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Soil Survey

The Upper Musselshell Valley Area Montana

By

F. K. NUNNS

Montana Agricultural Experiment Station

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY, SOILS, AND
AGRICULTURAL ENGINEERING

In cooperation with the
Montana Agricultural Experiment Station

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SOIL SURVEY OF THE UPPER MUSSELSHELL VALLEY AREA, MONTANA

By F. K. NUNNS, Montana Agricultural Experiment Station

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

CONTENTS

HOW TO USE THE SOIL SURVEY REPORT AND MAP

The soil survey report and map of the Upper Musselshell Valley area contain information—both general and specific—about the soils, crops, and agriculture of the area. They are prepared for the general public and are designed to meet the needs of numerous readers having varied interests. The individual reader may be interested in some particular part of the report or in all of it. Ordinarily he will not have to read the whole report to gain the information he needs.

Readers of the soil survey reports may be considered as belonging to three general groups: (1) Those interested in limited areas, such as communities, farms, and fields; (2) those interested in the area as a whole; and (3) students and teachers of soil science and related agricultural sciences. An attempt has been made to satisfy the needs of these three groups by making the report a comprehensive reference work on the soils and their relation to crops and agriculture.

The readers whose chief interest is in limited areas, such as some particular locality, farm, or field, include the farmers, agricultural technicians interested in planning operations in communities or on individual farms, and real-estate agents, land appraisers, prospective purchasers and tenants, and farm loan agencies. The first step of a reader in this group is to locate on the map the tract with which he is concerned. The second step is to identify the soils on the tract. This is done by locating in the legend on the margin of the map the symbols and colors that represent the soils in the area. The third is to locate the name of each soil in the table of contents, which refers the reader to the page or pages in the section on Soils where each soil is discussed in detail. Under the soil type heading he will find a description of the soil and information as to its suitability for use and its relations to crops and agriculture. He will also find useful information in the section on Estimated Yields and in that on Land Uses and Soil Management.

The second group of readers includes persons interested in the area as a whole, such as those concerned with land-use planning or the placement and development of highways, power lines, docks, urban sites, industries, community cooperatives, resettlement projects, private or public forest areas, recreational areas, and wildlife projects. The following sections of the report are intended for such users: (1) Area Surveyed, in which such topics as physiography, vegetation, water supply, population, and cultural development are discussed; (2) Agriculture, in which a brief history of the agriculture of the area is given and the present agriculture is described; (3) Estimated Yields; and (4) Land Uses and Soil Management, in which the present use and management of the soils are described, their management requirements are discussed, and suggestions for improvement in management are made.

The third group of readers includes students and teachers of soil science and allied subjects, such as crop production, forestry, animal husbandry, economics, rural sociology, geography, and geology. The teacher or student will find the section on Morphology and Genesis of Soils of special interest. He will also find useful information in the section on Soils, the first part of which presents the general scheme of classification and a discussion of the soils with regard to the area as a whole, and the second part of which presents a detailed discussion of each soil. If he is not already familiar with the classification and mapping of soils, he will find these subjects discussed in Soil Survey Methods and Definitions. The teachers of other subjects will find sections on the Area Surveyed, Agriculture, Estimated Yields, and the first part of the section on Soils of particular value in determining the relations between their special subjects and the soils in the area. Soil scientists or students of soils as such will find their special interest in the section on Morphology and Genesis of Soils.

AREA SURVEYED

LOCATION AND EXTENT

The Upper Musselshell Valley area is in the central part of Montana (fig. 1). It crosses the central part of Wheatland County in a general northwest-southeast direction and continues for a distance of about 7 miles into the eastern part of Meagher County. Harlowton, the county seat of Wheatland County, is in the center of the area and lies approximately 80 miles northwest of Billings by air line. The area surveyed is about 52 miles long and 1 to 3 miles wide. It comprises 60,160 acres, or 94 square miles, and embraces a major part of all the irrigated land in Wheatland County. All the low terraces and recently formed alluvial lands along the Musselshell River are included in the survey, and in addition a narrow strip of the adjacent uplands and high benches or old terraces.

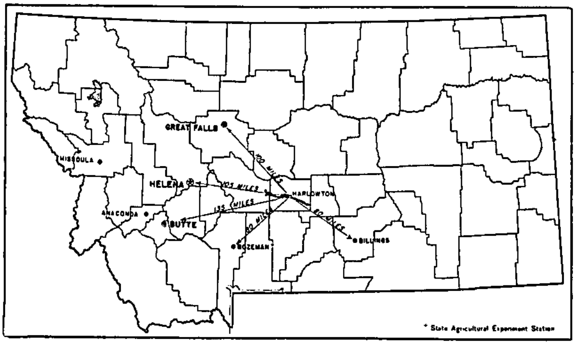

FIGURE 1.—Sketch map showing location of the Upper Musselshell Valley area, Montana.

Most of the rolling uplands and the highest parts of the gravelly benches surrounding the area are not favorably situated for irrigation and are generally utilized for grazing land.

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

The Upper Musselshell Valley area is in the northwestern part of the Great Plains physiographic province. In its general physiographic aspect, the area consists of an elongated basin or intermountain valley traversed by the Musselshell River. Big Snowy and Little Belt Mountains lie north of the area, the Castle Mountains west of it, and the rugged snow-clad Crazy Mountains southwest of it.

The area includes (1) nearly level alluvial lands, bottom lands, and low terraces along the Musselshell River; (2) high, smooth, gravelly terraces or benches on both sides of the river; and (3) a strip of moderately to deeply dissected uplands underlain by sandstone and shale bordering the high benches.

The alluvial lands comprise comparatively recent sediments deposited by the Musselshell River, whereas the high benches are remnants of much older gravelly mountain outwash or valley filling deposits in which the present drainage is deeply entrenched. The bedrock formations underlying the uplands are sandstones and sandy to clayey shales of Cretaceous age, chiefly of the Judith River and Colorado geological formations.[1]

Martinsdale, situated near the head of the Musselshell Valley, is 4,822 feet above sea level. Elevations of other towns are as follows: Twodot, 12 miles east of Martinsdale, 4,434 feet; Harlowton, near the center of the area, 4,167 feet; and Shawmut, near the eastern end, 3,857 feet. The high gravelly benches and undulating uplands that border the valley lie 60 feet or more above the level of the larger streams, and the uplands underlain by sandstone and shale rise in most places gradually but in some places sharply from the high benches toward the mountains.

The area is drained by the Musselshell River and its tributaries. North Fork heads in the Little Belt Mountains and flows southeastward. South Fork rises in the Crazy and Castle Mountains and flows northeastward. The two forks join about 2 miles east of Martinsdale and continue as the Musselshell River. The streams are at flood stage in March and early April and again in May and June, when they are swollen by seasonal rains and runoff from snow melting in the mountains and on the higher tablelands.

Daisy Dean, Haymaker, Hoplei, and Antelope Creeks are the chief tributaries entering the Musselshell River from the north; and Little Elk and Elk Creeks and American Fork are the chief ones entering it from the south.

These streams have a perennial flow in the mountains and foothills, but in the lower plains and benchlands they often disappear into the stream gravels during the late summer and fall.

The Musselshell River has a gradient of 20 to 30 feet to the mile, and the flow is rapid during periods of high water. It carries a fair volume of water during the spring and early summer, before part of the water is diverted to irrigated tracts. The river is commonly dry east of Harlowton during the late summer and fall, except for numerous water holes.

VEGETATION

The vegetation of the area is typical of the short-grass plains. The dominant grasses are western wheatgrass, or bluestem wheatgrass (locally known as bluejoint) (*Agropyron smithii* Rydb.), and blue grama (*Bouteloua gracilis* (H. B. K.) Lag.). Threadleaf sedge or niggerwool (*Carex filifolia* Nutt.), needle-and-thread or western needlegrass (*Stipa comata* Trin. and Rupr.) and junegrass (*Koeleria cristata* (L.) Pers.) are common on the sandier soils. Bluegrass (*Poa* sp.) occurs largely on the moist bottom lands. Desert saltgrass (*Distichlis stricta* (Torr.) Rydb.) and greasewood (*Sarcobatus vermiculatus* Torr.) are dominant on salty, poorly drained soils. Broom

[1] BOWEN, C. F. ANTICLINES IN A PART OF THE MUSSELSHELL VALLEY, MUSSELSHELL, MEAGHER, AND SWEETGRASS COUNTIES, MONT. *In* Contributions to Economic Geology (Short Papers and Preliminary Reports), 1918, pt. 2, Mineral Fuels. U. S. Geol. Survey Bul. 691, ch. (f), pp. 189–209, illus. 1919.

snakeweed or matchweed (*Gutierrezia sarothrae* (Pursh) Britt. and Rusby) is abundant on the areas of shallow soils, overgrazed pastures, and abandoned farms on the uplands. Curlycup gumweed (*Grindelia squarrosa* (Pursh) Dunal) and western wheatgrass are characteristic vegetation of the clayey soils. Pricklypear (*Opuntia* sp.) and silver sagebrush or valley sage (*Artemesia cana* Pursh) are abundant at places. Willow and cottonwood are the principal trees along the streams.

WATER SUPPLY

Most of the area is supplied with a satisfactory quality of water for domestic use. An excellent quality of water is usually obtained from the gravel beds underlying the benchlands and in the more massive sandstones of the Judith River formation and Eagle sandstone. Much of the water obtained from geological formations such as the Bearpaw shale and the Claggett and Colorado formations is highly mineralized and unfit for domestic use.

Water for irrigation is diverted from the Musselshell River, some directly to the land, and some to storage reservoirs for use when stream flow is low and not adequate to supply seasonal needs. As this water comes chiefly from melting snow and runoff from the mountains, it contains few injurious salts. The supply of water is limited, and in years of low precipitation it may be insufficient for optimum irrigation of all the lands within the area.

EARLY HISTORY

The area included in this survey was used chiefly as hunting grounds by the Sioux and Crow Indians prior to the discovery of gold in the nearby mountains in 1879. Only a few trappers and traders visited the area before the discovery of gold. Marauding Indians frequently raided the gold seekers and freighters who hauled supplies to the mine fields, until military posts were established to give them protection. Military roads were constructed between such posts as Fort Logan near the site of White Sulphur Springs in Meagher County, Fort Maginnis in Fergus County, and Fort Custer near the site of Hardin in Big Horn County. Several of the military roads passed through this area.

The protection provided by the forts encouraged the entrance of stockmen and the establishment of a few trading posts in the early eighties. Parts of the Musselshell Valley were divided into sections during the eighties and nineties, but most of the uplands were not surveyed until after 1910.

ORGANIZATION AND POPULATION

Wheatland County, embracing most of the Upper Musselshell Valley area, was created in 1919 from parts of Meagher and Stillwater Counties. It comprises 1,425 square miles. The Federal census report for 1940 gives the population of the county as 3,286;

of this number 1,759 live in incorporated towns. Aside from a few Chinese, Japanese, and Negroes in the larger towns, the population is chiefly native white.

Harlowton, the county seat, is near the center of the county. According to the Federal census for 1940, Harlowton has a population of 1,547. This town serves as a trade center for a large livestock-raising and farming area. It is a division point on the Chicago, Milwaukee, St. Paul & Pacific Railroad and also the location of a large flour mill. Twodot, having a population of about 200, serves as a minor trade center for a large livestock-raising area in the west-central part, and Shawmut is a small trading center near the eastern end of the area. These towns have most of the modern municipal improvements, such as electric light, telephone service, and water and sewerage systems. Educational facilities meet State standards.

TRANSPORTATION AND MARKETS

The main line of the Chicago, Milwaukee, St. Paul & Pacific Railroad traverses the area in an east-west direction along the valley of the Mussellshell River, and a branch line connects Harlowton with Lewistown and Great Falls to the north. The Billings-Great Falls branch of the Great Northern Railway passes through the northeastern part of Wheatland County. These railways provide excellent facilities for the shipment of livestock and crops to outside markets, such as Chicago, St. Paul, Spokane, Portland, and St. Louis. Butte, Billings, and Great Falls are the chief markets within the State.

Hard-surfaced State and Federal highways constructed of crushed rock and oil traverse the entire length of the area and connect it with outside points. County roads are generally of improved earth and gravel construction. In the uplands some of the roads are mere trails, but they are passable the greater part of the year.

CLIMATE

The climate of the Upper Musselshell Valley area is continental and characterized by abundant sunshine, low relative humidity, comparatively low rainfall, and wide daily and seasonal variations in temperature. Midsummer days are warm but not oppressive, as the humidity is low, and nights are cool. Winters are moderately cold. Cold waves occur almost every winter with varying severity, but as a rule they are not prolonged and often alternate with warm and pleasant weather as a result of chinook winds. In general the wind is westerly for a greater part of the year, and the velocity is highest during the late winter and early spring.

Tables 1 and 2 give the normal monthly, seasonal, and annual temperatures and precipitation at Harlowton and Martinsdale.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Harlowton, Wheatland County, Mont.*

[Elevation, 4,240 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1919)	Total amount for the wettest year (1915)	Snow, average depth
	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*	*Inches*
December	22.8	74	−45	0.45	0.32	0.61	5.0
January	19.3	61	−46	.42	(1)	.04	4.4
February	22.6	65	−38	.54	.40	.04	6.1
Winter	21.6	74	−46	1.41	.72	.69	15.5
March	29.6	75	−28	.57	.56	.09	6.3
April	39.4	87	−9	.71	0	.81	2.1
May	49.1	93	7	2.10	.15	2.40	2.8
Spring	39.4	93	−28	3.38	.71	3.30	11.2
June	58.3	96	24	2.11	0	3.98	(1)
July	63.8	100	29	1.54	1.40	3.50	0
August	61.6	98	25	.74	.15	1.90	0
Summer	61.2	100	24	4.39	1.55	9.38	(1)
September	51.8	91	17	1.18	.30	2.60	.7
October	43.3	89	−15	.68	2.22	.00	2.5
November	29.8	69	−30	.53	.72	.34	6.8
Fall	41.6	91	−30	2.39	3.24	2.94	10.0
Year	41.0	100	−46	11.57	6.22	16.31	36.7

[1] Trace.

TABLE 2.—*Normal monthly, seasonal, and annual temperature and precipitation at Martinsdale, Meagher County, Mont.*

[Elevation, 4,800 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1890)	Total amount for the wettest year (1891)	Snow, average depth
	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*	*Inches*
December	25.9	56	−26	0.74	1.60	1.75	5.2
January	22.6	54	−40	1.13	.28	.62	11.0
February	21.9	57	−52	.78	.90	2.55	6.0
Winter	23.5	57	−52	2.65	2.78	4.92	22.2
March	29.0	71	−25	1.07	1.77	1.63	9.3
April	41.2	84	−2	1.34	.48	.53	7.6
May	49.7	88	17	2.26	1.50	1.90	3.1
Spring	40.0	88	−25	4.67	3.75	4.06	20.0
June	57.6	104	26	2.77	1.89	4.21	0
July	65.2	103	32	1.59	.14	2.82	0
August	63.8	104	29	.69	.12	.75	0
Summer	62.2	104	26	5.05	2.15	7.78	0
September	50.2	90	8	1.38	1.06	1.85	1.0
October	40.6	79	3	.80	.17	2.00	2.1
November	31.8	65	−28	1.07	.80	1.28	9.9
Fall	40.9	90	−28	3.25	2.03	5.13	13.0
Year	41.6	104	−52	15.62	10.71	21.89	55.2

The average annual precipitation as recorded at Harlowton is 11.57 inches, of which about half falls during the growing season, June 1 to September 7. May and June are the months of greatest rainfall. Much of the summer precipitation comes in the form of quick local showers. The highest recorded precipitation for a given year is 16.31 inches, whereas that for the driest year is 6.22 inches.

At Martinsdale, which is closer to the mountains than Harlowton, the average annual precipitation is 15.62 inches, the maximum ever recorded is 21.89 inches, and the minimum 10.71 inches. Normally rainfall increases with an increase in elevation; consequently the higher benches and foothills receive more moisture than is recorded in the valley at Martinsdale. The distribution of precipitation and the length of the growing season are approximately the same as at Harlowton.

The average annual snowfall at Martinsdale is 55.2 inches, and at Harlowton it is 36.7 inches.

