years are only a part of a cycle of comparatively wet and dry years. Variations in moisture from year to year make it impossible to recommend standard, or fixed, systems of crop rotation. In fact, flexibility is a prerequisite of a rotation. Again, practices of land use and soil management, suitable for the wetter part of the cycle, prove to be unsuited or even detrimental for the drier years. Thus, the number of soil types that may be safely cultivated in the wetter years is reduced in the drier years. Practices of management necessarily are changed. For example, summer fallowing was much more successful before than during the recent drought years. Of course, changes in the structure and organic-matter content of soils, with continued tillage, may be partly responsible, but differences in climatic conditions also contribute. The following experimental data and recommendations are offered, with the realization that they do not apply to all soil types and in all years.

A common and suitable rotation for this section, according to recommendations of the Northern Great Plains Field Station, is a 3-year rotation of corn, wheat, and oats or barley. As corn seldom occupies as much as one-third of the acreage on many farms, summer fallow should be practiced on the remainder of this one-third. The primary object of including either an intertilled crop or summer fallow in the rotation, in a region of low rainfall where drilled or broadcast small grains occupy an important part of the acreage, is to keep down the weed growth and thereby conserve the moisture for the benefit of the crop to follow. For this purpose summer fallow is more efficient than growing intertilled crops, as the weed growth is more thoroughly suppressed, the acre cost of tillage is lower, and a moisture reserve is built up to the benefit of the following year's crop, at least during its early stages of growth. The growing of an intertilled crop, however, has the marked advantage of producing a crop during the same season that the weed-control measures are in operation. According to information from the Northern Great Plains Field station, a rotation including summer fallow, followed by wheat, yielded 21 bushels of wheat an acre, whereas a rotation including corn, followed by wheat, yielded 25 bushels of corn, plus forage, and 17 bushels of wheat an acre. Other crops that can be successfully used in this part of the rotation are sorghum and potatoes.

The most satisfactory grass and legume hay crops are sweetclover, alfalfa, crested wheatgrass, and western wheatgrass. Bromegrass

and slender wheatgrass are also well adapted to this region, although the former soon becomes sod-bound and the latter is comparatively short lived (*1*). Alfalfa is not suitable for grazing, and the other grasses must be protected against overgrazing, otherwise they will be partly or wholly destroyed. Western wheatgrass is not commonly seeded, but on some of the clay loam soils it frequently reestablishes itself if given an opportunity to do so before the roots of the native sod have been completely killed by tillage. It is the most desirable native grass for hay meadows. Sweetclover is a biennial but if allowed to develop sufficient seed, will reseed itself and at least a partial stand will continue into later years. It is suitable for both hay and grazing, but as a hay crop on areas suitable for alfalfa, the yields are not so high as those of alfalfa. Sweetclover as a pasture crop is a good supplement to crested wheatgrass, as it affords comparatively good midsummer grazing at a time when crested wheatgrass is dormant.

Crested wheatgrass, according to Technical Bulletin 307 (*8*), is especially well adapted to the northern Great Plains, as it is suitable for both hay and pasture and is hardier than alfalfa, alfalfa being a somewhat hazardous crop owing to its susceptibility to winter killing. Alfalfa, however, is probably the most satisfactory hay crop on the most productive soils, as the yields are much larger than those of crested wheatgrass and the chances of maintaining a stand on these desirable areas are comparatively good. Crested wheatgrass, however, is probably the most satisfactory of all crops for establishing a permanent meadow or a grazing crop on at least the better areas of those unproductive soils which should be removed from tillage. According to Department Bulletin 1301 (*7*), it is a very desirable grass for early spring and fall grazing but should be supplemented by a pasture crop better adapted to midsummer grazing, such as sweetclover or deferred native pasture, that is, pasture that has not been grazed early in the season, in order to provide grazing for livestock through midsummer when the crested wheatgrass is likely to be injured.

The most satisfactory method of establishing stands of these hay and grazing crops is to prepare the land by summer fallowing or by growing an intertilled crop. Alfalfa and sweetclover are seeded either with or without a nurse crop, but the best stands, according to Department Bulletin 1301 (*7*), are obtained where no nurse crop is used. The other hay and pasture crops should be seeded without a nurse crop.

Although these and some other forage plants are of great value to the agriculture of this section, the problem of reestablishing a good grazing crop in places where the native stand of grass has been destroyed by tillage, particularly on the sandy and the less fertile soils, has not as yet been solved satisfactorily.

Because of the danger of losing stands of these more permanent hay and grazing crops as a result of winter killing, dry weather, and other hazards, it is necessary to have some annual forage crops on which to rely. Millet, small grains cut before maturity, sorghums, Sudan grass, and corn are the most satisfactory for this purpose.

The stand of native vegetation on many areas, according to observations of cattlemen and investigators, has suffered considerably from

overgrazing, particularly during recent years. This practice has either suppressed or killed much of the more edible vegetation, and there has been a proportionate increase in the growth of weeds. As a result, both the carrying capacity and the quality of the grazing vegatation on such areas has been markedly reduced. Generally, the native vegetation will reestablish itself if grazing is curtailed sufficiently.

