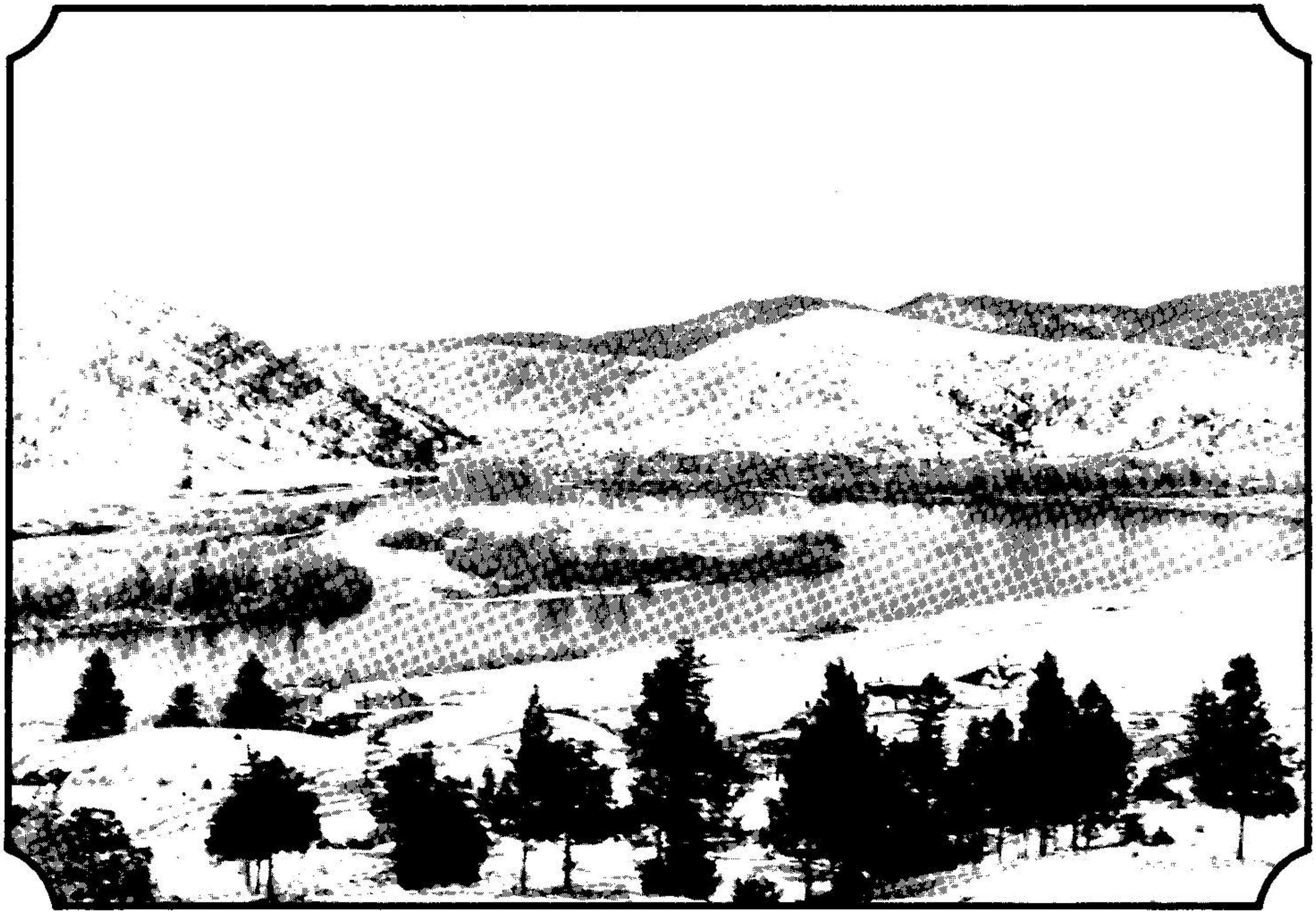
PART TWO

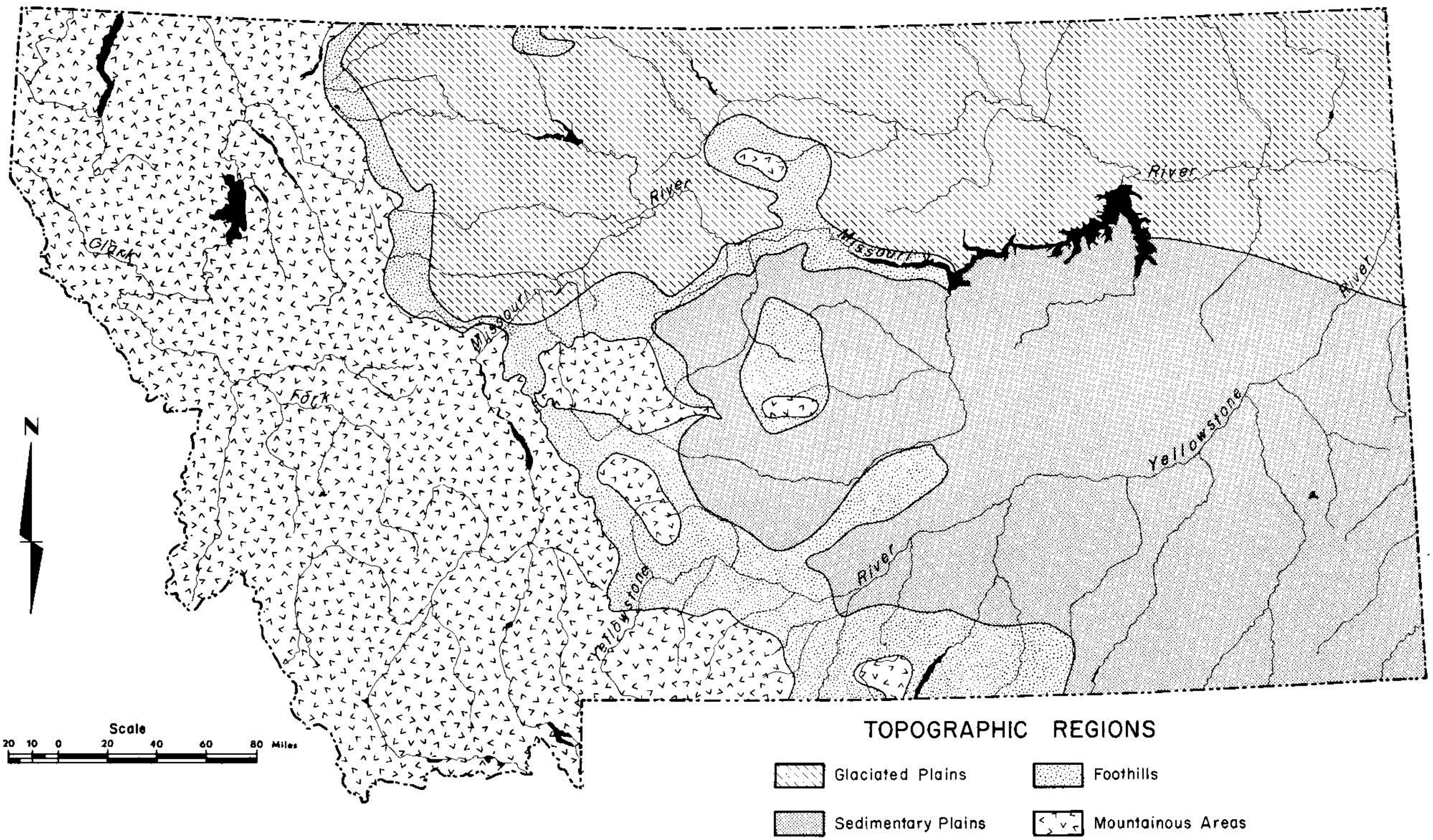
PHYSICAL FEATURES

Montana may be divided into four topographic regions: the glaciated plains of northeastern Montana, the sedimentary plains of southeastern Montana, the foothills of central Montana, and the mountainous regions of western and south-central Montana (see map on page 22). These divisions are not sharply defined, however, because the foothills region interrupts the plains throughout the central portion of the state, and intermittent mountain ranges extend well into both foothills and plains.

The topography of the glaciated plains, which lie generally north of the Missouri River and east of the Rocky Mountains, is subdued due to the erosive action of ancient glaciers that rounded the hills and filled in the valleys. The sedimentary plains, with more relief, extend east of the Continental Divide from the Missouri River south to the Wyoming border. These two areas, commonly known as the Great Plains of Montana, are characterized by flat, treeless expanses and large, gently rolling hills.



THE MISSOURI RIVER



TOPOGRAPHIC REGIONS

The Missouri River flows along the southern edge of the glaciated plains, and the Yellowstone River flows across the sedimentary plains. The divide between the Yellowstone and Missouri Rivers ranges from 500 to 1,500 feet above the low-lying river valleys. Along portions of both rivers, the landscape is marked by numerous cliffs, picturesque towers, and pinnacles which are known locally as the "breaks" and "rimrocks." The Missouri Valley, especially between Fort Benton and Fort Peck Reservoir, is very narrow, while the valley floor of the Yellowstone is much wider and more extensively irrigated.

The foothills region of central Montana, with elevations of 4,000 to 5,000 feet, is characterized by low-lying plateaus and ridges reaching well into the Great Plains area.

The Rocky Mountain region is characterized by a succession of more or less distinct mountain ranges and intervening valleys. Glaciation has been more intense in this western region, especially throughout what is known as the "Rocky Mountain Trench," running from northern British Columbia to near the southern extent of the Mission Mountains south of Flathead Lake. In the southern portion of the region, the intervening valleys or basins are wider than the mountain slopes and deeply filled by debris eroded from the surrounding high country. Glaciation has been less extensive here, with glaciers seldom moving from the mountains onto the main valley floor.

Since these elevations are generally higher than those in the eastern part of the state, one would not expect the lowest point in Montana to be located along the western boundary. Here, however, the Kootenai River drops to an elevation of 1,800 feet above sea level before flowing into Idaho. Granite Peak, the highest point Montana at 12,800 feet, is located in extreme southern Park County near the Wyoming-Montana border.

CLIMATE

The Rocky Mountains both structurally and climatically separate the state into two distinct regions. The mountains serve as a barrier for the warm, moist air from the Pacific and for the eastward passage of heavy snowfall. They also effectively obstruct the westward passage of much of the cold air from eastern Montana, a circumstance resulting in warmer, milder winters west of the divide. While favoring the western portion of the state with a type of climate often referred to as semi-Pacific, or semi-maritime, the mountains create a reverse situation for the eastern region, where the climate is commonly considered continental, with cold winters.

Besides physiography, other factors determining the nature of Montana's climate include altitude, the inland position of the state on the continent, and the movement of air masses and storms from varying locations.

Montana is an extremely diverse state in many respects, including its climate. Eastern Montana's weather, typical for the interior of a large land area located in a temperate zone, is variable. Rapid weather changes are caused by the invasion of large masses of air from the Gulf of Mexico, the south and southwest, the north Pacific Ocean, and the polar regions.

While winters are often moderately to extremely cold, many of them result in little snow at lower elevations and may be described as open winters. Cold waves occur almost every winter in varying numbers and with varying severity, but are often abruptly terminated by the occurrence of the windy, warming, or "chinook" condition along the east slope of the Rockies.

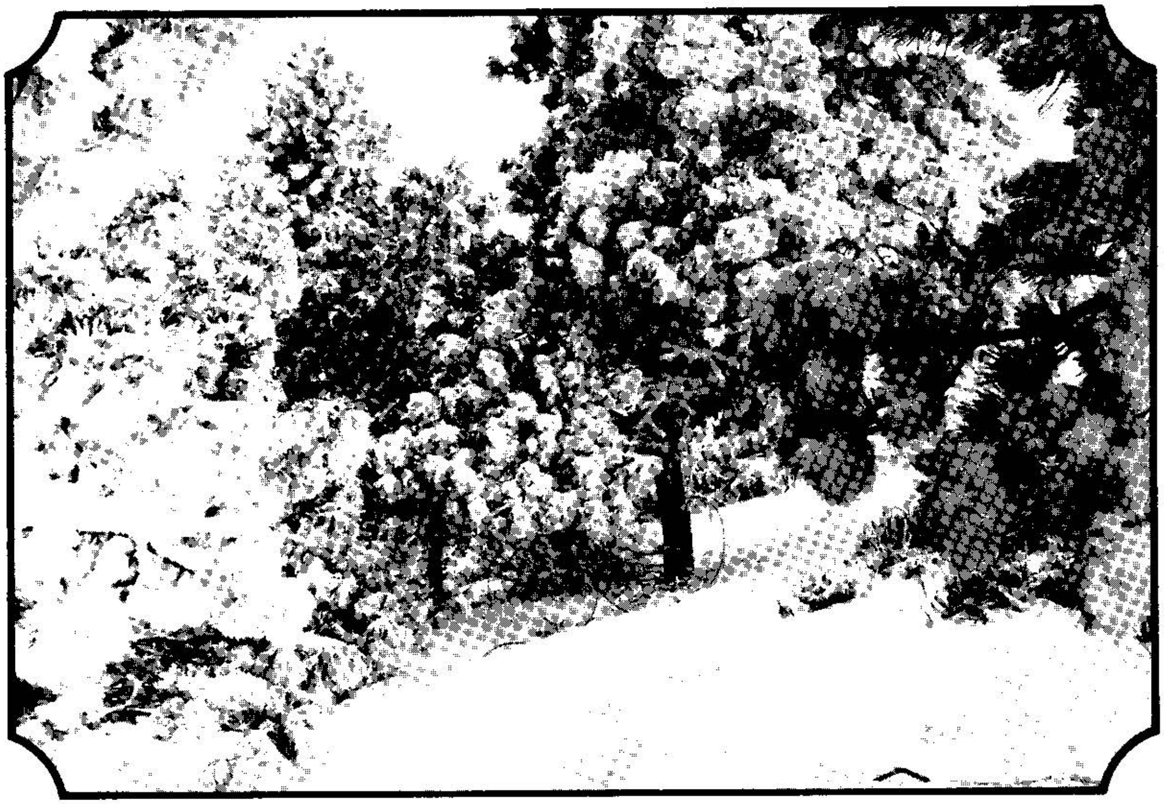
Freezing weather and snowfall in May, and in a few areas as late as June, lengthen some of the winters. The few excessively warm days are usually relieved by cool nights. While the summer season is not as long as in some areas, crop growth is stimulated by the longer daylight hours of northern latitudes, and moderate temperatures often extend well into the autumn season. The fall months are usually dry, with little cold weather until December. Because of moderate temperatures, "Indian Summers" are common during this season.

Montana is in the westerly wind belt throughout the year, with the result that much of its weather comes from the west and northwest. Because of the existence of a semipermanent thermal low-pressure area in the southwestern United States during the summer, however, the state experiences a rapidly changing sequence of weather conditions during that period. The summer weather patterns cause a flow of unstable air into the state which results in several types of severe storms, including numerous thunderstorms. These storms cause a variety of climatal problems, the most troublesome of which are the high-intensity rains and hailstorms which cause crop and property damage.

Intense wind storms can occur locally east of the divide several times a year. Tornadoes also occur at infrequent intervals and are almost entirely confined to the eastern one-third of the state.

Principal air masses originate over the Pacific and the Gulf of Alaska during the winter months and bring precipitation south and eastward across the north Pacific Coast and then into Montana. On occasion during the winter, a cold, dry air mass builds up over central Canada, dominating eastern Montana and sometimes the entire state. Blizzards, signaled by rapidly falling temperatures, strong winds, blowing snow, and poor visibility, occur at times in conjunction with the onset of a cold wave.

DARK CLOUDS OF A THUNDERSTORM



A WET SNOWFALL

PRECIPITATION

Montana is a headwaters state; approximately two-thirds of its water originates within the state rather than as inflow from other areas. Therefore, precipitation is a critical variable in determining Montana's annual water resources.

Table 2 (page 26) shows long-time recorded averages of annual precipitation. Montana's precipitation ranges from just over six inches in the southcentral part of the state to near 120 inches in the northwest (U.S. Dept. of Commerce 1974). However, more than one-half of the state receives only 14 inches or less of precipitation annually (See Average Annual Precipitation Zones Map on page 27).