The mean annual temperature at Harlowton is approximately 41° F. January and February are the coldest months, and July is the hottest month. Maximum temperatures of 100° and minimum temperatures of −46° have been recorded at Harlowton. Temperatures of 32° or lower have been recorded for every month in the year.

The short growing season necessitates the planting of varieties of small grains and forage plants that require only 90 to 110 days to mature. The frost-free period generally dates from June 1 to September 7. Small grains, usually seeded early in May, are rarely damaged by late spring frosts. Early fall frosts sometimes injure the less hardy crops. Hail causes crop losses over small areas in some years.

AGRICULTURE

EARLY AGRICULTURE

The area was largely open range under the control of stockmen from the early eighties up to the time of the construction of the railways in 1906 and 1908. Many of the early livestock companies were financed by English and Scotch capitalists, and their managers and laborers were chiefly of English and Scotch descent. Ranch headquarters were commonly in the foothills or stream valleys where the livestock was wintered and fed on hay and grain produced on irrigated land.

After the advent of the railways, much of the better range land was homesteaded and fenced in tracts of 160 and 320 acres. By 1915 most of the tillable land was under dry-land cultivation. Land values increased rapidly until 1918 because crop yields were fair and prices good. The acreage in cropland was greatly reduced and, as in other dry-farming areas, much farm land was abandoned during the severe drought period of 1918–21. Good and poor years for crops occurred between 1921 and 1930. Beginning in 1930 another dry period commenced and has continued almost to the present (1940). Since 1930 the acreage cultivated under dry-farming methods has further declined and migration from the farms and additional abandonment of farms have taken place. The land now under cultivation in Wheatland County is used chiefly for the production of supplemental feed crops for livestock.

Readjustments in land use and low returns from the land in recent years have created many social and economic problems that are yet unsolved. With the settlement and placing under cultivation of the better open-range grazing lands, many of the early stockmen either liquidated or curtailed their operations. Since the drought of 1918–21 the established stockmen are expanding their holdings, as are the remaining dry-land farmers who have adopted a combined cash-grain, hay, and livestock-raising program as the means of a more stable livelihood.

The area surveyed includes an irrigated part of the Musselshell Valley, which serves as a dependable source of forage for winter feeding of livestock and for carrying them through drought periods when feed on the range has become exhausted. This source of forage has reacted favorably as a stabilizing influence on livestock raising, the chief enterprise of the area adjacent to the Upper Musselshell Valley.

There were only 38 ranch and farm units within the area at the time of this survey (1939), but the number is expected to increase if the benchlands west of Harlowton are developed as an irrigated area.

CROPS AND LIVESTOCK

The agriculture of Wheatland County consists chiefly of the growing of small grain and hay and the raising of livestock.

According to the 1940 census, 820,384 acres, or 90 percent of the area of the county, is taken up by the 229 farms and ranches, averaging 3,582.5 acres in size. Crops were harvested, however, in 1939 from only 36,064 acres, of which 19,432 acres was irrigated. In addition 2,227 acres of pasture were irrigated. Hay, chiefly alfalfa and wild grasses, was cut from 23,830 acres. Of the remaining acreage harvested, 8,219 acres were in wheat and 3,117 acres in oats. Rye, barley, and flax account for most of the small remaining acreage of grains. The grains are chiefly of the early or medium early varieties that mature within 90 to 110 days from planting.

Within the Upper Musselshell Valley area, the production of crops is limited chiefly to hay. Some small grain is produced under irrigation-farming methods, and a small acreage of wheat is produced under dry-farming methods. Alfalfa, the principal hay crop, yields from 1 to 3 tons an acre in two cuttings. Western wheatgrass meadows, occupying imperfectly to poorly drained, moderately salty areas, comprise about 30 percent of the acreage devoted to hay and yield from one-half to three-fourths of a ton to the acre.

Nearly all of the hay is fed on the farm or is sold locally as winter feed for the livestock that graze on summer pasture in the rolling uplands and mountains adjacent to the Musselshell Valley.

Oats and barley are grown primarily for livestock feed, and some of the wheat is used for this purpose. A small acreage of corn is planted for grain and for forage, but only the very early maturing varieties will mature grain. At present potatoes are produced chiefly for home use, and any surplus is sold locally.

Sugar beets are not grown in the area at present; furthermore, it is questionable whether this crop can be grown successfully, because of the relatively cool summers and the short growing season. Careful experimental production and study of results should be made on the adaptability of this crop before any large-scale plantings are made.

Returns from nearly all of the grain crops, except possibly wheat,

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under dry-farming practices are unprofitable in this area. Under irrigation, however, oats and barley yield from 25 to 40 bushels an acre and wheat generally from 20 to 35 bushels and sometimes as much as 45 bushels.

Even though yields of wheat are moderately high, the large-scale production of this crop under irrigation practices probably would not prove profitable, because of the comparatively high overhead cost for irrigating.

Fertilization of crops is not extensively practiced, although barnyard manure is occasionally applied to the soil. Commercial fertilizers are rarely used, but certain soils may need soluble phosphates.

Livestock raising consists chiefly of the raising of beef cattle and sheep. Chiefly grade Hereford and Shorthorn cattle are kept on the farms and ranches. On January 1, 1920, the number of cattle of all ages in Wheatland County was 24,792. The total number of cattle over 3 months of age decreased from 14,502 on April 1, 1930, to 13,499 on April 1, 1940, although there was a slight increase in 1935. Of the cattle reported in the 1940 census, 854 head were kept mainly for the production of milk, which totaled 384,009 gallons in 1939. This represented a decided decline from the quantity produced in 1929—676,554 gallons. Many of the dairy cows are crossbreds of the beef breeds with the milking strain of Shorthorn. A few dairy herds are kept in the vicinity of Harlowton to supply the local demand for fluid milk.

During the period when cattle were decreasing, the number of sheep increased. There were 58,003 head of sheep of all ages in Wheatland County on January 1, 1920. The number of sheep over 6 months of age was 113,157 head on April 1, 1930, and 113,493 head on April 1, 1940. This increase since the drought of 1918–21 is due to a shift from grain farming to livestock raising in the marginal agricultural areas. Several factors, such as a fair price received for lambs and wool, the more complete utilization of forage grasses by sheep on the abandoned farm lands, and the greater speed at which flocks can be built up, probably account for the greater emphasis on sheep as compared with cattle during the dry years prevailing in the area since 1930. Wool shorn in 1939, however, totaled only 997,937 pounds, as compared with 1,114,054 pounds in 1929.

The number of horses on the farms and ranches has rapidly decreased during recent years, as horses have been replaced by small tractors and trucks in farm work. Swine and poultry are comparatively unimportant and are raised chiefly for home use.

The value of land and buildings in Wheatland County declined from $19,211 per farm and $7.60 per acre in 1930 to $13,406 per farm and $3.74 per acre in 1940. The proportion of tenancy is 26.2 percent.

SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field and the recording of their characteristics, particularly in reference to the growth of various crops, grasses, and trees.

The soils and the underlying formations 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, at regular intervals. Each excavation exposes a series of layers or horizons, called collectively the soil profile; and the entire soil, from the surface down to the weathered but otherwise unmodified parent material, is known as the solum. The classification is based on internal characteristics of the soil, such as thickness, color, structure, texture, consistence, reaction, and content of lime, salt, and organic matter, and on external features, such as drainage, relief, and stoniness. The plant cover, of either native or cultivated plants, is observed, and its relation to the soils is studied. In this way the productivity of the soils can be determined or estimated with a fair degree of accuracy. In classifying virgin lands that may be brought under cultivation, the observation of like soils now being farmed is an important part of the work.

Some of the terms mentioned in the preceding paragraph are in common use and need no explanation. Others have special meanings in soil science. For example, structure means the arrangement of the individual soil particles or grains within the soil mass; hence, it affects the tilth of the soil and the rate at which moisture can be absorbed. Common soil structures are granular, cloddy, platy, columnar, and prismatic. Soil material having no definite structure is designated as single grain if incoherent and as massive if coherent. Texture is concerned with the coarseness or fineness of the soil mass, as determined by the relative percentages of silt, clay, and the various grades of sand. Clay, clay loam, silt loam, loam, and fine sandy loam, named in the order of an increasing content of coarse material and a decreasing content of clay, are the main soil textures in this area. Consistence is concerned with the relative firmness or looseness of the soil mass and its resistance to crushing or distortion. Terms commonly used to describe consistence are "incoherent," as in sand; "friable," as in most silt loams; and "dense" or "compact," as in many clay soils.

Determinations are made of the reaction [2] of the soil, the content of lime (calcium carbonate),[3] and, where necessary, the total content of readily soluble salts.[4] "Alkali" as used in this report refers to a harmful accumulation of soluble salts without regard to chemical reaction.[5]

On the basis of their internal and external features the soils are grouped into classification units, of which the three principal ones are (1) series, (2) type, and (3) phase. In places two or more of these principal units may occur in such intimate or mixed pattern that they cannot be indicated clearly on the map but must be mapped as (4) a complex. In addition, areas of land—such as dune sand, riverwash, and stony mountainsides—that have no true soil are called (5) miscellaneous land types.

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[2] The reaction of a 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. Phenolphthalein solution is used to detect a strong alkaline reaction.

[3] Detected by means of dilute hydrochloric acid.

[4] Detected by the use of the electrolytic bridge.

[5] There are two types of soil alkali. White alkali is composed mainly of sodium chloride (table salt) and sodium sulfate (Glauber's salt), both of which are white crystalline substances that are neutral in reaction. Strictly speaking, soils high in their content of these salts are more properly spoken of as saline soils rather than alkali soils. High concentrations of these salts in the soils are injurious in that they upset the balance of plant nutrients, thus stunting or killing the plants. Black alkali is composed chiefly of sodium carbonate (sal soda). This substance is a true alkali and has a corrosive action on plants, destroying their tissues. It also has a strong deflocculating action on the soil, causing it to be quite impervious to water, to bake very hard, and on drying out to form black crusts and discolorations on the surface.

The most important of these groups is the series, which includes soils that have developed from similar, although not necessarily identical, kinds of parent material and that have the same genetic horizons, arranged alike in the soil profile. Thus, a series comprises soils having essentially the same color, structure, and other important internal characteristics and the same natural drainage conditions and range in relief. The texture in that part of the soil commonly plowed may differ within a series. The series are given geographic names taken from localities at or near which they were first identified. Musselshell, Crago, Martinsdale, Pierre, Orman, Havre, and Harlem are the names of some soil series in the Upper Musselshell Valley area.

Within a soil series are one or more types, defined according to the texture in the upper part of the soil, generally to about the depth of plowing. The name of the texture to this depth, such as silt loam, loam, clay loam, or fine sandy loam, is added to the series name to give the complete name of the soil types. For example, Orman silty clay loam and Orman clay are types within the Orman series. Except for differences in the texture of the surface layers, all types of the Orman series have approximately the same external and internal characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, differing from the type in some minor feature, generally external, that may be of special practical significance. A soil type may be very uniform throughout its distribution in all important profile features, but slight variations in its content of gravel or in the relief may cause marked differences in the capabilities of the soil for use in different localities. For example, within the range of relief of a soil type, certain areas may be adapted to the use of machinery and the production of cultivated crops and other areas may not. Even though no important differences may be apparent in the soil itself or in its ability to produce the native vegetation, important differences may exist in respect to the growth of cultivated crops, owing to variations in the relief. Under such conditions the different kinds of relief that are not normal for the soil may be segregated on the map as level, sloping, or hilly phases, as the case may be. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences have no influence on the more important properties of the soil or on the growth of native plants.

The soil surveyor makes a map of the area to be surveyed on an accurate base map—aerial photographs, United States Geological Survey topographic sheets, or plane-table traverse. The map shows the location of each of the soil types, phases, complexes, and miscellaneous land types in relation to roads, houses, streams, lakes, section and township lines, and other cultural and natural features of the landscape.

SOILS

SOILS AND THEIR RELATIONS

The Upper Musselshell Valley area comprises the alluvial lands of the Musselshell Valley and adjacent irrigable uplands and gravelly benches. The soils are developing under a vegetation of short grass from limy, silty to clayey alluvial sediments on the bottom lands and benches and from clayey to sandy shales on the uplands. The surface layers range in color from brownish gray to dark grayish brown but are dominantly grayish brown. This comparatively light color is the result of semiarid climate and sparse vegetation under which the soils are forming. The annual return of organic matter to the land under these conditions is not sufficient to darken the soils appreciably, except in places where they receive supplemental moisture from seepage or runoff from higher levels.

The soils on the high benches are silty and friable and have a soft granular or crumb structure in the surface layer, and they are underlain at a depth of 1 to 5 feet by water-rounded limestone gravel firmly embedded in a nearly white limy matrix. The texture, structure, and consistence of the soils on the undulating uplands depend in part on the character of the underlying bedrock. Those developed on the lighter textured shales are silty and friable and break into soft irregular aggregates when moist. Those developed on the heavy shales are clayey and have no structure, being hard and compact when dry and sticky or plastic when wet.

The soils occupying the valley slopes, low terraces, and bottom lands vary considerably in texture, structure, and consistence from one locality to another, but they are relatively uniform in these features in a given area. They are developing in colluvium or local alluvium washed from the adjacent higher lands and in alluvium brought down by streams and redeposited along the courses of the streams. These soils commonly have slightly darker surface layers than those developing on the adjacent uplands. The parent material is more recently formed, the profile is less mature, and the individual layers are less well defined, as compared with those features of the soils of the uplands and high benches.

The soils of the western part of the area are darker than those of the eastern part in comparable positions, a result of the general rise in elevation from east to west and the heavier precipitation and more luxuriant growth of grasses near the mountains.

Natural drainage of the soils and the presence of alkali salts vary considerably in different localities. Free salts, some injurious to plant growth, are present in most of the soils. The concentration of salts depends on the amount originally present, the degree of leaching that has taken place, the quantity of salts carried in seepage water, and the condition of drainage, which may tend to remove or to concentrate an excess of soluble salts.

With only a few exceptions, the soils of the area are friable and easily penetrated by plant roots, air, and moisture. The Pierre soils on the uplands and the Orman soils on the terraces are developed in heavy clay shale and wash from heavy shales, respectively, and the Moline soils, commonly having claypanlike upper subsoil layers and a high content of injurious salts, include most of the soils that offer any appreciable resistance to the penetration of plant roots and moisture. The moisture-holding capacity of the soils ranges from poor to good. Not only is the rainfall low, but some of it is lost through runoff and evaporation without becoming available to plants.

Drainage is good to excessive, except in some of the soils on the bottom lands that have a high ground-water level and in others on colluvial slopes that receive seepage water from higher levels.

Though some of the soils are somewhat deficient in organic matter, nearly all have some available plant nutrients in their natural state. Under irrigation and continuous cropping some of the nutrients may become deficient.

Under dry-farming practices, the adapted crops are restricted chiefly to hardy, early maturing small grains and native hay. Where an adequate supply of irrigation water is available, however, a variety of garden crops, grain, and tame hay can be grown on most of the soils.

GROUPING OF THE SOILS

The individual soils of the area vary considerably in many of their internal and external characteristics, with corresponding variations in their use capabilities and producing powers. Nevertheless, it is possible to group them so that the soils of each group occupy similar positions and have the same general external and internal characteristics. Certain relationships to productivity and capability for growing specific crops and response to management more or less follow such groupings. In this area seven such groups are recognized, namely: (1) Moderately deep friable soils of the well-drained uplands and higher terraces; (2) shallow friable soils of the excessively drained uplands and higher terraces; (3) moderately deep compact soils of the uplands, terraces, and valley slopes, having slow internal drainage; (4) moderately deep friable soils of the well-drained valley slopes and terraces; (5) well-drained friable soils of the bottom lands and low terraces; (6) imperfectly to poorly drained soils of the bottom lands, low terraces, and upland depressions; and (7) miscellaneous land types.