Grazing experiments (*6*) on an area comprised predominantly of Williams silt loam and Arnegard silt loam were conducted at the Northern Great Plains Field Station near Mandan, N. Dak., for several years starting with 1915. These trials demonstrated the results of different rates of continuous grazing and a system of deferred and rotation grazing. Two-year-old steers and a 5-month grazing period starting from May 15 to June 1 and continuing to October 15 to November 1 were used. The deferred and rotation system of grazing was designed to allow each division of the pasture to mature a crop for two successive years before it was harvested by the cattle in the fall of each year. Grazing on each division was deferred and rotated, so that each unit had an equal chance to produce a maximum crop normally before it was disturbed. Following are some of the conclusions drawn from the results of these experiments as set forth in Department Bulletin 1170 (*6*):

Native pastures deteriorate when grazed because of (1) too early grazing in the spring, (2) continuous grazing, and (3) overgrazing. All of these factors can be controlled.

The measure of efficiency of a pasture or system of grazing is not determined by one factor but by several of equal importance.

The most efficient system of grazing is one that will insure sufficient forage during the entire season to produce the greatest total gain in weight with the least number of cattle on the minimum unit of land without permanent injury to the native vegetation. The requirements of this measure of grazing efficiency are most nearly fulfilled by the deferred and rotation system of grazing.

The 70-acre pasture, grazed at the rate of one steer to 7 acres, provides approximately the area of land required to produce the maximum gains per head under a system of continuous grazing. The 50-acre pasture, grazed at the rate of one steer to 5 acres, is not large enough to allow the cattle to make maximum gains per head. This pasture is overgrazed. * * * Under a system of deferred and rotation grazing the number of acres required per head is reduced to between 4 and 5. This acreage will provide enough feed to allow the cattle to make gains per head intermediate between those made in the 50-acre pasture and those made in the 70-acre and 100-acre pastures. This system allows the maximum utilization of the vegetation without the injury to it accompanying overgrazing.

MORPHOLOGY AND GENESIS OF SOILS

The climatic conditions prevailing throughout McKenzie County favor the development of Chestnut soils. The average annual precipitation is approximately 15 inches, 12 inches of which falls between April 1 and November 1. Freezing conditions prevail within the ground for about 4½ months of the year. Ground moisture very seldom becomes sufficiently abundant to cause complete percolation through the soil, and the material at a depth of 3 feet is dry most of the time.

The native vegetation is dominated by short grasses. Blue grama is the most abundant species, yet buffalo grass, side-oats grama, and other short grasses are common but not abundant. Two sedges, nig-

gerwool and upland sedge, are the dominant species of short vegetation on the sand soils. Taller grasses that are commonly intermixed with the short grasses are needlegrass, western wheatgrass, little bluestem, and feathergrass, and sandgrass is common on the sand areas. The forest growth is confined to the floors of the larger stream valleys and the deeper upland draws. Cottonwood, willow, and ash predominate on the former, and ash and elm predominate on the latter. Western redcedar is common on the north slopes and draws throughout the Badlands. Oaks grow in a few upland draws in the vicinity of Charlson and Croff.

The soils of the uplands of McKenzie County are derived from two general classes of parent materials, (1) the more or less consolidated sedimentary formations and (2) the heterogeneous mixture of glacial drift. The sedimentary formations, which are exposed over more than half of the county, range lithologically from strongly indurated sandstones to beds of loosely consolidated sands and clays. These materials have been correlated by geologists with the Fort Union formation of the Tertiary period. The materials range in color from yellow to dark olive gray, and almost all of them contain a large percentage of carbonates. Comparatively thin deposits of lignite occur in the shale beds. Beds of red bricklike fragments of shale, locally known as scoria, were formed in the burning of lignite beds. The scoria beds are parent to a limited acreage of soil, and the lignite beds appear to have contributed no characteristics to any soil.

Throughout the northern half of the county a covering of glacial till—probably of Kansan age—occupies irregular areas of the smoother upland. This material for the most part is olive-drab friable slightly gravelly calcareous clay intermixed with irregular and variable quantities of granitic boulders. The till is noticeably more calcareous and more friable than is the clay of the Fort Union geologic formation.

The important characteristics of the Chestnut soils as they occur in McKenzie County are (1) a slightly eluviated layer ranging from 2 to 4 inches in thickness, (2) a layer below this having a dark-brown color and a well-developed prismatic structure, (3) insufficient carbonates above a depth of 12 inches to cause effervescence when the material is treated with acid, (4) visible accumulation of carbonates at a depth of about 16 inches, and (5) relatively unaltered parent material below a depth of about 28 inches.