Heavy precipitation in the high mountain areas occurs primarily as snow between October and June. The heaviest annual precipitation occurs in the region to the east of Kalispell near Glacier National Park. Summit, in Flathead County, has the maximum recorded number of days (116) yearly with precipitation over .01 inch.

June is the wettest month throughout most of Montana's valley locations, while the average driest month is February, east of the divide, and August, west of the divide. Heaviest precipitation occurs between April and September, with winter precipitation making up a larger percentage of annual precipitation at higher elevations.

Snowfall also shows great diversity in distribution, falling heavily over the western mountain region and lightly upon the eastern plains. Average annual snowfall in valley areas amounts to approximately 54 inches, with the extremes ranging from 22 inches at the Raymond Border Station in Sheridan County to over 300 inches at many mountain locations. The sustained flow of rivers and streams in the state during the summer is largely dependent upon a generous, slow-melting snowpack at the highest elevations. The snow that falls at the lower elevations, particularly over the eastern plains region, is generally diminished between storms through melting, evaporation, sublimation, and the action of strong winds.

There are several areas in the state where the annual precipitation rate is low, and four of them can be classified as desert: the Clarks Fork Yellowstone River Basin near the Wyoming border, the Helena Valley, the Whitehall-Twin Bridges Valley, and the lower Red Rock River Drainage.

TABLE 2
RECORDS OF AVERAGE PRECIPITATION FOR SELECTED STATIONS (in inches)

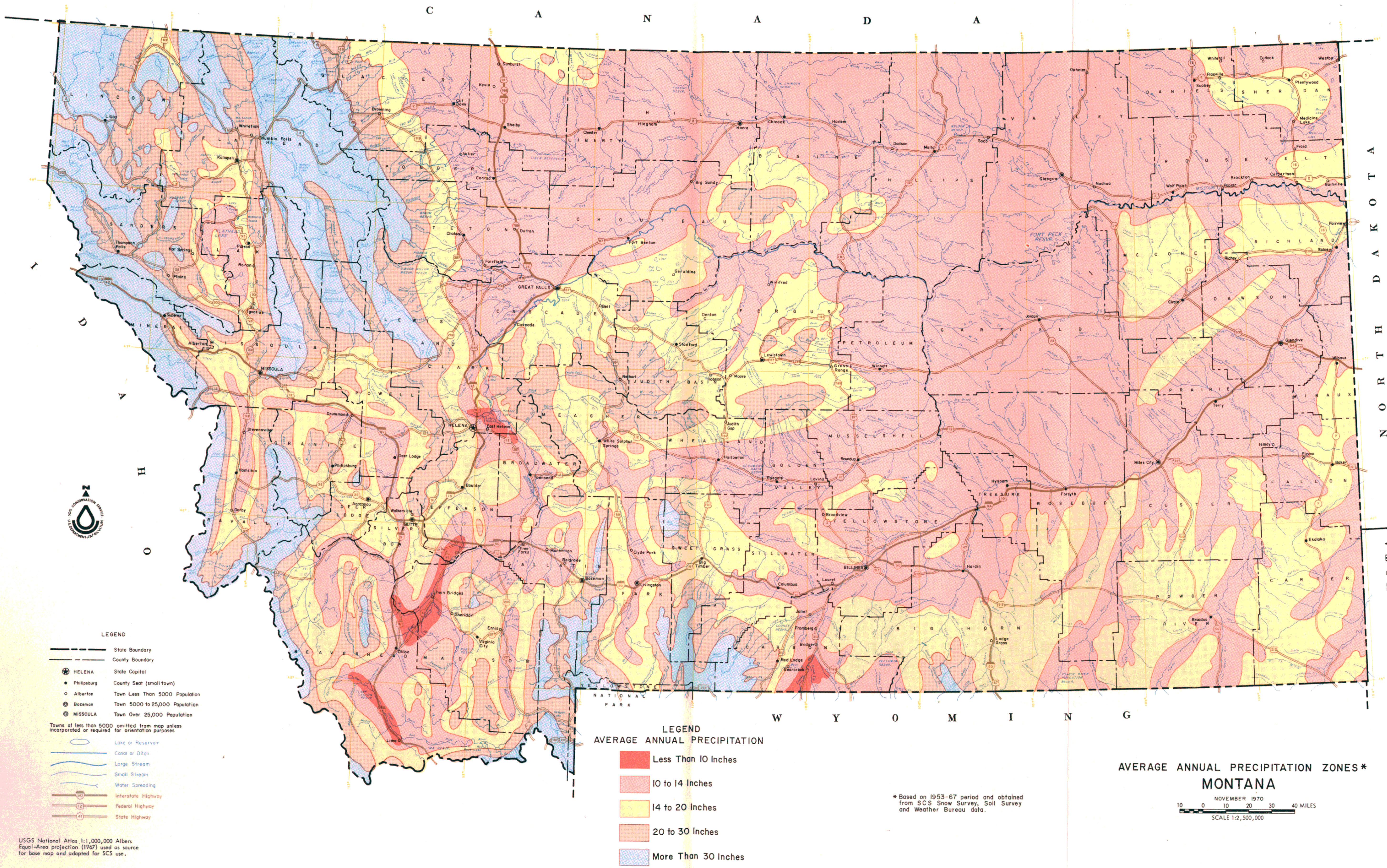
STATION*	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Y.O.R.**
Billings AP	.54	.60	1.05	1.31	1.88	2.55	.90	.90	1.19	1.09	.63	.59	13.23	38
Butte AP	.42	.44	.65	.90	1.74	2.41	1.20	1.03	1.08	.67	.49	.48	11.48	78
Culbertson	.34	.29	.42	.94	1.60	3.36	1.79	1.49	1.08	.76	.45	.32	12.84	65
Glasgow AP	.48	.41	.56	1.01	1.49	2.98	1.33	1.49	.96	.66	.47	.45	12.27	17
Glendive	.39	.39	.62	1.03	1.60	3.17	1.83	1.48	.90	.71	.41	.30	12.73	80
Great Falls AP	.61	.74	.92	.98	2.10	2.90	1.28	1.26	1.20	.73	.75	.60	14.07	81
Hamilton	.86	.88	.67	.74	1.61	1.85	.79	.64	1.04	1.02	1.08	1.04	12.22	62
Helena AP	.47	.43	.70	.83	1.56	2.23	1.03	.89	.95	.66	.57	.53	10.85	93
Kalispell AP	1.37	1.00	.96	1.04	1.67	2.21	1.04	1.09	1.04	1.24	1.43	1.33	15.42	23
Lewistown AP	.57	.61	.85	1.00	2.60	3.87	1.58	1.53	1.44	1.07	.71	.69	16.52	77
Miles City AP	.44	.37	.65	1.06	1.73	2.71	1.34	1.24	.96	.87	.43	.37	12.17	35
Missoula AP	.92	.87	.73	.97	1.87	1.91	.85	.72	1.02	.99	.90	1.08	12.83	37
Norris Madison PH	.76	.76	1.34	2.01	2.55	3.14	1.38	1.13	1.66	1.38	.87	.73	17.71	66
Red Lodge	.82	.79	1.71	2.85	3.07	3.21	1.39	1.16	1.71	1.42	1.20	.69	20.02	75

*AP — Airport, PH — Powerhouse
**Years of Record
SOURCE: U.S. Department of Commerce 1972

U.S. DEPARTMENT OF AGRICULTURE

MONTANA

SOIL CONSERVATION SERVICE



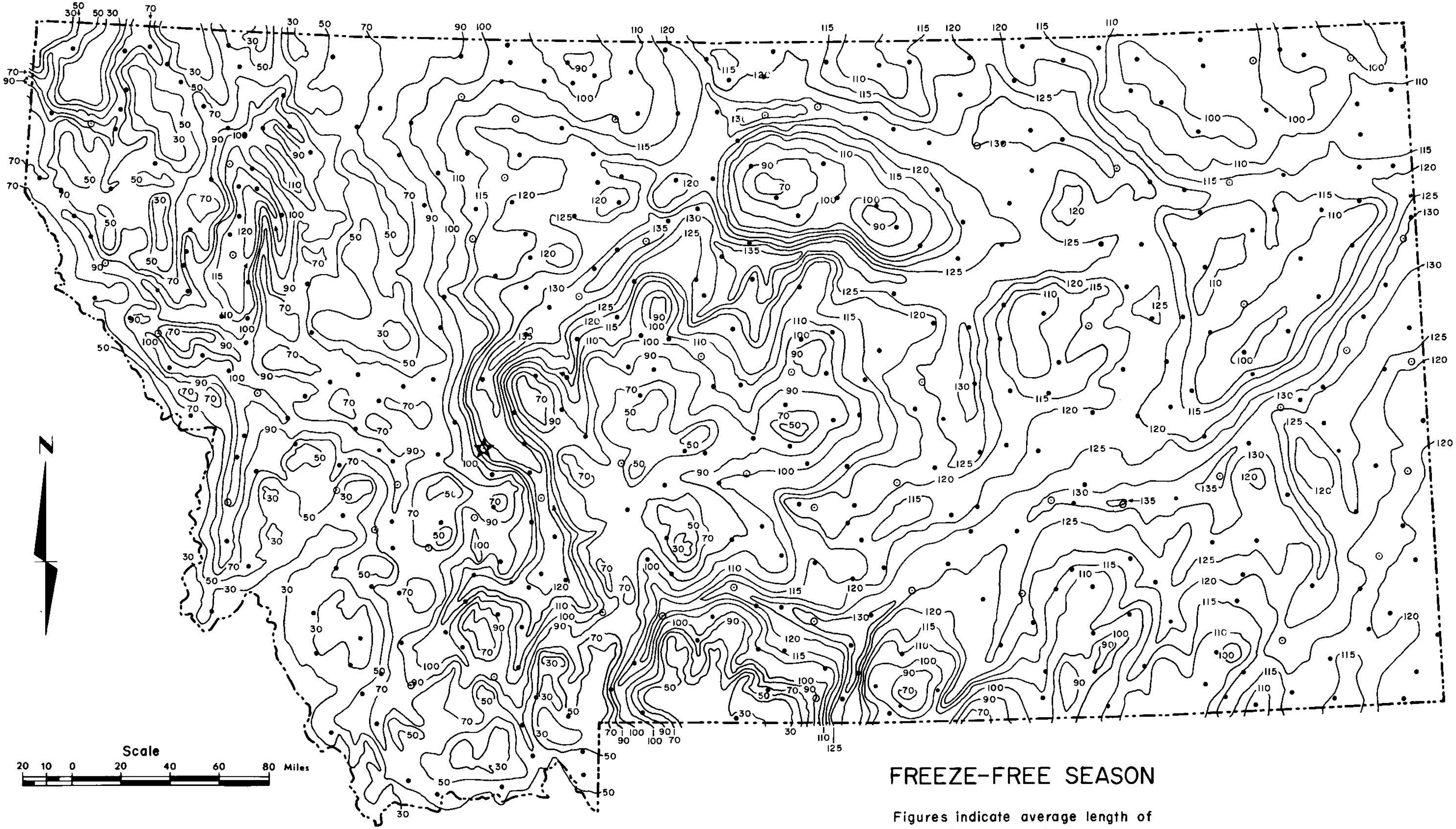
M7-S-21861-N

TABLE 3

RECORDS OF AVERAGE TEMPERATURE FOR SELECTED STATIONS

STATION*	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Y.O.R.**
Billings AP	23.2	25.7	33.7	46.0	56.8	65.1	74.7	71.9	60.4	49.5	35.1	29.2	47.5	38
Butte AP	15.1	19.5	26.3	38.5	47.3	54.3	62.5	60.3	51.2	42.6	27.7	20.1	38.7	73
Culbertson	9.5	13.4	25.5	42.6	55.9	62.6	70.5	68.2	57.2	45.3	27.9	17.5	41.3	53
Glasgow AP	9.8	13.6	26.7	43.4	55.1	62.3	70.7	67.8	56.7	45.4	28.2	17.7	41.5	17
Glendive	15.2	18.7	30.5	46.5	58.4	66.3	74.7	72.0	60.8	48.8	32.5	22.6	45.6	72
Great Falls AP	22.1	23.8	30.7	43.6	53,0	59.9	69.4	66.8	57.4	47.5	34.3	27.3	44,7	80
Hamilton	24.8	29.3	36.9	46.7	54.6	60.3	68.2	67.1	57.7	47.4	34.5	28.5	46.3	57
Helena AP	18.6	23.2	31.4	43.3	52.9	59.5	68.4	66.2	56.0	45.6	31.6	24.2	43.4	93
Kalispell AP	19.8	24.5	31.8	43.7	52.2	58.6	65.7	63.1	54.7	43.9	31.0	25.0	42.8	23
Lewistown AP	20.2	22.5	28.7	41.2	51.0	57.5	66.3	64.2	54.9	45.9	32.6	26.1	42.6	64
Miles City AP	16.5	30.3	30.9	45.7	57.4	65.6	75.3	72.6	61.0	49.0	32.6	23.2	45.8	35
Missoula AP	19.2	25.0	33.7	44.3	52.6	59.5	67.0	64.8	55.4	44.0	30.5	23.5	43.2	37
Norris Madison PH	25.5	28.4	34.5	45.2	54.4	61.4	70.8	69.2	59.9	49.7	36.5	30.3	47.2	65
Red Lodge	23.7	23.4	28.4	39.3	48.9	55.8	64.7	62.5	53.7	44.7	32.0	26.7	41.8	69

*AP — Airport, PH — Powerhouse
**Years of Record
SOURCE: U.S. Department of Commerce 1972

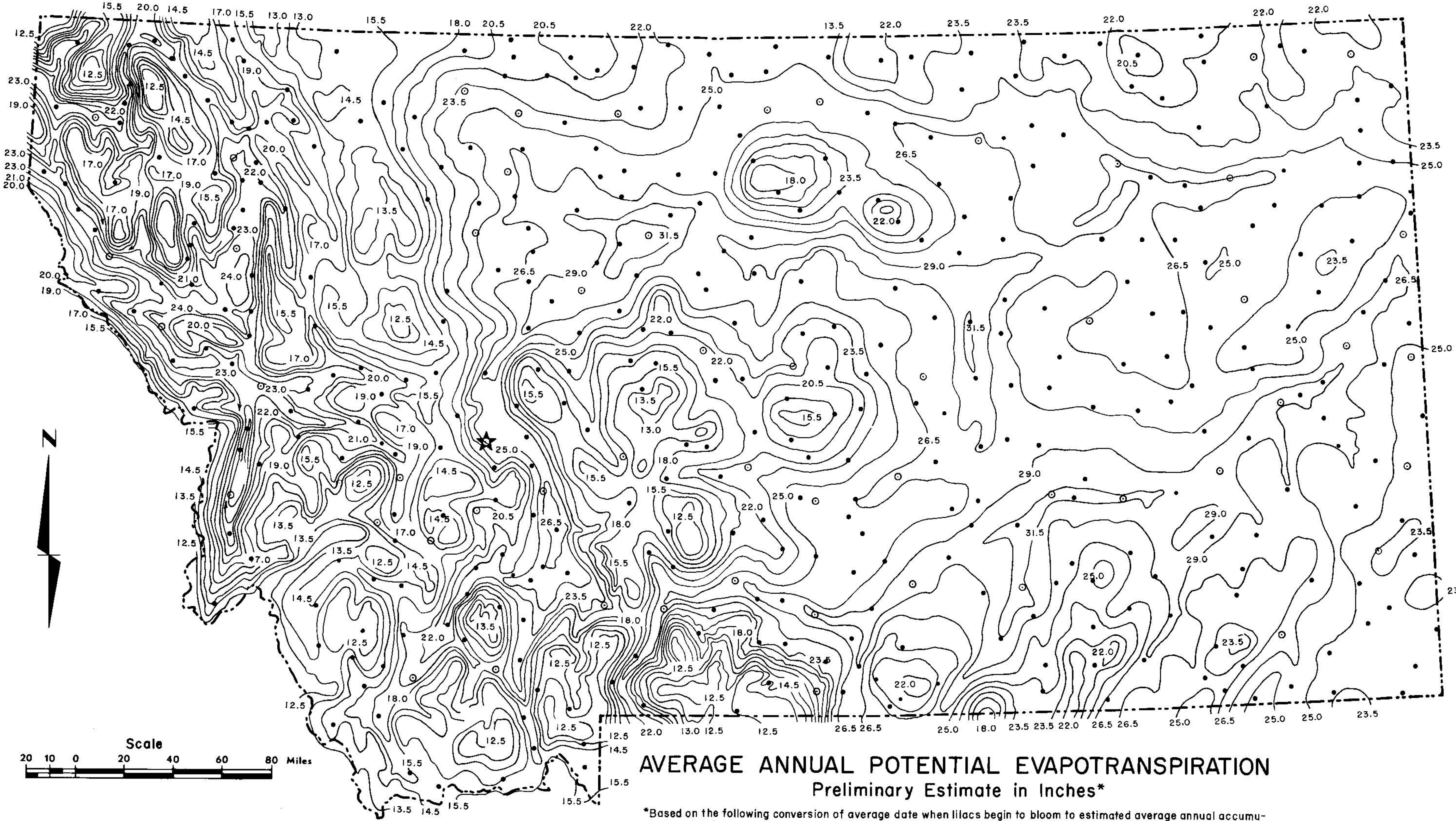


FREEZE-FREE SEASON

Figures indicate average length of freeze-free season in days.

