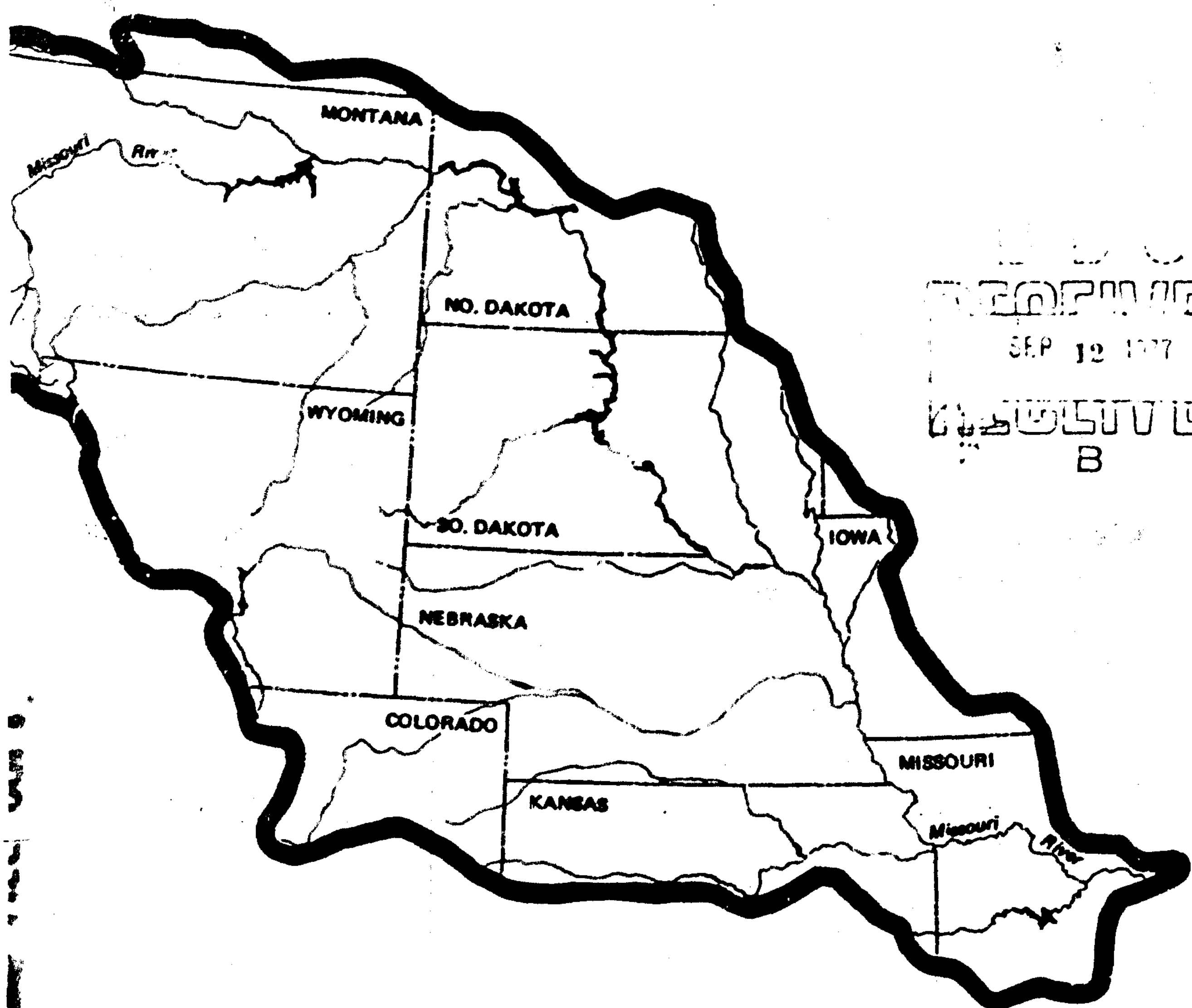
• Land Resources Availability
• Hydrologic Analyses and Projections

Volume 6

Appendix



Missouri Basin Inter-Agency Committee
Standing Committee
June 1969

Published December 1971

COMPREHENSIVE FRAMEWORK STUDY
MISSOURI RIVER BASIN

VOLUME 6

APPENDICES

LAND RESOURCES AVAILABILITY
HYDROLOGIC ANALYSES AND PROJECTIONS

MISSOURI BASIN INTER-AGENCY COMMITTEE

June 1969

427 p.

ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

REPORTS

Volume 1 — Comprehensive Framework Study

APPENDICES

Volume 2 — Historical Perspective of the Missouri River Basin

History of the Framework Study

Existing Water and Land Resources Development

Volume 3 — Laws, Policies, and Administration Related to Water Resources Development

Volume 4 — Economic Analysis and Projections

Volume 5 — Present and Future Needs

*Volume 6 — Land Resources Availability

Hydrologic Analyses and Projections

Volume 7 — Plan of Development and Management of Water and Related Land Resources

*Covered in this Volume

COMPREHENSIVE FRAMEWORK STUDY
MISSOURI RIVER BASIN

APPENDIX

LAND RESOURCES AVAILABILITY

MISSOURI BASIN INTER-AGENCY COMMITTEE

June 1969

CONTENTS

CONTENTS (Continued)

TABLES

CONTENTS (Continued)

FIGURES

CONTENTS (Continued)

PLATES

PHOTOGRAPHS

The photographs included in this appendix were furnished by:

Source

Bureau of Mines: Pages 18 (lower), 47 (upper).
Bureau of Outdoor Recreation: Pages 58 (upper), 59.
Bureau of Reclamation: Pages 28 (lower), 44.
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Forest Service: Pages 3, 6, 9, 10, 11, 13 (left), 16 (right), 18 (upper), 19, 20 (lower), 24, 27, 37 (lower), 38, 41 (upper), 42 (upper), 48, 49, 50 (lower), 64 (right), 65 (right), 66, 80.
National Park Service: Pages 50 (upper), 57.
Nebraska Civil Defense Agency: Page 23.
Nebraska Department of Roads: Pages 58 (lower), 70 (upper).
Nebraska Soil and Water Commission: Page 67.
North Dakota State Conservation Commission: Page 65 (left).
Soil Conservation Service: Pages 5, 13 (right), 16 (left), 20 (upper), 35, 36, 37 (upper), 39, 41 (lower), 42 (lower), 55, 62, 64 (left), 68 (upper), 79.

FOREWORD

The purpose of this Appendix is to present an inventory of existing land resources in the Missouri River Basin and their use, and to analyze the availability and adaptability of the resources for satisfying future requirements.

To fulfill these objectives, the Land Resources Availability Work Group divided this appendix into five chapters. These chapters cover (1) a general description of the basin's resources, (2) the current ownership and management patterns of the basin lands, (3) a classification and inventory of the land resources, (4) projections of future potentials and capabilities for the various classes of land, and (5) estimates of probable shifts in land use and management which will be necessary to achieve the goals of framework planning.

Acreage data are assembled for each subbasin. This data forms the basis for the surface areas, both land and water, in terms of acres utilized in the basin and subbasin studies. In this analysis, multiple use of the land and water resources is considered. For purposes of this appendix, multiple use means the use and management of all surface and subsurface resources in the combination that will best meet the present and future needs of the American people. The term may be applied to areas of land, areas of water, or to other resources. When applied to land areas, it refers to the various uses accomplished through protection and management of the resources on a given land unit. These include water, timber, forage, crops, wildlife, recreation, and minerals. When applied to water areas, it refers to uses that may be made of the water surface itself, or to water used for recreation, fish and waterfowl habitat, irrigation, municipal and industrial water supply, domestic purposes, livestock, or scenic beauty.

The area of the subbasins and areas of land and water were derived from 1960 U. S. Bureau of Census data. The 1965 land ownership was compiled using information from Federal and State agencies, including the Conservation Needs Inventory. The 1965 land use was developed from information from the Federal and State agencies, including the Agricultural Census of the U. S. Department of Commerce, Agricultural Statistical Reports, and the Conservation Needs Inventory of the U. S. Department of Agriculture.

The Standing Committee on Comprehensive Basin Planning for the Missouri Basin Inter-Agency Committee assigned the preparation of this appendix to the Work Group on Land Resources Availability. During the course of the study, the Work Group assigned work to seven task forces. They were composed of selected representatives from Federal and State agencies concerned with major land resources of the basin.

The Organization Chart, figure 1, shows the composition and structure of the Land Resources Availability Work Group and its task forces.

FIGURE 1

ORGANIZATION CHART - LAND AVAILABILITY

PARTICIPANTS

COLORADO	Colo.
AGRICULTURE, DEPARTMENT OF	
Agricultural Research Service	ARS
Agricultural Stabilization and Conservation Service	ASCS
Economic Research Service	ERS
Farmers Home Administration	FHA
Forest Service	FS
Rural Electrification Administration	REA
Soil Conservation Service	SCS
IOWA	Iowa
ARMY, CORPS OF ENGINEERS	C of E
KANSAS	Kans.
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U.S. Weather Bureau	USWB
MINNESOTA	Minn.
FEDERAL POWER COMMISSION	FPC
MISSOURI	Mo.
MONTANA	Mont.

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HEALTH, EDUCATION, AND WELFARE, DEPARTMENT OF	
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NEBRASKA	Nebr.
INTERIOR, DEPARTMENT OF THE	
Bureau of Commercial Fisheries	BCF
Bureau of Indian Affairs	BIA
Bureau of Land Management	BLM
Bureau of Mines	BM
Bureau of Outdoor Recreation	BOR
Bureau of Reclamation	BR
Bureau of Sport Fisheries and Wildlife	BSF & WL
Federal Water Quality Administration	FWQA
Geological Survey	GS
Interior Missouri Basin Field Committee	IMBFC
National Park Service	NPS
NORTH DAKOTA	N.Dak.
SOUTH DAKOTA	S.Dak.
LABOR, DEPARTMENT OF	
Man Power Administration	MPA
WYOMING	Wyo.

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CHAPTER 1

BASIN DESCRIPTION

PHYSIOGRAPHY

The Missouri River drains a total of about 529,350 square miles in the United States and Canada. While the Missouri River itself does not cross the International Boundary, there are about 9,715 square miles in Canada drained by its tributaries. Within the United States, the Missouri River Basin comprises one-sixth of the contiguous area of the Nation. It includes all of Nebraska; most of Montana, North Dakota, South Dakota, and Wyoming; about one-half of Kansas and Missouri; about one-fourth of Colorado and Iowa; and a small part of Minnesota.

In this Appendix, the Missouri River Basin includes all of the Missouri River drainage in the United States. That portion of the basin lying in Canada, the Great Divide Basin in Wyoming (a hydrologically closed basin on the divide between the Missouri River Basin and the Colorado River Basin), and several smaller non-contributing areas along the basin's boundary were excluded. With the exclusion of these areas, the basin contains about 513,295 square miles or nearly 329 million acres of land and water (table 1).

Table 1 – DRAINAGE AREA, MISSOURI RIVER BASIN, UNITED STATES AND CANADA

Location	Square Miles	Thousand Acres
Missouri River Drainage Area, Canada to Mississippi River near St. Louis, Including Non-Contributing Areas.	529,350	338,784
Drainage Area in Canada	9,715	6,218
Drainage Area in the United States, Including Non-Contributing Areas	519,635	332,566
Non-Contributing Areas Along the Basin Boundary in the United States Not Included in the Study:[1]		
Great Divide Basin and Contiguous Areas on Sweetwater River Drainage and in North Platte River Drainage in Vicinity of Rawlins, Wyoming.	4,160	2,663
Smoky Hill River Drainage, Colorado and Kansas.	180	115
Tributaries North of Garrison Reservoir, North Dakota	300	192
Tributaries of James and Big Sioux Rivers, North and South Dakota.	1,700	1,088
Total Non-Contributing Areas	6,340	4,058
Basin Land and Water Area	513,295	328,508

[1] Areas within given watersheds that do not contribute directly to surface runoff. Area figures are approximate.

Boundaries

The basin is an elongated area lying diagonally from the northern Rocky Mountains to the Ozark Plateaus and includes all or parts of 10 states. Its western boundary coincides with the Continental Divide from northern Montana to the headwaters of the South Platte River west of Colorado Springs, Colorado. From this area, the southern boundary of the basin extends east across the Great Plains of Colorado and Kansas and through the northern portion of the Ozarks in Missouri, to a junction with the Missouri River on the Mississippi River floodplains. This portion of the basin boundary follows a series of rather well defined divides between the drainage of the Arkansas River on the South and the South Platte, Smoky Hill, and Kansas rivers to the north.

The northern boundary of the basin extends from the Continental Divide in Glacier National Park, northeasterly to and thence easterly of Crosby, North Dakota. The boundary then continues in a southeasterly direction to the junction of the Missouri and the Mississippi rivers. Along this latter portion the basin boundary, the drainage divide follows the crest of a number of landforms between tributaries of the Missouri River on the west and the Souris, Red, and Mississippi rivers to the north and east.

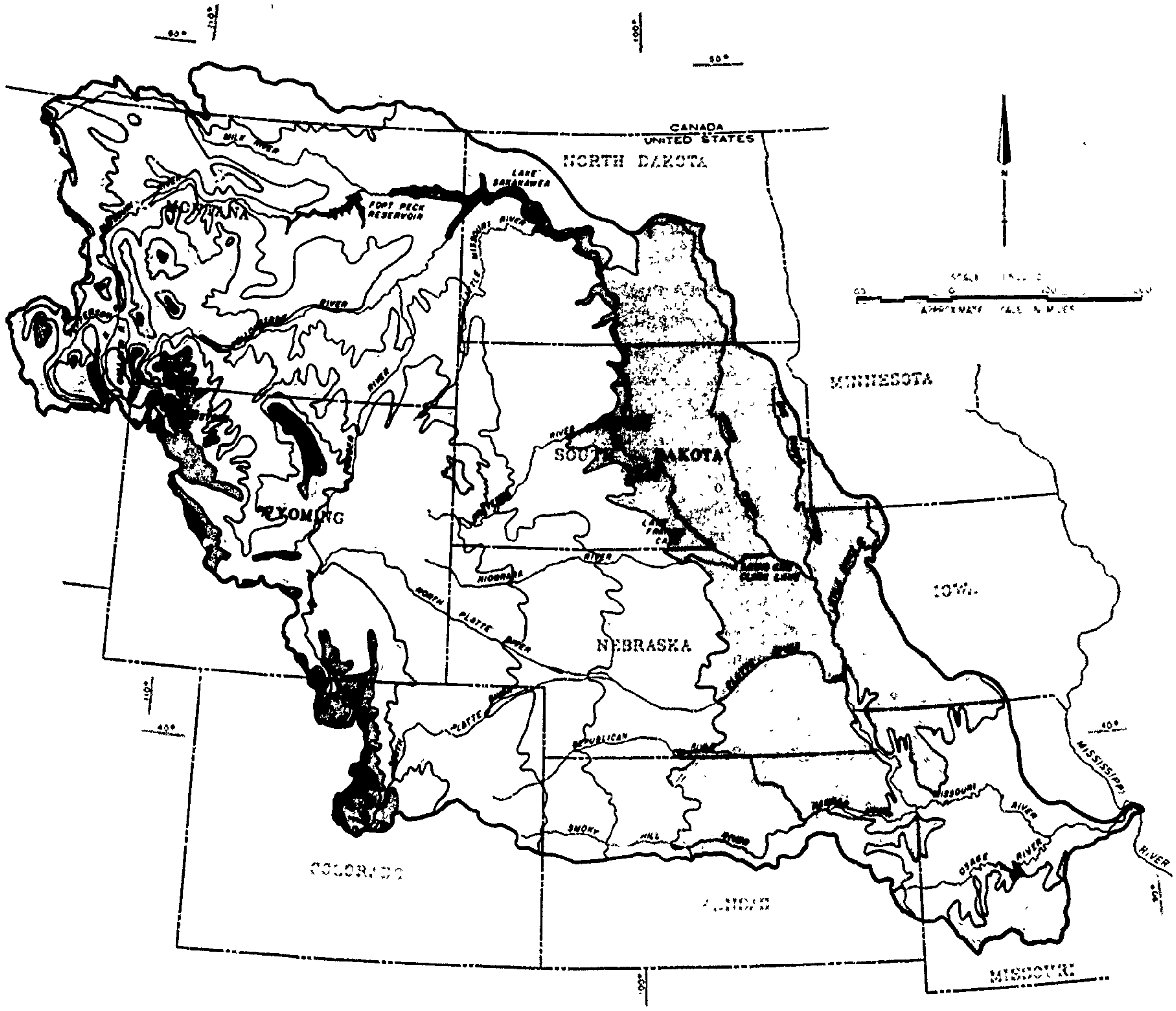
General Description

Elevations in the basin vary from high mountain peaks of 14,000 feet above mean sea level and high mountain passes of 11,000 feet in the Rocky Mountains through foothills, plains, and river bottomlands to about 450 feet mean sea level at the mouth of the Missouri River near St. Louis (figure 2).

The mountainous areas of the basin are generally composed of hard crystalline and sedimentary rocks with

FIGURE 2

TOPOGRAPHY



LEGEND

ELEVATION IN FEET

	0 - 1,000		4,000 - 6,000
	1,000 - 2,000		6,000 - 8,000
	2,000 - 3,000		8,000 - 10,000
	3,000 - 4,000		ABOVE 10,000

granite predominating. In the geologic past, these rocks have been sculptured by ice and water to produce the rugged peaks and steep-sided valleys which form the alpine topography seen today. Erosion tends to be slow in these areas and the mountain streams do not generally carry large silt loads.

A large portion of the Missouri Basin is composed of plains and prairies. These areas are underlain by sedimentary rock formations consisting predominantly of clays, shales, silts, sands, and sandstones. Such areas erode much more readily than the older and more consolidated rocks of the mountainous areas. Large sections are covered by recent deposits of unconsolidated glacial till, sand, gravel, silts, and clays left behind by the continental glaciers and the long-term effects of wind and water.

Most of the soils in the basin have developed under a grass cover. Major exceptions are the soils of the mountainous areas where forests have been the predominant vegetation. Over the basin, many kinds of soils are found with wide variations in profile characteristics and use capabilities. Zonal soils occupying various parts of the basin include: the Brunizem soils of eastern Kansas and Nebraska, Iowa, Missouri, Minnesota, and extreme southeastern South Dakota; the Chernozem soils in a zone that extends from eastern North and South Dakota through central Nebraska and Kansas; the Chestnut soils in northern Montana, western North and South Dakota and Nebraska, and northwestern Kansas; the Brown soils in eastern Montana and Wyoming and northeastern Colorado; the Sierozem soils in the intermountain basin and in the high dry plateaus in northwestern Wyoming; and the Podzolic soils in the forested areas of the Rocky Mountains in western Montana and Colorado and the Ozark Plateaus in Missouri.

Physical Divisions

Three distinguishable major physical divisions characterize the basin as delineated in figure 3. The Rocky Mountain System occupies 11 percent of the basin; the Interior Plains 86 percent; and the Interior Highlands three percent.

The Rocky Mountain System consists of the mountainous areas that form the western boundary of the watershed in Montana, Wyoming, and Colorado. This area is characterized by alternating prominent mountain ranges, intermountain basins, and relatively wide valleys. Elevations range from about 4,500 feet to more than 14,000 feet above sea level. Minor tributaries have steep gradients, and channels generally are "V"-shaped. The streams commonly flow through steep canyons before they reach the more level topography of the plains where stream gradients lessen.

Portions of four provinces of the Rocky Mountain System are within the basin. These provinces are the Northern Rocky Mountains, Middle Rocky Mountains, Wyoming Basin, and Southern Rocky Mountains. The Wyoming Basin province interrupts the continuity of the Rocky Mountain System. This basin extends across the Mountain System between the Middle Rocky Mountains and Southern Rocky Mountains provinces.

In the Wyoming Basin the Continental Divide has no distinct connecting crest. Here lies the Great Divide Basin from which no drainage reaches the sea. The term "Great Divide Basin" is used chiefly in a hydrographic sense for the area of internal drainage of about 4,160 square miles in extent (table 1). The floor of the Wyoming Basin is characteristically similar to a plateau and is continuous with the Great Plains through broad openings between mountain ranges. The basin includes extensive areas of plateau parks supporting mixed grasses and shrubs. This basin is used mainly for fall, winter, and spring grazing.

Three Rocky Mountain provinces include extensive areas of coniferous forests and intermingled mountain parks supporting mixed grasses and shrubs. There are a number of intermountain valleys between the mountain masses. These areas are used mainly for grazing, but some have been developed into rich farm lands. The Rocky Mountain portion of the basin is a primary source of water for the Missouri River and many of its tributaries.

Rocky Mountains

FIGURE 3

PHYSIOGRAPHIC DIVISIONS, PROVINCES, SECTIONS, AND SUBSECTIONS

Throughout their length, the Rocky Mountains accumulate tremendous reserves of snow from which originate a high percentage of spring and early summer stream flows.

The Great Plains province consists of a large area between the Rocky Mountains on the west and the Central Lowlands province on the east. The following subdivisions are used for the purpose of describing the province: (1) Glaciated Missouri Plateau, (2) Unglaciated Missouri Plateau, (3) Black Hills, (4) High Plains, (5) South-Central Loess Hills section, and (6) Central Kansas Rolling Plains.

The Glaciated Missouri Plateau is a broad expanse of ently rolling topography extending eastward from the Rocky Mountains across northern Montana and including those portions of North Dakota and South Dakota lying north and east of the Missouri River. Stream dissection and drainage are not well established except in areas adjacent to the Missouri River and along some of its larger tributaries. Local drainage is chiefly into pot holes, small intermittent lakes, and a few larger permanent lakes.

The Unglaciated Missouri Plateau comprises the broad rolling area west of the Missouri River in North and South Dakota. It also includes most of the eastern half of Montana and northeastern Wyoming. Numerous small hilly areas, buttes, and hogbacks have elevations higher than the general level of the plains. While the area as a whole is rolling and rather thoroughly dissected by

Great Plains

streams, there are small nearly level areas on the stream divides. A few relatively large areas of gently rolling relief are scattered throughout the region. Badlands and canyon areas occur along the White River in South Dakota, Little Missouri River in North Dakota, and in the plains adjacent to the Missouri, Yellowstone, and Powder rivers in Montana and Wyoming. The Black Hills section is an elliptical-shaped, mountainous area about 60 miles wide and 125 miles long in western South Dakota and northeastern Wyoming. Here the slopes are steep to precipitous and are covered typically with stands of ponderosa pine intermingled with areas of native grasses and bare craggy rocks.

The High Plains slope gently eastward from the Rocky Mountain front in north-central Colorado and south-central Wyoming. These plains are characterized by nearly level to rolling tablelands, with hilly to rough broken areas along the valley sides. Stream dissection is well established, with broad smooth divides between the larger drainages. A distinct subsection in the northern High Plains is the Sand Hills, an area of about 24,000 square miles in north-central Nebraska. There the sandy character of the soil allows a large portion of the annual precipitation to percolate into groundwater storage.

The South-Central Loess Hills section is an area interspersed with nearly level plains, rolling land, and long narrow undissected plains remnants which form divides between a rather complete pattern of canyon-like drainages.

In north-central Kansas, the Central Kansas Rolling Plains occupy a large area. Strongly rolling relief predominates over the northern and western parts of the area, with deeply entrenched drainages and occasional smooth divides between major streams. Smoother plains occur in the southern and southeastern parts.

Land use in the Great Plains is characterized by the vast areas of grassland used for grazing livestock, extensive areas of cropland such as the expanses of winter and spring wheat, and the tracts of irrigation along many of the major rivers and intermediate plateaus.

The Central Lowlands province of the Missouri Basin is a long north-south area bounded on the west by the Great Plains; on the northeast and south by the Missouri Basin boundary; and on the southeast by the Ozark Plateaus. This entire area has been developed by erosion of a mantle of glacial drift and till deposited by the continental glaciers. An abundance of rainfall and stream development has created a hilly topography in many places, especially in the south.

Land use in the Central Lowlands province is essentially the same as in the adjoining Corn Belt. Farm land is generally confined to the more level areas in the north and to areas between the hilly belts in the south. Lands of steeper slopes and having thin soils are used primarily for grazing.

Central Lowlands

The Ozark Plateaus province within the Interior Highlands division in the southeastern portion of the basin is two main tributary rivers draining the area. The plateaus are generally underlain by sedimentary formations of limestone and chert. These formations have numerous composed of hilly uplands intermixed with rolling plateaus. Their topography was developed by erosion of the ancient Ozark uplift. The Osage and Gasconade are the caverns and underground channels which produce springs throughout the area. Generally the Ozarks support a tree cover of mixed hardwoods and pines, with the hardwoods being dominant. Most of the farms in the area are small and many farmers obtain supplemental income from lumbering. Of the total land once in cultivation, about one-third has been returned to forests or grass. Timber production and grazing are the major land uses except in areas of better soils where general farming predominates.

Ozark Plateaus

Subbasins and Subregions

The Missouri Basin has significant variations in topography, climate, resources, economy, and social aspects. To facilitate the study, the basin was divided into eight planning areas. Because the source and composition of the basic data records used in this study varied with respect to boundary delineations, both "subbasins" and "subregions" were designated (figure 4).

Subbasins are hydrographic areas drained by designated major tributaries or groups of tributaries of the Missouri River, including associated closed basins. **Subregions** are groups of counties delineated to approximate the subbasins by county lines because of statistical data availability on this basis, and to facilitate economic analysis.

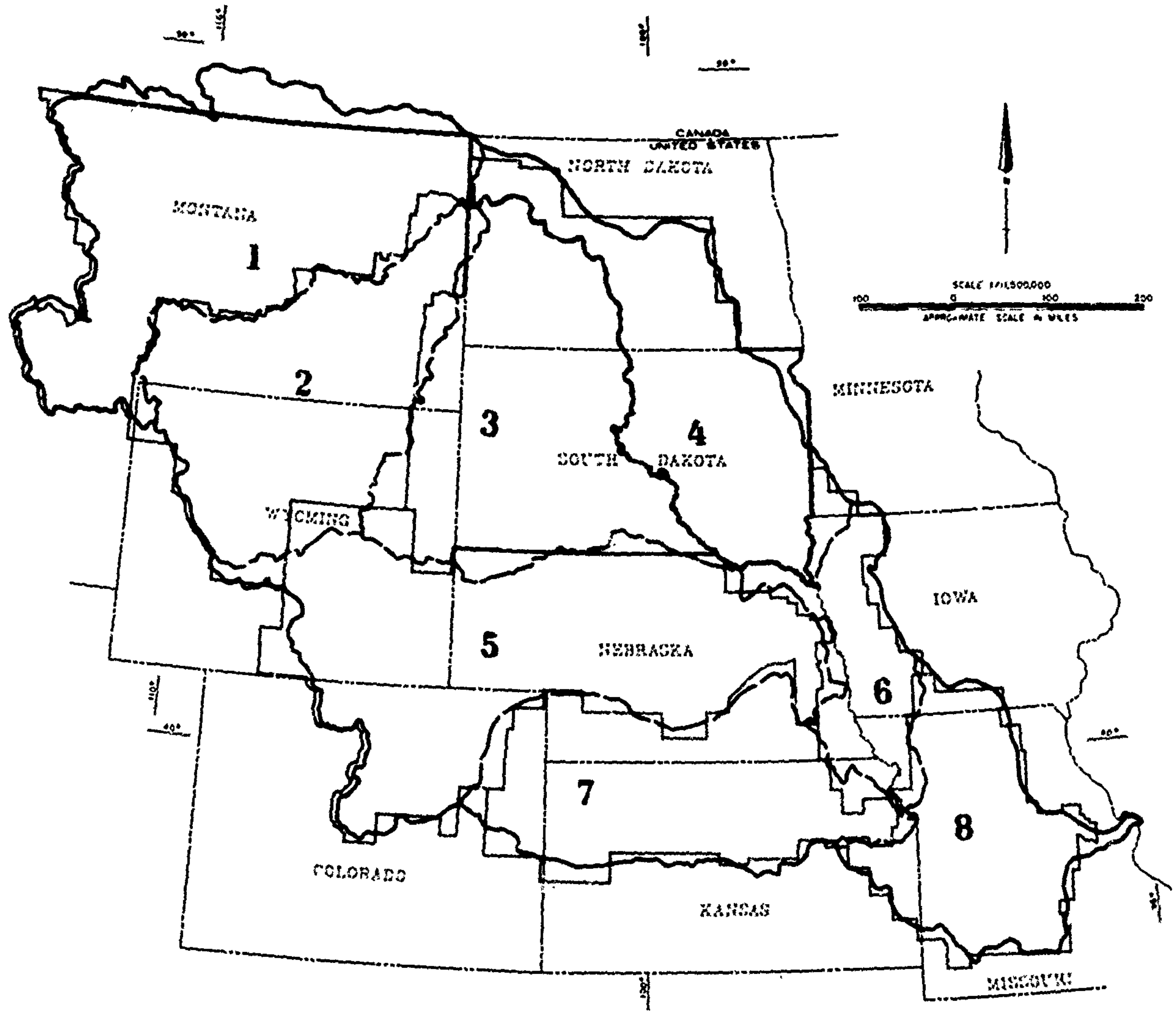
The terms "subbasins" and "subregions" are used in this appendix to designate the type of boundary area for which the data were developed. For planning purposes, the data developed by regions and subregions can be applied to the corresponding basin and subbasin areas with no significant loss of reliability.

Subbasins and subregions discussed in this report are:

Name	Narrative Abbreviation
Upper Missouri River Tributaries (Includes all of the drainage of the Missouri River above the mouth of the Yellowstone River)	Upper Missouri
Yellowstone River Subbasin (Includes all of the drainage of the Yellowstone River)	Yellowstone
Western Dakota Tributaries (Includes all the tributaries flowing from the west between the mouths of the Yellowstone and Niobrara rivers)	Western Dakota
Eastern Dakota Tributaries (Includes the drainage area east of the Missouri River from the mouth of the Yellowstone River to Sioux City)	Eastern Dakota
Platte-Niobrara Subbasin (Includes all of the drainage of the Platte and Niobrara rivers)	Platte-Niobrara
Middle Missouri River Tributaries (Includes tributaries to the Missouri River on the west bank from the mouth of the Niobrara River to the mouth of the Kansas River, excluding the Platte River, and the tributaries on the west bank from Sioux City to Kansas City)	Middle Missouri
Kansas River Subbasin (Includes all of the drainage of the Kansas River)	Kansas
Lower Missouri River Tributaries (Includes tributaries of the Missouri River below the mouth of the Kansas River)	Lower Missouri

FIGURE 4

SUBBASINS AND SUBREGIONS



LEGEND

BASIN BOUNDARY

SUBBASIN BOUNDARY

STATE OR NATIONAL BOUNDARY

SUBREGION BOUNDARY

SUBBASINS AND SUBREGIONS

1 UPPER MISSOURI RIVER TRIBUTARIES
2 YELLOWSTONE RIVER
3 WESTERN DAKOTA TRIBUTARIES
4 EASTERN DAKOTA TRIBUTARIES
5 PLATTE-NIOBRARA RIVERS
6 MIDDLE MISSOURI RIVER TRIBUTARIES
7 KANSAS RIVER
8 LOWER MISSOURI RIVER TRIBUTARIES

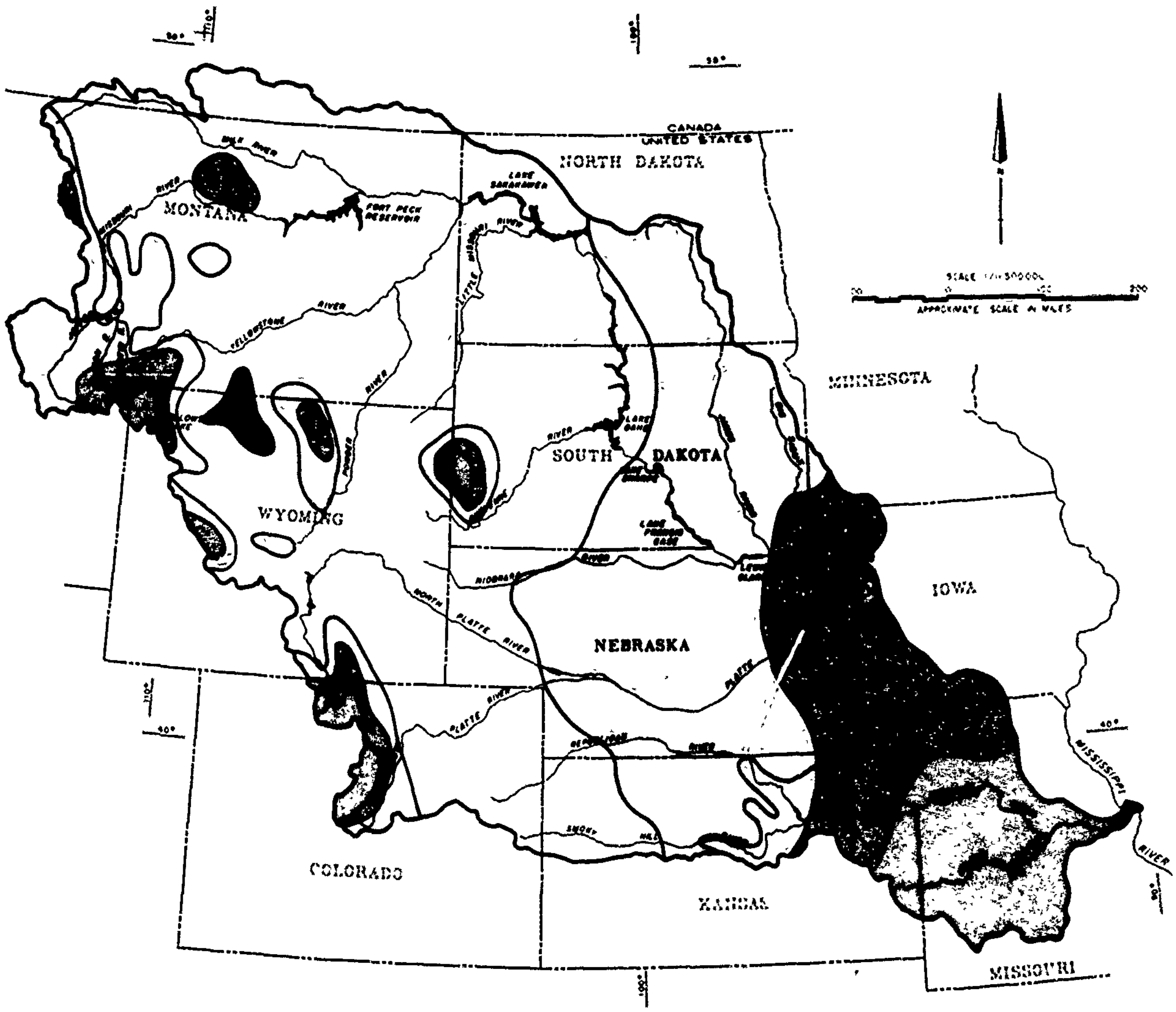
CLIMATE

The climate of the Missouri Basin is continental in type, being characterized by wide ranges in temperature and irregular annual and seasonal precipitation. This results in a range of climatic zones and associated natural vegetation over the basin, as shown in figure 5. Notable are the extremes in temperature induced by alternating cold air masses moving into the basin from the northwest and warm air masses moving from the Gulf regions. Under their influences the seasonal variation, and even the daily range in temperature, tend to be large. Except in the mountains, all localities have experienced summer temperatures over 100° F., and below-zero winter temperatures. Average annual temperatures range from 55° F. in the southeast to less than 40° F. in the northwest.

Wind is a significant factor in the climate throughout the basin. Average wind directions for the greater part of the basin are from south and southeast in summer and

FIGURE 5

CLIMATIC ZONES
WITH ASSOCIATED NATURAL VEGETATION



LEGEND

CLIMATES	NATURAL VEGETATION PREDOMINANT	NATURAL VEGETATION SECONDARY
HUMID	FOREST	TALL GRASS PRAIRIE
MOIST SUBHUMID	TALL GRASS PRAIRIE	FOREST
DRY SUBHUMID	MIXED GRASS PRAIRIE	TALL GRASS PRAIRIE FOREST
SEMIARID	MIXED GRASS PRAIRIE	SHORT GRASS PRAIRIE
ARID	SALT DESERT SHRUB	SHORT GRASS

from north and northwest in winter. Although the mountain and foothill areas have less wind movement than the plains, wind directions there have greater local variation. Maximum wind velocities range between 45 and 120 miles per hour with the higher velocities recorded in the Great Plains. Average monthly wind velocities range between seven and 13 miles per hour.

High winds with high temperatures increase evaporation, damage or dry out crops, and frequently cause severe dust storms in some areas. These hot dry winds are frequent during the spring and summer months.

During the winter, in most parts of the basin, blizzards are a normal hazard. These blizzards are often a menace to human life, livestock, wildlife, and property as well as to public services and transportation.

Annual precipitation is perhaps the most critical climatic factor since it affects directly the economic health of agriculture, the basin's primary industry. The amount of annual precipitation, its form, and its seasonal variation are related to the topographic areas within the basin. As a generalization, the annual precipitation patterns can be broken into three board classes which are related to the mountainous areas, the Great Plains, and the Central Lowlands.

The highest average annual precipitation within the basin occurs in the mountainous areas, ranging to over 40 inches in portions of the Rocky Mountains and the Ozarks. In the western mountains, much of the annual precipitation occurs as snow in the winter. Average snowfalls of 100 inches or more are common throughout the Rockies.

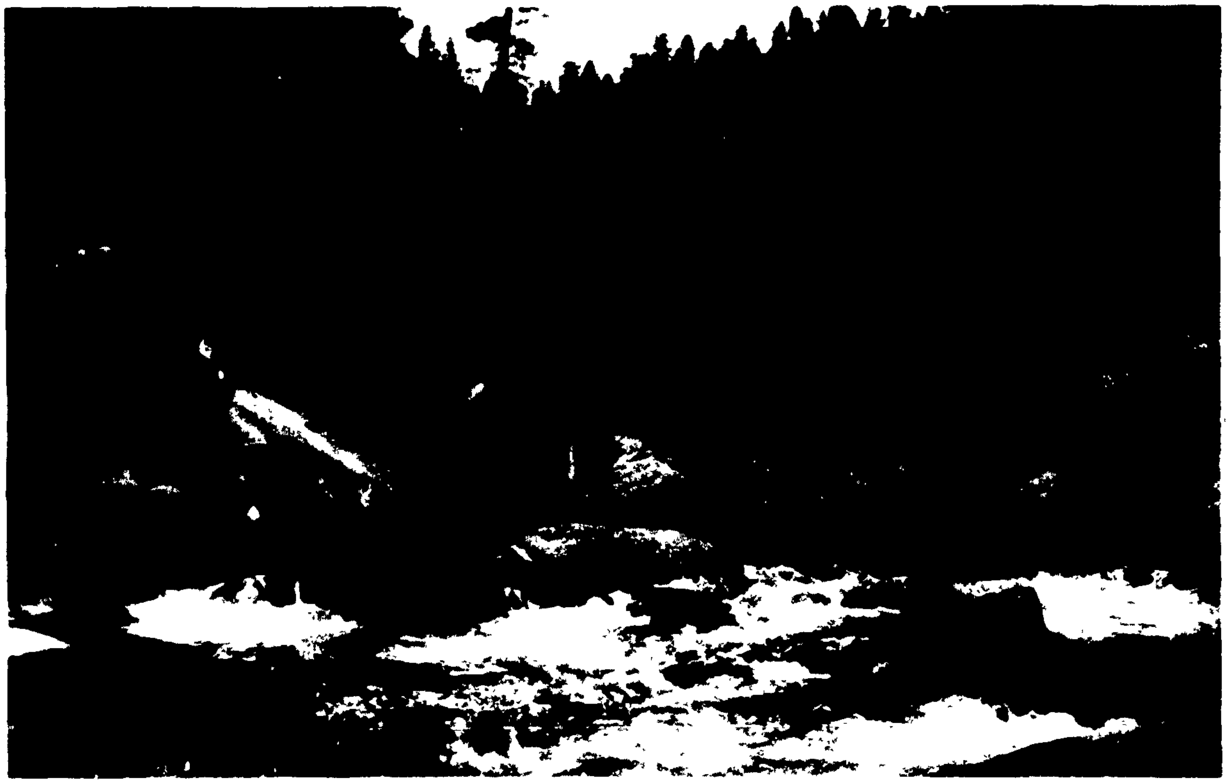
Mountain snow packs form important reservoirs of water, and melting snow during the spring and early summer supplies much of the annual stream flow in the basin. Much of the irrigation is dependent upon these snow-fed flows.

The Rocky Mountain area produces significantly higher annual runoff than other parts of the basin. Due to the melting of the snow packs, monthly runoff is greatest during the late spring months and decreases through the summer, fall, and winter. The base flows for most streams are sustained by melting snow and summer precipitation, much of it entering the streams as groundwater. In general, runoff increases with elevation.

Some flood flows in the Rocky Mountains occur in the warm season, usually as flash floods. High peak discharges are produced by relatively low volumes of flood runoff. The larger annual floods on streams with appreciable drainage are frequently caused by combined snowmelt and rainfall. In the smaller streams, rainfall is the primary cause of floods.

The Ozark Plateaus area yields average annual runoff in the range of from six to 12 inches. Flood runoff is comparatively high. The groundwater flow of most streams is moderate to high because of the numerous springs draining the aquifers of the area. Flood flows are

Accumulated Snow Contributes to a More Constant Streamflow Throughout the Year



Beautiful Cool Clear Mountain Streams Carry the Snowmelt to the Great Plains

flashy on all except the major streams of the area. Rainfall is the primary cause of floods with snowmelt and ice jams being infrequent and limited factors in flood occurrence.

The Great Plains are noted for their rather scanty and erratic annual precipitation. Average annual precipitation on the plains varies from lows under 12 inches to highs slightly over 20 inches. As a generalization, the highest annual precipitation in the plains portion of the basin occurs in the southeast and decreases steadily as one moves to the northwest.

Rainfall averages are a bit misleading for individual yearly precipitation tends to vary quite widely. The plains are well known for their noncyclic and often severe droughts. These droughts can last from a single summer to several years in duration, and there is no known means by which to accurately predict their occurrence. The drought is the most severe climatic hazard faced by the basin residents.

Despite the low average annual precipitation, agriculture is possible on the Great Plains in part because of the seasonal variation in the rainfall. The greatest amounts of rainfall come during the spring months of May, June, and early July in most years.

Occasionally, the plains experience high intensity thunder storms during the summer, often accompanied by high winds and hail. These storms commonly cause more crop damages than benefits from the rain they produce.

Winter snowfall is generally light in the plains with January and February being the driest months of the year.

The Great Plains have low annual runoffs, generally less than one inch. Groundwater flow in most streams is very limited. As a result, the typical plains' stream has a high flow during the spring rains but tends to dry up during the summer, with occasional short-duration high flows from passing thundershowers.

A distinct contrast to the general condition is found in the Loup Rivers which flow out of the Sand Hills of north-central Nebraska. The flow of these rivers is supplied, in most part, by a relatively steady discharge of groundwater due to the large area intake and the high porosity of the thick sands covering the area.

Flood flows in the plains are semi-flashy in most streams but the rolling to steep topography of some localities produces typical flash floods. Floods in the northern part are caused by either rainfall or combined rainfall and snowmelt, with ice jams being involved frequently in the early spring floods. In the southern part of the plains, rainfall is the primary cause of floods and neither snowmelt nor ice jams are important factors.

The Central Lowlands are generally well endowed with annual precipitation with the annual averages ranging from 20 to 40 inches. Yearly precipitation in the northern portion is divided between summer rains and winter snow while in the southern portion, annual precipitation is composed almost entirely of rainfall which occurs throughout the year.

The lowlands produce appreciable amounts of annual runoff and flood occurrences are relatively high. Most streams in the area for which records are available have average annual runoff in the range of four to eight inches. In general, low flows in the streams are derived from shallow groundwater supplies that are limited by and dependent upon the local infiltration of precipitation. Floods are semi-flashy on small streams and are moderate on the larger streams. Storm rainfall is the primary cause of floods, and ice jams are not a significant factor in flooding.

DEMOGRAPHY

Historically, the settlement of the Missouri River Basin has been related directly to its abundance of natural wealth, particularly its agricultural and mineral resources. The potentials of the Central Lowlands and the eastern portion of the Great Plains and the Rocky Mountain foothills attracted the livestock men; and the mineral wealth of the Rockies themselves brought the miners.

Each of these settlement groups spawned cities and towns to service their needs. Some of these urban centers went on to become growing regional centers and some soon became ghost towns when their economic base disappeared. This process of growth, recession, and death is still much in evidence within the basin.

Population shifts have been constant throughout the basin's history. Droughts, economic fluctuations, mechanization, and urbanization have all affected the basin. The result has been a large out-migration of the rural population, rapid growth in the large metropolitan areas, mixed rates of growth in the smaller cities and towns, and an increase in industrialization (plate 1).

In 1960, about 3.4 million people, or 42.5 percent of the basin's population lived in rural areas or towns of less than 2,500. The remaining 4.5 million people lived in urban and metropolitan areas having populations of 2,500 or more, including the 37.2 percent of the basin's population living in 11 standard metropolitan statistical areas (SMSA's) (table 2).

The total population of the Missouri Basin increased 17 percent between 1940 and 1960. During this period, rural population decreased 17 percent and urban population increased 68 percent. Improved transportation and communication facilities, improved equipment and technology in agriculture, increased emphasis on manufacturing activities, and increased demands for recreation are some of the factors that influenced divergent rates of growth and shifts of population within the basin (see figures 6 and 7).

Many Communities Had Their Heyday Such as This Ghost Mining Town

FIGURE 6

POPULATION DENSITY-1960 BY COUNTIES

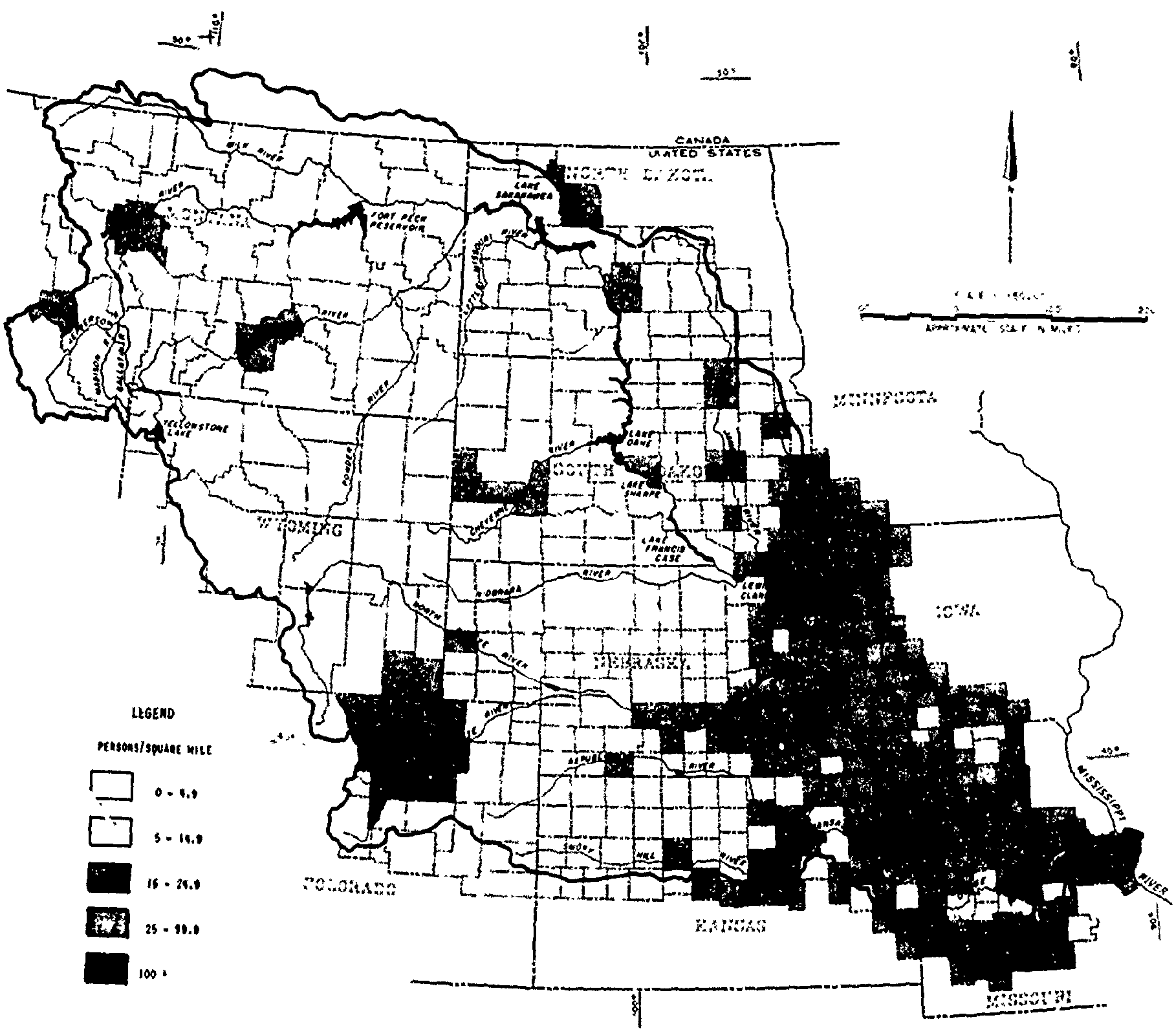


Table 2 – POPULATION DISTRIBUTION, URBAN AND RURAL, 1960

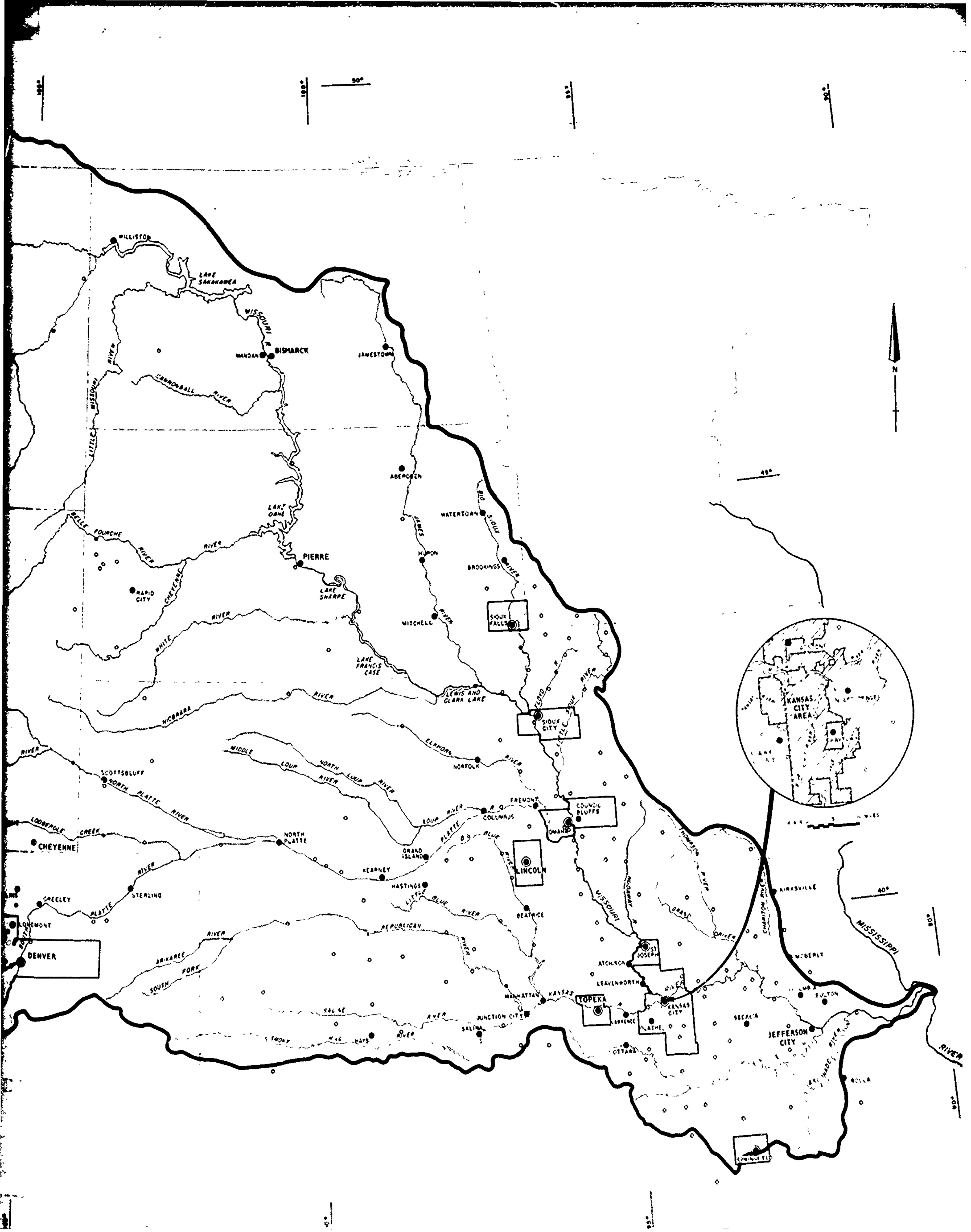
Category	Number	Percent of Population
Metropolitan Areas		
SMSA's over 50,000 population	11	37.2
Urban (towns)		
25,000 - 50,000	11	4.7
10,000 - 25,000	34	6.3
5,000 - 10,000	51	4.7
2,500 - 5,000	100	4.6
Rural (including towns less than 2,500)	--	42.5
Total	207	100.0

NATURAL RESOURCES

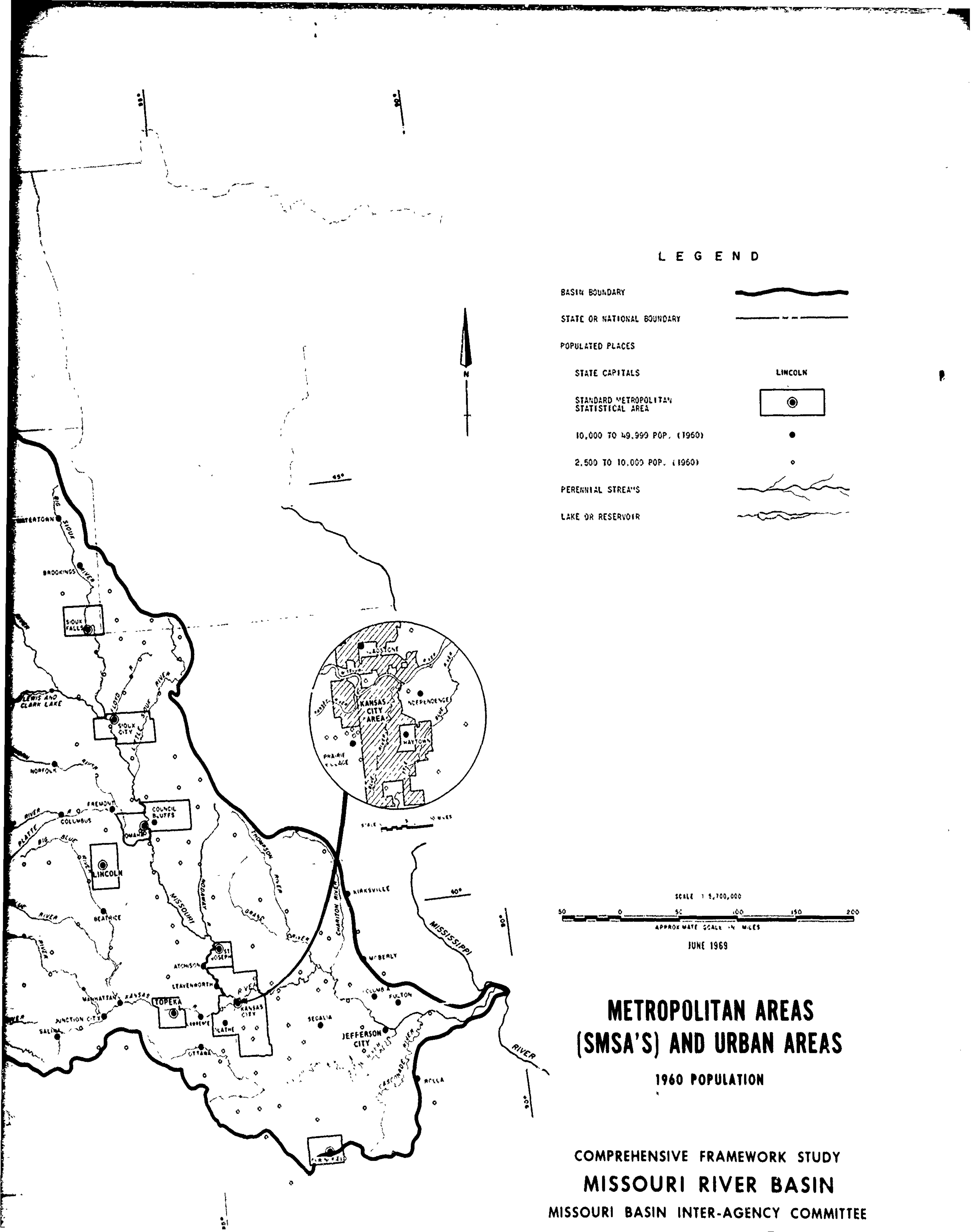
From land and water stem the natural and renewable resources of agriculture, grass, forests, recreation, fish, and wildlife. The land and water resources have the potential, if properly managed and skillfully developed, to contribute to the satisfaction of demands and to meet future regional and national needs.

The basin contains scenic mountains, narrow canyons, precipitous slopes, fertile valleys, broad plains, forests, grasslands, lakes, and streams. Below the surface are extensive supplies of groundwater, coal, oil, gas, and other minerals. All these natural resources have and will

LOCATION MAP
MISSOURI RIVER BASIN
HELENA
GREAT FALLS
HAVRE
WILLISTON
FORT PECK RESERVOIR
MILK RIVER
MARIAS RIVER
SUN RIVER
MISSOURI
MUSSELSHELL RIVER
BILLINGS
BOZEMAN
YELLOWSTONE
JEFFERSON RIVER
BIG HOLE RIVER
MADISON RIVER
GALLATIN RIVER
RED ROCK RIVER
YELLOWSTONE LAKE
SHOSHONE RIVER
BIGHORN
WIND RIVER
TONGUE RIVER
POWDER RIVER
SHERIDAN
LITTLE MISSOURI RIVER
CANNONBALL
BELLE FOURCHE RIVER
RAPID CITY
CHEYENNE
WHITE
NIOBRARA
CASPER
SWEETWATER RIVER
NORTH PLATTE R
LARAMIE RIVER
LARAMIE
SCOTTSBLUFF
NORTH PLATTE RIVER
LODGEPOLE CREEK
CHEYENNE
FORT COLLINS
GREELEY
STERLING
PLATTE RIVER
LONGMONT
BOULDER
DENVER
SOUTH
WESTMINSTER
THORNTON
ARVADA
WHEAT RIDGE
LAKEWOOD
DENVER AREA
AURORA
ENGLEWOOD
LITTLETON



WILLISTON
LAKE SAKAKAWEA
MISSOURI R.
MANDAN
BISMARCK
JAMESTOWN
CANNONBALL RIVER
LITTLE MISSOURI RIVER
ABERDEEN
LAKE OAHE
BELLE FOURCHE RIVER
CHEYENNE RIVER
WATERTOWN
BIG SIOUX RIVER
JAMES RIVER
HURON
PIERRE
BROOKINGS
RAPID CITY
LAKE SHARPE
MITCHELL
SIOUX FALLS
WHITE RIVER
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
NIOBRARA RIVER
SIOUX CITY
FLOYD R.
LITTLE SIOUX RIVER
ELKHORN RIVER
NORFOLK
MIDDLE LOUP RIVER
NORTH LOUP RIVER
SCOTTSBLUFF
NORTH PLATTE RIVER
FREMONT
COLUMBUS
COUNCIL BLUFFS
OMAHA
LOUP RIVER
PLATTE
LODGEPOLE CREEK
CHEYENNE
NORTH PLATTE
GRAND ISLAND
KEARNEY
LINCOLN
HASTINGS
LITTLE BLUE RIVER
BEATRICE
STERLING
GREELEY
LONGMONT
DENVER
REPUBLICAN
ARIKAREE
SOUTH FORK
KANSAS
MANHATTAN
TOPEKA
JUNCTION CITY
SALINA
HAYS
SMOKY HILL RIVER
ATCHISON
ST. JOSEPH
LEAVENWORTH
KANSAS CITY
LAWRENCE
OLATHE
OTTAWA
MISSOURI
THOMPSON RIVER
GRAND RIVER
CHARITON RIVER
KIRKSVILLE
MOBERLY
COLUMBIA
FULTON
SEDALIA
JEFFERSON CITY
OSAGE RIVER
ROLLA
SPRINGFIELD
MISSISSIPPI RIVER
KANSAS CITY AREA
N
40°
45°
90°
95°
100°



METROPOLITAN AREAS (SMSA'S) AND URBAN AREAS

1960 POPULATION

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

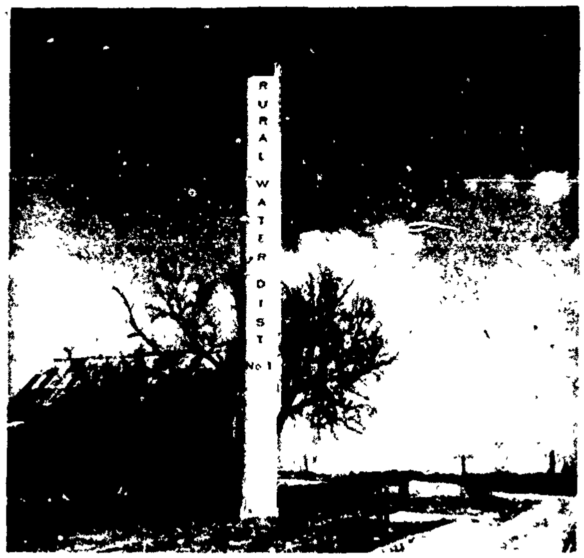
Table 3 – LAND AND WATER AREA

Subbasin	Water Area: Over 40 Acres	Water Area: Under 40 Acres	Water Area: Total	Land Area Total	Total Area
	(Thousand Acres)				
Upper Missouri	564	106	670	52,293	52,963
Yellowstone	273	72	345	44,853	45,198
Western Dakota	334	138	472	48,884	49,356
Eastern Dakota	662	240	902	36,402	37,304
Platte-Niobrara	466	188	654	63,021	63,675
Middle Missouri	125	49	174	15,571	15,755
Kansas	95	241	336	38,540	38,876
Lower Mis[illegible]ri	139	127	266	25,125	25,391
Missouri Basin	2,658	1,161	3,819	324,689	328,508

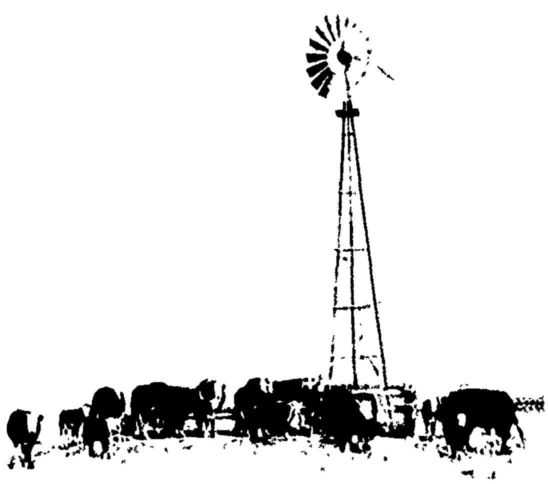
Source: Total area is U. S. Bureau of Census 1960 Land and Water Area, adjusted to basin boundary. Water areas over 40 acres include streams 1/8 mile in width or more. Water areas under 40 acres are from National Inventory of Soil and Water Conservation Needs, 1958, United States Department of Agriculture.

Table 4 – AVERAGE ANNUAL WATER FLOW PRODUCED IN EACH SUBBASIN AND AT HERMANN, MISSOURI, UNDER 1970 DEVELOPMENT CONDITIONS

Subbasin	Total Flow Produced by Subbasin Areas: Million Acre-Feet	Total Flow Produced by Subbasin Areas: Percent of Flow	Drainage Area: 1,000 Sq. Miles	Drainage Area: Percent of Drainage Area
Upper Missouri	7.7	14	92	17
Yellowstone	8.8	16	71	13
Western Dakota	2[illegible]	4	77	15
Eastern Dakota	3[illegible]	6	58	11
Platte-Niobrara	4.2	8	99	19
Middle Missouri	7.7	14	25	5
Kansas	4.2	8	61	12
Lower Missouri	17.3	30	40	8
Total	55.5	100	523	100
Less Main Stem Reservoir Evaporation	-1.9			
Remaining Flow at Hermann, Missouri	53.6			



Rural Water Systems Supply Areas Without Adequate Water

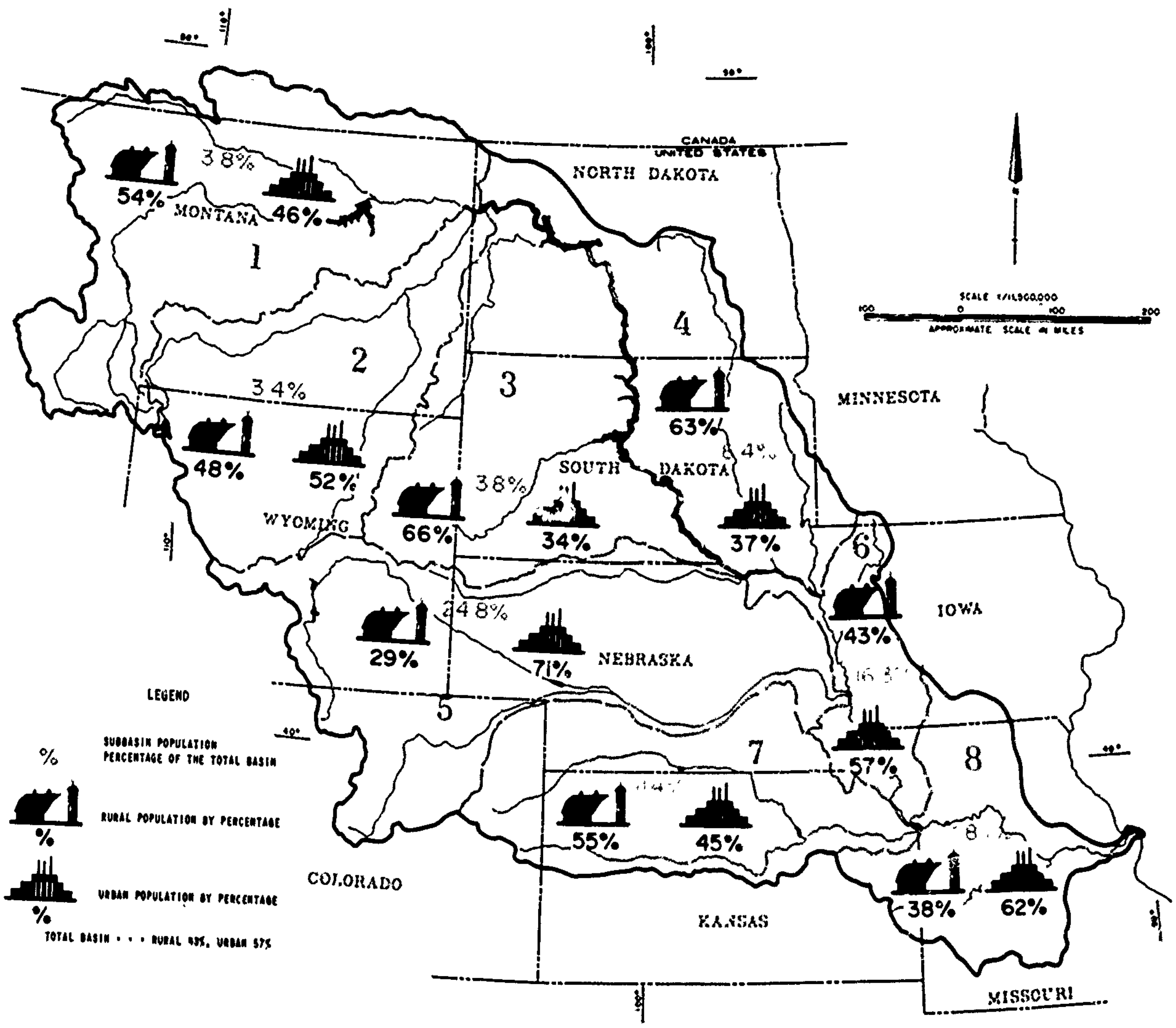


Water For Livestock Is Essential To Grazing

Most Rural Communities Are Dependent Upon Groundwater

FIGURE 7

POPULATION DISTRIBUTION-1960 BY SUBBASIN



continue to play a most important role in development of the basin.

One of the most important natural resources in the basin is its water which covers approximately 3.8 million acres. Of the total water surface, 2.7 million acres, or about 70 percent, comprise surface areas over 40 acres in extent and streams over one-eighth mile in width. About 1.1 million acres are in narrow streams and in water areas of less than 40 acres. There is wide variation among the eight subbasins in the distribution of water. The Eastern Dakota Tributaries Subbasin has the largest proportion of total water areas, about two and one-half percent of the subbasin being water area. In comparison, the Yellowstone Subbasin has the smallest proportion with only three-fourths of one percent being water area (table 3).

In most areas of the basin, the ground-water resources are related to the surface water resource. Ground water is the source of water for most of the rural population and smaller communities and for livestock on the Great Plains. Many areas in the basin are dependent on ground-water for municipal, industrial, domestic, and irrigation purposes.

The surface water of the basin is used and reused as it accumulates and flows to the mouth of the Missouri River. Under present conditions of development and usage, the estimated average annual flow of the Missouri River near its mouth at Hermann, Missouri, is 53.6 million acre feet. Table 4 shows the contributions to the Missouri River made by each of the subbasins.

The land resources of the Missouri Basin are closely associated with their present uses. The best method to describe these resources is to indicate the current uses and to give an idea of their potential for future expansion.

Agriculture

Today, as in the past, agriculture is the predominant means of livelihood and the major producer of wealth within the basin. No other major regions in the United States equal the Missouri Basin in the production of small grains and meat, the basin's specialities. Regularly, the basin produces a third or more of the Nation's wheat, 31 percent of its sorghum, 29 percent of its barley, 44 percent of its corn, and 21 percent of its oats. Also, the basin produces one-fourth of the Nation's red meat animals–cattle, hogs, and sheep. This is accomplished on only 15 percent of the land area within the United States.

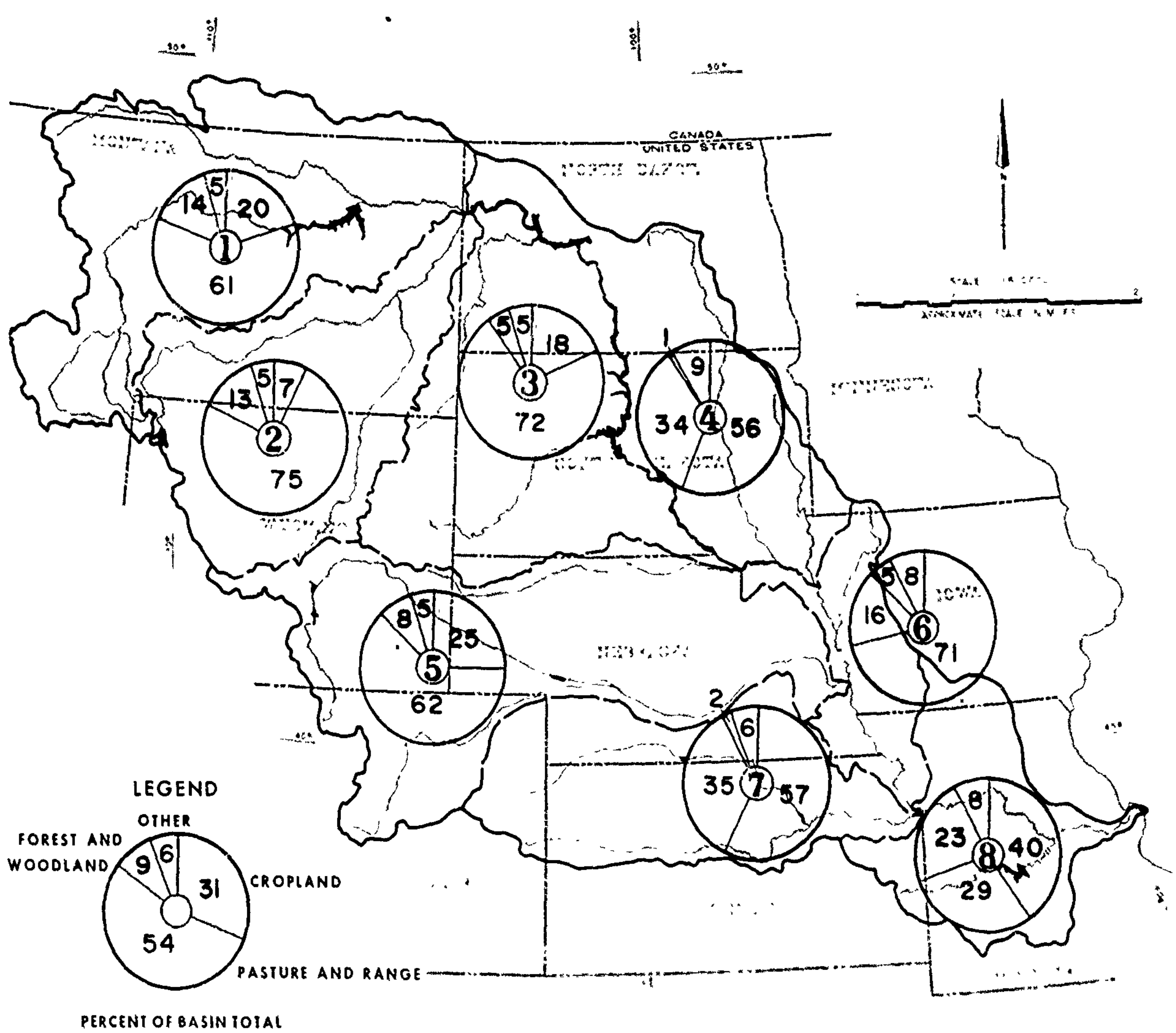
Much of the total economy of the basin, either directly or indirectly, is dependent upon agriculture. A large part of the non-commodity producing segment of the economy provides agricultural services such as machinery maintenance, feed grinding, fuel delivery, fertilizer, and similar services directly to the farmer. Food processing is the basin's largest manufacturing segment. The large livestock markets and numerous meat packing plants are important to the economy of the basin.

About 312 million acres of land in the basin are used for some agricultural purpose. Grasslands comprise the largest major use and account for 54 percent of the total area. In addition, about 31 percent of the land is cultivated, nine percent is in forest and woodland, and approximately six percent is devoted to miscellaneous agricultural and non-agricultural uses (see figure 8).

Shortage of water is a major limiting factor in agricultural production in the arid and semiarid climatic zones. Approximately 7.4 million acres, or seven percent, of the cropland are irrigated. Irrigation is practiced principally

FIGURE 8

MAJOR LAND USES



in the Upper Missouri, Yellowstone, Platte-Niobrara, and Kansas Subbasins.

Irrigation is important to the economy of several of the States. While surface water has made the greatest contribution, ground water provides one-fifth of the total irrigation water supply applied to about 30 percent of the irrigated land. Water for irrigation has contributed not only to increases in the production of crops and livestock, but to the stability of the total agriculture and overall economy of the region.

There are approximately 168 million acres, or 54 percent, of the Missouri Basin in grassland used for pasture

Irrigation In A Semi-Arid Region

and range for grazing of domestic livestock. About 86 percent of the pasture and range is in private ownership. About 14 percent is in the national forests, national grasslands, and in administrative districts of the public domain. Permits or leases are held by the farmers and ranchers for grazing their livestock on the Federal lands. The grassland areas are of major importance in the agricultural production and economy of the basin. In addition, these grasslands provide habitat for wildlife and are of vital importance to the existence of many wildlife species. The grasslands also provide areas for hunting and recreation.

Vast Expanses of Grassland are Utilized by Livestock

Forest and Woodland

Forest and woodlands comprise over nine percent of the Missouri Basin. There are two major forest types in the basin separated by the Great Plains (figure 9). Forests in the Lower Missouri Subbasin and adjacent tributaries east of the Great Plains are predominantly hardwood or broadleaf while those in the mountains are predominantly softwood or coniferous.

In the Lower Missouri Subbasin, woodlands cover one-fourth of the land area (table 5). They are almost all privately owned. Periods of poor markets for forest products have resulted in an accumulation of sawtimber stands. Half of the growing stock volume is in sawtimber trees, but the stands contain many cull trees. Sawtimber volume in the subbasin is mostly oak.

The 22 million acres of forest in the western portion of the Missouri Basin comprise 73 percent of all its forest lands. Fifteen million acres of this forest are commercially important for timber production. A large proportion of the forest lands is federally owned.