The Chestnut soils include members of the Williams, Morton, Flasher, Cheyenne, and Farland series. The Flasher soils are less truly representative than the other members. The Williams soils have developed on the till plains, the Morton soils on the silt and clay beds of the Fort Union geologic formation, the Flasher soils on the sandy beds of this formation, and the Cheyenne and Farland soils on the older well-drained alluvial benches. The Arnegard soils of the gentle depressions are, perhaps, more nearly representative of the Chernozems than the Chestnut soils.

The following description of Williams loam is that of a well-developed Chestnut soil as found in this county. The 4-inch surface layer is dark grayish brown and ranges in texture from very fine sandy loam to silt loam. The 1-inch surface layer (A_1) is a semimat of grass roots and fine-grained soil material. When the roots are pulled

apart, the soil material falls away from or is shaken out of the root mass easily. The underlying 3-inch layer (A_2) has a crumb structure, that is, the mass when crushed breaks to small irregular-shaped friable fragments that are easily powdered to a fine-grained mass. The lower part of this layer generally is darker colored and has a firmer structure. Ordinarily the material in this layer does not contain enough carbonates to cause effervescence when treated with an acid, although in some places effervescence occurs in the upper one-half inch.

The layer having a well-defined prismatic structure (B_2) begins at a depth of about 5 inches and continues to a depth of about 12 inches. The change from the layer above to this layer is gradual, at least as evidenced by the color and structure change. The color is dark grayish brown. When taken from place, the mass breaks readily to well-defined vertical pieces, or prisms, that range in diameter from ½ to 1½ inches. These pieces are firm but are easily broken to smaller vertical fragments. These prismlike pieces are brittle, their surface is rough, and when broken horizontally their outline is subangular or irregularly rounded, consisting of thick rounded, almost disklike fragments. The surfaces of horizontal breakage are much smoother than the surfaces of vertical breakage. Close examination shows these pieces to contain numerous fine vesicles. Grass roots and rootlets permeate the prisms vertically and tend to strengthen the structure. Thus, the prisms separate from each other, but when they in turn are broken horizontally, many maintain their prismatic shape until the roots are broken. The fragments are brittle and crush to a soft friable mass of the fine soil particles. The texture of this layer is clay loam or sandy clay loam. At a depth ranging from 12 to 14 inches, carbonates are plentiful enough to cause effervescence when the soil is treated with an acid. The material has a slightly lighter color below the depth where effervescence takes place.

Below this layer, lies a gradational zone (B_3). The dark grayish-brown color fades to a lighter shade approaching olive drab at a depth of about 18 inches. The prisms are well defined but do not break apart readily in the lower part. The material in this layer is vesicular and friable throughout.

At a depth of about 18 inches a layer containing visible grayish-white splotches of carbonate begins. The mass color is olive drab, and the texture is clay. The prismatic structure and vesicular characteristics do not extend into this layer but vertical cleavage generally extends to a depth of about 22 inches. The mass breaks easily to angular firm but friable pieces. The greatest concentration of carbonates is in the upper 5 or 6 inches of this layer, and below this zone, the grayish-white carbonate splotches are present but noticeably less prominent. Below a depth of approximately 30 inches lies relatively unaltered parent material composed of olive-drab friable clay with some grayish-white carbonate splotches. A few pebbles are in this layer as well as in the upper layers of this soil.

Williams loam has an undulating to gently rolling surface and is well drained. The native vegetation is dominantly short grasses with some taller grasses intermixed; the common species, named in the order of their abundance, are *Bouteloua gracilis*, *Stipa comata*, *Agro-*

pyron smithii, and a sedge, *Carex filifolia*. Most of the roots are in the upper 3 or 4 inches of the soil, but they are numerous to a depth of about 14 inches, and a few extend to a depth of 24 inches or deeper.

Williams clay loam differs from Williams loam principally in having a clay loam surface layer (A_1 and A_2). The structure of the fragments of the 4- or 5-inch surface layer is firmer, and the mass is friable but hardly crumbly.

The members of the Morton series are Chestnut soils developed from silts and clays of the Fort Union geologic formation. Morton loam differs from Williams loam in that (1) the prismatic structure is not so strikingly developed, (2) the zone of visible accumulation of carbonates is not so prominent, (3) the parent material contains more sand and is free from gravel, and (4) Solonetz spots occur more frequently than in Williams loam.

The Flasher series includes the grayish-brown and dark grayish-brown Chestnut soils developed from the sand layers of the Fort Union geologic formation. The prismatic structure common to the soils of the Williams and Morton series is not characteristic of the Flasher soils. The fine sandy loam member has a B_2 layer as evidenced by a higher content of fine material and a somewhat more chunky or brittle structure than that of the surface layer. The parent material, or C_2 layer, is light olive-green fine sand. Carbonates sufficient to cause effervescence when the soil is treated with an acid are at a noticeably greater depth than in the Morton and Williams soils. This is true, however, only of the smooth undisturbed areas, as elsewhere wind and water erosion has so disturbed this soil that in many places carbonates lie at or within a few inches of the surface.