These groups, however, are not based directly on the basis of agricultural use and suitability for irrigation. For example, certain well-drained soils of both the terraces and bottom lands appear in separate groups, although they may be recognized together as the best soils in the valley for irrigated crops. This method of grouping is not meant to imply that the agricultural practices are strictly uniform on the soils of any particular group or that the soils of that group are equally productive. Even within a group, some variation exists in the drainage conditions and other characteristics that affect agriculture, such as the surface features of the soil; direction of slope; content of moisture, lime, and organic matter; texture; and stoniness. In addition, the farming systems and the crops grown may vary somewhat on the different soils of a group, or even on the same soil in different localities, with differences in the requirements of the individual farmer and in the amount and distribution of the local precipitation. Over long periods, however, the soils of each group here recognized should give the largest returns if used chiefly for growing the crop or crops best suited to the natural supply of moisture or available supply of irrigation water and to the texture, consistence, and other characteristics of the soils. In establishing these groups, some recognition is given, therefore, to those internal and external characteristics of the soils that influence productivity and crop adaptations. A more detailed grouping of the soils of the Upper Musselshell Valley area on the basis of their suitability for irrigation agriculture is given in the section on Land Uses and Soil Management (p. 39).

None of the soil groups is confined to any particular part of the area, and many areas of the soils belonging to one group lie within larger areas of soils belonging to another group.

In the following pages the soil groups and the soil series and types assigned to these groups are described and their relationships, their influence on the agricultural development, and the farming practices of the area are discussed. The map accompanying this report shows the distribution of the soils in the area; and table 3 gives their acreage and proportionate extent.

TABLE 3.—*Acreage and proportionate extent of the soils mapped in the Upper Musselshell Valley area, Mont.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Musselshell gravelly loam	3,840	6.4	Berthoud loam	704	1.2
Musselshell gravelly loam, sloping phase	1,216	2.0	Berthoud clay loam	704	1.2
Musselshell gravelly fine sandy loam	192	.3	Harlem silt loam	1,408	2.4
Musselshell clay loam	1,280	2.1	Havre loam	3,392	5.6
Martinsdale stony loam	2,880	4.8	Havre silt loam	1,024	1.7
Martinsdale loam	192	.3	Banks fine sandy loam	5,824	9.7
Cushman silt loam	1,216	2.0	Harlem silt loam, poorly drained phase	1,408	2.4
Crago gravelly loam	2,880	4.8	Havre silty clay loam	384	.6
Crago gravelly loam, sloping phase	960	1.6	Havre loam, poorly drained phase	576	1.0
Crago loam	512	.9	Havre silt loam, poorly drained phase	1,088	1.8
Bainville silt loam	5,056	8.4	Laurel silty clay loam	1,152	1.9
Cushman-Bainville loams	3,328	5.5	Laurel silty clay loam, saline phase	2,048	3.4
Pierre clay loam	896	1.5	McKenzie clay	384	.6
Orman clay	960	1.6	Alluvial soils, undifferentiated	1,408	2.4
Orman silty clay loam	1,344	2.2	Rough broken land (Crago soil material)	7,040	11.7
Moline clay loam	448	.7	Riverwash	64	.1
Cherry-Moline clay loams	128	.2			
Cherry silt loam	2,240	3.7			
Cherry loam	704	1.2			
Berthoud silt loam	1,280	2.1	Total	60,160	100.0

MODERATELY DEEP FRIABLE SOILS OF THE WELL-DRAINED UPLANDS AND HIGHER TERRACES

The moderately deep friable soils of the well-drained uplands and higher terraces occupy 17.9 percent of the area. They belong to the Musselshell, Martinsdale, and Cushman series. These soils absorb precipitation and irrigation water readily and are easy to irrigate because of their smooth surface. Their internal drainage is rapid, but the moisture-holding capacity is generally adequate under careful irrigation management. This group of soils is satisfactory for irrigation farming, though the presence of gravel and stones in certain members limits the number of adapted crops. Sporadic attempts have been made to dry-farm them, but crop failures were common except in years of unusually favorable precipitation. These soils occupy the high benches or uplands in nearly all parts of the area.

MUSSELSHELL SERIES

The Musselshell series comprises the light-colored, moderately deep soils on the higher terraces, formed from fine earth material that is underlain by limestone gravel. The interstices between the pebbles in the upper layers of the gravel bed are filled with white soft or only slightly compact limy material. These soils have formed under a vegetation of short grass in a semiarid climate, have a well-developed zone of lime accumulation in their subsoil, and contain little or no injurious salts. The supply of organic matter in the surface layer is only moderate, but there is an adequate supply of available mineral plant nutrients.

The Musselshell soils are productive under dry-farming practices, in seasons of above average precipitation; but frequent droughts and crop failures have made it generally unprofitable to follow this system of farming. Under irrigation practices[6] they may be expected to produce adapted crops satisfactorily, even though their moisture-holding capacity is generally somewhat limited.

Musselshell gravelly loam.—Musselshell gravelly loam covers 3,840 acres, or 6.4 percent of the area surveyed. It occurs in nearly all parts of the area on the smooth high gravelly benches.

The surface soil consists of a 3- to 5-inch layer of grayish-brown friable loam that has a soft crumb structure. It is underlain by a layer of light grayish-brown prismatic or soft cloddy clay loam having about the same thickness. The next lower layer of brownish-gray highly calcareous gravelly silt loam continues to a depth of 19 to 30 inches, where the porous gravel substratum is reached. Some gravel is scattered over the surface and through the upper subsoil layers, but it is not abundant enough to interfere materially with tillage operations. The gravel consists chiefly of rounded limestone fragments but includes some siliceous and crystalline material in places. Sandstone and shale bedrock underlies the gravel deposits at a depth of 12 feet or more in most bodies of the soil.

The slope of the land facilitates irrigation and good external drainage, though care will have to be exercised in laying out irrigation ditches in order to prevent entrenchment in gravel beds and the consequent loss of water. The soil absorbs water readily, and the underlying gravel insures good internal drainage for the removal of excess irrigation water and any soluble salts present. However, the soil is only about 24 inches thick over the gravel and will not allow the storage of so much moisture as do the deeper soils; therefore the interval between applications of water necessarily have to be shortened and costs of operation are somewhat higher than for soils of greater depth.

As a whole, the soil may be expected to produce under irrigation average yields of 25 to 30 bushels of wheat, 30 to 35 bushels of oats, and 1 to 2 tons of alfalfa hay to the acre.

Musselshell gravelly loam, sloping phase.—The sloping phase of Musselshell gravelly loam differs from the typical soil mainly in occupying more sloping areas. It is less extensive than that soil, occurring on sloping edges of high terraces adjacent to streams and on points of the terraces at the confluence of streams where the slopes are dominantly in one direction and the gradients generally range between 3 and 10 percent.[7] Surface drainage is rather rapid, but little or no accelerated erosion has taken place, as most of the land remains in native sod.

On the average the surface and subsoil layers are somewhat thicker, and the depth to the gravel substratum is more variable, as compared

[6] Soils on the higher benches of the Upper Musselshell Valley area were just being brought under irrigation at the time this report was written. Estimates of expected crop yields on the soil type under discussion are based chiefly on yields obtained on soils of similar physical and chemical characteristics that have been under irrigation for a number of years, in a climatic environment comparable to that prevailing in this area.

with those features of the typical soil. The small areas of this soil that are under cultivation are as productive as those of typical Musselshell gravelly loam, but the greater slope makes them more difficult to irrigate and necessitates considerable care in applying water to the land in order to prevent erosion. Some of the areas of this soil in the vicinity of Harlowton lie too high to be irrigated from supply canals.

As a whole, this soil is unsuited for extensive cultivation because of the slope, the difficulty of applying irrigation water, and the likelihood of accelerated erosion if the surface is left bare. Its use as pasture land or hay land would probably give best returns over a period of years.

Musselshell gravelly fine sandy loam.—This type includes areas of sandy soil in association with other members of the Musselshell series. It occupies only 192 acres, mainly northwest of Harlowton. Aside from the higher content of sand throughout, this soil does not differ essentially from Musselshell gravelly loam.

Beneath a thin mulchlike layer in virgin areas, the surface soil is grayish-brown noncalcareous gravelly fine sandy loam to a depth of 5 or 6 inches, underlain by brownish-gray calcareous very fine sandy loam containing some gravel. This layer becomes more limy and slightly lighter colored in the lower part and grades into the underlying limestone gravel about 24 inches below the surface. The upper 1 or 2 feet of the gravel is embedded in a semicemented limy matrix.

This soil absorbs nearly all of the precipitation, is inclined to be a little droughty, and the downward movement of moisture is rapid to excessive. The soil is easy to irrigate, but it does not retain so much moisture as Musselshell gravelly loam and other more silty soils. Irrigation must necessarily be more frequent than on heavier textured soils to obtain comparable yields. Overirrigation results in a waste of water by internal drainage and loss of plant nutrients through leaching.

When the land is first put into cultivation, the yields about equal those obtained on Musselshell gravelly loam. In order to maintain yields on the two soils at the same level, however, the gravelly fine sandy loam requires more soil amendments.

Musselshell clay loam.—This soil comprises 1,280 acres in the Upper Musselshell Valley area. It includes the gravel-free soils on high benches associated with the gravelly members of the Musselshell series.

The surface and upper subsoil layers are relatively free of gravel. On the average, the surface and upper subsoil layers are slightly thicker over the underlying gravel and the surface soil is higher in clay than the corresponding layers of other Musselshell soils; otherwise the soil does not differ from Musselshell gravelly loam.

The surface soil consists of a 2- or 3-inch layer of grayish-brown mulchlike noncalcareous friable silt loam having a soft-crumb structure, underlain by grayish-brown noncalcareous firm or moderately compact clay loam having a prismatic or irregular cloddy structure.

[7] A slope of 10 percent is one in which the land rises or falls 10 feet vertically in a horizontal distance of 100 feet. All other percentages of slope are calculated similarly.

From 6 to 8 inches below the surface this layer grades abruptly into light brownish-gray highly calcareous silt loam or clay loam. This material becomes light gray in the lower part near the level where it merges into the underlying gravel bed, at a depth of 30 to 36 inches. A small quantity of gravel is present in the entire soil mass in places, especially in the transitional belt where this soil merges with the gravelly members of the Musselshell series.

In general, this soil retains more moisture than the gravelly members of this series and holds more of it available for the use of plants because of the greater thickness of the soil over the gravel substratum.

Musselshell clay loam is one of the best soils for crops under irrigation of the soils on high benches. It is essentially free of injurious salts, and under proper management it should return slightly higher yields of all crops than the gravelly members of this series.

MARTINSDALE SERIES

Soils of the Martinsdale series occupy high gravelly outwash benches or terraces similar to those on which the Musselshell soils are developed. They are characterized by brown friable surface soils that commonly contain some stones and gravel; brown noncalcareous prismatic or cloddy upper subsoil layers that in places are more gravelly or stony than the layer above; and grayish-brown highly calcareous gravelly lower subsoil layers. The interstitial spaces between the pieces of gravel and stone in the lower subsoil layers are filled with light-gray limy loam, and the lower sides of the pieces are thinly coated with precipitated lime. The substratum, beginning at depths ranging from 18 to 30 inches, consists chiefly of rounded and subangular siliceous and argillitic gravel and stone, instead of limestone gravel as in the Musselshell soils. Martinsdale stony loam and Martinsdale loam are mapped.

Martinsdale stony loam.—This soil occupies high benches and alluvial fans in the vicinity of Martinsdale. The soil has developed in stony and gravelly alluvium washed from nearby mountains. To a depth of 4 to 6 inches the surface soil is brown friable stony loam having a soft-crumb structure. Below this, brown firm or moderately compact noncalcareous stony or gravelly clay loam continues to a depth of 10 to 14 inches, where it grades abruptly into light brownish-gray massive highly calcareous stony loam. This material merges with the underlying loose gravel and cobbles at a depth of 18 to 24 inches. The upper subsoil layer has a definite reddish tinge in most places when it is moist.

Surface and internal drainage are good. The firm moderately heavy character of the soil gives it a fair water-holding capacity, although the soil is not deep over the more open gravelly substratum. Numerous large stones on the surface greatly hamper cultivation, and use of this soil is limited chiefly to the production of alfalfa hay or to pasture land. Irrigated areas that are free of seepage are capable of producing from 1½ to 2 tons of alfalfa hay to the acre.

Areas of Martinsdale stony loam in secs. 7, 8, and 17, T. 8 N., R. 12 E., are steeper and have a deeper mantle of soil over the open gravelly substratum than typical areas. Heavy irrigation over a period of years has overtaxed the drainage facilities of some areas in this same general vicinity, and some spots have become too wet for crops that are not tolerant of poor drainage conditions. These wet spots are used for the production of native hay, predominantly of western wheatgrass.

Martinsdale loam.—This soil is developed on high benches from parent material similar to that giving rise to Martinsdale stony loam, but only a sprinkling of gravel occurs on the surface and through the soil. The surface layer is a shade darker and the gravel substratum lies at a slightly greater depth than in the stony loam.

To a depth of about 4 inches the surface soil is brown friable loam having a soft-crumb structure. It is moderately well supplied with organic matter and dark brown in places. The upper subsoil layer is brown firm or slightly compact clay loam that has irregular cloddy or prismatic breakage when dry and is friable and has a reddish tinge when moist. Below a depth of 10 inches the lower subsoil layer is light grayish-brown silt loam containing a heavy concentration of soft lime just above the gravel substratum, which commonly occurs from 30 to 36 inches below the surface.

Martinsdale loam occurs chiefly on benches northwest of Martinsdale, and it occupies a relatively small total acreage. Because the soil is deeper over the loose gravel substratum, more moisture is stored than in the Musselshell soils or Martinsdale stony loam; and for this reason this is a more desirable soil for crops. Also, the absence of large stones on the surface makes it easier to cultivate than Martinsdale stony loam.

With irrigation, Martinsdale loam is a desirable soil for crop production and yields of all crops will probably average slightly higher than on the Musselshell soils.

CUSHMAN SERIES

Soils of the Cushman series occupy undulating to gently rolling uplands adjacent to the alluvial lands, terraces, and benches of the Musselshell River Valley. They are developed from friable, silty, or only slightly sandy parent material weathered from shale bedrock. Cushman silt loam is the only type mapped in this series.

Cushman silt loam.—This soil comprises 1,216 acres, or only 2 percent of the area surveyed. It occupies undulating uplands and is developed in silty material underlain by sandy shales. The surface soil of grayish-brown friable silt loam is about 5 inches thick, contains a fair supply of organic matter, and has a soft-crumb structure. To a depth of 14 inches the subsoil is grayish-brown friable structureless silt loam containing an abundance of lime in the lower part. Below this, light brownish-gray or yellowish-gray massive friable very fine sandy loam or silt loam continues down to bedded shale, which lies 30 inches or more below the surface. The lower part of this layer commonly contains fragments of sandy shale. The soil is thinner in the more sloping areas, and the shale outcrops in places on the steeper slopes. The largest area of this kind, indicated by outcrop symbol, is in the SW¼, sec. 9, T. 8 N., R. 14 E. Moisture and roots of plants readily penetrate the soil, and a good supply of moisture remains available for plant use.

Cushman silt loam is suited to the production of all crops that mature under the prevailing climate; and, given adequate irrigation, it is capable of producing from 30 to 35 bushels of wheat to the acre, about the same quantity of oats, and 1½ to 2½ tons of alfalfa hay. After the land has been irrigated for a period of years, some of the lower slopes are likely to become wet from seepage and unproductive of most crops if proper drainage is not maintained. The rolling and sloping relief necessitates irrigation on the contour if erosion and loss of water are to be minimized.

Some areas are not irrigable because they lie above the source of irrigation water; others are too rolling for satisfactory distribution of irrigation water. The largest rolling area of this kind is in the NE¼ sec. 13, T. 8 N., R. 13 E. The use of areas as steep as this one should be limited to grazing or the production of sod-forming crops.

SHALLOW FRIABLE SOILS OF THE EXCESSIVELY DRAINED UPLANDS AND HIGHER TERRACES

Shallow friable soils of the excessively drained uplands and higher terraces are less well developed, are thinner over the overlying gravel beds and shale formations, and occupy more sloping or rolling areas than the soils of the preceding group. Owing to the steep relief and the shallowness, they are difficult to cultivate and irrigate; and crop yields are commonly unsatisfactory under either dry-farming or irrigation practices. This group includes members of the Crago and Bainville series and the undifferentiated Cushman-Bainville soils and occupies 21.2 percent of the area.