Elevation has an important bearing on the distribution of forests and their species composition. In the western portion of the basin, trees seldom grow at less than 4,000 feet above sea level, except along river bottoms. A big proportion of the forests at lower elevations, from 4,000 to 6,000 feet, consists of low quality stands of

FIGURE 9

MAJOR FOREST TYPES

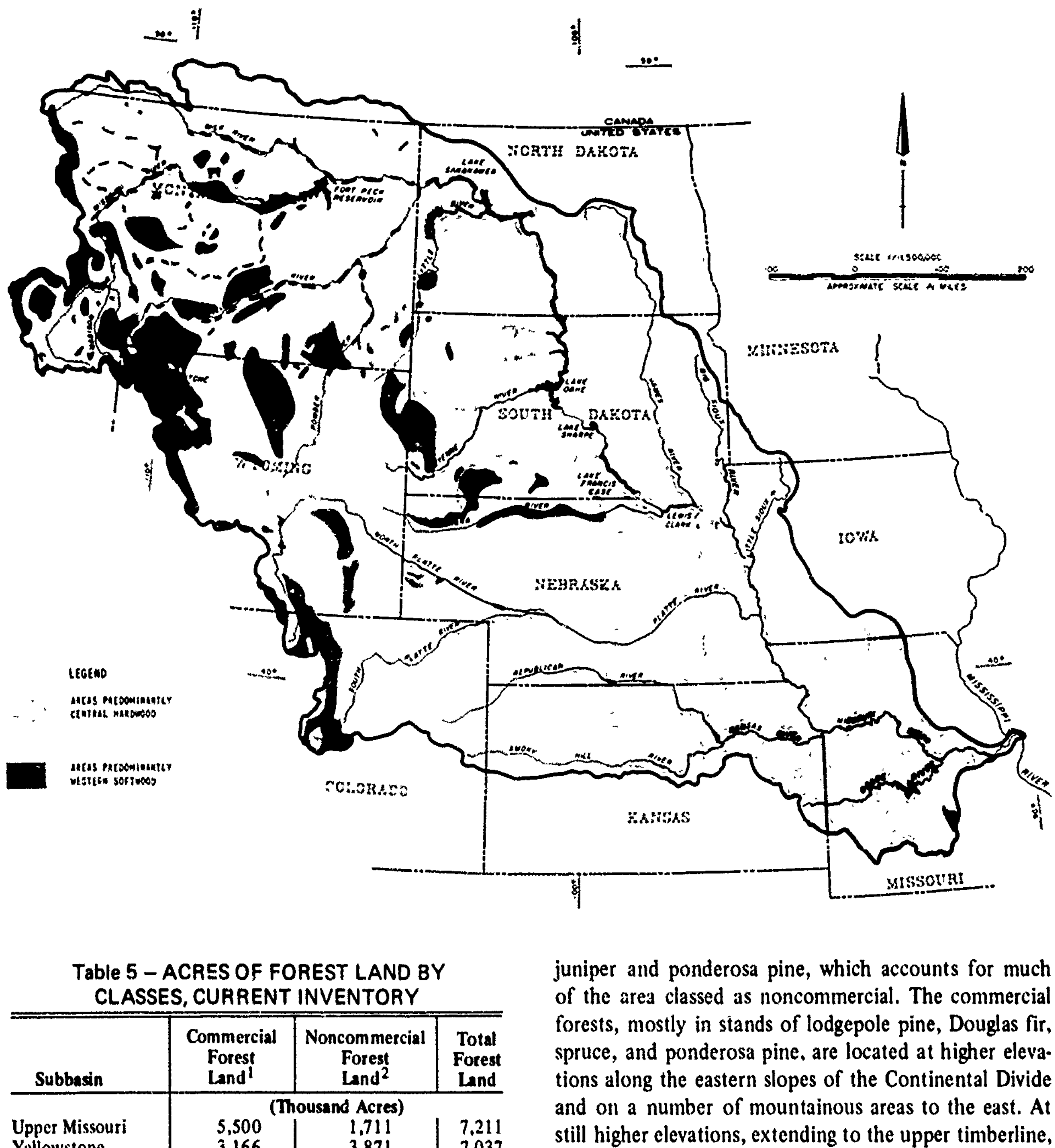
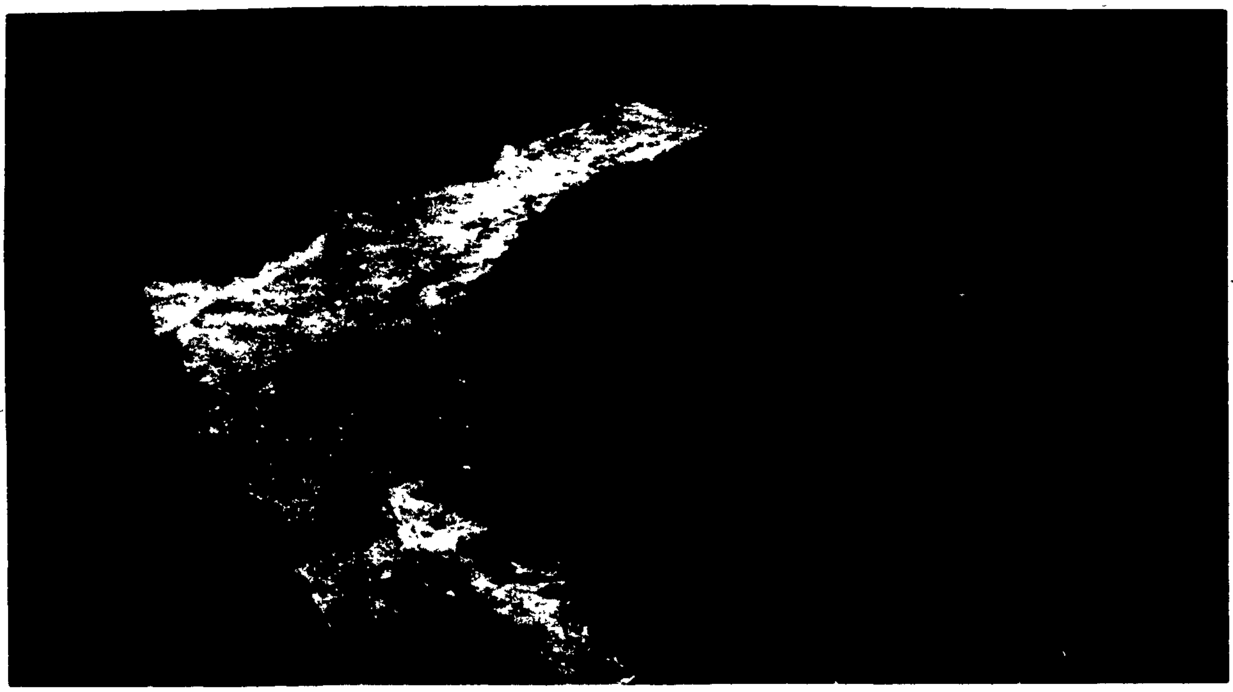


Table 5 – ACRES OF FOREST LAND BY CLASSES, CURRENT INVENTORY

Subbasin	Commercial Forest Land[1]	Noncommercial Forest Land[2]	Total Forest Land
	(Thousand Acres)		
Upper Missouri	5,500	1,711	7,211
Yellowstone	3,166	3,871	7,037
Western Dakota	2,218	206	2,424
Eastern Dakota	129	31	160
Platte-Niobrara	4,150	978	5,128
Middle Missouri	1,019	17	1,036
Kansas	500	20	520
Lower Missouri	6,651	206	6,857
Missouri Basin	23,333	7,040	30,373

[1]Forest land that is producing, or is capable of producing, crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation.
[2]Unproductive forest land incapable of producing crops of commercial industrial wood. This also includes productive forest land withdrawn from commercial timber use through statute or administrative regulations.

juniper and ponderosa pine, which accounts for much of the area classed as noncommercial. The commercial forests, mostly in stands of lodgepole pine, Douglas fir, spruce, and ponderosa pine, are located at higher elevations along the eastern slopes of the Continental Divide and on a number of mountainous areas to the east. At still higher elevations, extending to the upper timberline, there are additional noncommercial forest areas. The sites are rugged and the trees are largely subalpine fir, whitebark pine, and spruce.



Western Coniferous Forest

Minerals

Mineral resources of the Missouri River Basin are most conveniently described by grouping the many mineral commodities into three categories–metallics, nonmetallics, and fuels.

Metallic mineral resources are generally associated with mountainous areas and their peripheral outwash plains. Metallic ores are produced in significant quantities from the mountainous areas of central Montana, central Wyoming, north-central Colorado, and from the Black Hills of South Dakota. Principal mineral production includes gold, silver, copper, lead, zinc, molybdenum, and taconite with smaller amounts of minor minerals such as tungsten, beryllium, vanadium, chromium, uranium, and lithium.

Uranium Mining

Nonmetallic minerals include construction materials; a number of fertilizer minerals such as phosphate, potash and gypsum; and minerals for chemicals such as fluorspar, lime, mica, salt, and bentonite clays.

Fossil fuels consisting of crude oil and coal reserves comprise much of the basin's mineral wealth. The annual production value of oil and gas has been considerably more than 750 million dollars in recent years, representing about two-thirds of the total annual value of mineral production of the basin. Petroleum production is expected to increase moderately through the year 2000 and to decline thereafter.

Recoverable coal reserves are estimated to be more than 450 billion tons, or about 55 percent of the Nation's total. The states of North Dakota, Montana, and Wyoming possess about 80 percent of the basin's recoverable coal. However, with the exceptions of Nebraska and the small southwest section of Minnesota, all basin states have substantial coal reserves.

Most of the basin's coal is lignite or sub-bituminous. Its long-range future may be determined in large part by current research in synthetic liquid fuels, manufactured gasses, and coal chemicals. A sharp increase is anticipated in the use of the basin's coal for generation of thermal-electric power.

Fish and Wildlife

Fish and wildlife resources of the Missouri River Basin are among the most outstanding in the Nation. Much of the Nation's best big game, upland game, and waterfowl hunting and coldwater fishing is in the basin. Each year these resources attract large numbers of fishermen and hunters from all parts of the Nation. The basin also produces large numbers of migratory birds which are hunted in other parts of the Nation.

Forests Provide Outdoor Recreation

Deer -- The Major Big Game in the Basin

from north and northwest in winter. Although the mountain and foothill areas have less wind movement than the plains, wind directions there have greater local variation. Maximum wind velocities range between 45 and 120 miles per hour with the higher velocities recorded in the Great Plains. Average monthly wind velocities range between seven and 13 miles per hour.

High winds with high temperatures increase evaporation, damage or dry out crops, and frequently cause severe dust storms in some areas. These hot dry winds are frequent during the spring and summer months.

During the winter, in most parts of the basin, blizzards are a normal hazard. These blizzards are often a menace to human life, livestock, wildlife, and property as well as to public services and transportation.

Annual precipitation is perhaps the most critical climatic factor since it affects directly the economic health of agriculture, the basin's primary industry. The amount of annual precipitation, its form, and its seasonal variation are related to the topographic areas within the basin. As a generalization, the annual precipitation patterns can be broken into three board classes which are related to the mountainous areas, the Great Plains, and the Central Lowlands.

The highest average annual precipitation within the basin occurs in the mountainous areas, ranging to over 40 inches in portions of the Rocky Mountains and the Ozarks. In the western mountains, much of the annual precipitation occurs as snow in the winter. Average snowfalls of 100 inches or more are common throughout the Rockies.

Mountain snow packs form important reservoirs of water, and melting snow during the spring and early summer supplies much of the annual stream flow in the basin. Much of the irrigation is dependent upon these snow-fed flows.

The Rocky Mountain area produces significantly higher annual runoff than other parts of the basin. Due to the melting of the snow packs, monthly runoff is greatest during the late spring months and decreases through the summer, fall, and winter. The base flows for most streams are sustained by melting snow and summer precipitation, much of it entering the streams as groundwater. In general, runoff increases with elevation.

Some flood flows in the Rocky Mountains occur in the warm season, usually as flash floods. High peak discharges are produced by relatively low volumes of flood runoff. The larger annual floods on streams with appreciable drainage are frequently caused by combined snowmelt and rainfall. In the smaller streams, rainfall is the primary cause of floods.

The Ozark Plateaus area yields average annual runoff in the range of from six to 12 inches. Flood runoff is comparatively high. The groundwater flow of most streams is moderate to high because of the numerous springs draining the aquifers of the area. Flood flows are

Accumulated Snow Contributes to a More Constant Streamflow Throughout the Year

CHAPTER 2

LAND OWNERSHIP AND MANAGEMENT

OWNERSHIP

All of the Missouri Basin, in the United States, was included in the Louisiana Purchase of 1803. Title to the Louisiana Territory was delivered to the United States thereby placing all of the area in Federal ownership at the time of the purchase. Through sales, land grants, and various special and limited homestead acts passed by the Congress, most of the area passed to private and state ownership. Current ownership is shown in table 6.

Within the "private-county-state" category, the farmers and ranchers are the largest landowners in the basin. State-owned lands, mostly school-grant lands amounting to about four percent of the basin, are grouped with private lands as they are generally leased by the farmers and ranchers for agricultural purposes. Indian-owned lands are privately owned lands for which title is held in trust by the United States and for which the United States has certain management responsibilities as trustee. Lands owned by the United States are managed by several Federal agencies: The Forest Service, 19.4 million acres; Bureau of Land Management, 18.5 million acres; National Park Service, 2.3 million acres; Corps of Engineers, 2.0 million acres; and the Bureau of Reclamation, 1.0 million acres. Lesser acreages are managed by

Table 6 – LAND AND WATER OWNERSHIP

Subbasin	Unit	Total Subbasin Area	Subtotal Non-Federal State, County and Private[1]	Subtotal Federal	National Forest System	Public Domain	National Park System	Public Works	Reclamation	Other Federal[2]
		(Thousand Acres)								
Upper Missouri	Ac.	52,963	39,363	13,600	5,923	5,901	673	609	248	246
	%	100	74	26	11	11	1	1	1	1
Yellowstone	Ac.	45,200	29,766	15,434	5,830	7,750	1,250	0	536	68
	%	100	66	34	13	17	3	0	1	*
Western Dakota	Ac.	49,356	43,091	6,265	3,743	1,275	214	585	74	374
	%	100	87	13	8	3	*	1	*	1
Eastern Dakota	Ac.	37,304	36,529	775	3	3	0	599	6	164
	%	100	98	2	*	*	0	2	*	*
Platte-Niobrara	Ac.	63,675	55,807	7,868	3,694	3,586	170	5	110	303
	%	100	88	12	6	6	*	*	*	*
Middle Missouri	Ac.	15,744	15,696	48	0	0	0	27	0	21
	%	100	99	1	0	0	0	*	0	*
Kansas	Ac.	38,875	38,510	365	0	2	0	146	98	119
	%	100	99	1	0	*	0	1	*	*
Lower Missouri	Ac.	25,391	25,063	328	177	0	0	38	0	113
	%	100	99	1	1	0	0	*	0	*
Missouri Basin	Ac.	328,508	283,825	44,683	19,370	18,517	2,307	2,009	1,072	1,408
	%	100	86	14	6	6	1	1	*	*

Source: Data from Federal agencies and National Inventory of Soil and Water Conservation Needs, 1958, USDA.
Total is Bureau of Census 1960 Land and Water Areas, adjusted by basin boundary.
*Less than 0.5 percent and 1,000 acres.
[1]Includes Indian-owned land to which title is held in trust by the United States.
[2]Includes Federal lands managed by the Agricultural Research Service, the Bureau of Sport Fisheries and Wildlife, the Military, and the Federal lands administered by the Bureau of Indian Affairs which are predominantly submarginal, and also include school and administrative sites.

the Military, the Bureau of Sport Fisheries and Wildlife, the Bureau of Indian Affairs, and the Agricultural Research Service

Private land ownership including state and local government-managed lands amounts to 284 million acres, or about 86 percent of the total. Federally owned and managed lands amount to 45 million acres, or about 14 percent of the total area. The distribution of ownership varies by subbasins with private land ownership being the highest in the Middle Missouri Tributaries Subbasin where 99.7 percent of the area is in non-Federal ownership. The lowest percentage (approximately 66 percent) of non-Federal ownership is in the Yellowstone Subbasin.

Figure 10 shows the land and water ownership for each subbasin. The location of the Federal lands is shown in plate 2.

MANAGEMENT AND ADMINISTRATION

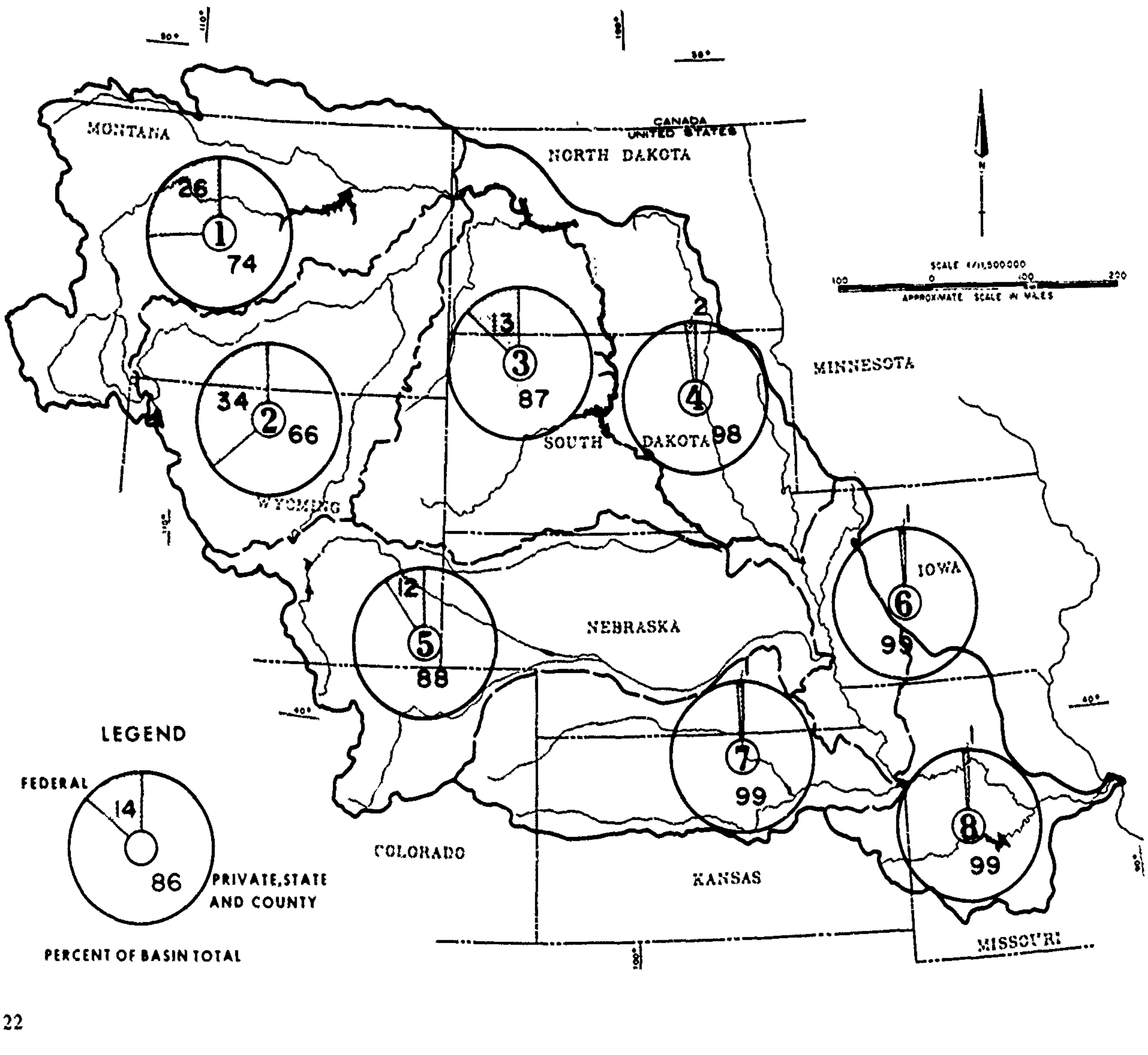
The management of the basin lands falls into two broad categories–private and Federal. Since the percentages of lands owned by the Indians, the States, and local governments are small, they have been included with the private lands (table 6).

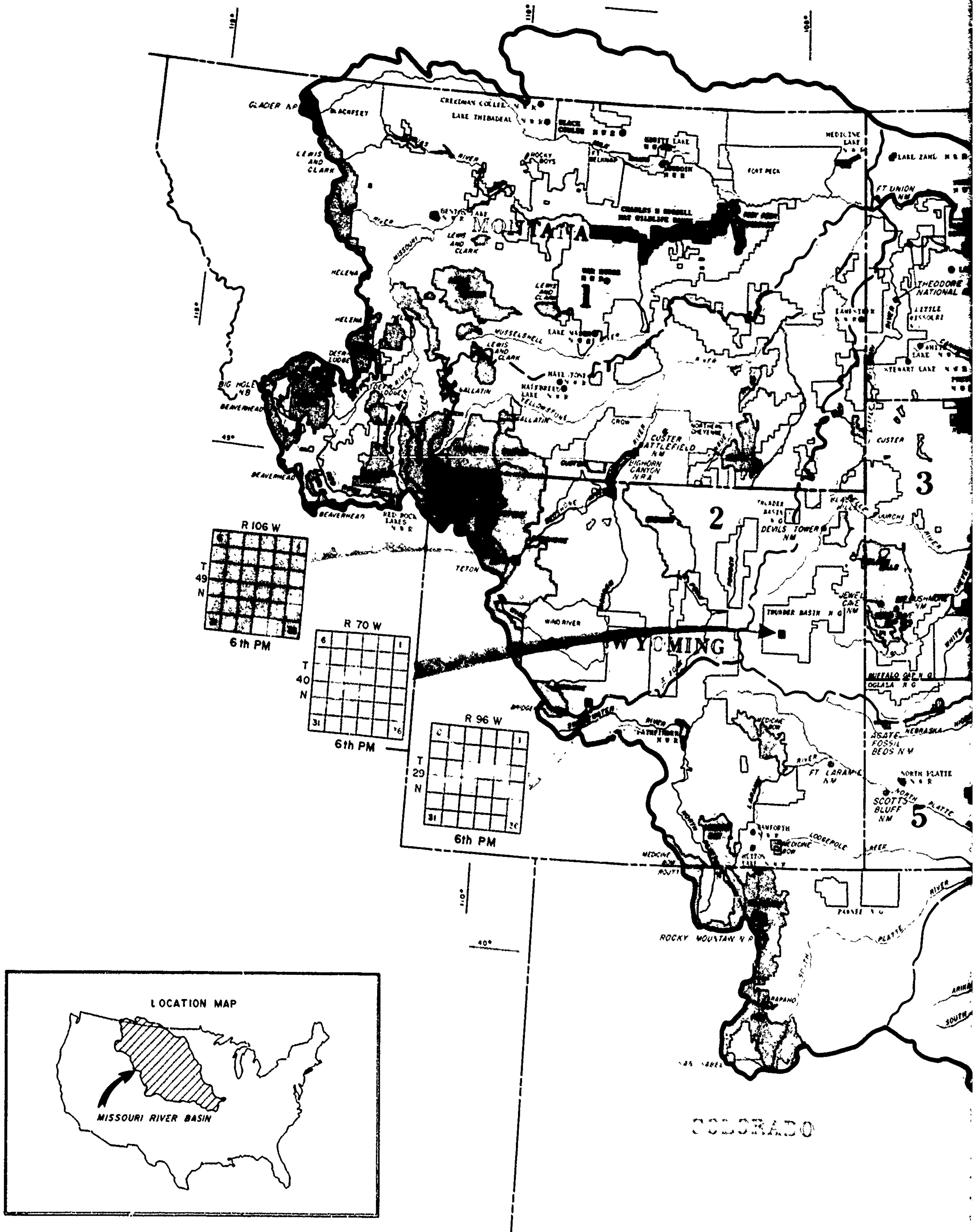
Private Lands

The management of private lands within the basin is vested with thousands of individuals, corporations, and legal entities. Except for some general restrictions, such as taxes and zoning laws, these individual managers have traditionally had the right to use their land much as they saw fit. It has been the decisions of these managers which have determined the present patterns of land use.

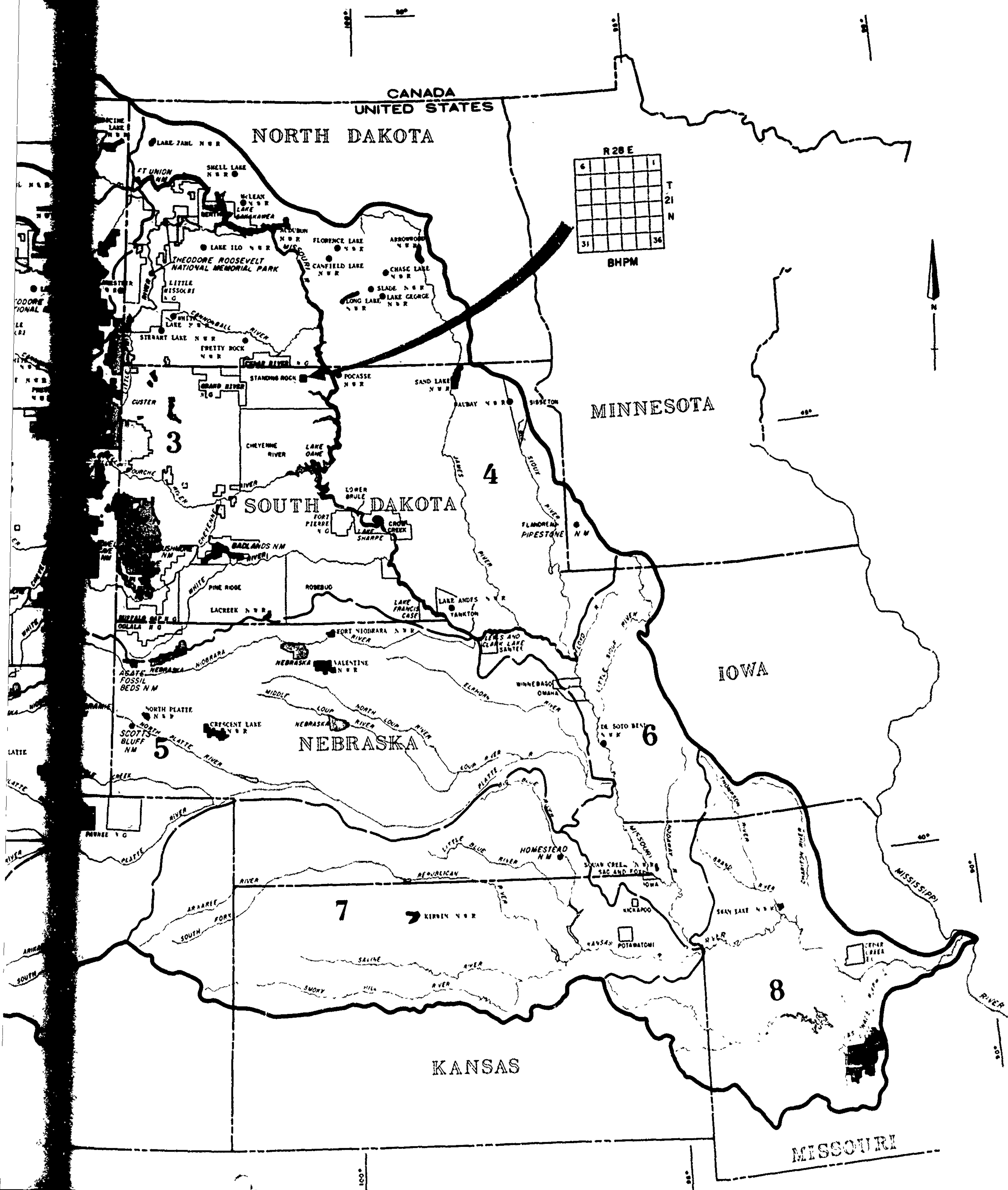
FIGURE 10

LAND AND WATER OWNERSHIP





MONTANA
WYOMING
COLORADO
1
2
3
5
GLACIER NP
LEWIS AND CLARK
HELENA
BIG HOLE NB
BEAVERHEAD
MISSOURI
MUSSELSHELL
YELLOWSTONE
GALLATIN
FORT PECK
CHARLES M RUSSELL NAT WILDLIFE RANGE
FT UNION NM
THEODORE NATIONAL
CUSTER BATTLEFIELD NM
BIGHORN CANYON NRA
DEVILS TOWER NM
JEWEL CAVE NM
THUNDER BASIN N G
WIND RIVER
TETON
BUFFALO GAP N G
OGLALA N G
AGATE FOSSIL BEDS N M
FT LARAMIE NM
SCOTTS BLUFF NM
ROCKY MOUNTAIN N P
R 106 W
T 49 N
6th PM
R 70 W
T 40 N
6th PM
R 96 W
T 29 N
6th PM
LOCATION MAP
MISSOURI RIVER BASIN



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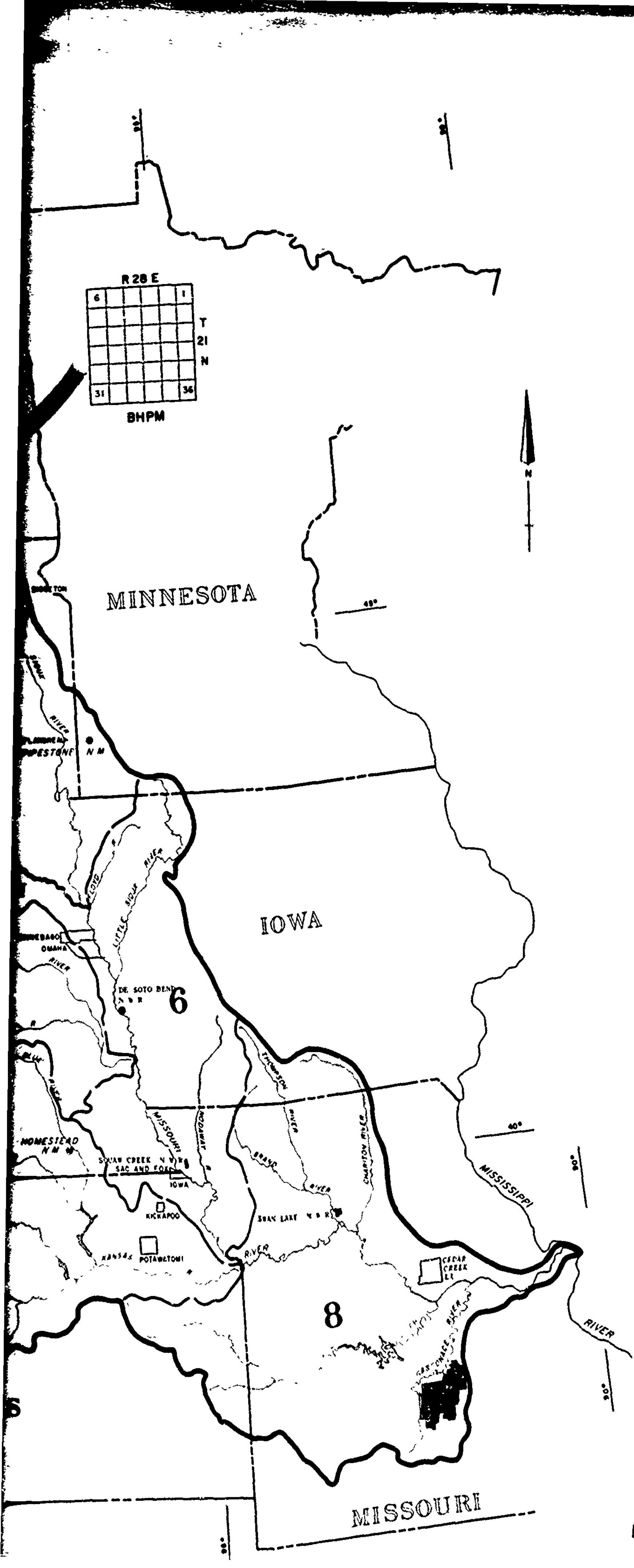


LEGEND

NATIONAL FOREST	
NATIONAL PARK, MONUMENT, BATTLEFIELD, OR RECREATION	●
NATIONAL GRASSLAND OR LAND UTILIZATION PROJECT	NG-LU
NATIONAL WILDLIFE REFUGE	●
INDIAN RESERVATION OR SETTLEMENT	
PUBLIC DOMAIN	
NON-FEDERAL LAND (PRIVATE, STATE, COUNTY, AND LOCAL)	

THE SCALE PERMITS ONLY MAJOR AREAS OF GENERAL LAND OWNERSHIP AND TRUSTEESHIP TO BE SHOWN, AND OMITS SCATTERED AREAS OF COMMINGLED FEDERAL, STATE, COUNTY AND LOCAL, AND PRIVATELY OWNED LANDS. EXCLUDED ARE MILITARY LANDS, RESERVOIR LANDS, FEDERAL AND STATE RIGHTS-OF-WAY AND MISCELLANEOUS LANDS. THE BOUNDARIES OF INDIAN LANDS, ESTABLISHED BY TREATIES AND PROCLAMATIONS, USUALLY ENCLOSE MORE ACREAGE THAN IS HELD IN TRUST.

BASIN BOUNDARY SUBBASIN BOUNDARY

1 UPPER MISSOURI SUBBASIN
2 YELLOWSTONE SUBBASIN
3 WESTERN DAKOTA SUBBASIN
4 EASTERN DAKOTA SUBBASIN
5 PLATTE-NIOBRARA SUBBASIN
6 MIDDLE MISSOURI SUBBASIN
7 KANSAS SUBBASIN
8 LOWER MISSOURI SUBBASIN

GENERALIZED

LAND OWNERSHIP STATUS
1965

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 2

Basically, the management practices in the private sector are controlled by economic conditions, and the resulting use of the private lands, in the broadest sense, is the optimizing of economic benefits. Thus, the broad patterns of livestock raising, cropping, timber, industry, and urbanization represent the best economic use of the land. Unless there is a major change in the general economic conditions of the Nation, the general land use patterns will continue into the future.

No large economic changes or massive shifts in primary land use within the basin are anticipated. However, there will be numerous small shifts in local patterns throughout the basin, and the total effect is expected to be a decrease, by a small percentage, in the land used for agriculture.

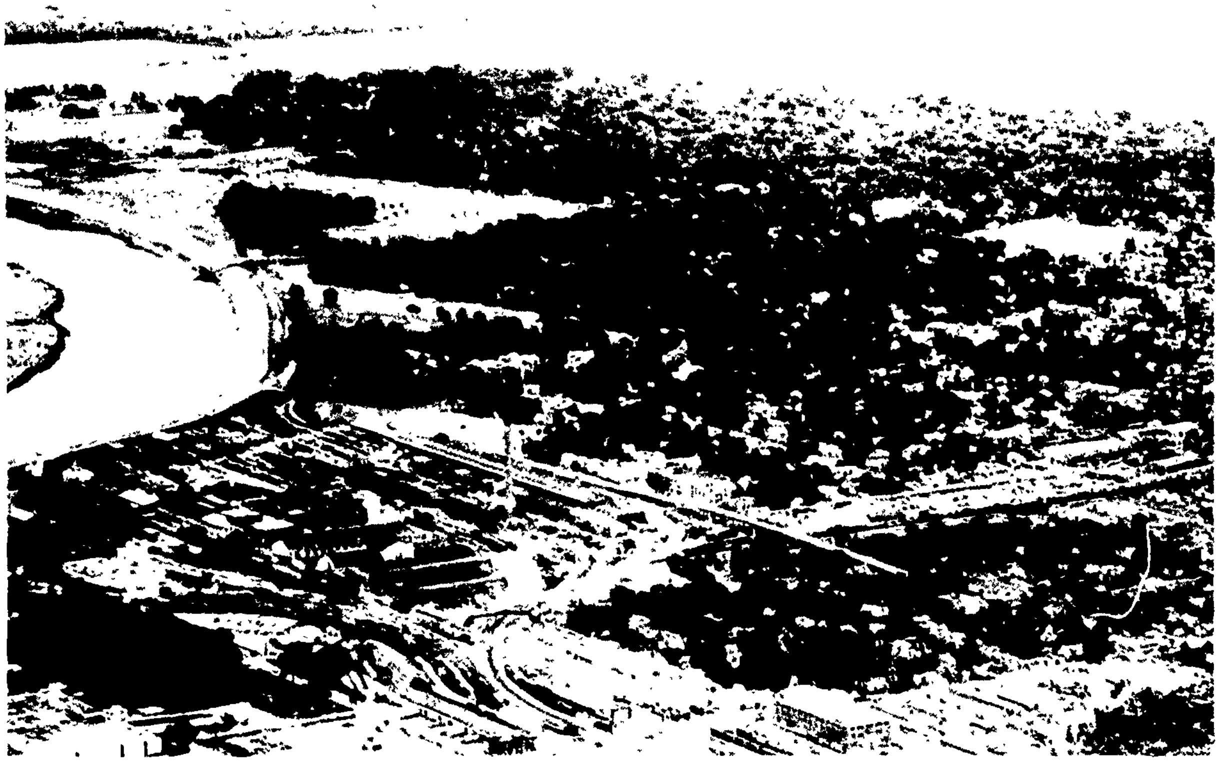
Even though shifts in primary land uses have not been large, the changes in management practices on the private lands have been significant. Perhaps three of the more important trends in management practices have been the consolidation of agricultural holdings, the intensifying of land use, and urbanization.

The consolidation of agricultural lands into fewer but larger units has been taking place for several decades. The obvious result of this consolidation has been the decrease in the number of landowners, but it has also speeded the adaptation of new management practices because the remaining landowners had the space upon which to use them. Particularly important have been mechanization, cropping practices, and conservation measures. It is expected that this trend will continue in the future.

Perhaps the most important trend in private land management is the increased intensity of use being made of agricultural lands. The cost squeeze between rising production costs and the stable or declining prices received for farm products has forced many agriculturalists to increase their efficiency in order to stay in business. The result has been an increasing implementation of such things as private irrigation, feedlot operations, and land and water conservation measures.

The third change in land management has resulted from the expansion of urbanization. There has been a continuing growth of the cities to accommodate the increasing numbers of people living in the basin. Although the total acreage affected is a small percent of the total basin, this change is significant because of the number of landowners involved and their density. This trend has increased the awareness that urbanization necessitates large, and often complicated, needs for specialized land management practices such as zoning, water run-off and flood control, transportation, recreation, and open space.

The drive of the private landowner, both urban and rural, to enhance his economic benefits is a potent force in land management. Such individual managers readily adopt those practices which will allow them to increase their economic returns while they resist those practices which interfere. Any future changes in land use or management practices which are considered desirable will have to cope with these responses from the private owners.



Much of the development in the planning framework for the basin is the expected private investment in new land practices and use, particularly irrigation. It is felt that these investments will occur unless they are legally constrained or unless economic incentives occur which emphasize differing goals.

Federal Lands

National Forest System– The National Forest System in the basin is comprised of all or parts of 18 national forests, eight national grasslands, and two Land Utilization Project areas totaling 19.4 million acres (table S-3). These lands are administered by the Forest Service of the Department of Agriculture.

As directed by Congress, renewable forest resources–water, timber, forage, wildlife, and recreation–are managed under the principles of multiple use and sustained yield. Multiple use means that resource management is coordinated so that areas of land produce a combination of values that best serves the American people. Sustained yield means that resources are managed so as to provide services and products at a level of supply as high as can be sustained without harming the land's ability to produce. Under such management, national forests represent the Nation's largest tangible accomplishment in forest resource conservation. There are many uses of the national forests, all tied together under comprehensive, coordinated multiple use plans.

Water from the forests irrigates agricultural lands and is used for domestic and industrial purposes. Timber from the forests is manufactured into wood products. National forests and national grasslands provide habitat for big and small game animals, game birds, and also fish. They also produce forage for cattle and for sheep. Outdoor recreation in the national forests includes scenic drives, wilderness travel, picnicking, camping, hiking, skiing, swimming, boating, and excellent fishing and hunting. The public has free access except where special user fees are charged for the use of well developed recreational facilities.

Timber from the national forests is harvested under term timber sale contracts by private logging and milling enterprises. Rangelands are used by ranchers for livestock grazing under paid permits. Most of the grazing permits are 10-year term permits to assure continued stability to the agricultural economy dependent upon this resource. Twenty-five percent of the income from the national forests and national grasslands goes to the states and counties where the forests are located for public roads and schools. In addition, ten percent of the income is returned to the Forest Service for construction and maintenance of forest roads and trails. The balance of 65 percent goes to the United States Treasury.

Public Owned Mountain Grasslands Provide Summer Range

The Forest Service gave early recognition to preservation of wilderness, and in 1924 the agency designated specific areas as wilderness areas within the national forests. The initial 1.6 million acres of the National Wilderness Preservation System created in 1964 are in nine national forests wildernesses, previously classified as Wilderness and Wild Areas. Another 900 thousand acres of the national forests, set aside in seven Primitive Areas, are being studied for possible inclusion in the Wilderness System (table 7 and plate 3). The wildernesses are an integral part of multiple use in the national forests. In management of these units, emphasis is placed on keeping and restoring the natural conditions for the many people who seek recreation and enjoyment away from civilization. Mechanized equipment is not permitted, except in cases of emergency involving lives or property; trees are not cut; and roads and all developments except foot and horse trails are prohibited. Fishing, hunting, camping, hiking, and grazing of domestic livestock are permitted.

Public Domain– The Bureau of Land Management manages the remaining public domain lands and resources, the basic administrative units being the eleven districts within the basin.

Within the Missouri Basin there are 18.5 million acres of public domain, located principally in Montana, Wyoming, Colorado, and the Western Dakotas. The basic Federal management objective for these lands is to achieve their maximum use in the public interest, consistent with conservation, and with development of the productive capacity of the renewable resources (table S-5).

The traditional concept of the public lands as a grazing resource only is gradually being broadened. In the Missouri Basin during periods of proper use, these lands support 1,200,000 cattle and twice that number of sheep. Over 190,000 big game animals graze the lands, utilizing forage reserved for their use. Approximately 26,000,000 board feet of sawtimber are cut annually. There are an estimated 1,440,000 annual recreation visits to the public domain. This includes those by sportsmen who harvest some 17,000 antelope, 27,000 deer, 53,000 upland game birds, and substantial numbers of other game and fish. Mineral products are extracted in quantity, particularly oil and gas; 37.5 percent of the revenue derived is returned to the state of origin, 52.5 percent to the Federal Reclamation Fund, and 10.0 percent to the United States Treasury. Public land watersheds contribute importantly to main-stem flows, and their vast acreages are being recognized for their contributions to the "open space" philosophy.

Public domain lands are managed by a decentralized organization with major responsibility delegated to its field representatives. Framework policies expressed by Congress are carried out to stabilize the livestock industry; conserve soil and other natural resources, to utilize and protect timber, mineral, and other resources, encourage such multiple uses as recreation and fish and wildlife utilization; and to make the lands available for urban occupancy and industrial development. Land classification is underway on a basinwide scale to designate areas adapted to continued Federal retention and management, for use and preservation of their public values, and to identify those needed in special local government programs and those best suited for private ownership.

Table 7 – NATIONAL WILDERNESS PRESERVATION SYSTEM

Unit	Area	Location		
		National Forest	State	Subbasin
Wilderness Areas:	(Thousand Acres)			
Anaconda-Pintlar	73	Beaverhead	Montana	Upper Missouri
Bob Marshall	240	Lewis & Clark	Montana	Upper Missouri
Gates of the Mountain	29	Helena	Montana	Upper Missouri
North Absaroka	351	Shoshone	Wyoming	Yellowstone
South Absaroka	506	Shoshone	Wyoming	Yellowstone
Teton	279	Shoshone	Wyoming	Yellowstone
Bridger	5	Bridger	Wyoming	Platte-Niobrara
Rawah	27	Roosevelt	Colorado	Platte-Niobrara
Mt. Zirkel	54	Routt	Colorado	Platte-Niobrara
Total	1,564			
Primitive Areas:				
Spanish Peaks	50	Gallatin	Montana	Upper Missouri
Absaroka	64	Gallatin	Montana	Yellowstone
Beartooth	175	Custer	Montana	Yellowstone
Stratified	204	Shoshone	Wyoming	Yellowstone
Glacier	177	Shoshone	Wyoming	Yellowstone
Popo Agie	70	Shoshone	Wyoming	Yellowstone
Cloud Peak	137	Bighorn	Wyoming	Yellowstone
Total	877			

***National Parks System*–** The National Parks System is composed principally of areas of land and water of exceptional scenic, historic, and recreational interest and value. In the national parks, all established by acts of Congress, geological features and all plant and animal life are carefully protected. The Act which established the National Park Service directs the Service to administer the areas of the National Parks System in accordance with the fundamental purpose of conserving their scenery, wildlife, natural and historic objects, and provide for their enjoyment "in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." They are, in a sense, great outdoor museums. Only such developments are permitted as are needed for the management, protection, and administration of the areas, or are required for the comfort and convenience of those who visit them for the recreation and inspiration they offer.

All animal species in the parks receive protection, subject to necessary controls. Virgin forests remain unlogged to go through their natural cycles. Grazing by domestic livestock is limited and is being steadily decreased; the ultimate objective is to eliminate it completely. National park lands, with a few exceptions specifically authorized by Congress, are not subject to mineral entry. Impoundment of lakes or streams for irrigation, hydroelectric power, or other purposes is opposed in accordance with the principle recognized when the parks and monuments were exempted from the provisions of the 1920 Federal Power Commission Act. The basic policy is to preserve nature, as created, and to provide areas for visitor appreciation and use.

The National Park Service administers 18 areas in the basin (plate 2). Three categories are used to classify park installations: Natural areas, historical areas, and recreational areas. Each year these properties, covering some 2.3 million acres, are enjoyed by more and more people (table S-5).

***Indian Reservations*–** Indian land within the Missouri River Basin is primarily concentrated within the reservation areas shown on plate 2. Title to this land is held in trust by the United States Government, but it is private land owned either by Indian tribes or by individual Indians. Although these reservation areas were at one time almost entirely in Indian ownership, land sales by individual Indians to non-Indians have resulted in many thousands of acres on these reservations now being owned in fee by non-Indians. However, almost 12 million acres of land in these reservation areas remain in tribal or individual ownership with the title held in trust by the United States. The acreages of Indian-owned land and Indian populations are as shown in table 8.

As a result of the title to Indian land being held in Federal trust, these lands are exempt from taxation, and because of this exemption, many state governments do not provide their Indian citizens all of the services that are provided for other citizens. In its role as trustee for Indian lands, the Federal Government, through the Bureau of Indian Affairs (BIA) generally performs the following functions: (a) supervises the leasing of both tribally owned and individually owned lands; (b) supervises the issuance of fee patents to individually owned lands that are sold to non-Indians, (c) supervises the sale of Indian timber, (d) supervises mineral leasing (including oil and gas), (e) assists in guarding against trespass on Indian lands, (f) develops and carries out land and water conservation programs, (g) assists in timber and range management, (h) maintains records of land titles, sales, and exchanges, and (i) receives and distributes income from surface leases, mineral leases, timber sales, and other sources.

In addition to the direct land management activities, special programs of the Bureau of Indian Affairs include activities in education, social welfare, law and order, credit, housing, employment assistance, road construction and maintenance, irrigation development and management, and other phases of economic development.

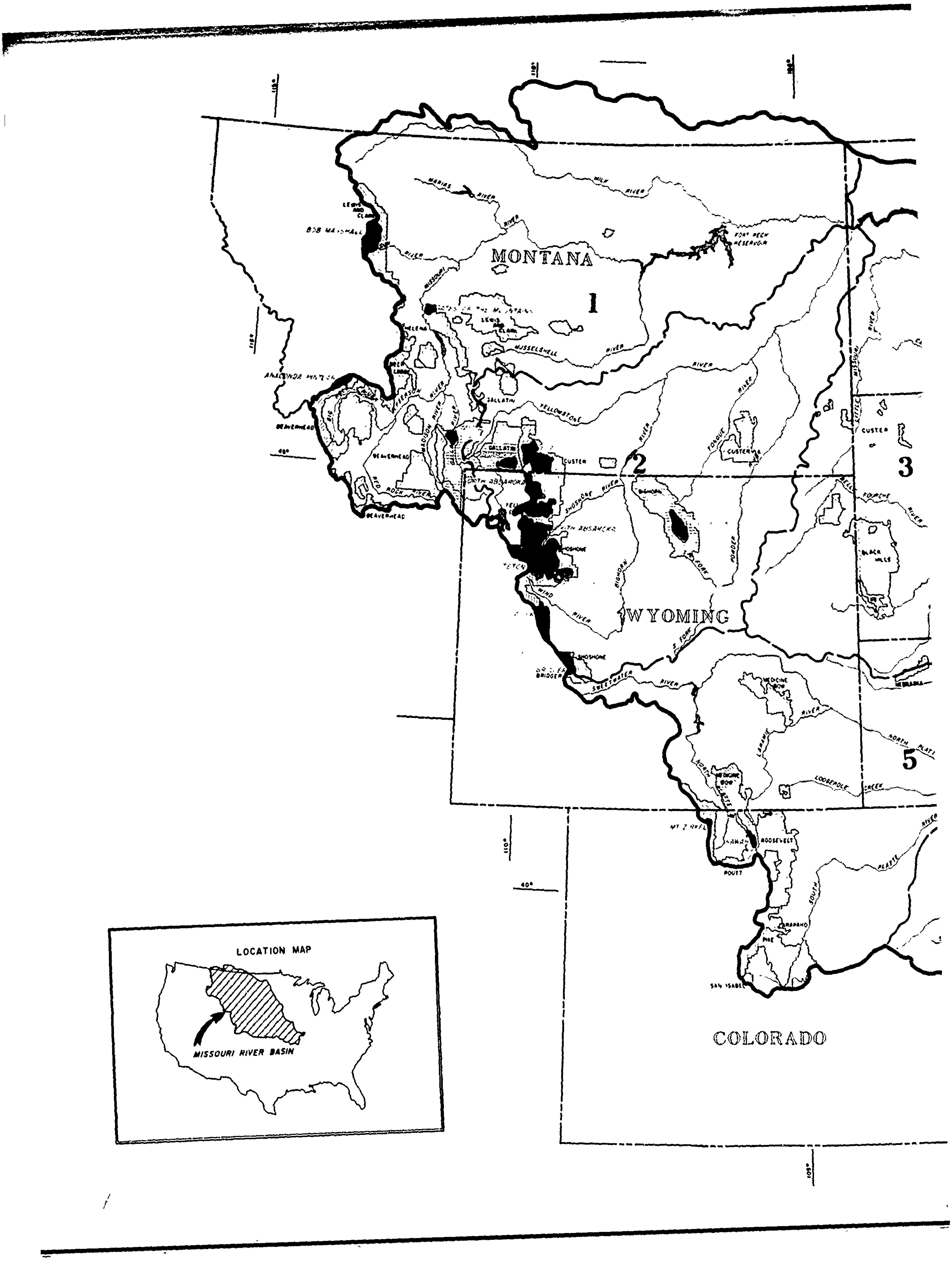
Table 8 – INDIAN-OWNED LAND AND POPULATION BY RESERVATION

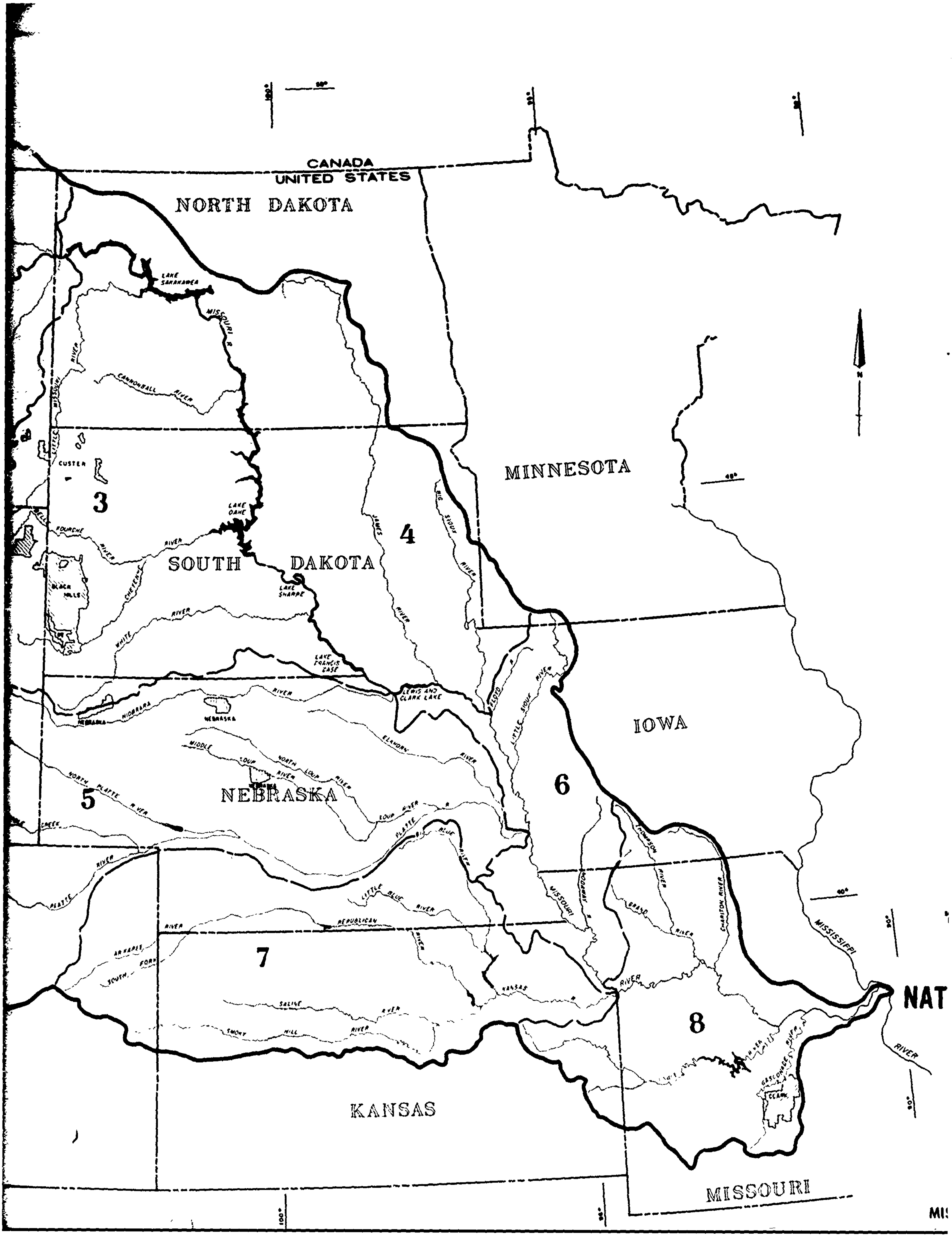
Reservation	Subbasin	1965 Indian-owned Land[1]	1965 Population
		(Acres)	(No.)
Blackfeet	Upper Missouri	945,008	6,600
Fort Belknap	Upper Missouri	595,768	1,635
Fort Peck	Upper Missouri	890,975	4,000
Rocky Boy's	Upper Missouri	107,612	880
Crow	Yellowstone	1,574,230	3,190
Northern Cheyenne	Yellowstone	433,227	2,495
Wind River	Yellowstone	1,887,372	3,580
Standing Rock	Western Dakota	851,866	4,640
Cheyenne River	Western Dakota	1,456,634	3,840
Fort Berthold*	Western Dakota	275,927	1,080
Lower Brule	Western Dakota	100,117	570
Pine Ridge	Western Dakota	1,501,394	9,600
Rosebud	Western Dakota	938,457	5,200
Yankton	Eastern Dakota	35,506	1,320
Crow Creek	Eastern Dakota	107,370	1,140
Fort Berthold*	Eastern Dakota	148,576	1,620
Sisseton[2]	Eastern Dakota	38,000	770
Santee	Middle Missouri	5,802	320
Omaha	Middle Missouri	27,703	1,090
Winnebago	Middle Missouri	29,368	750
Iowa	Middle Missouri	1,463	235
Sac and Fox	Middle Missouri	119	30
Kickapoo	Kansas	4,949	565
Potawatomi	Kansas	21,485	980
Missouri Basin		11,978,928	56,130

*Located in two subbasins, and land area and population distributed accordingly.

[1] Acres of land owned by Indians, the title of which is held in trust by the United States Government.

[2] Reservation land area and population within the hydrologic boundary of the Eastern Dakota Tributaries Subbasin, compares with a total of 108,621 acres, and 2,275 population in the entire reservation (see plate 2)


MONTANA
WYOMING
COLORADO
1
2
3
5
LOCATION MAP
MISSOURI RIVER BASIN
YELLOWSTONE
MUSSELSHELL RIVER
SWEETWATER RIVER
LARAMIE RIVER
SOUTH PLATTE RIVER
SHOSHONE
BEAVERHEAD
CUSTER
BIGHORN
BLACK HILLS
ROOSEVELT
ARAPAHO
PIKE



CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
KANSAS
MISSOURI
LAKE SAKAKAWEA
MISSOURI R
CANNONBALL RIVER
LAKE OAHE
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
JAMES RIVER
BIG SIOUX RIVER
LITTLE SIOUX RIVER
CHEYENNE RIVER
WHITE RIVER
NIOBRARA RIVER
ELKHORN RIVER
NORTH PLATTE RIVER
PLATTE RIVER
LOUP RIVER
NORTH LOUP RIVER
MIDDLE LOUP RIVER
BIG BLUE RIVER
LITTLE BLUE RIVER
REPUBLICAN RIVER
KANSAS R
SALINE RIVER
SMOKY HILL RIVER
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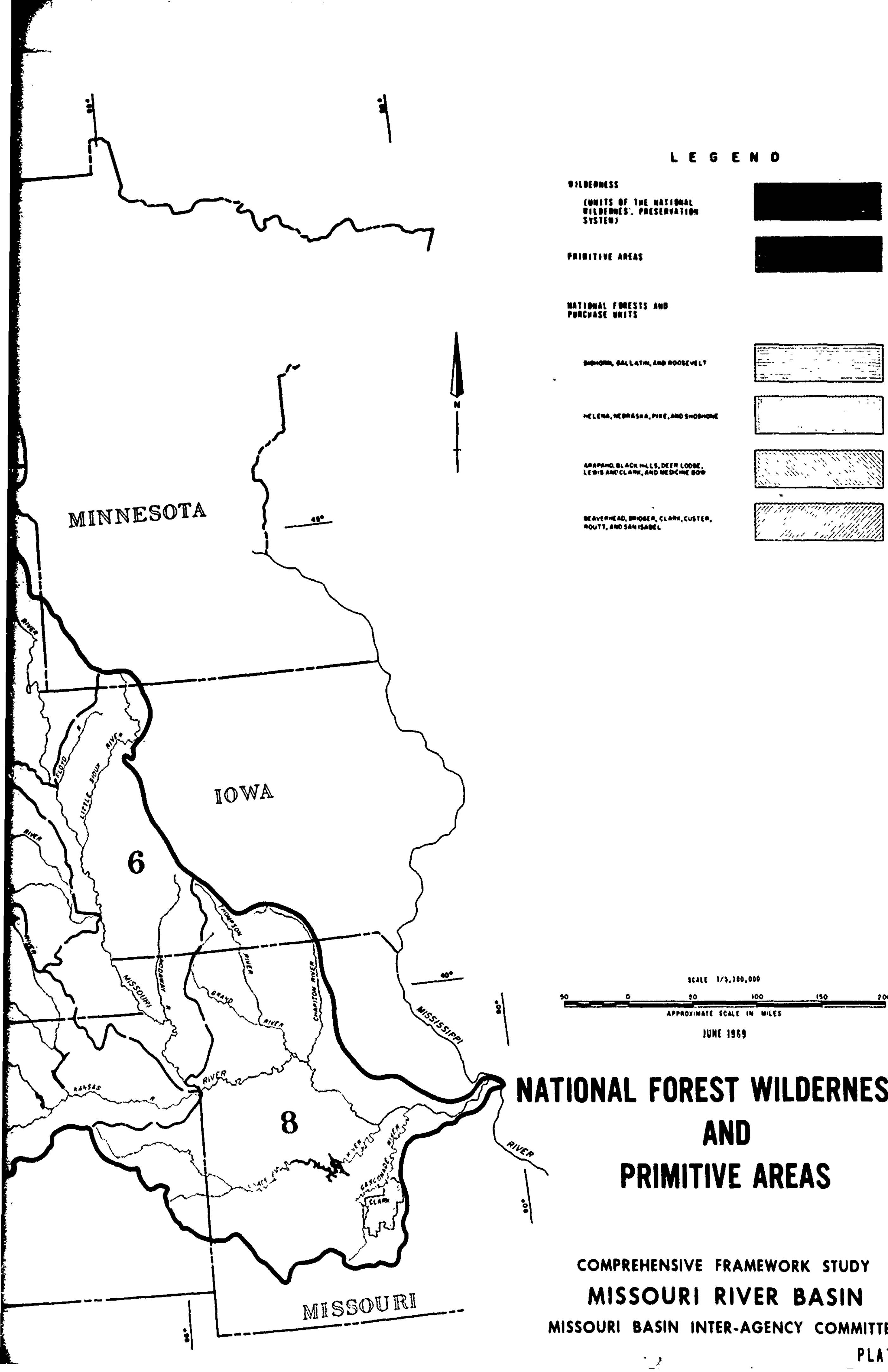


NATIONAL FOREST WILDERNESSES AND PRIMITIVE AREAS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 3

The U. S. Public Health Service provides medical facilities and other health oriented services. These programs stem from the trust relationship and the tax exempt status of Indian land.

The Bureau of Indian Affairs' role is that of supplying to the Indian people the technical services provided to non-Indians by other agencies. In nearly all of these activities the Bureau works closely with the tribal governments and is aware that attainment of the Indian's objectives will require the efforts of many agencies of both Federal and State government.

Reclamation Projects– The Bureau of Reclamation manages Federal lands that have been withdrawn and acquired for reclamation purposes. Multi-purpose management of these lands includes management for water storage, irrigation, and municipal water supplies, recreation, fish and wildlife, power, and project-service facilities (table S-5).

The operation and maintenance of the system of works, including associated lands for rights-of-way, normally is turned over to a local sponsor as soon as practicable after the project works have been tested. Annual or periodic joint inspections with district personnel help assure attention to proper operation, maintenance, and general management of the project works and lands. Operation of power facilities and sometimes dams, reservoirs, supply canals, and associated lands remains with the Bureau.

Flood Control Projects– The Corps of Engineers, Department of the Army, manages certain lands that were acquired primarily for flood control and for water resource development purposes. These lands are managed for multiple-purpose use that includes management for river flow control, flood control, power development, navigation, irrigation, municipal water supply, recreation, and fish and wildlife.

Civil work lands are also administered by the Corps of Engineers. These consist of over two million acres of land that were acquired primarily in fee or transferred from public domain for the construction and operation of water resource development projects, mostly reservoirs. Although the basic responsibility for management of project lands rests with the Corps of Engineers, Federal, State, and local governmental agencies do manage portions of the areas for various purposes including recreation and fish and wildlife. Some project lands are also made available by lease to private parties for agricultural purposes (table S-5).

Military– Military branches of the Department of Defense own and administer military areas such as Fort Leonard Wood, air bases, missile sites, and military cemeteries. Specific administration is by the respective Department (Army, Navy, or Air Force) that is using the land (table S-5).

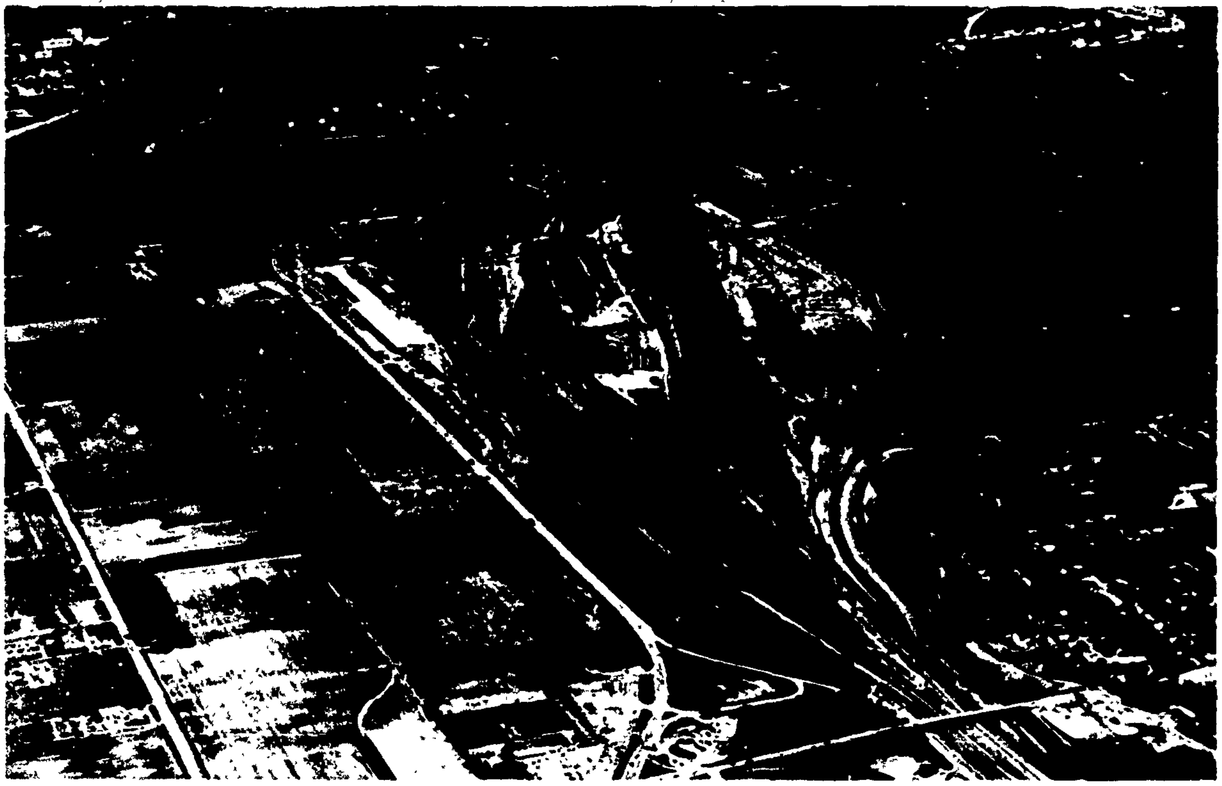
Military Uses Forest And Rangelands For Bivouac And Training Areas

Agricultural Research– The Agricultural Research Service conducts research relating to the production, utilization, and marketing of agricultural products, and to the control and eradication of pests and plant and animal diseases. It also conducts related research with respect to quarantine and to regulatory activities in marketing of farm products.

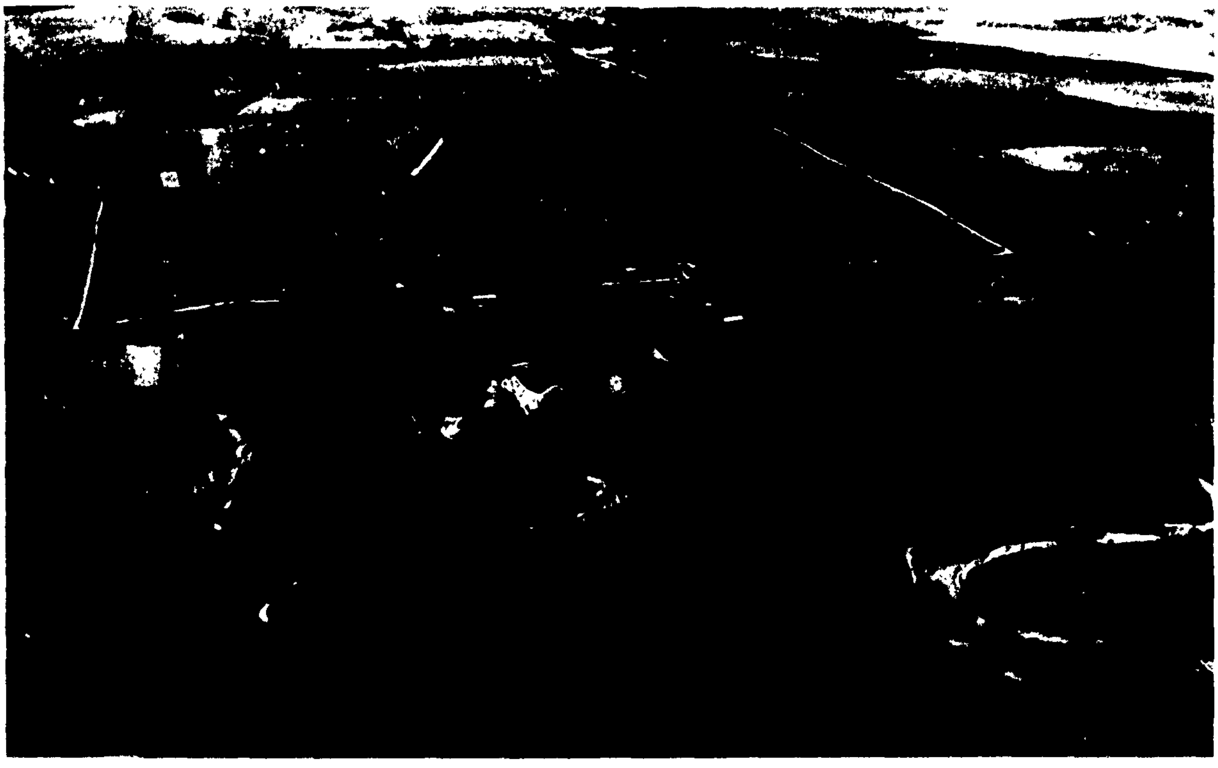
To carry out these assignments, the Agricultural Research Service administers and manages several tracts of land in the Yellowstone, Western Dakota, Platte-Niobrara, and Kansas subbasins (see table S-3). These lands include those withdrawn from the original public domain, lands acquired under Title III of the Bankhead-Jones Farm Tenant Act (7 U.S.C. 1010 **et seq.**), and lands acquired for research purposes.

Fish and Wildlife– The Bureau of Sport Fisheries and Wildlife administers tracts of Federal lands and waters in all subbasins (see table S-5). These include 65 National Wildlife Refuges, 10 National Fish Hatcheries, and 250 Waterfowl Production Areas (see plate 2). Management objectives are perpetuation of fish and wildlife species and the use and enjoyment of the fish and wildlife resources.

The National Wildlife Refuges contain 409,600 acres. They are managed for migratory birds, resident wildlife, endangered species, fish, and for the public enjoyment of natural resources. A principal purpose of the fish hatcheries is to enhance sport fishing through propagation and distribution of fish. Also, the Bureau of Sport Fisheries and Wildlife administers 250 tracts of Waterfowl Production Areas containing in all 48,000 acres. These areas were acquired and are managed to provide the best possible conditions for wildlife. The Bureau also administers about 1,400 acres in miscellaneous tracts acquired for specific fish and wildlife purposes.



Most Of The Agricultural, Transportation, Urban, And Built-Up Areas Are Privately Owned



CHAPTER 3

LAND CLASSIFICATION AND INVENTORY

LAND RESOURCE CATEGORIES

Information concerning land as a resource for agriculture, forestry, recreation, wildlife, and other uses in the basin has been assembled and classified in a national system that places all areas in the general categories of land resource regions, major land resource areas, land capability classes, and land capability units.

Land resource regions are geographically associated major land resource areas. They divide the United States into 20 physiographic regions which are sufficiently uniform to be significant for national planning. Parts of seven regions are in the Missouri Basin (figure 11). Table 9 lists the land resource regions of the basin with a brief description of the physical and climatic characteristics and principal crops.

Major land resource areas (LRA) are subdivisions of land resource regions and are defined as broad geographic areas having similar soil, climatic, geologic, vegetative, and topographic features. In the United States there are 156 such areas, of which all or parts of 40 are found in the Missouri River Basin. Table 10 lists the land resource areas of the basin along with a very brief description of the soils.

The land of the Missouri River Basin has a wide range of climatic and soil conditions and therefore a wide range in capacity for agricultural use. The National Inventory of Soil and Water Conservation Needs (CNI), 1958, USDA was used in developing acreages of land capabilities. Data from soil surveys were used in classifying the land. The inventory provides three major categories of land capabilities: (1) land capability class, (2) land capability subclass, and (3) land capability unit.

Of the 312 million acres of agricultural land in the basin, 273 million acres, which includes all privately owned land and all other land used for crop production, were classified into Department of Agriculture land capability units and classes. Land capability units (LCU), traditional soil classification nomenclature, and the smallest subdivision used in the study, are defined as "A grouping of one or more individual soil mapping units having similar potentials and continuing limitations or hazards. The soils are sufficiently uniform to produce similar crops, require similar conservation treatment, and have comparable productivity." Units are grouped into land capability classes and subclasses by subbasins in table S-54.

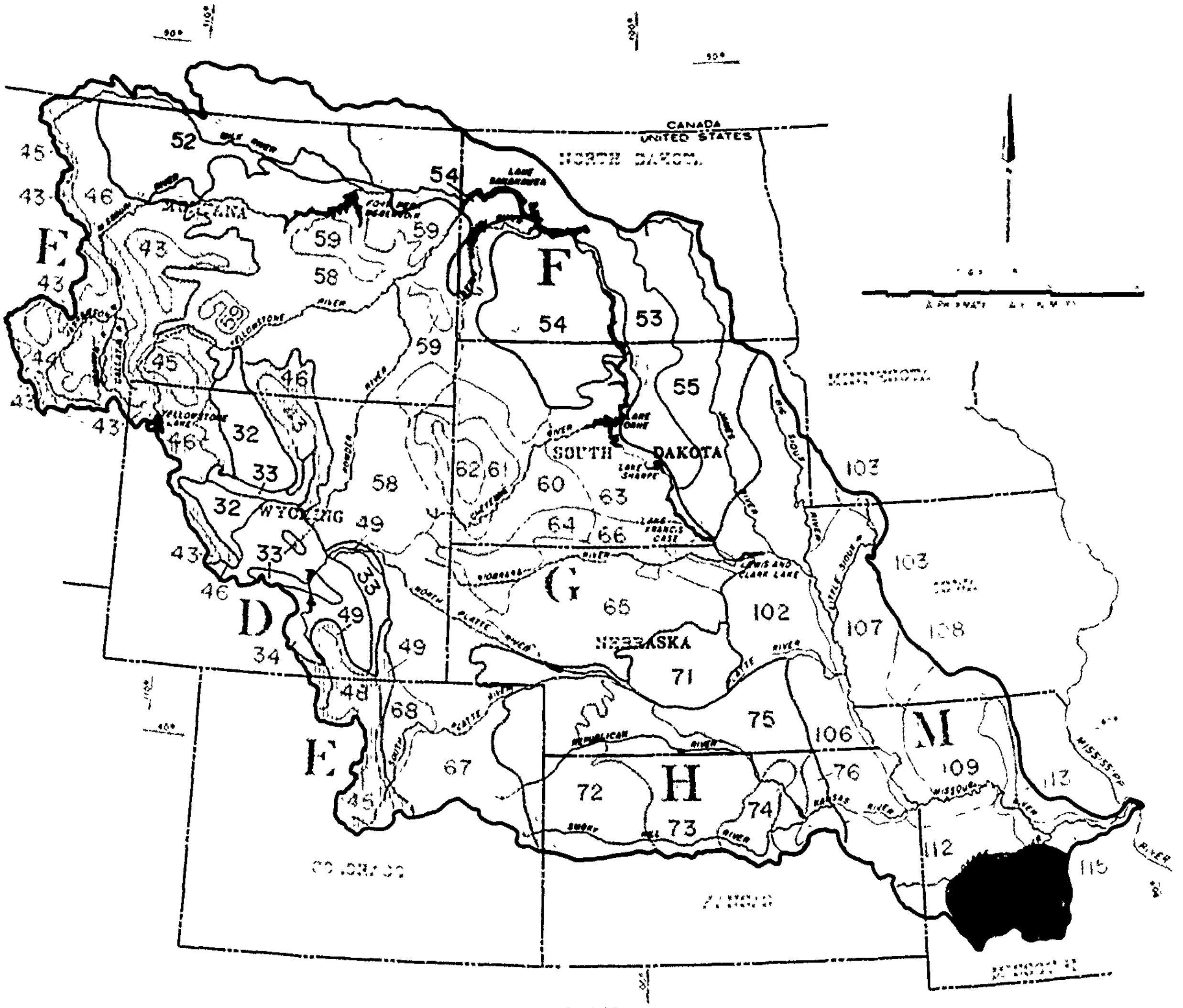
The land capability classes indicate potential for cultivation or other use and the intensity of soil problems. The risk of soil damage or the limitations in use become progressively greater from Class I to Class VIII. Land in Classes I through III is suitable for regular cultivation and a wide range of other uses; land in Class IV is marginal for cultivation; and land in Classes V through VIII is generally suitable for noncrop uses only. These land classifications are defined in figure 12.

The land capability subclasses are groups of capability units within land capability classes that have the same kind of dominant limitations for agricultural use. There are four subclasses of limitations designated by small letter. There are no subclasses in Class I. The subclasses are defined in figure 12.

In order to estimate the potential agricultural production capacity of the basin for study purposes from available soils information and Conservation Needs Inventory data, it was necessary to group soils of similar production capability rather than the traditional groupings of soils that emphasize erosion problems, climatic factors, and topographic features. Soil resource groups (SRG) reflect this similarity in production potential and are defined as "A grouping of land capability units, or soils that have similar cropping patterns, yield characteristics, response to fertilizer, management, and land treatment measures." This classification transcends land resource regions, land resource areas, and political boundaries. Present and projected yields, cropping patterns, production costs, and other production data were developed for soil resource groups. By using a 3-digit numbering system, the SRG groupings lend themselves to machine data processing and the production information can be aggregated or disaggregated in accordance with study requirements. Table S-45 describes the soil resource groups. Land capability units are listed by soil resource groups in the Statistical Supplement of this Appendix.

FIGURE 11

LAND RESOURCE REGIONS AND MAJOR LAND RESOURCE AREAS



LEGEND

D WESTERN RANGE AND IRRIGATED REGION

- Northern Intermountain Desertic Basins
- [illegible]
- Central Desertic Basins, Mountains, and Plateaus
- [illegible]

E ROCKY MOUNTAIN RANGE AND FOREST REGION

- Northern Rocky Mountains
- Northern Rocky Mountain Valleys
- [illegible]
- Northern Rocky Mountain Foothills
- [illegible]
- [illegible]

F NORTHERN GREAT PLAINS SPRING WHEAT REGION

- [illegible]
- [illegible]
- [illegible]
- [illegible]

G WESTERN GREAT PLAINS RANGE AND IRRIGATED REGION

- Northern Rolling High Plains
- Northern Smooth High Plains
- Pierre Shale Plains and Badlands
- Black Hills Foot Slopes
- Black Hills
- Rolling Pierre Shale Plains
- [illegible]
- Nebraska Sand Hills
- Dakota - Nebraska Eroded Tableland
- Central High Plains
- [illegible]

H CENTRAL GREAT PLAINS WINTER WHEAT AND RANGE REGION

- Central Nebraska Loess Hills
- Central High Tableland
- [illegible]
- Central Kansas Sandstone Hills
- Central Loess Plains
- [illegible]

M CENTRAL FEED GRAINS AND LIVESTOCK REGION

- [illegible]
- [illegible]
- Nebraska and Kansas Loess - Drift Hills
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

■ EAST AND CENTRAL GENERAL FARMING AND FOREST REGION

- [illegible]

Table 9 – LAND RESOURCE REGIONS, MISSOURI BASIN

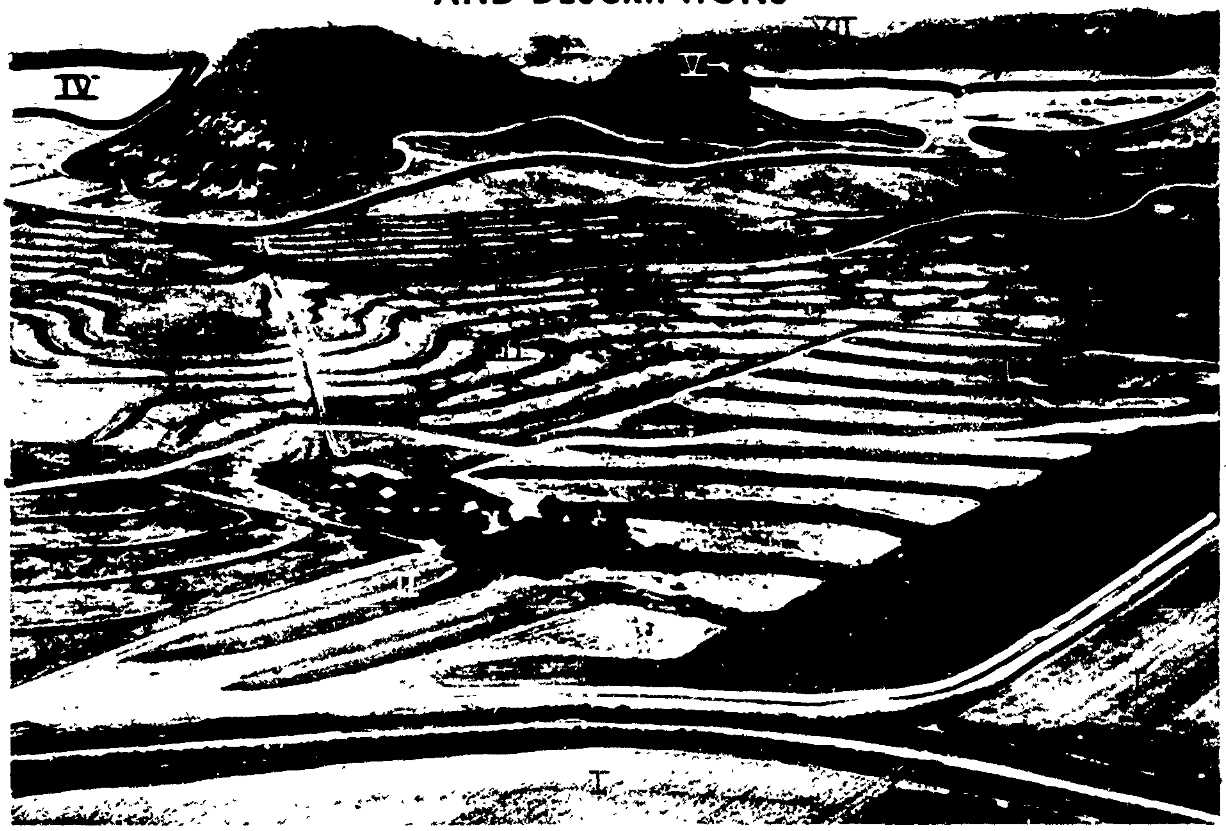
Land Resource Region	Description
D. Western Range and Irrigated Region	This is a semidesert region of plateaus, plains, basins, and isolated mountain ranges. The annual precipitation is 10 inches or less over most of the plains and basins but more than 50 inches on some of the higher mountains. Approximately 50 percent of the precipitation falls during the growing season. Average annual temperatures in most of the region are 40° to 50° F., but they range from 35° F. at the higher elevations to more than 70° F. on the plains. The freeze-free season ranges from less than 90 days in the north and in some of the higher mountains to more than 120 days on the plains. Much of the land in this region is used for range, but irrigation agriculture is practiced where water is available and soils are favorable. Feed crops for livestock occupy most of the irrigated land, and peas, beans, and sugar beets are grown in many places.
E. Rocky Mountain Range and Forest Region	Rugged mountains are the dominant feature of this region, but there are some broad valleys and remnants of high plateaus. The annual precipitation ranges from 20 to 40 inches over much of the region, but it is less than 10 inches in some valleys and 50 inches or more on some of the mountain peaks. Average annual temperatures are mostly 40° to 45° F., but they range from 35° to 50° F. The freeze-free season is 100 to 140 days in most valleys and basins but decreases to 40 days or less in the high mountains where frosts occur every month of the year. Some of the highest mountains are covered by glaciers and have permanently frozen ground. Foothills in the southern part have a freeze-free season as long as 160 days. Grazing is the leading land use in both valleys and mountains, but lumbering is important in some of the forested mountain areas. Recreation is an important land use throughout the region. Irrigation agriculture is practiced in some of the valleys and dryfarming in others. Grain and forage for livestock are the main crops; beans, sugar beets, peas, and seed crops are also grown where soils, climate, and markets are favorable.
F. Northern Great Plains Spring Wheat Region	The fertile soils and the dominantly smooth topography of this region are favorable for agriculture, but the low rainfall and short growing season severely restrict the crops that can be grown. The annual precipitation ranges from 10 to 24 inches, and a large part of it occurs during the growing season. Average annual temperatures are 40° to 45° F. over most of the region. The freeze-free season ranges from 100 to 145 days increasing in length from north to south. The production of spring wheat by dryfarming methods dominates the agriculture of the region. Other spring grains, flax, and hay are also grown. Potatoes are grown in many places, and sugar beets and corn are important.
G. Western Great Plains Range and Irrigated Region	In this section of the Great Plains unfavorable soils, strong slopes, or low moisture supplies make success at dryfarming very uncertain. The annual precipitation ranges from 11 to 24 inches but fluctuates widely from year to year. Average annual temperatures are 45° F. in much of the region, but they range from 40° F. in the north to 60° F. in the south. The freeze-free season ranges from 100 days in the north to 160 days in the south. A large part of the region is in range; some wheat is produced by dryfarming methods, mainly along the eastern margin. Irrigation agriculture is practiced along some of the major rivers. Forage and grain for livestock are the principal crops on irrigated land; potatoes, sugar beets, and vegetable crops are important locally.
H. Central Great Plains Winter Wheat and Range Region	Soils, topography, and climate are more favorable for agriculture in this region than in the Great Plains to the north and west. The longer freeze-free season permits a greater variety of crops to be grown than in the northern Great Plains. The average annual precipitation is 20 to 30 inches over much of the region but ranges from 15 to 35 inches, increasing from northwest to southeast. More rain falls during summer than in the rest of the year. Average annual temperatures are 50° to 65° F., increasing from north to south. The freeze-free season is 170 to 180 days in most of the region. Cash-grain farming with wheat as the principal crop is the major agricultural enterprise on most of the better soils. Grain sorghum is grown in many of the drier areas. The steeply sloping shallow and sandy soils are used for range.
M. Central Feed Grains and Livestock Region	Fertile soils and favorable climate make this one of the outstanding grain-producing regions of the world. The annual precipitation is 25 to 35 inches over much of the region but ranges from 20 inches in the extreme northwest to 45 inches along the eastern and southeastern fringe. Somewhat more than half falls during the growing season. Average annual temperatures are 45° to 55°F. in much of the region but range from 40° F. in the extreme northwest to 60° F. in the southeast. The freeze-free season is 140 to 180 days in most of the region. Corn, soybeans, oats, and other feed grains are the most extensively grown crops. Hay, winter wheat, and many other crops are grown also. Much of the grain is fed to beef cattle and hogs on the farms where it is grown, but a large amount is shipped to other regions for livestock feed. Part of the grain is processed for food and for industrial uses.