The Arnegard soils occupy positions in areas of Williams and Morton soils that are subject to accumulation of run-off water and fine-textured alluvium but are sufficiently well drained to prevent the accumulation of salts. These soils may be considered as a local counterpart of the Barnes soils of the Chernozem region, brought about by local moisture conditions simulating the regional conditions to the east. The material of the solum is darker throughout than that of Williams loam, in many places the color being very dark grayish brown, and the dark color generally extends to a greater depth than does the dark grayish-brown color of Williams loam. A visible accumulation of carbonates does not occur as commonly in this soil as it does in Williams loam. The layer having a well-developed prismatic structure, although darker, is otherwise similar to that of Williams loam.

The Bainville soils are immature and have developed from silts and clays of the Fort Union geologic formation, and, because of drier locations or erosion, the dark-brown soil has not developed. The thickness of the solum of the Bainville soils varies according to topographic position, and only a very weak prismatic structure is developed. The following description gives a general idea of Bainville loam: The 4-inch surface layer is grayish-brown loam, the topmost inch of which is a weakly bound root mat. The soil material comes from place in lumps that are easily crushed to a soft mass. From a depth of 4 inches to a depth of about 7 inches is a layer of material which in many places has a weakly developed vertical structure, although the prisms are ill defined or may be absent. The color ranges from brown to light brown, and the texture is loam or

silt loam. Below a depth of 7 inches, the color gradually fades, and at a depth of about 12 inches comparatively unaltered gray and yellow silt or clay parent material occurs. Below the 6- or 7-inch depth grayish-white carbonate flecks are abundant in most places. In general the entire profile of this soil shows effervescence when treated with an acid.

The Farland, Cheyenne, Cherry, Huff, Grail, and Patent soils are developed on alluvial benches and alluvial valley slopes. The Grail and Patent soils are on gentle alluvial valley slopes, and the parent material of both is clay or silty clay. The Grail soils are dark grayish brown or very dark grayish brown, whereas the Patent soils are brownish gray.

Considerable areas of soils in this county are, or have been, more or less affected by salts. These soils are included in the Moline, Rhoades, Wade, McKenzie, and Sage series. They are in positions that allow, or did allow at one time, the movement of salt-laden water into the soil.

According to the general scheme of evolution of Solonchak, Solonetz, and Soloth (*2*) the development of the claypan soils has been dominated by salt-laden capillary water and the development of the Sage and McKenzie soils has been dominated by salt-laden floodwater. The most common locations of those soils influenced predominantly by capillary water are on broad benches along streams or on gentle valley and upland slopes. Most of those developed under the influence of flooding by saline water are on old pond sites or alluvial fans.

All the soils developed under the influence of salt-laden capillary water are extremely spotted in their distribution—a condition that is due partly to differences in the extent of the salt intrusion and removal and partly to differential wind and water erosion of the eluviated surface layers. Figure 3 illustrates the development of soils under such conditions. Most of the soils in McKenzie County influenced by salts are included in the solodized-Solonetz and Solonchak complexes. The spots of the Solonchak complex are slight billows, mounds, or puff spots, the microrelief ranging from 2 to 12 inches. Their outlines are irregular but roughly circular, and the range in diameter is from 3 to 12 feet. Where strongly developed, very little vegetation other than a variable cover of *Dondia* sp. and saltgrass are on it. The interspot parts are slight depressions or comparatively broad troughs that meander about among the numerous puff spots. The vegetative cover between the spots is for the most part a dense growth of blue grama, with some western wheatgrass and saltgrass intermixed. The spots represent the Solonchak stage; the depressed parts represent the solonized stage, on which solodization has generally encroached to some extent. The generalized Solonchak profile is characterized by a thin gray crust underlain by a soft, structureless, mealy gray friable layer several inches thick, containing streaks and spots of salt. The Solonchak complex is not so common as is the solodized-Solonetz complex. Most of the areas of the former are included in Wade-Farland silty clay loams complex.

Since the distribution of the Solonchak condition is spotted and the areas are characterized by variability in soil profile characteristics, no one soil description can be representative of all areas. The