CRAGO SERIES

The soils of the Crago series are characterized by thin surface and subsoil layers and a porous limestone gravel substratum generally lying not more than 18 inches below the surface. They are the shallow soils of the high terraces and sloping edges of terraces and are developed in silty material similar to that giving rise to the Musselshell soils. They differ from the Musselshell chiefly in having more rapid surface or internal drainage and a slighter depth to the gravel substratum.

Crago gravelly loam.—This soil occupies 2,880 acres, or 4.8 percent of the area surveyed, occurring in nearly all parts of the area on the comparatively smooth, high gravelly benches. Despite the smooth surface, it is not well suited to cultivated crops and irrigation because of slight depth over the underlying gravel, excessive underdrainage, and low water-holding capacity.

The surface layer of grayish-brown gravelly loam has a soft-crumb structure and is underlain at a depth of about 3 inches by grayish-brown noncalcareous moderately gravelly silt loam of about the same thickness. This layer has irregular prismatic or cloddy breakage when dry and is massive and friable when moist. Below this, light-gray highly calcareous gravelly silt loam subsoil continues to a depth of 12 to 18 inches, where the underlying gravel is reached. The gravel in the upper part of the substratum is held firmly by nearly white limy material, but the material below is loose and open. Sandstone or shale bedrock commonly underlies the gravel 12 feet or more below the surface.

The slight depth over gravel limits the amount of water the soil will hold and restricts the area in which the roots of plants can grow and draw the necessary plant nutrients; hence low yields from most crops are the rule, even when the soil is first placed under irrigation. Subsequent harvests are further reduced by the rapid exhaustion of available plant nutrients. Although the roots of alfalfa commonly penetrate to a depth of several feet, they will not enter the gravel substratum; consequently the growth of the plant is restricted and the yields of hay from this crop seldom exceed 1 ton to the acre. Shallow irrigation ditches, placed on the contour, are necessary to prevent erosion of the ditches into the loose gravel substratum and the heavy loss of water if the soil is irrigated. Frequent irrigation will be required to maintain the supply of soil moisture, and this requirement increases the operating cost above that of the deeper, more productive soils, which are easier to irrigate and require less frequent applications of water.

Crago gravelly loam, sloping phase.—This soil differs from typical Crago gravelly loam mainly in occupying more sloping areas. A total area of 960 acres is mapped, all on the edges of terraces and points of terraces at the confluence of streams. Generally, the slopes are in one direction and the gradient ranges between 3 and 10 percent.

Where normally developed, the soil does not differ from Crago gravelly loam on the less sloping parts of the terraces; on the steeper slopes, however, natural erosion has thinned the soil considerably so that the gravel substratum lies only a few inches below the surface and in some places is exposed.

The slope makes the use of farm machinery difficult, and the returns from cultivated crops seldom more than repay operating costs. This soil is commonly irrigated with difficulty, although waste water or drainage water from higher lying irrigated fields could be spread on it in many places. Irrigation practices of this kind would be practicable only on pasture land, and, on the whole, this use of the land would probably give the highest net returns over a period of years.

Crago loam.—This soil occupies smooth terraces between Twodot and Harlowton. It covers a small total acreage and is relatively unimportant agriculturally. Like Crago gravelly loam, it has good surface drainage, excessive internal drainage, low water-holding capacity, and slight depth to the porous gravel substratum. It differs from Crago gravelly loam only in containing less gravel in the surface layer and upper subsoil layer.

This soil will produce about the same or slightly higher yields than Crago gravelly loam under the same cultural practices. Nevertheless, yields are low on the average, and the land is best left in native pasture. If water is available, frequent light applications on the sod would materially increase the amount of forage produced.

BAINVILLE SERIES

The soils of the Bainville series, like the Crago soils, have thin surface and subsoil layers, but they occupy uplands rather than terraces and are underlain by shale bedrock rather than gravel. They have the same kind of parent material as that giving rise to the Cushman soils. Compared with those soils, however, they have lighter colored surface soils, a shallower solum, and a larger quantity of rock and shale fragments on the surface and in the soil.

Soils of this series commonly occupy strongly rolling areas where the runoff of rainfall is rapid, and the rate of erosion under natural conditions nearly equals the rate at which the soil is formed. Therefore, the underlying bedrock everywhere lies at a slight depth, and outcrops of the silty and sandy shale are common on the steeper slopes.

Bainville silt loam.—This, a comparatively extensive soil, comprises 5,056 acres, or 8.4 percent of the area surveyed, occurring on the more sharply rolling uplands. The surface soil is grayish-brown friable silt loam having a massive or crumb structure. It is commonly calcareous and about 4 inches in thickness. The upper part of the subsoil is yellowish-brown highly calcareous friable very fine sandy loam or silt loam of massive or soft cloddy structure, and the lower part is yellowish-gray massive calcareous very fine sandy loam. This material merges with the partly weathered sandy shale bedrock from 8 to 14 inches below the surface. Fragments of the more resistant rock are scattered through the soil and are common on the surface in many places. Outcrops of the yellowish-gray platy shale are numerous on the steeper slopes.

In general this soil is not suited to any type of farming because of the steep slope, the rapid rate of runoff, and the slight depth of soil over the underlying bedrock. All the land should remain in pasture, except possibly for small areas of included soils that are deeper than normal and could be farmed in connection with adjoining soils suitable for cultivation.

Cushman-Bainville loams.—These represent a complex of soils belonging to the Cushman and Bainville series, described in preceding pages of the report. They occur as small, closely associated areas that could not be shown separately on the soil map. Many areas of this soil complex include normally developed Cushman and Bainville soils; others include a soil that is transitional in stage of development between the two. Loose stone on the surface and rather numerous outcrops of the bedrock mark many areas of the included Bainville soil, as indicated on the soil map by stone and outcrop symbols.

The areas of this land that are suitable for cultivation are too small and too irregular for normal tillage operations; hence most of the land should be left in native pasture. Should inexpensive water be available, light irrigation would improve the growth of grasses and increase the carrying capacity of pastures.

MODERATELY DEEP COMPACT SOILS OF THE UPLANDS, TERRACES, AND VALLEY SLOPES, HAVING SLOW INTERNAL DRAINAGE

All the moderately deep compact soils of the uplands, terraces, and valley slopes, having slow internal drainage, are developed from moderately heavy to heavy clayey parent material and contain varying, but commonly not large, quantities of soluble salts, except the Moline, which is quite salty in most areas. Internal drainage is slow or restricted, and much water is lost through runoff on slopes of more than 2- or 3-percent gradient. Plant roots and moisture penetrate the soil slowly and with difficulty. Although these soils have a fair to good water-holding capacity, they are so slowly permeable that water does not penetrate more than 12 to 18 inches below the surface, except during periods of prolonged wetting. Under such conditions the soils of this group that occupy lower slopes become saturated and poorly drained, owing to seepage from higher levels.

These soils are difficult to manage under any farming method; consequently they are used chiefly as dry-land pasture. Most of them have a rather low carrying capacity.

Soils of the Pierre, Orman, and Moline series of the uplands, terraces, and colluvial or valley slopes, respectively, and the undifferentiated Cherry-Moline soils are included in this group. These soils occupy 6.2 percent of the area.

PIERRE SERIES

Soils of the Pierre series are immature, medium deep soils developed in extremely fine textured clayey parent material weathered from heavy stratified clays or clay shale. They have shallow surface soils and tough compact subsoil layers in which water and plant roots penetrate very slowly. The subsoil layers are mildly to strongly calcareous and commonly contain white streaks and spots of alkali salts. They are much heavier and more compact at all depths than the Cushman and Bainville soils, which are forming over silty to sandy shales. They have a deeper profile development than the Bainville soils, and they contain no stone fragments, which are common to the Bainville soils in this area. Pierre clay loam is the only type of this series mapped in this area.

Pierre clay loam.—This soil covers 896 acres, or 1.5 percent of the area surveyed, occupying gently rolling to rolling uplands. Beneath a thin light grayish-brown mulchlike clay loam layer, the surface soil is grayish-brown heavy clay having no definite structure and reaching to a depth of about 8 inches. Below this the subsoil of gray or olive-gray compact calcareous heavy clay continues down to gray heavy clay shale, which lies from 24 to 30 inches below the surface. The soil is deficient in organic matter. It is commonly calcareous in the lower part of the surface soil, and the subsoil is streaked and splotched with accumulations of white salt. Surface drainage is good to excessive, owing to the slow rate of infiltration of moisture; and internal drainage is slow, owing to the dense compact subsoil.

Pierre clay loam is not suited to either dry-land or irrigation farming, because of the difficulty of carrying on tillage operations, the slow rate of infiltration of moisture, the slow internal drainage, and the presence of considerable alkali salts. Most or all of this land should remain in native pasture.

ORMAN SERIES

Soils of the Orman series are developed on smooth terraces and alluvial fans from clayey alluvium washed from the uplands consisting mainly of the Pierre soils. They differ from the Pierre soils chiefly in that they occupy terraces rather than the uplands and in having a heavy clay rather than a shale substratum. They occupy lower terrace positions than the Crago, Musselshell, and Martinsdale soils and differ from them in having more clay in all layers, no gravel in the surface and subsoil layers, and a compact clay rather than a gravel substratum.

The Orman soils absorb moisture slowly, and plant roots penetrate the soil with difficulty. Surface drainage is adequate, but internal drainage is slow. The concentration of salts is sufficient in places to injure growing crops.

Orman clay.—This soil is developed in relatively deep deposits of gray moderately calcareous alluvial clay on the low terraces and fans of the Musselshell River Valley. The surface soil, which consists of grayish-brown or light grayish-brown massive or structureless clay, is low in organic matter and is about 8 inches thick. The subsoil, of light grayish-brown blocky or coarse cloddy clay, merges with the olive-gray little-altered massive parent alluvium from 24 to 30 inches below the surface. The soil is commonly calcareous from the surface or near the surface downward, and white streaks and flecks of salt are present in most areas. The salt is sufficiently concentrated in places to injure growing vegetation.

The soil is plastic when wet and hard when dry, making it difficult to carry on tillage operations except within a very narrow range of moisture conditions. Moisture and roots of plants penetrate the soil slowly, and crops do not develop normally. The slow rate at which the soil absorbs water makes it unsatisfactory for irrigation purposes, and yields are too uncertain under dry-farming methods to warrant extensive farming of this soil.

A few areas in secs. 15, 16, and 22, T. 7 N., R. 17 E., that are less salty and more easily tilled, are now producing fairly satisfactory yields of crops after several years of good management under irrigation practices. On the whole, however, the land would give more profitable returns if left in pasture.

Orman silty clay loam.—This soil is developed in heavy-textured alluvium similar to the parent material of Orman clay, but it occupies gently sloping outwash fans on the terraces, rather than nearly level terraces; it contains somewhat more silt and sand throughout; and it has a substratum of alternating silty and clayey layers.

In an undisturbed condition the surface soil of grayish-brown silty clay loam is low in organic matter, granular or mulchlike in the upper 1-inch layer, laminated or platy in the succeeding 2-inch layer, and massive below this to a depth of about 8 inches. The subsoil is gray massive very compact silty clay loam that merges with the stratified gray silty and clayey parent alluvium about 24 inches below the surface. The entire soil is calcareous, and the subsoil commonly contains considerable white salt accumulations. Moisture infiltrates the soil slowly, and roots of plants penetrate it with difficulty.

A few areas of Orman silty clay loam under irrigation and careful management are producing fair yields of most crops. Additional areas, relatively free of injurious salts, could be similarly developed. As a whole, however, the land would probably give higher net returns over a period of years if left in native sod.

The soil is difficult to till when first brought under cultivation, and yields of crops are commonly low. Plowing under barnyard manure, crop residues, and green-manure crops improves the soil structure, adds to the rate of intake of water, stimulates the growth of crops, and makes the land easier to cultivate.

MOLINE SERIES

Soils of the Moline series are developed in moderately calcareous local colluvium on gentle terracelike slopes in narrow valleys and at the base of the uplands along the edges of the Musselshell Valley. They have light-colored shallow mulchlike friable surface soils, a compact or tough claypanlike upper subsoil layer that has distinct columnar structure, and lower subsoil layers that are tough and compact and show no development of structure. The soil contains large quantities of alkali salts, and in places salts are concentrated enough to prevent the growth of all but the most salt-tolerant of plants. Numerous bare spots mark places where the wind has removed the friable surface soil and exposed the heavy clay subsoil.

The Moline soils differ from the Pierre and Orman soils in having lighter colored surface layers, a higher content of salt, and a claypan layer in the subsoil. They are on colluvial slopes, whereas the Orman are on terraces and the Pierre on the uplands.

The dominant vegetation on the Moline soils is western wheatgrass, silver sagebrush (valley sage), and desert saltgrass.

Moline clay loam.—This soil comprises only a small part of the Upper Musselshell Valley area, occurring in narrow bands and small areas at the foot of slopes in or adjacent to the heavy-textured soils of the uplands underlain by shales.

To a depth of about 6 inches the surface soil consists of mulchlike clay loam in the upper part and coarse granular or crumb-structured clay loam in the lower part. This rests abruptly on the subsoil of brownish-gray compact clay having a columnar structure in the upper part and no definite structure in the lower part. The structure columns break horizontally into hard clods having an ill-defined prismatic form. The subsoil merges almost imperceptibly with the gray or brownish-gray little-altered heavy clayey parent colluvium at a depth of 18 to 24 inches.

Varying amounts of salts, including calcium carbonate, are present throughout. There are many slightly depressed slick spots, where the light-colored surface layer has been removed by the wind and the heavy clay subsoil is exposed. They are not so numerous, however, as in the Moline soils in other parts of Montana.

The heavy texture of the subsoil, the high concentration of salts, and the slow rate of moisture infiltration in this soil make most of it unsuited to cultivation, and it should remain in pasture.

Cherry-Moline clay loams.—This soil complex covers only a small total acreage on colluvial slopes and in narrow valleys in the shale uplands and on gentle valley slopes adjacent to the uplands in the Musselshell Valley. The parent soil material is washed from both heavy clay shales and friable silty shales. The complex comprises small areas of heavy-textured light-colored claypan soils belonging to the

Moline series just described, and slightly darker more friable soils belonging to the Cherry series, described on page 27. The two soils occur in small areas that are too intricately associated to be shown separately on the map.

Most areas of these undifferentiated soils occupy positions below the high terraces and uplands suitable for irrigation, and, when these soils are placed under irrigation, most of the Cherry-Moline soils will be subjected to seepage and additional salting by drainage from the higher lands. For a time, therefore, the soils representing this complex should not be considered for cultivation until a thorough investigation of drainage conditions is made for each individual area.

MODERATELY DEEP FRIABLE SOILS OF THE WELL-DRAINED VALLEY SLOPES AND TERRACES

Moderately deep friable soils of the well-drained valley slopes and terraces are developed in light-colored local alluvium washed from the adjacent uplands and high benches. They are silty and friable throughout and do not have the heavy clay substratum and the high salt content common to the Orman and Moline soils also on valley slopes and terraces. They lack the porous gravel substratum of the Crago, Musselshell, and Martinsdale soils and are similar to the Cushman soils on the uplands in most profile features.

Members of the Cherry and Berthoud series comprise this group of soils. They occupy 9.4 percent of the area. The Cherry soils occupy valley slopes and terraces in the western part of the Upper Musselshell Valley area, where the elevation is higher, the precipitation is heavier, temperatures are lower, and climatic conditions are favorable for the accumulation of considerable organic matter and the development of moderately dark surface soils. The Berthoud soils occur in the eastern part, where the climate is more arid and conditions are unfavorable for the accumulation of appreciable quantities of organic and dark surface layers; hence, these soils are light-colored. Developed in about the same kind of parent material on comparable slopes, the chief differences between the soils of these two series are in color, depth, and organic-matter content of their surface layers.

CHERRY SERIES

The Cherry series includes grayish-brown or moderately dark grayish-brown friable soils developed in local alluvium on gentle, terracelike valley slopes and fans in the western part of the Upper Musselshell Valley area. Although the parent material is light-colored, the soils have been in position long enough to accumulate a fair supply of organic matter in their surface layers. They have reached about the same stage of development as the Cushman soils on the uplands. They are among the best soils for crops in the locality where they occur, for either irrigation or dry-farming.