Table 10 (Continued)

Land Resource Area	Soil
G WESTERN GREAT PLAINS RANGE AND IRRIGATED REGION (Continued)	
64 – Mixed Sandy and Silty Tableland	Chestnuts are the dominant soils with bands of Lithosols and Regosols running through. Alluvial soils on floodplains are of small total extent.
65 – Nebraska Sand Hills	Stabilized dunes that have little evidence of soil formation except a slight darkening of the upper two or three inches occupy nearly one-third of the area. Regosols and Humic Gley soils make up the rest of the area.
66 – Dakota-Nebraska Eroded Tableland	Sandy and silty Chernozems occupy most of the gentle slopes and clayey Chernozems occupy the rolling hills. Brunizems are in sandy areas with better moisture supplies and Regosols on the more sloping sandy areas.
67 – Central High Plains	Brown and Chestnut soils are dominant on gentle slopes and Lithosols and Regosols are on the steeper slopes. Alluvial soils are on the narrow floodplains of the larger streams.
68 – Irrigated Upper Platte River Valley	Brown soils and Chestnut soils are the principal ones. Lithosols are on the more sloping areas. Alluvial soils on floodplains and younger fans are among the more important soils for crops.
H CENTRAL GREAT PLAINS WINTER WHEAT AND RANGE REGION	
71 – Central Nebraska Loess Hills	Chernozems are dominant on gentle slopes of uplands and terraces and Regosols on steep slopes. Solonetz soils occupy small, nearly level areas or terraces; their total area is small, but they are conspicuous and affect the use and management of adjacent soils.
72 – Central High Tableland	Chestnut soils occupy half or more of the area. Regosols and Lithosols are on steep slopes.
73 – Rolling Plains and Breaks	Chernozems in moderate to deep loess cover much of the area. Regosols are on the steep slopes bordering many of the valleys. Alluvial soils are on the floodplains of the larger streams.
74 – Central Kansas Sandstone Hills	Brunizems are the dominant soils with Lithosols on the steeper slopes. Chernozems and Alluvial soils also occur.
75 – Central Loess Plains	Chernozems are dominant with Planosols also occurring. Regosols are on strongly sloping valley sides and Alluvial soils on floodplains.
76 – Bluestem Hills	Lithosols are very extensive. Brunizems and Planosols are in the more deeply weathered clays, shales and limestones of nearly level and gently sloping upland. Alluvial soils are on the flood-plains of the larger streams.
M CENTRAL FEED GRAINS AND LIVESTOCK REGION	
102 – Loess, Till, and Sandy Prairies	Chernozems are dominant in the north. Regosols and Humic Gley and Solonetz soils are extensive. Alluvial soils are on the floodplains.
103 – Central Iowa and Minnesota Till Prairies	Brunizems and Gray-Brown Podzolic soils are dominant. Associated soils on wet flats and in depressions are Humic Gley soils.
106 – Nebraska and Kansas Loess-Drift Hills	Brunizems are the major soils. Regosols are on the steep slopes while Humic Gley soils are on the relatively narrow wet bottomlands along most streams.
107 – Iowa and Missouri Deep Loess Hills	Brunizems are the major soils. Regosols are extensive. Gray-Brown Podzolics occur where there is more moisture. Alluvial and Humic Gley soils are on the low lands.
108 – Illinois and Iowa Deep Loess and Drift	Brunizems are the dominant soils. Gray-Brown Podzolic soils are on the steep slopes of valley sides. Alluvial soils are on the broader floodplains.
109 – Iowa and Missouri Heavy Till Plain	Brunizems are the principal soils. On the broad uplands are Planosols and Humic Gley soils. Alluvial soils and Humic Gley soils are on the floodplains.
112 – Cherokee Prairies	Planosols are the dominant soils. Rendzinas and Lithosols are on the more sloping land. Alluvial soils and low Humic Gley soils are on the floodplains.
113 – Central Claypan Areas	Planosols with claypan are the major soils. On hilly ground Gray-Brown Podzolic soils are dominant, and on the floodplain are Alluvial soils and Humic Gley soils.
115 – Central Mississippi Valley Wooded Slopes	Gray-Brown Podzolic soils are dominant. Alluvial soils and Humic Gley soils on level flood-plains are important.
N EAST AND CENTRAL GENERAL FARMING AND FOREST REGION	
116 – Ozark Highland	Red-Yellow Podzolic soils occupy much of the area.

FIGURE 12

LAND CAPABILITY CLASSIFICATIONS AND DESCRIPTIONS



LAND CAPABILITY CLASSIFICATION

The capability classification is a practical method of grouping soils for use, treatment, and management. There are eight general classifications (Class I through Class VIII). The erosion hazards and limitations for use increase as the class number increases. In other words, Class I land has few hazards or limitations, whereas Class VIII has many.

Soils in Class I have few limitations that restrict their use when cultivated.

Soils in Class II have minor limitations that restrict their use. Easily applied conservation measures are needed when cultivated.

Soils in Class III have severe limitations and require special conservation measures when cultivated.

Soils in Class IV have very severe limitations, require intensive conservation measures and very careful management if occasionally cultivated.

Soils in Class V have no erosion hazard. They are wet or subject to overflow. Their use is limited to pasture, range or wildlife.

Soils in Class VI have limitations that make them unsuited for cultivation. Their use is limited to range, woodland, wildlife or recreation. Seeding or reseeding is practical.

Soils in Class VII have very severe limitations that limit their use to range, woodland, wildlife or recreation. Reseeding is generally not practical.

Soils in Class VIII are not suited to agricultural production. They have value for wildlife and recreation.

The above capability classes are further divided into sub-classes that show the principal kinds of problems involved. The sub classes are: erosion as indicated by e, such as IIIe; wetness indicated by w, such as Vw; soil limitations (shallowness or droughtiness) indicated by s, such as IVs; and climatic limitations indicated by c, such as IIc.

MAJOR LAND USE CATEGORIES

Agriculture

Approximately 312 million acres or about 95 percent of the land area in the Missouri River Basin is used for some agricultural purpose. With the exception of parts of the Lower Missouri Subbasin, the eastern portion of the basin has the highest intensity of cultivation. In general, the proportion of cropland declines from east to west except where conditions are favorable for wheat production or where irrigation is practiced. Table 11 shows the percentage distribution and table 12 shows the major uses of agricultural land by subbasins.

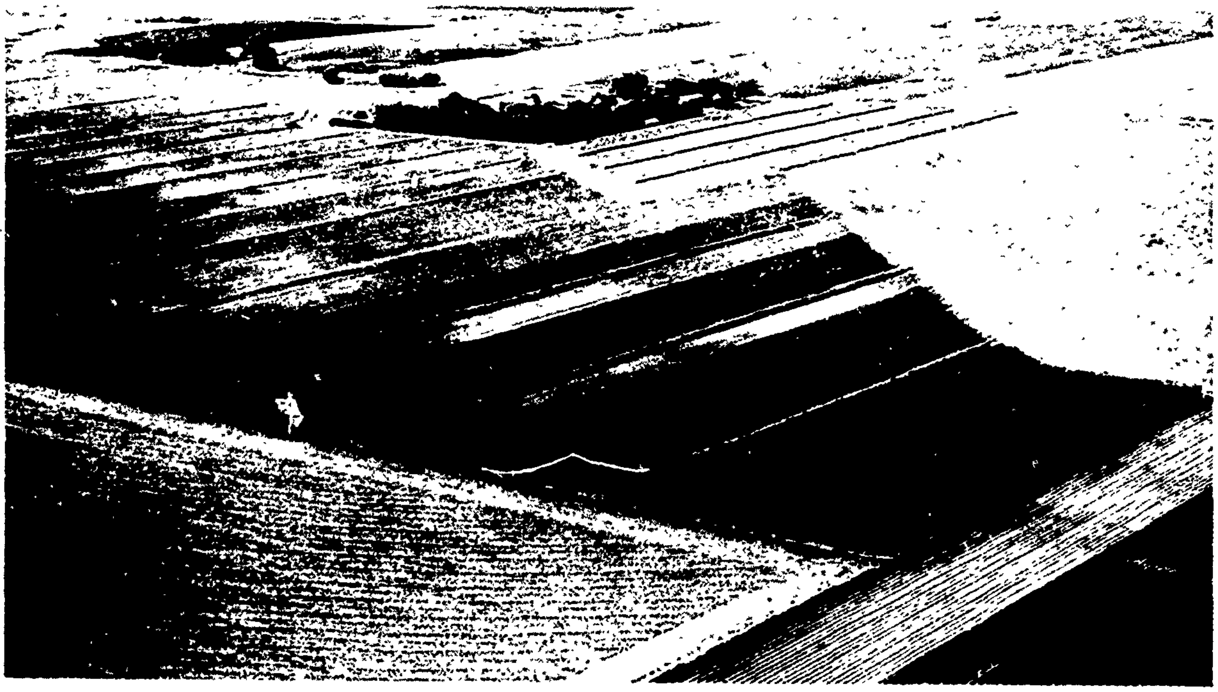
Grazing on pasture, range, and forest lands is the largest major use in the basin, and 189 million acres or about 61 percent of the area is devoted to this use. The highest proportion of grazing occurs in the Upper Missouri, Yellowstone, Western Dakota, and Platte-Niobrara subbasins where more than two-thirds of the area is pasture and grazed woodland and range. In the Eastern Dakota, Kansas, and Lower Missouri subbasins, approximately 40 percent of the land is in pasture and range, and in the Middle Missouri it is about 20 percent.

Table 11 – MAJOR LAND USE, PERCENT DISTRIBUTION OF TOTAL AREA DEVOTED TO AGRICULTURAL PRODUCTION, BY MAJOR USE AND SUBBASINS, CURRENT INVENTORY

Subbasin	Cropland	Pasture and Range	Forest and Woodland	Other Agric. Land	Total[1]
			(Percent)		
Upper Missouri	21	69	14	1	105
Yellowstone	8	81	14	--	103
Western Dakota	20	77	5	1	103
Eastern Dakota	61	37	1	2	101
Platte-Niobrara	26	70	8	1	105
Middle Missouri	75	20	5	3	103
Kansas	60	38	2	2	102
Lower Missouri	42	43	24	3	102
Missouri Basin	33	61	9	1	104

[1]Total is greater than 100 percent due to the grazing of forested land.

Non-Irrigated Cropland When The Wheat Harvest Is In Progress



Irrigated Cropland: Bench Leveling With Adjacent Windbreak And Farmstead

Table 12 – INVENTORY OF LAND PRODUCING AGRICULTURAL PRODUCTS, BY SUBBASINS

Item	Upper Missouri	Yellowstone	Western Dakota	Eastern Dakota
	(Thousand Acres)			
Private Agricultural Land:				
Cropland	10,710	3,374	9,295	21,008
(Irrig. Cropland)[1]	(953)	(1,031)	(198)	(119)
Pasture and Range	25,522	24,333	31,677	12,547
(Irrig.)	(149)	(157)	(11)	--
Forest and Woodland	1,964	1,550	977	211
(Grazed by Livestock)	(1,356)	(1,357)	(908)	(110)
Other Agricultural Land	254	91	209	594
Total Private Agricultural Land	38,450	29,348	42,158	34,360
Other Forest Land	--	--	--	--
Federal Land Producing				
Agricultural Products	11,932	13,804	5,131	39
(Grazed by Livestock)	(8,134)	(9,433)	(3,915)	(6)
(Forest)	(5,247)	(4,523)	(1,486)	(33)
Total Agricultural Land	50,382	43,152	47,289	34,399

Item	Platte-Niobrara	Middle Missouri	Kansas	Lower Missouri	Missouri Basin
	(Thousand Acres)				
Private Agricultural Land:					
Cropland	15,634	11,219	22,341	10.208	103,789
(Irrig. Cropland)[1]	(2,784)	(103)	(1,703)	(5)	(6,896)
Pasture and Range	35,147	2,485	13,619	7,334	152,664
(Irrig.)	(202)	--	--	--	(519)
Forest and Woodland	1,936	631	597	5,788	13,654
(Grazed by Livestock)	(1,410)	(560)	(382)	(3,103)	(9,186)
Other Agricultural Land	621	447	552	793	3,561
Total Private Agricultural Land	53,338	14,782	37,109	24,123	273,668
Other Forest Land	--	118	4	--	122
Federal Land Producing					
Agricultural Products	7,449	1	69	177	38,602
(Grazed by Livestock)	(6,037)	--	(49)	(7)	(27,581)
(Forest)	(2,952)	(1)	(20)	(170)	(14,432)
Total Agricultural Land	60,787	14,901	37,182	24,300	312,392

[1] Includes irrigated cropland in Bureau of Reclamation projects under construction or funded for construction.

Pasture Land In Missouri; 40 Percent Of The Land In The Four Eastern Subbasins Is Grazed By Livestock

Rangeland In Montana; Two-thirds Of The Four Western Subbasins Is Pasture And Range

Total cropland in the basin is estimated at 104 million acres or 33 percent of agricultural land (table 12). The Middle Missouri Subbasin is most intensively farmed with about 75 percent of the area devoted to crops. The Eastern Dakota and Kansas subbasins are 60 percent cropland, the Lower Missouri Subbasin 42 percent, and the Yellowstone Subbasin eight percent cropland.

Seven percent of the cropland in the basin is irrigated. The Platte-Niobrara Subbasin has the largest area of irrigated acreage, 2.8 million acres. Other important areas of irrigation are in the Kansas Subbasin with 1.7 million acres, and the Upper Missouri and Yellowstone subbasins with approximately one million acres each. Smaller areas of irrigation are found in the Western Dakota and Middle Missouri subbasins.

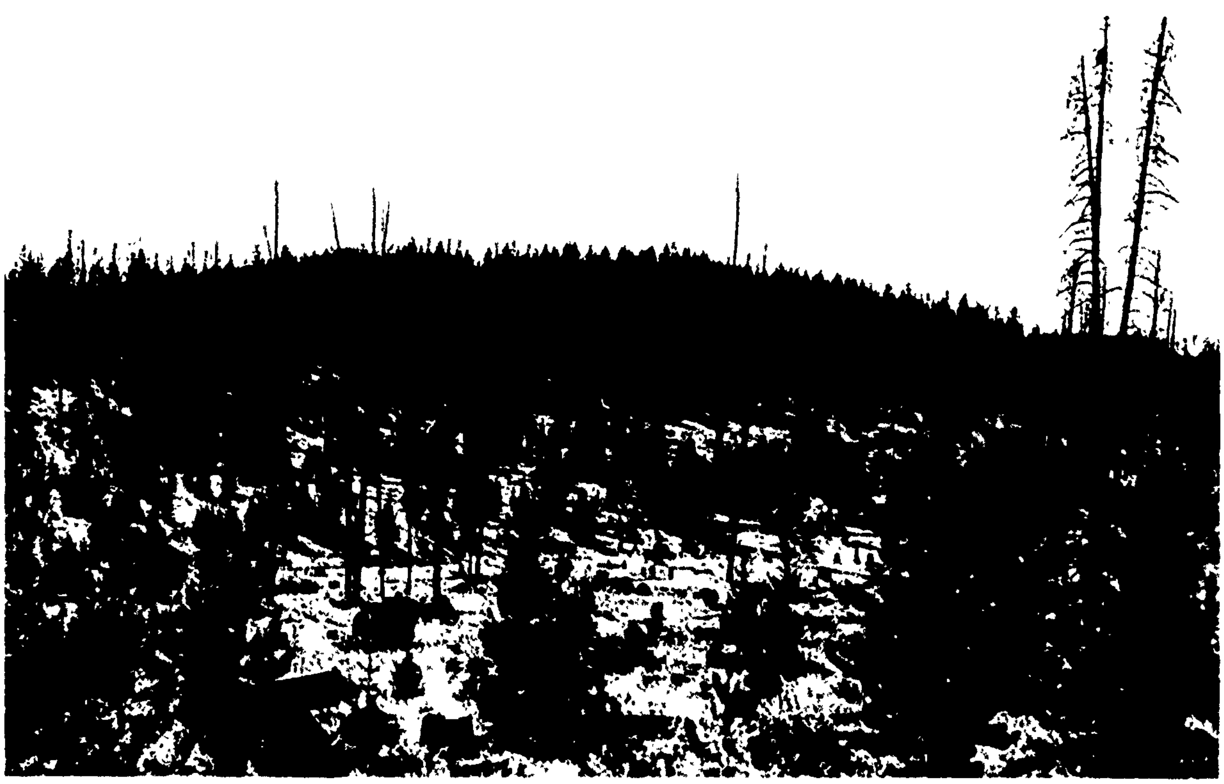
Forest and woodlands are estimated at 28 million acres, much of which are also grazed. Forest and woodland are important in the Lower Missouri Subbasin, with 24 percent of the agricultural land in this category, and in the Yellowstone and Upper Missouri subbasins where 14 percent of the agricultural land is classified as forests. Forest and woodlands are less important in the other subbasins but have some significance in each subbasin.

There are about 38.7 million acres of federally owned lands in the agricultural land category. These lands are largely in the mountains and in the western plains areas. Two-thirds of the publicly owned lands are located in the Yellowstone and Upper Missouri subbasins where Federal ownership comprises 32 and 24 percent of the agricultural land respectively. The remaining acreage is largely in the Platte-Niobrara and Western Dakota subbasins where public ownership of agricultural land is 12 and 11 percent respectively.

Federally owned lands were inventoried in respect to their contribution to agricultural output. No attempt was made to inventory the conditions and quality or to project the potential capacity of this land. Two uses were inventoried: grazing and forestry. This level of use was held constant for all time periods in the analysis of future production capacity of agricultural lands.

Privately owned agricultural land in the basin is estimated at 273.7 million acres. This inventory was adjusted for water resource development projects funded or under construction and assumed in place. These adjustments in land use and availability and the resulting effects on production were taken into account in estimating the land base available for agricultural production purposes.

Data from the Corps of Engineers and Bureau of Reclamation were used to adjust the current normal land base for large reservoirs funded for construction or constructed after the inventory was made. Table 13 shows the reservoirs that were assumed to be in place and the adjustments that were made in the land base.



Forested Areas Produce Timber Products, Wildlife Habitat, And Forage For Livestock

Other Agricultural Land Includes Farmsteads, Farm Roads, and Irrigation Facilities

Table 13 – LAND REMOVED FROM THE LAND BASE FOR RESERVOIRS FUNDED OR UNDER CONSTRUCTION, BY LAND RESOURCE AREA

Reservoir	Acres	Land Resource Area
Milford	44,500	75
Perry	39,300	106
Melvern	19,700	115
Harry S. Truman	140,000	115
Harry S. Truman	14,300	116
Stockton	58,700	116
Rathbun	33,900	109
Glen Elder	13,600	73
Chatfield	6,100	68
Total	370,100	

Data from the Bureau of Reclamation were used to adjust the land base for the amount of irrigated land on Federal projects which has been brought into production since the field survey or, is expected to be brought into production in the near future by irrigation facilities now under construction (table 14).

Thus the present land use and the analysis of agricultural production takes into account current normal production plus that from projects recently completed and those under construction that are expected to be in production by 1970 or shortly thereafter. The adjusted current inventory of major land use categories is shown in table 12.

Table 14 – TOTAL SERVICE AREA OF AUTHORIZED AND PARTIALLY COMPLETED IRRIGATION PROJECTS

Project or Unit	State	Acres	Land Resource Area
East Bench	Montana	21,800	44
Garrison[1]	North Dakota	59,300	55
Ainsworth	Nebraska	33,960	66
Farwell	Nebraska	41,671	71
Frenchman-Cambridge	Nebraska	8,896	73
Hitchcock-Red Willow	Nebraska	500	73
Bostwick	Nebraska	6,275	73
North Platte	Nebraska	9,000	67
Sargent	Nebraska	3,174	71
Almena	Kansas	5,350	73
Cedar Bluff	Kansas	2,583	73
Bostwick	Kansas	26,108	73
Kirwin	Kansas	2,820	73
Webster	Kansas	2,298	73
Casper-Alcova	Wyoming	2,469	58
Goshen	Wyoming	1,062	67
Total		227,266	

[1] Assumed in place for land accountability but included in future development program.

Fish and Wildlife

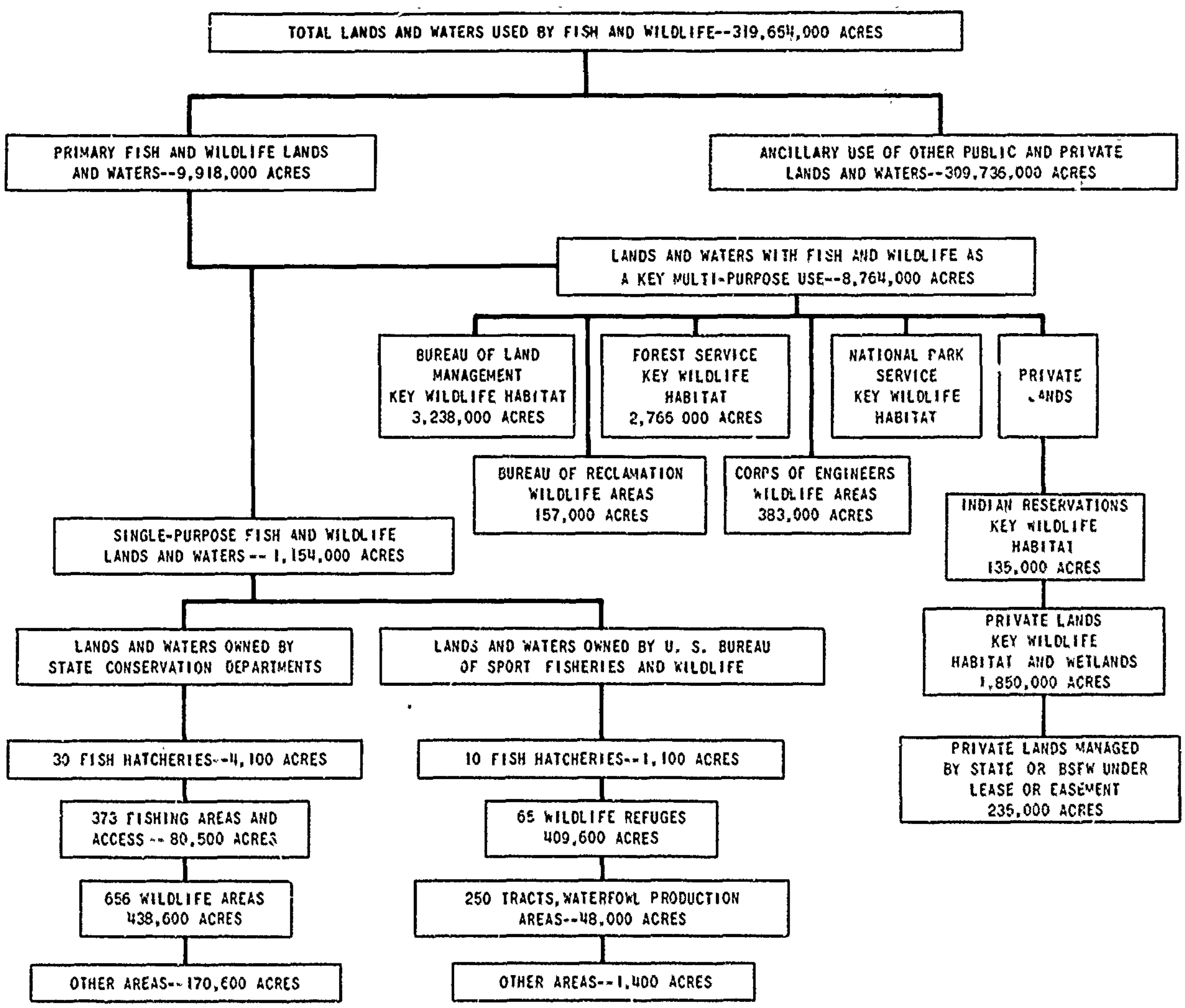
Fish and wildlife resources are important throughout the Missouri River Basin. Historically, the Indians, trappers, explorers, and early settlers depended on these resources for food, clothing, and shelter. Today, the fish and wildlife resources serve mainly to meet desires of fishermen, hunters, and other outdoor recreationists. The trades and services associated with these recreational pursuits are economically important locally and nationally. Commercial fish and fur animals possess significant economic values in addition to recreation. The basin is nationally important for the unusual recreational opportunities offered by the variety of animal life, much of it in pristine environment. Figure 13 illustrates the compobution of lands and waters of importance to fish and wildlife.

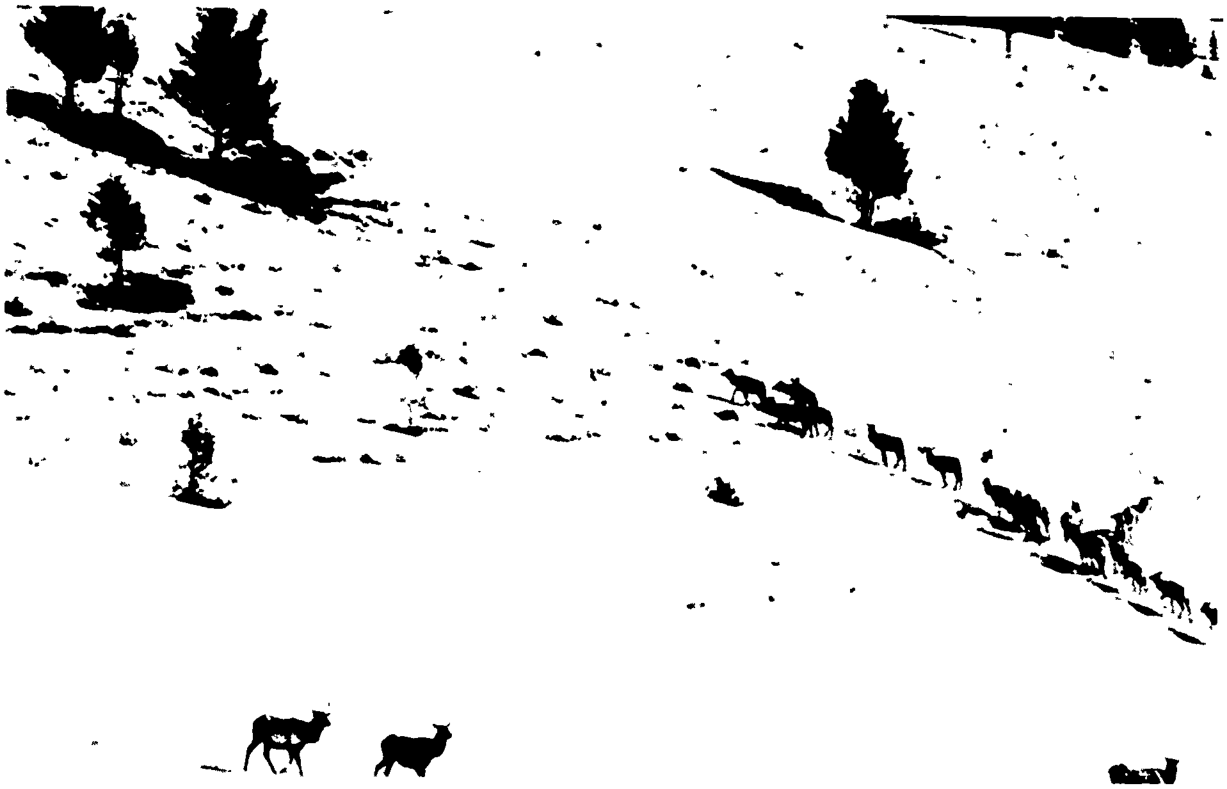
Virtually all of the basin area is of value for fish and wildlife use. For the purpose of this study, the total lands and waters used by fish and wildlife are divided into two broad categories: (1) lands devoted to fish and wildlife as a "primary" use (figures 14 and 15) and (2) lands where fish and wildlife uses are "ancillary" (figure 16). Primary fish and wildlife lands and waters are further Primary fish and wildlife lands and waters are further subdivided into two main categories: (1a) single-purpose or dedicated lands owned by the various state fish and game agencies and by the Bureau of Sport Fisheries and Wildlife, and (1b) public or private lands where fish and wildlife is one of the principal multi-purpose uses.

The bulk of the lands and waters used by fish and wildlife fall into the second category (ancillary use). This category includes most private lands and a substantial portion of the public lands. On most of this area, agriculture is the predominant use, but wildlife exists only where compatible with current agricultural practices.

Only 0.3 percent of the total basin is devoted to fish and wildlife as a single-purpose or dedicated use. An additional 2.7 percent is considered key multi-purpose

FIGURE 13
DISTRIBUTION OF FISH AND WILDLIFE LANDS AND WATERS





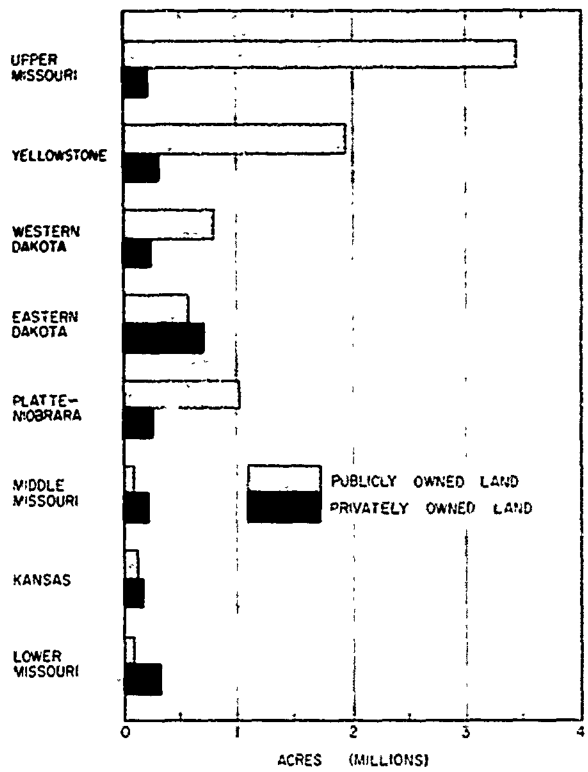
Forests And Grasslands Provide Habitat For Game Animals

Farm Ponds Furnish Water For Livestock, Fishing, Boating, And Recreation

Farm Ponds Provide Excellent Duck Shooting

FIGURE 14

OWNERSHIP OF LANDS AND WATERS ON WHICH FISH AND WILDLIFE MANAGEMENT IS THE PRIMARY USE



Migratory Waterfowl Feed And Rest On Private Cropland During Both Spring And Fall Migrations

FIGURE 15

DISTRIBUTION OF SINGLE-PURPOSE AND PRIMARY (KEY) FISH AND WILDLIFE LANDS AND WATERS BY SUBBASINS (SINGLE-PURPOSE IS INCLUDED IN PRIMARY)

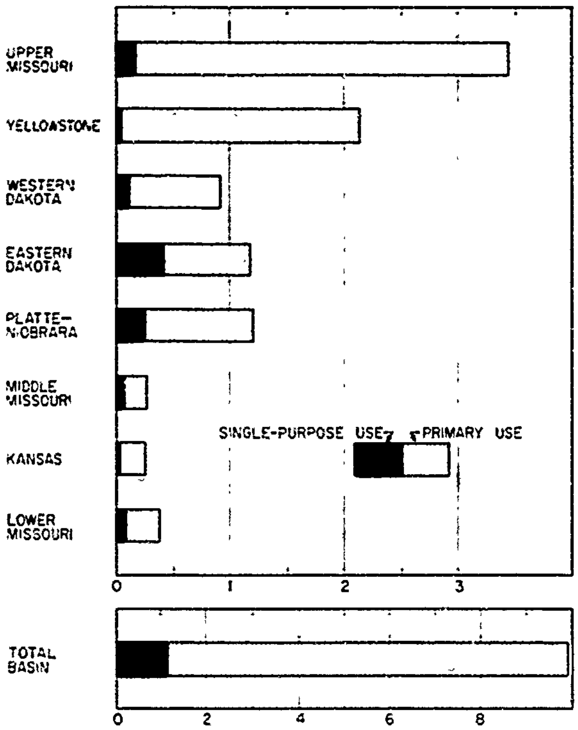
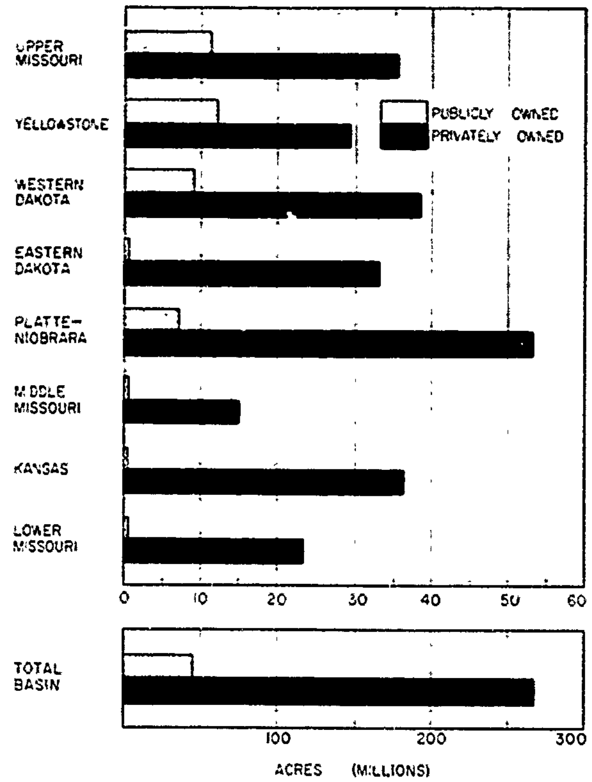


FIGURE 16

OWNERSHIP OF LANDS AND WATERS ON WHICH FISH AND WILDLIFE HAVE ANCILLARY USE



use. This area includes lands owned by several Federal agencies and numerous small blocks of privately owned lands. The combined areas considered as primary fish and wildlife land and water represents about three percent of the total basin.

In general, primary responsibility for management of the fish and wildlife resource rests with the State fish and game agencies. In addition, the Bureau of Sport Fisheries and Wildlife has basic responsibility for migratory birds, and various other public agencies have responsibilities on lands that they administer. The Bureau of Land Management, U. S. Forest Service, and National Park Service are the principal public agencies in this category. Wildlife areas associated with Bureau of Reclamation and Corps of Engineers reservoirs are usually managed by the States in keeping with provisions of the Fish and Wildlife Coordination Act.

Figure 14 indicates that almost 70 percent of the public lands considered primary fish and wildlife lands are in the Upper Missouri and Yellowstone subbasins. The major share of private lands in the primary fish and wildlife category is in the Eastern Dakota Subbasin. Most of these private lands are held under easement by the Bureau of Sport Fisheries and Wildlife for wetland preservation.

Apart from primary fish and wildlife lands, certain lands of ancillary importance, such as Indian reservations and state school lands, deserve special attention. Indian reservations encompass in excess of 16 million acres, or about 5 percent of the Missouri Basin. Although all land within the reservation boundaries is not Indian-owned, nearly 12 million acres or almost four percent of the land in the basin is in Indian ownership. Of this, 7 million acres are owned by individual Indians, and 5 million acres are in tribal ownership. On most Indian lands there has been very little management of fish and wildlife resources. However, in recent years the Bureau of Sport Fisheries and Wildlife has provided technical assistance to the Indians upon request.

There are about 12,250,000 acres of State school lands in the Missouri River Basin segments of Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming. Most of these lands are leased to private agricultural interests. Generally, state laws make no specific provision for fish and wildlife as a multi-purpose use on school lands, but they have habitat similar to adjoining lands and thus are important factors in the current supply.

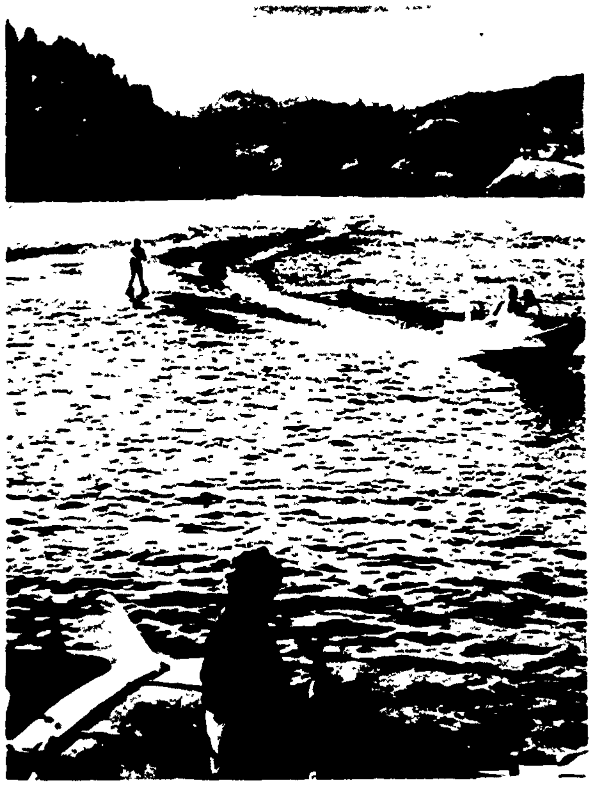
Recreation

Lands and waters considered to be valuable for outdoor recreation purposes and supporting a significant amount of recreation use total 50,252,000 acres, or 15 percent of the total land area of the basin. However, only 2,814,000 acres are dedicated primarily to recreation use.

Approximately 174,000 acres are intensively developed for recreation purposes. Most of the recreation lands are in public ownership, and in multiple-use areas dedicated to a variety of uses including recreation. Most ancillary recreation lands are also in publicly owned, multiple-use areas. National Park Service areas, which include the large Yellowstone, Rocky Mountain, and Glacier National parks, account for the bulk of the primary use recreational land.

Table 15 presents a summary of all existing recreation lands, waters, and other information by administrative categories. Recreation areas were classified as Type I (scenic, historic, and natural), Type II (land oriented) and Type III (water oriented).

Table 16 presents a summary of recreation lands and waters by both administrative categories and types of areas. Table 17 also provides primary and ancillary land and water use information for recreation acreages; however, data are broken down for individual subbasins and the public and private sectors only.



Multiple-Purpose Reservoirs Storing Water for Irrigation, Power and Municipal Supply Also Have Fishing and Recreation Opportunities

Table 15 - LANDS AND WATERS USED FOR RECREATION

Administrative Category	Areas (No.)[1]	Land (Acres)	Marsh (Acres)	Water (Acres)	Total (Acres)	Intensively Developed: Developed Acreage[2]	Intensively Developed: Percent of Land Area
Local Parks	2,875	127,992	737	61,482	190,211	54,020	42.2
St. Parks (Roadside)	500	2,880	...	35	2,915	2,680	93.1
St. Parks & Rec. Areas	310	258,960	1,106	314,849	574,915	17,226	6.6
St. Fish & Hunting Areas & Fish Hatcheries	997	505,086	30,509	98,566	634,161	1,752	0.4
St. Forest Lands	5	42,826	120	62	43,008	2	0.005
Nat'l Park Service Areas	18	2,959,385	12,200	124,468	3,096,053	5,213	0.2
Nat'l Wildlife Refuges & Fish Hatcheries	84[3]	1,424,165	33,594	392,129	1,849,888	739	0.05
Federal Reservoirs (Net)[4]	113	952,936	2,000	1,078,320	2,033,256	19,743	2.1
Indian Reservation Areas	108	6,874,336	8,485	26,723	6,909,544	2,200	0.03
Nat'l Forest & Grasslands	37	18,814,323	7,170	54,731	18,876,224	15,102	0.08
Bureau of Land Mgmt. Areas	39	14,957,516	160	1,780	14,959,456	300	0.002
Misc. Federal Lands	21	136,439	...	98	136,537	935	0.7
Private Sector	20[5]	574,953	...	243,149	818,102	54,446	9.5
Missouri River & Missouri River Access	67	660	...	127,400	128,060	10	1.5
Missouri Basin	5,194[5]	47,632,457	96,081	2,523,792	50,252,330	174,368	0.4

[1] Includes 12 registered National Historic Landmarks. Several of the figures shown include contiguous tracts.

[2] "Developed" land is land occupied with or immediately adjacent to recreation facilities or substantially modified from a natural condition for recreation purposes. Other recreation land area is considered to be undeveloped.

[3] Several entries consist of numerous tracts; includes privately owned areas administered by the BSFW.

[4] Land and water acreage figures for State administered waters, State parks, national wildlife refuges, and other such areas situated at Federal reservoirs are included under other categories.

[5] Does not include private areas, for which figures were not available, the 20 areas shown for private sector include only scenic and historic areas administered by the private sector.

Table 16 – SUMMARY OF RECREATION LANDS AND WATERS USED PRIMARILY FOR RECREATION PURPOSES AND FOR OTHER USES

Administrative Category	No. of Areas	Type I Rec. Areas (Scenic & Historic)		Type II Recreation Areas (Land-Oriented)			Type III Recreation Areas (Water-Oriented)		
		Recreation (Totals)	Other Uses	Recreation	Other Uses	Total	Recreation	Other Uses	Total
Lands:		(Acres)							
Type I Areas[1]	139	3,042,229	---	---	---	---	---	---	---
Local Parks	2,865	---	---	65,655	---	65,655	61,922	---	61,922
St. Parks & Rec Areas	728	---	---	34,790	---	34,790	148,283	---	148,283
St. Fish. &[2] Hunting Areas	997	---	---	200	248,873	249,073	1,552	254,461	256,013
St. Forests	5	---	---	2	42,824	42,826	---	---	---
Indian Reservations	102	---	---	1,998	6,847,060	6,849,058	202	25,052	25,254
Nat'l Wildlife Refuges[2]	84	---	---	24	21,636	21,660	715	1,401,790	1,402,505
Nat'l Forests[3]	35	---	---	15,102	18,799,207	18,814,309	---	---	---
Bureau of Land Mgmt. Lands	39	---	---	300	14,956,769	14,957,069	---	447	447
Misc. Fed. Lands	20	---	---	935	133,904	134,839	---	---	---
Fed. Reservoirs Existing and Under Const.[4]	113	---	---	---	---	---	22,513	930,423	952,936
Missouri River Access Points[5]	67	---	---	---	---	---	660*	---	660*
Private Sector	NA [6]	---	---	123,739	332,877	456,616	25,131	91,182	116,313
LAND TOTALS	5,194	3,042,229	---	242,745	41,383,150	41,625,895	260,978	2,703,355	2,964,333
All Rec. Waters		136,894	---	8,119	102,069	110,188	127,285	2,245,506	2,372,791
Missouri Basin	5,194	3,179,123	---	250,864	41,485,219	41,736,083	388,263	4,948,861	5,337,124

[1] All Type I areas dedicated primarily to recreation purposes include Yellowstone National Park, Glacier National Park, and Rocky Mountain National Park.
[2] Includes Fish Hatcheries.
[3] Includes national grasslands and land utilization projects.
[4] Net figures. Does not include lands administered by state and local agencies, and the Bureau of Sport Fisheries and Wildlife. These acreages carried under other categories.
[5] Federal, State, and locally administered areas.
[6] Number of private sector areas in Type II and III categories is not available. The 20 areas identified in table 15 are included in the 139 Type I areas in this table.
* Estimated or based partially on estimates.

Table 17 – EXISTING RECREATIONAL LAND USE BY INDIVIDUAL SUBBASINS

Subbasin	Category	Primary Use Area[1]		Ancillary Use Area[1]	
		Land	Water	Land	Water
		(Acres)			
Upper Missouri	Public	505,473	17,899	12,685,118	405,971
	Private	13,192	55	1,057,688	88,242
Yellowstone	Public	2,185,405	135,956	10,303,142	70,980
	Private	13,150	710	593,656	8,397
Western Dakota	Public	313,024	22,116	4,874,378	405,127
	Private	10,962	428	5,078,462	3,901
Eastern Dakota	Public	28,911	21,256	474,886	676,422
	Private	7,905	1,317	275,760	3,693
Platte-Niobrara	Public	290,783	8,679	7,582,024	162,759
	Private	86,500	7,600	173,500	68,400
Middle Missouri	Public	29,219	22,530	35,248	63,594
	Private	7,872	1,005	40,030	9,368
Kansas	Public	25,577	5,448	228,694	135,501
	Private	10,402	416	21,120	3,744
Lower Missouri	Public	60,144	26,164	564,422	169,280
	Private	5,045	711	50,765	72,204
Missouri Basin	Public	3,438,536	260,048	36,747,912	2,089,634
	Private	155,028	12,242	7,290,981	257,949

[1] Subregion (political boundary) figures used.

Mineral Industry

Land used by the mineral industry refers explicitly to land occupied and used exclusively in producing minerals on an annual basis; it does not refer to land owned, leased, or temporarily occupied for exploration. Total land use by the mineral industry in the basin is estimated to be 33,554 acres (table 18). Land actually used in harvesting timber for mine use or for oil and gas exploration is negligible with respect to surface acreage occupied. While total mineral and oil and gas leased on Federal and non-Federal lands in the basin are estimated to be in excess of 100 million acres, the surface land use figure is a realistic estimate of land use in the basin.

Table 18 – ESTIMATED MINERAL INDUSTRY LAND USE BY SUBBASINS AND STATES OF THE MISSOURI BASIN FOR 1963

Subbasin	State	Land Use (Acres)
Upper Missouri	Montana	2,973
Subtotal		2,973
Yellowstone	Montana	847
	Wyoming	8,309
Subtotal		9,156
Western Dakota	Montana	256
	North Dakota	649
	South Dakota	1,064
	Wyoming	1,218
Subtotal		3,187
Eastern Dakota	North Dakota	509
	South Dakota	913
Subtotal		1,422
Platte-Niobrara	Colorado	1,326
	Nebraska	761
	Wyoming	3,857
Subtotal		5,944
Middle Missouri	Iowa	672
	Kansas	76
	Minnesota	154
	Missouri	62
	Nebraska	536
Subtotal		1,500
Kansas	Colorado	30
	Kansas	5,676
	Nebraska	346
Subtotal		6,052
Lower Missouri	Iowa	188
	Kansas	704
	Missouri	2,428
Subtotal		3,320
Total by States	Colorado	1,356
	Iowa	860
	Kansas	6,456
	Minnesota	154
	Missouri	2,490
	Montana	4,076
	Nebraska	1,643
	North Dakota	1,158
	South Dakota	1,977
	Wyoming	13,384
Missouri Basin		33,554

Transportation, Urban, and Built-up Areas, and Other Uses

A small percentage of the land area is needed for the roads, railroads, and utility lines that crisscross the basin. A majority of the people served live in the villages, towns, and cities which occupy about one percent of the basin area. The total land inventory for the above is about 5,440,000 acres.

The land inventory did not account for other minor uses in the basin. The transportation, urban, and built-up areas category was expanded to include other uses. The acreage total for this designation was over 2,240,000, which brings the total for the combined designation to 7,680,000 acres or about two and one-half percent for the Missouri Basin.

Water Areas

The water area of the Missouri Basin was inventoried separately because of the multiplicity of uses and the corresponding difficulties likely to arise if a joint use concept were applied. Water areas can be used for recreation, fish and wildlife purposes, livestock watering, and other similar activities. Moving water can produce electricity, move goods, maintain quality, and provide the services already mentioned. Water also is used for municipal and industrial purposes, irrigating crops, and diverse activities.

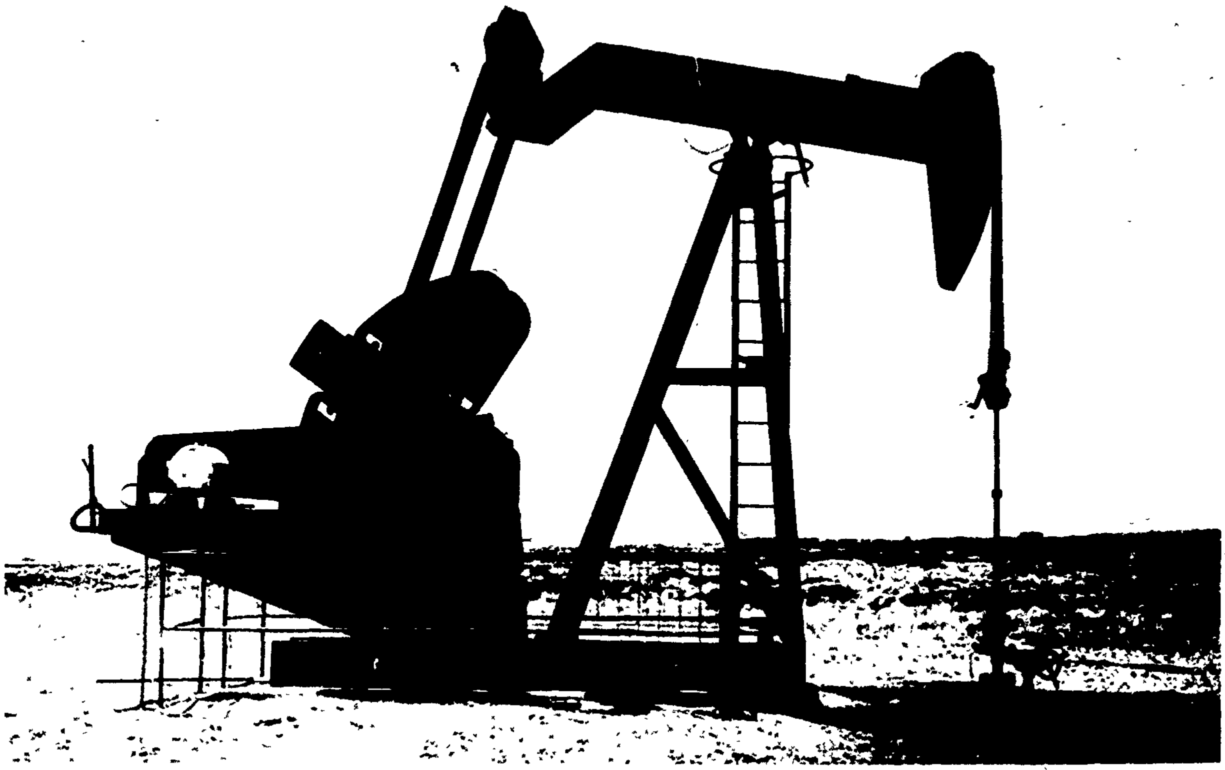
The area inventoried as water includes the water area reported by the 1960 Bureau of Census. In addition, the acreage of water areas of less than 40 acres in size, and streams less than one-eighth of a mile wide, were determined from Conservation Needs Inventory and from other sources. This acreage was subtracted from the Bureau of Census land area. The area of water totaled 3,819,000 acres (table S-1).

Military Areas

There are several military reservations and installations in the basin. Ft. Leonard Wood, Ft. Riley, and Strategic Air Command (SAC) Headquarters are widely known. These military areas are important to national defense. The inventory included these and also National Guard facilities. The total inventory acreage was 622,470 acres (table S-4).

PRIMARY AND ANCILLARY LAND UTILIZATION

Beginning with the settling of the basin and the development of its natural resources to meet needs, the



Mineral Industry - - Petroleum And Natural Gas

Rail, Air, and Water Transportation Have Been Developed Along the Missouri River people began changing and overlapping the land uses. Grasslands and woodlands were converted to the production of cultivated crops, or their products were used to build towns, cities, railroads, highways, and other service facilities. Several uses were made of easily accessible areas. For example, domestic livestock were grazed on forest and woodland areas already producing forest products, domestic livestock and wildlife were grazed on the same areas, and small game were hunted on cropland.

In the 1958 Conservation Needs Inventory, land uses were classified into seven major groups: cropland, pasture and range, forest and woodland, other agricultural land, urban and built-up areas, water areas, and Federal lands. This grouping identified land and water areas by primary use, but did not show to what extent these same areas were used to satisfy other needs of the people. To complete the inventory of land use, information on Federal lands was obtained from each Federal agency concerned, and was integrated with that from the Conservation Needs Inventory.

The land and water resources are not sufficient to meet the present needs or projected requirements of the basin on a single-use basis; thus, the multiple use of land and water must be considered. Through coordinated development and management, several uses are often made of the same area under the multiple use concept without serious conflict. Many uses are complementary to and enhance other uses; in fact, some resources are somewhat dependent upon other uses. For example, the large pheasant population and the excellent bird hunting in South Dakota are closely related to cropland production and land conservation practices.

In this framework study, basin lands were classified into ten major groups of primary use: cropland, pasture and range, forest and woodland, other agricultural land, recreation, fish and wildlife, transportation, urban and built-up areas, water, mineral industry areas, and military areas. In studying the use and requirements for land, each use was considered separately. Many areas are already serving more than one use. For example, a forested area may be producing timber products; at the same time it is used for grazing of domestic livestock, habitat for wildlife, recreation, and storage for snowfall producing spring and summer water supplies.

The primary use of land, by subbasins, is shown in table 19. A summary of present generalized multiple uses of land and water is shown in table 20.

Production of agricultural products, including timber, is the primary use on 312,392,000 acres or 95 percent of the basin. There is some duplication of use even within agriculture, as approximately four percent of the forest is grazed by domestic livestock. Grazing of domestic livestock and harvesting of hay is permitted on some military lands and some urban areas. The total effective area used for agriculture is 330,360,000 acres.

A Rocky Mountain Landscape Showing Forest And Grassland; This Area Contains Important Wilderness, Watershed, and Wildlife Habitat Values and Provides Many Recreation Opportunities

Table 19 - SUMMARY OF PRESENT GENERALIZED PRIMARY USES OF LAND AND WATER AREA

Item	Upper Missouri	Yellowstone	Western Dakota	Eastern Dakota
	(Thousand Acres)			
Agriculture[1]	50,382	43,152	47,289	34,399
Recreation[2]	519	1,408	334	38
Fish and Wildlife[2, 4]	142	31	92	162
Transportation, Urban, Built-up, and Other	1,240	246	897	1,801
Water Area[3]	670	345	472	902
Mineral Industry	3	9	3	1
Military	7	9	269	0
TOTAL	52,963	45,200	49,356	37,303

	Platte-Niobrara	Middle Missouri	Kansas	Lower Missouri	Missouri Basin
	(Thousand Acres)				
Agriculture[1]	60,787	14,901	37,182	24,300	312,392
Recreation[2]	377	37	36	65	2,814
Fish and Wildlife[2, 4]	220	25	15	51	738
Transportation, Urban, Built-up, and Other	1,508	600	1,195	603	8,090
Water Area[3]	654	174	336	266	3,819
Mineral Industry	6	2	6	3	33
Military	123	6	106	102	622
TOTAL	63,675	15,745	38,876	25,390	328,508

[1] Includes cropland, pasture and range, forest and other agricultural lands
[2] Subbasin land area only.
[3] Includes primary water area of recreation and fish and wildlife.
[4] Figures shown are for single-purpose lands, but an additional 9,174,000 acres are included in other categories that are jointly used and have primary value for fish and wildlife

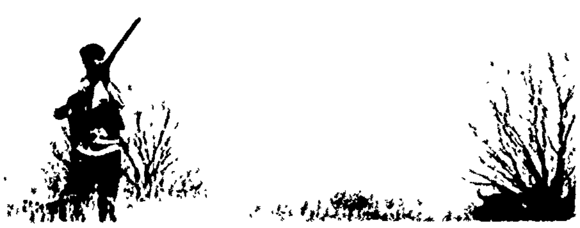
Recreation is the primary use on 2,814,000 acres. This includes areas such as Yellowstone and Rocky Mountain National Parks, national monuments, State parks, areas specifically dedicated and improved for recreation use as campgrounds and picnic grounds, and sports areas on Federal, State, and private lands. In addition, significant recreation use occurs along recreation trails and from hiking, riding, camping, picnicking, studying, or sight-seeing on forest and other croplands and on wildlife, military, and mineral industrial areas. The total area used for recreation is 50,252,000 acres.

Fish and wildlife makes the greatest use of the basin resource area-wise. The total area of such use is 319,648,000 acres; however, fish and wildlife has single-purpose use on only 1,148,000 acres. This is primarily in the National Wildlife Refuges and in State wildlife, waterfowl, and game management areas. Cropland, shelterbelts, and fence rows are used by wildlife. Reservoirs and associated lands for irrigation, flood control, recreation, and other purposes provide habitat for fish and waterfowl. While fish and wildlife are heavily dependent on multiple-use areas, there is not significant conflict or harmful effect to the other uses.

Table 20 – SUMMARY OF PRESENT GENERALIZED MULTIPLE USES OF LAND AND WATER AREA[1]

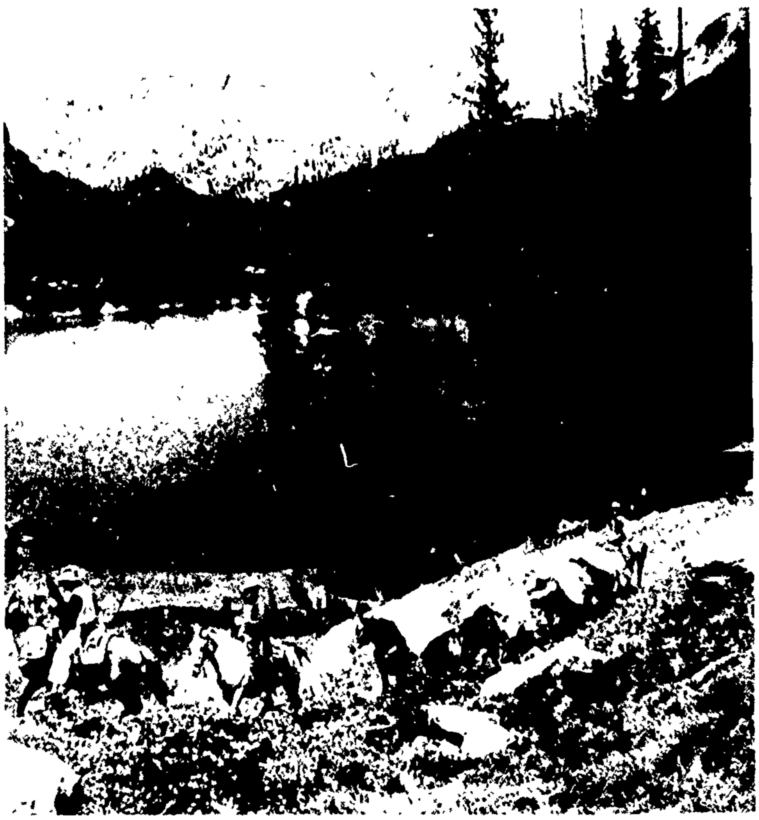
Subbasin	Agriculture[2]	Recreation	Fish and Wildlife
	(Thousand Acres)		
Upper Missouri	53,710	14,774	51,687
Yellowstone	45,742	13,311	44,914
Western Dakota	51,055	10,708	48,316
Eastern Dakota	34,520	1,490	35,615
Platte-Niobrara	64,054	8,380	61,985
Middle Missouri	15,580	209	15,057
Kansas	37,680	431	37,508
Lower Missouri	28,019	949	24,566

[1] Includes both primary and ancillary uses of land and water.
[2] Agriculture includes cropland, pasture and range, forest, and other agricultural lands.



Pheasant Hunting Is A Major Sport On Agricultural Lands

National and State Parks Provide Most of the Primary Recreation Use Areas



Most of the Basin's Total Recreation Acreage is in Multiple-Use Areas of the National Forests, Public Domain, and Indian Reservations

CHAPTER 4

POTENTIAL LAND USES AND CAPABILITIES

ADAPTABILITY OF LANDS FOR ALTERNATIVE USES

The Missouri Basin has a wide range of climatic, topographic, and soil conditions. The present use of the basin's lands is related both to present and to past economic conditions and policies. Future use and the intensity of such use will no doubt change since demands on the land and water resources and the capacity of those resources for satisfying these demands are changing. However, along with projections of future demands, projected production technology is essential for planning purposes to know the capability of the land resources to meet these demands.

Major Agricultural Uses

The agricultural use that can safely be made of lands under varying conditions, including intensity of treatment, can be studied by grouping the previously discussed land capability units into land capability classes. This widely accepted classification places all lands (see Chapter 3 of this Appendix) into one of eight recognized land classes.

Because of irregularities in topographic features such as geologic formations and glaciation, a mixing of land classes frequently occurs within small areas. Some of these areas are too small to be of significance when comprehensive decisions concerning land use and treatment are being made. These small areas, therefore, are not identified in soil mapping activity and must be considered as part of the predominant land class and land use. Though small, some of these areas might, for example, be of tremendous importance to wildlife when isolated in cropland.

From a practical standpoint, small classified areas, when located in a field with soil of a predominantly different classification sufficient to permit a change in land use, are considered as not being available for a change in use. An example is a small area of Class VI land, classified as such because of a shallow root zone, laying in a Class III cropland field. The Class VI land would be used for crop production even though its income may be marginal. Large machinery and extensive farming operations make it impractical to give special consideration in the use of such areas since they are "locked-in" with the predominant use. Table 21 shows the land capability class and land use for agricultural land in the basin.

As previously mentioned in Chapter 3 under "Land Resource Categories," land capability units were grouped in order to reduce the number of evaluation units. Although these soil resource groups combine some closely related land capability classes, in no case do they mix arable and nonarable land as determined by capability class designation. A brief description of the soil resource groups and a listing of land capability units they contain are given in table S-45. Because of the ready availability of the soil resource group data, land available for alternative uses was determined by using this classification along with an application of the "capability class" described earlier. Table 22 summarizes by subbasins and land uses the areas available for alternative uses. Table 23 shows the amount of pasture and rangeland that is suitable for crop use, while table 24 shows the amount of cropland which, by reason of its land capability class designation, should be in pasture and range.

Of the 103.8 million acres of land presently used for crop production in the basin, there are estimated to be 4.7 million acres classified in Classes V through VIII whose location would permit conversion to a less intense use such as grassland if it were economical for the owner to do so. Conversion of this land is desirable in order to reduce the erosion hazard. Estimates indicate that there are an additional 4.7 million acres in Classes V through VIII that, because of the size, shape, and location of the parcels, are impractical to convert to other uses.

There are 152.6 million acres of land under private ownership used for pasture, range, and hayland. Of this amount, it is estimated that about 20.2 million acres of arable land, Classes I through IV, exist in tracts large enough for conversion to cropland if the demand for increased food supplies should justify the change. This land is primarily in Classes II and III. Conversion to cropland will not create an erosion hazard if reasonable care in conservation treatment and management is exercised. There is an additional 29.8 million acres in the arable classes that are "locked in" the grassland areas of

Table 21 -- AGRICULTURAL LAND CAPABILITY CLASSES AND PRESENT LAND USE

Land Capability Class	Cropland	Pasture and Range	Forest and Woodland	Other Ag.	Total
		(Thousand Acres)			
		UPPER MISSOURI SUBBASIN[1]			
II	1,906	739	28	26	2,699
III	6,780	4,746	61	84	11,671
IV	1,367	2,963	50	20	4,400
V	1	200	27	2	230
VI	625	13,668	971	45	15,309
VII	31	3,149	803	4	3,987
VIII	---	57	24	73	154
TOTAL	10,710	25,522	1,964	254	38,450
		YELLOWSTONE SUBBASIN[1]			
I	127	11	1	3	142
II	725	400	29	10	1,164
III	1,531	1,890	24	19	3,464
IV	720	2,200	57	13	2,989
V	7	54	4	1	66
VI	241	11,168	557	20	11,986
VII	21	6,955	776	4	7,756
VIII	2	1,635	123	21	1,781
TOTAL	3,374	24,333	1,550	91	29,348
		WESTERN DAKOTA SUBBASIN[1]			
I	32	---	---	---	32
II	1,410	641	77	9	2,137
III	4,821	3,403	58	34	8,316
IV	1,925	5,866	53	23	7,867
V	24	560	57	3	644
VI	956	13,123	144	16	14,239
VII	127	8,039	583	40	8,789
VIII	---	45	5	84	134
TOTAL	9,295	31,677	977	209	42,158
		EASTERN DAKOTA SUBBASIN[1]			
I	653	48	5	27	733
II	11,908	3,285	121	270	15,584
III	6,375	3,416	34	98	9,923
IV	955	728	13	13	1,709
V	289	913	18	6	1,226
VI	814	3,392	12	40	4,258
VII	14	765	8	1	788
VIII	---	---	---	139	139
TOTAL	21,008	12,547	211	594	34,360
		PLATTE-NIOBRARA SUBBASIN[1]			
I	1,314	86	6	33	1,439
II	4,168	959	71	149	5,347
III	5,207	2,338	102	149	7,796
IV	3,326	4,320	97	60	7,803
V	13	249	20	1	283
VI	1,325	10,497	384	56	12,262
VII	278	16,409	927	45	17,659
VIII	3	289	329	128	749
TOTAL	15,634	35,147	1,936	621	53,338
		MIDDLE MISSOURI SUBBASIN[1]			
I	1,091	113	55	40	1,299
II	3,803	613	73	153	4,642
III	4,727	680	95	166	5,668
IV	1,171	339	55	36	1,601
V	41	103	9	9	162
VI	314	451	165	21	951
VII	72	185	174	20	451
VIII	---	1	5	2	8
TOTAL	11,219	2,485	631	447	14,782

[1] Does not include Federal lands producing agricultural products

Table 21 (Continued)

Land Capabilities Class	Cropland	Pasture and Range	Forest and Woodland	Other Ag.	Total
		KANSAS SUBBASIN[1]			
I	1,331	241	64	29	1,665
II	6,620	729	49	142	7,540
III	9,233	2,437	66	162	11,898
IV	2,676	1,626	28	53	4,383
V	3	17	7	---	27
VI	2,320	6,534	197	122	9,173
VII	157	2,029	184	21	2,391
VIII	1	6	2	23	32
TOTAL.....	22,341	13,619	597	552	37,109
		LOWER MISSOURI SUBBASIN[1]			
I	643	135	174	37	989
II	2,371	1,008	418	139	3,936
III	4,797	2,654	752	313	8,516
IV	1,378	1,373	929	136	3,816
V	9	28	27	2	66
VI	629	1,367	823	91	2,910
VII	378	760	2,634	72	3,844
VIII	3	9	31	793	46
TOTAL.....	10,208	7,334	5,788	793	24,123
		MISSOURI BASIN[1]			
I	5,191	634	305	169	6,299
II	32,911	8,374	866	898	43,049
III	43,471	21,564	1,192	1,025	67,252
IV	13,518	19,435	1,261	354	34,568
V	387	2,124	169	24	2,704
VI	7,224	60,200	3,253	411	71,088
VII	1,078	38,291	6,089	207	45,665
VIII	9	2,042	519	473	3,043
TOTAL.....	103,789	152,664	13,654	3,561	273,668

[1] Does not include Federal lands producing agricultural products.

Table 22 – ACREAGE OF LAND CONSIDERED FOR CONVERSION OF MAJOR USE

Subbasin	Acres of Grazing Land Converted to Crops	Land Converted From Crop To Pasture
	(Million Acres)	
Upper Missouri	3.9	0.7
Yellowstone	2.3	0
Western Dakota	4.9	0.7
Eastern Dakota	2.7	0.4
Platte-Niobrara	2.9	0.1
Middle Missouri	0.3	0.3
Kansas	0.9	2.0
Lower Missouri	2.3	0.4
Missouri Basin	20.2	4.6

the basin and are not considered available for conversion to more intense uses. This acreage is in small tracts and most of it is in the more hazardous land Class IV.

There are 13.6 million acres of forest and woodland in the basin that are privately owned. Although about 3.6 million acres of woodland are on arable land, none of it is considered as being available for conversion to cropland or grassland. Most of this woodland comprises areas of field and farmstead windbreaks or used for livestock shelter. Over 9 million acres of these private woodlands are on Class VI and VII land and only 165 thousand acres are on Class V wetland.

"Other Agricultural" land includes farmsteads, roads, rural churches, and other similar areas not of significant size to warrant an independent summary. There are 3.6 million acres of such land, none of which is considered as being available for alternate uses, although some changes will occur as farmsteads are obliterated and local roads abandoned.

Publicly owned lands make up 14 percent of the basin. Although these holdings are significant in size and strategically located, none of this land is considered for alternate uses even though it is recognized that when in the best interests of the public, some changes in use will occur. An example is the construction of a highway through national forest lands, if it provides the least costly or shortest route and the location is determined to be in the public interest. Certain lands now remaining in public ownership satisfy specific public purposes. Areas of significant natural beauty or historic interest are in the National Park System. Vast forested areas of the mountain states are managed for timber production, water yield, forage production, wildlife, and recreation as part of the National Forest System. The public domain lands are similarly managed for grazing, soil and watershed protection, military use, recreation, fish and wildlife production, research, and major reservoirs (see table 6, "Land and Water Ownership").

Table 23 – CURRENT NORMAL, PASTURE AND RANGE CONSIDERED FOR CONVERSION TO CROPLAND BY SUBBASINS, SOIL RESOURCE GROUP

Soil Resource Group	Subbasin								
	Upper Missouri	Yellowstone	Western Dakota	Eastern Dakota	Platte-Niobrara	Middle Missouri	Kansas	Lower Missouri	Missouri Basin
	(Thousand Acres)								
102	369	290	549	281	415	0	17	4	1,925
104	939	226	304	526	68	4	48	198	2,313
106	1,673	1,442	1,491	1,257	1,075	59	284	160	7,441
112	0	7	265	76	8	0	231	0	587
120	53	0	88	0	0	0	0	7	148
122	0	1	13	0	0	68	88	274	444
124	0	113	389	0	67	128	60	1,162	1,919
136	58	16	53	54	0	0	0	19	200
138	428	10	0	37	0	1	23	76	575
144	0	0	36	18	12	1	0	0	77
150	0	6	25	3	120	0	0	0	154
152	0	0	0	2	0	0	0	0	2
153	0	0	0	0	0	11	0	221	232
154	227	106	38	0	0	2	0	42	415
168	0	1	862	413	5	0	0	0	1,281
172	0	0	3	16	4	0	0	0	23
184	0	0	12	0	0	0	0	0	12
190	99	63	21	0	637	1	108	0	929
217	0	0	0	0	0	0	0	59	59
310	0	0	739	0	0	0	0	17	756
330	0	0	6	2	153	16	55	60	292
340	56	4	1	0	315	0	7	13	396
Total	3,902	2,285	4,895	2,685	2,879	301	921	2,312	20,180

Table 24 – CURRENT NORMAL, ACRES OF CROPLAND RECOMMENDED FOR CONVERSION TO LESS INTENSIVE PASTURE AND RANGE USE BY SUBBASINS AND SOIL RESOURCE GROUPS

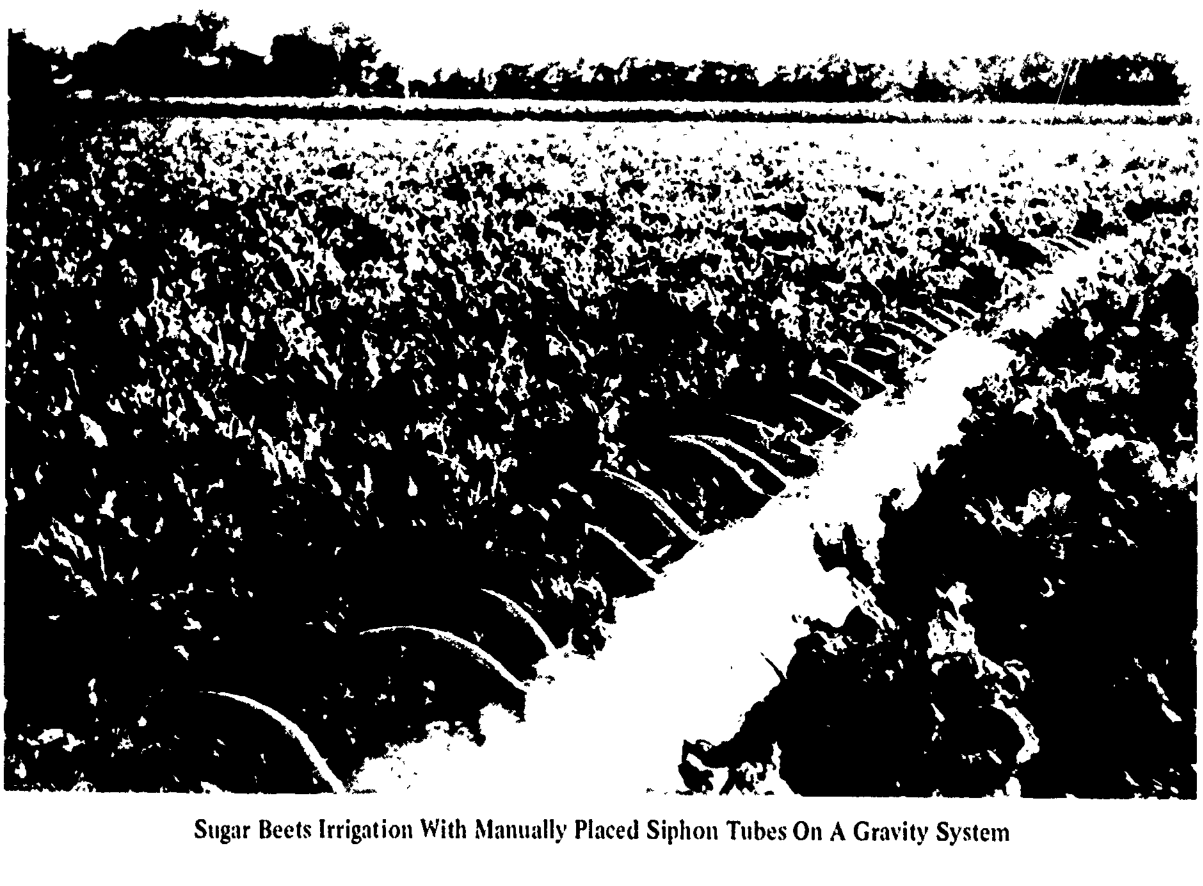
Soil Resource Group	Subbasin								
	Upper Missouri	Yellowstone	Western Dakota	Eastern Dakota	Platte Niobrara	Middle Missouri	Kansas	Lower Missouri	Missouri Basin
	(Thousand Acres)								
110	0	0	0	5	0	3	0	0	8
160	342	0	721	155	20	0	0	0	1,238
194	0	0	0	2	0	3	5	0	10
196	0	0	0	0	0	0	0	0	0
211	4	0	0	113	40	9	0	14	180
213	0	0	0	0	0	0	3	5	8
225	0	0	0	0	36	0	0	0	36
231	0	0	0	0	0	0	0	0	0
361	0	0	0	0	0	0	0	0	0
420	362	0	0	123	0	30	41	25	581
421	0	0	0	0	0	10	0	3	13
622	0	0	0	0	0	0	996	0	996
624	0	0	0	10	0	0	0	0	10
705	0	0	0	0	0	262	835	332	1,429
710	0	0	0	3	0	0	0	9	12
720	0	0	0	0	0	0	5	0	5
730	0	0	0	0	22	0	100	0	122
740	0	0	0	0	0	0	18	4	22
750	0	0	0	0	0	0	0	0	0
760	0	0	0	0	0	0	0	0	0
770	0	0	0	0	0	3	0	0	3
Total	708	0	721	411	118	320	2,003	392	4,673

Irrigation

The extent of land available for irrigation development was determined from analyses of the Conservation Needs Inventory compiled by the USDA, Soil Survey Reports, irrigation suitability classification data of the Department of the Interior, Experiment Station research data of the Land Grant Colleges, and from data from other sources.

The following definitions and criteria were developed in order to describe the potential for development of lands suitable for irrigation.

Potatoes Irrigated with Automatic Overhead Sprinkler System



Sugar Beets Irrigation With Manually Placed Siphon Tubes On A Gravity System

Irrigable Land is land having soil, topography, drainage, and climatic conditions favorable for irrigation and located in a position where a water supply is or can be made available.

Current Full Service Irrigation is land to which water is usually applied by controlled artificial means. This includes ditch, flood, and sprinkler irrigation, but excludes such things as sub-irrigation and floodwater spreading systems.

Current Intermittent Irrigation includes lands having partial or inadequate water supply. It also includes irrigation floodwater spreading systems by diversion of ephemeral stream floodflows to crop, hay, or pasture land.

Irrigable Land not now Irrigated is land with soil, topography, drainage, and climatic conditions suitable for irrigation but located where current water supply facilities are not now available, though they can be developed to supply water to the land.

There are approximately 64,255,000 acres of land having some kind of irrigation potential, if water were available (table 25). Largely because of extensive areas with favorable lands underlain with large amounts of ground water, Nebraska has the greatest acreage of irrigable lands, though other areas are tributary to potential surface water supplies. This is true to a lesser extent for Kansas, which shows the second highest amount of irrigable lands.

In determining the potentially irrigable lands, an allowance was made for very small completely isolated areas with no available water and for areas with insurmountable drainage or other development problems. However, some of the resource areas have potentially irrigable acreages larger than those reflected in the Conservation Needs Inventory data. This can be accounted for partially by the inclusion of lands in Capability Class IV and Bureau of Reclamation Class 6 in the irrigated lands, and partially by the fact that the CNI data covers only privately owned lands, whereas the total potentially irrigable area includes some publicly owned lands. The 64,255,000 acres of irrigable and potentially irrigable land is the total amount available for possible irrigation. All Bureau of Reclamation projects require detailed land classification investigations and certification to the Congress that the lands will sustain irrigation before service facilities are constructed.

Table 25 – SUMMARY OF IRRIGABLE AND IRRIGATED LANDS

Subbasin	Total Irrigable Lands	Current Full Service Irrigation	Current Intermittent Irrigation	Irrigable Lands not Now Irrigated
	(Thousand Acres)			
Upper Missouri	7,188	1,102	418	5,668
Yellowstone	3,722	1,188	235	2,299
Western Dakota	3,845	209	198	3,438
Eastern Dakota	9,797	119	113	9,565
Platte-Niobrara	12,115	2,986	150	8,979
Middle Missouri	7,683	103	0	7,580
Kansas	13,315	1,703	0	11,612
Lower Missouri	6,590	5	0	6,585
Missouri Basin	64,255	7,415	1,114	55,726

Recreation

There are approximately 7.2 million acres of privately owned forest and woodland areas in the basin considered to be available and adaptable to various recreation uses. The acreage of these lands by subbasins is shown in table 26. A very large share of the future needs for primary use recreation lands should be met by these "adaptable" private lands. Included in these lands with such potential are important private acreages within Indian reservations and settlements. A change of ownership would not be required to meet the recreation need shown in table 27.