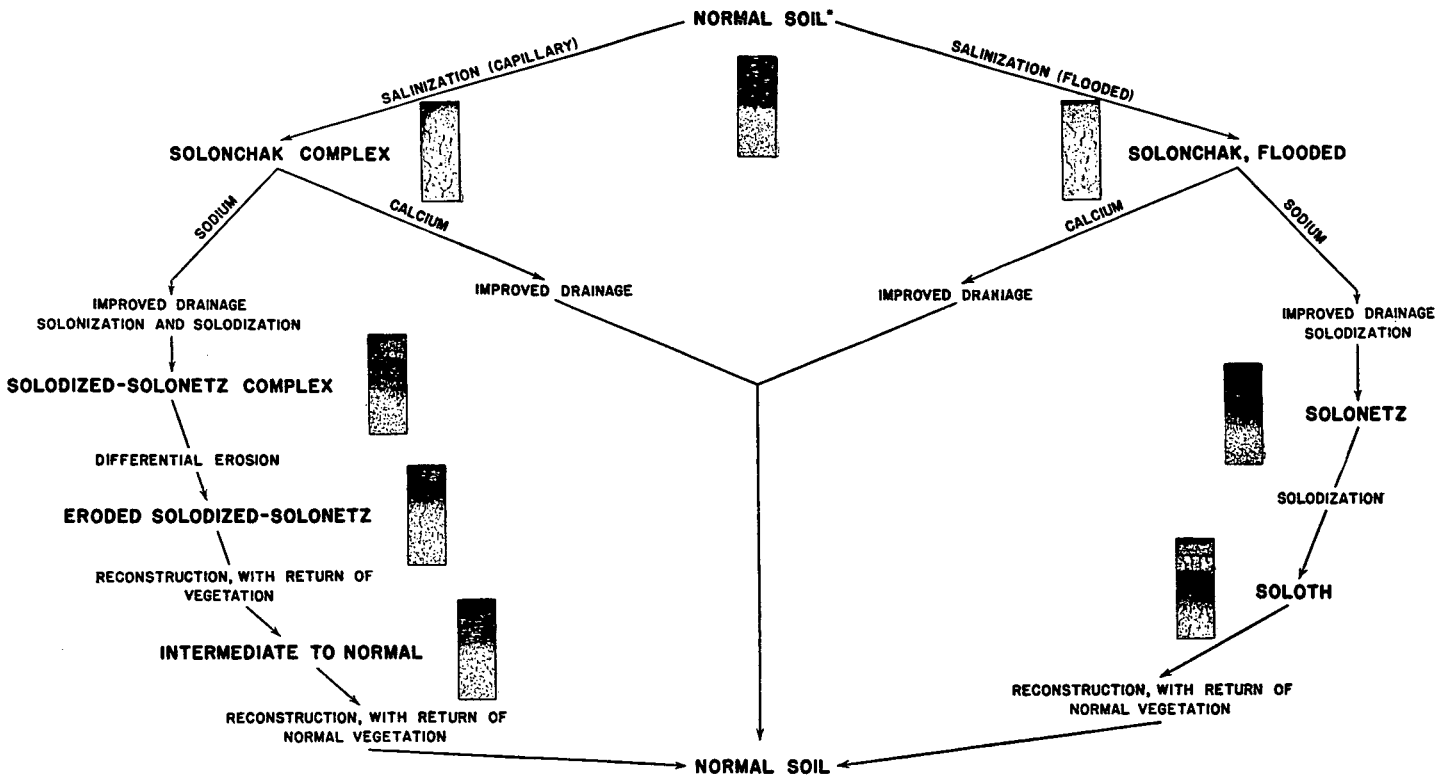

FIGURE 3.—Evolution of Solonchak, Solonetz, and Soloth (3).

following, however, gives the important characteristics of the Solonchak or salinized spots:

0 to ¼ inch, a gray very fine sand or very fine sandy loam vesicular crust. The appearance of this crust differs considerably according to the soil moisture condition, being much more evident when the soil is in a relatively dry state. Irregular patches of white fine salt efflorescence are on the surface.

¼ to 2½ inches, dingy-brown or very dark brown silty clay. In some areas the structure of this layer is fairly hard and breaks to firm, small, angular pieces, and in other areas it is friable and grainy, and a few salt crystals or flecks may be discernible.

2½ to 8 inches, dingy-brown soft friable grainy clay, through which is distributed an abundance of grayish-white carbonate flecks. In such places fine crystals are abundant, apparently concentrated along the cracks or cleavage surfaces. The mass is generally moist, is easily penetrated by a spade, and comes from place in soft angular pieces that are easily crushed to a more or less plastic mass.

8 inches +, the carbonate flecks and the crystals diminish and the color becomes lighter brown, and at a depth of 24 inches the material is olive-brown soft friable clay with practically no profile structure.

The profile of the interspot or solonized parts of this soil is similar to the solodized-Solonetz profile, a description of which follows. It differs from the typical Solonetz profile in one noticeable respect: The solodized condition is less well developed and is evidenced by a less gray color and a less floury or loose structure of the eluviated layers.

The solodized-Solonetz complex is by far the predominant condition found in the claypan soils. The spots in the solodized-Solonetz complex are shallow depressions ranging from 2 to 10 inches in depth. Their outlines are irregular, and their diameters range from 2 to 18 feet. The vegetative cover is sparse. The interspot parts are low moundlike or billowy, and they occupy that part of the landscape not taken up by the spots. Most of the interspot areas have a good grass cover comprised largely of blue grama.

One of the most common solodized-Solonetz soils is the Rhoades loam complex. The most extensive areas of this complex occur in the vicinity of Grassy Butte. Following is a description of an interspot part of this soil complex that is representative of a solonized area in which solodization has progressed to a marked degree. The observation was made in sec. 20, T. 145 N., R. 98 W.