Soils of the Cherry series have slightly darker and thicker surface and upper subsoil layers than the Berthoud soils developed in the same kind or similar parent material in the drier parts of the Upper Mussellshell Valley area.

Cherry silt loam.—This soil comprises 2,240 acres, or 3.7 percent of the area surveyed, chiefly in the western part of the area. It occupies valley slopes and terraces between the uplands and high benches and the bottom lands adjacent to the Musselshell River.

In cultivated fields the 5- to 7-inch surface soil is moderately dark grayish-brown friable silt loam, and in virgin areas it is grayish-brown, platy, or mulchlike in the upper part and dark grayish brown, soft granular, or crumb-structured in the lower part. The subsoil is light grayish-brown silt loam or very fine sandy loam that becomes somewhat lighter colored with depth and merges with the little-altered parent alluvium from 30 to 36 inches below the surface. The lower part of the subsoil contains some water-rounded gravel in places, and the substratum consists of stratified gravel and fine earth material. A few small areas of Cherry clay loam that are not large enough to show separately on the soil map are included with Cherry silt loam.

Bodies of this soil east of Elk Creek and south of the railroad just east of Martinsdale occupy steeper slopes than are typical for the soil. A body 1 mile east of Martinsdale has become permanently wet from seepage of irrigation water from higher levels. Along the eastern edge of the body, subsoil drainage is restricted and a few salty spots are forming. The salt or alkali content of these spots will continue to increase and their area will enlarge, unless adequate drainage is established. Small bodies of Cherry silt loam developed in mixed alluvium deposited on the broader terraces at the mouths of small drains have irregular slopes and are not suited to irrigation and cultivation.

Aside from the bodies mentioned in the foregoing paragraph, Cherry silt loam generally is an excellent soil for farming under irrigation practices. It is easy to cultivate, contains a fair supply of organic matter and an abundance of available plant nutrients, absorbs water readily, and holds a good supply available for plant use. Under proper management yields of wheat and oats should range from 30 to 35 bushels an acre and those of alfalfa average about 2 tons.

Cherry loam.—This soil covers 704 acres on valley slopes similar to those occupied by Cherry silt loam. The surface soil contains a little more fine sand than that of the silt loam; otherwise the two soils are nearly identical in all profile features. Bodies of this soil mapped in the S½ and NW¼, sec. 34, T. 9 N., R. 11 E., are affected by seepage at places, and in their present condition they are too wet for cultivation. The narrow upland valley in sec. 32, T. 9 N., R. 11 E., mapped as Cherry loam, includes spots of gravelly soils having a porous, open structure. These gravelly spots make the whole body unsuited for use as cropland because of the difficulty of laying out irrigation ditches and conducting water to the land.

Cherry loam is friable and easily penetrated by roots of plants and by moisture. Under similar management it will produce yields of crops comparable to those obtainable on Cherry silt loam.

BERTHOUD SERIES

Soil of the Berthoud series are developed in colluvium or local alluvium on sloping terraces and outwash fans at the base of slopes in the uplands and on high benches, chiefly in the more arid eastern part of the Upper Musselshell Valley area. They are light-colored and have a relatively low content of organic matter. Although they are calcareous from the surface or near the surface downward, they do not have the well-developed zone of lime accumulation common to the more mature soils of the uplands and high benches.

In surface color they closely resemble the Bainville soils on the uplands, but they have thicker surface and subsoil layers and are underlain by a heterogeneous mixture of colluvium or local alluvium, rather than shale bedrock. They closely resemble the soils of the Cherry series in all features except for the lighter colored surface layers.

As mapped in the Upper Musselshell Valley area, these soils have fewer broken stone fragments on the surface and in the soil than in typical areas mapped outside the area.

Berthoud silt loam.—A total area of 1,280 acres of this soil is mapped in widely distributed bodies over the eastern part of the area on valley slopes at the base of the uplands and in narrow upland valleys. The surface soil consists of light grayish-brown mildly calcareous friable silt loam, 5 to 7 inches thick. This material is mulchlike or platy in the upper part and has a soft granular or crumb structure in the lower part. The upper part of the subsoil is brownish-gray friable calcareous silt loam having a weakly developed cloddy structure. In the lower part it consists of alternating layers of light-gray massive friable highly calcareous silt loam and very fine sandy loam, which give way to little-altered light-gray parent soil material from 20 to 30 inches below the surface. Here and there the soil contains shale fragments and water-rounded gravel washed from the uplands and high benches.

The soil is easily penetrated by roots of plants and by moisture, and it contains a good supply of available plant nutrients. It is commonly free of injurious salts and occupies areas that are easy to irrigate. Under irrigation farm practices, it is only slightly less productive than Cherry silt loam; and, given proper management, it should produce yields of 27 to 32 bushels of wheat and oats and 1½ to 2 tons of alfalfa hay to the acre.

Berthoud loam.—This soil differs little from Berthoud silt loam except in the texture of the surface soil. It occupies valley slopes below bodies of the more sandy uplands, covering a total area of 704 acres. The soil material contains a little more fine sand than that composing the silt loam. Friable throughout, the soil forms an excellent medium in which the roots of plants can develop. It occupies smooth slopes that are easy to irrigate, and it absorbs water readily and retains a good supply available for use by growing plants. The soil is easily tilled, and, under management practices that include the use of barnyard manure or the plowing under of crop residues, it should produce as high yields of all adapted crops as Berthoud silt loam.

Berthoud clay loam.—This soil occupies 704 acres of the area on colluvial slopes and sloping terraces in the uplands underlain by moderately heavy to heavy shale. It contains more soluble salts and is slightly heavier throughout than the other members of the series.

In virgin areas the surface soil is grayish-brown mulchlike silt loam in the upper 1- or 2-inch layer, underlain by grayish-brown or light grayish-brown weakly calcareous friable clay loam to a depth of 6 or 8 inches. Below this, the subsoil consists of light grayish-brown friable clay loam having no definite structure. At a depth of 18 to 24 inches the subsoil merges with the underlying gray or light brownish-gray interbedded friable silt loam and clay loam parent material.

Surface and internal drainage are good, except that in places internal drainage is restricted by a more compact or heavier substratum than that commonly underlying the Berthoud soils. Alkali salts have accumulated in sufficient quantities to injure or prevent the growth of plants in some of the areas having restricted internal drainage. Such areas are indicated on the soil map by special alkali symbols.

Most areas of Berthoud clay loam occupy uniform slopes that are suitable for irrigation. The chief exception to this is two areas in secs. 5, 6, 8, and 9, T. 7 N., R. 17 E., that occupy slopes that are too irregular for satisfactory irrigation and tillage operations. The soil commonly has a low content of organic matter but a fair to good supply of most of the essential plant nutrients. Under irrigation it produces yields of most crops only slightly lower than those obtained on the moderately deep friable soils of the well-drained uplands and higher terraces.

WELL-DRAINED FRIABLE SOILS OF THE BOTTOM LANDS AND LOW TERRACES

Well-drained friable soils of the bottom lands and low terraces are developing in silty or only slightly sandy calcareous alluvium. These nearly level stream terraces and bottom lands lie considerably lower and are of more recent origin than the adjacent high gravelly terraces and benches formed by outwash from the mountains. They occur chiefly in small bodies and strips of various widths along the Musselshell River and some of the larger tributaries of this stream. Although rather slow, surface drainage is well established. Internal drainage is restricted at places by a high water table. These soils occupy 19.4 percent of the area.

The better drained Harlem and Havre soils and Banks fine sandy loam are included in this group. Imperfectly and poorly drained members of the Harlem and Havre series are included with a group of imperfectly to poorly drained soils described in subsequent pages of the report.

HARLEM SERIES

Soils of the Harlem series occupy low terraces and bottom lands along the Musselshell River in the western part of the area, where they are forming in alluvium washed from comparatively dark soils of the adjacent uplands and mountains. Well supplied with organic matter and available plant nutrients, they are the darkest and inherently the most productive soils of the Upper Musselshell Valley area. Generally, the Harlem soils are well drained in their upper layers, except that low areas adjacent to the river have a high water table. Slightly depressed areas are imperfectly to poorly drained, and some areas adjacent to the uplands and high terraces are subject to seepage, are poorly drained, and contain considerable alkali salts. Where the poorly drained areas are of sufficient size, they are shown on the soil map as poorly drained phases and are described under a subsequent group of imperfectly to poorly drained soils.

Harlem silt loam and a poorly drained phase, which will be described in subsequent pages, are the only soils of this series mapped in the area.

Harlem silt loam.—Although this soil occupies a total area of only 1,408 acres, it is an important farming soil because of the content of available plant nutrients, the smooth surface relief, and the friable consistence, which make it suitable for tillage operations and easy to irrigate.

This soil occurs on the bottom lands and low terraces along the Musselshell River. In a virgin condition, the surface soil beneath a 2-inch layer of fibrous organic mulch is dark grayish-brown friable crumb-structured or soft cloddy silt loam, about 6 inches thick. Below this the subsoil is grayish-brown mildly calcareous silt loam that breaks into irregular clods when disturbed, and which, in turn, can be crushed into a soft crumblike mass when moist. Light-gray highly calcareous spots and streaks are present in this layer in most places. At a depth of about 18 inches the subsoil rests on the little-altered light brownish-gray stratified loam and silt loam parent alluvium, which is streaked with lime in places and is commonly splotched or mottled with rust brown, indicating imperfect internal drainage or a high water table for at least part of the time. Water-worn gravel and sands underlie the soil at depths of several feet in most areas.

The soil is rather uniform in texture of the surface soil in most areas; however, a few scattered spots of Harlem loam and Harlem clay loam that are too small to show separately on the map are included with Harlem silt loam.

Although restricted, internal drainage is good enough to allow the production of any crop on this soil that is adapted to the region. The close proximity of the Twodot Canal to some areas of the soil may result in these areas becoming permanently wet from seepage if the bottom of the canal is not sealed or if drainage ditches are not properly located to intercept the seepage.

Permeable to air, roots of plants, and moisture, Harlem silt loam forms an excellent medium for the growth and development of plants. It retains a good supply of moisture, and, under irrigation farming practices, it should produce about 35 to 40 bushels of wheat, 40 to 45 bushels of oats, and 2 to 3 tons of alfalfa hay to the acre. No attempt has been made to dry-farm this soil, and there is less likelihood that this will be done in the future, because recently (1939) constructed flood-water reservoirs prevent the recurrence of seasonal high water tables for which the Musselshell River was responsible.

HAVRE SERIES

The Havre series includes rather light-colored friable silty or only slightly sandy soils developed in calcareous alluvium on nearly level bottom lands and low terraces. These soils occur chiefly along the Musselshell River in the eastern part of the Upper Musselshell Valley area, where the rainfall is lighter than in areas of the Harlem soils, which are developed from the same kind of parent alluvium. The surface soils are lighter colored and thinner and lime lies nearer the surface than in the Harlem soils. Results from dry-farming the

Havre soils are generally unsatisfactory, but under irrigation crop yields are nearly equal to those of the Harlem soils. Aside from the slightly darker surface layers, they do not differ greatly in profile features from the Berthoud soils, which occupy the adjacent sloping terraces and colluvial valley slopes.

Surface drainage is adequate for the low rainfall of this part of the area, but the low position of these soils adjacent to streams results in imperfect internal drainage in most places and a high water table and poor drainage in some places. Some areas adjacent to higher lands are wet most of the year from seepage. Where they are large enough, the poorly drained areas are shown separately on the map and are described in subsequent pages of the report under a group of imperfectly to poorly drained soils.

Havre loam and silt loam, together with poorly drained phases of these soils, and Havre silty clay loam are mapped.

Havre loam.—This soil is fairly extensive, occupying a total area of 3,392 acres, or 5.6 percent of the area surveyed. It is a comparatively important hay-producing soil in the eastern part of the area, where it comprises most of the land used for the production of alfalfa on some of the farms.

The surface soil of light grayish-brown friable loam is about 5 inches thick and has a rather low content of organic matter, although it is mellow and friable and has an ill-defined soft-crumb structure. The subsoil consists of thin alternating strata of brownish-gray very fine sandy loam, loam, and silt loam and continues with little change to a depth of 3 feet or more. The deeper substratum is chiefly gray alluvial sand or a mixture of loose and incoherent sand and gravel. The soil is limy from the surface or near the surface downward.

Havre loam is developed in recent alluvium deposited along the course of the Musselshell River and some of the tributaries of this stream. Although it occupies fairly smooth areas, some tracts require a moderate amount of leveling before they can be irrigated effectively. The soil absorbs moisture readily and retains a good supply for the use of plants. Under irrigation this soil should produce average yields of 25 to 30 bushels of wheat and oats and 1½ to 2 tons of alfalfa hay to the acre. Farm practices that tend to increase the organic-matter content of the soil should be followed.

Havre silt loam.—This soil differs from Havre loam chiefly in having a slightly higher content of silt and clay in the surface soil and upper subsoil layer and a moderate to strong concentration of alkali salts in some places. The more salty areas are indicated on the soil map by special alkali symbols.

The surface soil of grayish-brown friable mildly calcareous silt loam is about 6 inches thick and has a soft-crumb structure. It is only moderately well supplied with organic matter. The subsoil consists chiefly of thin alternating strata of friable silt loam and very fine sandy loam alluvium, which rest on loose sand or stratified sand and gravel in most places at a depth of 3 to 4 feet.

Havre silt loam has good surface drainage and adequate internal drainage. It is suited to the production of all crops adapted to the region, except that small spots have a high water table or are subject to seepage. The poorly drained spots are commonly salty. As already mentioned, the salty spots are indicated on the soil map.

Most of the soil occupies areas on the bottom lands and low terraces that are suitable for irrigation with little or no leveling. Under irrigation practices yields of crops do not differ from those obtained on Havre loam.

BANKS SERIES

The Banks series includes light-colored soils developing from recently deposited sandy alluvium on bottom lands and natural levees adjacent to the larger streams. The soils of this series occupy lower positions than the associated Harlem and Havre soils. They are subject to more frequent overflow, are much more sandy in their subsoil, and are less stable. They occupy slightly higher positions and have only slightly darker surface layers than areas classified as riverwash.

Most of the Banks soils in the Upper Musselshell Valley area are unsuited for cultivation and remain in the virgin state. They support sparse to dense stands of trees and brush and some coarse grasses. Banks fine sandy loam is the only soil of this series that is mapped in this area.

Banks fine sandy loam.—This soil is developing in recently deposited sandy alluvium along the Musselshell River. The surface soil consists of light grayish-brown mildly calcareous loose fine sandy loam, about 3 inches thick and having a single-grain structure. Below this, the subsoil of gray loose incoherent loamy fine sand continues to a depth of about 18 inches, where it merges with the gray sand and gravel substratum.

The soil is deficient in organic matter and available plant nutrients, has low water-holding ability, and is otherwise unsuited to cultivation. It is used for the scanty pasturage afforded by the grasses; and the brush and fair to dense stand of cottonwood trees provide useful shelter for the large number of livestock that are wintered along the Musselshell River.

IMPERFECTLY TO POORLY DRAINED SOILS OF THE BOTTOM LANDS, LOW TERRACES, AND UPLAND DEPRESSIONS

Imperfectly to poorly drained soils of the bottom lands, low terraces, and upland depressions include the poorly drained member of the Harlem series, the imperfectly and poorly drained members of the Havre series, all members of the Laurel and McKenzie series, and miscellaneous soils. These soils occupy areas that have a high water table or receive seepage or runoff from higher ground. The Havre and Harlem soils occur chiefly on the bottom lands and low terraces of the Musselshell River; the Laurel soils occur on the bottom lands of this stream and its tributaries; and the McKenzie soils occupy depressions in the uplands. This group of soils occupies 14.1 percent of the area.

Nearly all of these soils are more or less salty and are not suited to the production of most cultivated crops. Much of their area, however, is used for mowing wild hay, chiefly western wheatgrass; the rest is used for pasture, except that some of the soils that are only imperfectly drained are used for the production of alfalfa hay and some small grain.