Although complete data are not available, it is believed that at least several million acres of Federal land are either available for significant recreation use or are suitable for conversion from ancillary to primary recreation use. This might be accomplished through recreation development and/or establishment of large, designated areas of unusual interest and opportunity. Public domain lands undoubtedly have the greatest untapped potential

Table 26 – DESIRABLE PRIVATE LAND ACREAGES CONSIDERED AVAILABLE AND ADAPTABLE TO ALTERNATE RECREATION USES

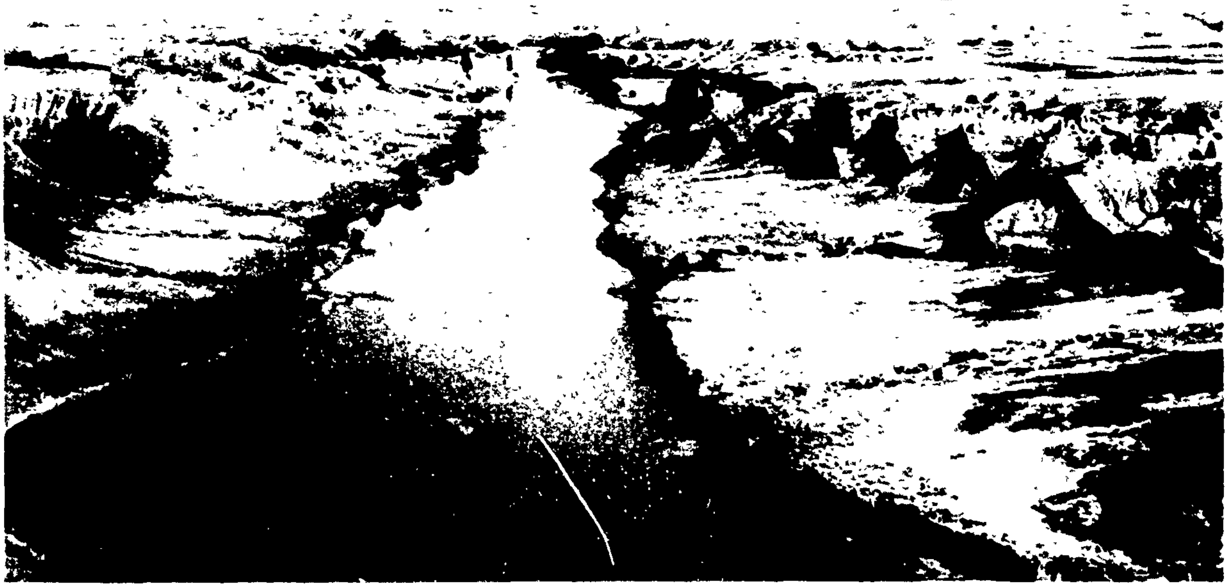
Subbasin	Estimated Land Acreage[1]
	(Thousand Acres)
Upper Missouri	1,155
Yellowstone	967
Western Dakota	523
Eastern Dakota	25
Platte-Niobrara	1,124
Middle Missouri	224
Kansas	250
Lower Missouri	2,926
Missouri Basin	7,194

[1] Acreages shown are not "total" acreages available. In addition, less desirable land will be developed or used for recreation purposes.

State and Private Lands Include Many Attractive Areas Suitable for Public Recreation

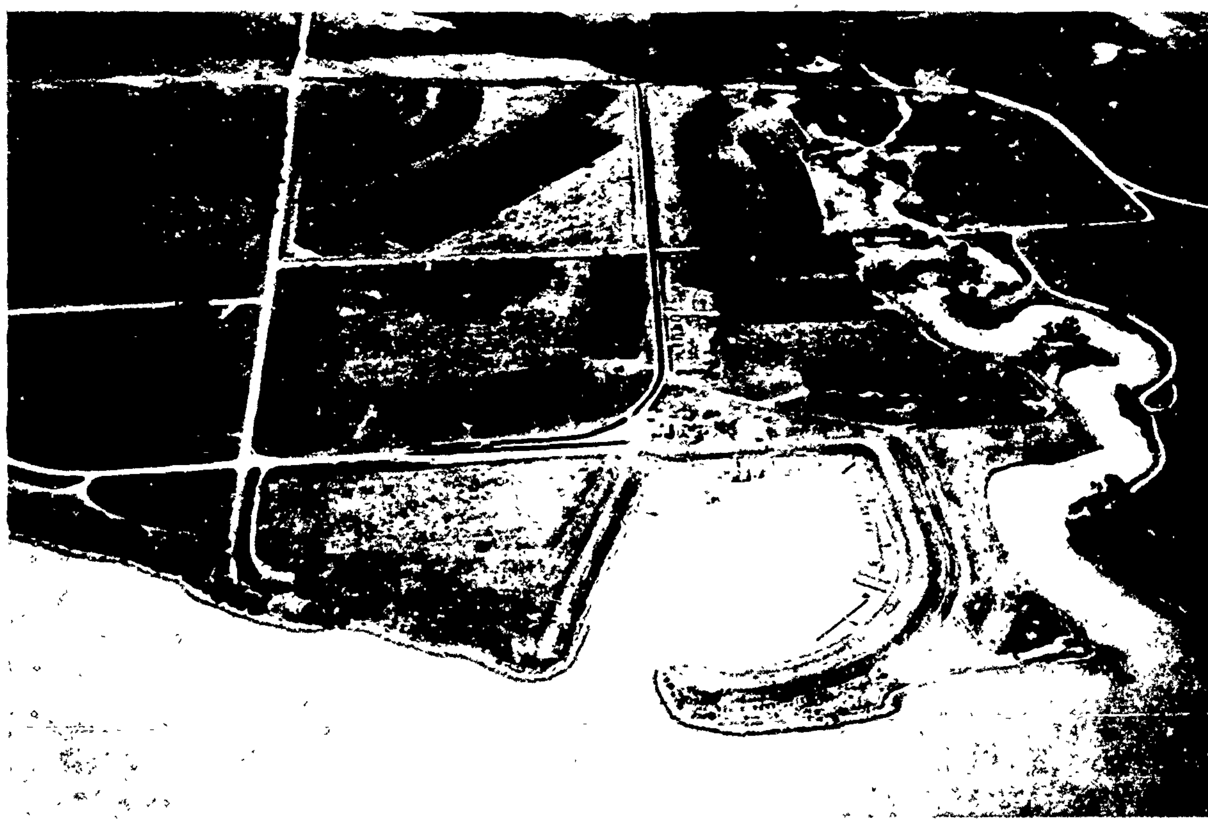
Table 27 – PROJECTIONS OF ADDITIONAL RECREATION LAND AND WATER NEEDED IN 1980, 2000, AND 2020, BY SUBBASINS

Subbasin	Target Year	Water Impoundments	Developed Recreation Areas	Undeveloped Land Used Primarily For Recreation
		(Surface Acres)	(Acres)	(Acres)
	1980	6,000	17,000	253,100
Upper Missouri	2000	11,000	38,100	445,100
	2020	30,000	59,400	657,100
	1980	3,500	12,600	129,000
Yellowstone	2000	14,500	32,000	393,000
	2020	30,000	57,200	723,000
	1980	4,000	13,500	115,600
Western Dakota	2000	12,000	48,300	428,100
	2020	41,000	70,700	605,200
	1980	18,700	14,400	219,900
Eastern Dakota	2000	36,900	32,000	376,500
	2020	65,800	54,600	583,800
	1980	21,000	40,000	113,000
Platte-Niobrara	2000	221,000	97,000	418,000
	2020	530,000	182,000	805,000
	1980	96,000	14,400	108,000
Middle Missouri	2000	220,000	30,100	174,000
	2020	360,000	50,000	363,000
	1980	17,600	11,700	138,200
Kansas	2000	60,600	26,300	230,200
	2020	113,600	43,700	343,800
	1980	60,000	29,000	64,400
Lower Missouri	2000	144,000	64,800	266,000
	2020	370,000	83,100	355,600
	1980	226,800	152,600	1,141,000
Missouri Basin	2000	720,000	368,600	2,371,000
	2020	1,541,000	600,700	4,437,000



Public Lands Along the Missouri River Breaks Offer Opportunities for Recreation Development

Man-Made Lakes Along Major Highways Offer Opportunities for Relaxation for Both Residents and Travelers



Tree Planting Enhances Recreation Use at Many Reservoirs

in both of these respects. However, the potential of Department of Defense areas, National Wildlife refuges, and national forests and national grasslands for similar recreation opportunities is also significant. In particular, national forest lands present many excellent opportunities for future recreation site development. Most opportunities for establishment of major recreation areas on existing Federal lands where significant increases in user intensity, capacity, and satisfaction could be realized will be associated with the Montana, Wyoming, and Western Dakota areas. Major opportunities to develop Federal lands for recreation use also exist at reservoirs and on other Federal lands in Colorado, Kansas, Nebraska, Missouri, and Iowa.

Too little is known about the availability of state and local government administered areas, for either recreation use or development, to permit any meaningful acreage estimates to be made. However, contributions from these lands are expected to be important. In the northern half of the basin, Indian lands, which are considered to be part of the private sector, offer many good-to-excellent potential areas for recreation uses and developments where only limited or tolerated use occurs now. In Iowa the existence of county conservation and park boards offers stimulus and a legal means of developing existing and acquiring additional lands for recreation purposes.

The possibilities for making state lands available for recreation and park purposes in the eastern and southern parts of the basin vary with the state and area. They are also partially dependent on changes in state laws and regulations and on the availability of money for interagency leases and acquisitions. However, what can be realized is exemplified by (1) the recent purchase of several thousand acres of state school land "inholdings" with Custer State Park in South Dakota, and (2) the proposal to convert the 72,000-acre Colorado State Forest in northern Colorado to a major state park. Another general state sector potential, especially applicable to the eastern half of the basin, lies in carefully located and greater general recreation development of fishing, hunting, and wildlife management areas. Nearly all such areas now serve recreation purposes, but facilities are frequently absent or inadequate.

Many of the recreational demands have not generated the market conditions necessary for private development. The private landowners have not developed the recreation potentials of their lands primarily because it would not pay them to do so.

There is no doubt that the potential for increasing recreation within the basin is present in large quantities. Further, this potential is spread throughout the basin. Thus, shortages of recreational opportunities have been caused from the failure to take advantage of the potential, not from any lack of land capability.

Table 27 presents projections of land areas needed for recreation in 1980, 2000, and 2020. The acreages shown are in addition to current supplies.

Fish and Wildlife

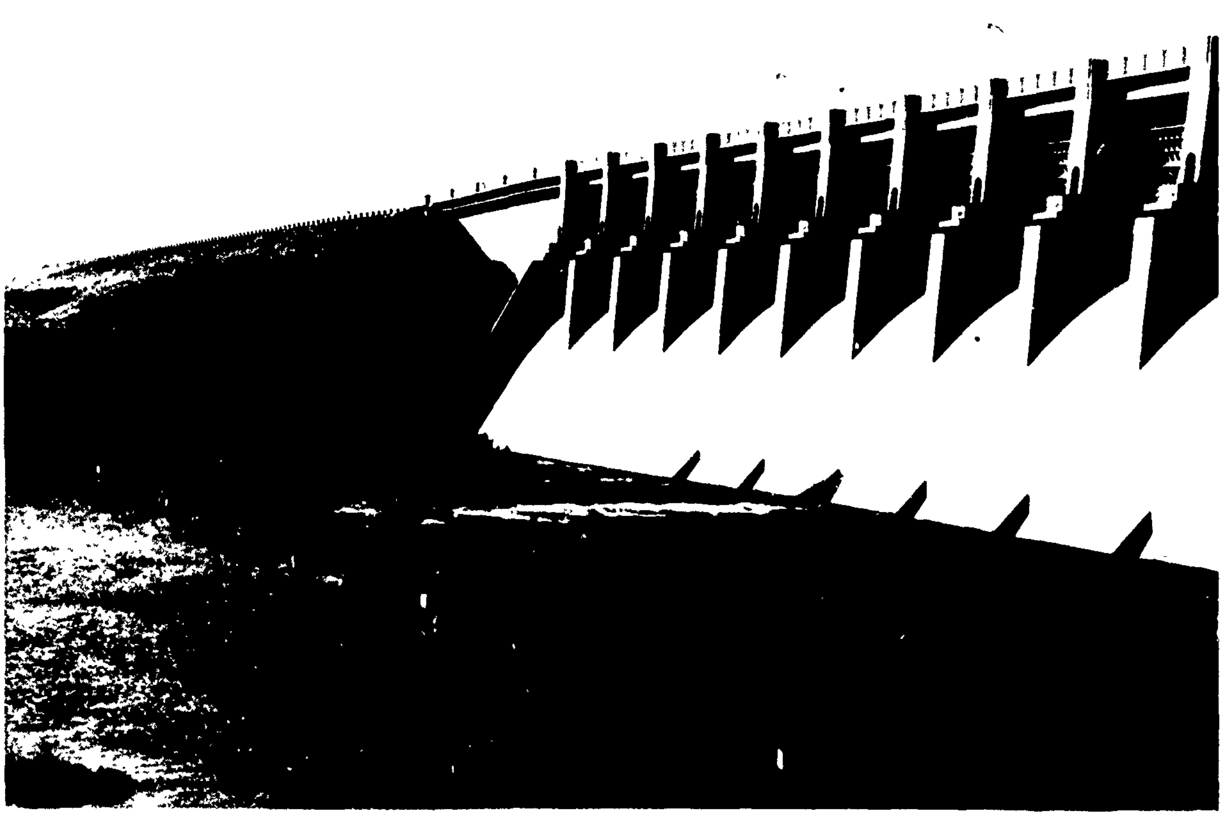
Approximately 320 million acres in the Missouri Basin are used by fish and wildlife, though the species vary by habitat and other conditions. Of primary importance is the intensity of fish and wildlife use in relation to how the basin lands and waters are used for other purposes. These conditions are indicative of the adaptability and availability of basin lands and waters for fish and wildlife use.

The total land and water area used by fish and wildlife falls into two broad categories described in Chapter 3 of this appendix: (1) lands and waters devoted to fish and wildlife as a primary use, and (2) lands and waters where fish and wildlife are secondary or ancillary users.

About 310 million acres of the lands and waters important to fish and wildlife fall into the category of ancillary use. This includes almost all of the private lands and a substantial portion of the public lands. Because of the tremendous acreage involved, these lands and waters support most of the basin's fish and wildlife, and offer most of the opportunities for further development.

There are about 10 million acres of land in the basin considered of primary use for fish and wildlife. This latter category includes lands managed by several Federal agencies and State agencies, and numerous small areas of privately owned land. Private lands and waters account for about 20 percent of this area. A substantial portion of the lands and waters in the National Parks and in some State parks is known to be of great importance to fish and wildlife. At present, limited data prevent classification and an estimate of the acreages of primary importance to fish and wildlife. The State conservation departments and the Bureau of Sport Fisheries and Wildlife lease or hold easement rights on nearly 250,000 of these acres. The bulk of this acreage is under Bureau of Sport Fisheries and Wildlife control for wetland preservation purposes in the Dakotas. Many State easements are for fishing or hunting access, and additional easements would provide opportunities for further development of this resource.

Over half of the total acreage on which fish and wildlife is a primary use lies in the Upper Missouri and Yellowstone subbasins, although these subbasins include only 30 percent of the total basin (figure 14). This is due to the large amount of public land, especially the National Forests and the Public Domain, and the suitability of these lands for fish and wildlife management. On the other hand, the Middle Missouri, Kansas, and Lower Missouri subbasins contain the smallest amounts of lands and waters on which fish and wildlife management is the primary use. These are the subbasins in which



Fishermen Below The Spillway Of A Missouri River Basin Dam agricultural land use is most intensive and the greatest need is to capitalize on all opportunities for developing fish and wildlife resources.

In general, those subbasins containing the most public land also have the most opportunities for developing land and water devoted to fish and wildlife. The Eastern Dakota Subbasin, a notable exception, contains a significant portion of the Nation's small marshes. Throughout the basin, the private lands account for millions of days of recreation and more millions of days of hunter and fishermen activity. For the most part, these services are provided free by the landowners and constitute an ancillary use (figure 16). However, it appears that the limits of these voluntary services by the private landowners are being reached. It will be necessary to provide some kind of inducement to these landowners to meet the projected future needs.

MAINTENANCE AND IMPROVEMENT OF LAND RESOURCES

Maintenance and improvement of the 325 million acres of basin lands for agriculture, recreation, fish and wildlife habitat, urban, and many other uses will require conservation measures on those lands not now adequately protected (table 28). Maintenance and periodic reinstallation of many measures now on the land will also be required. Measures that protect the land from the natural forces of water, wind, fire, and climate affect both yield and quality of water as well as land use and productivity. Conservation measures will also contribute to the reduction of flood hazards in rural and urban areas, improve water disposal or removal in areas where needed, and generally enhance recreational and fish and wildlife values. While treatments may vary from one area to another, the long-term result common to nearly all treatment measures is that of sustained or increased production. In some instances, such as forage yield, increases may not occur for a period of years because the deficit created by mismanagement or overuse in the past must first be satisfied.

Agricultural Land

Land conservation measures will diminish peak stream flows and sediment production caused by runoff from summer storms. However the identifiable effect diminishes as distance increases from the treatment areas. Intensive cropland, forest, range, or pasture management is needed to stabilize critical flood-source and sediment-producing areas.

Land conservation measures contribute directly to control and reduction of pollution. Sediment produced

Ducks Rising From Their Nesting And Feeding Area Of A Missouri River Basin Reservoir

Establishment And Maintenance Of Watershed Protection Measures Improve Productivity Of The Basin's Agricultural Lands

by erosion is a pollutant. It is both a mechanical abrasive and a contributor of unwanted foreign matter that must be removed before water can be used beneficially. Fine-grained sediment, particularly clay-sized particles, facilitate transport of agricultural pesticides, herbicides, chemical fertilizer, and animal wastes in water. Sediment yield is increased by improper land use and destructive agricultural and nonagricultural exploitive practices. Economically and aesthetically, sediment impairs water quality, contributes to swampy conditions, and depletes water storage capacity in reservoirs and streams.

Sediment causes turbidity in flowing streams and in some reservoirs. Therefore, it is an important factor when water quality problems associated with turbidity are under consideration. A reduction in volume of sediment entering streams will prevent serious damage to fish spawning beds and improve fish food supply; reduce the costs of water purification; extend the life of reservoirs and watershed structures; and decrease the cost of dredging channels and harbors for navigation.

Current and Projected Status of Land Conservation

Cropland, Nonirrigated– There are about 97 million acres of nonirrigated cropland in the basin with widely varying erosion hazards and conservation treatment needs.

In the eastern part of the basin, water erosion is the dominant problem on cropland. Sheet and gully erosion are the major hazards to tilled soils that occur on slopes exceeding two percent. Runoff is fairly rapid, due to the slope, except in the sandy soils. Vegetated waterways, terraces, contour farming, strip cropping, proper use of crop residues, adequate use of fertilizers, and conversion of marginal croplands to permanent vegetation are the major treatments needed to control water erosion and provide protection to cropland. Agricultural lands with excess water need draining before satisfactory crop yields can be obtained. On the floodplains, the nearly level well-drained soils, with little or no flooding except in abnormally wet seasons, have little erosion hazard. Simple precautions, such as the maintenance of perennial vegetation, are needed along stream channels to prevent streambank erosion.

In the western and northern portions of the basin, both wind and water erosion are the dominant problems on cropland. In the western part, inadequate moisture is a limiting factor in crop production. An alternate crop and fallow system is necessary to produce satisfactory yields of most nonirrigated crops. Residue management practices which allow the stubble or other crop residue to remain on or in the surface of the soil during the

Table 28 – CURRENT CONSERVATION TREATMENT AND NEEDS[1]

Item	Subbasins								
	Upper Missouri	Yellowstone	Western Dakota	Eastern Dakota	Platte-Niobrara	Middle Missouri	Kansas	Lower Missouri	Missouri Basin
NON-FEDERAL LAND	(Thousand Acres)								
Cropland (Non-Irrig.)									
Total	9,757	2,343	9,097	20,889	12,850	11,116	20,638	10,203	96,893
Adequate	4,683	960	3,184	7,520	4,369	3,891	7,223	3,469	35,299
Management	4,879	1,289	3,184	7,520	3,212	2,223	5,985	1,735	30,027
Mgmt., Veg., & Mech.	195	94	2,729	5,849	5,269	5,002	7,430	4,999	31,567
Cropland (Irrig.)									
Total	953	1,031	198	119	2,784	103	1,703	5	6,896
Adequate	267	258	79	75	1,002	34	886	2	2,603
Management	229	412	50	29	585	21	306	1	1,633
Mgmt., Veg., & Mech.	457	361	69	15	1,197	48	511	2	2,560
Pasture & Range									
Total	25,522	24,333	31,677	12,547	35,147	2,485	13,619	7,334	152,664
Adequate	8,677	9,003	15,839	4,893	15,816	721	4,767	2,420	62,136
Management	13,527	10,463	12,037	5,646	15,465	919	6,265	1,174	65,496
Mgmt., Veg., & Mech.	3,318	4,867	3,801	2,008	3,866	845	2,587	3,740	25,032
Forest & Woodland									
Total	1,964	1,550	977	211	1,936	631	597	5,788	13,654
Adequate	1,218	899	439	116	1,045	189	311	2,662	6,879
Management	727	605	352	38	639	335	113	2,547	5,356
Mgmt., Veg., & Mech.	19	46	186	57	252	107	173	579	1,419
Other (Ag. & Non-Ag.)									
Total	886	350	980	2,424	2,529	1,220	1,701	1,510	11,600
Adequate	806	326	784	2,085	2,276	1,062	1,122	1,192	9,653
Management	0	3	127	218	101	134	256	46	885
Mgmt., Veg., & Mech.	80	21	69	121	152	24	323	272	1,062
Total Private Land									
Total	39,082	29,607	42,929	36,190	55,246	15,555	38,258	24,840	281,707
Adequate	15,651	11,446	20,325	14,689	24,508	5,897	14,309	9,745	116,570
Management	19,362	12,772	15,750	13,451	20,002	3,632	12,925	5,503	103,397
Mgmt., Veg., & Mech.	4,069	5,389	6,854	8,050	10,736	6,026	11,024	9,592	61,740
FEDERAL LAND	(Thousand Acres)								
Pasture & Range									
Total	6,685	9,281	3,645	6	4,497	---	49	7	24,170
Adequate	3,677	5,290	2,369	2	2,428	---	17	4	13,787
Management	2,340	2,877	911	1	630	---	22	---	6,781
Mgmt., Veg., & Mech.	668	1,114	365	3	1,439	---	10	3	3,602
Forest & Woodland									
Total	5,247	4,523	1,486	33	2,952	1	20	170	14,432
Adequate	3,673	4,116	743	18	2,863	1	10	153	11,577
Management	1,049	180	430	6	60	T	4	---	1,729
Mgmt., Veg., & Mech.	525	227	313	9	29	T	6	17	1,126
Other (Ag. & Non-Ag.)									
Total	1,279	1,442	824	173	326	15	213	108	4,380
Adequate	1,151	1,409	700	149	326	13	111	80	3,939
Management	51	---	66	16	---	1	40	---	174
Mgmt., Veg., & Mech.	77	33	58	8	---	1	62	28	267
Total Federal Land									
Total	13,211	15,246	5,955	212	7,775	16	282	285	42,982
Adequate	8,501	10,815	3,812	169	5,617	14	138	237	29,303
Management	3,440	3,057	1,407	23	690	1	66	---	8,684
Mgmt., Veg., & Mech.	1,270	1,374	736	20	1,468	1	78	48	4,995

[1] Land Adequately Managed or Treated - Includes all land on which the use, management and treatment meets the minimum standards of the conservation programs of the SCS, Soil Conservation Districts, the Indian Service, or of the Federal Land Management Agency concerned. It includes all types of management, vegetation, and mechanical practices.

fallow periods are needed to reduce soil losses and conserve moisture. Strip cropping, contour farming, grassed waterways, and terraces may be necessary to control erosion.

It is estimated that about 35 million acres, or 36 percent, of the nonirrigated cropland are adequately treated at the present time. About 30 million acres need only the installation of improved management measures to be considered adequately treated. Many of these practices, such as stubble mulching and strip cropping, can be installed with minimum expense. About 32 million acres require vegetative and mechanical measures such as the construction of terraces and waterways to reduce erosion and soil loss as well as improved management measures.

Cropland: Nearly Two-Thirds Of The Cropland Still Needs Protection From Erosion With Practices Similar To Those Used On This Nebraska Farm

It is expected that the percentage of land adequately treated will increase to about 48 percent by 1980, to 63 percent by 2000, and to 77 percent by 2020.

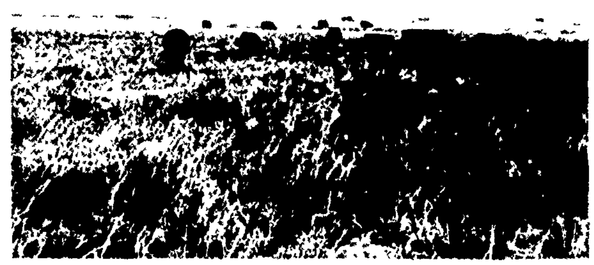
Cropland, Irrigated– Approximately 6,896,000 acres of cropland in the basin are irrigated. Most of this acreage is located in the western part of the basin. The addition of irrigation water to suitable cropland areas reduces the limitation of inadequate moisture. It is important to keep a good vegetative cover on or in the surface of irrigated soil. Water quality control, reducing water delivery losses, adequate storage facilities, drainage, maintenance of fertility, and improved on-farm irrigation water management are the major requirements for maintaining the land resources. About 2.6 million acres or 38 percent of the irrigated cropland is presently considered to be adequately treated. About 24 percent needs improved management practices such as the proper application of irrigation water, crop residue management, proper cropping systems, and maintenance of fertility to be adequately managed. About 38 percent needs mechanical measures, such as land leveling and smoothing, the installation of drainage ditches or tile, and the improvement of on-farm irrigation systems in addition to management measures to be adequately treated. It is expected that the proportion of land adequately treated will increase to about 50 percent by 1980, to 67 percent by 2000, and to 81 percent by 2020.

Pasture and Range– There are about 177 million acres of pasture and range in the Missouri Basin, with about 153 million acres of non-Federal privately owned and 24 million acres federally owned land. In the eastern part of the basin, the pastures are in small, scattered tracts. Most pastures are in lowland areas subject to frequent flooding or on areas where slopes are too steep or soils are too shallow for cultivation. The major problem of pasture [illegible]ement [illegible] over-grazing. The grass is grazed so close [illegible] are weakened. Where pastures are on rolling [illegible] the plants are unable to control soil erosion. The main practices needed to treat pastureland are proper use, rotation grazing, fertilizing, and reseeding depleted areas.

Rangeland mainly occurs in the Bluestem Hills area of Kansas Subbasin, Sand Hills of Nebraska, and the northern and western parts of the Missouri Basin. Much of the rangeland is on steep land, shallow soils, or areas generally not suitable to cultivation. The needs are proper use, rotation grazing, development of adequate stock water facilities, reseeding of depleted areas, and in some areas control of competing weedy vegetation.

The mountain parks and meadows and alpine grasslands are grazed mostly in summer. These lands, because of the short growing season, long-term recovery period, and their association with high water-yielding areas, are particularly important from a watershed protection standpoint. The vegetative turf common in these areas is the primary form of watershed protection. While this turf is quite hardy, continual overuse is extremely detrimental to it, and an erosion process can be started that is difficult to control. At the higher elevatio[illegible] [illegible]nge readiness, livestock distribution, proper use, and stock removal when proper use has been obtained are important in maintaining a good ground cover.

Grasslands: Almost Half Of The Basin's Grasslands Is Well Managed And Properly Treated



Range Revegetation, Fencing, And Proper Range Management Practices Are Improving Forage Production And Stabilizing Soils

About 62 million acres or 41 percent of the non-Federal and 14 million acres or 57 percent of the federally owned range and pasture land is currently adequately treated. About 65 million acres or 43 percent of the non-Federal and seven million acres or 28 percent of the Federal land need only the application of proper management practices such as proper grazing to maintain or improve the grass condition. About 25 million acres or 16 percent of the non-Federal land and 3.6 million acres or 15 percent of the federally owned range and pasture land need vegetative and mechanical practices such as reseeding, control of competing vegetation, or construction of water facilities. It is estimated that the non-Federal and Federal range and pasture land adequately treated will increase to 51 and 64 percent in 1980, to 66 and 83 percent in 2000, and 78 and 96 percent in 2020, respectively.

Forest and Woodland– There are about 28 million acres of forest and woodland in the Missouri Basin, with 13.6 million acres in non-Federal and 14.4 million in Federal ownership. The principal forested areas are in the Ozark Highlands, the Black Hills, and the Rocky Mountains. In the Ozark Highlands the forest is mainly of the oak-hickory type. The forested portions of the Black Hills area consist of ponderosa pine. In the Rocky Mountains, the forested areas consist principally of lodgepole pine, ponderosa pine, true fir, spruce, and Douglas fir. In the other parts of the basin, the cottonwood-elm-oak type occurs along the principal river bottoms and in areas too rough or shallow for cultivation. A considerable acreage of woodland consists of trees planted for field and farmstead windbreaks and shelterbelts.

Both lightning fires and man-caused fires have devastated certain critical mountain slopes by destroying plant cover and humus. Careless cutting and logging operations have caused erosion and streamflow disturbances along the eastern front of the Rocky Mountains, in parts of the Black Hills, and throughout the Ozarks. Uncontrolled woodland grazing, especially in the hardwood areas, has compacted the top soil and caused accelerated erosion on thousands of acres. The forest can be improved throughout the basin, particularly in enhancing water production and flood runoff reduction. Progress in these two aspects has been made on the Federal forest lands, but much still remains to be accomplished even on these areas.

Tree Planting in Windbreaks And Shelterbelts Gives Added Protection To Croplands And Farmsteads Of These North Dakota Farms

Fire Destroys Humus, Increasing Erosion and Runoff

Most of the non-Federal woodlands are in small holdings. Land conservation could be improved on these lands by range management practices to control grazing. When trees are harvested, proper road location and design, skidding methods, erosion control measures, and regeneration of new stands are needed.

The federally owned forest lands include some of the high water yielding areas of the basin. Management practices include timber stand improvement measures, thinning, timber harvest planning, slash and debris disposal, road location and design, and erosion control measures during the following timber harvest.

It is estimated that 6.9 million acres or 50 percent of the non-Federal owned land and 11.6 million acres or 80 percent of the federally owned forest and woodland are adequately managed or treated at the present time. Approximately 5.4 million acres of the non-Federal land and 1.7 million acres of the Federal land need proper management-type practices only such as protection from fire, disease, insects, and grazing control. The balance, 1.4 million acres of non-Federal land and 1.1 million acres of Federal land, needs establishment of practices such as removal of undesirable trees, replanting or reforestation and proper or timely harvesting in addition to improved management practices.

The percentage of land adequately treated is expected to increase, for non-Federal and Federal lands respectively, to 56 and 83 percent in 1980, to 62 and 89 percent in 2000, and to 68 and 93 percent in 2020.

Under Intensive Forest Management, Timber Harvesting In Designed Strips Or Small Openings, Reduces Evapotranspiration Losses, And Traps And Shades Snow

***Other Land*–** There are about 16 million acres classified as "Other Land" in the basin. Of this amount, about 11.6 million acres are in non-Federal ownership. This includes about 3.6 million acres of agriculture land, farmsteads and farm roads, wildlife areas on farms and ranches, or idle land. About 8 million acres are used for non-agricultural purposes such as urban areas, cemeteries, city and state parks, highways, rural non-farm residences, and other rural areas with non-agricultural uses. The 4.4 million acres of Federal land in this group are used for parks, wilderness areas, wildlife refuges, and recreation areas around large federally constructed impoundments.

Runoff is generally high on urban and transportation areas. The conservation measures are related to the control of erosion in the drainageways, by such means as establishment and maintenance of vegetation, drop structures, or similar installations. A significant part of the area needing treatment is associated with urban development and highway and road construction. Disturbed or raw areas are subject to high rates of runoff and severe erosion during high intensity rain storms. Strip mining and other mineral activities affect relatively small areas, but require intensive treatment and management to avoid widespread effects.

Parks and military areas generally have a good cover and require treatment of only the more intensively used areas. Conservation practices primarily are management measures required to maintain the vegetative cover for environmental considerations, wildlife habitat, as well as for erosion control purposes.

About 9.6 million or 83 percent of the non-Federal land and 3.9 million acres of the federally owned land or 90 percent in this category is adequately treated. About 0.9 million acres of the non-Federal land and four percent or 0.2 million acres of Federal land requires management type practices, such as improved fire and insect control or wildlife management. About 1.1 million acres of the non-Federal land and 0.3 million acres of the Federal land require establishment of vegetation or erosion control measures, such as drop structures or other vegetative and mechanical measures, to stabilize drainageways.

It is expected that adequate treatment of the non-Federal and Federal lands in this classification will increase to 86 percent and 91 percent by 1980, to 89 and 95 percent by 2000, and to 92 and 96 percent by 2020, respectively.

Recreation Lands

Some of the best known recreation lands of the United States are situated in the Missouri Basin. They are characterized by the cliche "wide open spaces". They offer ideal recreation environment and contain unusual potential for recreational opportunities attractive to

Other Lands: About Three-Fourths Of The Transportation, Urban, And Built-Up Area Has Been Treated For Erosion Prevention Measures tourists. Recreation and tourism are important enterprises in many locations in the basin. Completion of the interstate highway system will greatly enhance and increase recreational travel within the basin. Approximately 50,300,000 acres or 15 percent of the basin is used for recreation, and about 175,000 acres are intensively developed to serve this purpose. Detailed problems and needs for improving recreation lands are included in the Present and Future Needs Appendix.

The loss of lands which could probably serve their highest use through dedication to recreation and aesthetic purposes becomes more important each year. Generally, recreation problems are more acute in and near fast growing urban areas. The demands are great for lands along rivers, streams, and lake shores for both private uses and water resource developments.

The Demands Are Great For Access And Development of Recreation Use And Fish And Wildlife Habitat Along Rivers, Streams, And Lake Shores

The mounting loss of quality environment is intertwined with the loss of quality recreation lands. The problem is especially noticeable and difficult in and near the larger cities of the basin. A general failure to recognize creeping ugliness coupled with an absence of unified action to do anything about it are major factors.

Environmental problems are less serious in nonurban areas, but there is a potential for widespread and irreparable loss of aesthetics in many locales that could transcend the losses that have occurred in basin cities. Good land-use planning and controls, special recreation area zoning, and private owner cooperation will be essential. In the future, as now, roadside and waterfront zones will be problem areas and will demand special attention.

The job of meeting the transportation need in areas of difficult terrain, while preserving the adjacent scenic resource, could prove to be one of the most challenging future problems.

Many reservoir and other recreation areas in the Great Plains lack adequate shade and screening. The plains portion of the basin is noted for numerous clear and hot days, so the need for trees and shade is considerable not only in recreation areas, but in areas of proposed future development.

Thousands of miles of additional good access roads along the Missouri River are needed in Montana, the Dakotas, and Missouri in particular. Considerable county-State-Federal and private sector cooperative action will be needed to overcome these access limitations.

Recreation is one of the beneficial uses recognized by all of the basin States in the development of their water quality standards. Standards have been developed to maintain the high water quality required for body contact, aquatic sports, and other recreational activities.

Recent Congressional action has designated a number of rivers and lands adjacent thereto, as components of the National Wild and Scenic Rivers System. Although no rivers in the Missouri River Basin have been included in the system, two of the basin rivers have been designated for additional study and potential addition to the wild and scenic rivers system. They are the entire 265-mile length of the Gasconade River in Missouri and a 185-mile reach of the Missouri River between Fort Benton and Ryan Island in Montana. Six other Missouri Basin river reaches totaling 720 miles were considered in various proposals made prior to the establishment of the system. These rivers also should be considered to have potential for future addition to the system.

Several of the aesthetically unique candidate rivers included in earlier proposals, as well as several excellent reaches of non-candidate rivers, are or will be endangered by proposed water resource developments. Most commonly, impoundment or channelization will be involved. Careful planning and thorough consideration of needs and alternatives will be absolut[illegible] essential to retain some of the more outstanding free-flowing rivers and fisheries of the Missouri Basin and the Nation.

There are many historic and archeologic sites, notably the remnants of once bustling mining towns in Montana and Colorado, that will eventually be lost if sufficient interest and funding are not secured for their conservation.

Fish and Wildlife Lands

The more significant fish and wildlife problems, whether physical, legal, or institutional, are discussed in the appendix "Present and Future Needs." These include: (1) poor distribution of fishing and hunting demand relative to supply, (2) legal and physical restrictions on public access, and (3) changes in game habitat associated with land use and management. Many of the problems can be resolved or minimized with coordinated development planning.

In the eastern part of the basin, the major opportunity for increasing fishing lies in the construction and use of small reservoirs. Generally, single-purpose fishing lakes of 100 to 300 acres located within easy range of population centers will best serve the need. Such lakes can be efficiently managed for maximum production, fishing quality, and public use. Multi-purpose reservoirs also offer opportunities. Planning of such impoundments must be fully coordinated among agencies concerned and fishery enhancement features adequately considered in project formulation.

Only a limited number of resource development potentials exist for increasing hunting near the major population centers. Preservation, enhancement, or development of wildlife habitat in conjunction with urban-related development should receive a high priority in planning.

While there will be much less need for fish and wildlife development in the upper part of the basin to supply resident demand, considerable maintenance and improvement of land resources will nevertheless be required.

The Missouri Basin contributes significantly to national as well as regional waterfowl production. Maintenance and improvement of this resource, both within and without the basin, is heavily dependent on the wildlife habitat that is maintained within the basin.

Public use of private lands for hunting and fishing these resources is permissive by owners, a prerogative that certainly should not be changed. Nevertheless, a coordinated effort to provide effective arrangements from the land owner's point of view and to improve public access to fish and wildlife areas is necessary to gain a fuller use of these resources.

Acquiring land for public hunting and fishing, never a particularly popular idea in most of the basin, often will be prohibitive because of the high cost. Despite this, many fishing access sites should be acquired outright. More and better roads will be required in the future. Access to publicly controlled areas for hunting and fishing should be unlimited, except to the extent actually needed to be consistent with the purposes for which the areas are managed.

There are opportunities for maintaining and improving land and water areas and the enhancement of fish and wildlife habitat with land treatment measures and improvement in land management practices. These opportunities are particularly apparent along the eastern slope of the Rocky Mountains where outstanding natural trout waters and big-game habitat occur. However, opportunities for maintaining and improving hunting and fishing habitat are not confined to the west as there are important opportunities in the rest of the basin. Among the more notable examples are the streams in the Ozark Plateaus of Missouri and the Black Hills of South Dakota and Wyoming, the wetlands of the Dakotas, and the natural lake complexes remaining in the Dakotas and Nebraska.

A variety of wildlife habitat opportunities are identified for agricultural-related lands. Many opportunities for wildlife are realized through small watershed development when adequate consideration is given in the planning.

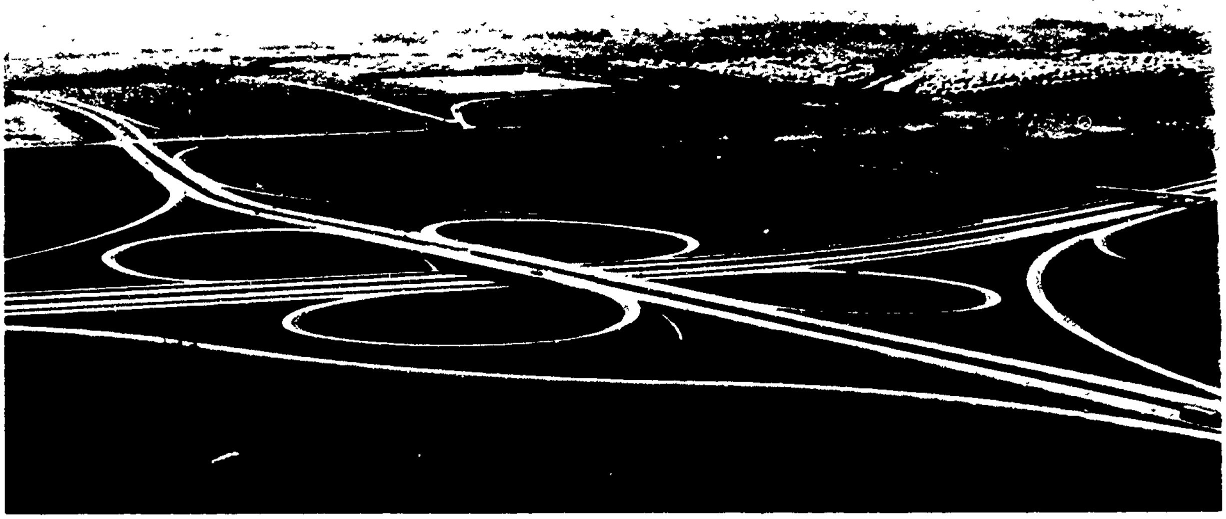
Highway construction and strip mining planned with adequate consideration of wildlife offer some excellent opportunities to retain and enhance wildlife usage and public enjoyment.

BASIC LAND DIVERSIONS NOT AVAILABLE FOR ALTERNATE USES

Full development of the basin's resources to help meet national requirements for goods and services means that towns, industries, and transportation systems must continue to grow. All such growth will require additional land. In most instances, use of land for these special purposes precludes its future use for other purposes. Lands will also be required for the use of mineral industries and for military purposes. Generally, these lands are not readily adaptable for returning to other resource use without extensive rehabilitation. In addition, other lands will be required for installations and developments for the implementation of the framework plan proposed by this report. Once diverted, most of such lands will not be available for future alternate uses.

Transportation, Urban, and Built-up Areas

Lands needed for the development of transportation, urban, and built-up areas will be available as needed. It must be presumed that land for these needs will always be made available. At the present time, there are about



Once Land Is Dedicated To Uses Such As Highways And Urban Development, It Is Not Available For Alternative Use

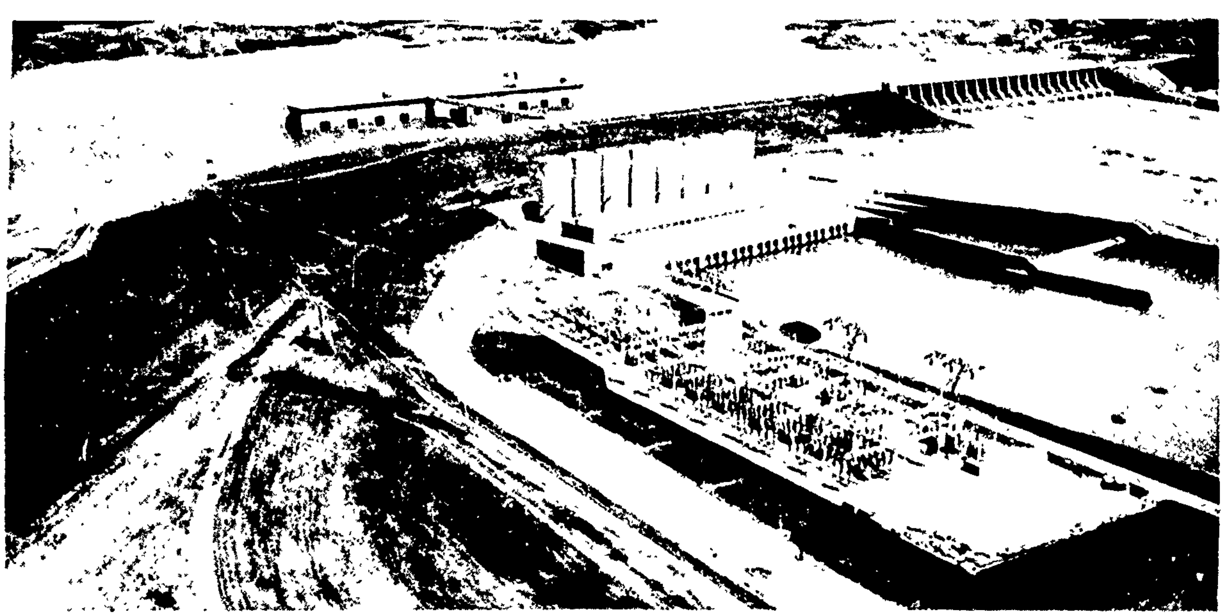
7,680,000 acres of land in this type of use. It is projected that it will increase to 8,492,000 acres in 1980, to 10,035,000 acres in 2000, and to 12,483,000 acres in 2020. Areas diverted for these developments will be almost entirely from lands whose primary use is agricultural, but other uses, such as recreation, fish, and wildlife, will also be affected.

Military Lands

Lands needed for military purposes will be available as needed and at locations desired, but it is not possible to predict the future demands. In 1965 the utilization of lands for primary military purposes was 622,000 acres. The projections for 1980, 2000, and 2020 are kept at this same level for purposes of this study.

Mineral Industry Lands

Lands used in the mineral industry amounted to 33,000 acres in 1965. This is projected to increase to 53,000 acres in 1980, 69,000 acres in 2000, and 88,000 in 2020. Almost all of this diversion will be from agricultural use and mostly from pasture and range. There is a growing public demand for the return of these lands to other beneficial uses after the mineral resources have been depleted.



Dams, Electric Power Plants, And Switchyards Are Permanent Installations Of River Basin Development

CHAPTER 5

FRAMEWORK PLAN-- PRIMARY AND ANCILLARY LAND USE SUMMARY

INTRODUCTION

The implementation of the framework plan for the development and protection of the basin's water and related land resources will change in the availability, nature of use, and also the intensity with which these resources are used. Only the changes in land use are covered in this chapter. The corresponding changes in intensity and productivity are evaluated and discussed in the appendix on Plan of Development and Management of Water and Related Land Resources.

The future use of land resources will be affected by many forces. Some factors are basic in nature and will occur independently of the planning effort. Future requirements for transportation, habitation, industrial sites, national defense, and projects currently funded but not constructed are basic to the well-being and economic existence of people. Generally, the prices necessary to divert such lands from existing uses are not a deterrent to their acquisition. Such basic land diversions and changes in land use must be included in an analysis of land use changes resulting from the proposed plan. Projections of these basic land diversions plus projections of land area which will be removed from agricultural production by uncontrolled gully erosion are shown in table 29.

Projected land use and availability, without implementation of any activities other than these basic diversions, is summarized in table 30. Projections of land availability are sequential by time period. Estimation and inclusions in the first time period affect the starting base inventory of each subsequent time period. Many changes, other than basic diversions, will occur. The table shown is not a projection of land use, but merely shows the adjustment in current normal for funded reservoirs being constructed and basic diversion in the projection period. It provides a 1980 base from which sequential changes will occur with implementation of the plan. In addition, the table lists projected land changes in subsequent time periods and land availability by 2020.

WATER AND LAND RESOURCE FRAMEWORK DEVELOPMENTS

To adequately plan future programs for water and land resource use and development, all foreseeable changes, both public and private, must be considered. The framework plan described in the appendix on Plan of Development and Management of Water and Related Land Resources considers both public and selected private development features. Such comprehensive coverage of foreseeable changes is a necessity for planning, analyzing, and projecting land availability in the future.

The framework plan for the Missouri Basin, which will be a guide for future action programs, consists of the following:

1. Continuation of current specified programs and activities.
2. Additions and modifications to existing developments.
3. Water control and related land developments.
4. Environmental enhancement features.
5. Non-structural measures.

To accomplish the purposes exemplified by these components, the framework plan provides for developments which are both single and multiple purpose in nature. The plan also outlines a scheduling for implementating the planned developments.

The comprehensive plan consists of two elements of projected changes. The first includes such things as research, technology, land conservation, and the trends in individual actions which are evaluated and projected only with respect to their contribution to the use and capability of the basin's resources in the future. The second element includes functional features of the recommended framework development plan which will change future land use, capability, and availability when implemented.

Clear separation of the elements of the framework plan into public and private activities is difficult due to the many varied Federal agencies' direct activities and Federal programs for cost-sharing and technical assistance. Furthermore, separation of elements with respect

Table 29 – PROJECTED LAND REQUIREMENTS FOR TRANSPORTATION, URBAN, BUILT-UP AREAS, FUNDED RESERVOIRS, MILITARY, AND MINERAL LANDS, AND GULLY EROSION, 1980, 2000, AND 2020

Subbasin and Target Year	Transportation, Urban, Built-up, & Military	Mineral Industry	Gully Erosion	Funded Reservoirs	Total Land Use Change
	(Thousand Acres Incremental)				
1980					
Upper Missouri	38	3	0	0	41
Yellowstone	56	7	5	0	68
Western Dakota	44	2	2	0	48
Eastern Dakota	63	0	13	0	76
Platte-Niobrara	234	2	9	6	251
Middle Missouri	68	1	95	0	164
Kansas	72	4	17	97	190
Lower Missouri	237	1	49	267	554
Missouri Basin	812	20	190	370	1,392
2000					
Upper Missouri	60	0	0	0	60
Yellowstone	98	7	9	0	114
Western Dakota	72	1	4	0	77
Eastern Dakota	109	1	26	0	136
Platte-Niobrara	444	2	17	0	463
Middle Missouri	136	0	189	0	325
Kansas	134	4	33	0	171
Lower Missouri	490	1	97	0	588
Missouri Basin	1,543	16	375	0	1,934
2020					
Upper Missouri	87	-2	0	0	85
Yellowstone	154	13	9	0	176
Western Dakota	104	1	4	0	109
Eastern Dakota	158	1	25	0	184
Platte-Niobrara	716	2	18	0	736
Middle Missouri	220	1	190	0	411
Kansas	198	2	33	0	233
Lower Missouri	811	1	97	0	909
Missouri Basin	2,448	19	376	0	2,843

Table 30 – CHANGES IN LAND USE AND LAND BASE WITH ONLY BASIC DIVERSIONS CONSIDERED, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020 MISSOURI BASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed in Place	Adjusted Current Normal	Land Use Change CN -1980	Projected 1980 Base	Land Use Change 1980-2000	Land Use Change 2000-2020	Resulting Land Availability by 2020
				(Thousand Acres)				
Agricultural Land	312,392	-370	312,022	-1,022	311,000	-1,934	-2,843	306,223
Irrigated Cropland	(6,896)	(-3)	(6,893)	(-56)	(6,837)	(-101)	(-183)	(6,553)
Non-Irrigated Cropland	(96,893)	(-194)	(96,699)	(-502)	(96,197)	(-1,105)	(-1,462)	(93,630)
Pasture & Range	(152,664)	(-96)	(152,568)	(-348)	(152,220)	(-534)	(-842)	(150,844)
Forest & Woodland	(13,654)	(-67)	(13,587)	(-94)	(13,493)	(-143)	(-248)	(13,102)
Other Ag. Land	(3,561)	(-10)	(3,551)	(-22)	(3,529)	(-51)	(-108)	(3,370)
Federal Ag. Land	(38,602)	(0)	(38,602)	(0)	(38,602)	(0)	(0)	(38,602)
Miscellaneous	(122)	(0)	(122)	(0)	(122)	(0)	(0)	(122)
Recreation	2,814	0	2,814	0	2,814	0	0	2,814
Fish & Wildlife	738	0	738	0	738	0	0	738
Other[1]	8,745	0	8,745	+1,022	9,767	+1,934	+2,843	14,544
Water	3,819	+370	4,189	0	4,189	0	0	4,189
Total	328,508		328,508		328,508			328,508

[1] Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

to those which can only be accomplished through comprehensive planning from those which are expected to occur in the absence of comprehensive planning is equally difficult. However, evaluation of the framework plan necessitates some recognition between elements of change which are largely individually motivated and those which require group action.

Two analyses and projections are presented as an evaluation of future land use and availability. First, the measurement base is a projection of basic land use changes that are expected with continuation of selected Federal and non-Federal programs and activities. The selected elements considered are discussed in detail in the Appendix on Plan of Development and Management of Water and Related Land Resources. The second is the projection of land use and availability expected with implementation of all the framework plan elements including the selected activities. The evaluation procedure is intended only as a measurement of land use to determine the output response attributable to the framework plan.

FUTURE PRIMARY USE OF LAND AND WATER

The acreage of some major uses of basin lands will be changed significantly in the future. Land available for agricultural use will be reduced by a total of 11.9 million acres, or less than 4 percent of the current normal base, by 2020. Reductions are estimated to be distributed as follows: 5.8 million acres by basic diversions, 3.1 million acres by selected activities, and 3.0 million acres by the other components of the plan as shown in table 31. Of this total, about 1.7 million acres will be used for water storage; 2.7 million acres for recreation; 0.8 million acres for fish and wildlife; and 5.8 million acres for habitation, transportation, industrial sites, and other miscellaneous plan facilities.

Though the loss of land available for agricultural use will adversely affect agricultural production, large acreages of land will benefit materially from implementation of the plan. It is estimated that development of groundwater for irrigation by individuals will increase irrigated

Table 31 – EFFECT OF TOTAL LAND DIVERSIONS ON AVAILABILITY OF LAND AND WATER BY MAJOR USE CATEGORIES, CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, & 2020

	Agriculture	Recreation	Fish & Wildlife	Other Land	Water
	(Thousand Acres)				
ADJUSTED CURRENT NORMAL	312,022	2,814	738	8,745	4,189
Basic Diversions[1]	-1,022			+1,022	
Selected Activities[2]	-398	+369			+29
Water Control & Related Land Developments					
Irrigation[3]	-18			+4	+14
Gully Stabilization	+84			-99	+15
Reservoirs[4]	-1,113	+5		+655	+453
Fish & Wildlife	-676		+555		+121
Recreation	-179	+153			+26
Miscellaneous[5]	-55			+22	+33
LAND AVAILABLE BY 1980	308,645	3,341	1,703	9,939	4,880
Basic Diversions[1]	-1,934			+1,934	
Selected Activities[2]	-893	+824			+69
Water Control & Related Land Developments					
Irrigation[3]	-35			+15	+20
Gully Stabilization	+284			-290	+6
Reservoirs[4]	-848			+514	+334
Fish & Wildlife	-183		+135		+48
Recreation	-148	+126			+22
Miscellaneous[5]	-62			+27	+35
LAND AVAILABLE BY 2000	304,826	4,291	1,838	12,139	5,414
Basic Diversions[1]	-2,843			+2,843	
Selected Activities[2]	-1,214	+1,114			+100
Water Control & Related Land Developments					
Irrigation[3]	-70			+15	+55
Gully Stabilization	+280			-283	+3
Reservoirs[4]	-462			+278	+184
Fish & Wildlife	-205		+160		+45
Recreation	-198	+122			+76
Miscellaneous[5]	-24			+4	+20
LAND AVAILABLE BY 2020	300,090	5,527	1,998	14,996	5,897
NET CHANGE	-11,932	+2,713	+850	+6,661	+1,708

[1]Includes land changes shown in detail in table 29.
[2]Includes public and private land conservation, groundwater irrigation, and recreation development
[3]Includes public and private development of surface water supplies.
[4]All reservoirs regardless of purpose.
[5]Includes land for miscellaneous facilities.

cropland by approximately 6.0 million acres, and continued land conservation activities will improve another 108 million acres. In addition, implementation of functional elements of the framework plan will reduce the flood hazard on 6.2 million acres of flood plain, improve the drainage on 0.8 million acres of non-irrigated cropland and 0.6 million acres of irrigated cropland, and provide irrigation water for an additional 4.9 million acres of cropland as shown in table 32.

Table 32 – ACREAGE OF AGRICULTURAL LANDS BENEFITED UPON IMPLEMENTATION OF FRAMEWORK PLAN

Type of Benefit	1980	2000	2020
	(Thousand Acres)		
Drainage (Project)[1]	393	943	1,388
Flood Protection[2]	3,257	5,103	6,163
Irrigation	2,735	6,202	10,855
Groundwater	(1,614)	(3,456)	(5,969)
Surface Water, Private	(543)	(1,313)	(2,502)
Surface Water, Public	(578)	(1,433)	(2,384)
Watershed Protection and Management	30,565	74,166	108,119

[1] Areas requiring only on-farm drainage are included in watershed protection and management. Drainage associated with irrigation rehabilitation is included.
[2] Includes varying degrees of protection

The projections of land use are grouped in two categories in tables 33 through 41.

Category A – Selected Agricultural, Recreation, and Fish and Wildlife Activities– This category of projected resource use and agricultural production capability assumes continuation of agricultural research programs; adoption of production technology on the farm; improvement of on-farm management practices; application of land treatment and conservation measures; and adoption of individual on-farm resource development measures affecting agricultural output, including the use of reserve idle lands as needed. Federal funding arrangements, cost sharing, and technical assistance are assumed to be maintained at the present levels. In addition, this category includes (1) the projections of groundwater irrigation development by individual farmers and (2) land acquisition and use for recreation and fish and wildlife development by State, local, and private interests. There are several forms of public programs and assistance that influence the individual or entity in the timing and decision to act when the initiative and decisions are nongroup and nonpublic activities. This category of land use does not include the effects of the components of the framework plan that involve diversions of agricultural land to more stable agricultural production, and to nonagricultural uses.

Category B – Full Implementation of Framework Plan– This category encompasses the selected activities described under Category A together with the additional resource development and inherent agricultural capability that would be achieved by full implementation of the framework plan. Such additional development includes the categories of water control and related land resource development, and environmental enhancement and nonstructural measures. These components of the plan include public and private irrigation to be developed from surface water supplies, flood control, group drainage systems, streambank and gully erosion control, and rehabilitation of existing irrigation systems. Also, this takes into account land taken from the agricultural base to satisfy future requirements for reservoirs, recreation, fish and wildlife, and other multiple-purpose and single-purpose features of the framework plan.

Non-irrigated cropland will decrease about 8.3 million acres by 2020 with the continuation of selected programs in Category A. With all features of the framework plan, the acreage will decrease another 4.4 million acres. On the other hand, irrigated cropland is projected to increase by about 5.8 million acres by 2020 with adoption of the framework plan. Federal lands producing agricultural products are not expected to be affected, but lands used primarily for fish and wildlife purposes will be increased 850 thousand acres by 2020 if the framework plan is fully implemented. Recreation lands are projected to be increased 2.3 million acres with continuation of selected programs, and full implementation of the plan will add another 400 thousand acres of recreation land.

FUTURE ANCILLARY USES OF LAND AND WATER

Most of the basin land and water serves more than one purpose. Uses other than that indicated by the primary land use classification categories are considered here as ancillary. Total ancillary use of an area often exceeds the primary use, especially when the area has more than one ancillary use. This trend is increasing with the continued acceptance of the multiple-use concept for natural resources.

Agriculture, fish and wildlife, and recreation are the more important ancillary uses in the Missouri Basin. Agriculture is an ancillary use on about 18 million acres, fish and wildlife on 309 million acres, and recreation on over 47 million acres. It is not expected that adoption of the framework plan would have an effect on agricultural ancillary use of land. It will have only a small effect on fish and wildlife and recreation ancillary uses in terms of acres used.

Fish and wildlife and recreation will be an ancillary use on almost all of the increased area in the "other" land use category and the "water" category. The "other" land category will increase by about one million acres and the "water" area by about 1.6 million acres by 2020. The principal effect on fish and wildlife and recreation will be the increased intensity of use for these purposes.

Table 33 – USE OF LAND AND WATER – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, 2020, MISSOURI BASIN

Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
	(Thousand Acres)						
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	96,699	94,765	93,325	92,020	89,373	88,395	83,992
Cropland Irrigated	6,893	8,451	9,540	10,192	12,887	12,522	17,344
Pasture & Range	152,568	151,765	150,440	150,452	147,925	148,408	144,953
Forest & Woodland	13,587	13,381	13,107	12,931	12,473	12,337	11,759
Other	3,551	3,516	3,509	3,456	3,444	3,332	3,318
Other Forest Land	122	122	122	122	122	122	122
Federal Land Producing Agricultural Products	38,602	38,602	38,602	38,602	38,602	38,602	38,602
Subtotal	312,022	310,602	308,645	307,774	304,826	303,718	300,090
Recreation	2,814	3,183	3,341	4,007	4,291	5,121	5,527
Fish & Wildlife	738	738	1,293	738	1,428	738	1,588
Other	8,745	9,767	1,349	11,701	12,549	14,544	15,406
Water	4,189	4,218	4,880	4,288	5,414	4,387	5,897
Total	328,508	328,508	328,508	328,508	328,508	328,508	328,508

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional resource development described.

Table 34 – USE OF LAND AND WATER – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, AND 2020, UPPER MISSOURI SUBBASIN

Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
	(Thousand Acres)						
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	9,757	9,742	9,649	9,685	9,517	9,590	9,351
Cropland Irrigated	953	950	1,139	977	1,349	1,001	1,490
Pasture & Range	25,522	25,485	25,332	25,406	25,083	25,298	24,880
Forest & Woodland	1,964	1,952	1,944	1,846	1,820	1,781	1,743
Other	254	253	253	252	252	251	251
Other Forest Land	...	...	...	...	...	...	...
Federal Land Producing Agricultural Products	11,932	11,932	11,932	11,932	11,932	11,932	11,932
Subtotal	50,382	50,314	50,249	50,098	49,953	49,853	49,647
Recreation	519	546	556	701	717	859	879
Fish & Wildlife	142	142	153	142	181	142	197
Other	1,250	1,291	1,296	1,351	1,359	1,436	1,450
Water	670	670	709	671	753	673	790
Total	52,963	52,963	52,963	52,963	52,963	52,963	52,963

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional resource development described.

Table 35 – USE OF LAND AND WATER – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, AND 2020, YELLOWSTONE SUBBASIN

Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
	(Thousand Acres)						
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	2,343	2,328	2,236	2,290	2,081	2,269	1,979
Cropland Irrigated	1,031	1,028	1,211	1,027	1,454	988	1,589
Pasture & Range	24,333	24,206	24,061	23,978	23,633	23,686	23,175
Forest & Woodland	1,550	1,496	1,490	1,388	1,377	1,250	1,231
Other	91	91	91	91	91	90	90
Other Forest Land	---	---	---	---	---	---	---
Federal Land Producing Agricultural Products	13,804	13,804	13,804	13,804	13,804	13,804	13,804
Subtotal	43,152	42,953	42,893	42,578	42,440	42,087	41,868
Recreation	1,408	1,538	1,566	1,796	1,853	2,107	2,175
Fish & Wildlife	31	31	37	31	45	31	57
Other	264	332	333	446	458	623	654
Water	345	346	371	349	404	353	446
Total	45,200	45,200	45,200	45,200	45,200	45,200	45,200

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional resource development described.

Table 36 – USE OF LAND AND WATER – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, AND 2020, WESTERN DAKOTA SUBBASIN

Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
	(Thousand Acres)						
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	9,097	9,073	8,927	9,012	8,708	8,895	8,280
Cropland Irrigated	198	205	353	235	561	313	955
Pasture & Range	31,677	31,624	31,534	31,517	31,313	31,392	31,140
Forest & Woodland	977	972	959	961	943	951	930
Other	209	208	208	205	205	200	200
Other Forest Land	---	---	---	---	---	---	---
Federal Land Producing Agricultural Products	5,131	5,131	5,131	5,131	5,131	5,131	5,131
Subtotal	47,289	47,213	47,112	47,061	46,861	46,882	46,636
Recreation	334	362	416	437	508	507	601
Fish & Wildlife	92	92	114	92	114	92	114
Other	1,169	1,217	1,221	1,294	1,350	1,403	1,468
Water	472	472	493	472	523	472	537
Total	49,356	49,356	49,356	49,356	49,356	49,356	49,356

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional resource development described.

Table 37 – USE OF WATER AND LAND – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, AND 2020, EASTERN DAKOTA SUBBASIN

Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
				(Thousand Acres)			
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	20,889	20,775	20,509	20,562	20,102	20,212	19,180
Cropland Irrigated	119	208	347	342	868	557	1,842
Pasture & Range	12,547	12,497	12,176	12,348	11,801	12,037	11,261
Forest & Woodland	211	210	201	190	179	134	122
Other	594	593	593	590	587	585	582
Other Forest Land	---	---	---	---	---	---	---
Federal Land Producing Agricultural Products	39	39	39	39	39	39	39
Subtotal	34,399	34,322	33,865	34,071	33,576	33,564	33,026
Recreation	38	39	56	149	166	467	486
Fish & Wildlife	162	162	430	162	432	162	456
Other	1,802	1,613	1,957	1,749	2,119	1,933	2,304
Water	902	902	995	907	1,010	912	1,031
Total	37,303	37,303	37,303	37,303	37,303	37,303	37,303

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional resource development described.

Table 38 – USE OF LAND AND WATER – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, AND 2020, PLATTE-NIOBRARA SUBBASIN

Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
				(Thousand Acres)			
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	12,850	12,333	12,096	11,849	11,378	11,181	10,543
Cropland Irrigated	2,784	3,281	3,493	3,707	4,145	4,278	4,884
Pasture & Range	35,141	34,878	34,602	34,443	33,984	33,774	33,136
Forest & Woodland	1,936	1,910	1,865	1,867	1,777	1,771	1,631
Other	621	618	618	612	612	597	597
Other Forest Land	---	---	---	---	---	---	---
Federal Land Producing Agricultural Products	7,449	7,449	7,449	7,449	7,449	7,449	7,449
Subtotal	60,781	60,469	60,123	59,927	59,345	59,050	[illegible]
Recreation	377	439	461	495	569	603	[illegible]
Fish & Wildlife	220	220	316	220	334	220	[illegible]
Other	1,637	1,882	2,001	2,345	2,561	3,081	[illegible]
Water	660	665	774	688	866	721	[illegible]
Total	63,675	63,675	63,675	63,675	63,675	63,675	[illegible]

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional [illegible] development described.

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Table 39 – USE OF LAND AND WATER – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, AND 2020, MIDDLE MISSOURI SUBBASIN

Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
	(Thousand Acres)						
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	11,116	10,750	10,695	9,885	9,907	8,962	8,786
Cropland Irrigated	103	319	340	854	945	1,380	1,729
Pasture & Range	2,485	2,454	2,371	2,416	2,258	2,381	2,163
Forest & Woodland	631	614	591	585	547	554	510
Other	447	442	442	435	435	414	414
Other Forest Land	118	118	118	118	118	118	118
Federal Land Producing Agricultural Products	1	1	1	1	1	1	1
Subtotal	14,901	14,698	14,558	14,294	14,211	13,810	13,721
Recreation	37	65	80	124	148	180	223
Fish & Wildlife	25	25	59	25	70	25	70
Other	608	772	762	1,097	943	1,508	1,260
Water	174	185	286	205	373	222	471
Total	15,745	15,745	15,745	15,745	15,745	15,745	15,745

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional resource development described.

Table 40 – USE OF LAND AND WATER – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, AND 2020, KANSAS SUBBASIN

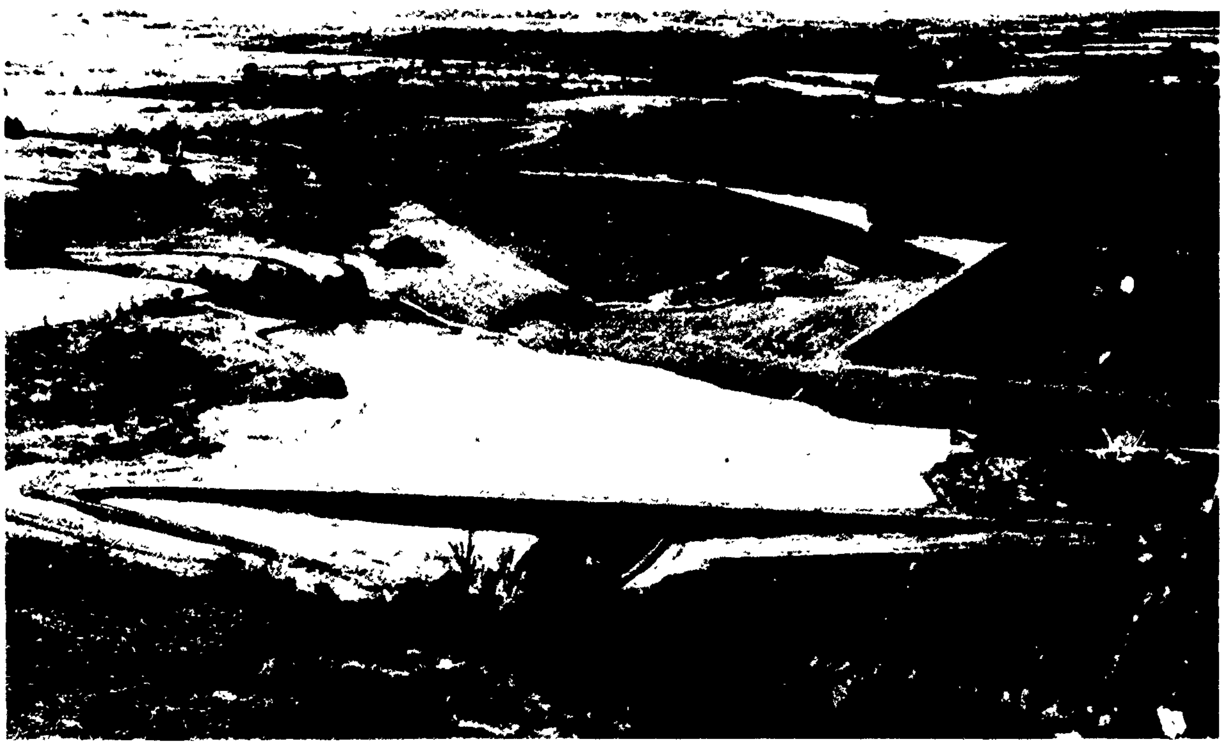
Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
	(Thousand Acres)						
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	20,587	19,964	19,767	19,454	19,035	18,559	17,952
Cropland Irrigated	1,700	2,347	2,422	2,779	2,971	3,588	3,880
Pasture & Range	13,589	13,461	13,386	13,355	13,166	13,203	12,912
Forest & Woodland	588	571	558	563	553	546	537
Other	548	531	531	517	516	497	495
Other Forest Land	4	4	4	4	4	4	4
Federal Land Producing Agricultural Products	69	69	69	69	69	69	69
Subtotal	37,085	36,947	36,737	36,741	36,314	36,466	35,849
Recreation	36	79	90	108	126	144	163
Fish & Wildlife	15	15	44	15	104	15	169
Other	1,307	1,400	1,504	1,571	1,756	1,804	2,054
Water	433	435	501	441	576	447	641
Total	38,876	38,876	38,876	38,876	38,876	38,876	38,876

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional resource development described.

Table 41 – USE OF LAND AND WATER – ADJUSTED CURRENT NORMAL WITH PROJECTIONS FOR 1980, 2000, AND 2020, LOWER MISSOURI SUBBASIN

Land and Water Use	Adjusted Current Normal	1980 Category A[1]	1980 Category B[2]	2000 Category A[1]	2000 Category B[2]	2020 Category A[1]	2020 Category B[2]
				(Thousand Acres)			
Agricultural Uses							
Privately Owned Land							
Cropland Nonirrigated	10,060	9,800	9,446	9,283	8,645	8,727	7,921
Cropland Irrigated	5	113	230	271	594	417	975
Pasture & Range	7,274	7,160	6,978	6,989	6,687	6,637	6,286
Forest & Woodland	5,730	5,656	5,499	5,531	5,277	5,350	5,055
Other	787	780	773	754	746	698	689
Other Forest Land	---	---	---	---	---	---	---
Federal Land Producing Agricultural Products	177	177	177	177	177	177	177
Subtotal	24,033	23,686	23,108	23,005	22,126	22,006	21,103
Recreation	65	115	116	197	204	254	261
Fish & Wildlife	51	51	140	51	148	51	172
Other	708	995	1,275	1,583	2,003	2,492	2,876
Water	533	543	751	554	909	587	978
Total	25,390	25,390	25,390	25,390	25,390	25,390	25,390

[1]Category A, current and projected current normal plus continuation of selected programs described.
[2]Category B, (1) current and projected current normal, plus (2) continuation of selected programs, plus (3) additional resource development described.



A Missouri Landscape Illustrating Many Land Uses: Cropland, Woodland, Grassland, And Permanent Water Which Provide Fish And Wildlife Habitat And A Variety Of Recreational Opportunities

Private Rangeland Produces Not Only Livestock But Also Provides Habitat For Antelope And Other Game Animals

Forested Areas Are Also Used For Summer Camping And Winter Recreation

STATISTICAL SUPPLEMENT

STATISTICAL SUPPLEMENT (Continued)

STATISTICAL SUPPLEMENT (Continued)

Table S-1 — LAND AND WATER AREAS, BY SUBBASINS AND STATES, MISSOURI BASIN

Subbasin and State	Water Area: Over 40 Ac.	Water Area: Under 40 Ac.	Subtotal	Land Area	Total Area
			(Thousand Acres)		
Upper Missouri					
Montana	552	105	657	51,550	52,207
North Dakota	11	1	12	366	378
Wyoming	1	0	1	377	378
Subtotal	564	106	670	52,293	52,963
Yellowstone					
Montana	110	34	144	22,597	22,741
North Dakota	21	0	21	490	511
Wyoming	142	38	180	21,768	21,948
Subtotal	273	72	345	44,855	45,200
Western Dakota					
Montana	1	6	7	2,492	2,499
North Dakota	179	21	200	11,772	11,972
South Dakota	131	91	222	25,517	25,739
Wyoming	15	16	31	7,441	7,472
Nebraska	8	4	12	1,662	1,674
Subtotal	334	138	472	48,884	49,356
Eastern Dakota					
Iowa	--	1	1	940	941
Minnesota	3	1	4	954	958
North Dakota	385	58	443	13,686	14,129
South Dakota	274	180	454	20,821	21,275
Subtotal	662	240	902	36,401	37,303
Platte-Niobrara					
Colorado	89	14	103	13,292	13,395
South Dakota	1	2	3	918	921
Wyoming	77	22	99	15,921	16,020
Nebraska	299	150	449	32,890	33,339
Subtotal	466	188	654	63,021	63,675
Middle Missouri					
Iowa	35	10	45	8,455	8,500
Kansas	15	18	33	931	964
Minnesota	3	--	3	135	138
Missouri	20	10	30	2,419	2,449
Nebraska	52	11	63	3,631	3,694
Subtotal	125	49	174	15,571	15,745
Kansas					
Colorado	16	7	23	5,703	5,726
Kansas	45	210	255	22,152	22,407
Missouri	--	--	--	19	19
Nebraska	34	24	58	10,666	10,724
Subtotal	95	241	336	38,540	38,876
Lower Missouri					
Iowa	1	2	3	1,666	1,669
Kansas	5	30	35	2,739	2,774
Missouri	133	95	228	20,719	20,947
Subtotal	139	127	266	25,124	25,390
Missouri Basin	2,658	1,161	3,819	324,689	328,508

Source: Bureau of Census 1960 land and water area, adjusted to basin boundary. Water area over 40 acres includes streams 1/8 mile in width or more. Water area under 40 acres from Conservation Needs Inventory.

Table S-2 – LAND AND WATER OWNERSHIP – PRIVATE, STATE, COUNTY, AND FEDERAL BY ADMINISTRATING AGENCIES, MISSOURI BASIN[1]

Subbasin And State	Department of Agriculture	Department of Defense	Department of the Interior	Private County State[2]	Total Land And Water
			(Thousand Acres)		
Upper Missouri					
Montana	5,870	616	6,469	39,038	51,993
North Dakota	53	0	0	325	378
Wyoming	0	0	592	0	592
Subtotal	5,923	616	7,061	39,363	52,963
Yellowstone					
Montana	1,969	--	1,675	19,097	22,741
North Dakota	143	--	--	368	511
Wyoming	3,774	9	7,864	10,301	21,948
Subtotal	5,886	9	9,539	29,766	45,200
Western Dakota					
Montana	89	0	481	1,929	2,499
North Dakota	839	247	146	10,740	11,972
South Dakota	1,986	607	550	22,596	25,739
Wyoming	697	0	489	6,286	7,472
Nebraska	134	0	--	1,540	1,674
Subtotal	3,745	854	1,666	43,091	49,356
Eastern Dakota					
Iowa	0	0	0	941	941
Minnesota	0	0	--	958	958
North Dakota	0	334	120	13,675	14,129
South Dakota	3	265	53	20,954	21,275
Subtotal	3	599	173	36,528	37,303
Platte-Niobrara					
Colorado	2,524	82	473	10,316	13,395
South Dakota	0	0	17	904	921
Wyoming	979	10	3,368	11,663	16,020
Nebraska	206	36	173	32,924	33,339
Subtotal	3,709	128	4,031	55,807	63,675
Middle Missouri					
Iowa	0	--	3	8,497	8,500
Kansas	0	--	0	964	964
Minnesota	0	--	0	138	138
Missouri	0	--	7	2,442	2,449
Nebraska	0	33	5	3,656	3,694
Subtotal	0	33	15	15,697	15,745
Kansas					
Colorado	0	0	9	5,717	5,726
Kansas	0	222	56	22,129	22,407
Nebraska	10	30	38	10,646	10,724
Missouri	0	0	0	19	19
Subtotal	10	252	103	38,511	38,876
Lower Missouri					
Iowa	0	0	--	1,669	1,669
Kansas	0	11	--	2,763	2,774
Missouri	177	129	11	20,630	20,947
Subtotal	177	140	11	25,062	25,390
Missouri Basin	19,453	2,631	22,599	283,825	328,508

[1]Data from Federal agencies.
[2]Includes Indian lands which actually are privately owned by the Indians; however, title is held in trust by the Federal Government.

Table S-3 – FEDERAL LAND OWNERSHIP – U. S. DEPARTMENT OF AGRICULTURE LANDS ADMINISTERED BY THE FOREST SERVICE AND AGRICULTURAL RESEARCH SERVICE, MISSOURI BASIN

Subbasin and State	Forest Service: National Forest	Forest Service: National Grasslands	Agricultural Research Service	Total
	(Thousand Acres)			
Upper Missouri				
Montana	5,870	0	0	5,870
North Dakota	0	53	0	53
Wyoming	0	0	0	0
Subtotal	5,870	53	0	5,923
Yellowstone				
Montana	1,913	0	56	1,969
North Dakota	0	143	0	143
Wyoming	3,726	48	0	3,774
Subtotal	5,639	191	56	5,886
Western Dakota				
Montana	89	0	0	89
North Dakota	0	837	2	839
South Dakota	1,121	865	--	1,986
Wyoming	172	525	0	697
Nebraska	40	94	0	134
Subtotal	1,422	2,321	2	3,745
Eastern Dakota				
Iowa	0	0	0	0
North Dakota	0	0	0	0
Minnesota	0	0	0	0
South Dakota	0	3	0	3
Subtotal	0	3	0	3
Platte-Niobrara				
Colorado	2,316	193	15	2,524
South Dakota	0	0	0	0
Wyoming	979	0	0	979
Nebraska	206	0	0	206
Subtotal	3,501	193	15	3,709
Middle Missouri				
Iowa	0	0	0	0
Kansas	0	0	0	0
Minnesota	0	0	0	0
Missouri	0	0	0	0
Nebraska	0	0	0	0
Subtotal	0	0	0	0
Kansas				
Colorado	0	0	0	0
Kansas	0	0	0	0
Missouri	0	0	0	0
Nebraska	0	0	10	10
Subtotal	0	0	10	10
Lower Missouri				
Iowa	0	0	0	0
Kansas	0	0	0	0
Missouri	164	13	0	177
Subtotal	164	13	0	177
Missouri Basin	16,596	2,774	83	19,453

Source: U. S. Forest Service, 1966.

Table S-4 – FEDERAL LAND OWNERSHIP – U. S. DEPARTMENT OF DEFENSE LANDS ADMINISTERED BY THE CORPS OF ENGINEERS AND MILITARY, MISSOURI BASIN

Subbasin and State	Water Development Areas Corps of Engineers	Military Army, Navy Air Force	Total
		(Thousand Acres)	
Upper Missouri			
Montana	609	7	616
North Dakota	0	0	0
Wyoming	0	0	0
Subtotal	609	7	616
Yellowstone			
Montana	0	0	0
North Dakota	0	0	0
Wyoming	0	9	9
Subtotal	0	9	9
Western Dakota			
Montana	0	0	0
North Dakota	247	--	247
South Dakota	338	269	607
Wyoming	0	0	0
Nebraska	0	0	0
Subtotal	585	269	854
Eastern Dakota			
Iowa	0	0	0
Minnesota	0	0	0
North Dakota	334	--	334
South Dakota	265	--	265
Subtotal	599	--	599
Platte-Niobrara			
Colorado	5	77	82
South Dakota	0	0	0
Wyoming	0	10	10
Nebraska	0	36	36
Subtotal	5	123	128
Middle Missouri			
Iowa	--	--	--
Kansas	0	--	--
Minnesota	0	--	--
Missouri	--	--	--
Nebraska	27	6	33
Subtotal	27	6	33
Kansas			
Colorado	0	0	0
Kansas	116	106	222
Missouri	0	0	0
Nebraska	30	--	30
Subtotal	146	106	252
Lower Missouri			
Iowa	0	0	0
Kansas	11	0	11
Missouri	27	102	129
Subtotal	38	102	140
Missouri Basin	2,009	622	2,632

Source: Department of Defense, Army Corps of Engineers, 1966.