A_1. 0 to ½ inch, dark-gray or grayish-brown very fine sandy loam containing many roots and fine particles of organic matter. The platy structure is not recognizable in this layer.

A_2. ½ to 6 inches, brownish-gray very fine sandy loam having a fine platy structure. The platelets break apart readily. They are distinct in outline and, although they crush easily, are brittle. The platelets are about one-sixtieth of an inch thick and one-tenth of an inch in diameter. The most striking platiness occurs between depths of 4 and 6 inches. The mass is lighter colored when crushed and browner when moist.

A_{22}. 6 to 8 inches, vertical cleavage is recognizable but is much less prominent than is the platy structure. The mass comes from place in vertical blocks that are easily cracked into definite horizontal sheets. The platelets are distinctly visible, but the mass structure is so firm as to prevent them from breaking apart easily. The color of the uncrushed mass is gray; when crushed and moistened, it is light brown. The unbroken mass is noticeably vesicular. The texture of this layer is very fine sandy loam.

A_{23}. 8 to 9 inches, this is the lightest colored layer of the solum. It includes the grayish-white covering on the tops of the columns, this covering

being about one-fourth inch thick and consisting of fine-grained material, part of which has a tendency to cling to the column caps. This thin layer serves as a weak plane or breakage plane in the structure of the solum. Any appreciable disturbance causes the columnar layer to break from the platy layers above at this plane. The texture of much of this thin layer is of very fine sand. The plane of separation between this layer and the columns below is very sharp.

B_2. 9 to 12 inches, this layer consists of well-developed columns ranging from ⅜ to 1 inch in diameter, which are hard and roughly circular. The tops of the columns are smooth and rounded. The mass, which is difficult to penetrate with a spade, breaks readily to angular hard columnar pieces. The texture of the material is clay, and the color is grayish brown in the upper part and grayish coffee brown in the lower part. When moistened and crushed, the mass color is lighter, having an olive-gray tinge. Roots extend throughout this layer and have a tendency to follow the cracks.

B_3. 12 to 17 inches, a transitional layer, in which the material is light olive-gray silty clay with a definite columnar structure, but the columns are larger and are more easily crushed than those in the layer above. Acid causes effervescence, at least in the lower part of this layer, although in many places mild effervescence takes place in part of the B_2 layer.

C_2. 17 to 24 inches +, the comparatively unaltered parent material composed of olive-gray very fine sandy loam. It digs from place easily and has no definite soil structure.

This description is by no means standard for all the interspot parts of the Rhoades loam complex. In most places the solonized layer, as described in this profile, is not so marked and the column caps are not everywhere so well developed. Grayish-white carbonate flecks commonly occur below a depth of 12 or 14 inches. Generally the parent material is harder and more nearly a clay in texture.

Most of the spots or nearly bare parts associated with the interspots have a profile similar to the one described below:

0 to 1¾ inches, light-gray strikingly platy and brittle very fine sandy loam.

1¾ to 2 inches, light-gray very fine sand resting on the rounded column caps, or what is considered a remnant of the columns.

2 to 5 inches, dark grayish-brown or nearly coffee-brown hard clay remnants of the columns. These columns are less symmetrical than the columns of the interspot solum, and they are larger and are crushed more easily. The pieces break easily to hard angular fragments about one-fifth of an inch in diameter.

5 to 10 inches, olive-drab clay. This layer has a vertical structure, but it is weaker and the fragments are more easily crushed than those of the layer above. Generally a few grayish-white carbonate flecks are in this layer, and in places a few are in the lower part of the layer above.

10 inches+, the relatively unaltered parent material. At least mild effervescence is obtained by treating the upper part of this layer with acid, and violent effervescence occurs in the material 6 or 7 inches deeper.

The profile of these spots varies considerably. The light-colored surface layer may be but a fraction of an inch thick, and in such places it appears as a brittle semicrust. The columnar layer in many places is even less prominent than it is in the profile described and may occur as a 1- or 2-inch layer of dark-brown clay that breaks into hard angular pieces showing no definite columnar structure. The columnar layer, or remnant of it, in many places is underlain by a layer of olive-drab friable clay that has an abundance of salt flecks distributed through it. These salt flecks may persist to a depth of more than 2 feet.

The degree of salt influence on the claypan soils differs considerably. Where the influence of salts has been extreme, the claypan and clay-spot condition is continuous over broad areas, but where their

influence is less marked, the columnar layer is less continuous and is more weakly constructed. In such places the clay spots are less numerous, and the profile of the interspot areas shows but little solonization, resembling more nearly the profile of the Chestnut soils.

The members of the McKenzie and Sage series have developed under the influence of flooding or ponding by salt-laden water. The outward appearance of these soils is strikingly different from that of the claypan soils, in that their surfaces and profiles are not spotted.