SOURCE:
J. M. Caprio, Professor and Agricultural Climatologist
Agricultural Experiment Station,
Montana State University
Bozeman, Montana

★ Capital
⊙ County Seats
• Towns



AVERAGE ANNUAL POTENTIAL EVAPOTRANSPIRATION

Preliminary Estimate in Inches*

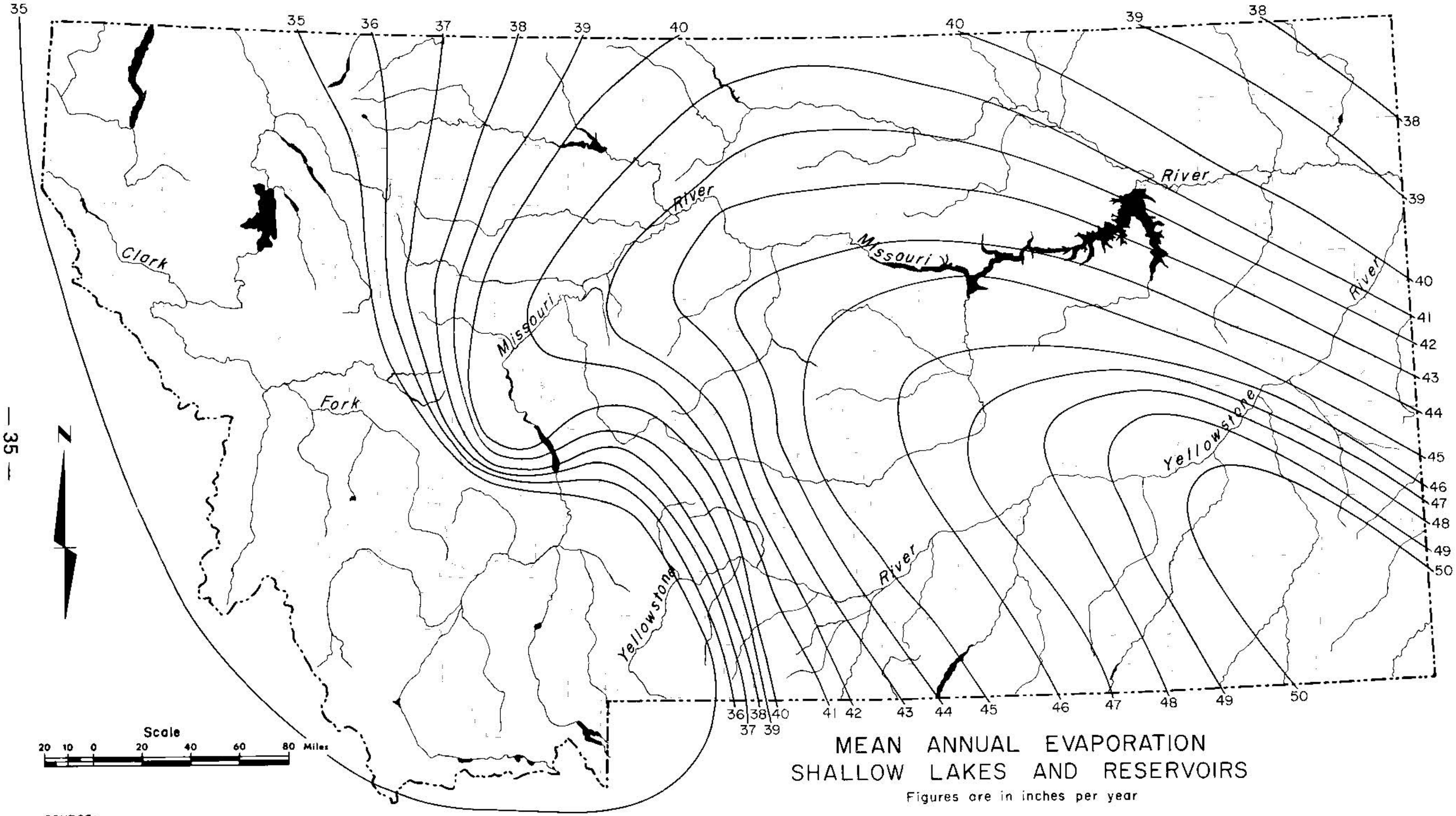
*Based on the following conversion of average date when lilacs begin to bloom to estimated average annual accumulation of Solar Thermal Units x 10^{-5} (See Montana Agricultural Experiment Station Circular 251 and Bulletin 607)

Average Date of Begin Bloom	East of Divide STU x 10^{-5}	West of Divide STU x 10^{-5}
May 12	31.5	25.0
May 15	29.0	24.0
May 18	26.5	23.0
May 21	25.0	22.0
May 24	23.5	21.0
May 27	22.0	20.0
May 30	20.5	19.0
June 4	18.0	17.0
June 9	15.5	15.5
June 14	14.5	14.5
June 19	13.5	13.5
June 24	12.5	12.5

★ Capital
⊙ County Seats
• Towns

SOURCE:

Joseph M. Caprio
Plant & Soil Science Dept.
Montana State University
Bozeman, Montana
May 15, 1973



MEAN ANNUAL EVAPORATION
SHALLOW LAKES AND RESERVOIRS
Figures are in inches per year

SOURCE:
Soil Conservation Service
U. S. Department of Agriculture

HYDROLOGIC SUBDIVISIONS

Three major river systems in North America have tributaries along the Continental Divide in western Montana.

East of the divide, the Missouri River has its headwaters in extreme southwestern Montana and flows northerly and then easterly through the state. It is joined just inside North Dakota by the Yellowstone, which flows from Yellowstone National Park across southeastern Montana, and by the Little Missouri River, which flows across extreme southeastern Montana. The water from these streams eventually reaches the Gulf of Mexico via the Mississippi River.

Across the divide, water from two basins in western Montana ultimately drains into the Pacific Ocean. The Clark Fork of the Columbia flows northwesterly from near Butte, adding to its flow the waters of such streams as the Blackfoot, Bitterroot, and Flathead. The Kootenai River originates in Canada, flows south into Montana, turns abruptly west near Libby, and flows through Idaho back into Canada, where it eventually joins the Columbia River.

The third river system originates in Glacier National Park and flows north through Canada to Hudson Bay. The St. Mary River of the Saskatchewan River Basin is the principal stream originating in this area.

Statistics concerning the drainage areas of the major river basins in Montana are presented in Table 4

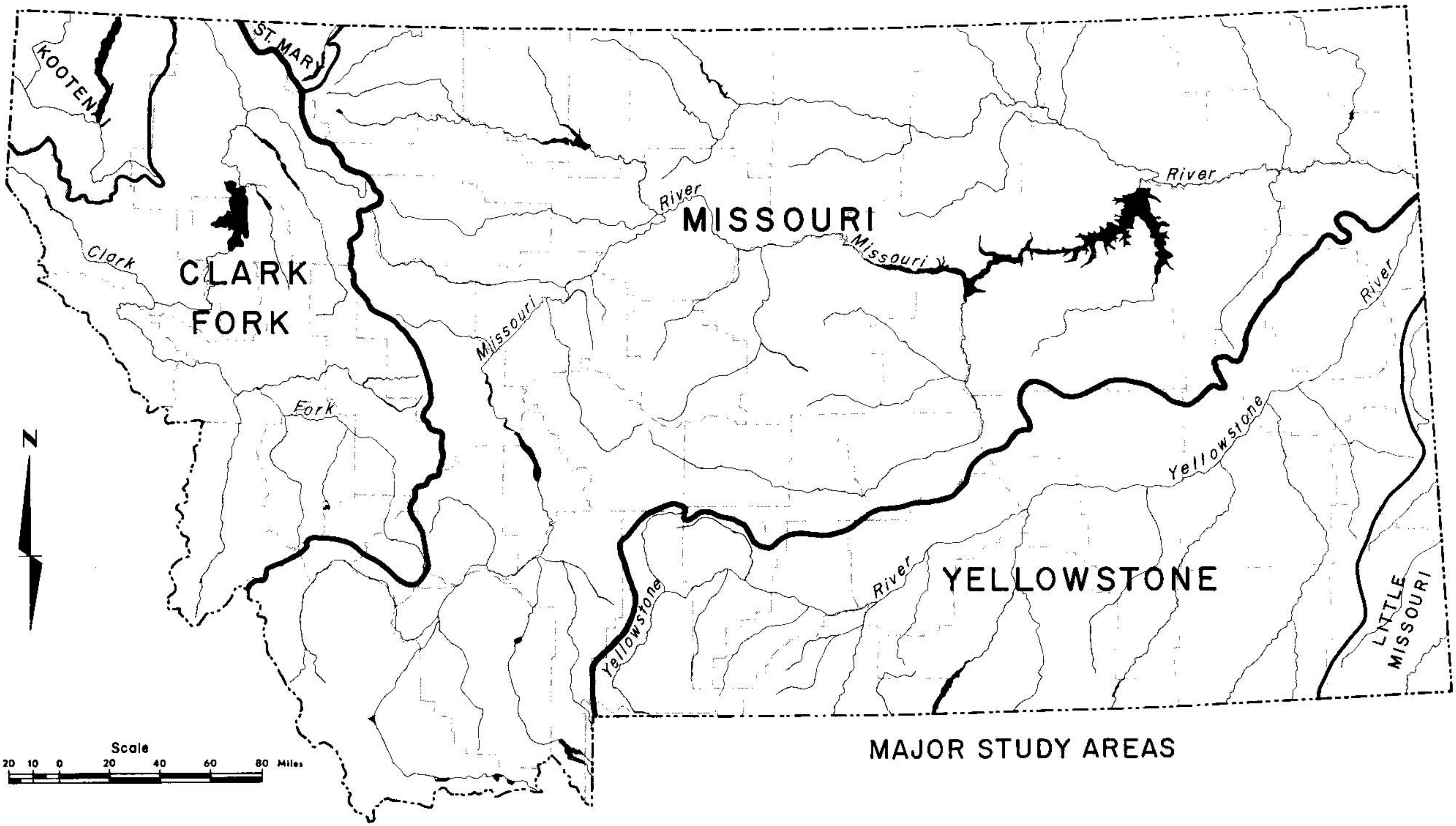
For this report and the State Water Plan, the state has been divided into three major study areas: the Columbia, Missouri, and Yellowstone River Basins (see Major Study Areas Map on the opposite page). The Columbia includes everything west of the Continental Divide (Kootenai and Clark Fork Basins), figures for the Missouri will often include those for the St. Mary Drainage, and Yellowstone Basin data will, where possible, include statistics on the Little Missouri Basin.

TABLE 4

DRAINAGE BASIN AREAS

	TOTAL DRAINAGE AREA		DRAINAGE AREA IN MONTANA		
River Basin*	Area (sq. mi.)	Percentage in Montana	Area (sq. mi.)	Percentage of Montana	Percentage of Montana's Water
Columbia	259,500	10%	25,400	17%	59%
Missouri	523,900	16%	82,000	56%	17%
Yellowstone	71,000	50%	35,600	24%	21%
Little Missouri**	8,500	40%	3,400*	2%	1%
Hudson Bay	Unknown	- - -	600	1%	2%
			147,000	100%	100%

*The Columbia and Missouri River Basins include parts of Canada; the Yellowstone River Basin includes part of Wyoming; the Little Missouri River Basin includes parts of Wyoming and North and South Dakota.
**Includes the Belle Fourche River Basin in southeast Montana.



MAJOR STUDY AREAS

WATER RESOURCES

Montana's water is one of the state's greatest resources. Water plays an essential role in agriculture, in industry, in power production, in the home, and in recreation.

SURFACE WATER

Quantity

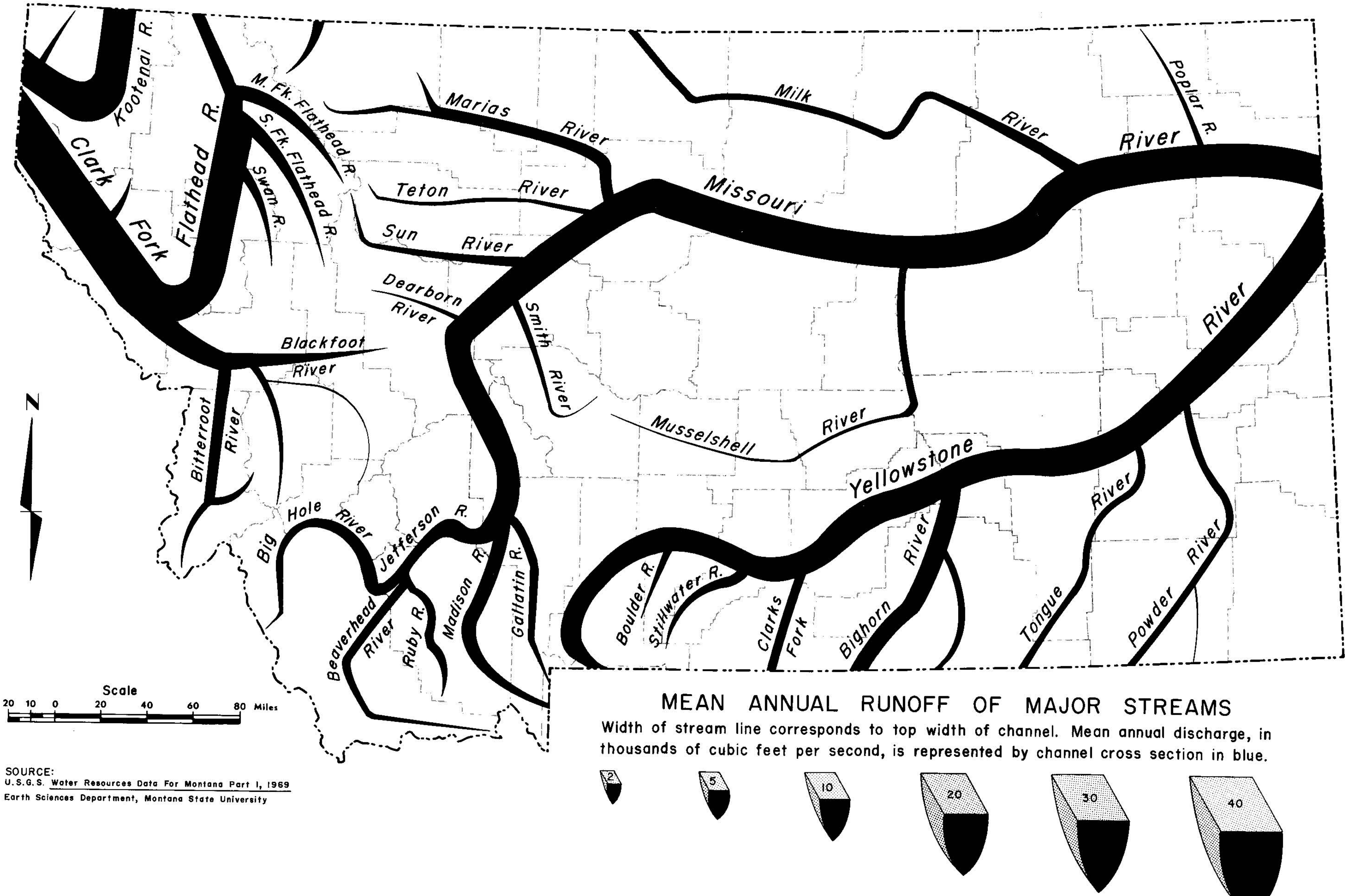
Surface water, defined as the water which rests upon or flows over the earth's surface, is an intrinsic part of the social, economic, and environmental values of Montana. Because most of the surface water originates within Montana as precipitation, the state does not have to rely primarily upon inflow from other areas.