It is possible to improve the drainage conditions of many areas of these soils by properly placed drainage ditches or tile drains. Some areas on which artificial drainage is impracticable will become permanently wet and of little value even for pasture, because of seepage from adjacent irrigated land.

HARLEM SERIES (POORLY DRAINED MEMBER)

Harlem silt loam, poorly drained phase.—This soil differs from typical Harlem silt loam chiefly in having pronounced gray and rust mottlings in the subsoil and a high water table, which restricts or prevents internal drainage and aeration of the subsoil. The poorly drained condition has favored the accumulation of excess alkali salts in at least part of nearly all areas of this soil. Surface drainage is adequate except where the soil occupies slight sags, depressions, and old cut-off channels. The low position of the soil with relation to the water level in the streams and seepage from higher irrigated land account for the high water table, which cannot be lowered by artificial drainage in many of the areas.

Drainage in the higher lying parts is sufficient to allow the production of small grains and alfalfa hay, but most of the land is best suited to the production of wild hay and pasture grasses. A common practice in the use of this land is to harvest the early growth of grasses for hay and utilize the summer and fall growth for winter pasture.

Subirrigation of an area in sec. 24, T. 8 N., R. 12 E., allows the production of small grain and alfalfa without surface irrigation.

HAVRE SERIES (IMPERFECTLY AND POORLY DRAINED MEMBERS)

Havre silty clay loam.—This soil differs from Havre loam and Havre silt loam, described under the preceding group, in containing considerably more clay in the surface soil and upper subsoil layer and in places in having a clayey substratum. Moreover, it occupies areas that are subject to seepage, slightly depressed, or have a high water table. As a whole, it has poorer surface and internal drainage than Havre loam and Havre silt loam. Many of the areas of this soil, however, occupy positions in which natural drainage could be improved by properly located drainage ditches. Given improved drainage, such areas are as productive as areas of the naturally well-drained soils of the Havre series.

The surface soil, about 8 inches thick, is grayish-brown silty clay loam having a massive or soft-crumb structure. It contains only a moderate amount of organic matter. The subsoil, consisting of alternate layers of gray massive friable silty clay loam and very fine sandy loam, continues to a depth of 3 feet or more with little change. In most places the soil is calcareous from the surface downward, and in the depressed and poorly drained spots it contains a varying amount of alkali salts. The more salty spots are indicated on the soil map by special alkali symbols.

Havre loam, poorly drained phase.—This phase differs from the typical better drained Havre soils chiefly in having a high water table, poor internal drainage, and pronounced gray and rust mottlings in the subsoil. The high water table, partly induced by irrigation of higher lying lands, serves as a source of subirrigation for native grasses, but it keeps most of the land too wet to be used for the production of small grains and alfalfa.

Much of the soil occupies unfavorable positions or positions too low for adequate drainage by artificial means. It is used chiefly for the production of native hay and winter pasture areas. The lowest areas and sags in the better drained areas contain considerable alkali salts. The salty areas support only salt-tolerant grasses that are unpalatable and have a low value for feeding. The more pronounced salty areas are shown on the soil map by special alkali symbols.

Havre loam, poorly drained phase, occurs chiefly in association with Havre loam in the eastern part of the area.

Havre silt loam, poorly drained phase.—This soil, like Havre loam, poorly drained phase, differs from the typical Havre soils chiefly in having poor internal drainage, a gray- and rust-mottled subsoil, and a high water table. Most areas of this soil are too wet to grow small grain and alfalfa hay and are used mainly for pasture and the production of native hay. The presence of alkali salts in many areas of the soil restricts the grasses to salt-tolerant species that give a low yield and poor quality of hay and forage. Subirrigated areas that are not salty produce an abundant growth of excellent quality hay and pasture grasses. The more salty areas are indicated on the soil map by special alkali symbols.

LAUREL SERIES

Where normally developed, the Laurel soils are light-colored, imperfectly drained, and moderately heavy textured and occur on the bottom lands and low terraces. They are commonly limy and contain some alkali salts in their subsoil. In the Upper Musselshell Valley area they are everywhere imperfectly to poorly drained and nearly everywhere moderately to strongly saline. The less salty and better drained areas are mapped as Laurel silty clay loam; the remaining areas are mapped as Laurel silty clay loam, saline phase.

These soils support salt-tolerant plants, chiefly grasses and rushes, and are essentially nonagricultural. They are commonly included with pasture land, and in some areas they are mowed for hay.

Laurel silty clay loam.—This soil chiefly occupies areas on the bottom lands that are poorly drained and a few others that are permanently wet and marshy. The surface soil, about 7 inches thick, is grayish-brown silty clay loam having a moderately high content of organic matter and containing rust mottlings. The subsoil consists of bluish-gray massive compact silts and clays, stained and splotched with rust brown. The soil is mildly calcareous from the surface downward. Alkali salts are present in most areas and in places the salts are concentrated enough to exclude all but the most salt-tolerant grasses. It is used for pasture land except for a few areas that are mowed for hay.

Western wheatgrass, desert saltgrass, and a variety of rushes and sedges make up the vegetation.

Laurel silty clay loam, saline phase.—The soil of this phase occupies poorly drained areas and depressions on the low terraces and bottom lands along the drainageways of the uplands and along the

Musselshell River. It differs from Laurel silty clay loam chiefly in having poorer drainage and a larger content of alkali salts in most areas.

The surface soil is grayish-brown massive compact clay loam, about 7 inches thick. Below this, the subsoil consists of alternate layers of gray compact calcareous clay loams and very fine sandy loams, which continue downward to a depth of several feet. The entire soil is commonly mottled with rust stains and white salt accumulations.

Surface drainage is slow or not established, and internal drainage is inadequate because of the low position of the soil or the compact clayey nature of the subsoil. Seepage from the adjoining irrigated uplands and high benches will, in all probability, serve to intensify the wet and alkali condition of the soil.

Laurel silty clay loam, saline phase, is best used for the scanty pasture it affords.

McKENZIE SERIES

The McKenzie soils occupy depressions and small intermittent lake basins in the uplands. Where normally developed, they have moderately dark heavy-textured surface soils that have no definite structure and gray or dark-gray dense massive calcareous clay subsoil layers. White streaks and crystals of salt are commonly present in the subsoil.

In the Upper Musselshell Valley area the McKenzie soils have lighter colored surface layers and contain more salts than the soils mapped in typical areas outside of this area. Only McKenzie clay occurs in the area.

McKenzie clay.—The surface soil is gray or grayish-brown massive clay, about 6 inches thick. The subsoil below this is compact massive gray clay. The soil is commonly calcareous from the surface or near the surface downward, and it contains considerable alkali salts in most areas.

This soil occupies shallow depressions in the uplands, where it is developed from heavy clay material washed from the surrounding soils. In wet seasons the depressions hold water for considerable periods, but they are dry more than half of the time. When wet, the soil is sticky and plastic; when dry, it bakes and cracks into large irregular hard blocks. It is suitable only for the small amount of pasturage it will afford.

Natural vegetation consists chiefly of saltgrass, greasewood, and other salt-tolerant plants.

MISCELLANEOUS SOILS

Alluvial soils, undifferentiated.—These soils occupy the bottom lands bordering the Musselshell River in the vicinity of Martinsdale. Areas of brush, willow, and cottonwood are interspersed with small grassy parks. Although subject to overflow during periods of high water, the soils drain quickly after the floods subside, because of the comparatively coarse substratum that underlies most areas. The surface soils of most areas are about 4 inches thick and consist of dark grayish-brown friable loam containing considerable organic matter. The subsoil of brownish-gray massive stratified loams and sandy loams continues to a depth of 14 inches, where it rests on loose water-worn cobbles and gravel. In some of the grassy parks the surface soil and subsoil layers are thicker than in typical areas, but such parks, as a rule, are small. Free lime is not commonly present.

Alluvial soils, undifferentiated, are best suited for pasture land and winter shelter for livestock. The dense brush and tree cover provides excellent protection for livestock in winter, and the open parklike areas make good feeding grounds and lambing sites for sheep. As a rule, the soils are too shallow for cropland.

MISCELLANEOUS LAND TYPES

Miscellaneous land types include rough broken land (Crago soil material) and riverwash, both of which have low agricultural value and are not suited for cultivation. These land types occupy 11.8 percent of the area.

Rough broken land (Crago soil material).—Steeply sloping gravelly escarpments below areas of the Crago soils are mapped as rough broken land (Crago soil material). It is nontillable land and generally supports a sparse grass cover. It consists of broken edges of the high gravelly terraces and gravelly colluvium that have rolled or washed down from the terraces. The gravelly material rests on shale bedrock from a few inches to several feet below the surface, although shale outcrops are common on most slopes. It is suitable only for the small amount of grazing it will afford.

Riverwash.—Riverwash includes the unmodified incoherent gravel and sand forming bars or low tracts along the Musselshell River that are periodically inundated by high water. The material is subject to shifting and change with each overflow in most places, and it supports little or no vegetation. It has no value except as a source of gravel and sand for local building or road-surfacing material.

ESTIMATED YIELDS

In table 4 the soils of the Upper Musselshell Valley area are listed alphabetically and estimated average acre yields of the principal crops are given for each soil under the prevailing farming practices.

Yields of crops and the carrying capacity of range lands are necessarily estimated because of a lack of specific yield data by soil types and management practices. The relatively short period during which irrigation has been practiced on some of the soils accounts in part for lack of yield data. In the column headed "Remarks," statements are made concerning characteristics of the soils and their capabilities for use. Yields are estimated for the prevailing practices of management, but it should be realized that the estimates may not apply directly to each specific tract of land for any particular year, as the soil areas shown on the map may vary somewhat, management practices may differ slightly, and climatic conditions fluctuate from year to year. The variations in management practices in irrigation farming from farm to farm, especially, may affect the yields obtained, because differences in the quantity of water applied, the time of application, the kind of fertilizer used, and the sequence of crops are significant factors that may affect productivity.

TABLE 4.—*Estimated acre yields of the more important crops on the soils of the Upper Musselshell Valley area, Mont.*

Soil[1]	Irrigation farming (under prevailing practices)					Grazing (nonirrigated)	Remarks
	Wheat	Oats	Barley	Alfalfa	Native hay		
	Bushels	*Bushels*	*Bushels*	*Tons*	*Tons*	*Acres per 1,000-pound steer per season of 10 months*	
Alluvial soils, undifferentiated							Shallow surface soil over loose gravel and sand; irregular surface furrowed by high-water channels. Best used as unimproved pasture. Scattered trees and brush provide winter protection for livestock.
Bainville silt loam						40–45	Unsuited for tillage or irrigation; sharp relief, shallow surface soil, and outcrops of rock slabs are features. Used as grazing land of low carrying capacity.
Banks fine sandy loam							Shallow surface soil over loose gravel and sand; irregular surface furrowed by high-water channels. Best used as unimproved pasture. Scattered trees and brush provide winter protection for livestock.
Berthoud clay loam	27–32	27–32	27–32	1.5–2.0	1	25–30	A productive soil under irrigation, as it is friable and well drained. Careful management includes the incorporation of organic matter. Locally affected by salt.
Berthoud loam	27–32	27–32	27–32	1.5–2.0	1	25–30	A productive soil under irrigation, as it is friable and well drained. Careful management includes the incorporation of organic matter.
Berthoud silt loam	27–32	27–32	27–32	1.5–2.0	1	25–30	Generally satisfactory for irrigation farming, as tilth, drainage, and productivity are commonly good. Local areas affected by seepage and salt.
Cherry loam	30–35	30–35	30–35	2	1	20	One of the better soils of the area; friable and productive and generally free of soluble salts; a few areas are affected by seepage.
Cherry-Moline clay loams						25–30	Largely unsuited for cultivation. Commonly affected by excessive soluble salts and inadequate drainage. Best used for dry-land pasture.
Cherry silt loam	30–35	30–35	30–35	2	1	20	One of the better soils of the area; generally free of soluble salts; friable and productive.
Crago gravelly loam				.5–1	.5	30	Poorly suited to cereals or alfalfa. A friable, shallow soil above thick layers of gravel. Drainage is excessive, and irrigation costs are relatively high.
Crago gravelly loam, sloping phase					.5	35	Generally unsuited to tillage.
Crago loam				.5–1	.5	30	Poorly suited to cereals or alfalfa. Drainage is excessive, and irrigation costs are relatively high.
Cushman-Bainville loams						35	Generally unsuited for cereals and poorly suited for alfalfa. Stoniness makes tillage difficult, and topography is poor for irrigation. Considerable seepage and alkali are likely to result from irrigation. This soil complex is best used for dry-land grazing.
Cushman silt loam	30–35	30–35	30–35	1.5–2.5	1	25	This is a friable and generally well-drained soil of limited extent. Some of the lower slopes may become seeped through irrigation.
Harlem silt loam	35–40	40–45	40–45	2–3	1–1.25		Good tilth, relatively high productivity, and generally adequate drainage make this one of the best soils in the area.
Harlem silt loam, poorly drained phase						12–15	A high water table results in poor drainage; generally free of soluble salts; only small areas can be used for cereals. Productive of pasture and native hay.
Havre loam	25–30	25–30	25–30	1.5–2	1		Good tilth, satisfactory drainage, and fair moisture-holding capacity help make this a productive soil under irrigation.

[1] Soils are listed alphabetically.

TABLE 4.—*Estimated acre yields of the more important crops on the soils of the Upper Musselshell Valley area, Mont.*—Continued

Soil	Irrigation farming (under prevailing practices)					Grazing (nonirrigated)	Remarks
	Wheat	Oats	Barley	Alfalfa	Native hay		
	Bushels	*Bushels*	*Bushels*	*Tons*	*Tons*	*Acres per 1,000-pound steer per season of 10 months*	
Havre loam, poorly drained phase						15–20	Poorly drained with areas affected by soluble salts. Productive of pasture and native hay; a few small areas used for cereals.
Havre silt loam	25–30	25–30	25–30	1.5–2	1		Productive with good tilth, good drainage, and fair to good moisture-holding capacity.
Havre silt loam, poorly drained phase.						15–20	Poorly drained, with areas affected by soluble salts. Productive of pasture and native hay; a few small areas used for cereals.
Havre silty clay loam	25–30	25–30	25–30	1.5–2	1		Requires more careful management than Havre loam and Havre silt loam in order to obtain the same yields. Locally affected by soluble salts, and includes some poorly drained swales.
Laurel silty clay loam						15	Too poorly drained for tilled crops. Best use is for pasture or native hay. Vegetation, depending on degree of wetness, varies from western wheatgrass to sedges and cattails.
Laurel silty clay loam, saline phase						35	Unsuited for tillage because of poor drainage, poor tilth, and excessive soluble salts. Use is limited to inferior pasture.
Martinsdale loam	30–35	35–40	35–40	1.5–2.5	1	18–20	One of the better soil types of the area. The soil is friable and of satisfactory depth and drainage.
Martinsdale stony loam				1.5–2.0	1	20	Stoniness limits the use largely to alfalfa and native hay.
McKenzie clay						75	Unsuited to irrigation farming. Tilth and drainage are poor. Concentration of alkali is excessive.
Moline clay loam						25–30	Poorly suited to irrigation; best use is probably for dry-land grazing, as tilth and internal drainage are poor. Alkali concentrations may be injurious.
Musselshell clay loam	28–32	32–37	32–37	1.5–2.5	1	24	A friable soil of adequate depth over thick gravel deposits. No problem of alkali accumulation. This is one of the more desirable soil types.
Musselshell gravelly fine sandy loam	25–30	30–35	30–35	1 –2	1	27	A friable soil of limited depth over thick gravel deposits. No problem of alkali accumulation, but frequent irrigation is required.
Musselshell gravelly loam	25–30	30–35	30–35	1 –2	1	25	Do.
Musselshell gravelly loam, sloping phase.	25–30	30–35	30–35	1 –2	1	25	Do.
Orman clay						40	Commonly unsuited for tillage; poor tilth and internal drainage; soluble salt content moderate to excessive.
Orman silty clay loam				.5– .75		25–30	Marginal for tillage. With time, irrigation, and careful management, tracts relatively free of salt may be made fairly productive.
Pierre clay loam						45	Unsuited for cereal or hay production. Characterized by poor tilth, high content of soluble salts, and low productivity for crop plants.
Riverwash						75	Consists of sand and gravel bars along the major drainage courses. Commonly bare of vegetation, and under water during flood periods.
Rough broken land (Crago soil material).						35–40	Unsuited for tillage, as the soil is very gravelly and the areas occupy steep slopes or escarpments. Use is restricted to dry-land grazing.