Table S-5 – FEDERAL LAND OWNERSHIP – U. S. DEPARTMENT OF THE INTERIOR, MISSOURI BASIN

Subbasin and State	BIA[1]	BLM	BR	BSFW	NPS	USDI
			(Thousand Acres)			
Upper Missouri						
Montana	122	5,901	248	117	81	6,469
North Dakota	0	0	0	0	0	0
Wyoming	0	0	0	0	592	592
Subtotal	122	5,901	248	117	673	7,061
Yellowstone						
Montana	--	1,617	21	--	37	1,675
North Dakota	--	0	--	0	0	--
Wyoming	2	6,133	515	1	1,213	7,864
Subtotal	2	7,750	536	1	1,250	9,539
Western Dakota						
Montana	0	481	0	0	0	481
North Dakota	4	54	13	5	70	146
South Dakota	84	269	45	10	142	550
Wyoming	0	471	16	0	2	489
Nebraska	--	0	0	0	0	0
Subtotal	88	1,275	74	15	214	1,666
Eastern Dakota						
Iowa	0	0	0	0	0	0
Minnesota	0	0	0	0	--	--
North Dakota	--	3	5	112	0	120
South Dakota	20	0	1	32	0	53
Subtotal	20	3	6	144	0	173
Platte-Niobrara						
Colorado	0	296	11	0	166	473
Wyoming	0	3,287	69	11	1	3,368
South Dakota	17	0	0	0	0	17
Nebraska	0	3	30	137	3	173
Subtotal	17	3,586	110	148	170	4,031
Middle Missouri						
Iowa	0	0	--	3	0	3
Kansas	0	0	0	0	0	0
Minnesota	0	0	0	0	0	0
Missouri	0	0	0	7	0	7
Nebraska	--	0	--	5	0	5
Subtotal	--	0	--	15	0	15
Kansas						
Colorado	0	2	7	0	0	9
Kansas	0	--	56	0	0	56
Missouri	0	0	0	0	0	0
Nebraska	0	0	35	3	--	38
Subtotal	0	2	98	3	0	103
Lower Missouri						
Iowa	0	0	0	0	0	0
Kansas	0	0	0	0	0	0
Missouri	0	0	0	11	0	11
Subtotal	0	0	0	11	0	11
Missouri Basin	249	18,517	1,072	454	2,307	22,599

[1] Lands listed under BIA are Federal lands administered by the Bureau of Indian Affairs, predominately submarginal lands, but also include Indian school lands and administrative sites, and do not include Indian-owned land.

Table S-6 – MAJOR LAND USE ACREAGES BY OWNERSHIP MISSOURI BASIN

Subbasin		Cropland Dry	Cropland Irr.	Pasture & Range	Forest & Woodland	Other Ag. Land	Subtotal Ag. Land	Other Non-Ag. Land	Total Land	Water Over 40	Water Under 40	Total Water Area	Total Land & Water
						(Thousand Acres)							
Upper Missouri	Pri.	9,757	953	25,522	1,964	254	38,450	632	39,082	175	106	281	39,363
	Fed.	---	---	6,685	5,247	---	11,932	1,279	13,211	389	---	389	13,600
	Total	9,757	953	32,207	7,211	254	50,382	1,911	52,293	564	106	670	52,953
Yellow-stone	Pri.	2,343	996	24,333	1,550	91	29,313	261	29,574	120	72	192	29,766
	Fed.	---	35 2/	9,281	4,523	---	13,839	1,442	15,281	153	---	153	15,434
	Total	2,343	1,031	33,614	6,073	91	43,152	1,703	44,855	273	72	345	45,200
Western Dakota	Pri.	9,097	198	31,677	977	209	42,158	771	42,929	24	138	162	43,091
	Fed.	---	---	3,645	1,486	---	5,131	824	5,955	310	---	310	6,265
	Total	9,097	198	35,322	2,463	209	47,289	1,595	48,884	334	138	472	49,356
Eastern Dakota	Pri.	20,889	119	12,547	211	594	34,360	1,830	36,190	99	240	339	36,529
	Fed.	---	---	6	33	---	39	173	212	563	---	563	775
	Total	20,889	119	12,553	244	594	34,399	2,003	36,402	662	240	902	37,304
Platte-Niobrara	Pri.	12,850	2,784	35,147	1,936	621	53,338	1,908	55,246	373	188	561	55,807
	Fed.	---	---	4,497	2,952	---	7,449	326	7,775	93	---	93	7,868
	Total	12,850	2,784	39,644	4,888	621	60,787	2,234	63,021	466	188	654	63,675
Middle Missouri	Pri.	11,116	103	2,485	631	447	14,782	772 3/	15,554	93	49	142	15,696
	Fed.	---	---	---	1	---	1	15	16	32	---	32	48
	Total	11,116	103	2,485	632	447	14,783	787 3/	15,570	125	49	174	15,744
Kansas	Pri.	20,638	1,703	13,619	597	552	37,109	1,148 3/	38,257	12	241	253	38,510
	Fed.	---	---	49	20	---	69	213	282	83	---	83	365
	Total	20,638	1,703	13,668	617	552	37,178	1,361 3/	38,539	95	241	336	38,875
Lower Missouri	Pri.	10,203	5	7,334	5,788	793	24,123	717	24,840	96	127	223	25,063
	Fed.	---	---	7	170	---	177	108	285	43	---	43	328
	Total	10,203	5	7,341	5,958	793	24,300	825	25,125	139	127	266	25,391
Missouri Basin	PRI.	96,893	6,861	152,664	13,654	3,561	273,633	8,039	281,672	992	1,161	2,153	283,825
	FED.	---	35	24,170	14,432	---	38,637	4,380	43,017	1,666	---	1,666	44,683
	TOTAL	96,893	6,896	176,834	28,086	3,561	312,270	12,419	324,689	2,658	1,161	3,819	328,508

1/ Federal water areas under 40 acres included in land area.
2/ 35,000 irrigable acres, Bureau of Reclamation Wind River Project.
3/ Other forested land producing agricultural products includes: Middle Missouri - 118,000 Acres, Kansas - 4,000 Acres.

Table S-7 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] MISSOURI BASIN

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE & RANGE	FOREST & WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	15,841,412	2,262,144	19,103,556	5,912,353	304,380	341,065	25,661,354
104	17,797,054	1,063,572	18,860,626	6,450,814	171,887	361,689	25,845,016
106	15,210,257	607,156	15,817,413	11,925,511	204,209	391,037	28,338,170
108	2,140,139	54,327	2,194,466	7,273,622	102,731	54,056	9,624,875
110	374,779	0	374,779	10,064,889	897,788	24,616	11,362,072
112	4,303,814	39,201	4,343,015	1,426,365	9,367	71,858	5,850,605
114	1,520,279	0	1,520,279	2,686,984	41,657	38,913	4,287,833
120	1,696,542	360,091	2,056,633	366,834	8,212	59,541	2,491,220
122	2,702,649	19,908	2,722,557	876,435	52,212	155,489	3,806,693
124	3,974,912	22,522	3,997,434	2,711,479	283,274	234,698	7,226,885
126	1,252,475	8,616	1,261,091	2,614,423	282,001	88,614	4,246,129
136	1,204,185	149,274	1,353,459	491,820	50,067	25,537	1,920,883
138	1,094,901	94,689	1,189,590	943,543	42,993	19,809	2,195,935
140	574,206	25,853	600,059	559,515	70,559	21,123	1,251,256
142	396,170	0	396,170	966,220	516,614	37,569	1,916,573
144	375,200	28,101	403,301	145,790	648	10,245	559,984
150	6,803	94,250	101,053	202,594	8,860	2,334	314,841
152	3,997	0	3,997	3,125	0	0	7,122
153	1,010,074	21,489	1,031,563	372,579	267,619	31,454	1,703,215
154	744,194	20,832	765,026	621,381	45,932	34,009	1,466,348
156	462,394	24,061	486,455	1,785,634	17,416	11,078	2,300,583
158	65,865	1,985	67,850	97,408	119	658	166,035
160	2,123,347	111,092	2,234,439	2,865,229	19,929	33,083	5,152,680
162	565,493	1,981	567,474	309,702	512	940	848,628
164	303,926	8,862	312,788	4,623,301	42,999	5,995	4,985,083
168	1,791,775	492	1,792,267	1,946,714	2,919	12,405	3,754,305
172	147,327	19,153	166,480	55,923	149	2,089	224,641
174	2,207,701	118,229	2,325,930	2,475,576	59,419	59,059	4,919,984
178	153,609	116,118	269,727	133,868	0	3,627	407,222
180	47,829	37,769	85,598	745,449	129,567	23,269	983,883
182	61,955	84,848	146,803	2,258,169	19,101	1,862	2,425,935
184	17,602	0	17,602	18,575	0	0	36,177
188	651,606	6,009	657,615	9,591,955	46,112	161,009	10,456,691
190	2,374,928	394,734	2,769,662	1,606,571	25,817	51,736	4,453,786
192	406,630	49,307	455,937	1,363,182	5,515	12,725	1,837,359
194	185,734	1,030	186,764	2,469,853	72,072	5,636	2,734,325
196	115,165	3,392	118,557	4,484,133	39,381	3,520	4,645,591
211	330,367	86,677	417,044	1,036,209	62,485	5,851	1,521,589
213	174,764	16,171	190,935	5,475,001	488,881	12,834	6,167,651
217	61,834	0	61,834	72,988	64,593	8,444	207,859
225	88,809	36,450	125,259	2,614,165	119,235	2,949	2,861,608
231	5,193	0	5,193	9,958	0	2,568	17,719
310	1,122,585	40,077	1,162,662	144,147	142,042	54,346	1,503,197
320	1,430,120	20,884	1,451,004	1,330,065	115,230	35,208	2,931,507
330	2,257,295	353,934	2,611,229	692,974	309,077	105,845	3,719,125
340	313,264	65,887	379,151	509,404	52,288	23,369	964,212
350	228,741	6,398	235,139	567,676	106,237	28,853	937,905
360	34,621	29,927	64,548	481,657	32,609	3,740	582,554
361	2,184	20,209	22,393	271,975	8,534	2,175	305,077
420	536,392	9,479	545,871	2,430,741	424,345	58,649	3,459,606
421	15,026	0	15,026	4,213	16,519	1,566	37,324
510	773,292	23,533	796,825	454,026	5,358	9,049	1,266,158
530	64,037	413	64,450	402,359	11,656	5,378	483,843
540	55,339	4,606	59,945	109,706	5,057	1,204	175,912
612	36,232	17,894	54,126	83,518	300	2,305	140,249
614	0	1,526	1,526	23,197	191	893	25,807
616	7,538	22,631	30,169	14,477	4,245	250	49,141
619	66,677	2,035	68,712	256,499	284	1,000	326,494
620	65,111	72,174	137,285	197,036	10,328	4,887	349,536
622	260,297	32,376	292,673	6,688,270	169,907	8,434	7,159,284
624	349,222	0	349,222	4,258,111	295	2,540	4,610,168
705	2,984,592	2,000	2,986,592	14,239,483	3,558,683	221,354	21,006,112
710	423,877	0	423,877	6,991,590	2,009,040	77,042	9,501,549
720	11,776	0	11,776	911,761	155,293	2,474	1,081,304
730	352,082	0	352,082	1,201,416	10,284	6,233	1,570,015
740	84,758	0	84,758	369,496	4,367	1,087	459,708
750	16,876	1,649	18,525	4,272,627	633,494	3,275	4,927,921
760	328	0	328	2,264,208	464,101	1,311	2,729,948
770	5,166	0	5,166	35,351	8,630	9,879	59,026
810	7,541	0	7,541	803,605	816,627	350,524	1,978,297
999	0	0	0	0	0	112,014	112,014
TOTAL	97,072,864	6,718,017	103,790,881	152,665,426	13,652,252	3,560,777	273,669,336

1/ Unadjusted for projects funded for construction.

Table S-8 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] UPPER MISSOURI SUBBASIN SUMMARY

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	649,010	202,224	851,234	674,421	67,233	30,698	1,623,586
104	4,227,985	241,366	4,469,351	2,290,691	27,783	47,878	6,835,703
106	1,644,726	200,609	1,845,335	2,552,725	26,945	35,497	4,460,502
108	612,677	8,930	621,607	1,663,624	8,932	3,416	2,297,579
110	171,418	0	171,418	4,809,482	586,829	7,826	5,575,555
120	14,467	6,824	21,291	71,257	2,418	1,342	96,308
136	102,020	49,419	151,439	110,696	143	3,156	265,434
138	317,745	61,195	378,940	630,823	20,026	2,280	1,032,069
140	151,529	1,288	152,817	125,528	3,658	1,315	283,318
142	0	0	0	10,370	0	0	10,370
152	0	0	0	371	0	0	371
154	118,370	9,891	128,261	315,498	3,718	3,699	451,176
156	278,397	20,265	298,662	1,215,077	15,647	6,159	1,535,545
158	20,455	0	20,455	21,721	0	0	42,176
160	470,259	66,962	537,221	442,267	2,520	10,831	992,839
162	12,164	530	12,694	8,045	0	0	20,739
164	123,153	2,444	125,597	708,248	12,440	3,412	849,697
172	371	0	371	554	0	0	925
174	0	0	0	462	0	0	462
188	192,335	1,859	194,194	203,626	2,119	1,807	401,746
190	123,465	34,839	158,304	163,744	396	252	322,696
192	58,826	740	59,566	29,051	270	685	89,572
194	11,684	19	11,703	221,296	12,615	607	246,221
196	2,891	0	2,891	58,513	5,062	10	66,476
211	96,979	32,654	129,633	499,475	28,319	3,798	661,225
225	33,581	0	33,581	772,384	100,072	829	906,866
231	0	0	0	487	0	1,941	2,428
310	0	0	0	2,826	0	0	2,826
320	41,248	3,181	44,429	404,471	11,362	1,824	462,086
340	12,656	3,830	16,486	54,242	1,762	0	72,490
420	397	0	397	176,853	2,182	199	179,631
530	43	19	62	41,231	10,141	168	51,602
619	425	0	425	1,507	0	0	1,932
622	174,259	3,733	177,992	2,603,531	102,349	3,942	2,887,814
705	3,330	0	3,330	347,712	31,350	0	382,392
710	86,336	0	86,336	2,913,933	589,302	50,292	3,639,863
720	361	0	361	520,841	14,049	1,406	536,657
760	328	0	328	669,094	204,544	1,293	875,259
810	2,835	0	2,835	185,771	69,448	27,395	285,449
999	0	0	0	0	0	185	185
TOTALS	9,756,725	952,821	10,709,546	25,522,448	1,963,634	254,142	38,449,770

1/ Unadjusted for projects funded for construction.

Table S-9 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] UPPER MISSOURI SUBBASIN, MONTANA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	648,014	202,110	850,124	672,206	67,233	30,698	1,620,261
104	4,213,397	241,366	4,454,763	2,280,720	27,783	47,878	6,811,144
106	1,644,726	200,609	1,845,335	2,552,725	26,945	35,497	4,460,502
108	612,677	8,930	621,607	1,663,624	8,932	3,416	2,297,579
110	171,418	0	171,418	4,809,482	586,829	7,826	5,575,555
120	14,467	6,824	21,291	71,257	2,418	1,342	96,308
136	102,020	49,419	151,439	110,696	143	3,156	265,434
138	317,745	61,195	378,940	630,823	20,026	2,280	1,032,069
140	151,529	1,288	152,817	125,528	3,658	1,315	283,318
142	0	0	0	10,370	0	0	10,370
152	0	0	0	371	0	0	371
154	118,370	9,891	128,261	315,498	3,718	3,699	451,176
156	278,397	20,265	298,662	1,215,077	15,647	6,159	1,535,545
158	20,455	0	20,455	21,721	0	0	42,176
160	470,259	66,962	537,221	442,267	2,520	10,831	992,839
162	12,164	530	12,694	8,045	0	0	20,739
164	123,153	2,444	125,597	708,248	12,440	3,412	849,697
188	192,335	1,859	194,194	203,626	2,119	1,807	401,746
190	123,465	34,839	158,304	163,744	396	252	322,696
192	58,826	740	59,566	29,051	270	685	89,572
194	11,684	19	11,703	221,296	12,615	607	246,221
196	2,891	0	2,891	58,513	5,062	10	66,476
211	96,979	32,654	129,633	499,475	28,319	3,798	661,225
225	33,581	0	33,581	772,384	100,072	829	906,866
231	0	0	0	487	0	1,941	2,428
310	0	0	0	2,826	0	0	2,826
320	41,248	3,181	44,429	404,471	11,362	1,824	462,086
340	12,656	3,830	16,486	54,242	1,762	0	72,490
420	397	0	397	176,853	2,182	199	179,631
530	43	19	62	39,845	10,141	168	50,216
619	425	0	425	1,507	0	0	1,932
622	174,259	3,733	177,992	2,603,531	102,349	3,942	2,887,814
705	189	0	189	324,904	31,350	0	356,443
710	86,336	0	86,336	2,913,933	589,302	50,292	3,639,863
720	361	0	361	520,841	14,049	1,406	536,657
760	328	0	328	669,094	204,544	1,293	875,259
810	2,835	0	2,835	185,771	69,448	27,395	285,449
TOTALS	9,737,629	952,707	10,690,336	25,485,052	1,963,634	253,957	38,392,979

Table S-10 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] UPPER MISSOURI SUBBASIN, NORTH DAKOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	996	114	1,110	2,215	0	0	3,325
104	14,588	0	14,588	9,971	0	0	24,559
172	371	0	371	554	0	0	925
174	0	0	0	462	0	0	462
530	0	0	0	1,386	0	0	1,386
705	3,141	0	3,141	22,808	0	0	25,949
999	0	0	0	0	0	185	185
TOTALS	19,096	114	19,210	37,396	0	185	56,791

1/ Unadjusted for projects funded for construction.

Table S-11 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] YELLOWSTONE SUBBASIN SUMMARY

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	417,335	191,454	608,789	514,510	36,961	13,225	1,173,485
104	366,527	165,025	531,552	415,856	263	4,358	952,029
106	642,563	201,173	843,736	2,013,739	11,052	10,453	2,878,980
108	134,776	28,521	163,297	2,251,293	14,292	3,877	2,432,759
110	49,719	0	49,719	2,993,186	301,769	11,163	3,355,837
112	4,834	4,149	8,983	10,157	0	0	19,140
120	3,350	112,085	115,435	25,079	1,077	3,807	145,398
122	6,293	7,529	13,822	4,947	0	426	19,195
124	28,497	14,251	42,748	151,353	1,386	481	195,968
126	9,102	6,339	15,441	594,231	31,498	1,206	642,376
136	15,106	15,007	30,113	27,501	98	1,269	58,981
138	140,935	30,173	171,108	55,663	0	2,444	229,215
140	55,384	15,664	71,048	187,122	361	520	259,051
142	5,337	0	5,337	91,439	0	0	96,776
144	8,447	21,935	30,382	1,496	31	330	32,239
150	0	6,132	6,132	9,684	118	0	15,934
154	21,895	10,163	32,058	140,519	3,718	495	176,790
156	40,970	3,796	44,766	350,565	86	1,377	396,794
158	1,289	343	1,632	7,619	0	0	9,251
160	46,834	16,816	63,650	256,699	2,497	1,547	324,393
162	10,759	1,451	12,210	21,135	0	0	33,345
164	32,184	5,979	38,163	658,433	270	773	697,639
168	3,881	0	3,881	2,033	0	0	5,914
172	0	10,772	10,772	0	0	1,539	12,311
174	1,096	10,949	12,045	4,714	154	193	17,106
180	11,005	7,013	18,018	9,089	0	0	27,107
182	25,371	32,995	58,366	1,128,266	14,030	1,344	1,202,006
188	8,649	2,355	11,004	21,616	1,533	342	34,495
190	20,819	13,136	33,955	87,906	2,169	11	124,041
192	24,398	2,344	26,742	157,551	235	1,082	185,610
194	9,329	98	9,427	246,441	23,072	331	279,271
196	3,230	406	3,636	147,903	31,440	291	183,270
211	12,261	5,524	17,785	151,649	24,839	450	194,723
213	0	6,585	6,585	1,947,165	139,326	1,050	2,094,126
225	0	4,296	4,296	1,434,438	7,250	152	1,446,136
231	0	0	0	482	0	479	961
320	329	490	819	52,964	11,888	1,685	67,356
340	14,106	619	14,725	8,310	1,059	43	24,137
420	0	241	241	72,653	26,204	834	99,932
530	0	0	0	3,036	0	0	3,036
614	0	1,526	1,526	0	191	381	2,098
616	0	21,287	21,287	1,151	4,199	246	26,883
619	0	0	0	9,465	0	0	9,465
620	0	25,482	25,482	31,002	5,819	1,827	64,130
622	63,013	25,037	88,050	2,774,924	67,558	3,631	2,934,163
705	1,675	0	1,675	96,240	20,456	0	118,371
710	101,600	0	101,600	2,184,398	350,639	799	2,637,436
720	37	0	37	229,795	1,833	321	231,986
730	0	0	0	17,376	0	0	17,376
750	265	1,396	1,661	1,220,292	37,307	0	1,259,260
760	0	0	0	1,320,654	180,461	18	1,501,133
770	0	0	0	18,727	0	0	18,727
810	0	0	0	170,754	192,416	16,354	379,524
999	0	0	0	0	0	739	739
TOTALS	2,343,200	1,030,534	3,373,734	24,333,220	1,549,555	91,893	29,348,402

1/ Unadjusted for projects funded for construction.

Table S-12 — MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] YELLOWSTONE SUBBASIN, MONTANA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	354,310	133,309	487,619	429,116	25,025	11,811	953,571
104	319,560	104,380	423,940	396,865	25	3,313	824,143
106	590,304	135,005	725,309	1,552,826	7,038	10,087	2,295,260
108	133,593	9,524	143,117	1,409,093	6,918	2,827	1,561,955
110	48,329	0	48,329	2,615,273	301,769	10,198	2,975,569
120	940	979	1,919	2,894	104	0	4,917
136	15,106	15,007	30,113	27,501	98	1,269	58,981
138	140,935	10,559	151,494	54,941	0	2,033	208,368
140	55,111	13,203	68,314	181,274	361	520	250,469
142	5,337	0	5,337	91,439	0	0	96,776
150	0	0	0	472	0	0	472
154	21,895	10,163	32,058	140,519	3,718	495	176,790
156	40,970	3,796	44,766	350,565	86	1,377	396,794
158	1,289	343	1,632	7,619	0	0	9,251
160	46,834	15,797	62,631	242,578	1,018	1,547	307,774
162	5,396	1,451	6,847	14,666	0	0	21,513
164	31,996	5,979	37,975	658,433	270	773	697,451
182	394	0	394	1,378	0	0	1,772
188	8,649	2,355	11,004	21,616	1,533	342	34,495
190	20,819	9,706	30,525	87,906	2,169	11	120,611
192	24,398	2,052	26,450	51,408	0	136	77,994
194	1,327	98	1,425	177,313	20,641	331	199,710
196	3,230	406	3,636	147,903	31,440	291	183,270
211	12,261	5,485	17,746	149,794	24,839	450	192,829
225	0	0	0	548,754	0	152	548,906
231	0	0	0	482	0	479	961
320	329	490	819	52,964	11,888	1,685	67,356
340	14,106	550	14,656	3,919	0	43	18,618
420	0	203	203	48,780	4,124	0	53,107
530	0	0	0	3,036	0	0	3,036
619	0	0	0	8,541	0	0	8,541
622	63,013	20,685	83,698	2,233,851	54,142	2,238	2,373,929
705	199	0	199	81,069	20,456	0	101,724
710	101,600	0	101,600	2,184,398	350,639	799	2,637,436
720	37	0	37	229,795	1,833	321	231,986
760	0	0	0	1,055,891	152,898	18	1,208,807
810	0	0	0	14,862	1,072	16,163	32,097
TOTALS	2,062,267	501,525	2,563,792	15,279,634	1,024,104	69,709	18,937,239

Table S-13 — MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] YELLOWSTONE SUBBASIN, NORTH DAKOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	48,090	2,238	50,328	21,955	7,208	0	79,491
104	46,967	0	46,967	17,932	0	0	64,899
106	369	0	369	185	0	0	554
108	0	0	0	4,436	0	0	4,436
112	4,834	0	4,834	10,157	0	0	14,991
160	0	0	0	13,860	1,479	0	15,339
162	5,363	0	5,363	6,469	0	0	11,832
164	188	0	188	0	0	0	188
168	3,881	0	3,881	2,033	0	0	5,914
174	1,096	10	1,106	739	0	0	1,845
213	0	0	0	2,957	0	0	2,957
619	0	0	0	924	0	0	924
705	1,476	0	1,476	15,171	0	0	16,647
730	0	0	0	17,376	0	0	17,376
750	0	0	0	40,653	0	0	40,653
999	0	0	0	0	0	739	739
TOTALS	112,264	2,248	114,512	154,047	8,687	739	278,785

1/ Unadjusted for projects funded for construction.

Table S-14 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] YELLOWSTONE SUBBASIN, WYOMING PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	14,935	55,907	70,842	63,439	4,728	1,414	140,423
104	0	60,645	60,645	1,059	238	1,045	62,987
106	51,890	66,168	118,058	460,728	4,014	366	583,166
108	1,183	18,997	20,180	837,764	7,374	1,050	866,368
110	1,390	0	1,390	377,913	0	965	380,268
112	0	4,149	4,149	0	0	0	4,149
120	2,410	111,106	113,516	22,185	973	3,807	140,481
122	6,293	7,529	13,872	4,947	0	426	19,195
124	28,497	14,251	42,748	151,353	1,386	481	195,968
126	9,102	6,339	15,441	594,231	31,498	1,206	642,376
128	0	19,614	19,614	822	0	411	20,847
140	273	2,461	2,734	5,848	0	0	8,582
144	8,447	21,935	30,382	1,496	31	330	32,239
150	0	6,132	6,132	9,212	118	0	15,462
160	0	1,019	1,019	261	0	0	1,280
172	0	10,772	10,772	0	0	1,539	12,311
176	0	10,939	10,939	3,975	154	193	15,261
180	11,005	7,013	18,018	9,089	0	0	27,107
182	24,977	32,995	57,972	1,126,888	14,030	1,344	1,200,234
190	0	3,430	3,430	0	0	0	3,430
192	0	292	292	106,143	235	946	107,616
194	8,002	0	8,002	69,128	2,431	0	79,561
211	0	39	39	1,855	0	0	1,894
213	0	6,585	6,585	1,944,208	139,326	1,050	2,091,169
225	0	4,294	4,294	885,684	7,250	0	897,228
340	0	69	69	4,391	1,059	0	5,519
420	0	38	38	23,873	22,080	834	46,825
614	0	1,526	1,526	0	191	381	2,098
616	0	21,287	21,287	1,151	4,199	246	26,883
620	0	25,482	25,482	31,002	5,819	1,827	64,130
622	0	4,352	4,352	541,073	13,416	1,393	560,234
750	265	1,396	1,661	1,179,639	37,307	0	1,218,607
760	0	0	0	264,763	27,563	0	292,326
770	0	0	0	18,727	0	0	18,727
810	0	0	0	155,892	191,344	191	347,427
TOTALS	168,669	526,761	695,430	8,898,739	516,764	21,445	10,132,378

1/ Unadjusted for projects funded for construction.

Table S-15 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] WESTERN DAKOTA SUBBASIN, SUMMARY

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	1,400,629	52,132	1,452,761	1,049,512	29,452	10,487	2,542,212
104	1,497,909	10,930	1,508,839	756,468	6,211	6,990	2,278,508
106	980,402	28,632	1,009,034	2,115,714	12,712	15,487	3,152,947
108	145,827	4,570	150,397	631,285	8,786	1,253	791,721
110	54,128	0	54,128	1,556,029	6,972	1,462	1,618,591
112	277,131	0	277,131	400,269	288	1,379	679,067
116	1,123	0	1,123	4,910	0	194	6,227
120	11,037	2,661	13,698	113,605	0	81	127,384
122	6,034	4,296	10,330	18,365	0	0	28,695
124	61,642	8,271	69,913	503,704	1,109	1,981	576,707
126	7,226	2,277	9,503	460,204	92	248	470,047
136	55,840	6,072	61,912	81,009	82	797	143,800
138	85,731	0	85,731	16,892	185	196	103,004
142	8,204	0	8,204	229,129	16,099	1,193	254,625
144	1,107	0	1,107	45,118	0	0	46,225
150	0	0	0	31,427	0	93	31,520
154	10,742	778	11,520	50,336	0	0	61,856
156	7,363	0	7,363	147,770	0	0	155,133
158	82	1,300	1,382	0	0	0	1,382
160	1,367,479	20,827	1,388,306	1,947,567	3,673	17,997	3,357,543
162	482,194	0	482,194	241,251	281	473	724,199
164	138,961	439	139,400	3,063,759	21,763	1,664	3,226,586
168	810,064	83	810,147	1,280,044	527	3,997	2,094,715
172	11,447	1,131	12,578	6,764	0	0	19,342
174	909,570	19,072	928,642	1,107,840	14,817	8,665	2,059,965
178	0	0	0	5,812	0	0	5,812
180	9,132	3,988	13,120	89,658	125,595	19,133	247,506
182	19,055	8,202	27,257	139,258	4,950	0	171,465
184	10,542	0	10,542	17,408	0	0	27,950
188	23,019	231	23,250	87,686	11,058	298	122,292
190	23,643	2,288	25,931	32,069	0	1,174	59,174
192	13,277	1,395	14,672	124,164	78	690	139,604
194	51,687	477	52,164	1,226,573	27,637	1,133	1,307,507
196	46	0	46	136,132	0	1,064	137,242
211	12,055	0	12,055	81,260	0	988	94,303
213	1,491	3,328	4,819	1,055,121	85,257	1,040	1,146,237
225	0	0	0	147,985	11,913	0	159,898
310	3,721	0	3,721	739	0	0	4,460
320	30,878	0	30,878	186,264	14,712	862	232,716
330	6,874	0	6,874	8,095	2,245	279	17,493
340	16,433	717	17,150	5,674	4,135	195	27,154
350	2,730	0	2,730	1,225	0	0	3,955
360	94	0	94	518	0	707	1,319
420	22,264	0	22,264	508,863	32,806	873	564,806
510	13,254	0	13,254	12,926	1,481	0	27,661
530	1,853	0	1,853	15,048	1,419	0	18,320
540	0	0	0	101	0	0	101
612	8,988	0	8,988	4,404	0	0	13,392
616	1,527	1,344	2,871	3,130	46	0	6,047
619	1,689	0	1,689	67,930	0	0	69,619
620	0	10,847	10,847	34,446	1,104	0	46,397
622	6,739	2,071	8,810	887,908	0	336	897,054
624	291,494	0	291,494	3,997,569	295	2,540	4,291,898
705	99,889	0	99,889	4,424,306	227,798	11,529	4,76[illegible]
710	4,016	0	4,016	57,089	0	0	61,105
720	377	0	377	12,134	0	0	12,511
730	73,403	0	73,403	407,316	384	188	481,291
740	375	0	375	5,960	0	0	6,335
750	14,656	0	14,656	1,838,250	291,344	1,003	2,145,253
760	0	0	0	30,428	2,016	0	32,444
810	0	0	0	164,404	7,416	56,155	227,975
999	0	0	0	0	0	33,819	33,819
TOTALS	9,097,073	198,359	9,295,432	31,676,824	976,738	208,643	42,157,637

1/ Unadjusted for projects funded for construction.

Table S-16 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] WESTERN DAKOTA SUBBASIN, MONTANA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	43,457	2,358	45,815	55,452	0	685	101,952
104	63,521	6,140	69,661	36,514	0	98	106,273
106	25,259	239	25,498	95,165	0	147	120,810
108	10,419	0	10,419	52,903	0	0	63,322
110	3,623	0	3,623	49,308	0	0	52,931
138	73,067	0	73,067	6,120	0	196	79,383
142	1,845	0	1,845	4,609	0	0	6,454
154	10,742	778	11,520	50,336	0	0	61,856
156	7,363	0	7,363	147,770	0	0	155,133
158	82	1,300	1,382	0	0	0	1,382
160	0	0	0	58,574	0	0	58,574
164	32,025	0	32,025	86,401	0	0	118,426
188	5,033	231	5,264	13,855	0	0	19,119
190	6,932	433	7,365	19,726	0	539	27,630
211	0	0	0	12,093	0	0	12,093
320	0	0	0	17,741	0	0	17,741
340	14,856	580	15,436	701	0	0	16,137
622	3,739	430	4,169	437,796	0	0	441,965
710	4,016	0	4,016	57,089	0	0	61,105
720	0	0	0	3,857	0	0	3,857
760	0	0	0	3,456	0	0	3,456
810	0	0	0	3,331	0	0	3,331
TOTALS	305,979	12,489	318,468	1,212,797	0	1,665	1,532,930

Table S-17 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] WESTERN DAKOTA SUBBASIN, NEBRASKA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	19,966	1,595	21,561	3,477	0	720	25,758
104	75,483	4,513	79,996	37,885	1,996	4,353	124,230
106	72,686	630	73,316	90,992	0	3,396	167,704
108	47,869	456	48,325	59,063	3,622	299	111,309
110	2,883	0	2,883	52,397	439	49	55,768
112	732	0	732	0	0	0	732
114	1,123	0	1,123	4,910	0	194	6,227
120	1,935	0	1,935	9,236	0	0	11,171
122	924	0	924	17,710	0	0	18,634
124	1,178	0	1,178	39,123	0	132	40,433
136	2,739	51	2,790	728	0	196	3,714
160	3,732	2,154	5,886	6,607	0	241	12,734
162	10,986	0	10,986	44,741	0	49	55,776
164	1,657	439	2,096	90,461	0	196	92,753
174	1,076	0	1,076	2,692	0	0	3,768
180	748	0	748	51,315	124,331	19,133	195,527
188	1,614	0	1,614	12,922	0	146	14,682
190	16,711	1,348	18,059	8,506	0	635	27,200
192	7,408	264	7,672	13,487	0	690	21,849
194	5,796	477	6,273	17,476	565	402	24,716
196	0	0	0	56,518	0	0	56,518
213	875	0	875	223,193	41,150	439	265,657
310	3,721	0	3,721	0	0	0	3,721
330	6,874	0	6,874	8,095	2,245	279	17,493
340	1,577	137	1,714	2,829	4,135	195	8,873
350	2,730	0	2,730	1,225	0	0	3,955
360	94	0	94	518	0	707	1,319
420	0	0	0	15,306	176	517	15,999
510	293	0	293	245	0	0	538
622	3,000	870	3,870	51,772	0	176	55,818
810	0	0	0	0	0	1,600	1,600
TOTALS	296,410	12,934	309,344	923,429	178,659	34,744	1,446,176

1/ Unadjusted for projects funded for construction.

Table S-18 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,1/ WESTERN DAKOTA SUBBASIN, NORTH DAKOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	921,821	6,858	928,679	290,674	27,027	3,015	1,249,395
104	1,357,257	0	1,357,257	681,641	4,215	2,539	2,045,652
106	15,012	0	15,012	22,008	0	0	37,020
108	5,752	0	5,752	154,221	3,349	489	163,811
112	197,354	0	197,354	204,860	190	799	403,203
120	2,457	0	2,457	2,606	0	0	5,063
136	43,543	0	43,543	13,372	0	189	57,104
138	12,664	0	12,664	10,772	185	0	23,621
160	146,141	2,531	148,672	35,022	281	615	184,590
162	471,208	0	471,208	196,510	281	424	668,423
164	566	0	566	3,225	0	0	3,791
168	399,427	0	399,427	432,230	93	1,668	833,418
172	11,447	0	11,447	6,764	0	0	18,211
174	689,052	6,811	695,863	453,970	14,550	4,245	1,168,628
184	10,542	0	10,542	17,408	0	0	27,950
188	16,372	0	16,372	60,909	11,058	152	88,491
196	46	0	46	18,719	0	1,064	19,829
211	12,055	0	12,055	69,167	0	988	82,210
213	371	0	371	16,627	0	0	16,998
310	0	0	0	739	0	0	739
420	591	0	591	188	355	0	1,134
510	3,044	0	3,044	5,215	1,481	0	9,740
530	1,853	0	1,853	15,048	1,419	0	18,320
540	0	0	0	101	0	0	101
612	8,988	0	8,988	4,404	0	0	13,392
616	1,527	0	1,527	3,130	46	0	4,703
619	1,689	0	1,689	67,930	0	0	69,619
624	58,916	0	58,916	451,770	0	93	510,779
705	94,004	0	94,004	875,329	0	1,638	970,971
720	377	0	377	8,277	0	0	8,654
730	73,403	0	73,403	407,316	384	188	481,291
740	375	0	375	5,960	0	0	6,335
750	14,011	0	14,011	1,324,565	28,824	942	1,368,342
810	0	0	0	24,268	1,848	41,257	67,373
999	0	0	0	0	0	33,819	33,819
TOTALS	4,571,865	16,200	4,588,065	5,884,945	95,586	94,124	10,662,720

Table S-19 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,1 WESTERN DAKOTA SUBBASIN, SOUTH DAKOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	396,141	38,877	435,018	458,633	2,053	4,682	900,386
106	785,598	6,518	792,116	732,205	5,187	10,537	1,540,040
108	72,180	0	72,180	354,668	1,815	465	429,128
110	47,318	0	47,318	1,232,499	1,256	817	1,281,890
112	79,045	0	79,045	195,409	98	580	275,132
136	9,558	6,021	15,579	66,909	87	412	82,982
142	6,359	0	6,359	224,520	16,099	1,193	248,171
160	1,217,606	16,142	1,233,748	1,847,364	3,392	17,141	3,101,645
164	104,713	0	104,713	2,883,672	21,763	1,468	3,011,616
168	410,637	83	410,720	847,814	434	2,329	1,261,297
174	219,442	12,261	231,703	651,178	267	4,420	887,568
194	44,343	0	44,343	1,000,529	16,164	546	1,061,582
196	0	0	0	60,895	0	0	60,895
320	30,878	0	30,878	168,523	14,712	862	214,975
420	21,673	0	21,673	479,385	32,275	356	533,689
510	9,917	0	9,917	7,466	0	0	17,383
624	232,578	0	232,578	3,545,799	295	2,447	3,781,119
705	5,885	0	5,885	3,548,977	227,798	9,891	3,792,551
810	0	0	0	84,306	2,486	13,298	100,090
TOTALS	3,693,871	79,902	3,773,773	18,390,751	346,171	71,444	22,582,139

1/ Unadjusted for projects funded for construction.

Table S-20 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] WESTERN DAKOTA SUBBASIN, WYOMING PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	19,244	2,444	21,683	241,276	372	1,385	264,721
104	1,648	277	1,925	428	0	0	2,353
106	81,847	21,245	103,092	1,175,344	7,530	1,407	1,287,373
108	9,607	4,114	13,721	10,430	0	0	24,151
110	304	0	304	221,825	5,277	596	228,002
120	6,645	2,661	9,306	101,763	0	81	111,150
122	5,110	4,296	9,406	655	0	0	10,061
124	60,464	8,271	68,735	464,581	1,109	1,849	536,274
126	7,226	2,277	9,503	460,204	92	248	470,047
144	1,107	0	1,107	45,118	0	0	46,225
150	0	0	0	31,427	0	93	31,520
172	0	1,131	1,131	0	0	0	1,131
178	0	0	0	5,812	0	0	5,812
180	8,384	3,988	12,372	38,343	1,264	0	51,979
182	19,055	8,202	27,257	139,258	4,950	0	171,465
190	0	507	507	3,837	0	0	4,344
192	5,869	1,131	7,000	110,677	78	0	117,755
194	1,548	0	1,548	208,568	10,908	185	221,209
213	245	3,328	3,573	815,301	44,107	601	863,582
225	0	0	0	147,985	11,913	0	159,898
340	0	0	0	2,144	0	0	2,144
420	0	0	0	13,984	0	0	13,984
616	0	1,344	1,344	0	0	0	1,344
620	0	10,847	10,847	34,446	1,104	0	46,397
622	0	771	771	398,340	0	160	399,271
750	645	0	645	513,685	262,520	61	776,911
760	0	0	0	26,972	2,016	0	28,988
810	0	0	0	52,499	3,082	0	55,581
TOTALS	228,948	76,834	305,782	5,264,907	356,322	6,666	5,933,672

1/ Unadjusted for projects funded for construction.

Table S-21 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] EASTERN DAKOTA SUBBASIN, SUMMARY

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	6,857,726	43,292	6,901,018	1,548,546	80,152	125,745	8,655,461
104	3,598,940	0	3,598,940	1,253,282	11,394	29,967	4,893,583
106	4,937,103	0	4,937,103	2,349,456	32,538	116,313	7,435,410
108	60,874	0	60,874	199,912	2,829	2,540	266,155
110	43,911	0	43,911	215,004	276	1,217	260,408
112	204,549	0	204,549	125,858	368	6,827	337,602
114	8,423	0	8,423	2,404	0	190	11,017
120	124,203	0	124,203	13,844	47	1,237	139,331
136	670,067	1,355	671,422	181,604	5,953	12,422	871,401
138	217,700	0	217,700	81,832	1,209	1,364	302,105
140	7,168	0	7,168	1,665	0	190	9,023
142	55,125	0	55,125	72,457	558	2,171	130,311
144	137,144	0	137,144	45,059	190	2,946	185,339
150	3,833	0	3,833	3,798	0	0	7,631
152	3,997	0	3,997	2,754	0	0	6,751
160	213,609	2,348	215,957	185,604	11,239	2,109	414,909
162	40,760	0	40,760	25,752	0	0	66,512
164	272	0	272	94,075	0	0	94,347
168	977,035	409	977,444	658,761	2,392	8,408	1,647,005
172	133,849	203	134,052	42,686	149	0	177,087
174	754,401	4,954	759,355	304,901	12,634	10,437	1,087,327
184	7,060	0	7,060	1,167	0	0	8,227
188	8,299	37	8,336	21,632	7,447	0	37,415
194	3,459	0	3,459	10,256	5,929	0	19,644
196	0	0	0	41,284	0	1,291	42,575
211	175,701	0	175,701	244,048	0	190	419,939
213	282	0	282	3,098	0	0	3,380
231	1,771	0	1,771	1,981	0	0	3,752
310	10,696	0	10,696	192	0	0	10,888
320	572,586	6,919	579,505	337,205	16,541	14,170	947,421
330	10,367	13	10,380	4,258	0	818	15,456
420	295,714	0	295,714	853,548	6,581	9,551	1,165,394
421	0	0	0	1,998	0	0	1,998
510	513,432	0	513,432	391,139	3,208	2,840	910,619
530	33,076	0	33,076	322,935	96	0	356,107
540	11,341	0	11,341	50,135	0	0	61,476
612	2,085	0	2,085	3,443	0	0	5,528
616	5,914	0	5,914	9,364	0	0	15,278
619	28,994	0	28,994	158,869	0	0	187,863
624	54,768	0	54,768	241,573	0	0	296,341
705	152,814	0	152,814	2,294,343	7,868	7,546	2,462,571
710	3,870	0	3,870	617	0	142	4,629
730	3,178	0	3,178	24,426	0	0	27,604
750	96	0	96	90,060	0	0	90,156
770	0	0	0	867	0	0	867
810	2,645	0	2,645	29,088	1,067	156,395	189,195
999	0	0	0	0	0	77,271	77,271
TOTALS	20,948,837	59,530	21,008,367	12,546,980	210,665	594,297	34,360,309

1/ Unadjusted for projects funded for construction.

Table S-22 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] EASTERN DAKOTA SUBBASIN, IOWA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	37,465	0	37,465	3,379	0	2,426	43,270
104	263,045	0	263,045	20,744	836	11,421	296,016
106	151,193	0	151,193	16,603	0	4,177	171,973
108	1,773	0	1,773	1,915	2,551	337	6,576
112	29,916	0	29,916	2,449	0	625	32,990
114	8,423	0	8,423	2,404	0	190	11,017
120	61,764	0	61,764	5,889	47	1,237	68,937
136	5,210	0	5,210	[illegible]26	0	0	5,836
138	8,135	0	8,135	323	0	477	8,945
140	5,859	0	5,859	1,385	0	190	7,434
142	1,669	0	1,669	332	0	144	2,145
144	14,380	0	14,380	7,538	0	238	22,156
174	1,105	0	1,105	524	0	0	1,629
211	4,198	0	4,198	2,013	0	0	6,211
231	48	0	48	668	0	0	716
310	3,274	0	3,274	192	0	0	3,466
320	26,174	204	26,378	20,815	0	1,778	48,971
330	8,965	13	8,978	3,503	0	818	13,299
420	5,140	0	5,140	22,390	0	1,141	28,671
421	0	0	0	1,998	0	0	1,998
705	1,193	0	1,193	20,752	1,059	526	23,530
710	3,015	0	3,015	524	0	94	3,633
770	0	0	0	867	0	0	867
810	0	0	0	4,488	0	0	4,488
TOTALS	641,944	217	642,161	142,331	4,463	25,819	814,774

Table S-23 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] EASTERN DAKOTA SUBBASIN, MINNESOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	144,920	0	144,920	9,032	191	4,976	159,119
104	387,351	0	387,351	31,517	0	17,015	435,883
106	21,906	0	21,906	8,766	0	466	31,138
108	3,330	0	3,330	3,936	0	284	7,550
120	139	0	139	0	0	0	139
136	9,388	0	9,388	1,183	0	517	11,088
138	15,742	0	15,742	1,549	0	887	18,178
140	1,309	0	1,309	280	0	0	1,589
142	2,005	0	2,005	804	0	143	2,952
144	122,764	0	122,764	37,521	190	2,708	163,183
211	6,745	0	6,745	1,632	0	190	8,567
213	282	0	282	3,098	0	0	3,380
231	1,723	0	1,723	1,313	0	0	3,036
320	16,678	0	16,678	20,844	0	233	37,755
330	1,402	0	1,402	755	0	0	2,157
420	4,240	0	4,240	14,724	0	1,868	20,832
510	12,150	0	12,150	4,890	0	373	17,413
540	187	0	187	190	0	0	377
705	747	0	747	9,763	95	666	11,271
710	855	0	855	93	0	48	996
TOTALS	753,863	0	753,863	151,890	476	30,374	936,603

1/ Unadjusted for projects funded for construction.

Table S-24 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] EASTERN DAKOTA SUBBASIN, NORTH DAKOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	2,049,798	25,672	2,075,470	308,493	43,700	10,523	2,438,256
104	2,948,544	0	2,948,544	1,201,021	10,588	1,531	4,161,684
106	369,477	0	369,477	350,539	1,013	146	721,175
108	1,543	0	1,543	57,134	0	0	58,677
112	12,458	0	12,458	13,060	0	0	25,518
120	62,300	0	62,300	7,955	0	0	70,255
136	266,251	0	266,251	42,838	2,813	0	311,902
138	193,823	0	193,823	79,950	1,209	0	274,982
150	3,833	0	3,833	3,798	0	0	7,631
152	3,997	0	3,997	2,754	0	0	6,751
160	73,849	1,152	75,001	2,638	10,962	0	88,601
162	40,760	0	40,760	25,752	0	0	66,512
168	232,944	0	232,944	108,363	49	0	341,356
172	133,849	203	134,052	42,886	149	0	177,087
174	351,392	3,041	354,433	137,988	2,153	1,439	496,013
184	7,060	0	7,060	1,167	0	0	8,227
188	8,299	37	8,336	21,632	7,447	0	37,415
196	0	0	0	41,284	0	1,291	42,575
211	164,758	0	164,758	240,403	0	0	405,161
310	7,422	0	7,422	0	0	0	7,422
510	129,323	0	129,323	102,637	1,526	0	233,486
530	33,076	0	33,076	322,935	96	0	356,107
540	11,154	0	11,154	49,945	0	0	61,099
612	2,085	0	2,085	3,443	0	0	5,528
616	5,914	0	5,914	9,364	0	0	15,278
619	28,994	0	28,994	158,869	0	0	187,863
624	2,587	0	2,587	49,785	0	0	52,372
705	120,677	0	120,677	1,320,001	3,433	0	1,444,111
730	3,178	0	3,178	24,426	0	0	27,604
750	96	0	96	90,060	0	0	90,156
810	146	0	146	4,893	0	68,626	73,665
999	0	0	0	0	0	77,271	77,271
TOTALS	7,269,587	30,105	7,299,692	4,826,013	85,138	160,897	12,371,740

Table S-25 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] EASTERN DAKOTA SUBBASIN, SOUTH DAKOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	4,625,543	17,620	4,643,163	1,227,642	36,261	107,750	6,014,816
106	4,394,527	0	4,394,527	1,973,548	31,525	111,524	6,511,124
108	54,228	0	54,228	136,927	278	1,919	193,352
110	43,911	0	43,911	215,004	276	1,217	260,408
112	162,175	0	162,175	110,349	368	6,202	279,094
136	389,218	1,355	390,573	136,957	3,140	11,905	542,575
142	51,451	0	51,451	71,321	558	1,884	125,214
160	139,760	1,196	140,956	182,966	277	2,109	326,308
164	272	0	272	94,075	0	0	94,347
168	744,091	409	744,500	550,398	2,343	8,408	1,305,649
174	401,904	1,913	403,817	166,389	10,481	8,998	589,685
194	3,459	0	3,459	10,256	5,929	0	19,644
320	529,734	6,715	536,449	295,546	16,541	12,159	860,695
420	286,334	0	286,334	816,434	6,581	6,542	1,115,891
510	371,959	0	371,959	283,612	1,682	2,467	659,720
624	52,181	0	52,181	191,788	0	0	243,969
705	30,197	0	30,197	943,827	3,281	6,354	983,659
810	2,499	0	2,499	19,707	1,067	87,769	111,042
TOTALS	12,283,443	29,208	12,312,651	7,426,746	120,588	377,207	20,237,192

1/ Unadjusted for projects funded for construction.

Table S-26 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] PLATTE-NIOBRARA SUBBASIN, SUMMARY

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	2,300,337	825,403	3,125,740	1,039,877	10,018	68,476	4,244,111
104	2,451,518	329,687	2,781,205	570,676	7,791	78,907	3,438,579
106	1,426,489	143,675	1,570,164	1,541,089	12,731	52,898	3,176,882
108	373,822	12,306	386,128	1,877,888	28,125	12,803	2,304,944
110	19,969	0	19,969	198,194	308	573	219,044
112	1,416,670	29,701	1,446,371	264,403	3,645	27,637	1,742,056
114	240,938	0	240,938	1,246,289	9,954	11,577	1,509,358
120	96,967	55,837	152,804	10,686	393	4,584	168,467
122	67,561	1,131	68,692	5,766	0	2,260	76,718
124	56,510	0	56,510	88,360	47	846	145,763
126	1,069	0	1,069	466,659	0	0	467,728
136	125,520	62,389	187,909	40,278	1,570	2,914	23[illegible],671
138	9,029	3,233	12,262	647	0	878	13,787
140	6,068	8,901	14,969	1,315	0	270	16,554
142	1,016	0	1,016	15,952	0	0	16,968
144	16,409	6,166	22,575	18,151	0	211	40,937
150	2,970	88,118	91,088	157,685	8,742	2,241	259,756
153	0	19,190	19,190	2,343	0	154	21,687
160	25,024	4,139	29,163	32,139	0	599	61,901
162	4,941	0	4,941	4,426	48	98	9,513
164	7,277	0	7,277	81,650	8,526	146	97,599
168	795	0	795	5,876	0	0	6,671
172	1,660	7,047	8,707	5,719	0	550	14,976
174	410,559	77,118	487,677	966,931	28,161	35,173	1,517,942
178	45,934	104,960	150,894	34,696	0	2,660	188,250
180	24,443	26,768	51,211	601,278	3,783	3,470	659,742
182	17,529	43,651	61,180	990,645	121	518	1,052,464
188	235,137	1,527	236,664	8,704,553	22,132	89,848	9,053,197
190	1,467,640	296,029	1,763,669	1,060,300	15,400	38,160	2,877,529
192	227,654	43,991	271,645	1,007,653	4,584	8,551	1,292,433
194	95,077	430	95,507	729,227	2,819	2,080	829,633
196	97,432	1,144	98,576	3,321,371	2,879	237	3,423,063
211	4,289	48,499	52,788	34,957	0	99	87,844
213	142,556	6,258	148,814	2,318,812	225,354	8,048	2,701,028
225	55,228	32,156	87,3[illegible]	259,358	0	1,968	348,710
310	99,562	21,966	121,528	18,660	0	1,189	141,377
320	4,846	0	4,846	12,493	0	0	17,339
330	477,137	238,201	715,338	306,295	13,159	23,428	1,058,220
340	121,277	55,170	176,447	401,469	15,593	12,163	605,672
350	34,015	5,198	39,213	470,371	22,499	5,876	537,959
360	28,504	29,417	57,921	459,413	23,725	2,277	543,336
361	2,184	20,209	22,393	267,247	7,895	2,175	299,710
420	47,437	5,427	52,864	375,363	65,462	7,424	501,113
510	54,040	1,338	55,378	5,870	137	1,036	62,421
530	15,823	0	15,823	5,791	0	2,270	23,884
540	11,532	4,116	15,648	41,094	1,225	46	58,013
612	22,209	17,683	39,892	69,479	300	2,210	111,881
614	0	0	0	23,197	0	512	23,709
616	0	0	0	832	0	0	832
619	33,266	2,035	35,301	18,477	277	872	54,927
620	44,335	35,845	80,180	125,931	3,356	2,767	212,234
622	15,287	1,535	16,822	399,526	0	525	416,873
624	2,960	0	2,960	18,969	0	0	21,929
705	167,662	2,000	169,662	1,153,447	120,950	6,741	1,450,800
710	124,656	0	124,656	919,348	244,694	4,473	1,293,171
720	0	0	0	123,726	139,212	747	263,685
730	102,059	0	102,059	436,780	0	2,424	541,263
740	27,775	0	27,775	186,709	0	247	214,731
750	1,859	253	2,112	1,124,025	304,843	2,272	1,433,252
760	0	0	0	244,032	77,080	0	321,112
770	0	0	0	2,838	0	0	2,838
810	646	0	646	229,421	498,601	79,365	808,033
TOTAL	12,915,108	2,719,847	15,634,955	35,147,252	1,936,139	620,473	53,336,819

1/ Unadjusted for projects funded for construction.

Table S-27 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] PLATTE-NIOBRARA SUBBASIN, COLORADO PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	999,036	256,383	1,255,419	484,161	3,895	12,440	1,755,915
104	147,243	55,231	202,474	148,945	715	2,877	355,011
106	33,580	13,385	46,965	50,742	188	2,353	100,248
108	18,790	10,378	29,168	159	0	1,019	30,346
112	56,419	6,860	63,279	96,483	0	868	160,630
136	21,600	29,348	50,948	3,627	0	1,369	55,944
138	9,029	2,384	11,413	647	0	878	12,938
140	6,068	8,901	14,969	1,315	0	270	16,554
150	0	76,933	76,933	48,173	94	1,055	126,255
153	0	19,190	19,190	2,343	0	154	21,687
160	22,185	2,925	25,110	15,131	0	599	40,840
178	45,934	104,960	150,894	34,696	0	2,660	188,250
180	3,685	8,774	12,459	1,421	0	121	14,001
182	17,529	9,971	27,500	1,446	121	51	29,118
190	664,769	167,681	832,450	463,492	684	6,899	1,303,525
192	24,993	6,901	31,894	15,191	0	375	47,460
196	96,128	1,144	97,272	687,173	0	237	784,682
211	0	47,461	47,461	669	0	0	48,130
225	54,656	32,156	86,812	6,584	0	1,968	95,364
350	1,492	2,739	4,231	19,148	14,088	363	37,830
360	0	26,332	26,332	28,613	5,116	94	60,155
361	0	20,209	20,209	28,306	0	121	48,636
420	8,704	838	9,542	57,546	17,830	481	85,399
510	9,569	0	9,569	1,171	0	379	11,119
612	0	2,882	2,882	30,922	0	318	34,122
622	596	0	596	11,279	0	479	12,354
705	165,608	2,000	167,608	817,834	117,376	5,612	1,108,430
710	124,656	0	124,656	919,348	244,694	4,473	1,293,171
720	0	0	0	121,036	138,118	200	259,354
730	102,059	0	102,059	436,780	0	2,424	541,263
740	27,775	0	27,775	186,709	0	247	214,731
750	1,109	0	1,109	97,762	260,057	2,272	361,200
770	0	0	0	478	0	0	478
810	0	0	0	81,975	278,452	69,810	430,237
TOTALS	2,663,212	915,966	3,579,178	4,901,305	1,081,421	123,466	9,685,377

1/ Unadjusted for projects funded for construction.

Table S-28 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] PLATTE-NIOBRARA SUBBASIN, NEBRASKA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	1,091,161	543,072	1,634,233	110,456	6,123	53,711	1,804,523
104	2,259,392	248,319	2,507,711	295,782	7,076	75,878	2,886,447
106	1,290,361	88,011	1,378,372	453,759	6,609	47,459	1,886,199
108	354,729	1,928	356,657	356,863	4,127	10,407	728,054
110	15,508	0	15,508	98,837	308	485	115,138
112	1,359,133	22,355	1,381,488	161,778	3,645	26,725	1,573,636
114	240,938	0	240,938	1,246,889	9,954	11,577	1,509,358
120	51,820	41,366	93,186	4,811	393	3,050	101,440
122	62,918	0	62,918	3,279	0	2,260	68,457
124	38,985	0	38,985	4,456	47	340	43,828
136	100,958	33,041	133,999	33,116	1,216	1,545	169,876
160	2,839	1,214	4,053	11,977	0	0	16,030
162	4,941	0	4,941	4,426	48	98	9,513
164	7,277	0	7,277	69,724	8,526	146	85,673
174	354,900	68,195	423,095	849,988	28,161	34,461	1,335,705
180	15,959	0	15,959	474,976	3,783	2,646	497,364
188	235,137	905	236,042	8,704,553	22,132	88,915	9,051,642
190	778,802	120,087	898,889	519,689	14,716	30,625	1,463,919
192	194,575	34,419	228,994	414,377	4,584	7,154	655,109
194	31,465	430	31,895	243,991	2,819	1,149	279,854
196	1,002	0	1,002	2,617,528	2,879	0	2,621,409
211	3,411	638	4,049	32,141	0	99	36,289
213	130,013	1,699	131,712	722,889	26,341	7,907	888,849
310	99,562	21,966	121,528	18,660	0	1,189	141,377
330	477,137	238,201	715,338	306,295	13,159	23,428	1,058,220
340	121,277	55,170	176,447	390,708	14,489	12,163	593,807
350	32,523	2,459	34,982	451,223	8,411	5,513	500,129
360	28,504	3,085	31,589	430,800	18,609	2,183	483,181
361	2,184	0	2,184	238,941	7,895	2,056	251,076
420	38,245	36	38,281	183,888	39,265	6,943	268,377
510	44,471	1,338	45,809	3,767	137	657	50,370
530	15,823	0	15,823	5,791	0	2,270	23,884
540	11,532	4,116	15,648	41,094	1,225	46	58,013
612	22,209	14,801	37,010	38,557	300	1,892	77,759
619	33,266	2,035	35,301	18,477	277	872	54,927
620	44,335	23,636	67,971	29,352	3,356	2,767	103,446
622	14,691	1,535	16,226	15,558	0	46	31,830
705	2,054	0	2,054	298,790	3,574	1,129	305,547
720	0	0	0	2,690	1,094	547	4,331
810	576	0	576	38,467	3,583	9,113	51,739
TOTALS	9,614,613	1,574,057	11,188,670	19,949,343	268,861	479,449	31,886,323

Table S-29 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] PLATTE-NIOBRARA SUBBASIN, SOUTH DAKOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	7,025	0	7,025	2,245	0	0	9,270
106	1,517	0	1,517	7,663	0	0	9,180
108	0	0	0	7,640	0	0	7,640
110	4,461	0	4,461	70,520	0	88	75,069
112	620	0	620	6,142	0	44	6,806
136	2,962	0	2,962	3,535	354	0	6,851
142	1,016	0	1,016	15,952	0	0	16,968
160	0	0	0	5,031	0	0	5,031
164	0	0	0	11,926	0	0	11,926
168	795	0	795	5,876	0	0	6,671
174	55,381	0	55,381	115,772	0	220	171,373
194	47,735	0	47,735	241,922	0	931	290,588
320	4,846	0	4,846	12,493	0	0	17,339
420	488	0	488	33,970	0	0	34,458
510	0	0	0	932	0	0	932
624	2,960	0	2,960	18,969	0	0	21,929
705	0	0	0	36,823	0	0	36,823
810	0	0	0	0	0	442	442
TOTALS	129,806	0	129,806	597,411	354	1,725	729,296

1/ Unadjusted for projects funded for construction.

Table S-30 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] PLATTE-NIOBRARA SUBBASIN, WYOMING PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	203,115	25,948	229,063	443,015	0	2,325	674,403
104	44,883	26,137	71,020	125,949	0	152	197,121
106	101,031	42,279	143,310	1,026,925	5,934	3,086	1,181,255
108	303	0	303	1,513,226	23,998	1,377	1,538,904
110	0	0	0	28,837	0	0	28,837
112	498	486	984	0	0	0	984
120	45,147	14,471	59,618	5,375	0	1,534	67,027
122	4,643	1,131	5,774	2,487	0	0	8,261
124	17,525	0	17,525	83,904	0	506	101,935
126	1,069	0	1,069	466,659	0	0	467,728
130	0	849	849	0	0	0	849
144	16,409	6,166	22,575	18,151	0	211	40,937
150	2,970	11,185	14,155	109,512	8,648	1,186	133,501
172	1,660	7,047	8,707	5,719	0	550	14,976
174	278	8,923	9,201	1,171	0	492	10,864
180	4,799	17,994	22,793	124,881	0	703	148,377
182	0	33,680	33,680	989,199	0	467	1,023,346
188	0	622	622	0	0	933	1,555
190	24,069	8,261	32,330	77,119	0	636	110,085
192	8,086	2,671	10,757	578,085	0	1,022	589,864
194	15,877	0	15,877	243,314	0	0	259,191
196	302	0	302	16,670	0	0	16,972
211	878	400	1,278	2,147	0	0	3,425
213	12,543	4,559	17,102	1,595,923	199,013	141	1,812,179
225	572	0	572	252,774	0	0	253,346
340	0	0	0	10,761	1,104	0	11,865
420	0	4,553	4,553	99,959	8,367	0	112,879
614	0	0	0	23,197	0	512	23,709
616	0	0	0	832	0	0	832
620	0	12,209	12,209	96,579	0	0	108,788
622	0	0	0	372,689	0	0	372,689
750	750	253	1,003	1,026,263	44,786	0	1,072,052
760	0	0	0	244,032	77,080	0	321,112
770	0	0	0	2,360	0	0	2,360
810	70	0	70	108,979	216,566	0	325,615
TOTALS	507,477	229,824	737,301	9,699,193	585,496	15,833	11,037,823

1/ Unadjusted for projects funded for construction.

Table S-31 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] MIDDLE MISSOURI SUBBASIN, SUMMARY

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	208,411	6,838	215,249	14,807	4,239	9,800	244,095
104	2,162,047	7,242	2,169,289	245,543	37,940	102,052	2,554,824
106	2,897,323	1,994	2,899,317	387,524	41,125	94,724	3,422,690
108	423,555	0	423,555	120,228	22,677	14,247	580,707
110	5,869	0	5,869	20,686	1,439	24	28,068
112	740,587	0	740,587	60,219	3,804	16,556	821,166
114	262,126	0	262,126	135,521	30,860	7,078	435,585
120	408,648	540	409,188	35,491	1,111	10,687	456,477
122	499,652	0	499,652	130,932	6,545	24,333	661,462
124	395,947	0	395,947	186,490	8,511	14,248	605,196
126	254,526	0	254,526	149,163	16,692	10,189	430,570
136	45,834	0	45,834	2,677	554	1,784	50,849
138	12,553	0	12,553	2,681	0	708	15,942
140	14,825	0	14,825	2,656	7	705	18,193
142	4,319	0	4,319	293	191	330	5,133
144	210,471	0	210,471	35,633	188	6,758	253,050
153	112,656	947	113,603	24,924	2,492	1,917	142,936
154	4,279	0	4,279	2,432	815	0	7,526
160	142	0	142	0	0	0	142
162	6,430	0	6,430	2,199	0	119	8,748
164	947	0	947	15,630	0	0	16,577
174	20,340	2,360	22,700	6,457	2,429	287	31,873
180	483	0	483	564	0	0	1,047
188	3,413	0	3,413	3,734	326	0	7,473
190	48,185	4,942	53,127	6,306	2,653	2,421	64,507
192	17,513	0	17,513	4,306	235	615	22,669
194	4,598	0	4,598	14,766	0	96	19,460
211	10,142	[illegible]	10,142	674	0	326	11,142
213	3,755	0	3,755	33,114	3,662	700	41,231
231	3,422	0	3,422	7,008	0	148	10,578
310	400,780	17,886	418,666	25,959	17,482	20,975	483,082
320	622,928	10,294	633,222	229,502	17,154	13,150	893,028
330	835,331	49,253	884,584	115,970	68,553	23,959	1,093,066
340	43,368	261	43,629	3,110	1,472	4,885	53,096
350	18,225	0	18,225	1,664	2,038	2,266	24,193
360	769	0	769	5,541	1,625	0	7,935
420	49,462	0	49,462	150,068	56,778	22,124	278,432
421	11,122	0	11,122	567	13,272	1,001	25,962
510	15,738	0	15,738	5,398	0	284	21,420
540	94	0	94	279	0	0	373
612	2,647	0	2,647	0	0	0	2,647
705	322,233	0	322,233	280,541	244,678	24,862	872,314
710	5,387	0	5,387	4,612	5,863	305	16,167
720	199	0	199	0	199	0	398
740	50	0	50	76	0	0	126
770	4,167	0	4,167	7,441	6,794	8,831	27,233
810	1,177	0	1,177	1,823	6,410	3,277	12,687
TOTALS	11,116,675	102,557	11,219,232	2,485,209	630,863	446,771	14,782,075

1/ Unadjusted for projects funded for construction.

Table S-32 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] MIDDLE MISSOURI SUBBASIN, IOWA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	133,443	0	133,443	5,407	571	5,859	145,280
104	1,415,008	0	1,415,009	113,953	10,709	67,201	1,606,871
106	2,069,365	0	2,069,365	235,164	19,133	67,742	2,391,404
108	223,229	0	223,229	56,827	13,958	4,849	298,863
112	168,576	0	168,576	16,472	1,358	4,987	191,393
114	171,172	0	171,172	23,916	2,820	3,469	201,377
120	373,838	0	373,838	33,367	797	9,543	417,545
124	46,298	0	46,298	13,638	227	695	60,858
126	111,941	0	111,941	41,112	2,994	1,788	157,835
136	41,887	0	41,887	2,003	554	1,495	45,939
138	10,548	0	10,548	2,233	0	696	13,477
140	14,150	0	14,150	2,514	0	602	17,266
142	1,602	0	1,602	95	191	232	2,120
144	162,851	0	162,851	29,381	188	3,621	196,041
153	12,046	0	12,046	3,183	0	226	15,455
154	4,279	0	4,279	2,432	815	0	7,526
174	2,270	0	2,270	707	0	46	3,023
211	6,760	0	6,760	379	0	326	7,465
231	1,808	0	1,808	1,299	0	0	3,107
310	229,800	10,758	240,558	12,440	1,149	2,467	256,614
320	622,507	10,294	632,801	228,344	17,154	13,150	891,449
330	389,904	906	390,810	42,982	10,843	13,132	457,767
340	29,461	0	29,461	144	0	4,885	34,490
350	4,074	0	4,074	0	100	2,015	6,189
420	32,605	0	32,605	100,467	7,224	19,216	159,512
421	11,122	0	11,122	567	13,272	1,001	25,962
510	5,909	0	5,909	2,553	0	139	8,601
612	1,343	0	1,343	0	0	0	1,343
705	158,226	0	158,226	148,285	84,026	8,189	398,726
710	4,587	0	4,587	2,000	0	237	6,824
770	4,167	0	4,167	7,441	6,794	8,831	27,233
810	1,177	0	1,177	1,674	0	2,570	5,421
TOTALS	6,465,953	21,958	6,487,911	1,130,979	194,877	249,209	8,062,976

Table S-33 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] MIDDLE MISSOURI SUBBASIN, KANSAS PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	34,556	2,991	37,547	7,913	3,620	811	49,891
104	36,417	0	36,417	4,305	710	594	42,026
106	183,781	0	183,781	24,111	5,917	2,789	216,598
108	19,338	0	19,338	6,948	1,495	430	28,211
120	18,431	0	18,431	1,592	75	287	20,385
122	86,833	0	86,833	16,643	505	1,253	105,234
124	68,052	0	68,052	12,934	853	1,316	83,155
126	42,235	0	42,235	16,821	2,144	981	62,181
138	592	0	592	202	0	12	806
140	282	0	282	142	7	5	436
190	237	0	237	29	3	36	305
192	22	0	22	8	0	3	33
310	17,077	0	17,077	2,337	6,061	301	25,776
330	3,406	0	3,406	419	660	70	4,555
350	11,339	0	11,339	475	1,848	202	13,864
420	8,490	0	8,490	12,540	15,605	584	37,219
705	23,843	0	23,843	24,512	20,789	1,088	70,232
710	800	0	800	2,338	3,670	68	6,876
740	50	0	50	76	0	0	126
810	0	0	0	0	1,580	68	1,648
TOTALS	555,781	2,991	558,772	134,345	65,542	10,898	769,557

1/ Unadjusted for projects funded for construction.

Table S-34 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] MIDDLE MISSOURI SUBBASIN, MINNESOTA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	12,896	0	12,896	493	0	1,367	14,756
104	52,012	0	52,012	4,028	0	5,321	61,361
106	5,411	0	5,411	1,662	0	542	7,615
108	0	0	0	430	0	0	430
138	1,413	0	1,413	246	0	0	1,659
140	393	0	393	0	0	98	491
142	2,717	0	2,717	198	0	98	3,013
144	47,620	0	47,620	6,252	0	3,137	57,009
211	3,382	0	3,382	295	0	0	3,677
231	1,614	0	1,614	5,709	0	148	7,471
320	421	0	421	1,158	0	0	1,579
420	0	0	0	1,329	0	0	1,329
510	9,829	0	9,829	2,845	0	145	12,819
TOTALS	137,708	0	137,708	24,645	0	10,856	173,209

Table S-35 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] MIDDLE MISSOURI SUBBASIN, MISSOURI PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
104	152,856	0	152,856	58,067	18,107	5,207	234,237
106	176,523	0	176,523	52,901	10,690	7,398	247,512
108	84,460	0	84,460	24,943	3,564	4,660	117,627
122	94,469	0	94,469	64,006	4,385	7,868	170,728
124	197,891	0	197,891	147,697	6,859	10,277	362,724
126	100,350	0	100,350	91,230	11,554	7,420	210,554
153	100,610	947	101,557	21,741	2,492	1,691	127,481
310	44,948	0	44,948	0	4,934	11,238	61,120
330	210,179	4,575	214,754	23,040	33,209	1,370	272,373
340	7,127	0	7,127	0	0	0	7,127
705	138,777	0	138,777	101,492	127,579	13,431	381,279
710	0	0	0	274	2,193	0	2,467
TOTALS	1,308,190	5,522	1,313,712	585,391	225,566	70,560	2,195,229

1/ Unadjusted for projects funded for construction.

Table S-36 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] MIDDLE MISSOURI SUBBASIN, NEBRASKA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	27,516	3,847	31,363	994	48	1,763	34,168
104	505,754	7,242	512,996	65,190	8,414	23,729	610,329
106	462,243	1,994	464,237	73,686	5,385	16,253	559,561
108	96,528	0	96,528	31,080	3,660	4,308	135,576
110	5,869	0	5,869	20,686	1,489	24	28,068
112	572,011	0	572,011	43,747	2,446	11,569	629,773
114	90,954	0	90,954	111,605	28,040	3,609	234,208
120	16,379	540	16,919	532	239	857	18,547
122	318,350	0	318,350	50,283	1,655	15,212	385,500
124	83,706	0	83,706	12,221	572	1,960	98,459
136	3,947	0	3,947	674	0	289	4,910
160	142	0	142	0	0	0	142
162	6,430	0	6,430	2,199	0	119	8,748
164	947	0	947	15,630	0	0	16,577
174	18,070	2,360	20,430	5,750	2,429	241	28,850
180	483	0	483	564	0	0	1,047
188	3,413	0	3,413	3,734	326	0	7,473
190	47,948	4,942	52,890	6,277	2,650	2,385	64,202
192	17,491	0	17,491	4,298	235	612	22,636
194	4,598	0	4,598	14,766	0	96	19,460
213	3,755	0	3,755	33,114	3,662	700	41,231
310	108,955	7,128	116,083	11,182	5,338	6,969	139,572
330	231,842	43,772	275,614	49,529	23,841	9,387	358,371
340	6,780	261	7,041	2,966	1,472	0	11,479
350	2,812	0	2,812	1,189	90	49	4,140
360	769	0	769	5,541	1,625	0	7,935
420	8,367	0	8,367	35,732	33,949	2,324	80,372
540	94	0	94	279	0	0	373
612	1,304	0	1,304	0	0	0	1,304
705	1,387	0	1,387	6,252	12,284	2,154	22,077
720	199	0	199	0	199	0	398
810	0	0	0	149	4,830	639	5,618
TOTALS	2,649,043	72,086	2,721,179	609,849	144,878	105,248	3,581,104

1/ Unadjusted for projects funded for construction.

Table S-37 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] KANSAS SUBBASIN, SUMMARY

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	4,956,194	940,694	5,896,888	1,060,522	67,149	80,959	7,105,518
104	3,048,838	309,188	3,358,026	648,656	20,085	55,797	4,082,564
106	2,293,477	31,073	2,324,550	744,658	33,779	48,710	3,151,697
108	356,867	0	356,867	469,552	5,987	15,241	847,647
110	29,765	0	29,765	272,308	145	2,351	304,565
112	1,660,043	5,351	1,665,394	565,459	1,262	19,459	2,251,574
114	1,007,669	0	1,007,669	1,297,260	843	19,874	2,325,646
120	995,566	182,144	1,177,710	84,669	2,575	36,157	1,301,111
122	1,109,638	6,952	1,116,590	300,063	4,781	34,651	1,456,085
124	586,370	0	586,370	174,272	1,887	14,671	777,200
126	298,250	0	298,250	196,741	22,925	8,039	525,955
136	65,676	14,725	80,401	13,320	0	1,803	95,524
138	130,512	88	130,600	50,424	1,111	1,973	184,108
140	75,617	0	75,617	44,280	774	1,713	122,384
154	727	0	727	314	282	30	1,353
156	705	0	705	418	254	26	1,403
158	34,491	342	34,833	55,453	6	498	90,790
160	0	0	0	953	0	0	953
162	8,245	0	8,245	6,894	183	250	15,572
164	1,132	0	1,132	1,506	0	0	2,638
174	111,639	3,776	115,415	84,224	1,224	4,304	205,167
178	107,675	11,158	118,833	93,360	0	967	213,160
180	2,766	0	2,766	44,860	189	666	48,481
188	180,754	0	180,754	549,108	1,497	68,714	800,073
190	691,176	43,500	734,676	256,246	5,199	9,718	1,005,839
192	64,962	837	65,799	40,457	113	1,102	107,471
194	9,900	6	9,906	21,294	0	1,389	32,589
196	11,566	1,842	13,408	778,930	0	627	792,965
213	15,530	0	15,530	66,294	1,280	338	83,442
310	219,688	225	219,913	33,054	16,571	5,115	274,653
320	10,019	0	10,019	12,772	551	83	23,425
330	183,418	63,585	247,003	108,888	41,449	8,532	405,872
340	6,990	5,290	12,280	10,711	1,643	967	25,601
350	100,292	1,200	101,492	38,080	10,581	3,230	153,383
360	5,254	510	5,764	16,185	7,259	756	29,964
361	0	0	0	4,728	639	0	5,367
420	87,471	3,811	91,282	243,318	173,953	15,388	523,941
510	176,828	22,195	199,023	38,693	532	5,789	244,037
530	13,242	394	13,636	14,318	0	2,940	30,894
540	32,372	490	32,862	18,097	3,832	1,158	55,949
612	303	211	514	6,192	0	95	6,801
616	97	0	97	0	0	4	101
619	2,303	0	2,303	250	7	128	2,688
620	20,776	0	20,776	5,657	49	293	26,775
622	999	0	999	22,381	0	0	23,380
705	1,680,871	0	1,680,871	3,955,180	100,259	61,286	5,797,596
710	58,795	0	58,795	646,699	49,370	6,014	760,878
720	10,802	0	10,802	25,265	0	0	36,067
730	173,364	0	173,364	315,510	9,832	3,621	502,327
740	51,760	0	51,760	172,960	3,447	745	228,912
810	238	0	238	7,834	3,529	5,281	16,882
TOTALS	20,691,632	1,649,587	22,341,219	13,619,267	597,033	551,452	37,108,971

1/ Unadjusted for projects funded for construction.

Table S-38 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES [1] KANSAS SUBBASIN, COLORADO PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	1,734,195	170,345	1,904,540	516,223	0	7,626	2,428,389
104	100,856	24,647	125,503	45,370	0	776	171,649
106	22,829	4,193	27,022	49,734	0	1,150	77,910
112	240,501	0	240,501	221,896	0	2,631	465,028
136	32,629	10,133	42,762	7,256	0	239	50,257
138	637	88	725	0	0	0	725
160	0	0	0	953	0	0	953
178	107,675	11,158	118,833	93,360	0	967	213,160
190	277,604	19,295	296,899	111,503	0	1,844	410,246
192	1,594	129	1,723	10,102	0	0	11,825
196	11,519	1,842	13,361	719,733	0	529	733,623
350	0	195	195	1,159	0	0	1,354
420	4,090	3,235	7,325	11,451	0	575	19,351
510	23,366	0	23,366	16,887	0	97	40,350
622	0	0	0	20,198	0	0	20,198
705	157,915	0	157,915	319,854	0	242	478,011
710	14,838	0	14,838	68,477	0	292	83,607
720	10,802	0	10,802	25,265	0	0	36,067
730	140,399	0	140,399	174,105	0	2,793	317,297
740	2,545	0	2,545	19,840	0	0	22,385
810	0	0	0	6,394	0	5,034	11,428
TOTALS	2,883,994	245,260	3,129,254	2,439,764	0	24,795	5,593,813

Table S-39 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] KANSAS SUBBASIN, KANSAS PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	2,268,459	239,128	2,507,587	450,400	63,402	33,337	3,054,726
104	1,832,560	40,416	1,872,976	485,581	14,865	22,959	2,396,381
106	1,361,707	0	1,361,707	558,498	31,706	25,744	1,977,655
108	236,563	0	236,563	369,406	5,841	11,052	622,862
112	1,052,662	0	1,052,662	279,326	348	6,743	1,339,079
114	734,343	0	734,343	309,074	225	6,409	1,050,051
120	380,635	17,431	398,066	60,899	2,431	7,907	469,303
122	866,917	1,958	868,875	256,873	4,494	21,253	1,151,495
124	522,842	0	522,842	144,043	1,887	11,702	680,474
126	298,250	0	298,250	196,741	22,925	8,039	525,955
136	100	0	100	21	0	0	121
138	129,875	0	129,875	50,424	1,111	1,973	183,383
140	75,617	0	75,617	44,280	774	1,713	122,384
154	727	0	727	314	282	30	1,353
156	705	0	705	418	254	26	1,403
158	34,491	342	34,833	55,453	6	498	90,790
162	7,436	0	7,436	6,894	183	250	14,763
174	25,884	8	25,892	40,417	1,224	311	67,844
190	179,060	1,713	180,773	90,771	4,077	3,403	279,024
192	678	0	678	563	113	42	1,396
310	218,443	0	218,443	33,054	16,477	5,115	273,089
320	10,019	0	10,019	12,772	551	83	23,425
330	83,310	0	83,310	59,691	12,973	2,047	158,021
350	92,508	0	92,508	25,921	9,033	2,557	130,019
360	3,767	0	3,767	10,187	354	327	14,635
420	58,075	0	58,075	116,714	123,684	9,391	307,864
510	5,655	0	5,655	937	45	45	6,682
530	52	0	52	932	0	0	984
616	97	0	97	0	0	4	101
619	2,303	0	2,303	250	7	128	2,688
620	19,879	0	19,879	5,657	49	293	25,878
705	1,520,891	0	1,520,891	3,359,401	99,541	60,526	5,040,359
710	43,957	0	43,957	578,222	49,370	5,722	677,271
730	32,965	0	32,965	141,405	9,832	828	185,030
760	49,215	0	49,215	153,120	3,447	745	206,527
810	48	0	48	301	3,142	54	3,545
TOTALS	12,150,695	300,996	12,451,691	7,898,960	484,653	251,256	21,086,560

1/ Unadjusted for projects funded for construction.