Table 5 (page 41) shows the relationship between river basin inflow and the amount of water originating in the state. Over forty-three million acre-feet of water flows from the state each year, 65 per cent of which originates in Montana.

The map on the opposite page portrays the relative amount of mean annual streamflow in larger streams throughout the state. The maximum discharge, mean annual flow, minimum daily flow, and average monthly flow of most of these streams are presented in the Appendix, "Streamflow Hydrographs."

The seasonal and annual dependability of streamflow is largely dependent on runoff. Mean annual runoff in the state ranges from less than .25 inch to more than 100 inches. Though nearly half the state discharges less than one inch per year, mountainous areas along the Continental Divide discharge a high amount of runoff. Melting of snowpack that accumulates in the high mountains during the winter begins in April and usually reaches a peak in late May or early June. Runoff is essentially completed in July, after which normal summer flows may be modified by diversion or by summer rains.

STREAM-GAGING STATION ON NORTH MEADOW CREEK, NORTHWEST OF ENNIS



MEAN ANNUAL RUNOFF OF MAJOR STREAMS

Width of stream line corresponds to top width of channel. Mean annual discharge, in thousands of cubic feet per second, is represented by channel cross section in blue.

SOURCE:
U.S.G.S. Water Resources Data For Montana Part I, 1969
Earth Sciences Department, Montana State University

TABLE 5

RIVER BASIN INFLOW AND OUTFLOW (in Acre-Feet)

Drainage	Inflow	Originating in the State	Leaving the State	Percentage Originating in State
Clark Fork	703,500	15,216,500	15,920,000	95
Kootenai	7,600,000	2,520,000	10,120,000	25
Missouri	893,600*	6,431,400	7,325,000	88
Hudson Bay	0	989,150	989,150**	100
Yellowstone	6,227,000	3,126,000	9,353,000	33
Little Missouri	55,930	132,500	188,430	70
TOTAL	15,480,030	28,415,550	43,895,580	65

*U.S. Department of the Interior 1964b and 1969.
**U.S. Department of the Interior 1964a.
SOURCE: U.S. Department of the Interior 1972, except as otherwise noted.

Streams originating in the plains area are usually extremely low or not flowing during the winter. Snow and channel ice accumulated during the winter normally melt in late March or early April and may produce the peak flow of the year. Recession from the peak is rapid, and subsequent increases in flow are dependent upon rain of sufficient intensity and duration to cause surface runoff. Streams in the foothills and plains often cease flowing during the hottest part of the year; however, it is possible for these streams to reach their peak flow during the summer following isolated cloudbursts.

Montana's surface water resource — streams, lakes, and reservoirs — is illustrated by the Major Water Features Map on page 43. Information concerning natural lakes, stock ponds, and resevoirs is also presented in Table 6. With few exceptions, these are estimates; exact figures are not known.

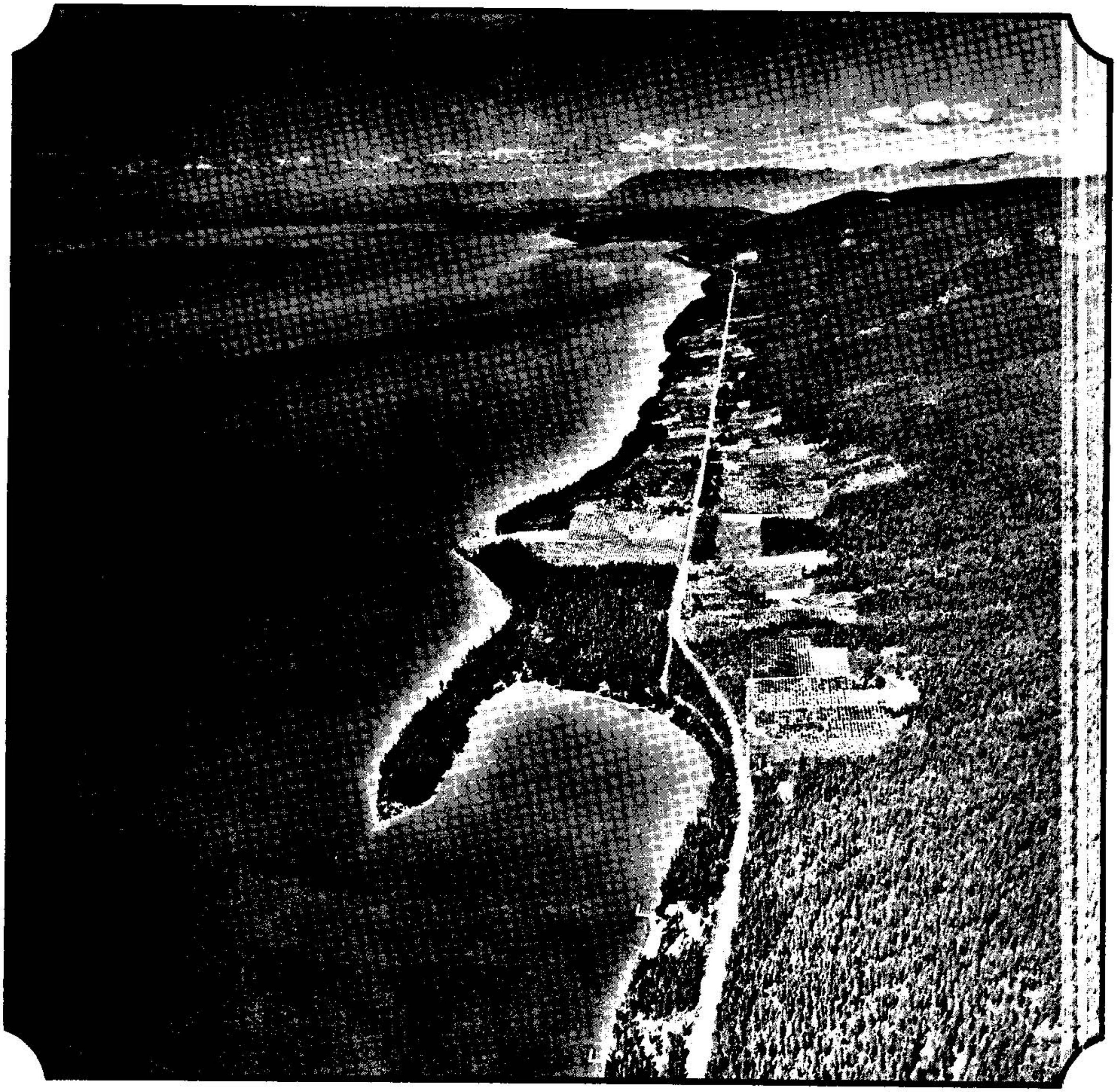
TABLE 6

SURFACE WATER AREA

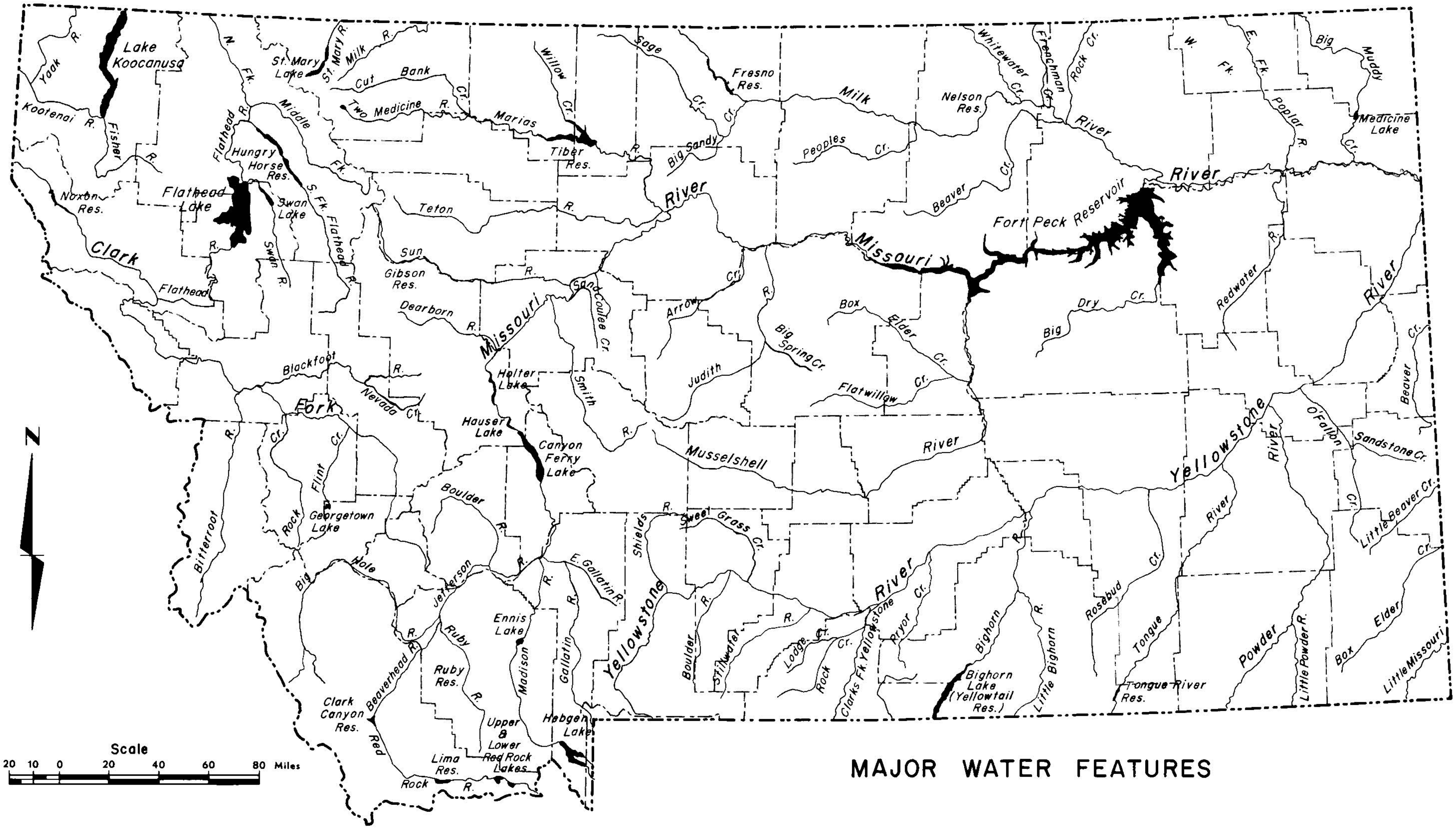
	Number	Surface Area (acres)
Lakes	1,500-1,700	34,000
Stock Ponds	61,000	147,000
Reservoirs of 50 to 5,000 acre-feet	1,000-1,200	87,000
Reservoirs over 5,000 acre-feet	67	632,000
	TOTAL	900,000

There are more than 1,500 natural lakes in Montana, mainly in the mountainous areas of western and south-central Montana. The largest is Flathead Lake (126,000 acres), located in northwestern Montana. While still relatively unchanged, Flathead was increased in storage capacity by the construction of Kerr Dam in 1938. For this reason, Flathead Lake is considered a reservoir in this report.

Reservoirs in Montana vary in size from small stock-water ponds to the immense Fort Peck Reservoir. Information concerning the largest reservoirs is summarized in Table 7 (page 45). As used there and in subsequent tables, "Total Storage" indicates the capacity for which the reservoir was designed. Often the total storage is less than the actual storage (if the reservoir was originally a natural lake) or the maximum capacity of the reservoir. "Active Storage" is generally the amount of water which may be removed through the dam. The combined total storage of these larger reservoirs is over 38.5 million acre-feet.



LOOKING NORTH ON FLATHEAD LAKE



MAJOR WATER FEATURES

SOURCE:

U. S. G. S. Major, Sub-Major & Minor Drainage Basins

Earth Sciences Department, Montana State University

TABLE 7

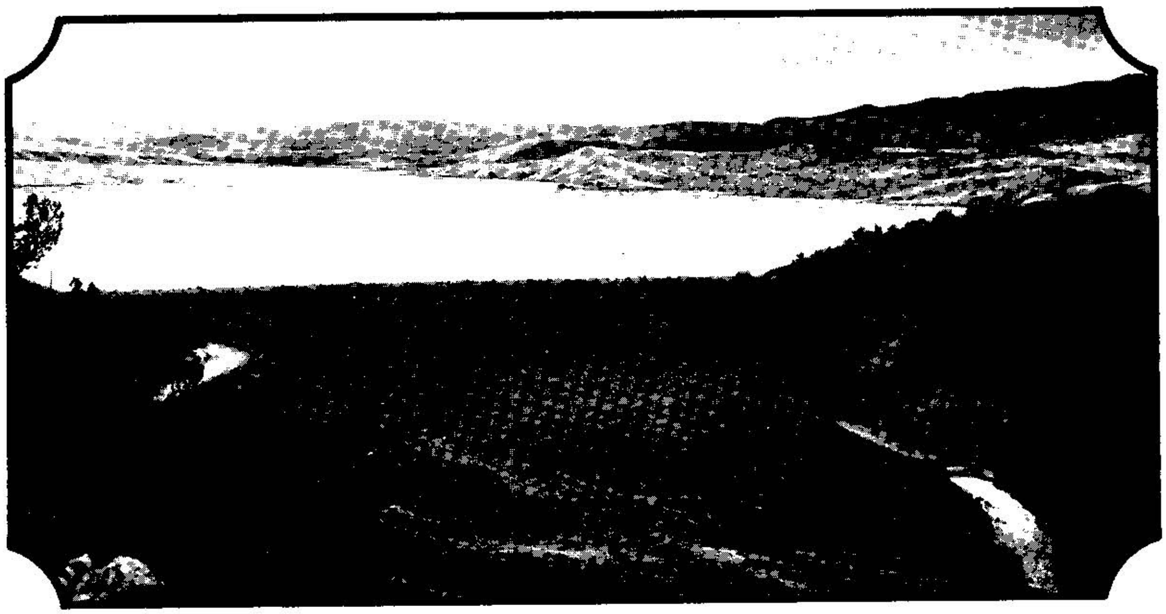
MONTANA RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE

Basin	Number of Reservoirs	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)
Columbia	22	11,978,365	9,811,057	223,293
Missouri	38	25,017,221	18,633,565	384,411
Yellowstone	7	1,537,429	1,517,030	24,130
TOTAL	67	38,533,015	29,961,652	631,834

Only 30 of the larger reservoirs were originally constructed for multi-purpose benefits, including power generation, flood control, municipal and industrial water supply, fish and wildlife, and recreation, as well as irrigation storage. The majority of reservoirs in Montana were constructed as single purpose projects for either irrigation or stock-water storage. Incidental flood control, fish and wildlife, and recreational benefits have increased the value of these projects over the years.

Storage from flood control and power generation reservoirs follows a pattern of release during the late summer, fall, and winter months and storage during the spring and early summer. These releases have variable short-term effects on river flow. The changes in discharge due to power demands are abrupt, and, when power generation is lessened, flows may be low. Irrigation water is supplied at a fairly constant rate from several reservoirs during April through September, while most recreational use takes place during the summer. Recreation on most reservoirs is often adversely affected during late summer because of drawdown of reservoir levels for downstream water demand.