NOTE.—Blank spaces indicate that the crop is not commonly grown.

LAND USES AND SOIL MANAGEMENT

The problems of land uses and soil management in the Upper Musselshell Valley area are related chiefly to the uses of the land under irrigation-farming practices. As a large part of the irrigable land is just coming under cultivation, the problems of irrigation, drainage, and requirements of management may seem, on first consideration, purely problematical. This, however, is not true if due consideration is given to the physical and chemical characteristics, the depth, the drainage conditions, the topographic position and slope, and the relations of the soils to the water table and to the underlying geological formations.

All these factors, singly or in combination, are directly or indirectly related to or determine the productivity, the workability, and the adapted uses of the land. For example, a gently sloping, well-drained, deep, friable silty soil, free of injurious salts and well supplied with organic matter and available plant nutrients, would be ideal in all respects for irrigation and tillage operations and for the production of crops. On the other hand, a heavy intractable clay soil containing large quantities of alkali salts would be practically worthless for crops regardless of favorable relief, depth of soil, or supply of plant nutrients. Hence, if observable or determinable factors influencing or limiting the growth of plants, tillage, and irrigation operations are properly evaluated, the productive capacity and the requirements of the land for management can be determined in advance with reasonable accuracy for a given soil.

The soils of the Upper Musselshell Valley area are dominantly friable and medium-textured—silty to moderately sandy; hence they absorb water readily and are easy to cultivate. Some of them, however, have too steep a slope or contain too many stones for satisfactory tillage and irrigation operations; others have a loose gravel substratum near the surface, resulting in a low water-holding ability and excessive underdrainage; still others overlie bedrock or clay substrata that impede internal drainage. Some of them occupying low positions, adjacent to the streams, have a high water table, are poorly drained internally, and in places are wet throughout the year.

The Pierre, Orman, Moline, McKenzie, and Laurel soils are chiefly clayey, have poor tilth, are slowly permeable to moisture, and have very slow or restricted internal drainage. All contain considerable alkali salts, and all except the Pierre occupy positions that may subject them to seepage and runoff water from higher lands and as a result cause them to become increasingly salty. Except in a few areas here and there, they are unsuited for use as cropland.

Excessive subsoil drainage and low water-holding capacity are the chief problems in connection with the use of the Crago and Banks soils and alluvial soils, undifferentiated. In most places these soils have less than 18 inches of coherent material above the open gravel or gravel and sand strata; consequently they have a small capacity for water storage and are droughty. Heavy irrigation will not overcome the droughty condition but will only entail a waste of water and the loss of plant nutrients through leaching. In addition to being droughty, some of the Crago soils occupy slopes too steep for cultivation.

The Musselshell and Martinsdale soils, like the Crago soils, have a gravelly subsoil and substratum, but the soil is sufficiently thick over the loose gravel to give them a fair though still restricted capacity for water storage. These soils are suitable for the production of all crops adapted to the area, although Martinsdale stony loam would be difficult to cultivate because of the large stones on the surface, and Musselshell gravelly loam, sloping phase, is too steep in places for satisfactory tillage operations and irrigation. Extreme care will be necessary in laying out irrigation laterals on these soils in order to prevent erosion of the ditches into the loose gravel and subsequent heavy loss of water. Ditches should be placed near the contour level, and the bottom of the ditches should be sealed if the gravel substratum is reached.

The Bainville soils and Cushman-Bainville loams occupy areas where the shale bedrock lies near the surface and outcrops in places. These soils have a medium texture, are friable, and absorb water readily; however, they occupy rolling to moderately steep areas, and some of the Bainville soil is stony. At the time of the survey (1939) few areas of these soils had been placed under irrigation, and it is questionable whether they should be used at all for farming. Although they may contain a fair supply of plant nutrients and their physical properties are such that they would be suitable for irrigation, much of their area would become seeped and salty because the underlying rock stratum would check internal drainage and force the water to the surface on lower slopes if the land were irrigated.

The Berthoud and Cherry soils occupy gentle valley slopes and sloping terraces in an intermediate position between the high terraces or gravelly benches and uplands and the low terraces or bottom lands. The physical properties of these soils and the slopes on which they occur make them suitable for irrigation and cultivation in nearly all areas. Their position, however, below higher irrigated lands, will result in numerous spots and small areas becoming wet from seepage and subsequently salty. The seepage, however, might be intercepted and the land maintained in a productive condition by properly placed deep drains.

On the low terraces and bottom lands, the Harlem and Havre soils, with the exception of Havre silty clay loam and poorly drained phases of these soils, are suitable in nearly all respects for irrigation farming. Some leveling is necessary in areas having an uneven surface, in order to facilitate the application and even distribution of the water. In some places Havre silty clay loam is subject to seepage; in others the soil remains wet for a good part of the year because of a high water table. Properly placed deep drainage ditches would improve many areas of this soil that are now poorly drained and make them suitable for cultivation.

The poorly drained phases of Harlem silt loam, Havre loam, and Havre silt loam have a high water table and generally occupy positions that are too low for adequate artificial drainage. Some areas made wet only by seepage could be sufficiently improved by drainage to insure a better quality of native hay and pasture grasses. In some areas of these soils the high water table serves as a means of subirrigation, and they produce good yields of native hay and, in places, small grains and alfalfa, without benefit of surface irrigation. All areas that remain wet from seepage over a considerable period of time accumulate fairly large quantities of alkali salts and eventually will have little or no value as crop or hay land.

Yields of the different crops vary rather widely on the same soil, partly because of differences in soil management, but chiefly because of the length of time the soil has been under irrigation. Soils recently placed under irrigation commonly have poor tilth and are more difficult to irrigate. Some leveling is necessary on many of them, and additions of organic matter are needed to bring them into good production. Any practice tending to increase the content of organic matter and nitrogen would be beneficial.

The most common practice at present is a crop rotation containing a legume, generally alfalfa. The deep root system of alfalfa loosens the subsoil, and the decaying roots supply needed organic matter, leaving channels for the penetration of moisture and air. An ideal crop for soil improvement would be one that includes both deep and shallow-rooted plants, such as a mixture of alfalfa and bromegrass. This combination, however, has had little practical trial in Montana.

The addition of barnyard manure and the plowing under of crop residues and green manures would greatly improve the tilth and would increase crop yields.

Fall plowing is the general practice and is considered indispensable, especially in the heavier soils. The land is left rough in order to hold snow on the fields and get the fullest benefit of freezing and thawing, which aids greatly in improving tilth. The land is prepared for spring seeding by thorough disking and harrowing. Small grains are seeded in late April or the first half of May, and the grain commonly matures by the middle of August. The grain is either harvested and threshed by combines in one operation or bound and later threshed.

Commercial fertilizers have not been used in the area, but when intensive farming under irrigation is practiced their use may become necessary in order to supply plant nutrients that are deficient or if present are in an unavailable form. Chemical analysis of a number of soils in the area indicate the presence of sufficient nitrogen for present crop needs in most of the arable soils. The phosphorus content is about average for the soils of other regions of the country that require no supplemental phosphorus for normal growth of plants. The amount of phosphorus present in the soils, however, does not necessarily mean that this material is available for plant use. Applications of available phosphorus on similar soils in other areas in Montana give a marked increase in crop yields, indicating that much of the phosphorus originally present in the soils is in unavailable form.

IRRIGATION AND DRAINAGE

The successful production of small grain, hay, and forage crops in the Upper Musselshell Valley area depends on irrigation to supplement the moisture supplied by the low mean annual precipitation. Approximately 24,900 acres of land is irrigable on the lower benches and broader bottom lands. Of this total, 4,600 acres are in Meagher County and 20,300 acres in Wheatland County. The area actually irrigated is somewhat less, because irrigation facilities for the last 9,200 acres of irrigable land were not provided until 1940. Furthermore, there is a question as to the adequacy of the water supply for irrigation of the entire 24,900 acres.

Irrigation had its beginning in the early eighties along the major streams that had a continuous flow through the irrigation season. The early projects were developed by individuals, were local in extent, and were used in connection with the livestock ranches for supplementary production of feed. Usually the cost of irrigating the low bottom lands consisted only of the cost of constructing the canals and perhaps a small diversion dam at the point of intake. A series of such projects was established throughout the valley and served as the sole means of irrigation prior to 1940.

The most recent project, known as the Upper Musselshell Valley Storage and Irrigation Project, was completed in 1940 and provides irrigation facilities for approximately 1,820 acres of irrigable uplands northwest of Martinsdale and 7,400 acres of irrigable uplands and benches north of the Musselshell River between Twodot and Harlowton. In addition, supplementary waters are supplied for lands previously irrigated in the valley. The project was developed under the direction of the Montana State Water Conservation Board. A local water users' association is responsible for the distribution of the water and the collection of fees for the water used.

Water for this project is stored from the floodwaters of the North and South Forks of the Musselshell River. The upper storage dam is located on the North Fork near Delpine. Water is diverted from the North Fork about 5 miles below Delpine in Meagher County, released in the South Fork 3 miles west of Martinsdale, and recovered by another diversion canal, which taps the South Fork at Martinsdale. This canal carries the water into a secondary reservoir 2 miles southeast of Martinsdale, where it is stored for release through a canal into the Musselshell River and is again recovered 4 miles west of Twodot by the Twodot Canal for irrigating the rolling uplands and benches between Twodot and Harlowton.

The earliest irrigation in the area consisted of diverting water to the bottom lands and low terraces most accessible to the source of water. The acreage under irrigation was limited, and the demand for water was not general; hence, more or less continuous flooding and excessive use of water was an early practice. This practice, however, resulted in many seeped, wet, and poorly drained areas in which the more desirable forage grasses disappeared and were replaced by unpalatable water-tolerant species having a low nutrient value.

The present demand for irrigated acreage, the limited water supply available, and the increased cost of irrigation structures point to the need for better conservation of the land suitable for irrigation and a wiser use of the water.

Applications of water in excess of the storage capacity of a soil involves not only a waste of water but the loss of soluble plant nutrients through excessive leaching of the soil. Furthermore, as demonstrated by early practices, excessive irrigation may result in the loss of the ability of the land to produce palatable forage. Once a soil is wet to carrying capacity, any additional water only serves to bring about a saturated condition or to create a seepage hazard on lower lying areas.

Irrigation laterals should be located near the contour line in order to avoid erosion of the walls and deeper entrenchment of the ditches. This is especially important in soils where the gravel stratum is near the surface. Runs should be short, and streams should be as large as possible, in order to wet the soils rapidly.[8]

Seepage from canals in use several years has resulted in poor drainage in soils occupying adjacent lower areas. It is reasonable to expect that similar conditions will develop adjacent to the Twodot Canal when it is put into use, if the bottom of the canal is not sealed reasonably well. Extensive irrigation of the high benches between Twodot and Harlowton will create conditions favorable for increased seepage on the slopes below the benches and on the adjacent low terraces and bottom lands. If and when this condition develops, deep interception ditches, properly placed, will aid materially in relieving the wet condition and prevent salting of the lower areas.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of weathering and development acting on the parent soil materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point depend on (1) the physical and mineralogical composition of the parent material, (2) the climate under which the soil material has accumulated and has existed since accumulation, (3) the plant and animal life in and on the soil, (4) the relief, or lay of the land, and (5) the length of time the forces of development have acted on the material. Although the general climatic conditions are important to soil development, the internal soil climate depends not only on temperature, rainfall, and humidity, but also on the physical characteristics of the soil or soil material and on the relief, which, in turn, strongly influences drainage, aeration, runoff, erosion, and exposure to sun and wind.

The Upper Musselshell Valley area is in the western semiarid part of the Missouri Plateau section of the Great Plains physiographic province and lies within the zone of the Brown soils of the great soil groups of the United States. The area is comprised of alluvial lands (bottom lands, low terraces, terracelike slopes, outwash fans, and high benches) and rolling upland slopes of the Musselshell River Valley. The relief and climatic environment do not vary sufficiently to produce marked differences in the soils. In the western part of the area, however, the soils are slightly darker, as a whole, than in the eastern part, owing to the gradual rise in elevation from east to west, a slight increase in total precipitation, and a few degrees lower mean annual temperature. The soils have developed chiefly in light-colored highly calcareous parent material under the influence of a vegetation chiefly of short grass. The stand of grasses is a little thicker and the growth a little more luxuriant in the western than in the eastern part of the area, yet the chief differences among the soils in the area are related to local differences in geological material and relief.

The soils are dominantly light-colored, and they are alkaline or calcareous from the surface downward. Soluble salts in varying quantities are present in most of them, but only the heavy clayey soils retain enough of the original salts to hinder or injure the growth of vegetation. The more salty areas are a result of external flooding and seepage, which have tended to concentrate the salts. Free lime has been leached from the surface layers of all the soils that have reached the stage of approximate zonal development. A well-developed layer

[8] BINGHAM, G. H. IRRIGATING FIELD CROPS IN MONTANA. Mont. Agr. Col. Exten. Bul. 169, 20 pp., illus. 1939.

of lime accumulation is present in the subsoil of all the better drained soils that have lain undisturbed long enough to acquire zonal characteristics. The lime is commonly in a finely divided or disseminated form, and the accumulation is greatest in soils developed from parent material high in lime.

The chief differences in the soils of the area are due to the differences in age, character, and mode of deposition of the geological formations. The soils are developed from fine-grained sandstones, medium to heavy-textured shales, old mountain outwash or valley fill material on high benches, colluvium washed from these formations, and comparatively young alluvium on low terraces and bottom lands. The Musselshell and Martinsdale soils on the high benches and the Cushman soils on the smoother uplands are the only mature soils in the area. The others are azonal, intrazonal, or immaturely developed chiefly because of the steep slope, the heavy texture of the parent material, and the short time that some of the soil material has been in place. The inhibiting factors of poor drainage and large quantities of soluble salts in some of the soils account for their lack of development.

The Musselshell soils are fairly typical of the more mature soils in the area. They have developed from fine earth material, containing some gravel, which is underlain by a thick bed of loose gravel from 20 to 36 inches below the surface. In the upper part of the gravel bed the interstices between the gravel pieces are filled with soft or moderately compact white limy material. The gravel consists chiefly of water-rounded limestone fragments commonly not more than 3 inches in diameter. A typical profile of Musselshell gravelly loam is as follows:

1. 0 to 5 inches, grayish-brown noncalcareous friable loam having a soft-crumb structure. In a virgin condition the upper 1-inch layer is gray and mulchlike or has phylliform or thin platy structure.
2. 5 to 9 inches, grayish-brown or light grayish-brown clay loam having a prismatic or soft cloddy structure and containing no free lime.
3. 9 to 12 inches, brownish-gray transitional calcareous material.
4. 12 to 24 inches, gray or light brownish-gray highly calcareous friable clay loam or silt loam having no regular structural development.
5. 24 inches +, loose gravel substratum.

Considerable rounded limestone gravel is on the surface and through the soil, becoming more abundant in the lower subsoil.

The Crago soils are the Lithosols and immaturely developed soils associated with the Musselshell soils. They are developing in the same kind of parent material, except that the gravel substratum is only 10 to 18 inches below the surface, and in places it is even at the surface. Much of this soil occupies the sloping edges of the terraces. The Martinsdale soils occupy high benches in association with the Musselshell soils and differ from the Musselshell chiefly in that their substratum is composed mainly of siliceous and argillitic gravel and cobbles. Their surface and upper subsoil layers are a little browner than the corresponding layers in the Musselshell soils; otherwise their profiles are nearly identical.

The Cushman, Bainville, and Pierre series include all the soils on the uplands developing in situ over bedrock. The parent material of the Cushman and Bainville soils is derived from silty or moderately sandy shales. The former occupies undulating and gently rolling areas and has attained about normal profile development for the region; the latter is on rolling to steep areas and is the Lithosol associate of the Cushman soils. The Pierre soils are developing in heavy parent material weathered from clayey shales. They are immaturely developed, heavy and intractable, slowly permeable, and little leached. Free salts are commonly present in the soils at a slight depth, and as a rule the soils are calcareous from the surface or near the surface downward.