Table S-40 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] KANSAS SUBBASIN, NEBRASKA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	953,540	531,221	1,484,761	93,899	3,747	39,996	1,622,403
104	1,115,422	244,125	1,359,547	117,705	5,220	32,062	1,514,534
106	908,941	26,880	935,821	136,422	2,073	21,816	1,096,132
108	120,304	0	120,304	100,146	146	4,189	224,785
110	29,765	0	29,765	272,308	145	2,351	304,569
112	366,880	5,351	372,231	64,237	914	10,085	447,467
114	273,326	0	273,326	988,186	618	13,465	1,275,595
120	614,931	164,713	779,644	23,770	144	28,250	831,808
122	242,721	4,994	247,715	43,190	287	13,398	304,590
124	63,528	0	63,528	30,229	0	2,969	96,726
136	32,947	4,592	37,539	6,043	0	1,564	45,146
162	809	0	809	0	0	0	809
164	1,132	0	1,132	1,506	0	0	2,638
174	85,755	3,768	89,523	43,807	0	3,993	137,323
180	2,766	0	2,766	44,860	189	666	48,481
188	180,754	0	180,754	549,108	1,497	68,714	800,073
190	234,512	22,492	257,004	53,972	1,122	4,471	316,569
192	62,690	708	63,398	29,792	0	1,060	94,250
194	9,900	6	9,906	21,294	0	1,389	32,589
196	47	0	47	59,197	0	98	59,342
213	15,530	0	15,530	66,294	1,280	338	83,442
310	1,245	225	1,470	0	94	0	1,564
330	100,108	63,585	163,693	49,197	28,476	6,485	247,851
340	6,990	5,290	12,280	10,711	1,643	967	25,601
350	7,784	1,005	8,789	11,000	1,548	673	22,010
360	1,487	510	1,997	5,998	6,905	429	15,329
361	0	0	0	4,728	639	0	5,367
420	25,306	576	25,882	115,153	50,269	5,422	196,726
510	147,807	22,195	170,002	20,869	487	5,647	197,005
530	13,190	394	13,584	13,386	0	2,940	29,910
540	32,372	490	32,862	18,097	3,832	1,158	55,949
612	303	211	514	6,192	0	95	6,801
620	897	0	897	0	0	0	897
622	999	0	999	2,183	0	0	3,182
705	2,065	0	2,065	275,925	718	518	279,226
810	190	0	190	1,139	387	193	1,909
TOTALS	5,656,943	1,103,331	6,760,274	3,280,543	112,380	275,401	10,428,598

1/ Unadjusted for projects funded for construction.

Table S-41 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] LOWER MISSOURI SUBBASIN, SUMMARY

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	51,770	107	51,877	10,158	9,176	1,675	72,886
104	443,290	134	443,424	269,642	60,420	35,740	809,226
106	388,174	0	388,174	220,606	33,327	16,955	659,062
108	31,741	0	31,741	59,840	11,103	679	103,363
120	42,304	0	42,304	12,203	591	1,646	56,744
122	1,013,471	0	1,013,471	416,362	40,886	93,819	1,564,538
124	2,845,946	0	2,845,946	1,607,300	270,334	202,471	4,926,051
126	682,302	0	682,302	747,425	210,794	68,932	1,709,453
136	124,122	307	124,429	34,735	41,667	1,392	202,223
138	180,696	0	180,696	104,581	20,462	9,966	315,705
140	263,615	0	263,615	196,949	65,759	16,410	542,733
142	322,169	0	322,169	546,580	499,766	33,875	1,402,390
144	1,622	0	1,622	333	239	0	2,194
153	897,418	1,352	898,770	345,312	765,127	29,383	1,538,592
154	588,181	0	588,181	112,282	37,399	29,785	767,647
156	134,959	0	134,959	71,804	1,429	3,516	211,708
158	9,548	0	9,548	12,615	113	160	22,436
174	96	0	96	47	0	0	143
211	18,940	0	18,940	24,146	9,327	0	52,413
213	11,150	0	11,150	51,397	34,002	1,658	98,207
217	61,834	0	61,834	72,988	64,593	8,444	207,859
310	388,138	0	388,138	62,717	107,989	27,067	585,911
320	147,286	0	147,286	94,394	43,022	3,434	288,136
330	744,168	2,882	747,050	149,468	183,671	48,829	1,129,018
340	98,434	0	98,434	25,888	26,624	5,116	156,062
350	73,479	0	73,479	56,336	71,119	17,481	218,415
420	33,647	0	33,647	50,075	60,379	2,256	146,357
421	3,904	0	3,904	1,648	3,247	565	9,364
705	556,118	0	556,118	1,687,714	2,805,324	109,390	5,158,546
710	39,217	0	39,217	264,894	769,172	15,017	1,088,300
730	78	0	78	8	68	0	154
740	4,798	0	4,798	3,791	920	95	9,604
770	999	0	999	5,478	1,836	1,048	9,361
810	0	0	0	14,510	37,740	6,302	58,552
TOTALS	10,203,614	4,782	10,208,396	7,334,226	5,787,625	793,106	24,123,353

Table S-42 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] LOWER MISSOURI SUBBASIN, IOWA PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	529	0	529	0	48	0	577
104	34,062	0	34,062	3,980	862	1,711	40,615
106	66,096	0	66,096	19,098	475	2,714	88,383
108	11,535	0	11,535	19,555	1,931	606	33,627
120	10,022	0	10,022	190	238	242	10,692
122	46,978	0	46,978	7,354	637	3,405	58,374
124	335,888	0	335,888	133,098	10,000	18,570	497,556
126	135,123	0	135,123	112,466	17,890	4,059	269,538
138	540	0	540	0	0	0	540
144	1,622	0	1,[illegible]22	333	239	0	2,194
153	30,730	0	30,730	1,001	0	997	32,728
154	51,513	0	51,513	6,778	1,425	1,498	61,214
174	96	0	96	47	0	0	143
310	2,050	0	2,050	853	1,890	382	5,175
320	73,069	0	73,069	73,857	16,521	899	164,346
330	16,266	0	16,266	10,823	6,356	1,097	34,542
420	14,227	0	14,227	25,585	24,176	2,057	66,045
421	514	0	514	236	1,270	0	2,020
705	78,564	0	78,564	173,378	80,974	4,807	337,723
710	373	0	373	1,125	0	140	1,638
770	999	0	999	5,478	1,836	1,048	9,361
810	0	0	0	0	95	0	95
TOTALS	910,796	0	910,796	595,235	166,863	44,232	1,717,126

1/ Unadjusted for projects funded for construction.

Table S-43 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] LOWER MISSOURI SUBBASIN, KANSAS PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
102	51,241	107	51,348	10,158	9,128	1,675	72,309
104	232,672	0	232,672	144,504	11,412	9,561	398,149
106	172,920	0	172,920	72,722	14,711	8,146	288,499
108	1,499	0	1,499	488	103	73	2,163
120	32,282	0	32,282	12,013	353	1,404	46,052
122	198,861	0	198,861	102,693	9,403	13,816	324,773
124	265	0	265	106	5	5	381
126	76,817	0	76,817	88,949	28,964	3,555	198,285
136	6,498	0	6,498	1,691	218	17	8,424
138	94,658	0	94,658	75,325	8,055	3,474	181,512
140	24,953	0	24,953	40,845	20,448	1,194	87,440
154	29,346	0	29,346	10,355	231	687	40,619
156	134,959	0	134,959	71,804	1,429	3,516	211,708
158	9,548	0	9,548	12,615	113	160	22,436
310	88,354	0	88,354	30,711	28,615	1,957	149,637
320	13,969	0	13,969	4,142	11,439	13	29,563
330	27,047	0	27,047	5,169	5,142	794	38,352
350	3,887	0	3,687	161	711	63	4,822
420	18,880	0	18,880	24,490	35,073	199	78,642
705	45,815	0	45,815	221,127	26,490	2,614	296,046
710	2,408	0	2,408	28,906	34,800	265	66,459
730	78	0	78	8	68	0	154
740	4,798	0	4,798	3,791	920	95	9,604
810	0	0	0	1,095	2,665	5,730	9,490
TOTALS	1,271,755	107	1,271,862	984,068	250,576	59,013	2,565,513

Table S-44 – MAJOR LAND USE OF PRIVATE AGRICULTURAL LAND BY SOIL RESOURCE GROUPS, CURRENT NORMAL ACRES,[1] LOWER MISSOURI SUBBASIN, MISSOURI PORTION

SRG	NON-IRRIGATED CROPLAND	IRRIGATED CROPLAND	TOTAL CROPLAND	PASTURE RANGE	FOREST WOODLAND	OTHER AG LAND	TOTAL AG LAND
104	176,556	134	176,690	121,158	48,146	24,468	370,462
106	149,158	0	149,158	108,786	18,141	6,095	282,180
108	18,707	0	18,707	39,797	9,069	0	67,573
122	767,632	0	767,632	306,315	30,846	76,598	1,181,391
124	2,509,793	0	2,509,793	1,474,096	260,329	183,896	4,428,114
126	470,362	0	470,362	546,010	163,940	61,318	1,241,630
136	117,624	307	117,931	33,044	41,449	1,375	193,799
138	85,498	0	85,498	29,256	12,407	6,492	133,653
140	238,662	0	238,662	156,104	45,311	15,216	455,293
142	322,169	0	322,169	546,580	499,766	33,875	1,402,390
153	866,688	1,352	868,040	344,411	265,127	28,386	1,505,864
154	507,322	0	507,322	95,149	35,743	27,600	665,814
211	18,940	0	18,940	24,146	9,327	0	52,413
213	11,150	0	11,150	51,397	34,002	1,658	98,207
217	61,834	0	61,834	72,988	64,593	8,444	207,859
310	297,734	0	297,734	31,153	77,484	24,728	431,099
320	60,248	0	60,248	16,395	15,062	2,522	94,227
330	700,855	2,882	703,737	133,276	172,173	46,938	1,056,124
340	98,434	0	98,434	25,888	26,624	5,116	156,062
350	69,592	0	69,592	56,175	70,408	17,418	213,593
420	540	0	540	0	1,130	0	1,670
421	3,390	0	3,390	1,412	1,977	565	7,344
705	431,739	0	431,739	1,293,209	2,697,860	101,969	4,524,777
710	36,436	0	36,436	234,863	734,292	14,612	1,020,203
810	0	0	0	13,415	34,980	572	48,967
TOTALS	8,021,063	4,675	8,025,738	5,754,923	5,370,186	689,861	19,840,708

1/ Unadjusted for projects funded for construction.

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Table S-45 – SUMMARY OF LAND CAPABILITY

Soil Resource Group Number and Description	Colorado	Kansas	Iowa
UPLANDS AND TERRACES			
102 Deep, well and moderately well drained, medium to moderately fine textured soils. Moderately to moderately slowly permeable. Bedrock or gravel may be encountered deep within profile. Nearly level.	1-1L 1-2L 2C1 2C1L 2C2L 2E1 2E1L 2E2 2E2L 2E3 2E3L 2E4L 2E5L 2S1L 3C1 3C1L 3C2 3C2L 3E3 3E3L 3E4L 3E5 3E10 3E12L 3E13L 3E16 3S1 3S3L 4E10 4E11 4E24	1-H 1-1H 1-M 1-1M 2C1M 2C2M 2C3M 2C4M 2C5M 2C6M 2E2M 2WL' 3C1L 3C2L	1A21P 1A41 1C11 1C13 1C14 1C15
104 Same as above except gently sloping.	3E1 3E5L 3E6L 3E11 3E14L 3E15 3E15L 3E19 4E1 4E12 4E23L 4E25 4E37	2E1H 2E1L 2E1M 2E2H 2E3M 2E4H 2E4M 2E5H 2E6H 2E8H 2E8M 2E9H 3E1L	2Ea21 2Ea41 2Ec11 2Ec12 2Ec13 2Ec14 2Ec15 2Ec16
106 Same as above except sloping.	4E3 4E17 4E24L 4E26L 4E27L 4E30 4E31 4E38 4E39	3E4H 3E6H 3E6M 3E7H 3E8H 3E9H 3E9M 3E10M 3E12H	3Ea21 3Ea41 3Eb11 3Eb12 3Ec11 3Ec12 3Ec13 3Ec14 3Ec15 3Ec16 3EL11
108 Same as above except moderately steep.	4E32 6E1L 6E2L	4E5H 4E5M	4Ea21 4Ea41 4Ec11 4Ec12 4Ec13 4Ec14 4Ec15 4Ec16
110 Same as above except steep.			
112 Deep, well drained medium textured soils. Moderately permeable. Calcareous. Nearly level to sloping.	3E4 4E2 4E4	3E1M 3E8M 4E2L 4E5L	2Ea22 3Ea22
114 Same as above except moderately steep.		4E2M 4E9M	4Ea22
120 Deep, moderately well to somewhat poorly drained, moderately fine to fine textured soils. Moderately to slowly permeable soils with firm to very firm subsoils. Nearly level to gently sloping.		2S1H 2S1M 2S2H 2S2M	1b11 1b12 2Eb11 2Wd11 2Wd12 2Wd21 2WL11 2Wm82
122 Same as above except gently sloping.		2E3H 2E5M 2E10H 2E10M 3E3H 3E3M 3E5H	2Ed11 2Ed12 2Ed21
124 Same as above except sloping.		3E11H 3E11M 4E3H 4E7H 4E8H 4E10M	3Ed11 3Ed12 3Ed21 3Ee21 3Ee22 3Ee31 4Ef11 4Wf11
126 Same as above except sloping to moderately steep including eroded phase.		4E3H 4E8M 4E11H 4E11M	4Ed11 4Ed12 4Ed21 4Fe21 4Ee22 4Ee31 4Ef11 4Wf11
136 Moderately deep, well to somewhat poorly drained, medium to moderately fine textured soils overlying sand and gravel or bedrock. Nearly level.	2E6L 2E7L 2S2L 2S3L 3E2 3E7L 3E9L 3E10 3E10L 3E11L 3E16L 3E17 3E17L 3E18 3E18L 3S4L 3S5L 3S6L 3S7L 3S8L 3S9L 3S10L 4C1 4C1L 4E5 4E9L 4E11 4E14L 4E18 4E21L 4E30L 4E31L 4E32L 4S4L 4S6L 4S7L 4S8L 4S9L 4S13L 4S16L 4S17L 4S18L	2S5H	2S111 2S112 2S121
138 Same as above except gently sloping.	4E3L 4E4L 4E5L 4E10L 4E12 4E13L 4E28L 4E29L 4E33L 4E34L	3E1H 3E12M 3E13H 3E14H 3E13M 3E14M 3E17H 3S2H 4E6M	2E111 2E112 2E121 2FJ11
140 Same as above except sloping.	4E6L 4E7L 4E8L 4E11L 4E12L 4E25L 4E33 4E35L 4F36L	3E5H 3E5M 4E2H 4E10H 4E12H 4E13H 4E14H 4E7M 4E12M 4E13M 4E14M 4E15M	3E111 3E112 3E121 3EJ11 3F11 3Eg11 3We11
142 Same as above except sloping to moderately steep.	4E34		4Fd12 4E111 4E112 4E121 4EJ11 4EJ12 4SJ12 4Fe11 4Eg11
144 Deep, poorly drained, medium to moderately fine textured soils. Moderate slowly permeable. Includes moderately deep soils over bedrock and/or gravel. Nearly level.			2Wm31 2Wm32 2Wm33 2Wm41
150 Deep to moderately deep, medium textured soils over gravel and sand, with fluctuating water table primarily due to irrigation water application. Somewhat poorly drained or seeped. Nearly level to gently sloping.	2W1L 2W2L 2W3L 2W4L 3W1L 3W2L 3W3L 3W4L 3W5L 3W6L 3W7L 3W9L 3W10L 3W13L 3W14L 3W15L 3W17L 3W18L 3W19L 3W20L 3W21L 3C4L 3FS7L 4S28L 4S29L 4S30L 4W2L 4W3L 4W4L 4W5L 4W6L 4W7L 4W8L 4W13L 4W14L 4W15L 4W16L 4W18L 4W20L 4W22L 3W8L 3W16L		

UNITS IN SOIL RESOURCE GROUPS BY STATES

Minnesota	Missouri	Montana	Nebraska	N. Dak.	South Dakota	Wyoming
1-01 1-02 1-03 1-04 1-05		1-1 1-2 1-3 2C1 2C2 2C3 2C4 2C5 2C6 2C12 2E3 2E13 3C1 3C2 3C3 3C4 3C14 3E2 4C2 4C3 4C6	1- 2C1 3C1	[illegible] 2E11	1-[illegible] 1-[illegible] 2C0 2C1 [illegible] 2S21 [illegible] 2W01 2W03 2W11 3C02 [illegible] 3C01	1- 2C2 3C2 4C2
2E01 2F02 2E03 2E04 2E05 2E06 2E07 2E15 2E51 2E52 2E53 2C08 2C09 2S51 2S52 2S53	2E01	2F8 2E10 2E12 2E14 3E11 (3F12) 3E13 (3E14) 3E15 3F17 3E19 3E22 4E11	2E1 (3E1)	2E15 3F11 3E13		2E2 3E[illegible]
3F01 3E02 3E03 3F04 3F05 3E08 3E09 3F15 3E22 3E24 3E51 4E52 3E53 3F04 3C08	3E01	3F10 3E12 3E14 (3F15) 3E16 4F11 4F13 4F15 4F16 4E17 (4F18) 4F19 4E26	3E1 (4E1)	(3E13) 4E11 4E13	4E02 2E21 4F22 3F02 3E08 3E21 3E25	(3F2) 4E2
4F01 4E02 4E03 4E05 4E06 4F08 4F09 4E12 4F14 4E15 4E23 4E24 4E51 4E53 5C08 4C26 4C47	4E01	(4E11) (4F13) 4E14 (4E17) 4E18 4E22 4E24 4E26	4F1 (6E1)	6E16	4F02 4E08 4E21	(4E[illegible]) 6E2
		6F1 6F7 6E9 6F10 6E12 6E14 6F16 6E15 6E22	6F1		6E0[illegible] 6E0[illegible] 6[illegible] 6E[illegible] 6E13	(6E2)
			3F8 4F[illegible] 4F8 4F[illegible]	4F8 4E[illegible] 4F[illegible]	4F[illegible] 4F[illegible] 4F[illegible]3 4C22 4C24	3C3 3F3
			(4E36) (4F[illegible])			
2E12 2E13 2C06 2S10 2S11 2S12 2S14 2W05 2W09 3E12 3S1 3S10 3S21 3S33 3S53 3W05 3W07		2W6 2W9 2W10	2E[illegible] 2[illegible] 2W[illegible] 4[illegible]	[illegible]		2C1 2C1 2C4 3C1 4C1
2F06 2S19 2F11 2E14	2E06		(2E[illegible]) 3F[illegible]			3F1
4E06 4S10 4F14	3E05 3E06		(3F[illegible]) 4E[illegible]			4F1
4F10	4F05 4E06		6F[illegible]			6F6
2S16 2S17 2S18 2S19	2C01	2S09 3S10 3S12 3S14 3S16 4S26 4S27 4S28	2S5 3S5	3S[illegible] 3S3[illegible]	4[illegible]5 4F35 3C05 4E05 4F07 4F35 4C05 4C06	
2F16 2F17 2E18 2E19 2E20	2F02	2E12 2E36 3E4 3F43 3E46 3F60 3F62 3F64 3S1[illegible] 4C12 4F1[illegible] 4F26 2S18		4F1[illegible]		4F1[illegible]
3E16 3E17 3E18 3F19 3E20 3F[illegible] 3F[illegible] 4C25 3C[illegible]	3F02	3E[illegible] 3F54 3F63 3F[illegible] 3F64 4E16 4F[illegible] 4F51 4E53 4F55 6F[illegible]				4F1[illegible]
4F16 4F17 4F18 4F19 4F20 4F2[illegible] 4E25 4E26 4F27 4E28 4F29 4F30 4F3[illegible] 4E33 4E34 4E55	4E02 4E04	4E14 6F7 6F40 4F50 6E33 6E46 6E56			6F06 6F06 6F07 6E07	
2W03 2W04 2W06 2W07 2W03 3W14 3W15 3W16 3W19 3W20 3W21						[illegible] 4C[illegible] 4C7 4C1
		2W7 3W45		[illegible]		[illegible]

Table S-45 – (Continued)

Soil Resource Group Number and Description	Colorado	Kansas	Iowa
152 Deep, poorly drained, moderately fine and fine textured, moderately slow to slowly permeable soils. Nearly level.			
153 Poorly drained, fine textured, slowly permeable soils. Includes seasonally wet areas due to seepage. Level to moderately steep.	2W5L 2W6L 2W7L 2W9L 2W10L 3W25L 3W30L 3W31L 3W32L 3W35L 3W36L 3W37L 3W38L 3W39L 4W27L 4W28L 4W29L	2S4H 2S4M 3W6H	2Wm51
154 Deep planosols with fine textured subsoils very slowly to slowly permeable. Nearly level.		3E15H	2Wm11 2Wm21 2Wm22 3Wm11 3Wm21
156 Same as above except gently sloping.			
158 Planosols with thin surface and heavy clay subsoil. Nearly level to gently sloping.		2E2M 2S3M 3E4M 3E18H 3S1L 4E6H 4S3H	
160 Deep well drained granular clay soils nearly level to gently sloping.	3E1L 3E2L 3S1L 3S2L 4E2L 4S1 4S2		
162 Same as 160 above except sloping.	4E35		
164 Same as above except moderately steep.	4F36		
168 Moderately deep loamy soils with columnar B horizons in complex with deep loamy soils. Nearly level to gently sloping.			
172 Deep to moderately deep, well to somewhat poorly drained, moderately coarse soils overlying sand and gravel or bedrock, nearly level to sloping.			
174 Deep moderately well to excessively drained, coarse textured soils. Nearly level to sloping.		3E2H 3E2M 4E1H 4E1L 4E1M 4E3M	4Sk12
176 Deep poorly to somewhat poorly drained, moderately coarse to coarse textured soils with rapid permeability. Nearly level.			
178 Shallow to deep well drained coarse textured soils of low moisture capacity and rapid permeability; level. Includes stony cobbly soils.	3E22L 3E25L 3E38L 3E41L 3E43L 3E44L 3E45L 3E49L 3E51L 3E53L 3S14L 3S16L 3S17L 3S18L 3S19L 3S20L 4E8 4E9 4E21 4E48L 4E49L 4E56L 4E57L 4E58L 4E62L 4E66L 4E67L 4E68L 4E69L 4S24L 4S25L 4S26L 3E55L		
180 Same as above except gently sloping.	4E37L 4E53L 4E65L		
182 Same as above except sloping.	4E39L 4E40L		
184 Moderately deep soils with moderately coarse "A" horizons and clayey columnar "B" horizons. Nearly level to gently sloping.			
188 Deep fine sands and loamy fine sands. Nearly level to rolling.			
190 Deep well drained sandy loam soils nearly level to gently sloping.	13L 2C2 2E2 2E8L 2E9L 2S4L 2S5L 3C3L 3E6 3E7 3E8 3E9 3E12 3E13 3E14 3E27L 3E28L 3E30L 3E32L 3E33L 3E35L 3E37L 4E7 4E13 4E14 4E15 4E16 4E20 4E26 4E27 4E28 4E29 4E41L 4E43L 4E44L 4E45L	2E3H 2E3M 2E6M 2S3H 3E2L 3E3L 3E6M 3E7M 4E4L 4E6L	

Minnesota	Missouri	Montana	Nebraska	No. Dak.	South Dakota	Wyoming
[illegible] 2W0? 4?57		2W3 2W4 4W1 4W?		2W?2 2W?4		
	4W??					
	2W?3 2W?5	2E? 2?? 2E14 2E25 3?? 3?4 3E6 3E8 4E18 4E56 4E76 4E22 4E23 4E25				
		2E2 2E30 2E32 3E35 3E34 3E36 3F38 3E39 3E4? 3E44 3E48 4E43 4E45 4E49 4E59 4E52 4F56 6E25 6E29 6F56 4F84 4E50				
		2E? 2E3 2E4 2EC 2?4 2?5 2E7 2E9 3E3 3E6 3E7 3E9 4E54 4?? 6F4 6E? 6?8	2F? 3F4 4?? 6W?2	?E08 3E38	2E01 [illegible] ?E? [illegible] 4E?1 4??	4?
		(3E?) 3E4 3E5 (3e6) (3E7) 3E8 4E1 4E3 4E5 4F6 4F10 4E12	4E4	4E06&8 4E09 6E14		
		4E1 4E2 4E3 4E4 4E6 4F8 4E10 4E60 4E6? 4F64 4F84 6E1 6E2 6F3 6E4 6E5 6E6 6F8 6E31	6E4		6E01 6E11	
				3E0? 3E37	2E0? 2E09 3E0? 3E?? 3E01 4E?? 4E?1 4E?? 4E01	
				3F07		??5
4?35 4?38 4?40 4?56			3F5 4F5	3F0? 3F03 4F01 4F02	2F?? 3F03 4F3 3F?3 4F?? 4F03 4F04 ?	??
4W? 4W08 4W?? 4W3? ?W3? 4W?						
43??						??? ??2 (???
			70?			??? 4F4 4?? (4F?) 4?? 4?? ??? 6?? ???
		4?? 6?? 6??				
				3F4		
		4F3? 4?? 4F4? 4F44 4?? 4F6? 4?? 4?14 6?17 6??8 6??? 6F42 6?? 6?16	6F?	6F15		4??
		3F2? 2F?4 ?17 3F?? 3E?? 3F?6 3F?7 3F?8 3F3? 3F?? 4F33 4F34 4F4?	2F3 4F?			3?? ??

Table S-45 – (Continued)

Soil Resource Group Number and Description	Colorado	Kansas	Iowa
192 Same as above 190 except sloping.	4E6 4E14	4E4H 4E4M	
19[illegible] Same as above 190 except steep.			
196 Deep choppy sands and coarse sands. Nearly level to steep.	7E1 7E2 7E25		
211 Moderately well drained, medium to moderately coarse textured soils. Shallow to bedrock and sand or gravel. Nearly level to sloping.	3E19L 3E20L 3E21L 3S11L 3S12L 3S13L 4E22L		3EJ12 3SJ11 3CJ12
213 Well drained, moderately fine to moderately coarse textured soils. Shallow to bedrock or sand and gravel. Sloping to steep.			4Sh11
217 Well drained, shallow medium textured soils of moderate to moderately low moisture-holding capacity. Gently sloping.		3F16H	
225 Very shallow clay soils over marine shales.	4E1L 4E16L 4E17L 4E18L 4E19L 4S1L 4S11L		
231 Organic soils. Agricultural soils when drained.			3Wn51 4Wn51
BOTTOMLANDS			
310 Deep poorly drained fine textured soils. Slowly to very slowly permeable. Level to nearly level.		2W3H 3S3H 3S3M 3W3H	2Wm31 2Wm32 [illegible]Wm33 2Wm41
320 Deep poorly drained medium to moderately fine textured soils. Moderate to moderately slowly permeable. Subject to overflow. Level to nearly level.		2W2H 3W3M 3W4H 4W2L 4W2M	2Wm71
330 Deep and moderately deep well to somewhat poorly drained, medium to moderately fine textured soils. Moderate to moderate slowly permeable. Fine textured lower horizons may occur throughout lower portion of profile. Level to gently sloping.		3W2H 3W2M	1a11 1a12 1a13 2Ea11 2Ea12 2Ea13 3Ea11
340 Deep moderately coarse to coarse textured soils overlying moderately coarse to moderately fine textured substratums. Level to gently sloping. Moderately well to well drained.			2F122 2S122 3EJ13 3SJ13
350 Deep well drained coarse to gravelly soils. Level to gently sloping.	6E12	3W5H 3W1H 3W1M 2W1H	4EJ11 4Sk11
360 Deep loamy and sandy soils with high water table.	5W1 5W10	5W1H 5W1L 5W1M 6S2M	
36[illegible] Deep coarse soils. Moderately high water table or seeped by irrigation water.	3W40L 3W41L 3W42L 4W39L 4W41L 4W43L 4W10L 4W12L 4W24L 4W25L 4W30L 4W38L 6W1L 6W11L		
4[illegible] Bottomlands subject to frequent overflow or so severely dissected by old stream channels as to make cultivation infeasible.		5W2H 6W1H 6W1L 6W1M 7W1H 7W1L 7W1M	5P1. 5WP11
4[illegible] Poorly drained moderately coarse to coarse textured soils of low to very low moisture-holding capacity, moderate to rapidly permeable. Cropping feasible with considerable risk.			3Wr61
DEPRESSIONS AND FLATLANDS			
510 Deep, poorly drained medium to fin textured, moderately slow to slowly permeable depressional soils. Occasionally ponded.	7W1	2W2M 2W4H 4W1L 4W1M	
530 Same as above except frequently ponded.		6S4L 6W[illegible]L 6W2M	
540 Deep, somewhat poorly drained, moderately coarse textured, calcareous or noncalcareous soils [illegible] flat and shallow depressions. Moderate to rapid permeability. Occasionally to frequently ponded.			

Minnesota	Missouri	Montana	Nebraska	No. Dak.	South Dakota	Wyoming
		3E7 4E32 4E32 4E34 4E38 4E40 4E44 4E46 6E13 6E18 6E20 6E22 6E24	4E3			4E, 4E51 6E4
		(4E38) 6E18 6E20 6E22 6E24 6E36	6E3		6E03 6E04 6E32 6E44	(6F4)
		4C25 4C35 6E58 6S24 6C30	7E5	6E18 7E21 7E22	7E04	7C15
3E27 3E28 3E29 3E30 3C27 3C28 3C29 3C30 3C32 3C34 3C35 3C55	3C1	3E47 3E49 3E76 3S7 3C9 3C11 4E59 4E63 4E66 4E74 4E76 4E78 4E80 4E82 4C20 4S29 4S31 4S38 4S40 4S42 4S46 6E35 6E37 6S14 6S16 6C18 6S20				
4S36 4S37 4S41	4S06		4S4 6S4 7S4	6E17 6S47		6E14 7S14
	3F05					
		7E2		7S49		7S1
3W36 3W37 4W35 4W36 4W37	3W09	3W52				
3Wn21	3W45	2W3 2W4 2W6 4W1	2S2x 3S2x 3W1x 3W2x 432x 6W1x	3W27		
	3Wo1	2W7 2W8 2W12 2W27 3W16 3W18 3W20 4W9 4W18 4W56 5W1			3W01 3W11 3W15 4W01 4W11	
2W39	I		1x 2C1x 2E1x 2S5x 2W3x 2W4 2W4x 3C1x 3S5x			
	3S04	2E5 2E16 3F19 3E20 3E22 4E26 4E28	2F3x 2W6x 3E1x 3E3x 3W6x 4E3x 4W6x			5W 5W1
	4S04		3E5x 3W5x 4E5x 4W5x			
			4S4x 4W4x 5W 5Wx 6S4x 6W4x 6W5 6W5x			
5W22 5W24 5W33 5W34 5W35 5W36 5W37 5W41 5W42 5W45 6W40 6W44	5W 5W14	3W4 3W18 6W2 6W6	6E5x 6Wx		5W01 5W06 5W09 5W11 5W12 5W19 6W01 6W09 6W19	6W
3W41	3W15					
			3W2	2W25 2W26 2W54	4W09	
		6W10	6W2	3W30 5S42 5W32 6W33		
3W18 3W22 3W23 3W24 3W25 4W12 4W26 4W27 4W42			2W3 2W6 3W6 4W5	3W29 3W31		(6W)

Table S-45 – (Continued)

Soil Resource Group Number and Description	Colorado	Kansas	Iowa
SALINE AND ALKALI SOILS			
Bottomlands			
612 Deep poorly drained fine textured soils. Very slowly permeable. Moderately saline or alkaline. Nearly level.	6E11 6S11		4W01
614 Deep and moderately deep. Moderate to rapidly permeable, medium to coarse textured. Moderately saline or alkaline. Nearly level to gently sloping.			
616 Deep loamy or clayey soils. Nearly level. Moderately saline or alkaline.		4S2H 4S2M 6S2L	
619 Deep loamy or clayey soils. Nearly level. Severely saline or alkaline.		6S2H 6S4M	
Uplands			
620 Moderately saline or alkaline.	6E23	3S4M 4S1H 4S1M 4S3M	
622 Severely saline or alkaline.	6E24 6S24		
624 Strongly solonized. Level to sloping.			
NON-ARABLE LANDS			
705 Deep and moderately deep. Includes very stony soils on gentle slopes.	5S1 6E3 6E4 6E5 6E9 6E14 6E15 6E16 6E17 6E20 6E22 6E25 6E35 6E3L 6S1 7E9 7E16 7E21	6E1H 6E1L 6E1M 6E3H 6E3L 6E3M 6E4H 6E4L 6E4M 6E5H 6E5M 6E7H 6E9H 6S3M 7E2M	6Ea21 6Ea22 6Ea41 6Ec11 6Ec12 6Ec13 6Ec14 6Ec15 6Ec16 6Ed11 6Ed12 6Ed21 6Ee11 6Ee21 6Ee22 6Ee31 6Ef11 6Fg11 6Ei11 6Ei12 6Ei21 6Ej11 6Ej12 7Ea21 7Ea22 7Ea31 7Ea41 7Ec11 7Ec13 7Ec14 7Ec15 7Ec16 7Ed11 7Ed12 7Ed21 7Ee21 7Ee22 7Ee31 7Ef11 7Eg11 7Ei11 7Ei12 7Ei21 7Ej11 7Ej12 7Sr12
710 Shallow.	6E6 6E13 6F21 7E3 7E11 7E14 7E22 7E23	6E6H 6E6L 6E6M 7E2H 7S1H 7S1L 7S1M 7S2H 7S2L 7S2M 7S4L	
720 Very shallow.	7E4 7E7 7E13		
730 Sandy and moderately sandy soil, shallow to deep. Variable slopes.	6E1 6E2 7E10 7E12 7E26	6E2H 6E2L 6E2M 7E1H 7E1L 7E1M	
740 Clayey soils, shallow to deep. Variable slopes. Includes very stony soils on gentle slopes.	6E7 6E8 6E18 6E19 7E8 7E17 7E18 7E24	6E8H 6S1M 7S3L 7S3M	
750 Mixed soils--10 to 40 percent rock or shale outcrops.	7E6 7E19 7E20		
760 Badlands--40 to 75 percent shale or rock outcrop.			
770 Lands destroyed for cultivation because of severe gullying. Gently sloping to steep.	8E4		7Es11
NONAGRICULTURAL LAND TYPES			
810 Marsh land, riverwash, strip pits and mine dumps, rock outcrops, active blow-outs, barren and salted lands.	7W5 8E3 8E1 8E5 8F6 8E7 8E2 8E8	8H	7Wq11 7Sr11 7Sr20

1/ For computer data processing the Roman numeral of the land capability unit was changed to an arabic number and lower case letters to capitals. For example, IIC-1 is changed to 2C1.

Minnesota	Missouri	Montana	Nebraska	No. Dak.	South Dakota	Wyoming
			3S1x 4S1x	4W27		
						3S11 4S11 6S11
				3W28		4S12
		2W3 6W1 6W4	6S1x	6S45		
			3S1 4S1			4S10 6S10
		4E37 4S13 4S15 6E34 6E36 6S3 6S10 6S12 6S17 6S19 6S32 7S10	6S1			7S1?
				6S44	6S01 6S91 7S99	
5S42 6e01 6e02 6e03 6e04 6e05 (6e06) 6e07 6e08 6e09 6e10 6e14 6e15 6e16 6e17 6e18 6e19 6e20 6e22 6e23 6e24 6e25 6e26 6e27 6e28 6e29 6e30 6e32 6e33 6e34 6e51 6e52 6e53 6e55 6S07 6S08 6S15 6S26 6S28 6S41 6S42 6S47 7e02 7e03 7e04 7e07 7e08 7e09 7e10 7e15 7e16 7e18 7e20 7e22 7e23 7e24 7e25 7e26 7e27 7e28 7e29 7e30 7S15 7S26 7S28 7S40 7S41 7S42 7S45 7S46 7S47 7S55 8S08	6E01 6E02 6E03 6E04 6E05 6E06 6S06 7S06	7S2 7S4 7S8	7E1	4S41 6E19 6S46 7S50	7E01 7E02 7E03 7E06 7E07 7E11 7E22 7S07 7S17 7S21 7S27 7S81 7S8? 7S87	
6E30 6E37 6S35 6S37 6S38 6S39 6S43 6S56 7E32 7E35 7E36 7E37 7E43 7S38 7S39 7S43 7S44	6S04 7S	6E37 6E38 6E40 6E42 6E44 6E46 6E48 6E50 6E52 6E56 6S18				
		7S14 7S20 7S24	7S3x			
				4S40 6E20		
				6S43		7S17
		7E2 7E4 7E6		7E53 7S48		8F1 8E2 8F3
						8E?
8W 8W10 8W19 8W26 8W33 8W34 8W35 8W36 8W37 8W41 8W42 8W45 8W48 8W58	8S 8S04	8W1 8S1 8S3 8S?	8S 8W 8Wx	8E23 8S51 8W34	8S01 8W01	(8F?) 8?1 8W

Table S-46 – CHANGES IN LAND USE AND LAND BASE WITHOUT PLAN IMPLEMENTATION, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020
UPPER MISSOURI SUBBASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed in Place	Adjusted Current Normal	Land Use Change CN-1980	Projected 1980 Base	Land Use Change 1980-2000	Projected 2000 Base	Land Use Change 2000-2020	Projected 2020 Base
					(Thousand Acres)				
Agricultural Land	50,382	0	50,382	-41	50,341	-60	50,281	-85	50,196
Irrigated Cropland	(953)	(0)	(953)	(-3)	(950)	(-3)	(947)	(-1)	(946)
Non-irrigated Cropland	(9,757)	(0)	(9,757)	(-11)	(9,746)	(-16)	(9,730)	(-46)	(9,684)
Pasture & Range	(25,522)	(0)	(25,522)	(-22)	(25,50[illegible]	(-37)	(25,463)	(-20)	(25,443)
Forest & Woodland	(1,964)	(0)	(1,964)	(-4)	(1,960)	(-3)	(1,957)	(-17)	(1,940)
Other Ag. Land	(254)	(0)	(254)	(-1)	(253)	(-1)	(252)	(-1)	(251)
Federal Ag. Land	(11,932)	(0)	(11,932)	(0)	(11,932)	(0)	(11,932)	(0)	(11,932)
Miscellaneous	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Recreation	519	0	519	0	519	0	519	0	519
Fish & Wildlife	142	0	142	0	142	0	142	0	142
Other[1]	1,250	0	1,250	+41	1,291	+60	1,351	+85	1,436
Water	670	0	670	0	670	0	670	0	670
Total	52,963	--	52,963	--	52,963	--	52,963	--	52,963

[1] Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

Table S-47 – CHANGES IN LAND USE AND LAND BASE WITHOUT PLAN IMPLEMENTATION, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020
YELLOWSTONE SUBBASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed In Place	Adjusted Current Normal	Land Use Change CN-1980	Projected 1980 Base	Land Use Change 1980-2000	Projected 2000 Base	Land Use Change 2000-2020	Projected 2020 Base
					(Thousand Acres)				
Agricultural Land	43,152	0	43,152	-68	43,084	-114	42,970	-176	42,794
Irrigated Cropland	(1,031)	(0)	(1,031)	(-10)	(1,021)	(-16)	(1,005)	(-46)	(959)
Non-Irrigated Cropland	(2,343)	(0)	(2,343)	(-8)	(2,335)	(-30)	(2,305)	(-15)	(2,290)
Pasture & Range	(24,333)	(0)	(24,333)	(-48)	(24,285)	(-63)	(24,222)	(-101)	(24,121)
Forest & Woodland	(1,550)	(0)	(1,550)	(-2)	(1,548)	(-5)	(1,543)	(-13)	(1,530)
Other Ag. Land	(91)	(0)	(91)	(0)	(91)	(0)	(91)	(-1)	(90)
Federal Ag. Land	(13,804)	(0)	(13,804)	(0)	(13,804)	(0)	(13,804)	(0)	(13,804)
Miscellaneous	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Recreation	1,408	0	1,408	0	1,408	0	1,408	0	1,408
Fish & Wildlife	31	0	31	0	31	0	31	0	31
Other[1]	264	0	264	+68	332	+114	446	+176	622
Water	345	0	345	0	345	0	345	0	345
Total	45,200	--	45,200	--	45,200	--	45,200	--	45,200

[1] Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

Table S-48 – CHANGES IN LAND USE AND LAND BASE WITHOUT PLAN IMPLEMENTATION, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020 WESTERN DAKOTA SUBBASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed In Place	Adjusted Current Normal	Land Use Change CN-1980	Projected 1980 Base	Land Use Change 1980-2000	Projected 2000 Base	Land Use Change 2000-2020	Projected 2020 Base
					(Thousand Acres)				
Agricultural Land	47,289	0	47,289	-48	47,241	-77	47,164	-109	47,055
Irrigated Cropland	(198)	(0)	(198)	(0)	(198)	(-2)	(196)	(-2)	(194)
Non-irrigated Cropland	(9,097)	(0)	(9,097)	(-12)	(9,085)	(-13)	(9,072)	(-23)	(9,049)
Pasture & Range	(31,677)	(0)	(31,677)	(-31)	(31,646)	(-52)	(31,594)	(-73)	(31,521)
Forest & Woodland	(977)	(0)	(977)	(-4)	(973)	(-7)	(966)	(-6)	(960)
Other Ag. Land	(209)	(0)	(209)	(-1)	(208)	(-3)	(205)	(-5)	(200)
Federal Ag. Land	(5,131)	(0)	(5,131)	(0)	(5,131)	(0)	(5,131)	(0)	(5,131)
Miscellaneous	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Recreation	334	0	334	0	334	0	334	0	334
Fish & Wildlife	92	0	92	0	92	0	92	0	92
Other[1]	1,169	0	1,169	+48	1,217	+77	1,294	+109	1,403
Water	472	0	472	0	472	0	472	0	472
Total	49,356	--	49,356	--	49,356	--	49,356	--	49,356

[1] Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

Table S-49 – CHANGES IN LAND USE AND LAND BASE WITHOUT PLAN IMPLEMENTATION, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020 EASTERN DAKOTA SUBBASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed In Place	Adjusted Current Normal	Land Use Change CN-1980	Projected 1980 Base	Land Use Change 1980-2000	Projected 2000 Base	Land Use Change 2000-2020	Projected 2020 Base
					(Thousand Acres)				
Agricultural Land	34,399	0	34,399	-76	34,323	-136	34,187	-184	34,003
Irrigated Cropland	(119)	(0)	(119)	(-1)	(118)	(-1)	(117)	(-2)	(115)
Non-irrigated Cropland	(20,889)	(0)	(20,889)	(-51)	(20,838)	(-98)	(20,740)	(-143)	(20,597)
Pasture & Range	(12,547)	(0)	(12,547)	(-22)	(12,525)	(-33)	(12,492)	(-32)	(12,460)
Forest & Woodland	(211)	(0)	(211)	(-1)	(210)	(-1)	(209)	(-2)	(207)
Other Ag. Land	(594)	(0)	(594)	(-1)	(593)	(-3)	(590)	(-5)	(585)
Federal Ag. Land	(39)	(0)	(39)	(0)	(39)	(0)	(39)	(0)	(39)
Miscellaneous	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Recreation	38	0	38	0	38	0	38	0	38
Fish & Wildlife	162	0	162	0	162	0	162	0	162
Other[1]	1,802	0	1,802	+76	1,878	+136	2,014	+184	2,198
Water	902	0	902	0	902	0	902	0	902
Total	37,303	--	37,303	--	37,303	--	37,303	--	37,303

[1] Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

Table S-50 – CHANGES IN LAND USE AND LAND BASE WITHOUT PLAN IMPLEMENTATION, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020 PLATTE-NIOBRARA SUBBASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed In Place	Adjusted Current Normal	Land Use Change CN-1980	Projected 1980 Base	Land Use Change 1980-2000	Projected 2000 Base	Land Use Change 2000-2020	Projected 2020 Base
					(Thousand Acres)				
Agricultural Land	60,767	-6	60,781	-245	60,536	-463	60,073	-736	59,337
Irrigated Cropland	(2,784)	(0)	(2,784)	(-37)	(2,747)	(-76)	(2,671)	(-125)	(2,546)
Non-irrigated Cropland	(12,850)	(0)	(12,850)	(-90)	(12,760)	(-169)	(12,591)	(-266)	(12,325)
Pasture & Range	(35,147)	(-6)	(35,141)	(-109)	(35,032)	(-192)	(34,840)	(-280)	(34,560)
Forest & Woodland	(1,936)	(0)	(1,936)	(-6)	(1,930)	(-20)	(1,910)	(-50)	(1,860)
Other Ag. Land	(621)	(0)	(621)	(-3)	(618)	(-6)	(612)	(-15)	(597)
Federal Ag. Land	(7,449)	(0)	(7,449)	(0)	(7,449)	(0)	(7,449)	(0)	(7,449)
Miscellaneous	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Recreation	377	0	377	0	377	0	377	0	377
Fish & Wildlife	220	0	220	0	220	0	220	0	220
Other[1]	1,637	0	1,637	+245	1,882	+463	2,345	+736	3,081
Water	654	+6	660	0	660	0	660	0	660
Total	63,675	--	63,675	--	63,675	--	63,675	--	63,675

[1] Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

Table S-51 – CHANGES IN LAND USE AND LAND BASE WITHOUT PLAN IMPLEMENTATION, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020 MIDDLE MISSOURI SUBBASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed In Place	Adjusted Current Normal	Land Use Change CN-1980	Projected 1980 Base	Land Use Change 1980-2000	Projected 2000 Base	Land Use Change 2000-2020	Projected 2020 Base
					(Thousand Acres)				
Agricultural Land	14,901	0	14,901	-164	14,737	-325	14,412	-411	14,001
Irrigated Cropland	(103)	(0)	(103)	(-2)	(101)	(-1)	(100)	(-2)	(98)
Non-irrigated Cropland	(11,116)	(0)	(11,116)	(-127)	(10,989)	(-286)	(10,703)	(-355)	(10,348)
Pasture & Range	(2,485)	(0)	(2,485)	(-23)	(2,462)	(-22)	(2,440)	(-20)	(2,420)
Forest & Woodland	(631)	(0)	(631)	(-7)	(624)	(-9)	(615)	(-13)	(612)
Other Ag. Land	(447)	(0)	(447)	(-5)	(442)	(-7)	(434)	(-21)	(413)
Federal Ag. Land	(1)	(0)	(1)	(0)	(1)	(0)	(1)	(0)	(1)
Miscellaneous	(118)	(0)	(118)	(0)	(118)	(0)	(118)	(0)	(118)
Recreation	37	0	37	0	37	0	37	0	37
Fish & Wildlife	25	0	25	0	25	0	25	0	25
Other[1]	608	0	608	+164	772	+325	1,097	+411	1,508
Water	174	0	174	0	174	0	174	0	174
Total	15,745	--	15,745	--	15,745	--	15,745	--	15,745

[1] Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

Table S-52 – CHANGES IN LAND USE AND LAND BASE WITHOUT PLAN IMPLEMENTATION, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020 KANSAS SUBBASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed In Place	Adjusted Current Normal	Land Use Change CN-1980	Projected 1980 Base	Land Use Change 1980-2000	Projected 2000 Base	Land Use Change 2000-2020	Projected 2020 Base
					(Thousand Acres)				
Agricultural Land	37,182	-97	37,085	-93	36,992	-171	36,821	-233	36,588
Irrigated Cropland	(1,703)	(-3)	(1,700)	(-3)	(1,697)	(-2)	(1,695)	(-5)	(1,690)
Non-irrigated Cropland	(20,638)	(-51)	(20,587)	(-49)	(20,538)	(-124)	(20,414)	(-174)	(20,240)
Pasture & Range	(13,619)	(-30)	(13,589)	(-29)	(13,560)	(-39)	(13,521)	(-41)	(13,480)
Forest & Woodland	(597)	(-9)	(588)	(-8)	(580)	(-1)	(579)	(-9)	(570)
Other Ag. Land	(552)	(-4)	(548)	(-4)	(544)	(-5)	(499)	(-4)	(495)
Federal Ag. Land	(69)	(0)	(69)	(0)	(69)	(0)	(69)	(0)	(69)
Miscellaneous	(4)	(0)	(4)	(0)	(4)	(0)	(4)	(0)	(4)
Recreation	36	0	36	0	36	0	36	0	36
Fish & Wildlife	15	0	15	0	15	0	15	0	15
Other[1]	1,307	0	1,307	+93	1,400	+171	1,571	+233	1,804
Water	336	+97	433	0	433	0	433	0	433
Total	38,876	--	38,876	--	38,876	--	38,876	--	38,876

[1]Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

Table S-53 – CHANGES IN LAND USE AND LAND BASE WITHOUT PLAN IMPLEMENTATION, CURRENT NORMAL AND ADJUSTED CURRENT NORMAL, WITH PROJECTIONS FOR 1980, 2000, AND 2020 LOWER MISSOURI SUBBASIN

Land and Water Use	Current Normal	Adjustment for Reservoirs Assumed In Place	Adjusted Current Normal	Land Use Change CN-1980	Projected 1980 Base	Land Use Change 1980-2000	Projected 2000 Base	Land Use Change 2000-2020	Projected 2020 Base
					(Thousand Acres)				
Agricultural Land	24,300	-267	24,033	-287	23,746	-588	23,158	-909	22,249
Irrigated Cropland	(5)	(0)	(5)	(0)	(5)	(0)	(5)	(0)	(5)
Non-irrigated Cropland	(10,203)	(-143)	(10,060)	(-154)	(9,906)	(-369)	(9,537)	(-440)	(9,097)
Pasture & Range	(7,334)	(-58)	(7,276)	(-64)	(7,212)	(-96)	(7,116)	(-275)	(6,841)
Forest & Woodland	(5,788)	(-60)	(5,728)	(-62)	(5,666)	(-97)	(5,569)	(-138)	(5,431)
Other Ag. Land	(793)	(-6)	(787)	(-7)	(780)	(-26)	(754)	(-56)	(698)
Federal Ag. Land	(177)	(0)	(177)	(0)	(177)	(0)	(177)	(0)	(177)
Miscellaneous	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Recreation	65	0	65	0	65	0	65	0	65
Fish & Wildlife	51	0	51	0	51	0	51	0	51
Other[1]	708	0	708	+287	995	+58	1,583	+909	2,492
Water	266	+267	533	0	533	0	533	0	533
Total	25,390	--	25,390	--	25,390	--	25,390	--	25,390

[1]Includes land used for transportation, urban, built-up, mineral, military, and agricultural land destroyed by gully erosion.

Table S-54 – AGRICULTURAL LAND USE BY CAPABILITY CLASSES AND SUBCLASSES
UPPER MISSOURI SUBBASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	---	---	---	---	---
II	1,906	739	28	26	2,699
E	1,544	523	18	19	2,104
W	16	9	1	0	26
S	307	51	8	7	373
C	39	156	1	---	196
III	6,780	4,746	61	84	11,671
E	5,143	3,744	31	61	8,979
W	63	265	2	1	331
S	1,574	737	28	22	2,361
C	---	---	---	---	---
IV	1,367	2,963	50	20	4,400
E	666	986	37	5	1,694
W	21	52	---	0	73
S	680	1,925	13	15	2,633
C	---	---	---	---	---
V	1	200	27	2	230
E	---	---	---	---	---
W	1	200	23	2	226
S	---	---	4	---	4
C	---	---	---	---	---
VI	625	13,668	971	45	15,309
E	---	50	1	---	51
W	10	216	1	1	228
S	615	13,402	969	44	15,030
C	---	---	---	---	---
VII	31	3,149	803	4	3,987
E	2	1,603	675	4	2,284
W	---	---	---	---	---
S	29	1,546	128	---	1,703
C	---	---	---	---	---
VIII	---	57	24	73	154
E	---	---	---	---	---
W	---	---	---	1	1
S	---	57	24	72	153
C	---	---	---	---	---
Subtotal by Subclasses					
NP[1]	---	---	---	---	---
E	7,355	6,906	762	89	15,112
W	111	742	27	5	885
S	3,205	17,718	1,174	160	22,257
C	39	156	1	---	196
Total Land Capability Classes	10,710	25,522	1,964	254	38,450

[1] Land Capability Class I lands have few limitations for agricultural use.

Table S-54 (Continued) — YELLOWSTONE SUBBASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	127	11	1	3	142
II	725	400	29	10	1,164
E	577	321	24	6	928
W	18	4	1	1	24
S	104	58	4	3	169
C	26	17	---	---	43
III	1,531	1,890	24	19	3,464
E	1,150	1,473	15	11	2,649
W	63	23	3	1	90
S	318	394	6	1	719
C	---	---	---	6	6
IV	720	2,220	36	13	2,989
E	282	1,429	15	6	1,732
W	2	5	---	1	8
S	414	643	15	5	1,077
C	22	143	6	1	172
V	7	54	4	1	66
E	---	---	---	---	---
W	7	37	4	1	49
S	---	17	---	---	17
C	---	---	---	---	---
VI	241	11,168	557	20	11,986
E	28	2,783	126	6	2,943
W	20	191	37	1	249
S	193	8,193	394	12	8,792
C	---	1	---	1	2
VII	21	6,955	776	4	7,756
E	---	1,249	302	1	1,552
W	---	---	---	---	---
S	21	5,706	474	3	6,204
C	---	---	---	---	---
VIII	2	1,635	123	21	1,781
E	---	236	54	---	290
W	---	19	---	1	20
S	2	1,380	68	20	1,470
C	---	---	1	---	1
Subtotal by Subclasses					
NP[1]	127	11	1	3	142
E	2,037	7,491	536	30	10,094
W	110	279	45	6	440
S	1,052	16,391	961	44	18,448
C	48	161	7	8	224
Total Land Capability Classes	3,374	24,333	1,550	91	29,348

[1]Land Capability Class I lands have few limitations for agricultural use.

Table S-54 (Continued) – WESTERN DAKOTA SUBBASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	32	---	---	---	32
II	1,410	641	77	9	2,137
E	339	152	29	2	522
W	30	75	5	1	111
S	99	71	1	1	172
C	942	343	42	5	1,332
III	4,821	3,403	58	34	8,316
E	3,025	1,775	45	18	4,863
W	34	129	3	---	166
S	1,346	1,050	8	10	2,414
C	416	449	2	6	873
IV	1,925	5,866	53	23	7,867
E	833	2,070	32	8	2,943
W	10	105	10	1	126
S	1,072	3,532	11	12	4,627
C	10	159	---	2	171
V	24	560	57	3	644
E	---	---	---	---	---
W	9	393	33	1	436
S	15	167	24	2	208
C	---	---	---	---	---
VI	956	13,123	144	16	14,239
E	519	6,704	91	12	7,326
W	2	12	1	---	15
S	435	6,407	52	4	6,898
C	---	---	---	---	---
VII	127	8,039	583	40	8,789
E	28	3,693	100	32	3,853
W	1	37	---	---	38
S	98	4,309	483	8	4,898
C	---	---	---	---	---
VIII	---	45	5	84	134
E	---	40	3	30	73
W	---	1	2	---	3
S	---	4	---	54	58
C	---	---	---	---	---
Subtotal by Subclasses					
NP[1]	32	---	---	---	32
E	4,744	14,434	300	102	19,580
W	86	752	54	3	895
S	3,065	15,540	579	91	19,275
C	1,368	951	44	13	2,376
Total Land Capability Classes	9,295	31,677	977	209	42,158

[1] Land Capability Class I lands have few limitations for agricultural use.

Table S-54 (Continued) — EASTERN DAKOTA SUBBASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	653	48	5	27	733
II	11,908	3,285	121	270	15,584
	5,611	1,787	56	137	7,591
W	409	112	3	12	536
S	775	240	3	11	1,029
C	5,113	1,146	59	110	6,428
III	6,375	3,416	34	98	9,923
E	3,675	1,746	16	60	5,497
W	206	452	2	1	661
S	2,494	1,215	16	37	3,762
C	---	3	---	---	3
IV	955	728	13	13	1,709
E	134	116	2	1	253
W	732	450	7	12	1,201
S	89	162	4	---	255
C	---	---	---	---	---
V	289	913	18	6	1,226
E	---	---	---	---	---
W	247	753	14	6	1,020
S	42	80	4	---	126
C	---	80	---	---	80
VI	814	3,392	12	40	4,258
E	400	1,777	7	18	2,202
W	---	---	---	---	---
S	414	1,615	5	22	2,056
C	---	---	---	---	---
VI	14	765	8	1	788
E	12	596	6	1	615
W	---	3	---	---	3
S	2	166	2	---	170
C	---	---	---	---	---
VIII	---	---	---	139	139
E	---	---	---	1	1
W	---	---	---	138	138
S	---	---	---	---	---
C	---	---	---	---	---
Subtotal by Subclasses					
NP[1]	653	48	5	27	733
E	9,832	6,022	87	218	16,159
W	1,594	1,770	26	169	3,559
S	3,816	3,478	34	70	7,408
C	5,113	1,229	59	110	6,511
Total Land Capability Classes	21,008	12,547	211	594	34,360

[1]Land Capability Class I lands have few limitations for agricultural use.

Table S-54 (Continued) – PLATTE-NIOBRARA SUBBASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	1,314	86	6	33	1,439
II	4,168	959	71	149	5,347
E	2,899	419	35	102	3,455
W	398	436	27	6	867
S	178	4	---	2	184
C	693	100	9	39	841
III	5,207	2,338	102	149	7,796
E	4,405	1,714	64	135	6,318
W	212	409	28	3	652
S	221	76	6	3	306
C	369	139	4	8	520
IV	3,326	4,320	97	60	7,803
E	2,604	3,559	65	49	6,277
W	32	89	9	1	131
S	178	203	16	5	402
C	512	469	7	5	993
V	13	249	20	1	283
E	---	---	---	---	---
W	13	248	20	1	282
S	---	1	---	---	1
C	---	---	---	---	---
VI	1,325	10,497	384	56	12,262
E	1,111	8,980	215	48	10,354
W	35	225	33	2	295
S	170	1,223	108	6	1,507
C	9	69	28	---	106
VII	278	16,409	927	45	17,659
E	206	11,666	503	25	12,400
W	15	8	---	---	23
S	57	4,734	423	20	5,234
C	---	1	1	---	2
VIII	3	289	329	128	749
E	---	194	211	102	507
W	3	79	118	17	217
S	---	16	---	9	25
C	---	---	---	---	---
Subtotal by Subclasses					
NP[1]	1,314	86	6	33	1,439
E	11,225	26,352	1,093	461	39,311
W	708	1,494	235	30	2,467
S	804	6,257	553	45	7,659
C	1,583	778	49	52	2,462
Total Land Capability Classes	15,634	35,147	1,936	621	53,338

[1]Land Capability Class I lands have few limitations for agricultural use.

Table S-54 (Continued) – MIDDLE MISSOURI SUBBASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	1,091	113	55	40	1,299
II	3,803	613	73	153	4,642
E	2,397	227	25	118	2,767
W	1,264	372	46	30	1,712
S	119	10	1	4	134
C	23	4	1	1	29
III	4,727	680	95	166	5,668
E	4,094	586	59	127	4,866
W	483	78	32	30	623
S	69	8	1	6	84
C	81	8	3	3	95
IV	1,171	339	55	36	1,601
E	1,128	324	55	35	1,542
W	35	11	---	1	47
S	8	4	---	---	12
C	---	---	---	---	---
V	41	103	9	9	162
E	1	---	---	---	1
W	40	103	9	9	161
S	---	---	---	---	---
C	---	---	---	---	---
VI	314	451	165	21	951
E	292	374	95	17	778
W	16	61	68	4	149
S	6	16	2	---	24
C	---	---	---	---	---
VII	72	185	174	20	451
E	60	136	138	13	347
W	---	---	---	---	---
S	12	49	36	7	104
C	---	---	---	---	---
VIII	---	1	5	2	8
E	---	---	---	---	---
W	---	1	5	2	8
S	---	---	---	---	---
C	---	---	---	---	---
Subtotal by Subclasses					
NP[1]	1,091	113	55	40	1,299
E	7,972	1,647	372	310	10,301
W	1,838	626	160	76	2,700
S	214	87	40	17	358
C	104	12	4	4	124
Total Land Capability Classes	11,219	2,485	631	447	14,782

[1]Land Capability Class I lands have few limitations for agricultural use.

Table S-54 (Continued) – KANSAS SUBBASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	1,331	241	64	29	1,665
II	6,620	729	49	142	7,540
E	3,906	370	4	83	4,363
W	328	108	39	10	485
S	288	35	3	3	329
C	2,098	216	3	46	2,363
III	9,233	2,437	66	162	11,898
E	8,142	2,185	45	151	10,523
W	241	57	20	8	326
S	118	48	1	1	168
C	732	147	---	2	881
IV	2,676	1,626	28	53	4,383
E	2,404	1,409	27	48	3,888
W	29	34	1	4	68
S	10	61	---	1	72
C	233	122	---	---	355
V	3	17	7	---	27
E	---	---	---	---	---
W	3	17	7	---	27
S	---	---	---	---	---
C	---	---	---	---	---
VI	2,320	6,534	197	122	9,173
E	2,256	6,300	52	112	8,720
W	43	162	143	9	357
S	21	72	2	1	96
C	---	---	---	---	---
VII	157	2,029	184	21	2,391
E	110	1,458	176	16	1,760
W	21	22	5	---	48
S	26	549	3	5	583
C	---	---	---	---	---
VIII	1	6	2	23	32
E	---	---	---	17	17
W	1	6	2	3	12
S	---	---	---	3	3
C	---	---	---	---	---
Subtotal by Subclasses					
NP1/	1,331	241	64	29	1,665
E	16,818	11,722	304	427	29,271
W	666	406	217	34	1,323
S	463	765	9	14	1,251
C	3,063	485	3	48	3,599
Total Land Capability Classes	22,341	13,619	597	552	37,109

[1] Land Capability Class I lands have few limitations for agricultural use.

Table S-54 (Continued) – LOWER MISSOURI SUBBASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	643	135	174	37	989
II	2,371	1,008	418	139	3,936
E	1,140	580	80	95	1,895
W	1,175	406	334	42	1,957
S	56	22	4	2	84
C	---	---	---	---	---
III	4,797	2,654	752	313	8,516
E	3,872	2,417	579	262	7,130
W	848	174	134	46	1,202
S	77	63	39	5	184
C	---	---	---	---	---
IV	1,378	1,373	929	136	3,816
E	1,313	1,313	885	128	3,639
W	5	4	---	---	9
S	60	56	44	8	168
C	---	---	---	---	---
V	9	28	27	2	66
E	---	---	---	---	---
W	9	28	27	2	66
S	---	---	---	---	---
C	---	---	---	---	---
VI	629	1,367	823	91	2,910
E	565	1,241	712	83	2,601
W	32	50	29	1	112
S	32	76	82	7	197
C	---	---	---	---	---
VII	378	760	2,634	72	3,844
E	189	458	770	28	1,445
W	---	---	---	---	---
S	189	302	1,864	44	2,399
C	---	---	---	---	---
VIII	3	9	31	3	46
E	---	---	---	---	---
W	---	---	---	---	---
S	3	9	31	3	46
C	---	---	---	---	---
Subtotal by Subclasses					
NP[1]	643	135	174	37	989
E	7,079	6,009	3,026	596	16,710
W	2,069	662	524	91	3,346
S	417	528	2,064	69	3,078
C	---	---	---	---	---
Total Land Capability Classes	10,208	7,334	5,788	793	24,123

[1] Land Capability Class I lands have few limitations for agricultural use.

Table S-54 (Continued) – MISSOURI BASIN

Land Capability Classes and Subclasses	Cropland	Pasture and Range	Forest and Woodland	Other Ag. Land	Total
			(Thousand Acres)		
I[1]	5,191	634	305	169	6,299
II	32,911	8,374	866	898	43,049
E	18,413	4,379	271	562	23,625
W	3,638	1,522	456	102	5,718
S	1,926	491	24	33	2,474
C	8,934	1,982	115	201	11,232
III	43,471	21,564	1,192	1,025	67,252
E	33,506	15,640	854	825	50,825
W	2,150	1,587	224	90	4,051
S	6,217	3,591	105	85	9,998
C	1,598	746	9	25	2,378
IV	13,518	19,435	1,261	354	34,568
E	9,364	11,206	1,118	280	21,968
W	866	750	27	20	1,663
S	2,511	6,586	103	46	9,246
C	777	893	13	8	1,691
V	387	2,124	169	24	2,704
E	---	---	---	---	---
W	330	1,779	137	22	2,268
S	57	265	32	2	356
C	---	80	---	---	80
VI	7,224	60,200	3,253	411	71,088
E	5,171	28,209	1,299	296	34,975
W	158	917	312	18	1,405
S	1,886	31,004	1,614	96	34,600
C	9	70	28	1	108
VII	1,078	38,291	6,089	207	45,665
E	607	20,859	2,670	120	24,256
W	37	70	5	---	112
S	434	17,361	3,413	87	21,295
C	---	1	1	---	2
VIII	9	2,042	519	473	3,043
E	---	470	268	150	888
W	4	106	127	162	399
S	5	1,466	123	161	1,755
C	---	---	1	---	1
Subtotal by Subclasses					
NP[1]	5,191	634	305	169	6,299
E	67,061	80,763	6,480	2,233	156,537
W	7,183	6,731	1,288	414	15,616
S	13,036	60,764	5,414	510	79,724
C	11,318	3,772	167	235	15,492
Total Land Capability Classes	103,789	152,664	13,654	3,561	273,668

[1] Land Capability Class I lands have few limitations for agricultural use.

COMPREHENSIVE FRAMEWORK STUDY
MISSOURI RIVER BASIN

APPENDIX

HYDROLOGIC ANALYSES AND PROJECTIONS

MISSOURI BASIN INTER-AGENCY COMMITTEE

June 1969

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

TABLES

CONTENTS (Continued)

Number *Page*

FIGURES

Number *Page*

CONTENTS (Continued)

PLATES

CONTENTS (Continued)

CHAPTER 1

INTRODUCTION

PURPOSE

Hydrology, the science which treats of water, its properties, phenomena, and distribution, must be a basic consideration in development of any plan for water and related land resources development. It becomes of especial significance in the Missouri River Basin because of the basin's large size and the great variation in hydrologic characteristics encountered in this large area.

This appendix has been prepared as part of the Report on the Comprehensive Framework Study for the Missouri River Basin. It describes the hydrologic studies undertaken for framework planning, and it summarizes the results of those studies.

SCOPE

The Comprehensive Framework Study for the Missouri River Basin involves an evaluation of the basin's current (1970) physical, economic, and water and related land resources development; projections of economic development to years 1980, 2000, and 2020; and an evaluation, for each of these three future years, of the needs and development opportunities associated with water and related land resources. It involves also the formulation of framework plans for water and related land resources development in 1980, 2000, and 2020, each designed for optimum satisfaction of then-existing needs and for optimum realization of then-existing development opportunities.

The hydrologic studies involved primarily the determination of the quantity, quality, and location of both the surface-water supply and the ground-water supply of the Missouri River Basin under several conditions of water and related land resources development. Analyses were made on the basis of historical water use and availability, and on the basis of water and related resources development as it can be foreseen for 1970. Finally, framework plans as initially developed for 1980, 2000, and 2020 were analyzed to determine their effects on the available water supply, from the standpoint of both quantity and quality, and to insure consistency of final plans with the available water supply and with established standards of water quality.

Hydrologic data as assembled are voluminous, and the analyses performed are numerous and varied. It is not practicable to present all of this material in detail in this appendix. Summaries of data are in enough detail for an understanding of the Missouri River Basin's hydrology; analyses are described in enough detail to permit understanding of the procedures used; and the results of these analyses are summarized.

Hydrologic data assembled and analyses performed are presented in detail in a series of working papers which have not been incorporated in the appendix. Working papers prepared in connection with the hydrologic studies are listed in table 1.

The reliability of hydrologic analyses is particularly sensitive to the adequacy of basic data available. Accordingly, an evaluation has been made of existing data collection programs, needs for expansion of these have been defined, and needs for research in connection with collection and use of hydrologic data have been determined. Data collection and research needs, in connection with hydrology as well as other purposes, are summarized in the Comprehensive Framework Study report.

ACKNOWLEDGEMENTS

This appendix has been prepared and the studies it describes have been performed by the Hydrologic Work Group and its member task forces. The place of this work group and its task forces in the overall organization established to conduct the comprehensive framework study is illustrated by the organization chart shown as figure 1. This figure also lists the membership of the work group and its several task forces, and indicates the States and agencies they represent.

Table 1 – LIST OF WORKING PAPERS PREPARED BY THE HYDROLOGIC WORK GROUP

Selected Climatic Maps
Multi-Annual Precipitation Probabilities for Each of Eight Subbasins, the Total Missouri River Basin, and the Basin Above [illegible]x City (9 volumes)
Precipitation Probabilities, Levels, and Durations, Missouri River Basin, 1, 2, 4, and 8 Weeks.
Snow Survey and Soil Moisture Data
Infiltration Data, Missouri River Basin
Evaporation Estimates, Missouri River Basin
Analysis of Freeze-Thaw Dates, Missouri River Basin Streams
Sedimentation, Eight Subbasins (8 volumes)
Streamflow Characteristics, Eight Subbasins and the Missouri River Main Stem (9 volumes)
Generalized Streamflow Probabilities, High Flows for Eight Subbasins, the High Altitude Snow Region and the Plains Snow Region (10 volumes)
High-Flow Volume-Frequency Curves for Eight Subbasins and the Missouri River Main Stem (9 volumes)
Low-Flow Volume-Frequency Curves, Lower Missouri River Tributaries
Generalized Estimates of Mean Annual Runoff in Inches (Map)
Monthly Streamflow Tables and Depletion Estimates for Eight Subbasins and the Missouri River Main Stem, 1970 Level (9 volumes)
Map of General Availability of Ground Water and Depth to Water Level in the Missouri River Basin
Ground-Water in the Missouri River Basin (12 maps with associated text)
Selected Bibliography, Ground-Water Hydrology
Quality Characteristics of Streams in the Missouri River Basin

FIGURE 1
ORGANIZATION CHART - HYDROLOGIC

PARTICIPANTS

COLORADO	Colo.
AGRICULTURE, DEPARTMENT OF	
Agricultural Research Service	ARS
Agricultural Stabilization and Conservation Service	ASCS
Economic Research Service	ERS
Farmers Home Administration	FHA
Forest Service	FS
Rural Electrification Administration	REA
Soil Conservation Service	SCS
IOWA	Iowa
ARMY, CORPS OF ENGINEERS	C of E
KANSAS	Kans.
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MINNESOTA	Minn.
FEDERAL POWER COMMISSION	FPC
MISSOURI	Mo.
MONTANA	Mont.

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NEBRASKA	Nebr.
INTERIOR, DEPARTMENT OF THE	
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Bureau of Indian Affairs	BIA
Bureau of Land Management	BLM
Bureau of Mines	BM
Bureau of Outdoor Recreation	BOR
Bureau of Reclamation	BR
Bureau of Sports Fisheries and Wildlife	BSF & WL
Federal Water Quality Administration	FWQA
Geological Survey	GS
Interior Missouri Basin Field Committee	IMBFC
National Park Service	NPS
NORTH DAKOTA	N.Dak.
SOUTH DAKOTA	S.Dak.
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James A. Power, Jr.	Kans.

TASK FORCE ON INFILTRATION

Keith H. Beauchamp, Chairman	SCS
Harold P. Grout	BR
Charles F. Thomas	C of E
Charles A. Burgtorf	C of E

TASK FORCE ON STREAMFLOW DEPLETIONS

Phil Q. Gibbs, Chairman	BR
William J. Owen	SCS
Hugh H. Hudson	GS
James A. Power, Jr.	Kans.
Marion E. Ball	Nebr

TASK FORCE ON SURFACE WATER QUALITY

Donald C Draper, Chairman	FWQA
T B. Dover	GS
James W. Bowman	BR
T. C Ferris	PHS
James A Power, Jr	Kans

CHAPTER 2

BASIN DESCRIPTION

The Missouri River Basin has an area of 529,300[1] square miles, including about 9,700 square miles in Canada. That part within the United States includes all of the state of Nebraska and parts of the states of Montana, Wyoming, North Dakota, South Dakota, Minnesota, Colorado, Iowa, Kansas, and Missouri.

The basin is entirely within the continental interior, everywhere at a substantial distance from any seacoast and from any major source of atmospheric moisture. It extends over a substantial range of both latitude and longitude, from about 37° to about 50° north latitude and from about 90° to about 114° west longitude. The basin size and its great expanse are both major factors in its varied hydrologic characteristics.

PHYSIOGRAPHY

The Missouri River Basin extends into three major physiographic divisions – the Interior Highlands, the Interior Plains, and the Rocky Mountain System. The basin's physiography, accordingly, exhibits a great deal of variety, in both physiographic features and the effect of these features on the basin's hydrology.

In the extreme southeastern part of the basin, in southeastern Missouri, a comparatively small part lies in the Ozark Plateaus province of the Interior Highlands. Characteristic of submature to mature plateaus, this is an area of rugged ridges and valleys.

The greatest part of the basin, by far, lies in the Interior Plains Division. The Central Lowlands province of this division includes an area of old scarped plains with well entrenched main streams in east-central Kansas and southwestern Missouri; an area of submaturely to maturely dissected till plains in northeastern Kansas, northern Missouri, southern and western Iowa, and extreme eastern Nebraska; and a young glaciated plains area of moraines, lakes, and lacustrine plains in eastern South Dakota, eastern and north-central North Dakota, and southwestern Minnesota.

The Great Plains province of the Interior Plains includes a submaturely to maturely dissected plateau in central Kansas and a small part of south-central Nebraska; an area of broad intervalley fluvial-plain remnants in northwestern Kansas, extreme northeastern Colorado, extreme southeastern Wyoming, and most of Nebraska; a late-mature to old elevated plain in part of northeastern Colorado; an area of maturely dissected domed mountains in the Black Hills area of southwestern South Dakota and northeastern Wyoming; an area of unglaciated old plateaus, terrace lands, local badlands, and isolated mountains in northwestern South Dakota, southeastern and south-central Montana, and extreme southwestern North Dakota; and an area of glaciated old plateaus and isolated mountains in northeastern Montana and northwestern and south-central North Dakota.

The rest of the Missouri River Basin, along its western edge, is within the Rocky Mountain System. North-central Colorado and part of southeastern Wyoming lie in the Southern Rocky Mountains province. Part of northwestern Wyoming lies in the Middle Rocky Mountains province. Both are areas of complex mountains and intermontane basins. Western Montana lies in the Northern Rocky Mountains province, an area of deeply dissected mountain uplands and intermontane basins. South-central Wyoming and part of northwestern Colorado lie in the Wyoming Basin province, an area of elevated plains in various stages of erosion, with isolated low mountains.

Major physiographic divisions, provinces, sections, and subsections within the Missouri River Basin are depicted in figure 2.

TOPOGRAPHY

Most of the Missouri River Basin is plains country, a large part of it originally grassland. Gently undulating in places and elsewhere table-like over great distances, the plains stretch nearly 800 miles from the Canadian border to the southern margin of the basin, and from the Rocky Mountains eastward to the Mississippi River. Here and there the plains are interrupted by ribbons of hill lands which have been dissected along the valleys of the major streams.

[1] This includes about 6,300 square miles in the Red Desert closed basin area and other noncontributing areas near the basin divide.

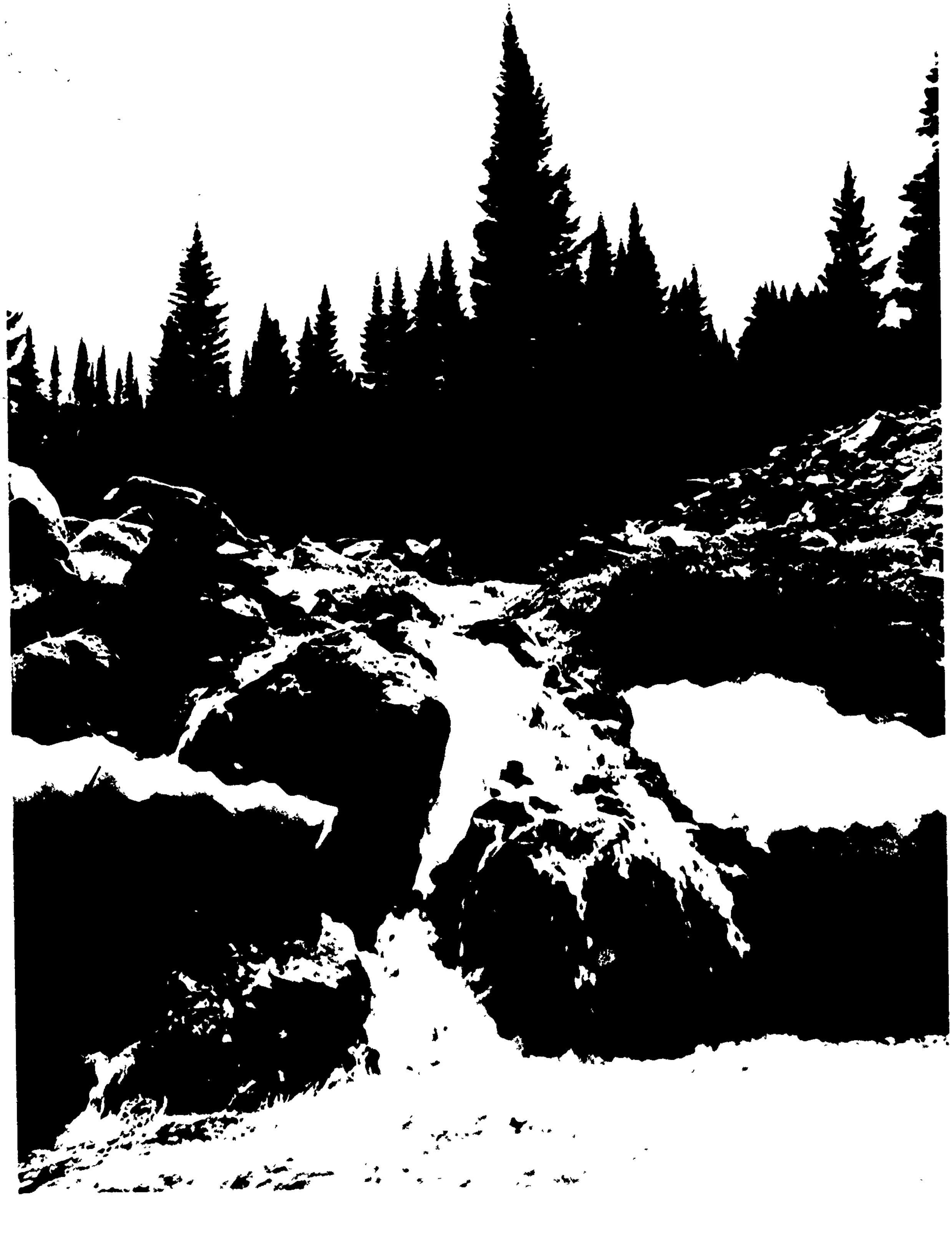

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FIGURE 2

PHYSIOGRAPHIC DIVISIONS, PROVINCES, SECTIONS, AND SUBSECTIONS

Several areas within the basin are notably different, among them the Rocky Mountains, the Big Horn Mountains, the Sand Hills of north-central Nebraska, and the Black Hills of southwestern South Dakota and northeastern Wyoming. The Rocky Mountains definitely terminate the plains everywhere along the western side of the basin. Many peaks and ridges here approach 14,000 feet above sea level in elevation. Even these major mountain ranges, however, are dwarfed by the great size of the plains area to the east.

Some of the major topographic features of the Missouri River Basin are shown in figure 2.

GEOLOGY

Rocks of igneous, metamorphic, and sedimentary origin constitute the geologic framework of the Missouri Basin. The basin's geologic history is reflected in its stream patterns, its soils, and its ground-water reservoirs. Also significant hydrologically are the relationships of geology to the chemical quality of both surface water and ground water and to the sediment content of surface waters.