Farm or stock-water ponds provide a significant amount of water storage within the state. Records of the number of farm ponds are incomplete, but a conservative estimate by the Soil Conservation Service places the number at 61,100 ponds with a combined storage of 586,560 acre-feet. Although an extremely large volume of water both flows from and is stored within the state, it is not evenly distributed. These farm or stock-water ponds are especially important in that many are located in the more arid sections of the state and provide late-season water for stock, domestic, and agricultural use.



RUBY RIVER RESERVOIR, NEAR ALDER

PAINTED ROCKS LAKE, WEST FORK BITTERROOT RIVER

Columbia River Basin. The Columbia River Basin includes all land in Montana west of the Continental Divide. It is this portion of the state that could be best described as "water rich." While containing only 17 per cent of the land mass of Montana, this basin is the source of 59 per cent of the state's total surface water outflow.

As in the other two major basins in Montana, seasonal and yearly flows vary considerably. The two largest streams are the Clark Fork and the Kootenai Rivers. The Clark Fork has an average annual flow of 15,920,000 acre-feet near Cabinet, Idaho, at the border, as compared to the Kootenai's average outflow of 10,120,000 acre-feet per year. Major tributaries of the Clark Fork are the Bitterroot, Blackfoot, and Flathead Rivers. The majority of the flow of the Kootenai, 7,600,000 acre-feet, originates in Canada. The Yaak and Fisher Rivers are the Kootenai's major tributaries in Montana.

The Clark Fork subbasin contributes about 14 inches of runoff in an average year. The upper Clark Fork Drainage above Missoula lies in the precipitation shadow of the Bitterroot Range and contributes only about six inches of runoff per year. When compared to the nearly 27 inches of runoff from the area drained by the South Fork of the Flathead River, the wide variation of water distribution even within the same subbasin becomes obvious. The Kootenai drainage contributes only about 11 inches of runoff per year in Montana. A large part of the basin's total flow results from the 18 inches of runoff contributed by that portion of the basin located in Canada.

Table 8 lists 22 large reservoirs with a total storage of almost 12 million acre-feet in the Columbia River Basin in Montana. Lake Koocanusa, with a storage capacity of 5,850,000 acre-feet, provides the largest usable storage of the reservoirs within the basin. Hungry Horse Reservoir and Flathead Lake are the other two major storage sites, with capacities of 3,468,000 and 1,791,000 acre-feet of total storage, respectively.

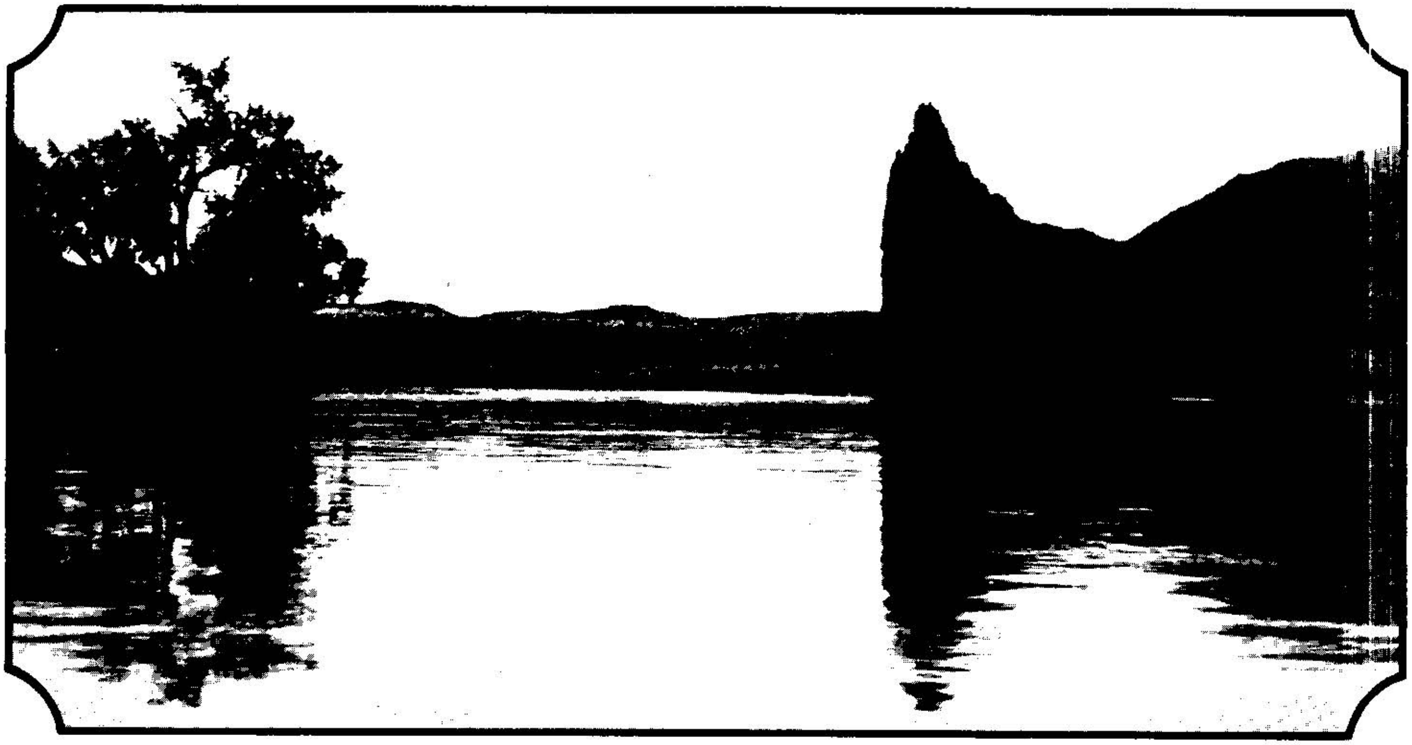
There is little information available on the number or size of smaller farm and stock-water ponds in the basin. However, it is estimated that the Columbia Basin has fewer of such impoundments than either the Missouri or the Yellowstone Basin because fewer are necessary; the Columbia Basin enjoys a more constant water supply throughout the year.

TABLE 8

COLUMBIA BASIN RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purposes*
Ashley Lake	Ashley Creek	20,000	20,000	3,000	I
East Fork	East Fork Rock Creek	16,040	16,040	442	I
Flathead Lake	Flathead River	1,791,000	1,219,000	126,000	P
Georgetown Lake	Flint Creek	31,040	31,040	3,000	M, P, FW
Hubbart	Little Bitterroot River	12,120	12,120	460	I
Hungry Horse	South Fork Flathead River	3,468,000	2,982,000	23,750	FC, I, P
Kicking Horse	Offstream Crow Creek	8,420	8,350	785	I
Lake Como	Rock Creek	36,693	34,920	940	I
Lake Koocanusa	Kootenai River	5,850,000	4,965,000	46,500	FC, P, FW
Little Bitterroot Lake	Little Bitterroot River	26,400	26,400	2,994	I
Lower Crow	Crow Creek	10,350	10,350	340	I
Lower Jocko	Middle Fork Jocko River	7,580	6,380	116	I
Lower Willow Creek	Willow Creek	5,100	4,819	170	I
McDonald	Post Creek	10,600	8,220	200	I
Mission	Mission Creek	7,250	7,250	290	I
Nevada Creek	Nevada Creek	12,640	12,628	375	I
Ninepipe	Offstream Flathead River	14,870	14,870	1,600	I
Noxon Rapids	Clark Fork	495,600	334,600	7,900	P
Pablo	Offstream Flathead River	29,600	27,100	2,040	I
Painted Rocks	West Fork Bitterroot River	32,362	31,700	655	I
Tabor (St. Mary Lake)	Dry Creek	23,300	23,300	286	I
Thompson Falls	Clark Fork	69,400	14,970	1,450	P
Total		11,978,365	9,811,057	223,293	

*Purposes — I — Irrigation, P — Power, M — Municipal, FW — Fish & Wildlife, FC — Flood Control.



CITADEL ROCK, MISSOURI RIVER BELOW VIRGELLE

Missouri River Basin. The Missouri River Basin is by far the largest of the three major basins of the state, containing approximately 56 per cent of the land yet only 17 per cent of the water. Over a forty-year period, the Missouri has discharged an average of 7,325,000 acre-feet of water per year from the state — less than the Yellowstone, Clark Fork of the Columbia, or Kootenai Rivers.

Above Three Forks, the Jefferson, Madison, and Gallatin Rivers form the Missouri. Other tributaries to the Missouri, arising in the mountain and foothill regions or flowing across Montana's plains, include the Dearborn, Smith, Sun, Teton, Marias, Judith, and Musselshell Rivers. The Milk River and its tributaries, adjacent to Glacier Park, flow north into Canada, re-enter Montana in northwestern Hill County, and drain into the Missouri just below Fort Peck Dam.

Aside from the water arising in Yellowstone National Park, the only inflow from out of state into the Missouri River system is from the Milk and Poplar Rivers and their tributaries arising in Canada. Nearly 448,000 acre-feet of water per year enters the Missouri drainage from Canada, accounting for only six per cent of the outflow of the Missouri River at Culbertson.

Average annual runoff in the mountainous one-third of the basin varies from two inches in the foothills to 20 inches in the higher mountain areas. Even so, most of the basin is semiarid. In the eastern two-thirds of the basin, the glaciated and sedimentary plains, an annual runoff as low as 0.5 inch per year is not uncommon.

Fort Peck Reservoir, with a total storage capacity of 19,410,000 acre-feet on the mainstem of the Missouri River, is by far the largest reservoir in the state and is the fifth largest in the United States. Canyon Ferry and Tiber are the next largest reservoirs in the Missouri River Basin, with total storage capacities of 2,051,000 and 1,368,000 acre-feet, respectively. Table 9 lists 38 reservoirs in the basin with storage capacities of 5,000 acre-feet or more. The total storage of these reservoirs is over 25,000,000 acre-feet.

In addition to the larger impoundments, there are several hundred smaller reservoirs in the basin providing irrigation, flood prevention, and stock-water benefits.

The Hudson Bay drainage in Montana consists of the Waterton, Belly, and St. Mary Rivers, arising in Glacier National Park and flowing northward to the Saskatchewan River in Canada. Each year, these three rivers and other small tributaries, draining less than one per cent of Montana's land area, discharge an average of 989,150 acre-feet, or two per cent of the state's water to Canada. Lake Sherburne in Glacier Park provides 66,200 acre-feet of storage on Swiftcurrent Creek, and the St. Mary Canal conveys an average seasonal flow of 142,000 acre-feet to the North Fork of the Milk River in Montana, helping provide for the extensive irrigation between Havre and Glasgow.

TABLE 9

MISSOURI BASIN RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purposes*
Ackley Lake	Offstream Judith River	6,140	5,815	250	I
Bair	North Fork Musselshell River	7,030	7,010	252	I
Bynum	Offstream Teton River	75,000	74,500	4,120	I
Canyon Ferry	Missouri River	2,051,000	2,043,000	35,200	FC,I,FW,P
Clark Canyon	Beaverhead River	328,900	328,900	10,000	FC,I,FW
Deadman's Basin	Offstream Musselshell River	76,900	72,220	2,042	I
Delmoe Lake	Pipestone Creek	6,600	6,600	479	I
Ennis Lake	Madison River	42,060	42,060	3,800	P
Eureka	Teton River	5,500	5,000	400	I
Fort Peck	Missouri River	19,410,000	13,915,000	245,000	M,FC,P,I
Four Horns	Badger Creek	20,000	19,250	897	I
Frenchman	Frenchman Creek	7,010	7,010	806	I
Fresno	Milk River	129,000	127,200	5,757	FW,M,I,FC
Gibson	Sun River	105,000	104,800	1,360	I,FW
Hauser Lake	Missouri River	98,230	51,420	3,800	P
Hebgen Lake	Madison River	384,800	377,500	12,668	P
Holter Lake	Missouri River	240,420	81,920	4,800	P
Kipps Lake	Offstream Willow Creek	5,009	4,500	335	L,I
Lake Francis	Offstream Dupuyer & Birch Creek	117,000	111,900	5,536	I
Lake Helena	Missouri River	10,450	10,450	610	I,M
Lake Sherburne	Swiftcurrent Creek	66,200	66,200	1,730	FW,I
Lima	Red Rock River	84,050	84,050	6,400	I
Lower Two Medicine Lake	Two Medicine Creek	13,500	11,880	806	I
Martinsdale	Offstream So. Fork Musselshell River	23,185	23,105	1,050	I
Middle Creek	Middle or Hyalite Creek	8,030	7,821	223	M,I
Morony	Missouri River	13,260	7,900	300	P
Nelson	Offstream Milk River	85,450	66,800	4,560	FW,I
Nilan	Offstream Smith & Ford Creeks	10,990	10,092	535	I
North Fork Smith River	North Fork Smith River	11,600	11,550	335	I
Petrolia	Flatwillow Creek	9,192	8,822	515	I
Pishkun	Offstream North Fork Sun River	48,450	32,050	1,550	I
Ruby River	Ruby River	38,850	38,500	970	I
Swift	Birch Creek	30,015	29,980	455	I
Tiber	Marias River	1,368,000	762,000	22,180	FW,I,FC,M
Warhorse Lake	Offstream Ford Creek	23,800	23,800	1,560	I
Whitetail	Whitetail Creek	6,200	4,000	830	I
Willow Creek	Offstream Sun River	32,400	32,230	1,450	I,FW
Willow Creek	Willow Creek	18,000	17,730	850	I
Total		25,017,221	18,633,565	384,411	

*Purposes — I — Irrigation, FC — Flood Control, FW — Fish & Wildlife, P — Power, M — Municipal, L — Livestock

Yellowstone River Basin. The Yellowstone River Basin is divided nearly equally between the states of Montana and Wyoming. The Yellowstone arises in Yellowstone National Park and northern Wyoming and flows northeasterly to join the Missouri just inside North Dakota. The basin in Montana contains 24 per cent of the state's land surface and yields 21 per cent of Montana's water. At their point of confluence, the Yellowstone yields 22 per cent more annual flow than the Missouri, though it drains 14 per cent less area.

The Yellowstone River receives over one-half of its total flow from tributaries rising in the mountain ranges upstream from Billings. These tributaries include those in Yellowstone National Park as well as the Shields, Boulder, Stillwater, and Clarks Fork Yellowstone Rivers. The Bighorn, Tongue, and Powder Rivers, originating in the mountains of Wyoming, provide much of the remaining flow.

The Yellowstone Basin is similar in many respects to the Missouri Basin; much of its plains area is classified as semiarid. As a result, the stream runoff follows the same general pattern exhibited in the Missouri Basin: relatively high total runoff from mountain streams, and low total runoff from plains streams.

The discharge of the major tributaries of the Yellowstone is small when compared to the total drainage area. The Powder River, for example, has an average flow of only 600 cubic feet per second (cfs) from a drainage area of 13,194 square miles. Almost no flow has been recorded on numerous occasions, and on February 19, 1943, the stream discharge reached an all-time recorded high of 31,000 cfs.

Seven reservoirs in the Yellowstone River Basin in Montana each have a total storage capacity of 5,000 acre-feet or more. Yellowtail Reservoir, with a total capacity of 1,375,000 acre-feet, is the largest in the basin. The second largest in the Montana portion of the basin is the Tongue River Reservoir, constructed by the state and containing 69,439 acre-feet of water. Together, the seven reservoirs provide over 1.5 million acre-feet of water storage.

In addition to the major projects listed in Table 10, several hundred smaller irrigation projects and probably as many stock-water ponds are scattered throughout the basin.

The Little Missouri River Basin in Montana consists of the Little Missouri River, which passes through the southeastern corner of the state, and Box Elder, Little Beaver, and Beaver Creeks, which are tributaries arising in Carter, Fallon, and Wibaux Counties. These four streams discharge 188,430 acre-feet of water per year to North Dakota, 132,500 acre-feet of which originates in Montana. The basin includes 2 per cent of Montana's land area, but accounts for less than 1 per cent of the water leaving the state.