The soils of the Sage series represent the Solonchak stage. They occur in areas that are noticeably subject to seepage water, such as along the edges of stream bottom lands just below the upland or alluvial fans at the mouths of drainageways or draws. Drainage is poor, and the vegetation is sparse. Gray sagebrush and saltgrass are the most common plants. The profile of Sage clay varies, especially in regard to color, hardness, and quantity of and depth to plainly visible carbonate flecks. The profile as a whole is gray. The surface layer generally has a thin strikingly vesicular siliceous very fine sandy loam crust, on the surface of which may occur a thin irregular covering of salt efflorescence. Below this siliceous crust the material is gray or dark-gray clay. In general, it is fairly hard in place but on being crushed is fairly friable. Below a depth of 6 inches, the material is a clay that is a little lighter gray and is flecked with white carbonates. The mass is fairly friable and has no definite soil structure. The color becomes lighter with depth. The material throughout the entire profile effervesces abundantly when treated with an acid.

Most areas of the McKenzie soils occur on old pond or lake sites that are not now subject to either seepage or flooding by salt-laden water. Following is a description of McKenzie clay, as observed in the SW¼SW¼ sec. 14, T. 150 N., R. 99 W.:

0 to ¾ inch, a granular dark-gray crust, which contains numerous large vesicles. When the surface is moist, this crust is not easily recognized. The material may or may not show reaction when treated with an acid.

¾ to 4 inches, very dark gray or grayish-black clay. A fair columnar structure exists throughout this layer, and the mass breaks fairly easily to hard angular pieces. Effervescence with an acid ordinarily does not take place. The columns range from 1½ to 2 inches in diameter.

4 to 9 inches, the columnar structure becomes more massive and the fragments do not break away from each other easily. The color is approximately the same as in the layer above.

9 to 23 inches, the color of this layer is noticeably lighter gray than that of the layer above. The material is gummy when moist, and the texture is clay. The columnar structure hardly extends into this layer, and the soil fragments do not break apart easily. Effervescence with an acid is violent below a depth of about 16 inches.

23 to 30 inches +, dark-gray waxy clay. The material comes from place in large chunks, which, if not crushed to a plastic mass, break to angular pieces. When moist, this structure is easily lost by crushing or kneading. Clusters of dingy-gray crystals that effervesce when treated with acid are in the upper 6 inches of this layer. Below a depth of 29 inches are a few grayish-white splotches of carbonates.

The physical condition of McKenzie clay varies considerably according to its moisture content. When it is wet a spade can be thrust into it fairly easily, but when dry it is very hard and can be dug from place only with the use of a pick. It is extremely sticky when moist and has the consistence of a well-dispersed clay. When

thoroughly dried, the mass cracks into irregular blocks ranging from 8 to 20 inches in diameter. The cracks are from 1 to 3 inches wide and extend to a depth of 15 inches or more, depending on the amount of drying the soil has undergone. The cracks, so prominent when the soil is dry, are barely noticeable when the soil mass is thoroughly moistened. This extreme hardness and the tendency to crack are not characteristic of the Sage soil.

The vegetation on McKenzie clay also varies considerably according to whether the soil is moist or dry during the growing season. During exceptionally dry seasons the vegetation consists of a sparse short growth of western wheatgrass, but during extremely wet seasons the vegetation is a luxuriant growth of short reeds, wild barley, and western wheatgrass. On rare occasions the moisture condition of this soil is such as to allow tillage and the luxuriant growth of those plants commonly grown on mellow pervious soils.

SUMMARY

McKenzie County occupies an area of 2,847 square miles in the western part of North Dakota. The greater part lies between the Yellowstone, Missouri, and Little Missouri Rivers. About 175 square miles in the Fort Berthold Indian Reservation was not included in this soil survey.

Physiographically, the county is part of a high plateau into which the larger streams have cut deep valleys. The streams, particularly the Little Missouri River, are bordered by belts of dissected land, some of it so rough as to be termed "Badlands."

The climate, in common with a vast area in the Great Plains, is characterized by rather low precipitation, short summers, and long cold winters. The annual precipitation ranges in different years from 6.14 to 23.88 inches, with a mean of 14.67 inches. The mean annual temperature is 40.1° F., with extremes of −45° and 112°.

Before 1900 the land was used almost entirely for grazing cattle and horses, but the greater part of the public land was homesteaded between the years 1904 and 1910. The county was organized in 1905.

The census of 1930 gives the county a population of 9,709, all classed as rural. The density of the population in that year was 3.4 persons a square mile.

The agricultural activities of the county are divided between the production of cash crops on the smoother land and the grazing of livestock, principally beef cattle, on the rougher land. Some dairy cattle and a few sheep are raised.

Spring wheat, the most important crop grown, ordinarily occupies almost one-half of the total cropland. The average yield is less than 11 bushels an acre. Flax generally ranks second in acreage among cultivated crops. Sugar beets, barley, oats, rye, corn, potatoes, and other crops are also grown to some extent. Wild hay is cut from a small acreage, and tame hay is increasing in acreage.