Rocks of pre-Paleozoic age, older than 570 million years, underlie the entire basin. The aggregate area of their outcrop, however, even including an area in South Dakota where they are mantled by a thin veneer of glacial deposits, is only about 21,000 square miles, slightly less than 4 percent of the basin area. The outcrops, which occur in South Dakota, Colorado, Wyoming, and parts of Montana, consist of igneous and metamorphic rocks crisscrossed by dikes. Granite, gneiss, schist, and quartzite are the most common rock types. Relatively little is known about the pre-Paleozoic rocks where they are deeply buried, since exploratory drilling for oil or water ordinarily is terminated before or when these rocks, commonly referred to as the basement complex, are reached. Locations of outcrops of pre-Paleozoic age are shown on plate 1.

Rocks of Paleozoic age, formed between 570 million and 225 million years ago, underlie about 87 percent of the basin. In addition to cropping out on the flanks of nearly all the exposed uplifts of pre-Paleozoic rocks in the western part of the basin, the also crop out extensively in the southeastern part of the basin. The total area of Paleozoic rock outcrops is estimated at 74,200 square miles, about 14 percent of the total basin area. About 87 percent of the total outcrop is within an area comprised of northeastern Kansas, southeastern Nebraska, southwestern Iowa, and all of Missouri within the basin. The maximum thickness of Paleozoic rocks here probably does not exceed 5,000 feet. The extent of Paleozoic rocks and their outcrops also are shown on plate 1.

Consisting principally of dolomite, limestone, shale, and sandstone, most of the Paleozoic rocks were deposited in a succession of shallow marine environments. Dolomite and dolomitic shale are the predominant rock types in the lower part of the sequence but are relatively uncommon in the upper part. Limestone and calcareous shale are common throughout all but the uppermost part of the sequence, which is characterized by an abundance of redbeds, composed of shale and sandstone deposited in an arid environment, and evaporites. Sandstone is a minor rock type in the lower part of the sequence but is much more common in the upper part.

Rocks of Mesozoic age, deposited or formed between 225 million and 65 million years ago, are present everywhere in the basin except where pre-Paleozoic or Paleozoic rocks are exposed. Their areal extent is about 83 percent of the total basin area. The outcrop of Mesozoic rocks has an area of about 251,000 square miles, or about 48 percent of the total basin area. Their greatest development is in south central Wyoming, where their thickness exceeds 12,000 feet. The extent of Mesozoic rocks in the basin is depicted on plate 2. On this plate, the Mesozoic rocks are shown as buried where they are overlain by rock of Tertiary age but as outcropping where they are mantled by unconsolidated deposits of Quaternary age.

Unlike the Paleozoic rocks, those of Mesozoic age include no dolomite and little limestone. They do include some redbeds, however, in the lower part of the sequence. Much of the sequence consists of shale, shaly sandstone, and sandstone deposited mostly in a marine, but some in a continental, environment. Limestone and chalk occur only in the upper part of the sequence and are limited to the eastern and southern parts of the overall areal extent of Mesozoic rocks.

Rocks of Tertiary age, deposited or formed between 65 million and 2 million to 3 million years ago, have an areal extent of about 182,000 square miles in the Missouri River Basin, equivalent to about 34 percent of the basin area. Included are about 8,300 square miles of rock formed from magma extruded during Tertiary time. The extent of Tertiary rocks in the basin is depicted on plate 3.

Virtually all of the Tertiary sedimentary rocks were deposited in a continental environment, the only exception being some marine beds in the lowermost part of the sequence in western North Dakota. Except for some thin fresh-water limestones and a few widespread deposits of lignite, the entire sedimentary sequence consists of shale, sandy shale, sandstone, clay, silt, and sand.

East of the mountainous part of the basin, the Tertiary deposits form an extensive sheet; and where the youngest of the Tertiary stratigraphic units, the Ogallala Formation, remains intact, its upper surface is referred to as the High Plains. Within the mountainous region, Tertiary deposits constitute a major part of the fill occupying the intermontane basins. The greatest thicknesses of Tertiary rocks are in locations near to the mountainous sources of the sediments.

Rocks of Quaternary age, deposited during the last 2 million to 3 million years, consist principally of unconsolidated glacial deposits, mostly till, outwash, and lakebeds; fluviatile deposits, including terrace deposits and stream alluvium; and eolian deposits, including dune sand and loess. The fluviatile and eolian deposits are the youngest of the Quaternary rocks. The areal distribution of the several types of Quaternary deposits is shown on plate 4.

Glacial till, a heterogeneous mixture of rock debris transported by expanding ice sheets and deposited when those ice sheets melted, mantles the older consolidated and semiconsolidated rocks throughout an area of about 161,000 square miles along the north and east sides of the basin. Associated with the till are bodies of outwash and lakebeds. Some of these are buried by or are included within the till mass, while others rest on or are adjacent to the till mass.

The fluviatile deposits are of particular importance to the water-supply situation in the Missouri River Basin. Most have a high capacity to store water, and in addition to serving as reservoirs that are tapped by tens of thousands of wells, they provide temporary storage for flood flows and they maintain the flow of many streams during periods of no overland runoff. The largest accumulation of fluviatile deposits is in south-central Nebraska. Since these deposits extend westward an unknown distance beneath the Sand Hills, their areal extent is somewhat greater than shown on plate 4. Other fluviatile deposits are much less extensive, but they are widely distributed since they underlie the flood plain and adjacent terraces along most of the important drainageways in the basin.

Eolian deposits, dune sand and loess, form a surficial mantle on older rocks throughout a large area in the southeastern and southern parts of the basin. The largest area of dune sand, about 20,000 square miles in extent, is in north-central Nebraska. The principal smaller areas, having a combined extent of about 4,500 square miles, are in southwestern Nebraska and northeastern Colorado. Loess mantles the older rocks throughout an area 3 to 4 times larger than the total sand area. Accumulations greater than 30 feet thick, more than 60 feet thick in some places, are present throughout three large areas. One of these is a broad band extending from Thomas County, Kansas, northeastward to Cuming County, Nebraska. The others, 10 to 20 miles wide, border both sides of the Missouri River valley from the vicinity of Sioux City, Ia., to about St. Joseph, Mo. Elsewhere, the thickness ranges from 30 feet to less than 1 foot. Although generally suitable for grazing cattle and, suitable in some places for growing hay, the sand-dune areas contain little land suitable for cultivation. Loessial soils, on the other hand, ordinarily are ideal for growing crops.

STREAMS

The Missouri River rises along the Continental Divide in the northern Rocky Mountains and flows generally easterly and southeasterly to join the Mississippi River near St. Louis, Mo. It is the longest river in the United States, flowing 2,315 miles from its source, the headwaters of the Red Rock River in Montana, to its junction with the Mississippi River.

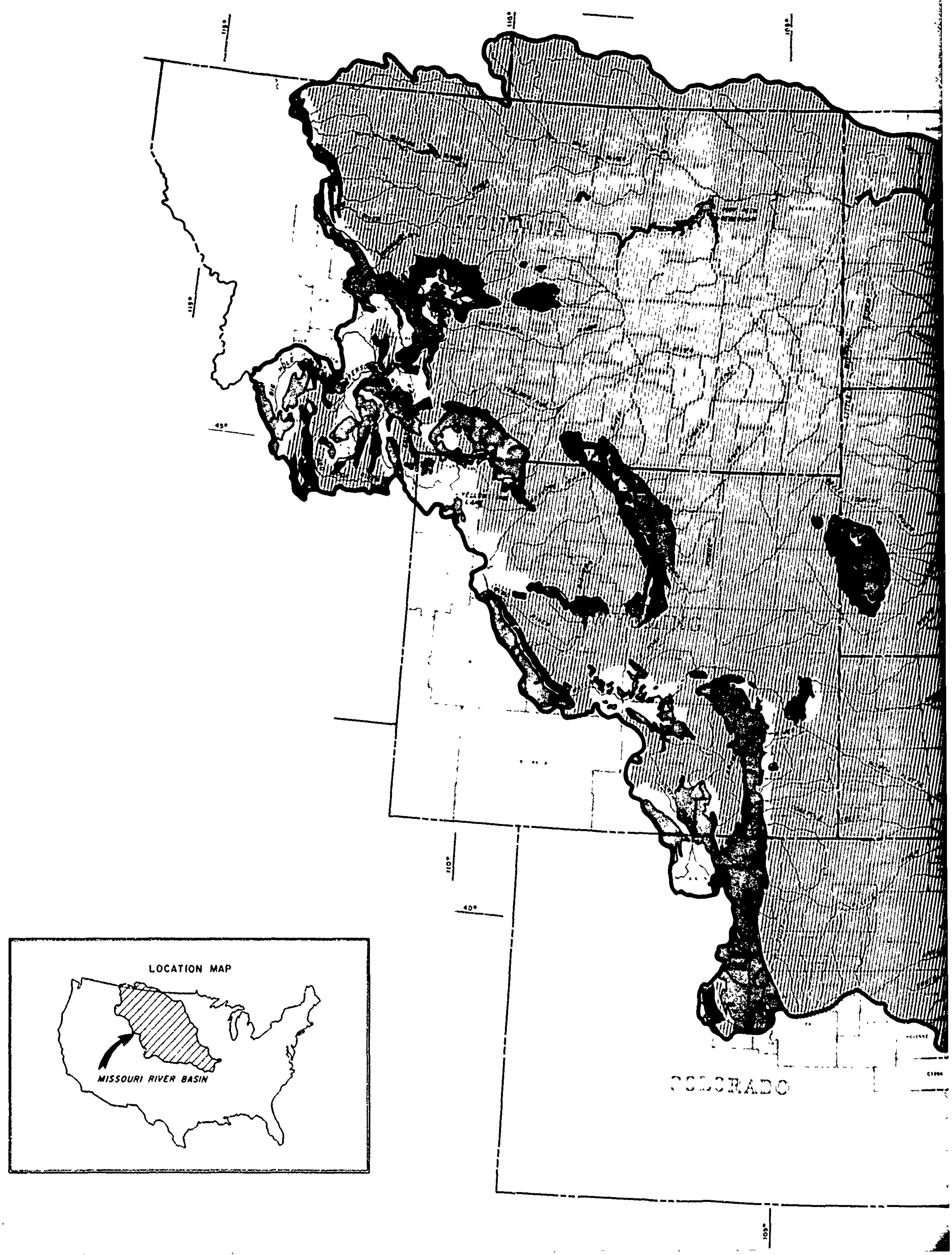
The headwaters of the Missouri River and of its largest tributaries, the Yellowstone and Platte rivers lie among snow-clad peaks reaching up to nearly 14,000 feet above sea level along the Continental Divide. The headwaters streams lose elevation rapidly in their upper reaches, dropping to elevations some 10,000 feet lower than those of their sources before they leave the headwaters states of Colorado, Wyoming, and Montana. Slopes are much flatter in the long reaches across the plains states, but the Missouri River at its mouth is only about 400 feet above sea level.

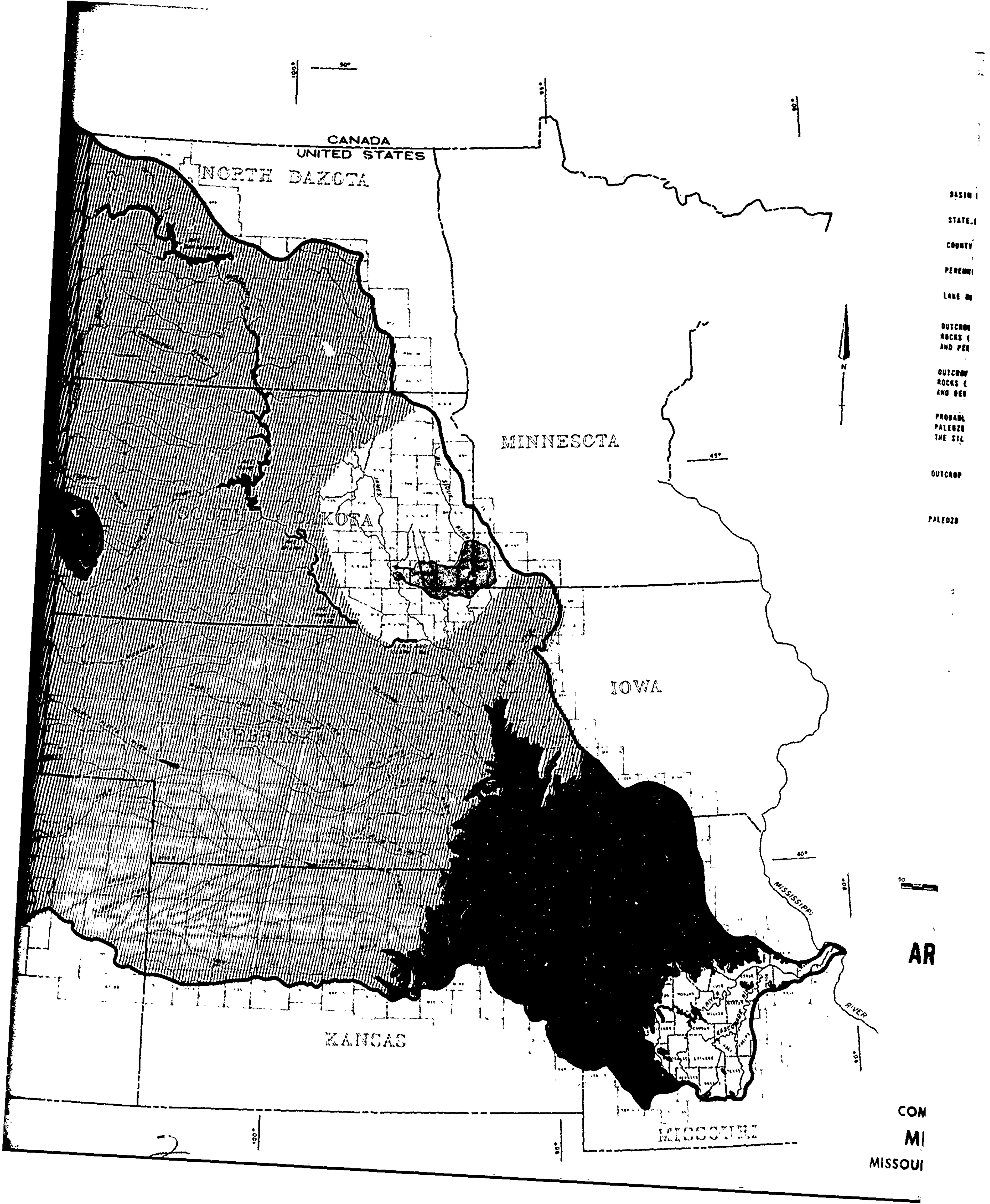
Wide variations in seasonal flow characterize the Missouri River. The winter season is a period of low flow. From December to February, ice may cover the river as far south as Kansas City, Mo. Serious ice jams and resultant flooding may occur with breakup of the ice cover.

Spring thaws greatly increase stream discharges. A typical rise on the Missouri River during late March or April is caused by melting of the snow cover over the plains area. This rise sometimes results in major flows and resultant flood damage. A rise which is generally lower in peak flow but greater in volume is usually experienced in June when snowmelt from the higher plateaus and mountains may combine with runoff from prolonged spring rainfall in the lower basin. This is the usual period of maximum flow of tributaries, such as the Yellowstone River, which are fed primarily by mountain snowmelt.

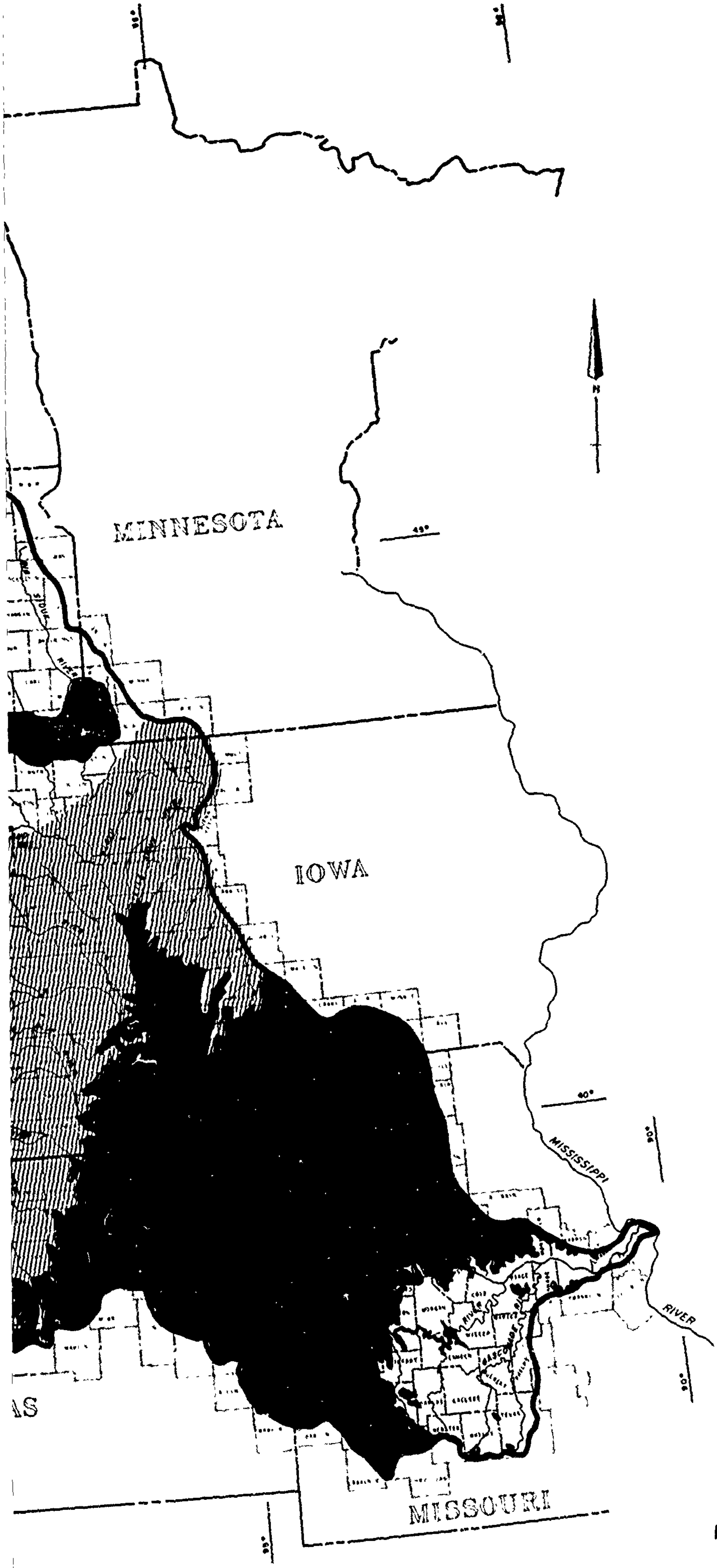
Following the June rise, low flows usually prevail during the late summer and early autumn, interrupted by rises caused by occasional heavy rains in the lower basin.

Streamflow characteristics in the Missouri River Basin, however, defy generalization. This is due to the range of climatological, topographic, and other factors that control streamflow in this large and diverse region. Streams that drain the mountain areas are generally productive and relatively stable. The most highly variable streams are those that originate in southeastern North Dakota and northeastern South Dakota. Streams that drain the Sand Hills area of Nebraska are among the most stable in the Nation, with average monthly flows differing very little from the average of annual flows.


LOCATION MAP
MISSOURI RIVER BASIN
COLORADO



CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
IOWA
KANSAS
MISSISSIPPI
RIVER
AR
CON
MI
MISSOUI



LEGEND

- BASIN BOUNDARY
- STATE OR NATIONAL BOUNDARY
- COUNTY BOUNDARY
- PERENNIAL STREAMS
- LAKE OR RESERVOIR
- OUTCROPS OF YOUNGER PALEOZOIC ROCKS (MISSISSIPPIAN, PENNSYLVANIAN AND PERMIAN SYSTEMS)
- OUTCROPS OF OLDER PALEOZOIC ROCKS (CAMBRIAN, ORDOVICIAN, AND DEVONIAN SYSTEMS)
- PROBABLE EXTENT OF BURIED PALEOZOIC ROCKS (INCLUDING THE SILURIAN SYSTEM)
- OUTCROPS OF PRE-PALEOZOIC ROCKS
- PALEOZOIC ROCKS NOT PRESENT

SCALE 1/5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

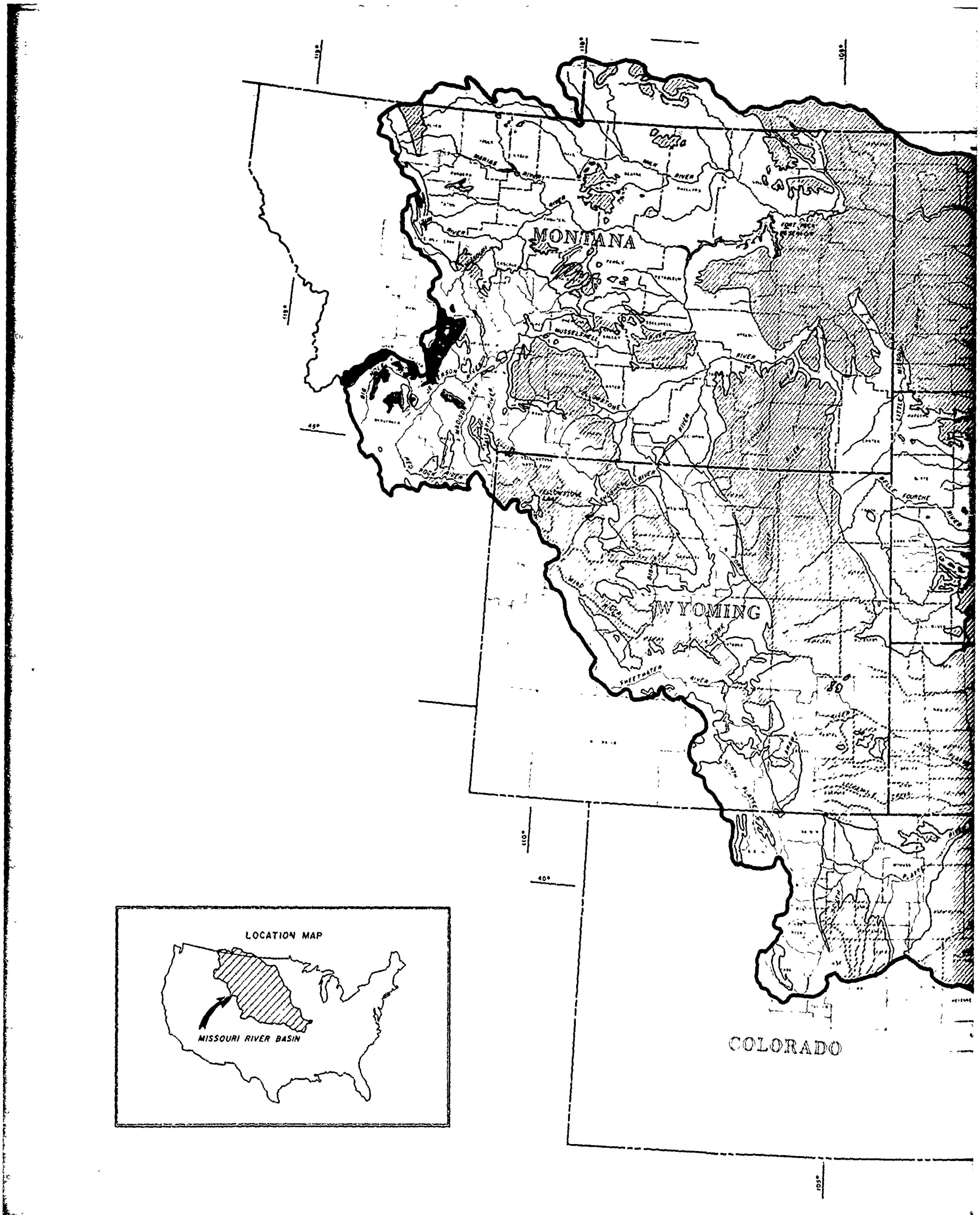
AREAL DISTRIBUTION OF PALEOZOIC AND OLDER ROCKS

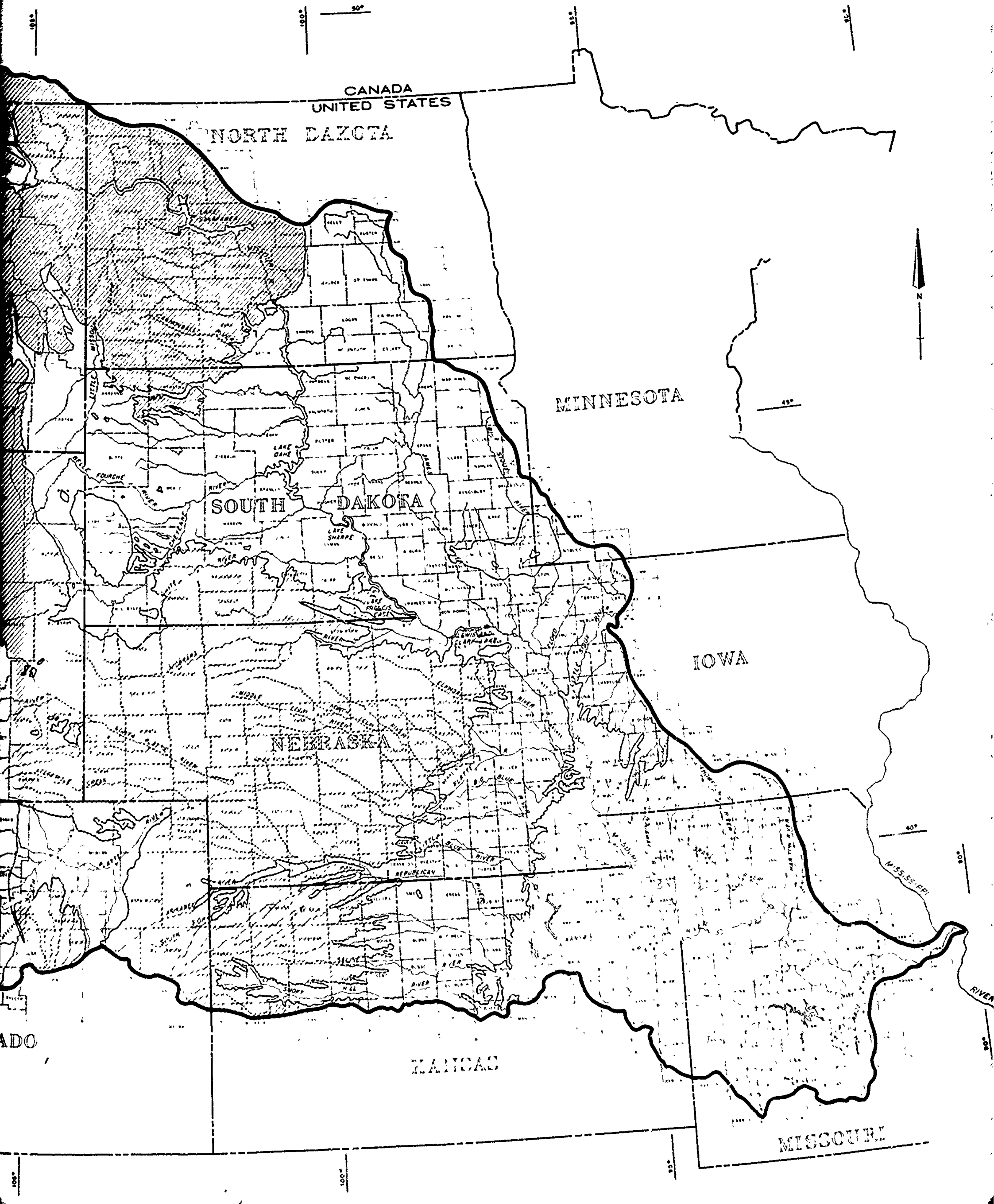
COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

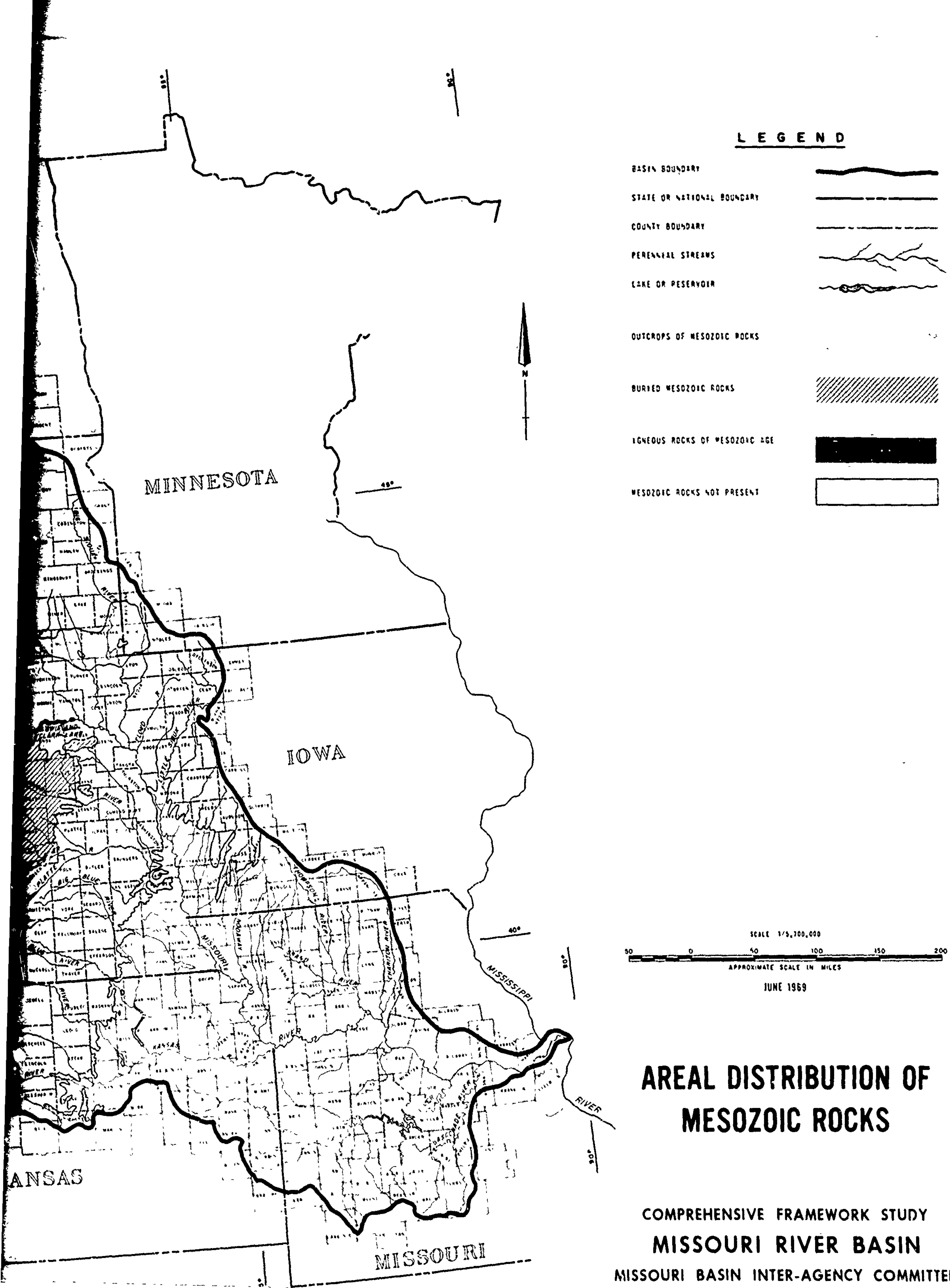
MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 1


MONTANA
WYOMING
COLORADO
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
ADO
KANSAS
MISSOURI
LAKE SHARPE
LAKE FRANCIS CASE
BELLE FOURCHE
REPUBLICAN
RIVER



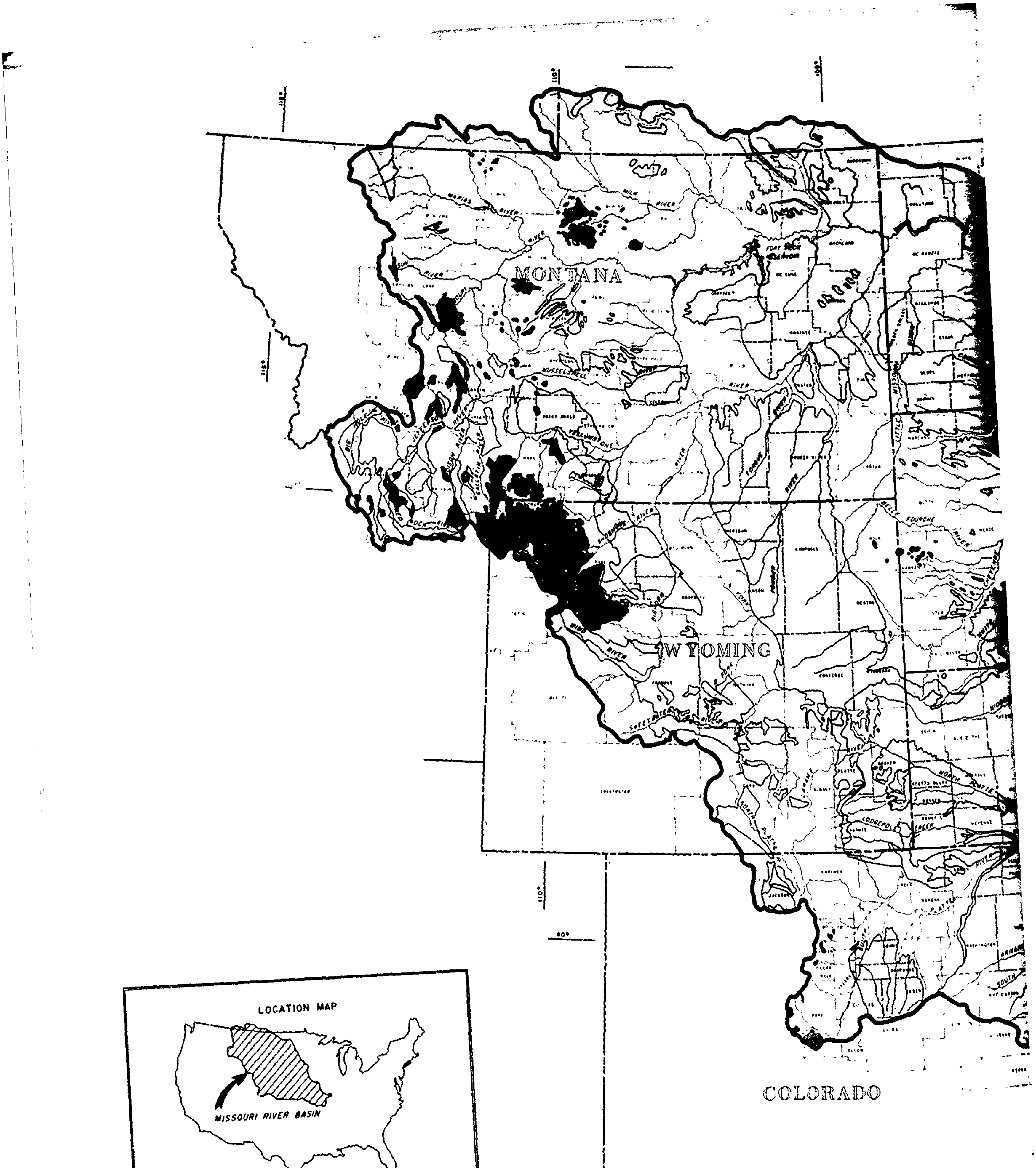
AREAL DISTRIBUTION OF MESOZOIC ROCKS

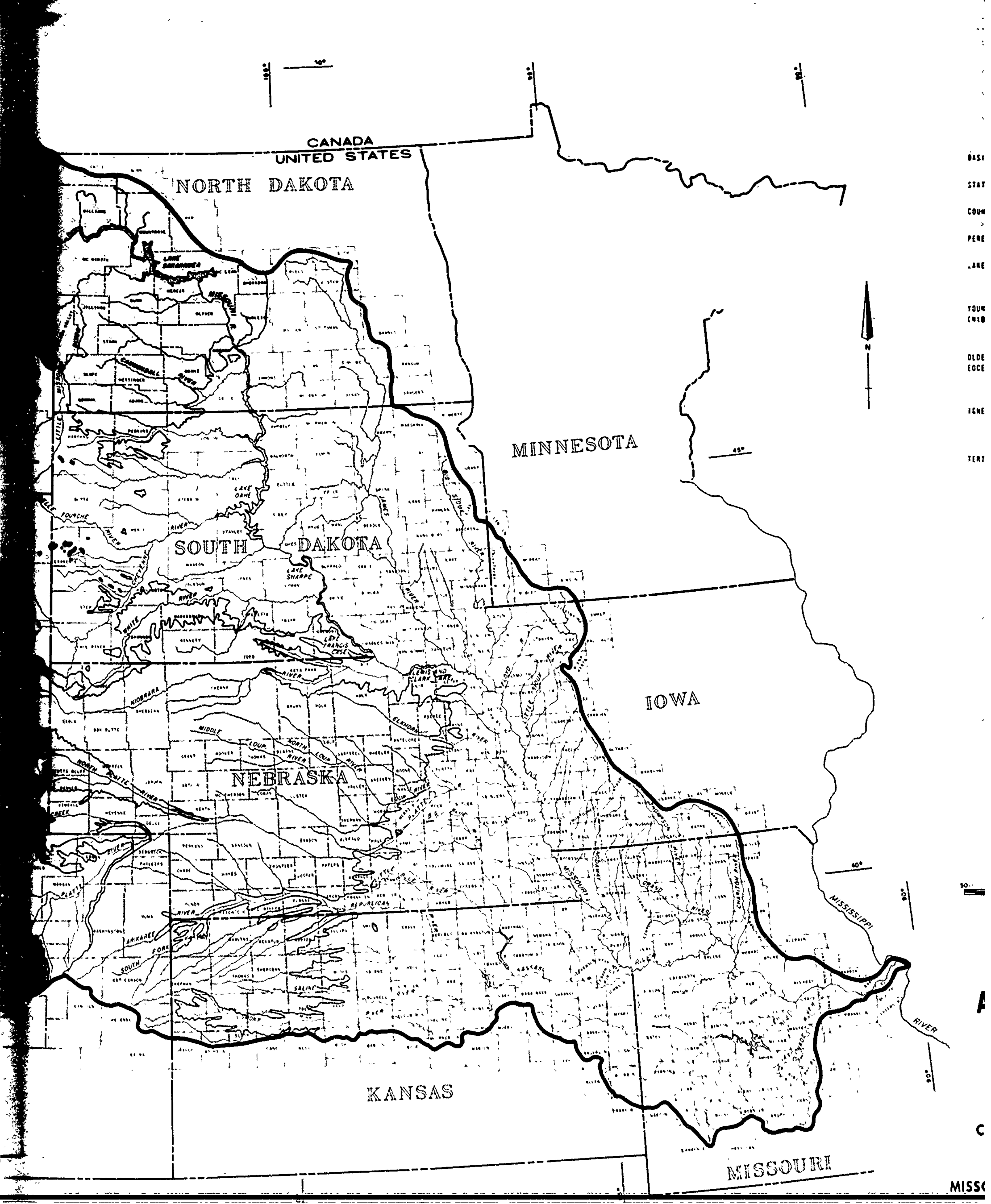
COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 2


MONTANA
WYOMING
COLORADO
LOCATION MAP
MISSOURI RIVER BASIN
40°
110°
105°


CANADA
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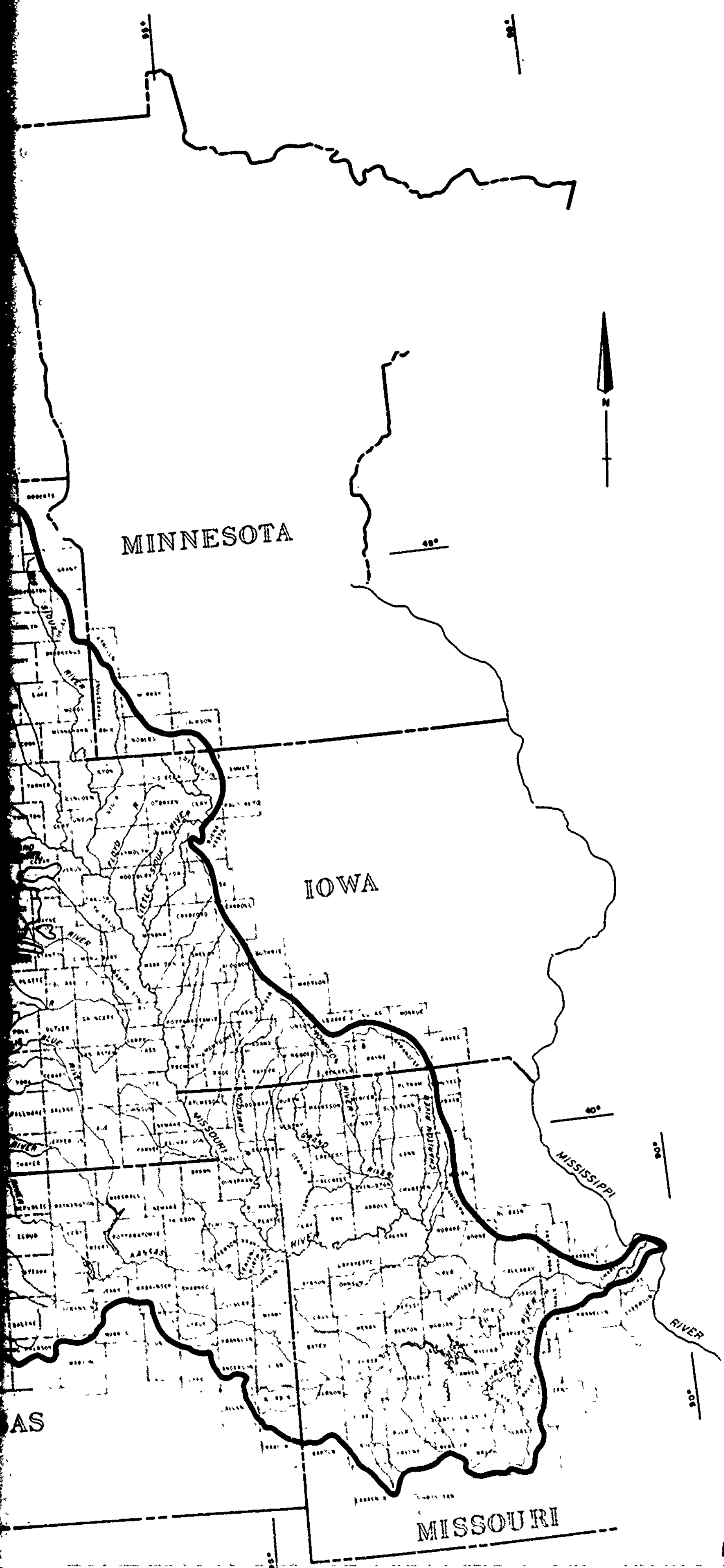
MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
KANSAS
MISSOURI
LAKE SAKAKAWEA
LAKE OAHE
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
CANNONBALL RIVER
WHITE RIVER
CHEYENNE RIVER
NIOBRARA
NORTH PLATTE RIVER
MIDDLE LOUP
NORTH LOUP RIVER
ELKHORN
PLATTE RIVER
REPUBLICAN
SALINE
ARIKAREE
SOUTH FORK
BIG SIOUX RIVER
JAMES RIVER
GRAND RIVER
CHARITON RIVER
OSAGE RIVER
MISSISSIPPI RIVER
MISSOURI
N



L E G E N D

BASIN BOUNDARY
STATE OR NATIONAL BOUNDARY
COUNTY BOUNDARY
PERENNIAL STREAMS
LAKE OR RESERVOIR
YOUNGER TERTIARY ROCKS (MIOCENE AND PLIOCENE SERIES)
OLDER TERTIARY ROCKS (PALEOCENE EOCENE AND OLIGOCENE SERIES)
IGNEOUS ROCKS OF TERTIARY AGE
TERTIARY ROCKS NOT PRESENT

SCALE 1/5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

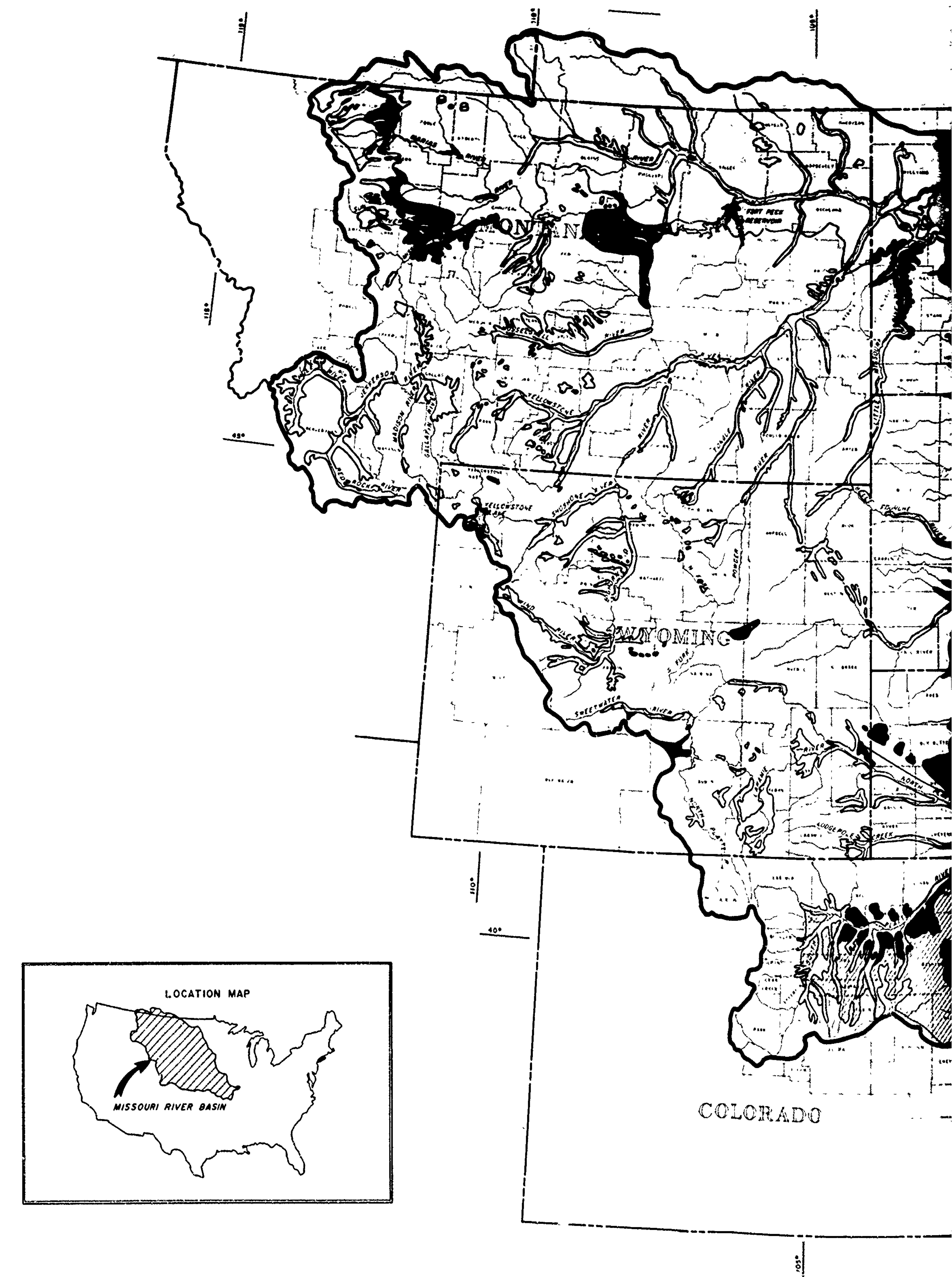
JUNE 1969

AREAL DISTRIBUTION OF TERTIARY ROCKS

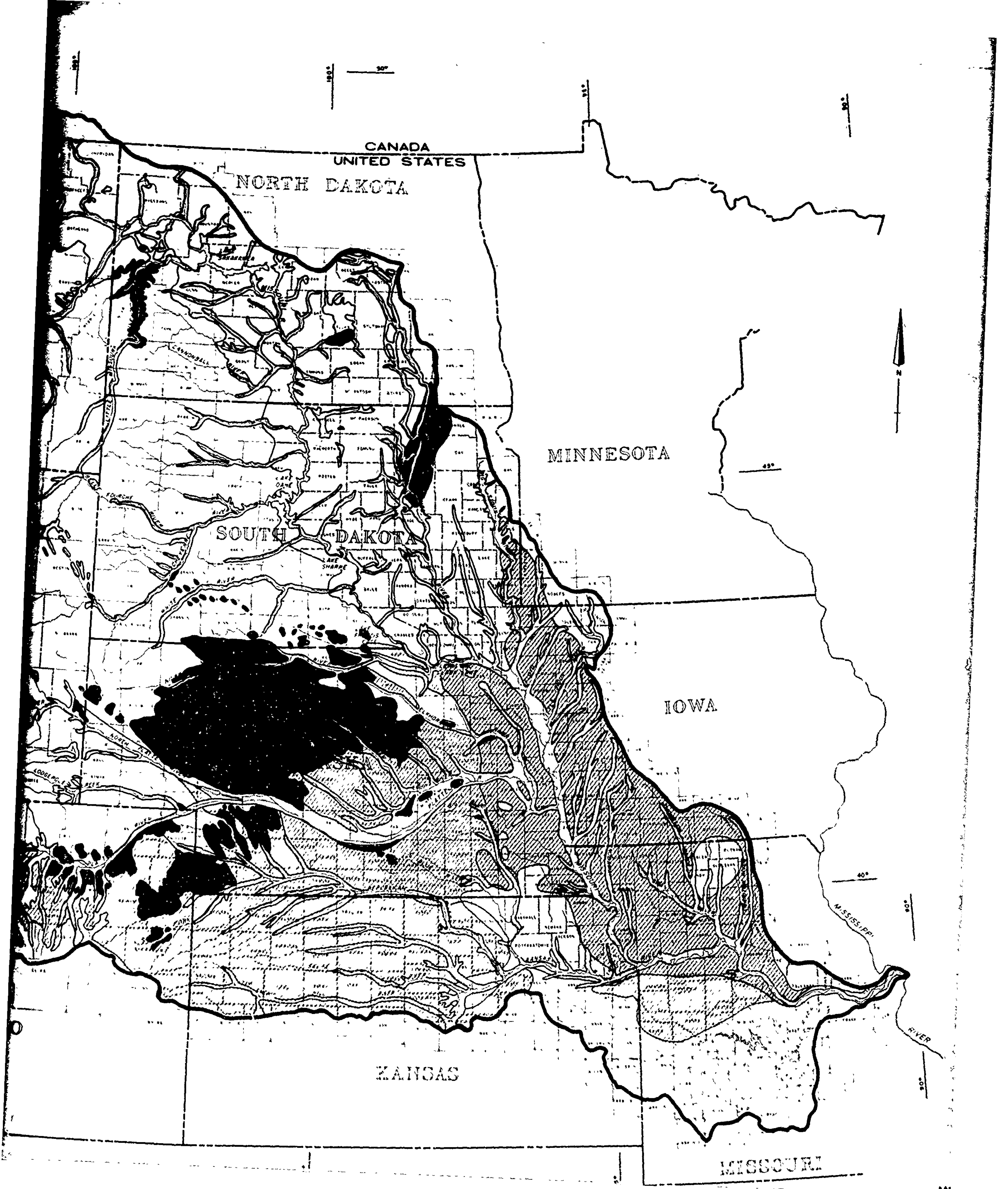
COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

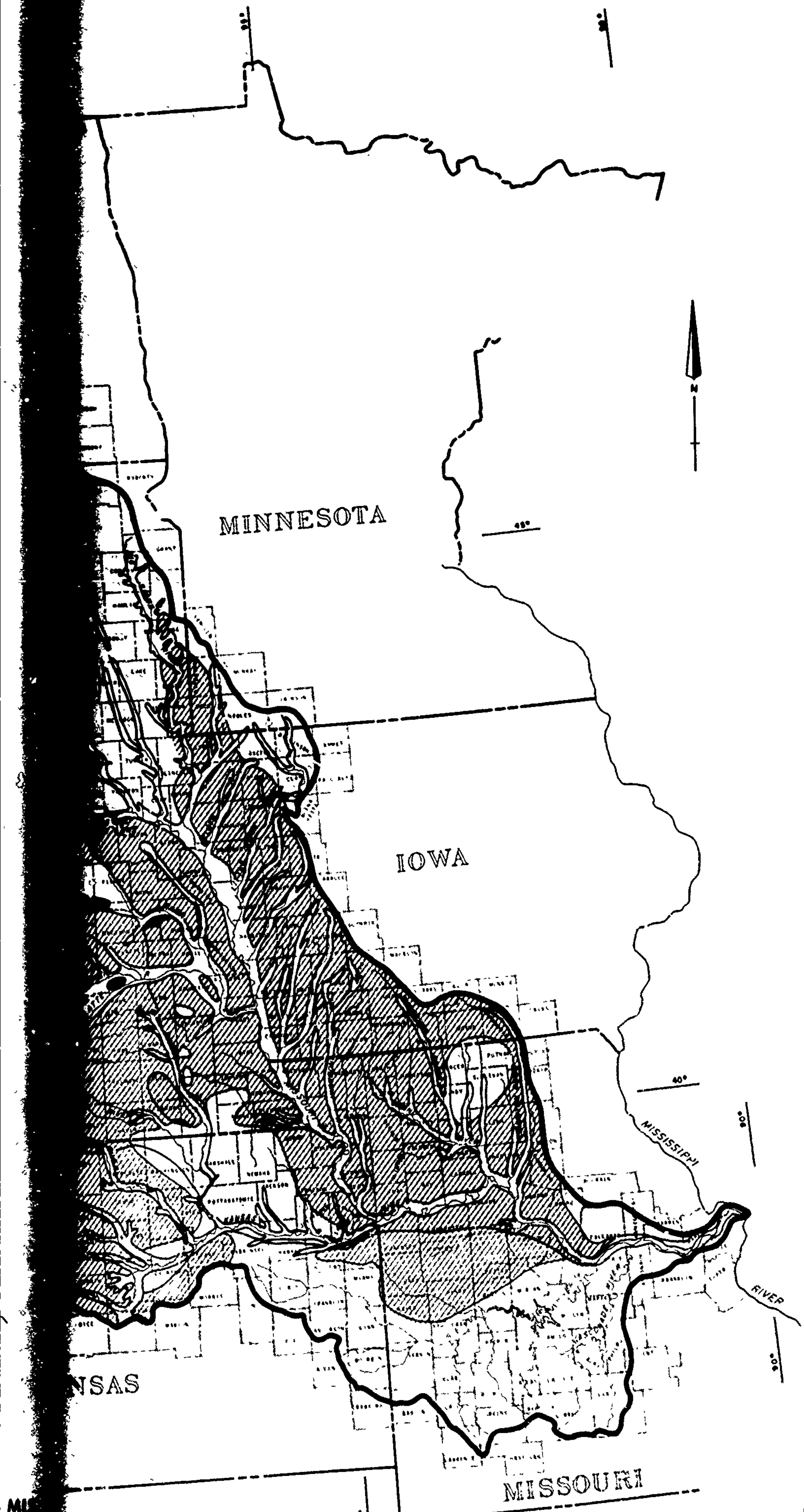


MONTANA
WYOMING
COLORADO
FORT PECK RESERVOIR
YELLOWSTONE RIVER
MADISON RIVER
GALLATIN RIVER
JEFFERSON RIVER
RED ROCK RIVER
SHOSHONE RIVER
WIND RIVER
SWEETWATER RIVER
NORTH PLATTE RIVER
POWDER RIVER
TONGUE RIVER
LODGEPOLE CREEK
LOCATION MAP
MISSOURI RIVER BASIN
45°
40°
110°



CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
KANSAS
MISSOURI
MISSISSIPPI
RIVER
N

MI



LEGEND

BASIN BOUNDARY

STATE OR NATIONAL BOUNDARY

COUNTY BOUNDARY

PERENNIAL STREAMS

LAKE OR RESERVOIR

GLACIAL TILL: OVERLIES AND CONTAINS SCATTERED DEPOSITS OF WATER-LAID SAND AND SANDY GRAVEL. DISCONTINUOUS IN SOME AREAS. PATTERN INDICATES CONTINUOUS OR NEARLY CONTINUOUS MANTLE OF LOESS MORE THAN 4 FEET THICK.

GLACIAL LAKE DEPOSITS

STREAM ALLUVIUM, TERRACE DEPOSITS, AND GLACIAL OUTWASH: EXTEND UNKNOWN DISTANCE WESTWARD BENEATH SAND DUNES IN CENTRAL NEBRASKA. PATTERN INDICATES CONTINUOUS OR NEARLY CONTINUOUS MANTLE OF LOESS MORE THAN 4 FEET THICK.

SAND DUNES

LOESS: GENERALLY MORE THAN 4 FEET THICK. DISCONTINUOUS IN SOME AREAS.

QUATERNARY DEPOSITS: VERY THIN OR NOT PRESENT.

SCALE 1:5,300,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

AREAL DISTRIBUTION OF UNCONSOLIDATED ROCKS OF QUATERNARY AGE

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

CHAPTER 3

CLIMATE

GENERAL DESCRIPTION

As might be expected in so large an area, major climatic differences exist within the Missouri Basin. Many of the meteorological phenomena which define the basin's climate vary somewhat uniformly but quite drastically in a southeast to northwest direction. In general, the range of climatic variation is from subhumid in the southeast to semi-arid in the north and west.

Summers are hot and winters are cold in all of the basin, but with lower average temperatures in the higher latitudes than in the lower latitudes during all seasons. The length of the freeze-free growing season decreases rapidly from southeast to northwest. Precipitation occurs both as rain and as snow in all of the basin states, but snowfall is greatest in the mountainous areas and snowfall in the plains area increases in a southeast to northwest direction. Relative humidity is generally high throughout the year except in the higher altitude areas in and near the mountains. Cloudiness is comparatively uniform throughout the basin, with the mean annual percentage of possible sunshine not far from 67 percent at any locality.

Storms occur in all parts of the basin and in all seasons of the year. They are most frequent in the mountainous areas and in the southeastern part of the basin, decreasing in frequency from southeast to northwest in the plains area.

CLIMATE CONTROL

The interior continental location of the Missouri River Basin and the absence of inland water bodies large enough to exert a significant influence on the climate make this region one of great daily, seasonal, and annual variation in weather phenomena. The north-south oriented Rocky Mountains along the basin's western boundary restrict inflow of air from the Pacific Ocean, and the Gulf of Mexico accordingly is the major source of moisture inflow into the basin.

The basin's expanse over a comparatively wide range of both latitude and longitude, the resultant significant range in distance from the major moisture source in the Gulf of Mexico, and the progressive modification of the moisture-laden air masses as they penetrate the basin are responsible for a marked decrease in precipitation from southeast to northwest. Similarly, the significant range in distance from Canadian sources of colder air is responsible for a marked increase in average temperature from north to south.

PRECIPITATION

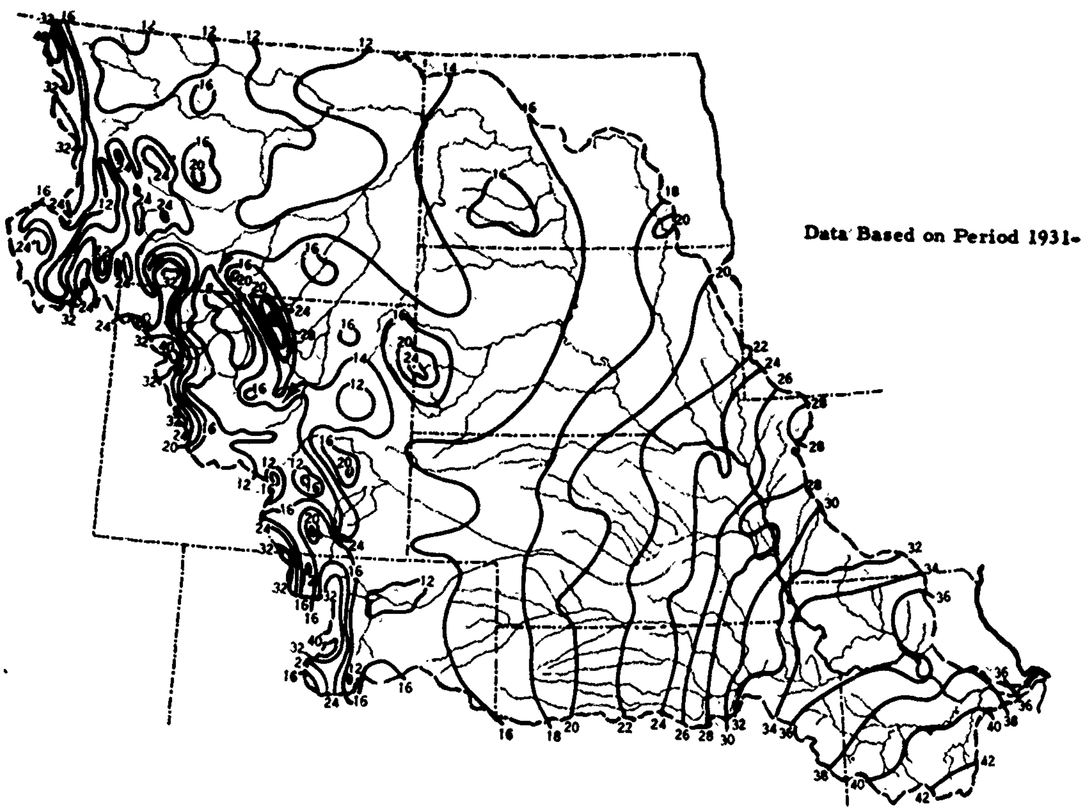
Throughout the Missouri Basin, precipitation is experienced in the form of both rain and snow. Generally, rain is much the larger contributor to annual precipitation. Normal annual precipitation decreases somewhat uniformly from more than 42 inches at the southeastern tip of the basin to less than 12 inches along the western edge of the high plains, where heavily moisture laden air from the Gulf of Mexico seldom penetrates and where the Rocky Mountains block off any sizeable amount of moisture from the Pacific Ocean. Farther west, in Rocky Mountain areas of higher elevation, annual precipitation increases to 30 to 40 inches, or more. The range of normal annual precipitation over the Missouri Basin is shown by figure 3.

With the great range in normal annual precipitation, obviously there are great differences in average precipitation over the basin's several subbasins. Also, everywhere in the basin, there are major differences in annual precipitation from year to year. Both of these differences are illustrated by plate 5, which shows, for the entire basin and for each of its several subbasins, adjusted average annual precipitation by years and the weighted mean for the period of record. The adjusted average annual values shown were obtained by Theissen-polygon weighting of individual station records and by transformation of station annual precipitation values to percent of normal.

Precipitation in the Missouri Basin is normally greater during the spring months and smaller during the fall and winter months. June is generally the month of greatest precipitation. Like annual precipitation, monthly precipitation varies greatly from year to year. Distribution of precipitation by months and the range of precipitation amounts during each month are illustrated by figure 4, which shows, for four representative localities in the

FIGURE 3

NORMAL ANNUAL TOTAL PRECIPITATION, (INCHES)



basin, the monthly distribution of normal annual precipitation and the maximum and minimum monthly amounts experienced.

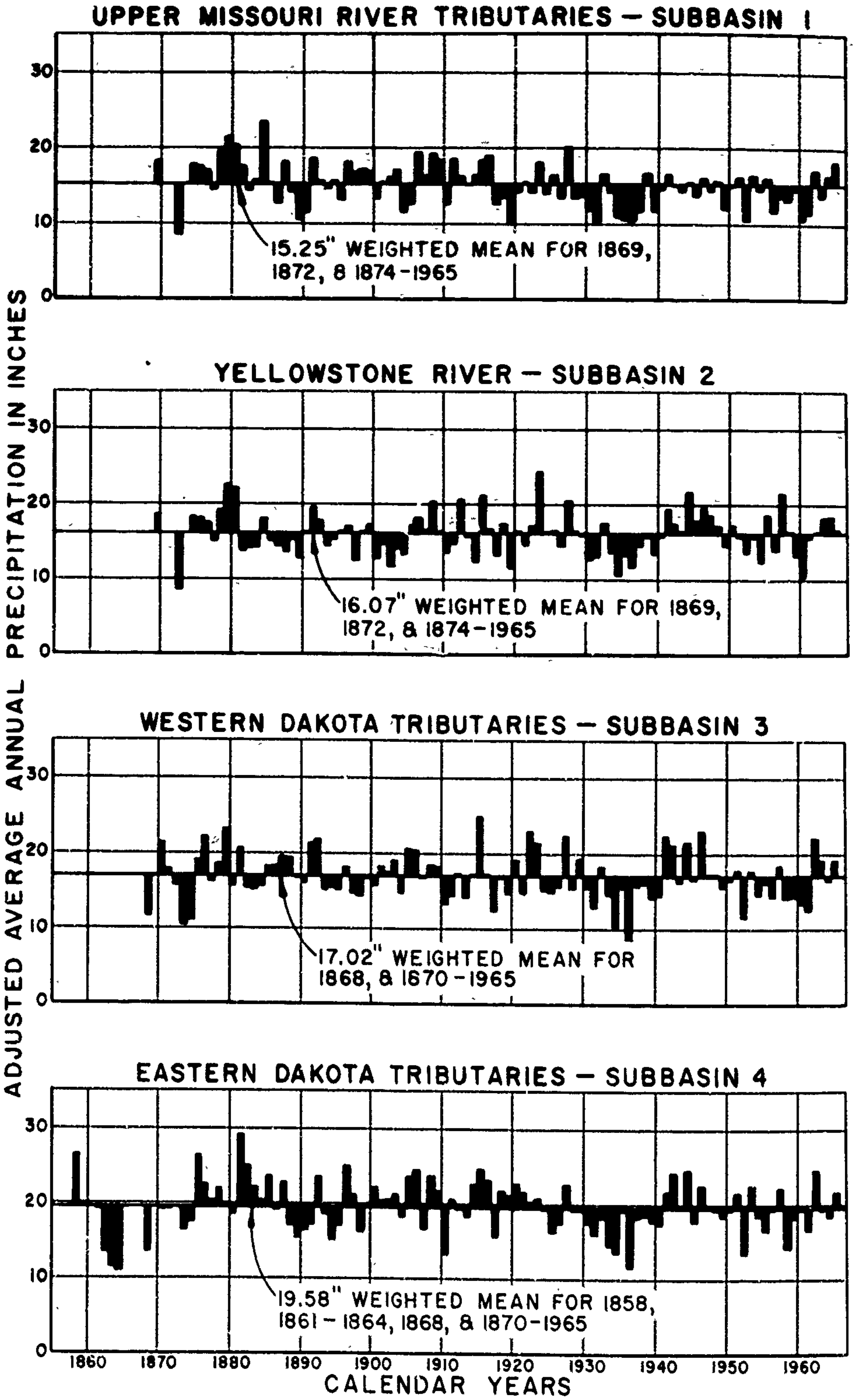
Rainfall

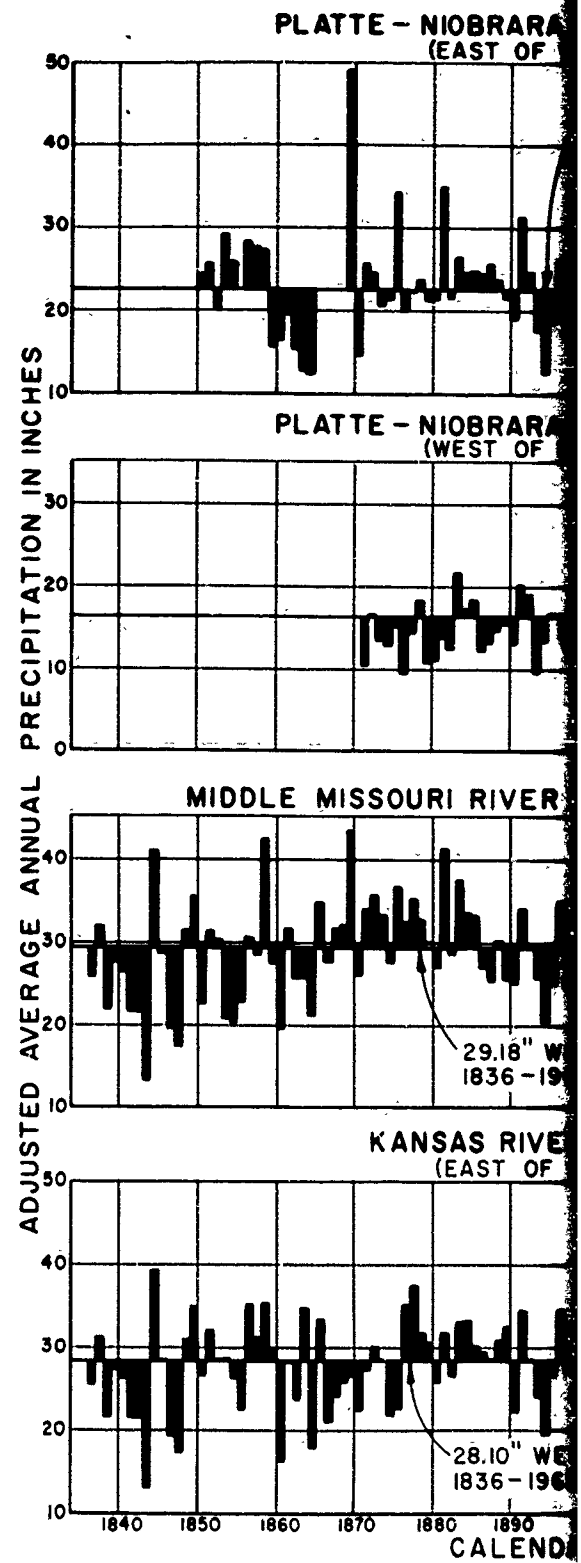
The influence of high-moisture air from the Gulf of Mexico is all important to the rainfall regimen of the basin. In those areas where air from the Gulf penetrates infrequently, rainfall is smaller in amount and it varies greatly from season to season and year to year. Like total precipitation, annual rainfall also decreases somewhat uniformly and quite drastically from southeast to northwest.

With the great range in annual rainfall, the intensity and amount of rainfall for any specific probability of occurrence also vary over a significant range. This is illustrated by figure 5 which shows, for the entire basin, the 24-hour precipitation amounts with a 4-percent probability of occurrence at any locality, that is, precipitation amounts that may be expected to be equalled or exceeded not oftener than once in 25 years, on the average. It will be noted that 24-hour precipitation with a 4-percent probability of occurrence ranges from over 6 inches in the southeastern portion of the basin to less than 2 inches in the northwestern portion, a ratio of over 3 to 1. Similar data for other time periods and for other probabilities are available in the U.S. Weather Bureau Technical Paper No. 40.

Precipitation probabilities for periods of time longer than 1 day are useful in determining irrigation requirements, in short-range planning of farming operations, as the basis for estimating streamflow probabilities, and as the basis for estimating carry-over storage requirements in ponds and small reservoirs. Studies of precipitation in the Missouri Basin for 1-week, 2-week, 4-week, and 8-week periods between March 29 and November 7 and for probability levels of 10, 50, 80, and 95 percent show that, in each case, the precipitation amounts in the southeastern part of the basin exceed those in the northwestern part. One of these studies is illustrated by figure 6, which shows the 1-week, 2-week, 4-week, and 8-week total precipitation amounts with a 10-percent probability of occurrence between March 29 and May 23, that is, amounts that may be expected to be equalled or exceeded during these periods not oftener than once in 10 years, on the average.

Rainfall often is in the form of major rainstorms, runoff from which is capable of producing damaging floods. Historical major flood-producing storms are described in Chapter 6 of this appendix. It is interesting to note that rain which fell at Holt, Mo., on June 22,


UPPER MISSOURI RIVER TRIBUTARIES – SUBBASIN 1
15.25" WEIGHTED MEAN FOR 1869, 1872, & 1874-1965
YELLOWSTONE RIVER – SUBBASIN 2
16.07" WEIGHTED MEAN FOR 1869, 1872, & 1874-1965
WESTERN DAKOTA TRIBUTARIES – SUBBASIN 3
17.02" WEIGHTED MEAN FOR 1868, & 1870-1965
EASTERN DAKOTA TRIBUTARIES – SUBBASIN 4
19.58" WEIGHTED MEAN FOR 1858, 1861-1864, 1868, & 1870-1965
ADJUSTED AVERAGE ANNUAL PRECIPITATION IN INCHES
0
10
20
30
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
CALENDAR YEARS


PLATTE – NIOBRARA
(EAST OF
PLATTE – NIOBRARA
(WEST OF
MIDDLE MISSOURI RIVER
29.18" W
1836-19
KANSAS RIVE
(EAST OF
28.10" WE
1836-196
ADJUSTED AVERAGE ANNUAL PRECIPITATION IN INCHES
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40
50
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1850
1860
1870
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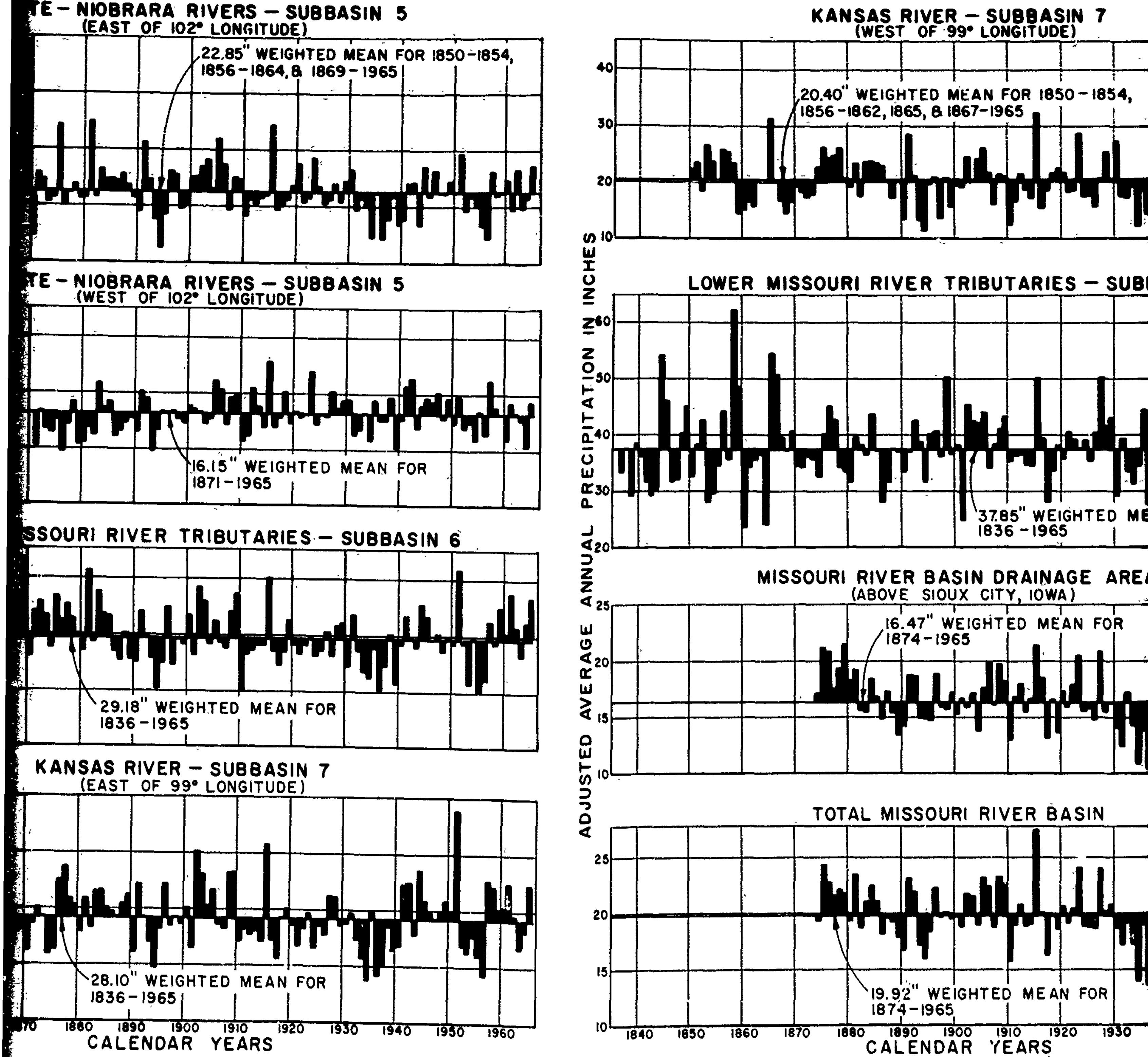
1890
CALEND



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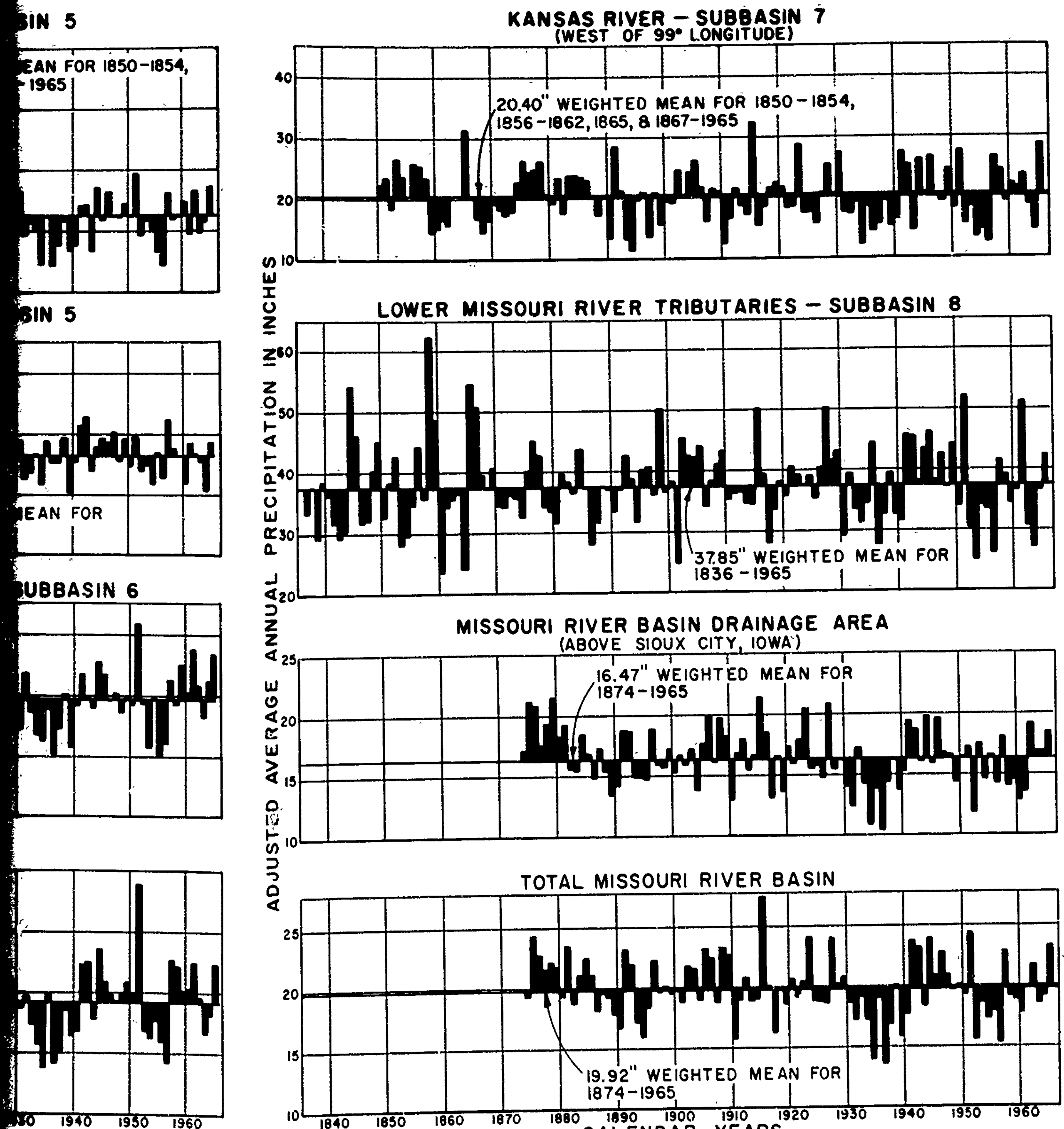
MISSOURI BASIN INTER-A



ADJUSTED AVERAGE ANNUAL PRECIPITATION IN INCHES

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

1947, amounting to 12 inches in 42 minutes, established a world record for rainfall of this duration.

Mountain Snowfall

Much of the usable water in the upper portion of the Missouri Basin originates as mountain snowfall. Advance knowledge of water supply, through forecasting of streamflow from this source, aids water managers and users both in planning and in actual use of this water for maximum economic benefit. Snow surveys and soil-moisture determinations accordingly are carried out in the mountainous portions of Montana, Wyoming, Colorado, South Dakota, and the Canadian Province of Alberta.