Quality

Montana's surface waters are generally rated from good to excellent for both chemical and bacterial quality. The principal exceptions are local bacterial contamination below municipal discharges, chemical and toxicity problems below mining and petroleum operations, and suspended sediment from periods of high stream runoff, geologic erosion, and improper land use activities. The subject of surface water quality is further discussed in **Volume Two of The Framework Report.**

TABLE 10

YELLOWSTONE BASIN RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purposes*
Cooney	Red Lodge Creek	24,190	24,190	790	I
Lake Adam	Sweet Grass Creek	11,000	11,000	585	I
Lake Wolvoord	Sweet Grass Creek	14,000	14,000	768	I
Mystic Lake	West Rosebud Creek	20,800	20,800	440	P
Tongue River	Tongue River	69,439	68,040	3,497	I
Lodge Grass	Willow Creek	23,000	23,000	750	I
Yellowtail	Bighorn River	1,375,000	1,356,000	17,300	I,FC,P,FW
Total		1,537,429	1,517,030	24,130	

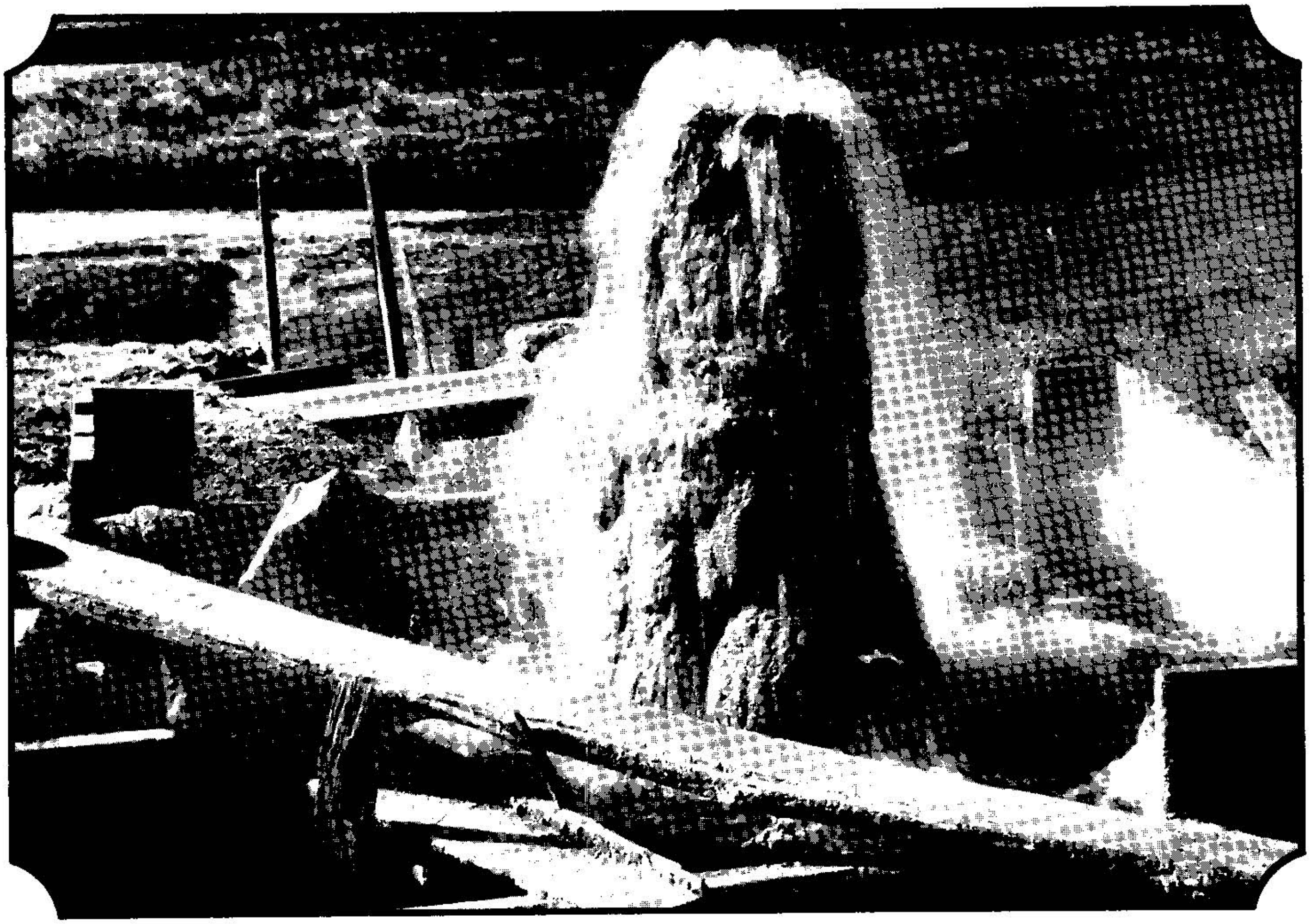
*Purposes — I — Irrigation, P — Power, M — Municipal, FW — Fish & Wildlife, FC & Flood Control.

GROUND WATER

Springs were the most important source of fresh water for early settlers. With the development of modern drilling techniques, the relative importance of springs has diminished, and wells have become the dominant means of utilizing this valuable resource. Depths to ground water are governed by the geologic structure and the amount of erosion and deposition at the drilling site.

The most widespread uses of ground water are for domestic and stock watering purposes. Those persons who rely on surface water live primarily in the cities and larger towns, while the population in rural areas and in most of the smaller towns almost exclusively utilizes ground water for domestic consumption. Of the 695,000 people in the state in 1970, about half used only ground water in their homes.

Because of the significant role of ground water, its availability and purity have been the subject of numerous studies. The Ground-Water Studies Map on page 53 shows the areas of the state in which such studies have been completed.



ARTESIAN WELL

Quantity

An aquifer is a water-bearing geological formation. There are basically two types of ground-water aquifers: the consolidated rock aquifer, in which the gravels, sands, or rock are cemented together, and the water lies within the consolidated material; and the unconsolidated aquifer, such as streambed alluvium, in which the water lies within or flows through loose gravel and sands.

The Extensive Aquifers Map on page 55 shows the principal ground-water aquifers in Montana. Geologic conditions differ widely from one region of the state to the next, and aquifers of primary importance on one side of the divide may be insignificant on the other. Because of this, the following discussion of principal aquifers is organized by region. Alluvium, an important source of ground water throughout the state, is included as a separate category.

East. The consolidated rock aquifers of primary significance exist in the stratified formations underlying most of the area east of the Rockies. There are many water-bearing formations in eastern Montana, but, owing to the complexity of the area's geology, not all the aquifers are present in any one area.

The Great Plains province is predominantly underlain by the Fort Union geologic formation made up of stratified sandstones, shale, and coal beds. The sandstones and coal beds are often important aquifers for small yields of less than 30 gallons per minute (gpm). Beneath the Fort Union Formation lie thousands of feet of older stratified rock, containing as principal aquifers the Hell Creek-Fox Hills, important because of the artesian conditions present, and the much deeper Muddy, Dakota and Kootenai sandstones. Along the western edge of the plains area, the Judith River Formation is a useful source of ground water.

Central. The ground-water situation in the central portion of the state is more complex due to the greatly eroded geologic structures in which many ancient, stratified formations are exposed at the surface. Porous and permeable rocks are thus favorably situated to receive surface water recharge, and some streams actually disappear beneath the surface at locations where such aquifers are exposed.

Aquifers such as the Judith River, Eagle-Virgelle, First Cat Creek-Dakota, and Third Cat Creek-Kootenai are recharged along their outcrops in upturned flanks of the mountains. These water-bearing formations frequently yield water under artesian conditions and are the source of large springs. High water-table conditions are characteristic of these aquifers and also of the gravel benches found adjacent to the larger isolated mountain ranges, particularly the Big Snowys. These gravel benches may, however, be well drained due to their relatively higher topography, but in many localities small to moderate amounts of ground water can be obtained.

The Madison limestone, a much deeper formation, has a potential for producing water in large quantities in both eastern and central Montana. It varies in depth throughout Montana but outcrops and is not as deeply buried in the central region. The water is normally under pressure — so much pressure, in fact, that special precautions must be taken to prevent damage to equipment releasing the water. Because the withdrawal of massive amounts of water from this aquifer has been proposed for use in the shipment of coal by slurry pipeline (Rahn 1975), the future of the Madison limestone is currently controversial. There is concern that continued large withdrawals will result in the drawdown of other wells and springs in this aquifer. Madison water varies in quality, but in some places contains only 450-550 parts per million (ppm) of dissolved solids (Rahn 1975). At other sites, chemical quality may limit its use for irrigation and some industrial production.

West. Western Montana has numerous intermontane valleys containing rock material eroded from the nearby mountains. The mountains themselves, too impervious to hold ground water, allow a large amount of runoff to the valleys. The sediments in many of these valleys are often several thousand feet thick, porous, and permeable, forming vast ground-water reservoirs.

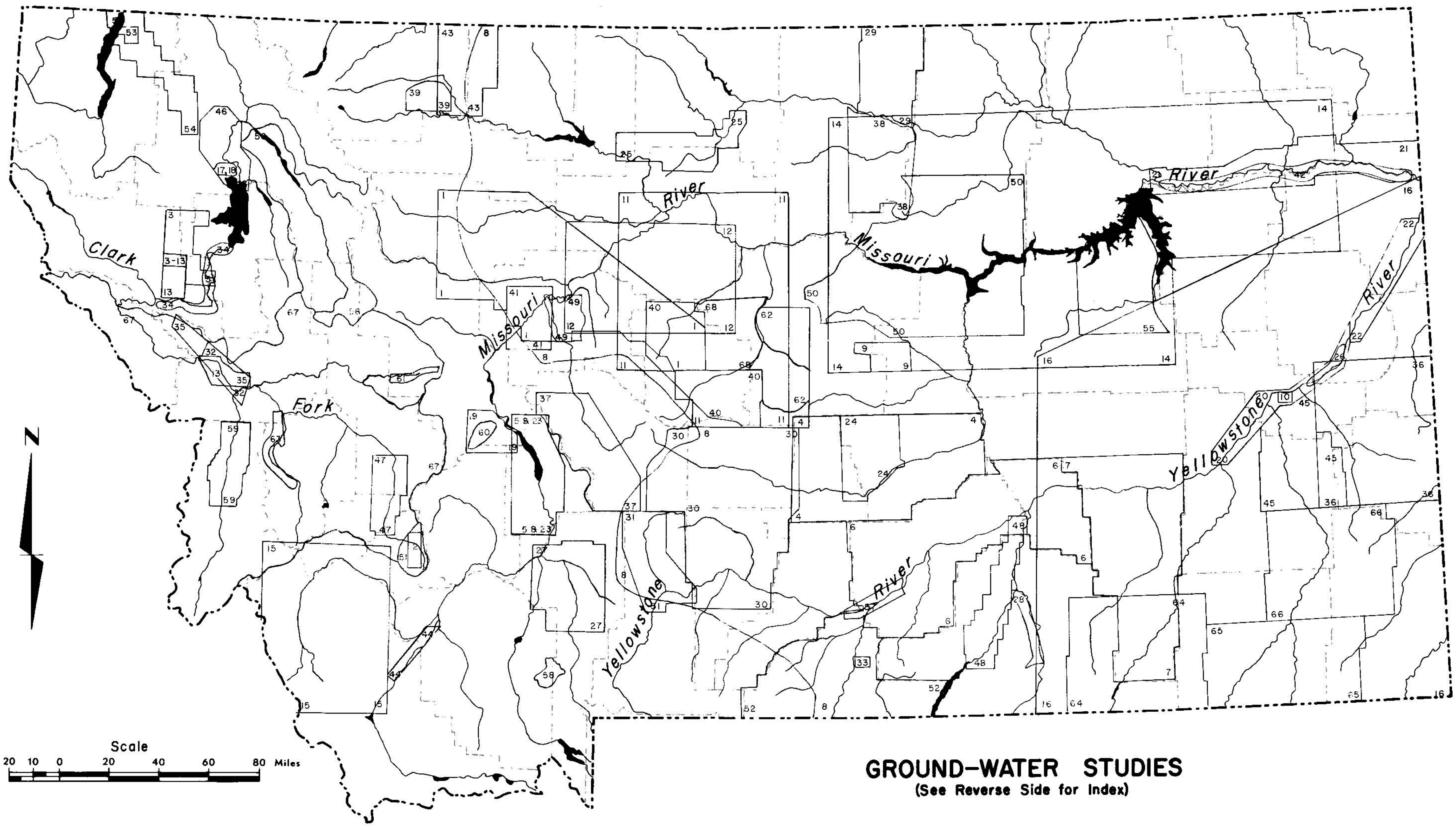
Alluvium. The alluvium deposited by rivers throughout the state is a valuable source of large quantities of ground water. These deposits of gravel, sand, silt and clay are of recent geological age and therefore are not cemented or consolidated. The higher fill deposits, which form rolling hills in the valleys, are less porous and permeable than the alluvium below. The alluvial gravels near the streams are capable of yielding sufficient water for most uses, while the higher deposits produce lesser quantities.

Extensive alluvium deposits are found along the Yellowstone and Milk Rivers east of the Rockies and along many rivers in western Montana. Small deposits of alluvium are found along and beneath almost all ephemeral and perennial streams and generally yield supplies of water adequate for domestic use.

The alluvium in much of the northern half of Montana is complicated by the effects of glaciation. The vast deposits left by glaciers in the valleys and on the plains are less permeable than alluvium and in some areas cause the valley fill to be devoid of producible water. This is especially true in the valleys of the Kootenai and Flathead Rivers in northeastern Montana. Some glacial deposits, however, do yield small supplies of ground water.

Quality

Ground water in western Montana, which generally contains less than 1,000 ppm of total dissolved solids (TDS), is of higher quality than that in eastern Montana (see Ground-Water Quality Map on page 57). The subject of ground-water quality is further discussed in **The Framework Report, Volume Two.**



GROUND-WATER STUDIES
(See Reverse Side for Index)

BIBLIOGRAPHY OF GROUND-WATER INVESTIGATIONS

1. 1909. Fisher, C.A., Geology and water resources of the Great Falls region, Montana: USGS WSP-221.

2. 1914. Meinzer, O.E., The water resources of Butte, Montana: USGS WSP-345-G.

3. 1916. Meinzer, O.E., Artesian water for irrigation in Little Bitterroot Valley, Montana: USGS WSP-400-B.

4. 1924. Ellis, A.J., and Meinzer, O.E., Ground water in Musselshell and Golden Valley Counties, Montana: USGS WSP-518.

5. 1925. Pardee, J.T., Geology and ground-water resources of the Townsend Valley, Montana: USGS WSP-539.

6. 1929. Hall, G.M., and Howard, C.S., Ground water in Yellowstone and Treasure Counties, Montana: USGS WSP-599.

7. 1929. Renick, B.C., Geology and groundwater resources of central and southern Rosebud County, Montana: USGS WSP-600.

8. 1931. Perry, E.S., Ground water in eastern and central Montana: MBMG M-2.

9. 1932. Perry, E.S., Artesian wells as a source of water for the Winnett Irrigation Project, Montana: MBMG MC-1.

10. 1932. Perry, E.S., Shallow wells near Terry, Montana as a source of irrigation water: MBMG MC-3

11. 1932. Perry, E.S., Ground-water resources of Judith Basin, Montana: MBMG M-7.

12. 1932. Perry, E.S., Artesian wells as a source of water for municipal supply at Fort Benton, Montana: MBMG MC-4.

13. 1933. Perry, E.S., Shallow wells as a source of irrigation water in Frenchtown and Camas Prairie Valleys, Montana. MBMG MC-5.

14. 1934. Perry, E.S., Geology and artesian water resources along Missouri and Milk Rivers in northeastern Montana: MBMG M-11.

15. 1934. Perry, E.S., Physiography and groundwater supply in the Big Hole Basin, Montana: MBMG M-12.

16. 1935. Perry, E.S., Geology and ground-water resources of southeastern Montana: MBMG M-14.

17. 1941. Cady, R.C., Effect upon ground-water levels of proposed surface water storage in Flathead Lake, Montana: USGS WSP-849-B.

18. 1951. Hilpert, F.H., An investigation of the groundwater of an area north of the Flathead Lake, Montana. MBMG (unpublished paper).