The different soils of McKenzie County are nearly coextensive with the surface features. On the smooth upland where dissection has not been active, dark grayish-brown soils are developed. The soils of three principal series occupy the greater part of this type of land—the Williams soils on the glacial till, which occurs only in portions of the northern part of the county, and the Morton and Flasher soils

on the sedentary sands and clays throughout the remaining upland part. The Arnegard, Farland, Cheyenne, and Grail soils include the dark-colored mellow soils developed on the terraces and alluvial valley slopes; the Bainville, Patent, Cherry, and Huff soils include the lighter colored soils of the county. The Bainville soils are on the sedentary silts and clays of the upland part, and the remaining lighter colored soils are on the alluvial valley slopes and terraces. The Havre and Banks soils are on the first-bottom lands of the river valleys.

The soils used principally for grazing include the rolling and steep phases of several of the upland soils; the alkali claypan soils of the complex areas of the Moline, Rhoades, and Wade soils; the poorly drained bottom soils; and the rough and broken lands.

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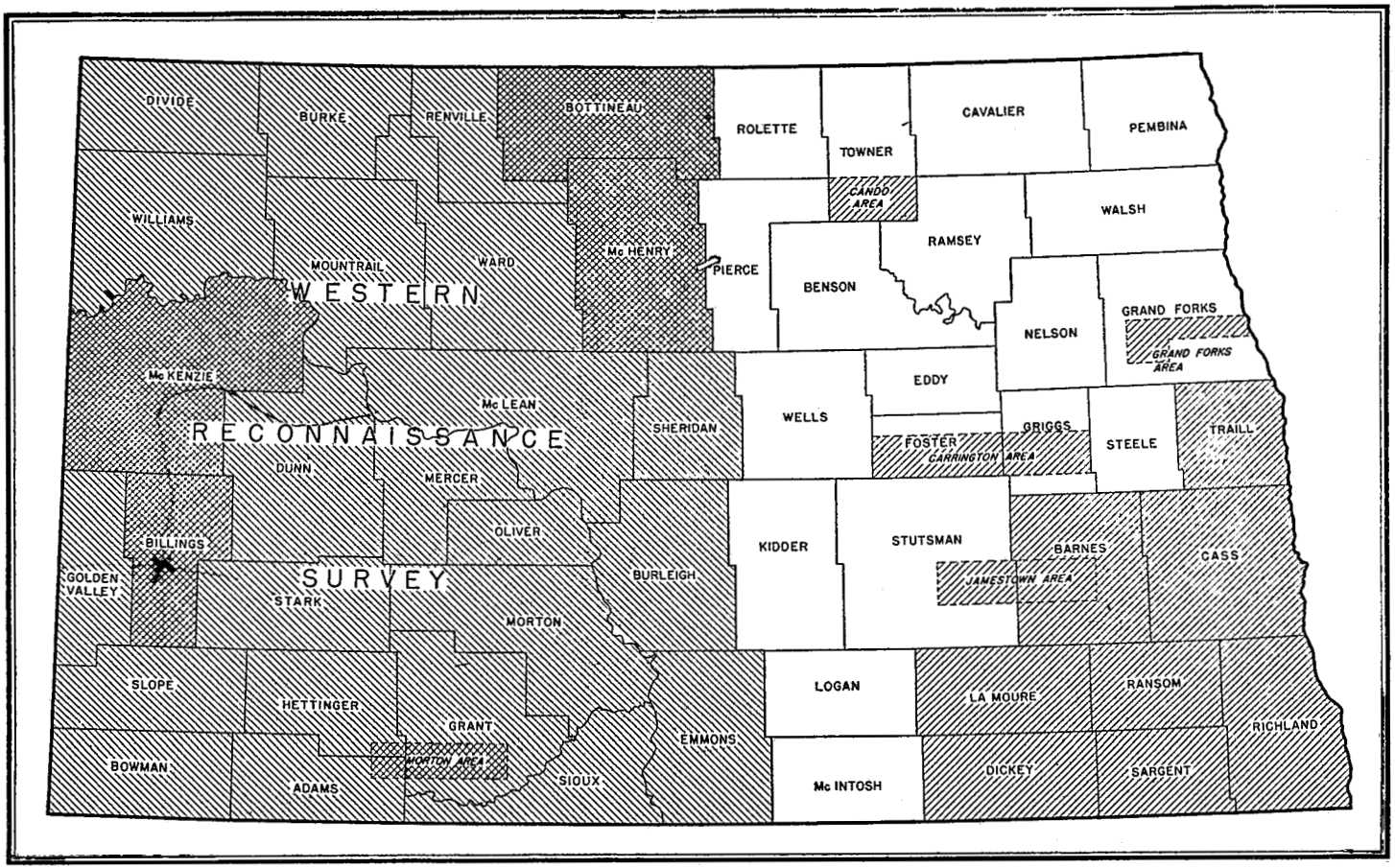

Areas surveyed in North Dakota shown by shading. Detailed surveys shown by northeast-southwest hatching; reconnaissance surveys shown by northwest-southeast hatching; cross-hatching indicates areas covered by both surveys.

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