A typical profile of Cushman silt loam is as follows:

1. 0 to 5 inches, grayish-brown friable silt loam having a soft-crumb structure and containing no free lime.
2. 5 to 14 inches, light grayish-brown friable silt loam that is calcareous in the upper part and contains an abundance of lime in the lower part. The material has no definite structure.
3. 14 to 30 inches, brownish-gray or yellowish-gray massive friable highly calcareous very fine sandy loam or silt loam having no definite structure.
4. 30 inches +, disintegrated and partly weathered calcareous sandy shale.

The soils on colluvial-alluvial valley slopes, sloping terraces, and outwash fans are intrazonal or immaturely developed, depending on position, character of the parent material, drainage conditions, and the length of time they have remained undisturbed. The Orman and Moline soils occupy positions on sloping terraces and colluvial slopes, where much of the parent material is washed from heavy-textured shale material in the uplands. The Orman soil is immaturely developed because of the heavy texture, compact or dense structure, and high content of salts in the parent materials. Moisture penetrates at a very slow rate, and little or no internal drainage takes place for the removal of excess soluble salts. The soil is commonly limy at or near the surface, and there is no visible lime accumulation in the subsoil except in places where the entire soil mass is more friable than is typical. The Moline soils consist chiefly of complex areas of Solonchak and Solonetz soils in all stages of development. They are characterized by microrelief that includes puff spots, or mounds of highly deflocculated and decidedly salty soil, and slightly depressed slick spots, which are bare of vegetation and from which the surface soil has been removed by the wind, exposing the round-top columns of the Solonetz layer.

The Cherry and Berthoud soils comprise the friable soils on the colluvial-alluvial slopes and fans. They are developed in light-colored calcareous silty parent material and differ chiefly in the color of their surface soils. The Cherry soils occur in the western, higher part of the area, where the rainfall is slightly higher and the soils a little darker in general than in the eastern lower part of the area, where the Berthoud soils occur. The Cherry soils have moderately dark grayish-brown commonly noncalcareous surface layers and grayish-brown and brownish-gray or gray upper and lower subsoil layers respectively. The Berthoud soils have grayish-brown commonly calcareous surface layers and gray or light grayish-brown highly calcareous subsoil layers.

The soils developing in recent alluvium on the low terraces and bottom lands are included in the Harlem, Havre, Banks, and Laurel series and a miscellaneous classification, alluvial soils, undifferentiated. They are strongly alkaline or calcareous throughout and are essentially azonal in all respects. Their recognizable differences are due to the character and color of their parent material, which determines the differences in color, texture, and structure.

The Harlem and Havre soils are developing from silty or only slightly sandy friable alluvium, and they have moderately sandy lower subsoil layers commonly underlain by loose sandy substrata. They differ only in that the Harlem soils are developing in darker alluvium and have dark grayish-brown surface soils, whereas the Havre are grayish brown in the corresponding layers. The Banks soils occupy areas of light-colored sandy alluvium adjacent to the streams and have gray or brownish-gray semicoherent surface soils and gray incoherent subsoil layers. The Harlem and Havre soils commonly have good surface drainage; but internal drainage, owing to an intermittently high water table, is restricted. Areas of these soils in which the water table is near enough to the surface to keep them wet most of the year are mapped separately as poorly drained phases. The poorly drained areas and seep spots in the better drained types of these soils contain varying amounts of soluble salts, which in many places are sufficiently concentrated to injure most plants.

The Laurel soils occupy imperfectly to poorly drained areas of heavy alluvium commonly containing soluble salts. The more salty areas of these soils are classed as a saline phase. They have grayish-brown surface soils stained or streaked with rust mottlings, and gray massive clayey subsoil layers mottled with rust brown. The vegetative cover on these soils consists chiefly of western wheatgrass and desert saltgrass.

McKenzie clay, occupying playa or shallow undrained basin areas on the uplands, has a grayish-brown massive clay surface soil and gray compact massive subsoil. The soil is alkaline or calcareous from the surface downward and contains moderate to fairly large quantities of soluble salts.

The miscellaneous classification rough broken land (Crago soil material) includes rock escarpments or steep slopes below the high benches where the gravelly terrace material has rolled down and thinly mantled the slopes.

Table 5 gives the chemical analyses of samples of certain soils from the Upper Musselshell Valley area.

SUMMARY

The Upper Musselshell Valley area is in the western semiarid part of the Great Plains physiographic province in the central part of Montana. About 1 to 3 miles wide and about 52 miles long, it comprises an area of 94 square miles. The Musselshell River traverses the area in a general southeasterly direction for its entire length.

The climate is continental and is characterized by low annual precipitation, dry atmosphere, moderately warm to hot summers, cold winters, and a large proportion of sunny days. Prevailing winds are westerly and are strongest in late winter and early spring. The

TABLE 5.—*Chemical analyses of samples of soils from the Upper Musselshell Valley area, Mont.*

Soil type and sample No.	Depth	Location	Nitrogen[1]	Phosphorus[2]	Carbonates	pH[3]
	Inches		*Percent*	*Percent*	*Percent*	
Musselshell clay loam: 2314	0 - 5	NE¼NW¼ sec. 15, T. 8 N., R. 14 E.	0.21	0.06	0.82	7.2
	5 -15		.11	.06	12.65	7.7
	15 -24		-------	.05	-------	7.8
Musselshell gravelly loam: 2317	0 - 8	SE¼SW¼ sec. 34, T. 9 N., R. 11 E.	.15	.03	1.97	7.7
	8 -16		.11	.06	24.07	8.2
	16 -24		-------	.06	-------	8.0
	24+		-------	.04	-------	8.1
Harlem silt loam: 2318	0 - 8	Sec. 11, T. 8 N., R. 11 E.	.20	.09	.90	6.7
	8 -21		.13	.10	8.85	7.7
	21+		-------	.10	-------	7.4
Martinsdale stony loam: 2319	0 - 4	Sec. 14, T. 8 N., R. 11 E.	.20	.11	1.14	7.2
	4 -10		.10	.07	7.98	6.8
	10 -20		-------	.09	-------	7.8
	20+		-------	.08	-------	8.2
Musselshell gravelly fine sandy loam: 2320	0 - 6	NE¼ sec. 12, T. 8 N., R. 14 E.	.22	.05	10.27	7.8
	6 -24		.06	.03	24.75	8.3
Havre loam: 2321	0 - 5½	NE¼NE¼ sec. 20, T. 8 N., R. 14 E.	.19	.10	2.10	7.5
	5½-33		.06	.08	9.23	8.5
Banks fine sandy loam: 2322	0 - 3½	NE¼SE¼ sec. 22, T. 8 N., R. 14 E.	.08	.09	8.43	8.1
	3½+		.04	.07	8.93	7.8
Cushman silt loam: 2324	0 - 6	NE¼ sec. 9, T. 8 N., R. 12 E.	.20	.09	9.35	7.7
	6 -12		.08	.09	13.15	8.0
	12 -40		-------	.09	-------	7.9
Cherry silt loam: 2326	0 - 5	SE¼SE¼ sec. 22, T. 8 N., R. 13 E.	.19	.08	9.33	7.6
	5 -32		.08	.08	18.93	8.1
McKenzie clay: 2328	0 -10	Sec. 17, T. 8 N., R. 14 E.	.06	.05	3.07	8.2
	10+		.017	.06	16.95	7.7
Pierre clay loam: 2329	0 -18	NE¼SE¼ sec. 12, T. 8 N., R. 14 E.	.05	.05	7.51	8.3
	18 -38		.03	.05	10.27	8.4
	38+		-------	.03	-------	8.4
Banks fine sandy loam: 2330	0 - 3	Sec. 27, T. 8 N., R. 15 E.	.25	.08	5.75	7.7
	3 -16		.12	.08	10.79	7.7
Havre loam: 2331	0 -12	NE¼SE¼ sec. 26, T. 8 N., R. 15 E.	.15	.08	3.05	7.8
	12 -24		.11	.07	8.33	8.1
	24 -36		-------	.07	-------	7.9
Orman clay: 2333	0 - 8	Sec. 36, T. 7 N., R. 18 E.	.14	.07	2.54	7.5
	8 -36		.09	.06	8.85	8.5
Orman silty clay loam: 2334	0 - 8	NE¼NE¼ sec. 31, T. 7 N., R. 18 E.	.12	.08	3.13	8.1
	8 -23		.11	.08	10.42	7.7
Berthoud silt loam: 2335	0 - 8	Sec. 19, T. 7 N., R. 18 E.	.14	.08	8.60	7.7
	8 -39		.04	.07	10.55	7.9
Berthoud clay loam: 2336	0 - 8	SW¼ sec. 20, T. 7 N., R. 18 E.	.15	.08	5.35	7.6
	8 -36		.05	.06	10.10	8.3

[1] A. O. A. C. Kjeldahl method used.
[2] A. O. A. C. volumetric method used. Data represent total phosphorus.
[3] Glass electrode method used, with a soil-water ratio of 1:2.

cold winter weather in most years is interrupted by warm chinook winds, drying winds that make winter precipitation largely ineffective.

The area includes approximately 25,000 acres of irrigable lands on the bottom lands and low terraces of the Musselshell River and on the adjacent high benches, colluvial valley slopes, and uplands. In addition it includes a slightly larger acreage of nonirrigable lands, consisting chiefly of the higher parts of the smooth uplands above irrigation supply canals and rolling and rough broken areas and steep valley slopes within the irrigated districts.

The natural vegetation of the Upper Musselshell Valley and the surrounding area is chiefly grass, which encourages the raising of livestock, mainly beef cattle and sheep, as the chief agricultural enterprise. The agriculture of the area is based largely on the production of hay, grain, and forage crops under irrigation methods, for use as supplemental and winter feeds for livestock grazed on the adjacent range lands and nearby mountainous areas. Alfalfa and native hay occupy the largest acreage of harvested crops.

Although practiced by stockmen on the alluvial lands adjacent to the Musselshell River since early 1880, irrigation is only at this time (1940) being developed to its fullest possibilities. Much of the lands included in the present irrigation projects is still undeveloped.

The soils have developed under the influence of vegetation of short grasses, and, in common with nearly all of the soils in the drier parts of the Great Plains, they are light-colored, are strongly alkaline or calcareous, and have only a moderate supply of organic matter in their surface layers. Soluble salts are present in nearly all of the soils and are sufficiently concentrated in places to injure or prevent the growth of all vegetation except the most salt-tolerant plants.

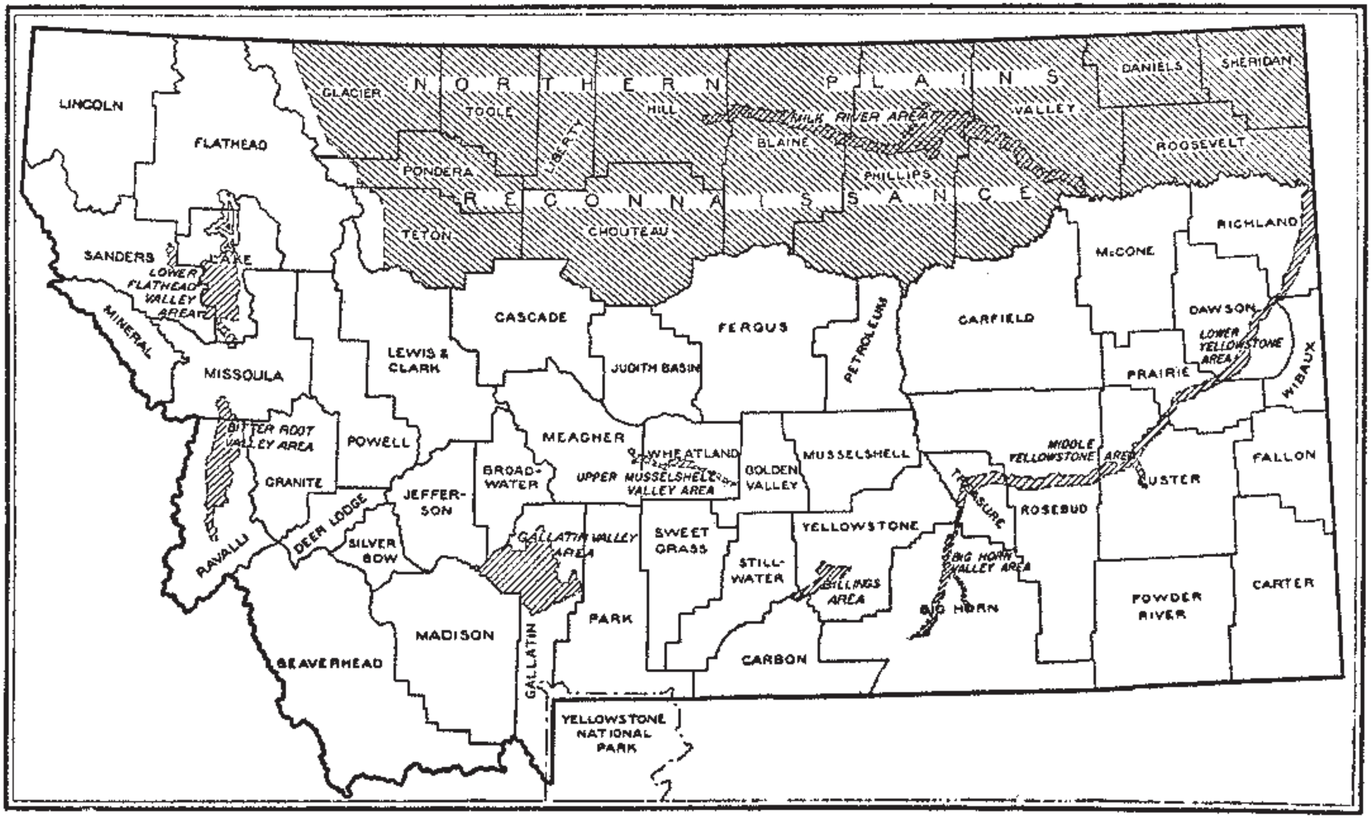
The Cushman, Bainville, and Pierre series include the upland soils developing in material weathered in place from shales, the two former on silty or slightly sandy shales, and the latter on dense clay shales. The Cushman soils occupy smooth areas, are silty and friable, and are well suited to irrigation farming. The Bainville soils are shallow, occupy areas of rolling, irregular relief, and are unsuited for the production of crops. The Pierre soil, on relatively smooth areas, is too dense and compact for successful irrigation; furthermore, it contains salts in injurious quantities in many places.

The Martinsdale, Musselshell, and Crago soils have developed from old mountain outwash material on high benches or terraces underlain by porous gravel substrata. These soils have medium texture in all layers and are suitable for irrigation farming, except the Crago soils, which have the gravel substratum near the surface; and some areas of the Martinsdale that are too stony for suitable tillage operations.

The Cherry and Berthoud series includes the moderately deep friable silty soils developed in colluvial-alluvial material on smooth valley slopes and sloping terraces. Most areas of these soils are suited to the production of crops under irrigation. The Moline and Orman soils occupy slopes similar to those on which the Cherry and Berthoud occur, but they are too heavy and intractable or are too saline in most areas for successful irrigation and production of crops. The McKenzie soils, occupying upland depressions, are similar to the Moline and Orman in many respects and likewise are unsuited as croplands.

The Harlem, Havre, Banks, and Laurel series and alluvial soils, undifferentiated, include the soils developing in the bottom lands. The first two include some of the best irrigation farming soils of the area. The poorly drained phases of these soils and Havre silty clay loam, however, are imperfectly to poorly drained and in places too salty for use other than pasture land or the production of native hay. The Laurel soils are imperfectly to poorly drained, contain considerable soluble salts, and are suited chiefly for pasture land. The Banks soils and alluvial soils, undifferentiated, occupy areas of recently deposited alluvium and are suited chiefly for pasture land.

Areas classed as rough broken land (Crago soil material) occupy steep slopes below the high benches and are used only for the sparse grazing they afford.



Areas surveyed in Montana shown by shading.

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