19. 1951. Lorenz, H.W., and Swenson, F.A., Geology and ground-water resources of the Helena Valley, Montana: USGS Circ. 83.

20. 1951. Torrey, A.E., Swenson, F.A., Ground-water resources of the Lower Yellowstone River Valley between Miles City and Glendive, Montana: USGS Circ. 93.

21. 1955. Swenson, F.A., Geology and ground-water resources of the Missouri River Valley in northeastern Montana: USGS WSP-1263.

22. 1956. Torrey, A.E., and Kohout, F.A., Geology and ground-water resources of the Yellowstone River Valley, between Glendive and Sidney, Montana: USGS WSP-1355.

23. 1956. Lorenz, H.W., and McMurtrey, R.G., Geology and occurrence of groundwater in the Townsend Valley, Montana: USGS WSP-1360-C.

24. 1956. Zimmerman, E.A., Preliminary report on the geology and ground-water resources of parts of Musselshell and Golden Valley Counties, Montana: MBMG IC-15.

25. 1957. Swenson, F.A., Geology and ground-water resources of the Lower Marias Irrigation Project, Montana: USGS WSP-1460-B.

26. 1958. Moulder, E.A., and Kohout, F.A., Ground-water factors affecting drainage in the first diversion, Buffalo Rapids Irrigation Project, Prairie and Dawson Counties, Montana: USGS WSP-1424.

27. 1960. Hackett, O.M.; Visher, F.N.; McMurtrey, R.G.; and Stainhilker, W.L., Geology and ground water resources of the Gallatin Valley, Gallatin County, Montana: USGS WSP-1482.

28. 1960. Moulder, E.A.; Klug, M.F.; Morris, D.A.; and Swenson, F.A., Geology and ground-water resources of the lower Little Bighorn River Valley, Big Horn County, Montana: USGS WSP-1487.

29. 1960. Zimmerman, E.A., Geology and ground-water resources of northern Blaine County, Montana: MBMG B-19.

30. 1962. Groff, S.L., Reconnaissance ground-water studies, Wheatland, eastern Meagher and northern Sweet Grass Counties, Montana: MBMG SP-24.

31. 1962. Groff, S.L., Reconnaissance ground-water studies northern Park County, Montana: MBMG SP-26.

32. 1962. Brietkrietz, A., Basic water data report No. 1, Missoula Valley, Montana: MBMG B-37.

33. 1964. Zimmerman, E.A., Geology and water resources of the Bluewater Springs area, Carbon County, Montana: USGS WSP-1779.

34. 1965. Soward, K.S., Geology of damsites on Flathead River mouth to Flathead Lake, Lake and Sanders Counties, Montana: USGS WSP-1550.

35. 1965. McMurtrey, R.G.; Konizeski, R.L.; and Brietkrietz, A., Geology and ground-water resources of the Missoula Basin, Montana: MBMG B-47.

36. 1965. Taylor, O.J., Ground-water resources along Cedar Creek anticline in eastern Montana: MBMG M-40.

37. 1965. Groff, S.L., Reconnaissance ground-water and geological studies, western Meagher County, Montana: MBMG SP-35.

38. 1965. Alverson, D.C., Geology and hydrology of the Fort Belknap Indian Reservation, Montana: USGS WSP-1576-F.

39. 1965. Paulson, Q.F., and Zimmerman, T.V., Geology and ground-water resources of the Two Medicine Irrigation Unit and adjacent areas, Blackfeet Indian Reservation, Montana: USGS Open-file report.

40. 1966. Zimmerman, E.A., Geology and ground-water resources of western and southern parts of the Judith Basin, Montana: MBMG B-50-A.

41. 1966. Fox, R.D., Geology and ground-water resources of the Cascade-Ulm area, Montana: MBMG B-52.

42. 1966. Hopkins, W.B., Tilstra, J.R., Availability of ground-water from the alluvium along the Missouri River in northeastern Montana: USGS HA-224.

43. 1967. Zimmerman, E.A., Water resources of the Cut Bank area, Glacier and Toole Counties, Montana: MBMG B-60.

44. 1967. Botz, M.K., Hydrogeology of the East Bench Irrigation Unit, Madison and Beaverhead Counties, Montana: Montana Geological Society, 18th Annual Field Conf. Guidebook.

45. 1968. Taylor, O.J., Ground-water resources of the northern Powder River Valley, southeastern Montana: MBMG B-66.

46. 1968. Konizeski, R.L.; Brietkrietz, A.; and McMurtrey, R.G., Geology and ground-water resources of the Kalispell Valley, northwestern Montana: MBMG B-68.

47. 1968. Konizeski, R.L., McMurtrey, R.G. and Brietkrietz, A., Geology and ground-water resources of the Deer Lodge Valley, Montana: USGS WSP-1862.

48. 1968. Hamilton, L.J., and Paulson, Q.F., Geology and groundwater resources of the lower Bighorn Valley, Montana: USGS WSP-1876.

49. 1968. Goers, W.J., Geology and groundwater resources of the Stockett-Smith River area, Montana: (unpublished thesis) Univ. of Montana.

50. 1968. Osterkamp, W.R., Occurrence of groundwater in the Judith River formation, north-central Montana. USGS HA-308.

51. 1969. Botz, M.K., Hydrogeology of the upper Silver Bow Creek drainage area, Montana: MBMG B-75.

52. 1969. Mancini, A.J., Groundwater Inventory, Carbon County, Montana: MDNRC Groundwater Inventory Series.

53. 1970. Coffin, D.L., A preliminary evaluation of bank storage associated with Libby Reservoir in northwestern Montana: USGS WSP-1899-L.

54. 1971. Coffin, D.L.; Brietkrietz, A.; and McMurtrey, R.G., Surficial geology and water resources of the Tobacco and Upper Stillwater River Valleys, northwestern Montana: MBMG B-81.

55. 1971. Van Lewen, M.C., and King, N.J., Prospects for developing stockwater supplies from wells in northeastern Garfield County, Montana: USGS WSP-1999-F.

56. 1971. Simons, W.D., and Rorabaugh, M.I., Hydrology of the Hungry Horse Reservoir, northwestern Montana: USGS Professional Paper 682.

57. 1971. Gosling, A.R. and Pashley, E.F., Water resources of the Yellowstone River Valley between Billings and Park City, Montana: USGS Open-file report.

58. 1972. VanVoast, W.A., Hydrology of the west fork drainage of the Gallatin River, southwestern Montana, prior to commercial recreational development: MBMG SP-57.

59. 1972. McMurtrey, R.G.; Konizeski, R.L.; Johnson, M.V.; and Bartells, J.H., Geology and water resources of the Bitterroot Valley, southwestern Montana: USGS WSP-1889.

60. 1972. Wilke, K.R., Coffin, D.L., Appraisal of the quality of ground water in the Helena Valley, Montana: USGS WRI 32-73.

61. 1972. Coffin, D.L., and Wilke, K.R., Water resources of the Upper Blackfoot River Valley, west-central Montana: MDNRC Technical Series Report #1.

62. 1973. Feltis, R.D., Geology and water resources of the eastern Judith Basin, Montana: MBMG (unpublished as of this date).

63. 1973. Boettcher, A.J., and Halloran, J.E., Geology and ground-water resources of the Rock Creek Valley, western Montana: MDNRC (unpublished as of this date).

64. 1973. Hopkins, W.B., Water resources of the Northern Cheyenne Indian Reservation: USGS (unpublished as of this date).

65. 1973. Hopkins, W.B., and Miller, W.R., Water resources of the southern Powder River area, southeastern Montana: MBMG (unpublished as of this date).

66. 1973. Miller, W.R., Water resources of the central Powder River area, southeastern Montana: MBMG (unpublished as of this date).

67. 1973. Boettcher, A.J., and Gosling, A.R., Water resources of the Clark Fork drainage basin above St. Regis: MBMG (unpublished as of this date).

68. 1973. Feltis, R.D., Water resources of the central Judith Basin, central Montana: MBMG (unpublished as of this date).

Other References Pertinent to Montana, But Not Outlined on the Index Map

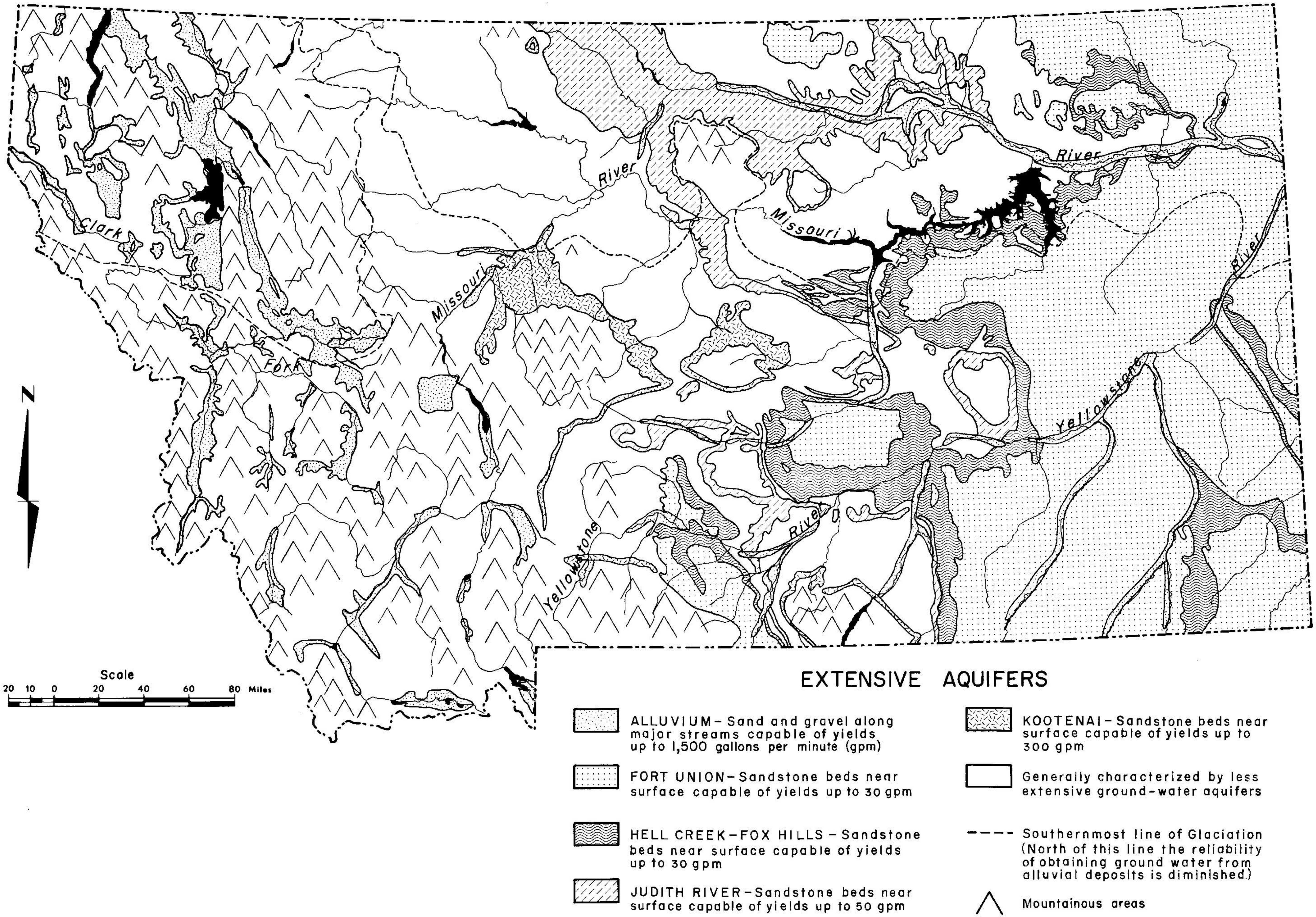
1905. Darton, N.H., Geology and underground water resources of the central Great Plains: USGS Professional Paper 32.

1924. Renick, B.C., Some geochemical relations of ground water and associated natural gas in the Lance formation; Montana Journal of Geology, 32: 668-684.

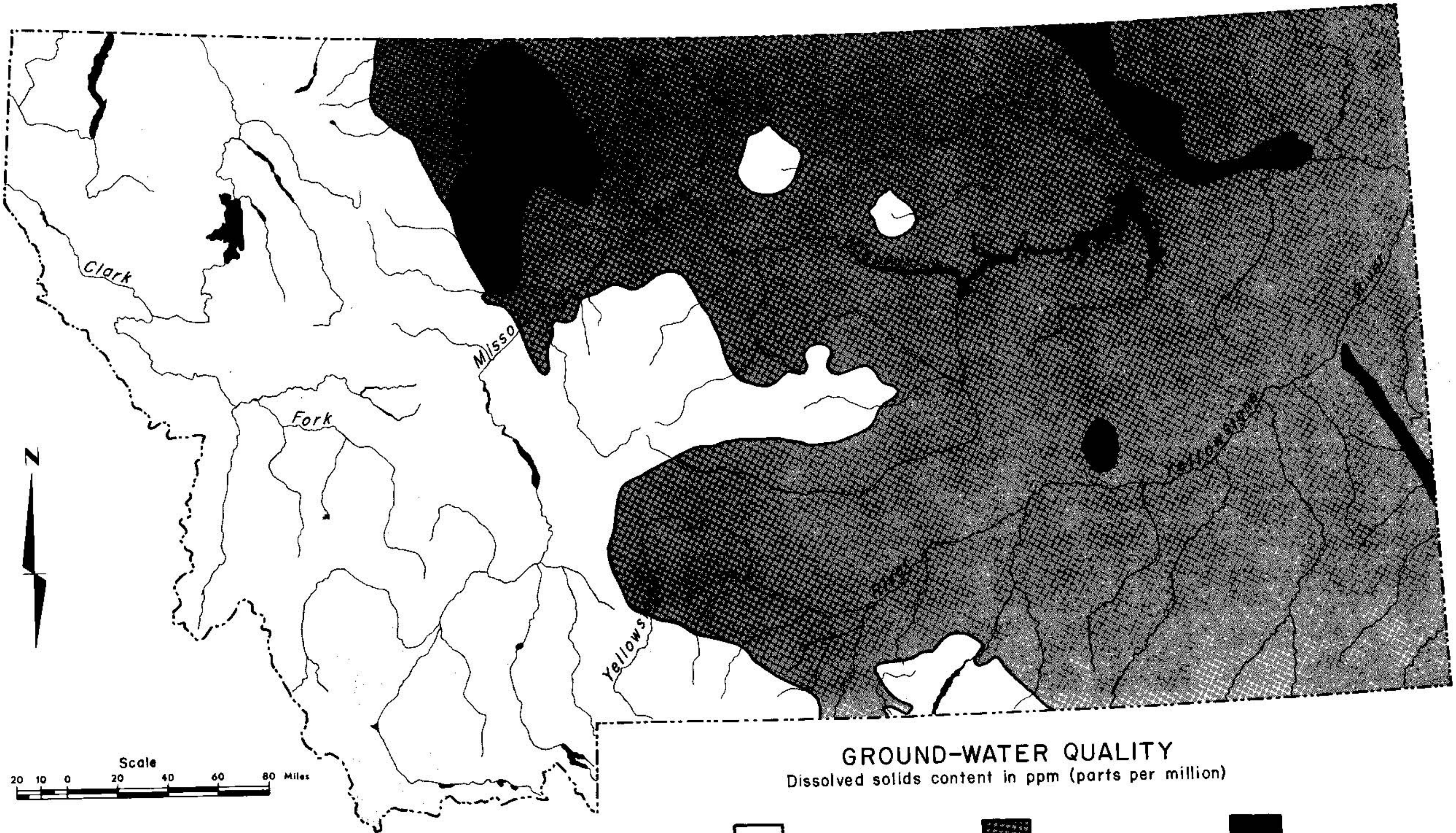
1973. Hopkins, W.B., Ground-water resources of eastern Montana: USGS Open-file report.

EXPLANATION OF ABBREVIATIONS

USGS — United States Geological Survey
MBMG — Montana Bureau of Mines and Geology
MDNRC — Montana Department of Natural Resources and Conservation
WSP — Water Supply Paper
M — Memoir
B — Bulletin
MC — Miscellaneous Contribution
Circ. — Circular
IC — Information Circular
SP — Special Publication
HA — Hydrologic Atlas
WRI — Water-Resources Investigations



Clark
Fork
Missouri
River
Missouri
River
Yellowstone
Yellowstone
River
River
N
Scale
20 10 0 20 40 60 80 Miles
EXTENSIVE AQUIFERS
ALLUVIUM - Sand and gravel along major streams capable of yields up to 1,500 gallons per minute (gpm)
FORT UNION - Sandstone beds near surface capable of yields up to 30 gpm
HELL CREEK - FOX HILLS - Sandstone beds near surface capable of yields up to 30 gpm
JUDITH RIVER - Sandstone beds near surface capable of yields up to 50 gpm
KOOTENAI - Sandstone beds near surface capable of yields up to 300 gpm
Generally characterized by less extensive ground-water aquifers
Southernmost line of Glaciation (North of this line the reliability of obtaining ground water from alluvial deposits is diminished.)
Mountainous areas



GROUND-WATER QUALITY

Dissolved solids content in ppm (parts per million)

Generally less than 1,000 ppm

1,000 to 3,000 ppm

3,000 to 10,000 ppm

LAND RESOURCES

Montana, the nation's fourth largest state, averages 500 miles in length and 275 miles in width. The state contains 94,168,000 acres (147,138 square miles), of which 900,000 acres (1,400 square miles) is water area.

LAND AREA AND OWNERSHIP

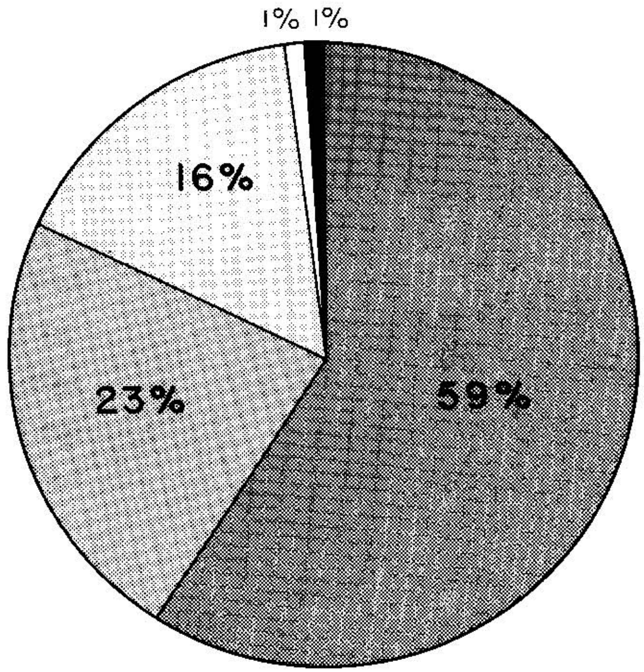
Table 11 catalogs land area and ownership in Montana, which are also illustrated in Figure 1.

The federal government owns or administers 27,600,000 acres in the state, 29.6 per cent of the total land area. The Forest Service of the U.S. Department of Agriculture administers over 16 million acres of forested public land, and the Bureau of Land Management of the U.S. Department of the Interior administers over 8 million acres of rangeland. The National Park Service of the U.S. Department of the Interior, the only other major land administrator, is responsible for over 1 million acres of Glacier and Yellowstone National Parks. Other federal agencies manage the remaining federal land in Montana.

TABLE 11

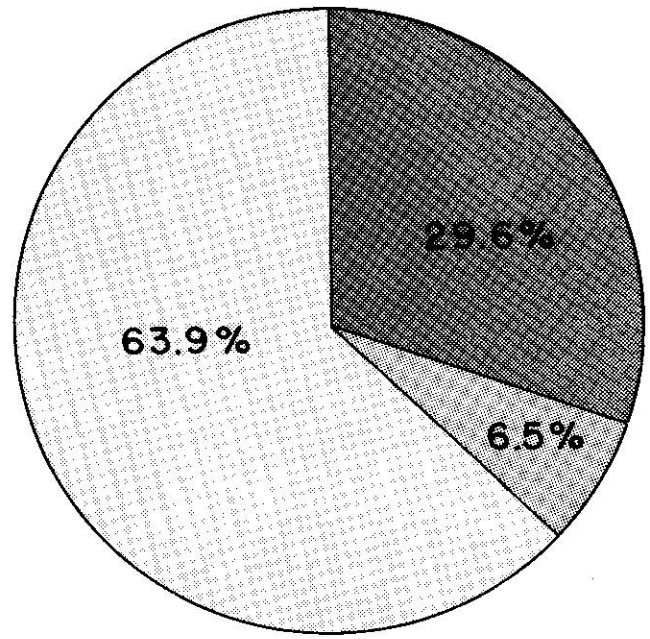
LAND AREA AND OWNERSHIP

Administrator	Acres	Percentage of Total Land Area
Federal Government	27,607,034	29.6
Dept. of Agriculture	16,710,126	17.9
Dept. of the Interior	10,295,070	11.0
Dept. of Defense	601,203	.6
Federal Aviation Agency	275	
General Services Admin.	154	
Veterans Administration	149	
Dept. of Health, Ed., & Welfare	33	.1
Dept. of Justice	12	
Post Office Department	6	
Treasury Department	5	
State Government	6,097,910	6.5
Dept. of State Lands	5,275,892	5.7
Forestry Division, DNRC	489,189	.5
Dept. of Fish and Game	130,000	.1
Dept. of Highways	81,000	.1
University Units	47,733	.05
Institutions	38,444	.05
Water Resources Division, DNRC	24,980	
Other	640	
Private Ownership	59,566,096	63.9
Indian Reservations	6,420,000	6.9
Railroads	1,290,198	1.0
Other Private Land	51,855,898	56.0
Total Land Area	93,271,040	
Total Water Area	897,280	
Total Area of State	94,168,320	



LAND USE

Pasture & Range	55,327,000	59%
Forest & Woodland	22,048,000	23%
Cropland	15,078,000	16%
Urban, Built up & Other	818,000	1%
Water Area	897,000	1%
Total Area	94,168,000	



LAND OWNERSHIP

Federal	27,607,000	29.6%
State	6,098,000	6.5%
Private	59,566,000	63.9%
Total	93,271,000	

USE AND OWNERSHIP
OF MONTANA'S LAND

FIGURE 1

The State of Montana's agencies or institutions own or administer over 6 million acres of land, 6.5 per cent of the land area of the state. School trust lands alone, administered by the Department of State Lands, total over 5 million acres. State forest lands amount to just under one-half million acres and are administered by the Division of Forestry of the Department of Natural Resources and Conservation. The Water Resources Division, DNRC and other state agencies oversee the remaining one-third million acres of state land.

The remaining 63.9 per cent of the land in Montana (nearly 60 million acres) is privately owned. Of this, 6.4 million acres is Indian-owned reservation land.

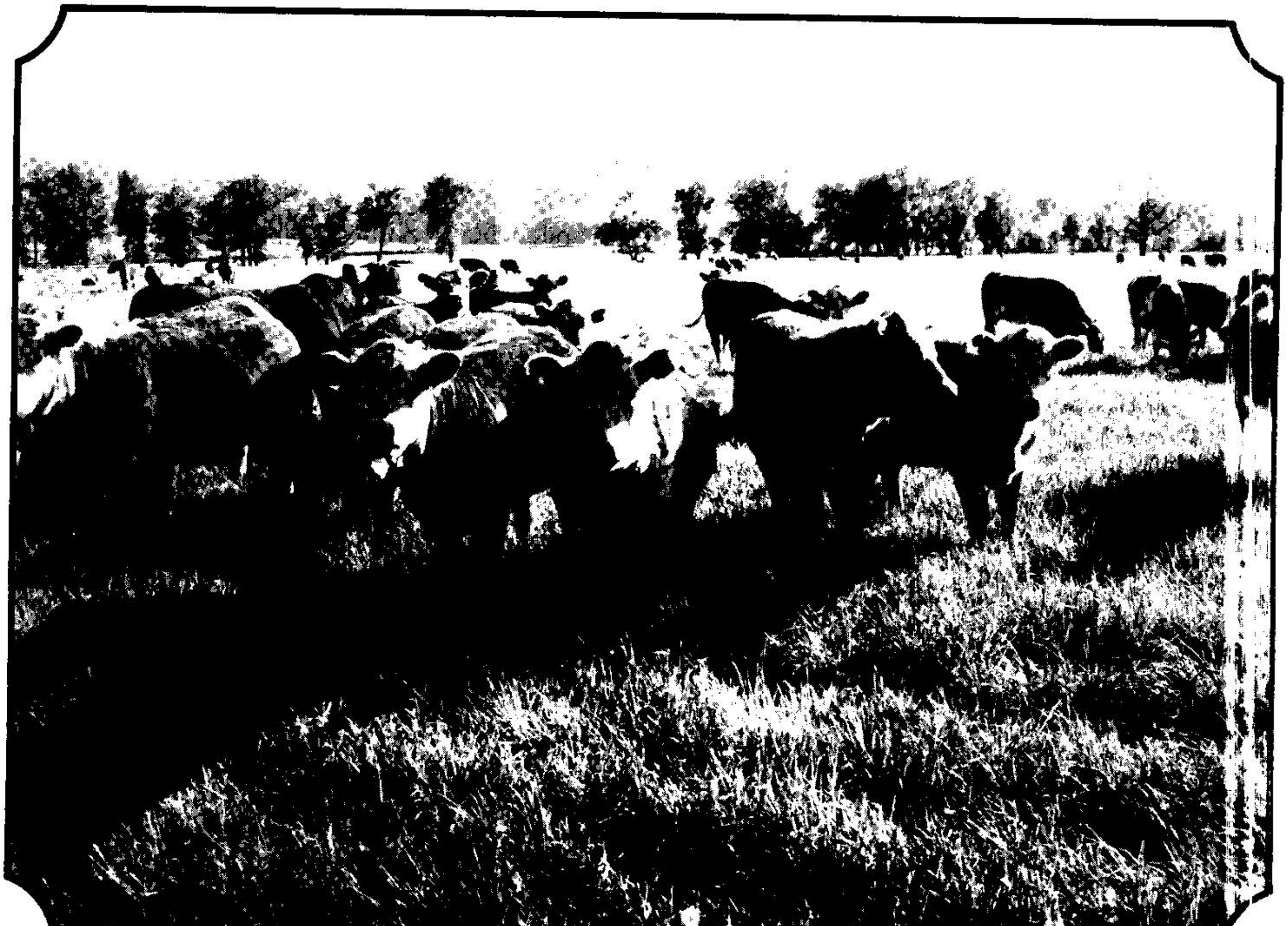
LAND COVER AND USE

The predominant use of Montana's land resource is for pasture and range for livestock grazing. Even the vast forest and woodland resource is used in part for livestock grazing. Twenty-five per cent of the pasture and less than one per cent of the range are irrigated.

While rangeland dominates eastern Montana, woodland areas, primarily evergreen forests, dominate the western half of the state. In addition to the 1 and one-half million acres administered by the federal and state governments, five and one-half million acres are owned by private concerns, including large corporations. Much of our state's water originates as runoff from forested areas. Snowfall and precipitation are controlled to a great degree by the ground cover upon which they fall, and the forest cover perhaps best controls runoff and regulates the timely release of the water supply.

Fifteen million acres of cropland are in production in the state. Most, 12.5 million acres, is dryland, and the remainder is irrigated. Montana's major water use is irrigating these 2.5 million acres of cropland.

Urban, built up, and other land uses occupy less than one per cent of the land. Water areas also cover approximately one per cent.



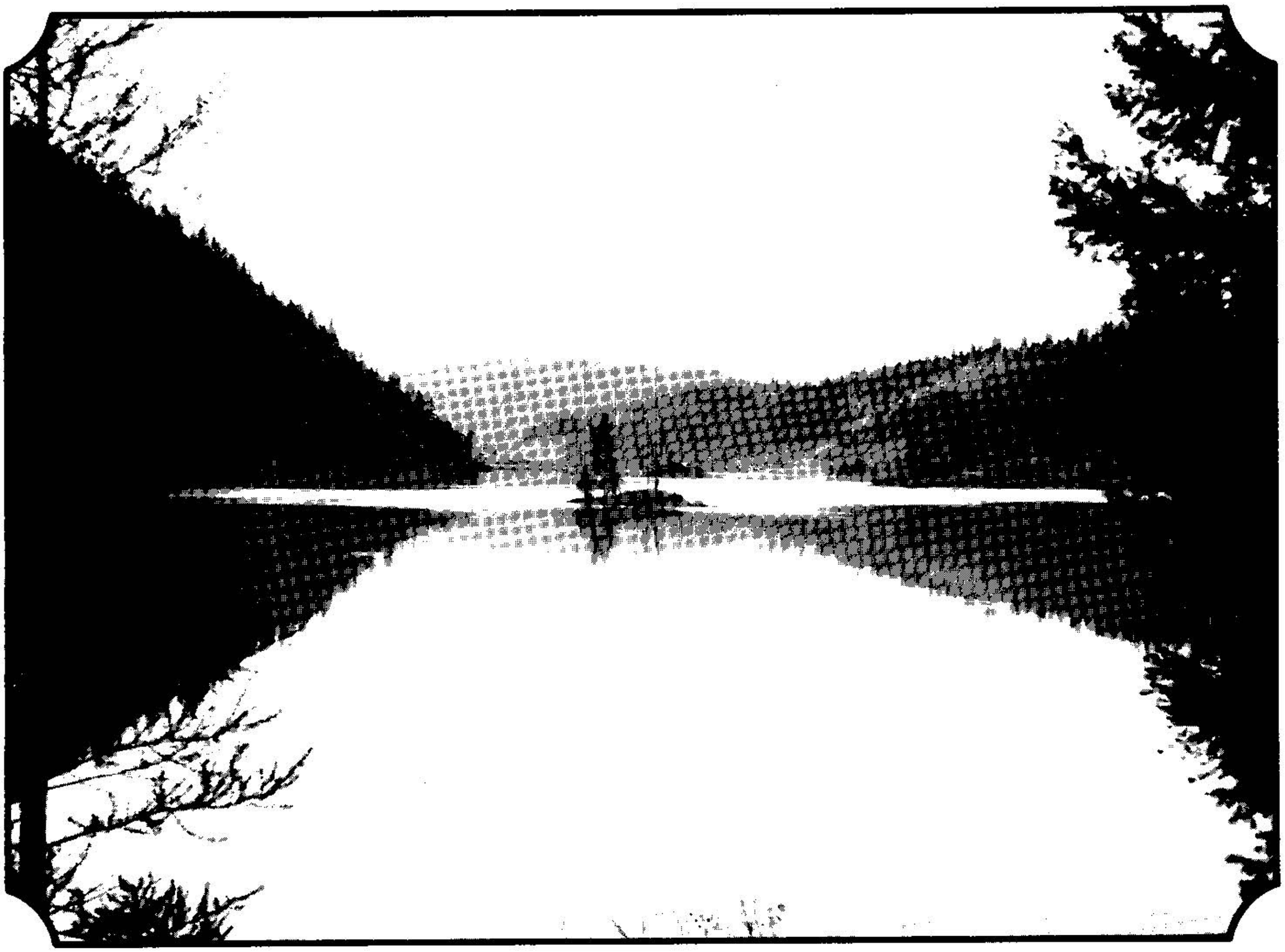
FERTILE GALLATIN VALLEY PASTURELAND

CONCLUSION

Volume One has presented a general description of water planning and the water-related resource situation in Montana. Certainly much more could be said about the physical characteristics, hydrology, and land use of the state, but the intent of this volume is to introduce the reader to subjects which will be discussed in greater detail in **Volume Two**.

Various aspects of water resource — availability, use, problems, and opportunities — will be the subjects of **Volume Two**. The land resource will be discussed as it is related to the water resource, and population projections will present a picture of water use in the future.

Volume Three will not only discuss legal and institutional constraints and considerations, but will also draw conclusions and make recommendations based on the material in all three reports.



QUIET SPLENDOR OF SALMON LAKE