The usefulness of water-supply forecasting is due largely to the time lag between winter snowfall and spring runoff and to the greater effectiveness of winter

FIGURE 4
MONTHLY DISTRIBUTION OF PRECIPITATION

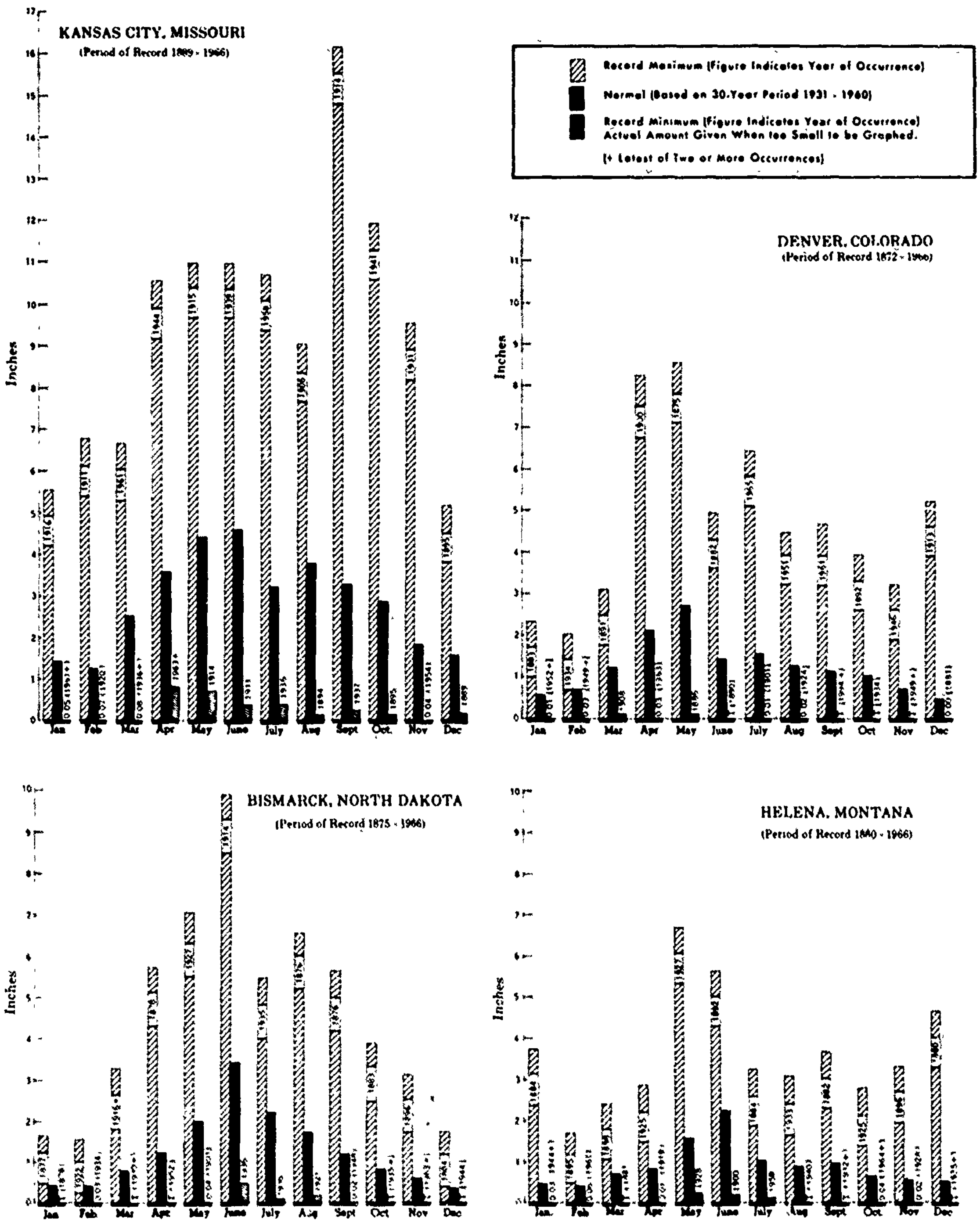
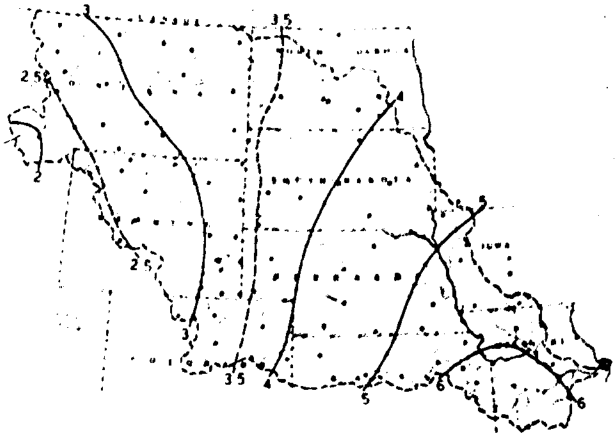


FIGURE 5

24-HOUR, 25-YEAR RAINFALL, (INCHES)



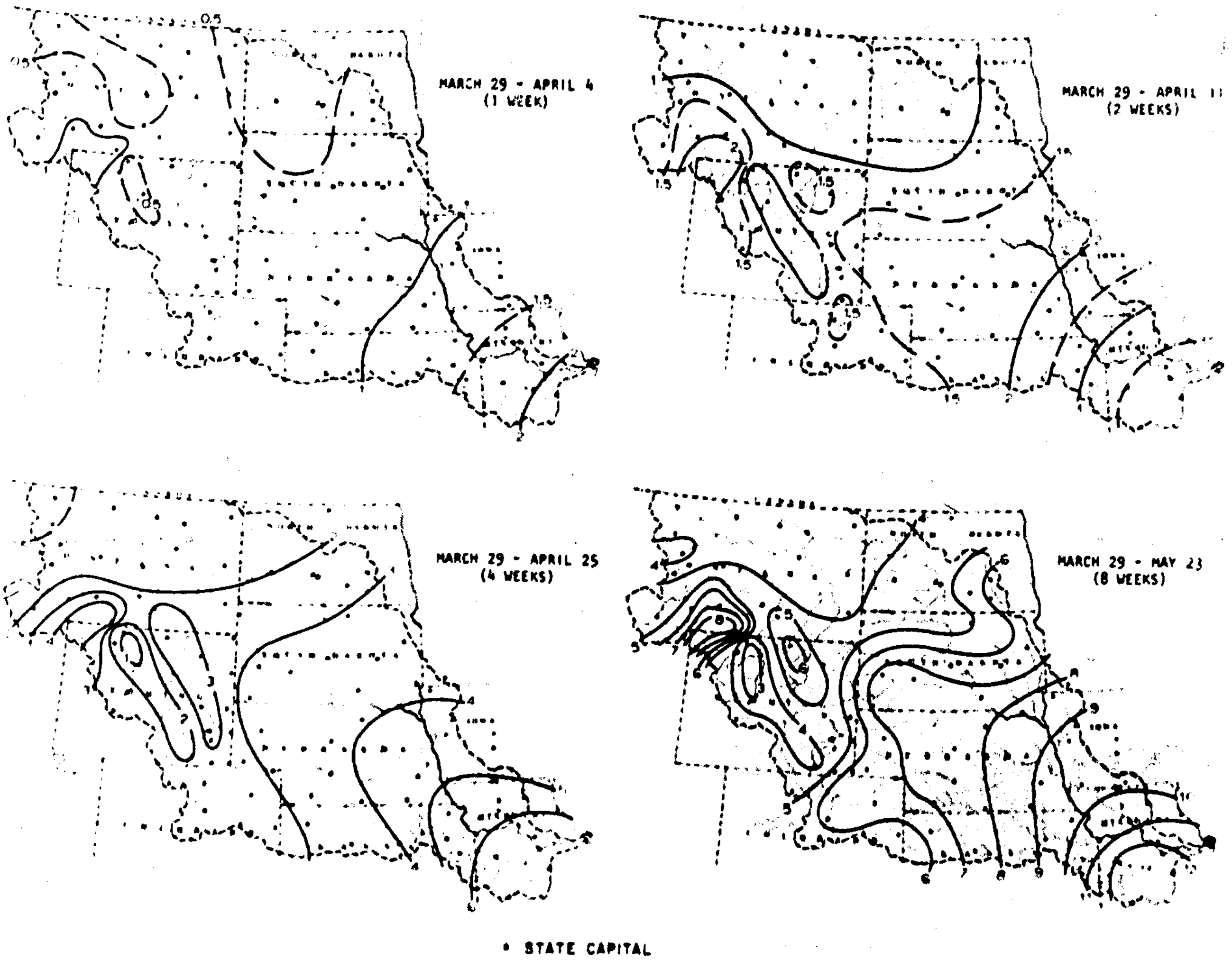
• STATE CAPITAL
• PRECIPITATION STATION

snowfall, as compared to summer rainfall, in producing runoff. Users of irrigation water particularly find streamflow forecasts useful in preparing their annual cropping plans. During years of predicted limited supply, they are able to adopt conservation measures and avoid demands in excess of supply; and during years of predicted plentiful supply, they are able to plan with confidence for expanded crop production. Streamflow forecasts are of value also to water users in the fields of power production and municipal water supply and to industries whose operations are affected by a fluctuating water supply.

There are currently 200 snow courses in operation in the Missouri Basin. Records extending back to 1919 are available for some snow courses, but data for the earlier years are not comparable to data currently being collected. Longest continuous records providing first-of-the-month data are for a 34-year period through 1967.

FIGURE 6

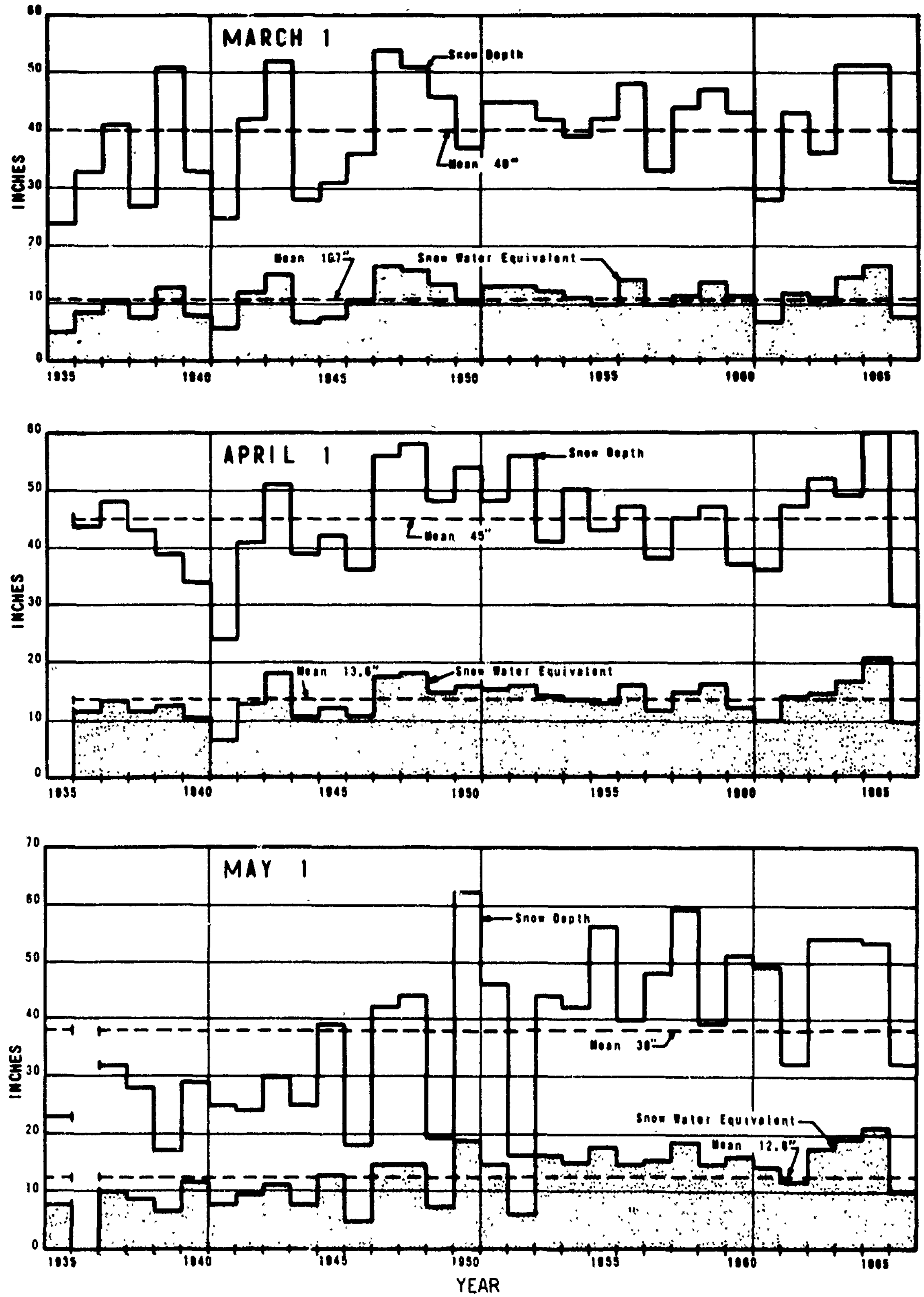
1-, 2-, 4-, AND 8-WEEKS PRECIPITATION TOTALS (INCHES) EXCEEDED 10 YEARS IN 100



• STATE CAPITAL
• PRECIPITATION STATION

FIGURE 7
TYPICAL SNOW COURSE MEASUREMENTS

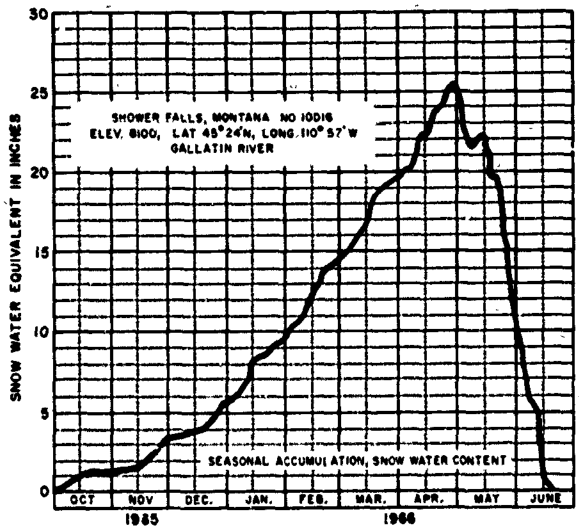
TEN MILE UPPER, MONTANA — NO. 12C04 — ELEV. 8000
MISSOURI RIVER MAIN STEM — LAT. 46°25'N — LONG. 112°17'W



Records for some snow courses are of such short duration that they cannot be considered as representative. Typical snow-course measurements, showing snow depth and snow water equivalent, are illustrated by figure 7.

Some snow courses are now being equipped with so-called snow pillows, which measure the water equivalent in the snow by variations in pressure. These are recorded automatically by instruments at the site and are transmitted to a base station by a telemetry system. The snow pillows provide continuous records of snow water equivalent. A typical record of snow water equivalent at a pillow-equipped snow course is illustrated by figure 8.

FIGURE 8
TYPICAL SNOW PILLOW CURVE

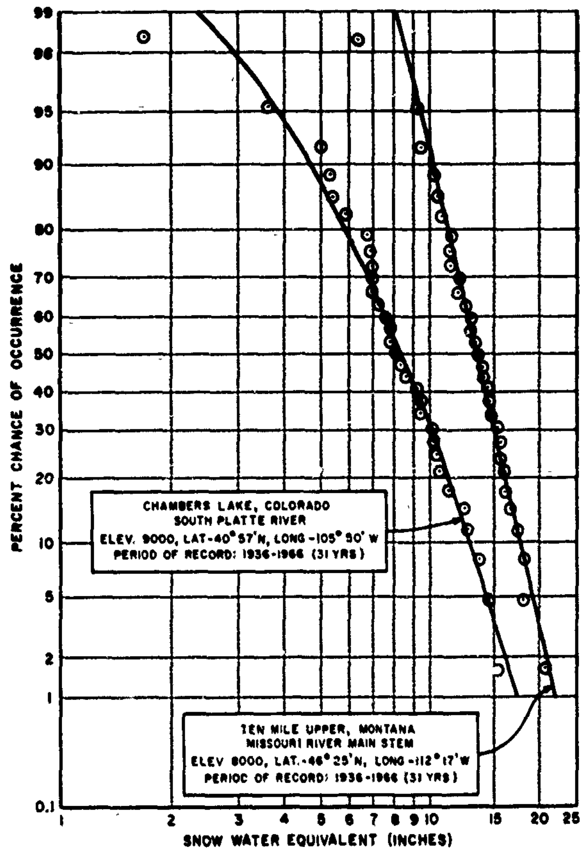


About 30 soil-moisture stations are in operation in the Missouri River Basin. Records are available for a maximum of 14 years, through 19o7. Some of the stations are located on or near snow courses. Soil-moisture data permits determination of the amount of snowpack moisture that will be absorbed in the soil before snowmelt runoff begins.

An analysis has been made of data from 144 snow courses within the basin and from 23 others outside of but adjacent to the basin, all with at least 6 continuous years of April 1 record, and of data from 16 soil-moisture stations within the basin and from three others adjacent, all with at least 3 years of record. As an illustration of the nature of the basin's mountain snowpack, table 2 has been compiled to show the range of maximum, minimum, and median water equivalents for snow courses in several tributary basins.

Based upon the preceding analysis, frequency curves have been prepared to show the probability of occurrence at each snowcourse of a snowpack with a given water equivalent. Typical frequency curves at two snow courses, for water equivalent in the snowpack on 1 April, are shown on figure 9.

FIGURE 9
TYPICAL FREQUENCY CURVES
SNOW WATER EQUIVALENT (APRIL 1)



Plains Snowfall

The plains portion of the Missouri Basin extends westward from its eastern boundary to the edge of the mountainous areas in the west and northwest. It slopes gently upward from elevations belov. 1,000 feet, mean sea level, in the southeast to elevations in excess of 5,000 feet, mean sea level, near the mountainous areas. A part or all of each of the 10 basin States lies within this plains area.

Snowfall has been experienced everywhere in this area. Average annual precipitation decreases from southeast to northwest in the plains area, but this is not true for snowfall. Average annual snowfall is about 50 inches in the western high plains, is about 40 inches in the eastern Dakotas, and decreases to about 15 inches in southern Missouri.

Maximum 24-hour snowfall at first order weather stations in the plains area has ranged from 10 to 26 inches, maximum monthly snowfall has ranged from 20 to 48 inches, and annual snowfall, from July to the

Table 2 – SNOW SURVEY DATA, MOUNTAIN SNOW WATER EQUIVALENT IN INCHES

Range of Maximum, Minimum, and Median Amounts Experienced at Snow Courses in Tributary Basins

Tributary Basin	Approximate Date of Measurement				
	January 1	February 1	March 1	April 1	May 1
UPPER MISSOURI RIVER TRIBUTARIES (Marias, Sun, Teton, Milk, Judith, Musselshell Rivers)					
Maximum	5.0-15.0	6.6-20.6	6.6-26.8	7.1-35.1	7.8-33.0
Median	1.5- 7.5	2.9-12.2	3.8-19.4	4.5-21.9	1.5-14.0
Minimum	0.1- 2.0	0.8- 4.2	0.2-11.3	0 -13.7	0 - 4.6
JEFFERSON RIVER					
Maximum	5.0-19.5	5.5-23.8	6.6-29.7	7.5-32.4	0 -29.2
Median	2.4- 9.7	2.8-14.6	3.9-19.5	4.6-23.4	3.2-21.4
Minimum	0.7- 4.4	1.1- 5.6	1.8-10.2	0.7-14.9	0 - 9.9
MADISON RIVER					
Maximum	7.8-13.5	11.5-24.4	15.3-30.8	15.6-34.9	11.5-21.0
Median	3.8- 6.5	6.6-11.3	8.5-17.7	8.9-21.8	2.3-15.9
Minimum	0.8- 1.9	2.7- 5.6	4.9- 9.2	5.4-10.4	0 - 9.2
GALLATIN RIVER					
Maximum	6.8-15.4	8.7-23.1	11.6-27.0	14.4-29.8	12.1-32.0
Median	4.4- 6.2	4.8-10.4	6.8-17.3	9.3-20.5	5.7-23.4
Minimum	1.6- 1.9	3.0- 4.2	4.4- 9.4	3.0-12.7	0 -15.2
UPPER YELLOWSTONE RIVER (above Billings, Montana)					
Maximum	6.6-27.3	10.4-37.5	8.6-47.8	10.9-52.4	10.2-27.0
Median	3.5-11.8	5.7-19.0	4.5-24.1	5.2-29.1	0.2-16.8
Minimum	1.2- 4.8	2.8- 8.2	1.3-10.1	2.7-15.6	0 -12.9
LOWER YELLOWSTONE-BIGHORN RIVER					
Maximum	---	3.3-32.3	4.3-36.2	5.2-43.2	0 -47.4
Median	---	1.6-18.6	4.3-24.4	3.0-27.7	1.0-32.7
Minimum	---	0 - 8.5	0.8-17.5	0.6-16.9	0 -23.9
LOWER YELLOWSTONE-TONGUE RIVER					
Maximum	---	7.4-19.5	9.2-24.3	10.8-26.1	12.6-32.5
Median	---	5.0-11.7	6.6-16.5	7.6-19.8	8.6-22.0
Minimum	---	1.0- 7.6	1.0-10.0	3.8-13.2	4.6-16.6
LOWER YELLOWSTONE-POWDER RIVER					
Maximum	---	4.4-12.5	5.2-14.0	5.5-19.0	5.7-23.4
Median	---	2.3- 5.4	3.4-19.5	4.0-12.3	3.6-15.5
Minimum	---	1.2- 2.5	1.7- 3.8	2.0- 5.9	0 -10.0
CHEYENNE-BELLE FOURCHE RIVERS (1 snow course)					
Maximum	---	8.7	9.9	10.4	---
Median	---	4.3	6.0	8.0	---
Minimum	---	1.2	2.3	2.7	---
NORTH PLATTE RIVER					
Maximum	---	6.8-30.5	8.0-36.1	9.4-47.8	7.8-47.9
Median	---	2.8-18.5	4.9-23.6	5.9-31.0	0 -33.0
Minimum	---	1.0-12.2	1.4-16.0	1.2-23.0	0 -25.1
SOUTH PLATTE RIVER					
Maximum	---	4.5-22.2	4.1-32.0	5.0-38.9	3.4-38.9
Median	---	1.6-13.2	2.1-17.8	2.5-24.8	0 -17.2
Minimum	---	0 - 7.8	0.5-11.7	0 -16.1	0 -17.3

following June, has ranged from 40 to 87 inches. Distribution of these maximum indicates that heavy snowfall for short periods is as likely in the lower plains of Nebraska, Kansas, and Missouri as it is elsewhere in the plains area.

About 50 percent of the average annual snowfall in the high plains area occurs during the 3-month period, January through March. This percentage increases to 65 percent in the middle plains area, and to 70 percent in the lower plains area. March is normally the month of greatest snowfall throughout the plains area.

Plains snowfall during the fall months usually melts during periodic thaws and, accordingly, it rarely accumulates on the ground for a significant time. Accumulation during the winter months is much more likely, and there have been years of accumulation from February to late March without significant thawing. Years of major accumulation were 1881, 1948, 1949, 1950, 1952, and

1960; and in each of these years, there existed centers of water equivalent in excess of 6 inches in the snow cover. In each of these years devastating floods occurred when the accumulated snow melted.

As does average annual snowfall, the water equivalent of the snow cover in the plains area increases in a general northeasterly direction. The water equivalent is usually highest during the first half of March. Plate 6, an adaption of data shown on page 19 of the U. S. Weather Bureau Technical Paper No. 50, shows the maximum March 1-15 water equivalent of the plains snow cover that may be expected to be equalled or exceeded, on the average, not oftener than once in 25 years. The secondary maximum shown on this plate in western South Dakota and eastern Wyoming is influenced by the existence of the Black Hills, where the topography and characteristics of snow accumulation resemble those of the mountainous areas of the basin.

TEMPERATURE

Basin Temperature Characteristics

All parts of the Missouri Basin experience a great range of temperature variation between winter and summer because of the frequent presence of cold continental polar air in the winter and warm continental air in the summer. Temperatures higher than 100°F in the summer and appreciably lower than 0°F in the winter have been experienced in all the basin states. Maximum and minimum temperatures recorded in the basin have been 121°F in both Kansas and North Dakota in July 1936 and -70°F at Rogers Pass in Montana in January 1954. The range of temperature variations in the basin is illustrated by figure 10 which shows temperature distribution by months for selected stations.

In the absence of any east-west oriented mountain barrier in the basin, temperatures show a definite latitudinal variation. In all seasons of the year, average temperatures generally are significantly higher in the southern part of the basin than in the northern part. This latitudinal variation in temperature is illustrated by figures 11 and 12, which show normal daily maximum and minimum temperatures throughout the basin during January, normally the coldest month of the year, and during July, normally the warmest month.

The isotherms shown on the preceding figures for January indicate the general path of cold polar outbreaks moving from northwest to southeast and the associated moderation of these outbreaks as they progress to the south and east. The summer isotherms are much less indicative of the penetration of a particular type of air mass, and they reflect, to a considerable degree, the presence of continental air greatly influenced by land use. The preceding figures also illustrate the influence of the rugged western topography on local temperatures.

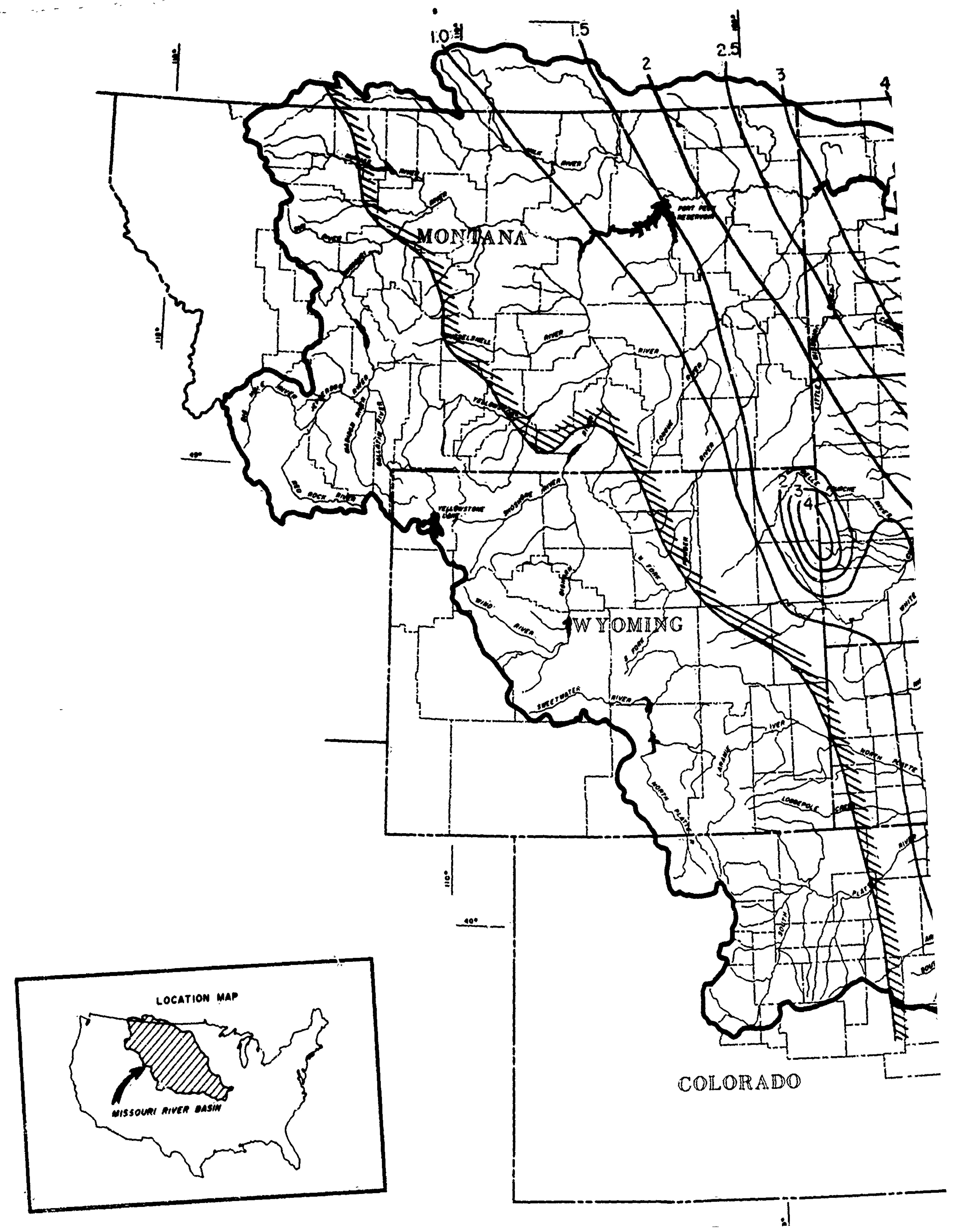
Diurnal temperature variation is quite pronounced throughout the basin. This is particularly true during the warmer months of the year. The variation may amount to as much as 30 degrees in late summer.

Latitude and elevation play important roles in the occurrence of the higher summer temperatures and the lower winter temperatures. High temperatures are experienced most frequently in the lower latitudes and in the plains area, less frequently in the higher latitudes, and least frequently in the mountainous areas. Similarly, low temperatures are experienced least frequently in the lower latitudes, more frequently in the higher latitudes, and most frequently in the mountainous areas. This is illustrated by figures 13 and 14 which show, respectively, the mean annual number of days that maximum temperatures are 90°F and above, and the mean annual number of days that minimum temperatures are 32°F and below. It is illustrated also by figures 15 and 16, which show, respectively, the normal annual total heating degree-days, or degree-days below 65°F, and the normal annual total cooling degree-days, or degree-days above 65°F.

Growing Season

The length of the crop-growing season in the Missouri River Basin also is influenced by latitude and elevation. It has an extremely wide range. The very short growing seasons occur in the mountainous areas where they are not particularly significant. Even in the plains area, however, the variation in length of growing season is substantial.

The mean date of the last occurrence of a temperature of 32°F or lower in the spring varies from before April 10 in small areas in the extreme southeastern part of the basin to after May 30 in the northern part of the plains area and to after June 30 in some of the mountainous areas. The mean date of the first occurrence of a temperature of 32°F or lower in the autumn varies from before July 30 in some of the mountainous areas and before September 10 in the northern part of the plains area to after October 20 in the extreme southeastern part of the basin. The mean length of the freeze-free period, the period available for crop growth, ranges from over 180 days in the extreme southeastern part of the basin to less than 120 days in the northern part of the plains area and to less than 30 days in some of the mountainous area. Figures 17 and 18 show, respectively, the variation in mean date of the first occurrence of a temperature of 32°F or lower in the autumn and the variation in mean date of last occurrence of a temperature of 32°F or lower in the spring. Figure 19 shows the variation in the mean length of the freeze-free period.



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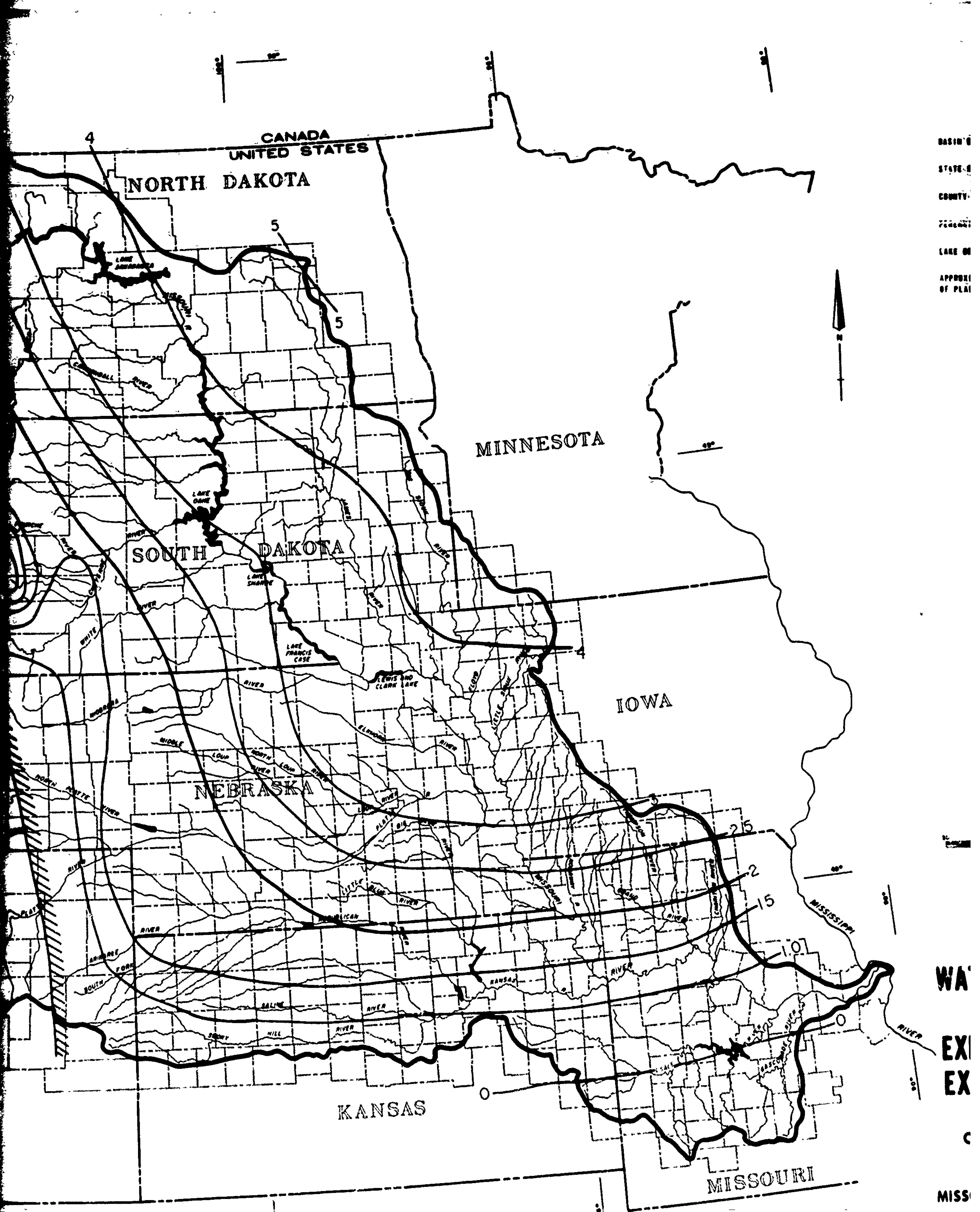
4
MONTANA
WYOMING
COLORADO
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
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MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
KANSAS
MISSOURI
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
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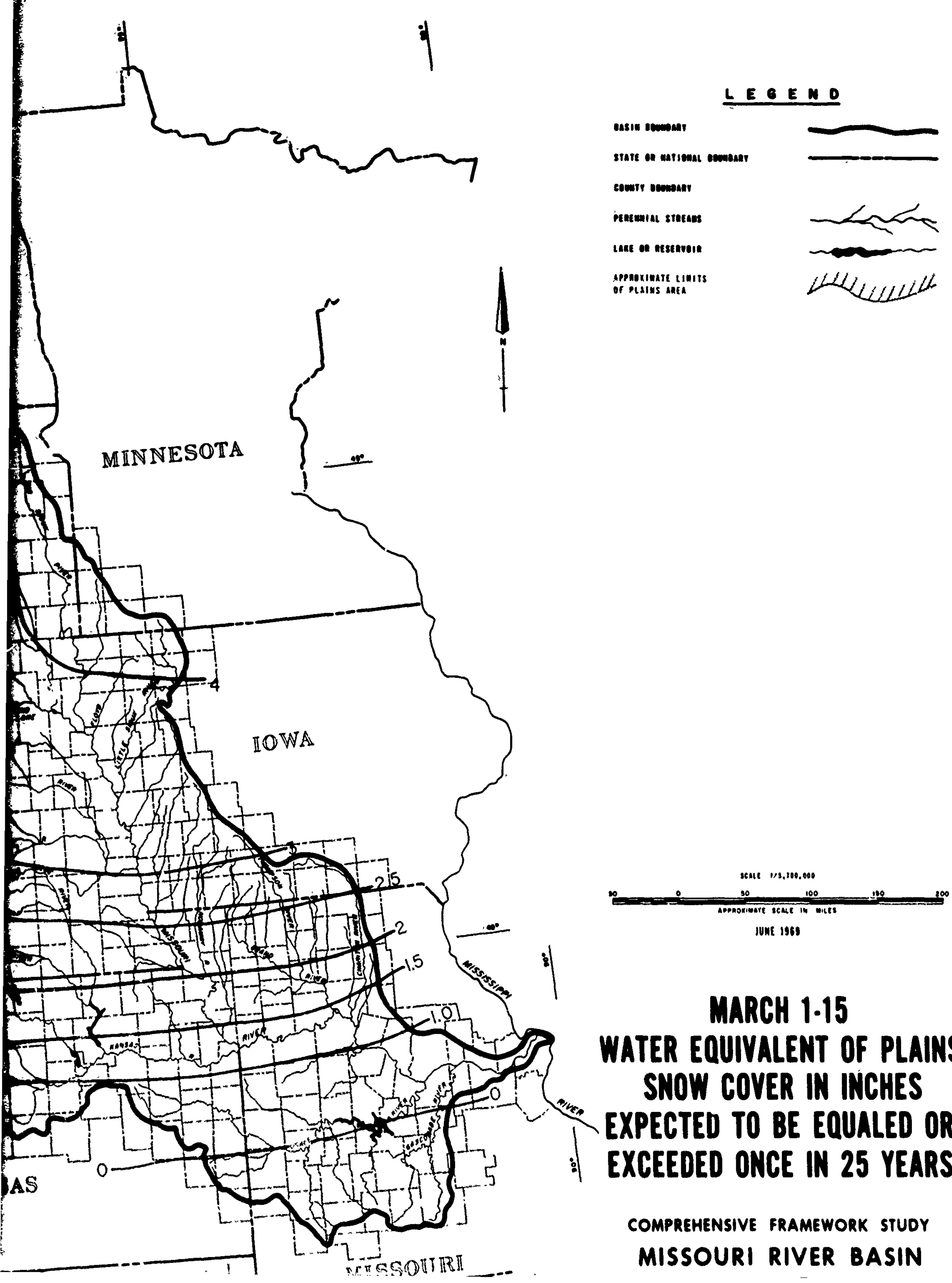


JUNE 1969

MARCH 1-15 WATER EQUIVALENT OF PLAINS SNOW COVER IN INCHES EXPECTED TO BE EQUALED OR EXCEEDED ONCE IN 25 YEARS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

FIGURE 10
TEMPERATURE DISTRIBUTION BY MONTHS

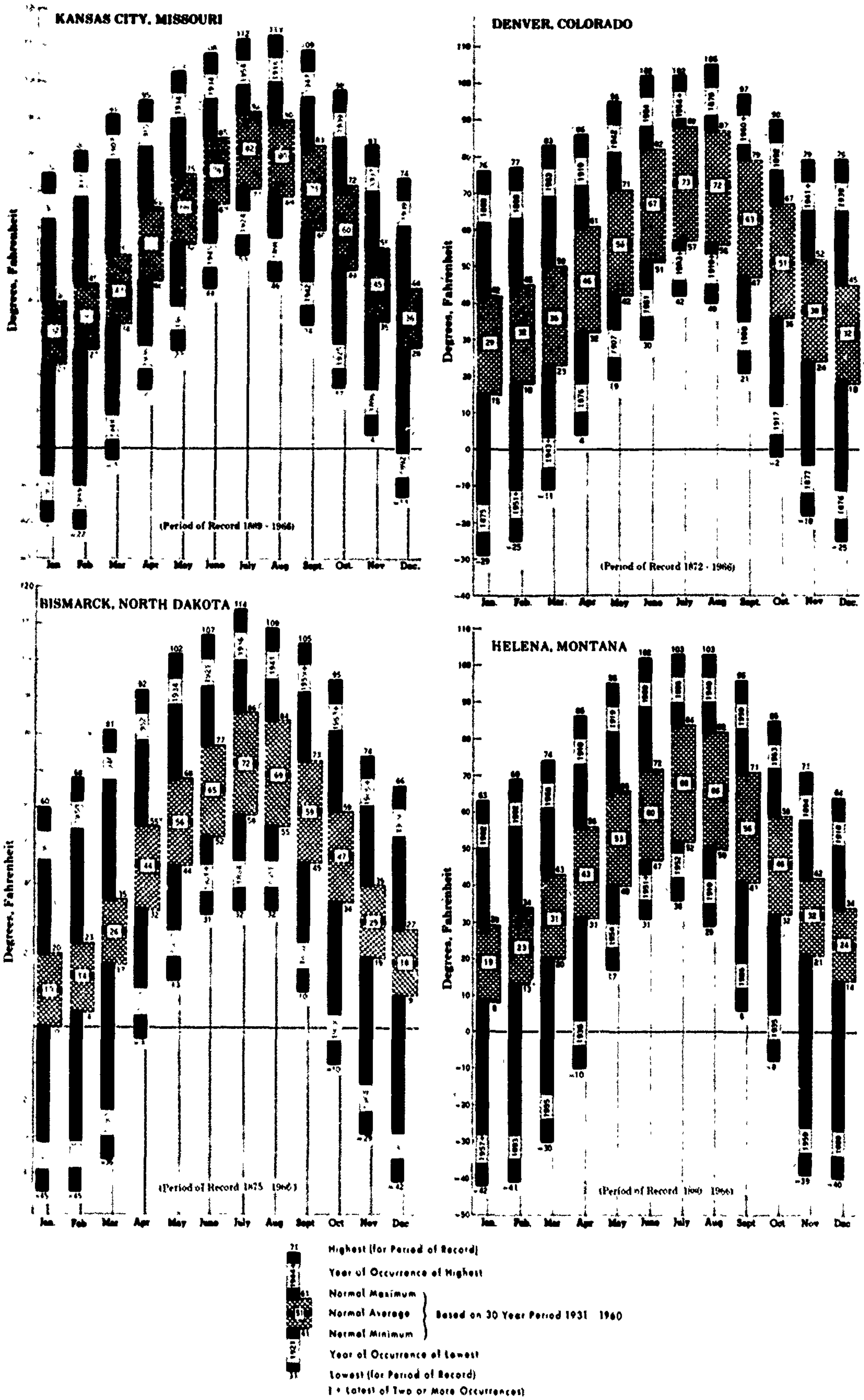
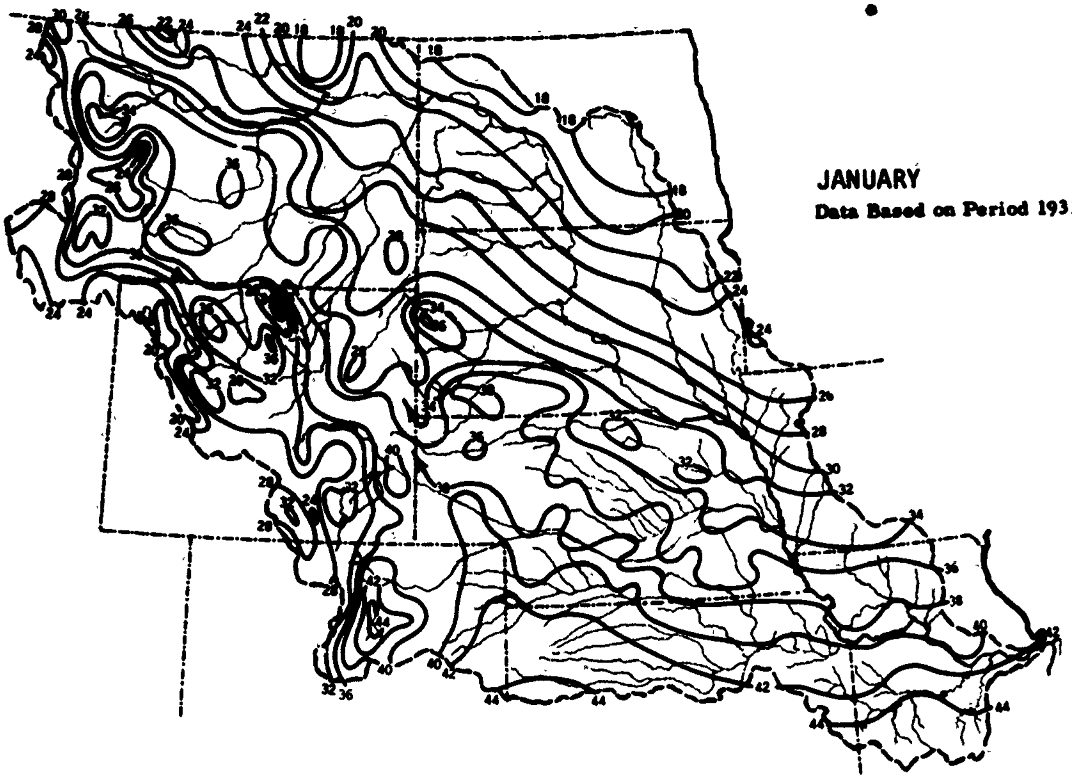
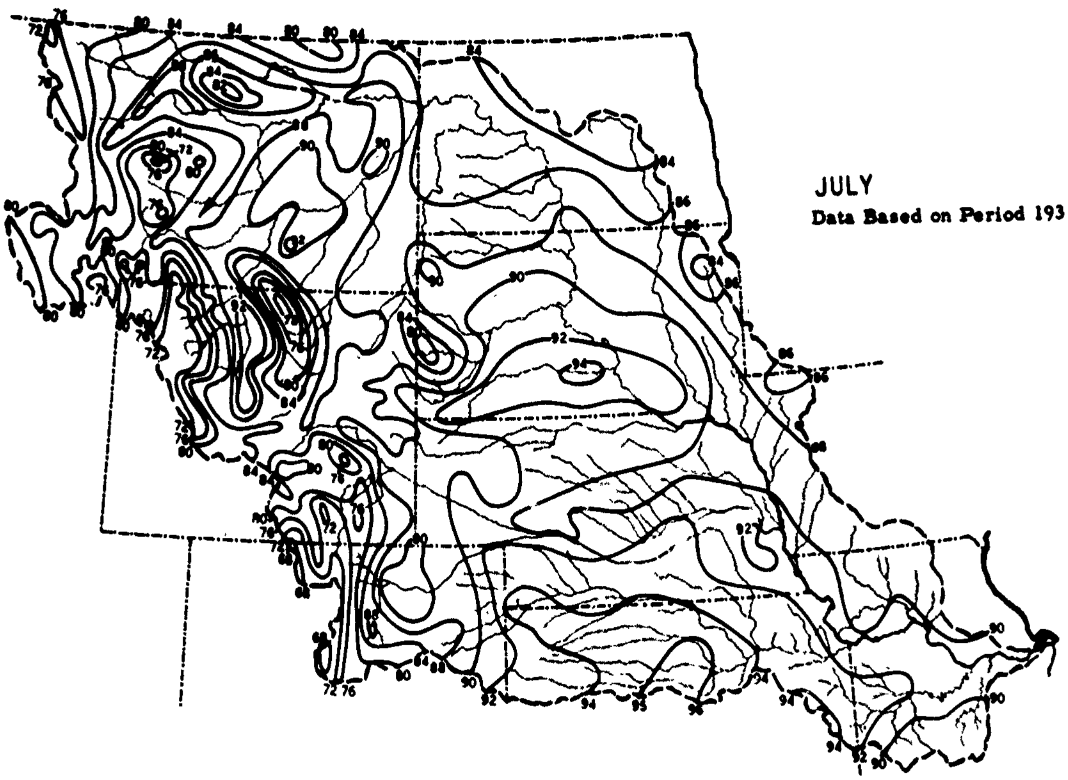


FIGURE 11

NORMAL DAILY MAXIMUM TEMPERATURES (°F)



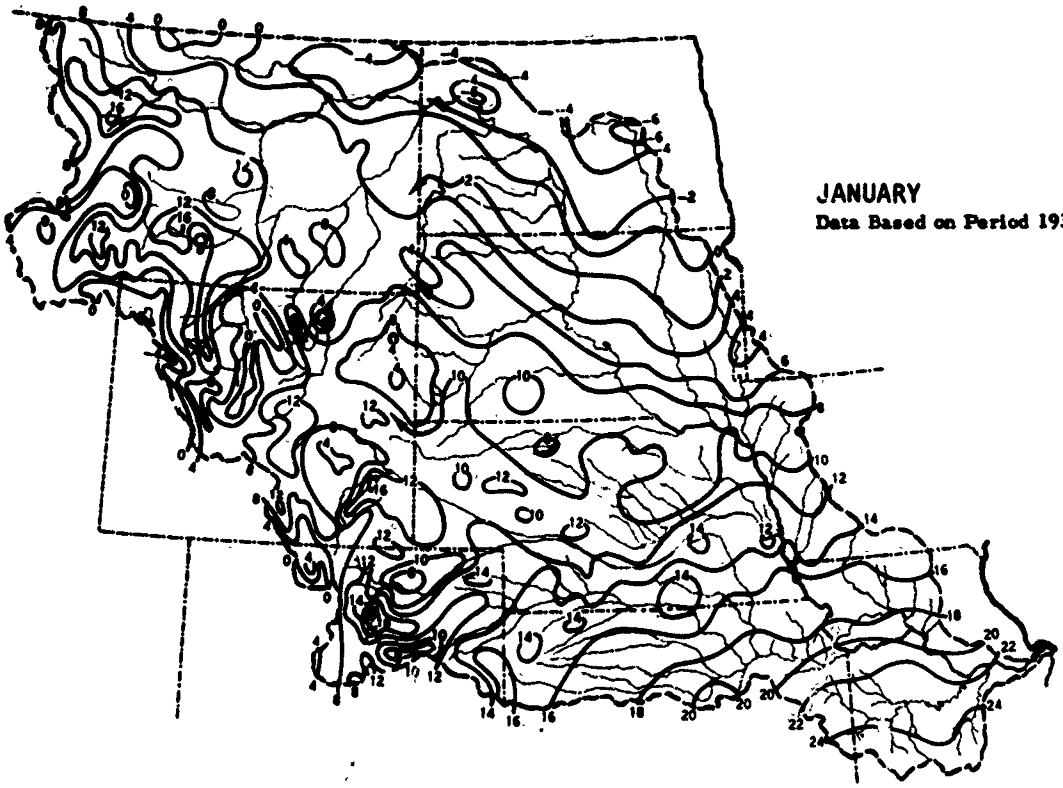
JANUARY
Data Based on Period 1931-1960



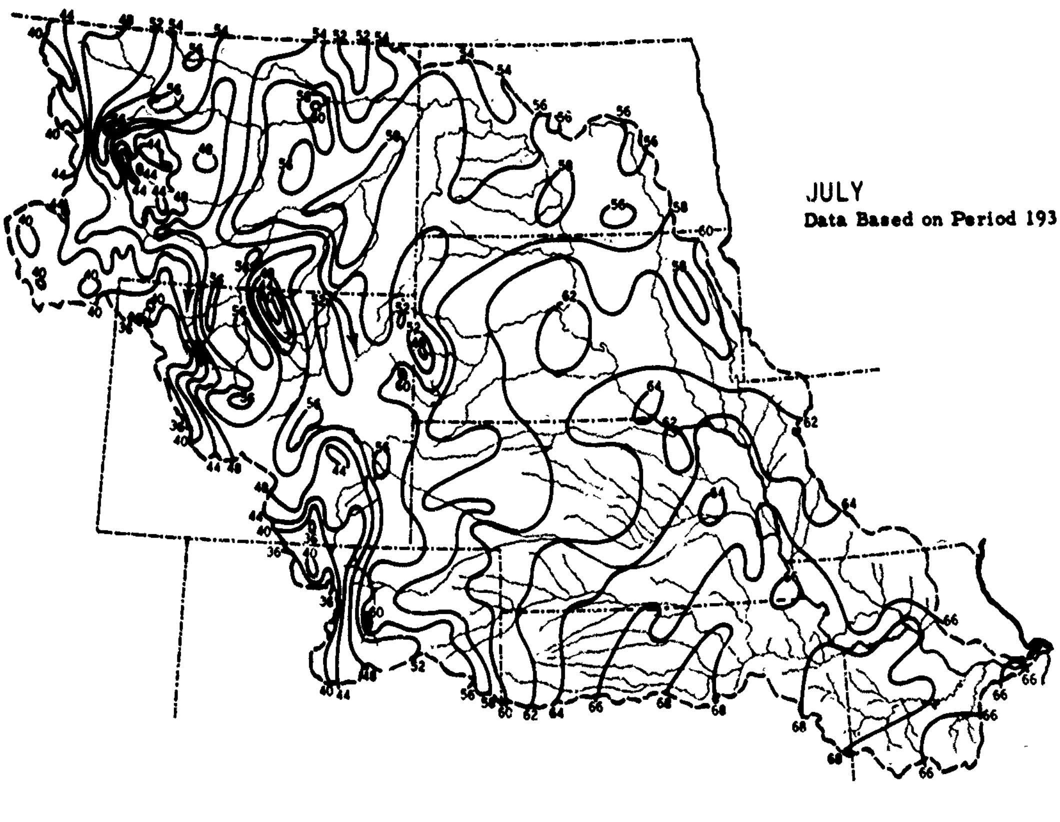
JULY
Data Based on Period 1931-1960

FIGURE 12

NORMAL DAILY MINIMUM TEMPERATURES (°F)



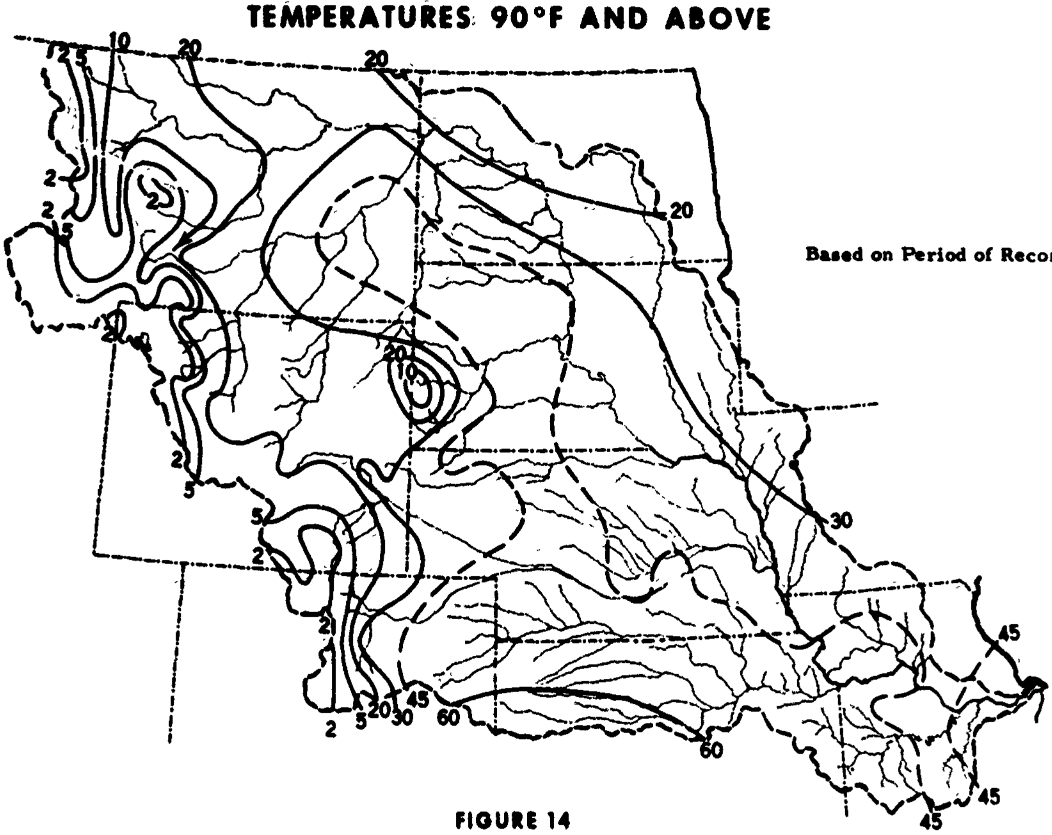
JANUARY
Data Based on Period 1931-1960



JULY
Data Based on Period 1931-1960

FIGURE 13

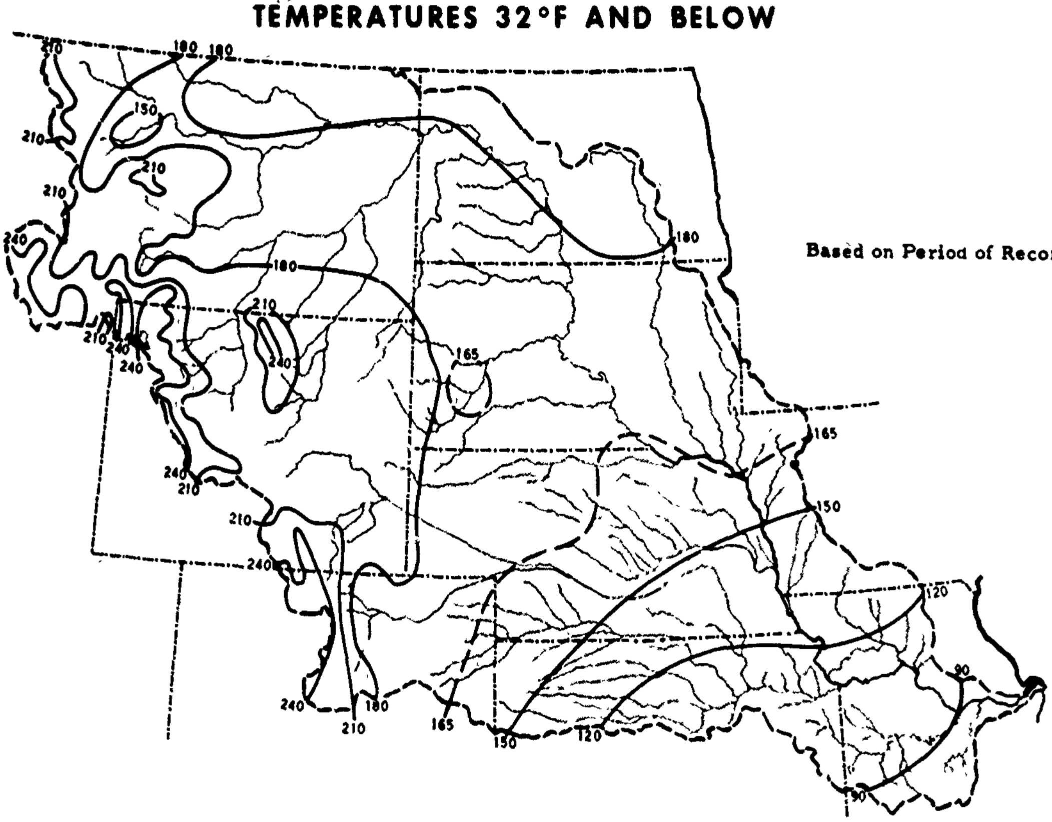
MEAN ANNUAL NUMBER OF DAYS MAXIMUM TEMPERATURES 90°F AND ABOVE



Based on Period of Record Through 1964

FIGURE 14

MEAN ANNUAL NUMBER OF DAYS MINIMUM TEMPERATURES 32°F AND BELOW



Based on Period of Record Through 1964

FIGURE 15

NORMAL ANNUAL TOTAL OF DEGREE DAYS BELOW 65°F

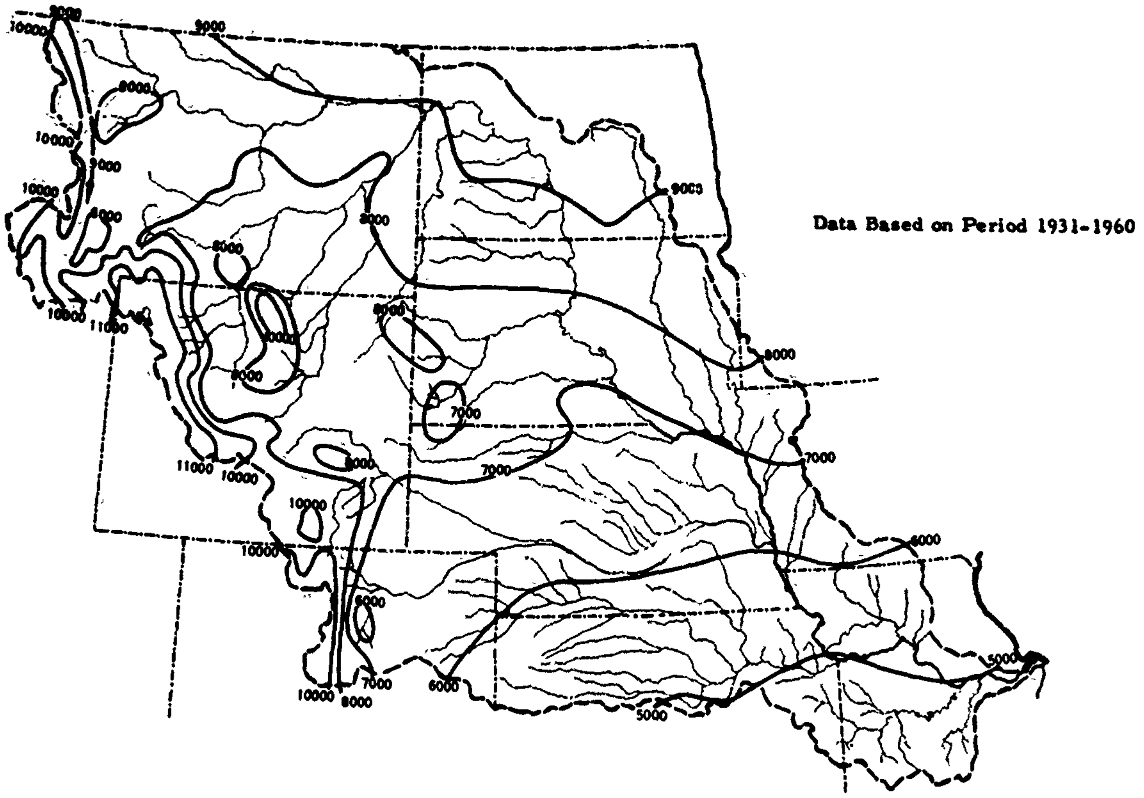


FIGURE 16

NORMAL ANNUAL TOTAL OF DEGREE DAYS ABOVE 65°F

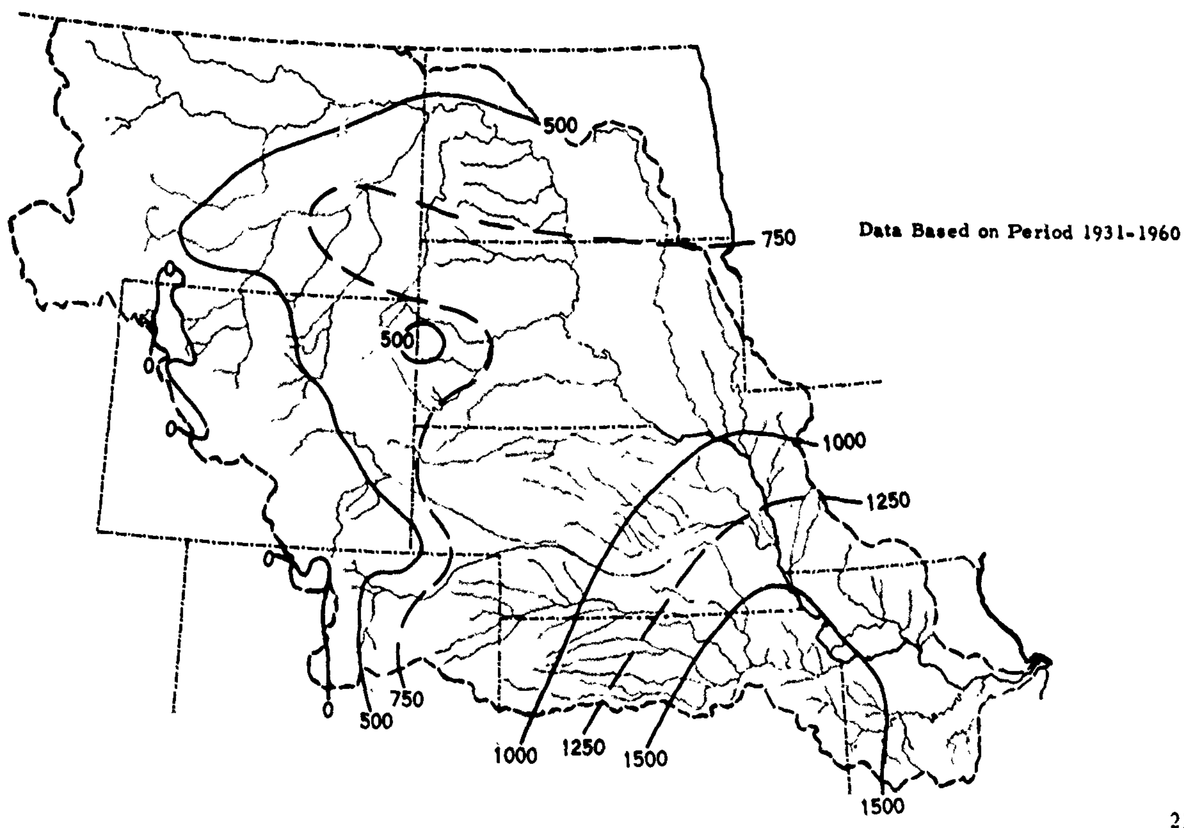
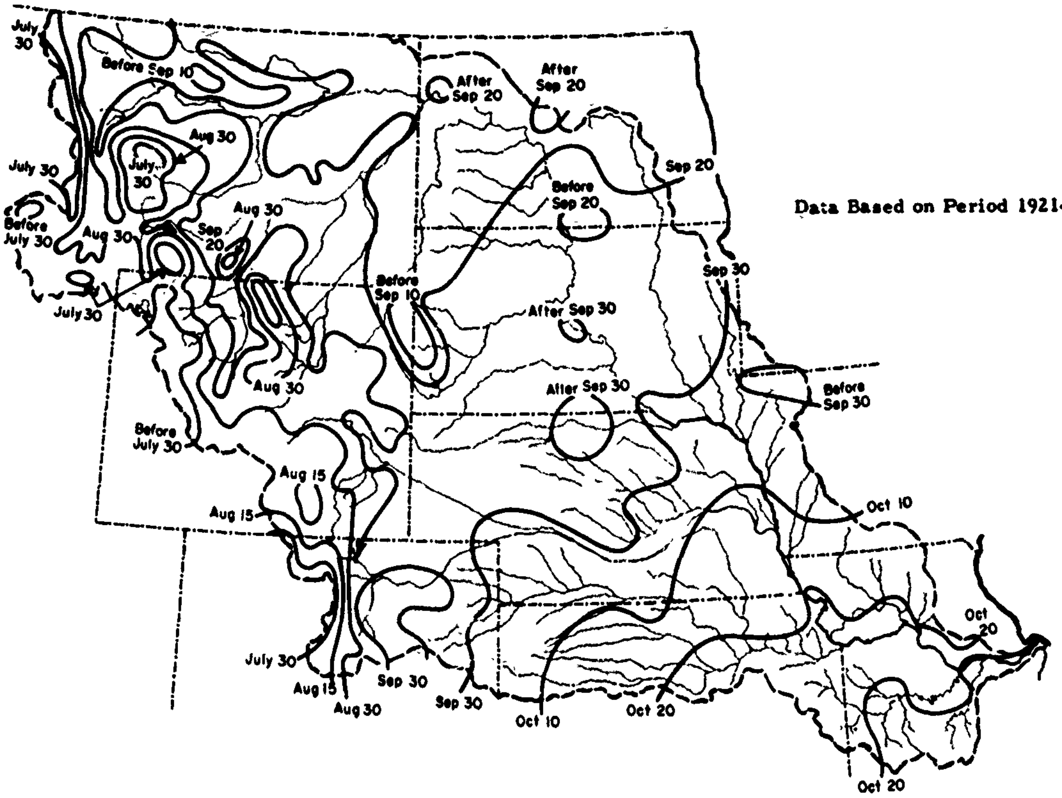


FIGURE 17

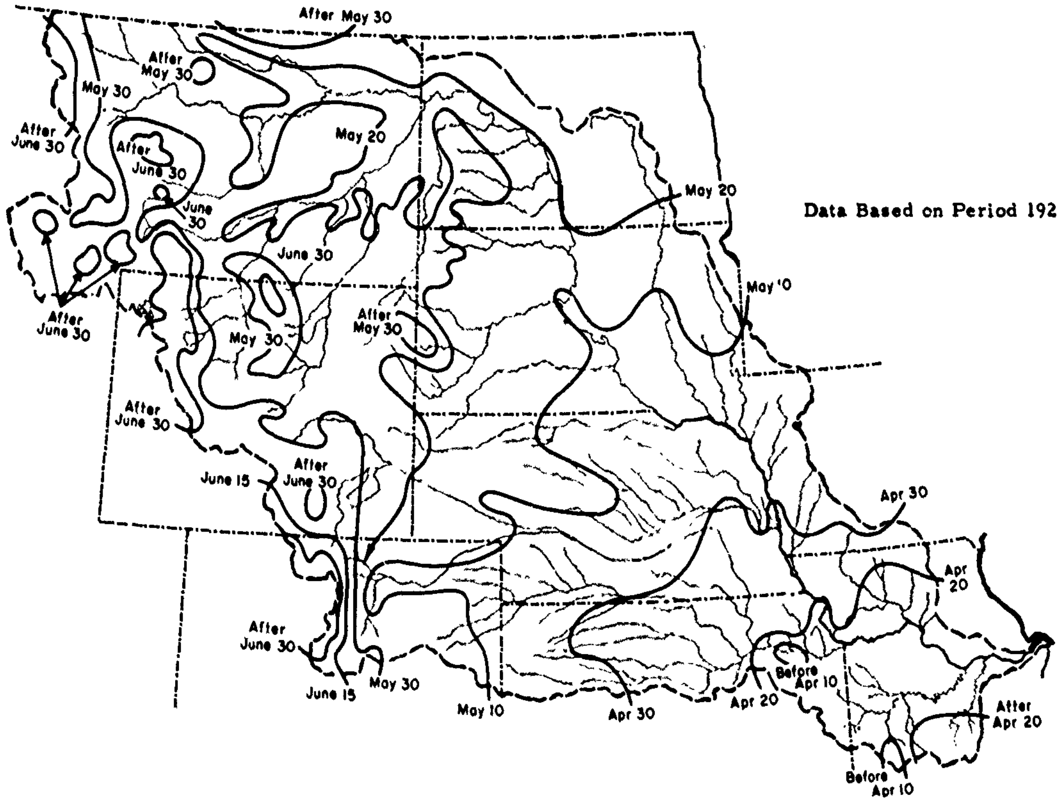
MEAN DATE OF FIRST 32°F TEMPERATURE IN AUTUMN



Data Based on Period 1921-1950

FIGURE 18

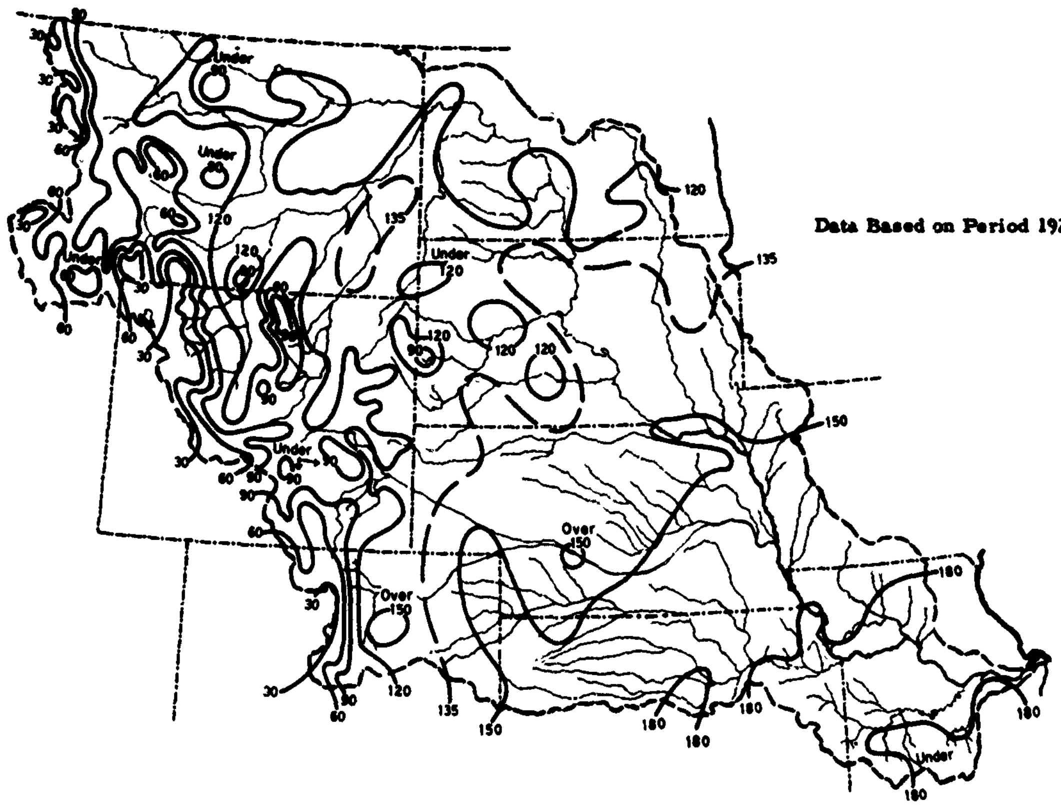
MEAN DATE OF LAST 32°F TEMPERATURE IN SPRING



Data Based on Period 1921-1950

FIGURE 19

MEAN LENGTH OF FREEZE-FREE PERIOD, (DAYS)



SURFACE WINDS

Local topography and seasonal weather phenomena are largely responsible for the type and severity of surface winds in the Missouri River Basin. In the mountainous areas west of 105° longitude, winds of the orographic type rarely exceed a velocity of 30 miles per hour for durations of 60 minutes or more, and local drainage winds are normally light and shallow. East of 105° longitude, the generally uniform topography of the vast plains area offers a minimum resistance to air movement. During any single year, major variations in wind velocity and direction occur throughout the plains area, but these variations are greatly dampened when seasonal or annual means are considered.

Annual mean wind velocities in the basin vary from about 7 to about 14 miles per hour. Monthly mean velocities vary from about 6 to about 18 miles per hour, with the greater means during the late autumn, winter, and early spring months. Summer, overall, is normally the calmest period of the year. Most of the high-intensity, short-period winds, however, occur during the warmer months in association with individual thunderstorms, squall lines, frontal passages, and tornadoes. Tornadoes, often with estimated velocities on the order of 500 miles per hour, are most frequent during the spring and summer months and in the states of Kansas, Nebraska, Iowa, and Missouri. Sustained winds of high velocity show little seasonal variation in frequency of occurrence in the mountain areas. In the plains area, greater sustained velocities are likely in the winter and spring. Some of the major windstorms that have occurred in the basin are illustrated by data presented in table 3. Data presented are for only a few of the storms that have occurred. Nevertheless, major windstorms of this nature are not of common occurrence in the basin.

In the mountainous areas, wind directions are generally westerly, from the southwest through the northwest, throughout the year. In the plains area, wind direction has a definite seasonal pattern. Here, winds are primarily northerly, from the northwest or north, during the winter and early spring; primarily southerly, from the south or southeast, during late spring, summer, and early autumn, and primarily westerly, from the west or northwest, during the late autumn in the upper plains area but continuing primarily southerly during this period in the lower plains area.

SUNSHINE AND CLOUDINESS

Factors influencing the degree of cloudiness at any locality at any time are available moisture, presence of condensation nuclei, season and length of day, and

Table 3 – MAJOR WINDSTORMS

Location	Date	Maximum Velocity Miles per Hour for 1 Minute	Average Velocity Miles per Hour for 5 Minutes	Average Velocity in Miles per Hour for Duration in Hours of 1	2	3	4	5	6	Prevailing Direction
Kansas										
Concordia	11-19-48	42	37	36	32	30	29	28	27	N
Topeka	3-26-50	59	--	45	43	41	40	39	38	SW
Missouri										
Columbia	4- 5-47	--	--	24	23	23	22	22	21	SW
Montana										
Helena	12- 2-41	56	52	46	44	42	41	41	39	S
	1-17-44	67	52	41	38	37	35			W
	2-16-49	67	44	38	38	36	34	32		W
Nebraska										
Omaha	4-24-37	60	49	43	41	41	40	39	39	NW
North Dakota										
Bismarck	3-15-41	60	44	39	38	36	36	35	34	NW
	5- 6-45	57	47	41	40	38	38	37	36	NW
	11-24-47	60	47	42	39	37				NW
South Dakota										
Huron	5-23-39	65	59	40	30	25				NE
	4-27-42	65	48	46	45	41	38			NW
	11-23-54	68	44	43	42	41	40	39	38	NW
Rapid City	9-25-42	65	59	56	54	53	52	50	49	NW
	4- 5-47	64	54	49	47	47	46	46	46	NW
Wyoming										
Cheyenne	1-24-46	70	--	53	51	49	47	46	46	NW
Sheridan	9- 7-41	56	50	47	45	44	43	43	42	NW

Note: The above velocities have been adjusted to a common base of 25 feet above the ground.

presence of contrasting air masses and frontal activity. It is understandable, therefore, that the amount of sunshine experienced, expressed as a percentage of the total possible amount of sunshine, does not vary greatly from one locality to another in the basin. Table 4 shows the mean percentage of possible sunshine experienced at representative localities. It will be noted that the maximum variation in the mean annual percentages of possible sunshine is only 19 percent.

In an average year, almost any locality in the basin will have about one-third of its days clear, about one-third cloudy, and about one-third partly cloudy. Low clouds and fog occur along the eastern slopes of the Rocky Mountains when the prevailing winds are easterly. There are infrequent periods of frontal fog and radiational ground fog almost everywhere in the basin.

HUMIDITY

Humidity in much of the Missouri Basin is comparatively high. There are favored localities, however, where oppressive humidity is seldom encountered. The most prominent of these are the high-altitude areas of the western basin such as in the vicinity of Denver, Colo., and Cheyenne, Wyo. Relative humidity is generally highest during the morning hours and lowest during the afternoon. Table 5 presents data concerning mean annual and mean monthly relative humidity at selected locations throughout the basin and for selected times.

DAMAGING STORMS

Damaging storms occur in the Missouri Basin during all seasons of the year. Winter blizzards, ice storms, and excessive snowfall have been experienced in all parts of the basin. The more devastating storms occur during the spring and summer when thunderstorms, hailstorms, and tornadoes are common. Although for the most part these are of short duration at any specific location and seldom of great areal extent, they may be locally severe.

In most thunderstorms, it is not uncommon to have winds gusting to at least 50 miles per hour. Most thunderstorms do not produce hail, and hailstones which are produced are generally of small size. Large hailstones, however, are sometimes produced, and occurrence of hailstones weighing 1.5 pounds has been definitely recorded.

Tornadoes have been experienced in most parts of the basin, but they are rare in the mountainous areas and in the northern part of the plains area. They are more frequent in the southern part of the plains area in Nebraska and Kansas, and most frequent in northeastern

Kansas. Tornadoes follow paths varying in length from a few feet to as much as 300 miles, they range in width to over a mile, they travel overland at a speed of about 40 miles per hour, and their internal winds are estimated to reach speeds on the order of 500 miles per hour. They occur most frequently during the 3-month period, May through July.

Table 4 – MEAN PERCENTAGE OF POSSIBLE SUNSHINE

State	Station	Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Colorado	Denver	64	67	67	65	63	61	69	68	68	71	71	67	65	67
Iowa	Des Moines	66	56	56	56	59	62	66	75	70	64	64	53	48	62
	Sioux City	52	55	58	58	59	63	67	75	72	67	65	53	50	63
Kansas	Concordia	52	60	60	62	63	65	73	79	76	72	70	64	58	67
	Dodge City	70	67	66	68	68	68	74	78	78	76	75	70	67	71
Missouri	Kansas City	69	55	57	59	60	64	70	76	73	70	67	59	52	65
	St. Louis	68	48	49	56	59	64	68	72	68	67	65	54	44	61
	Springfield	45	48	54	57	60	63	69	77	72	71	65	58	48	63
Montana	Havre	55	49	58	61	63	63	65	78	75	64	57	48	46	62
	Helena	65	46	55	58	60	59	63	77	74	63	57	48	43	60
Nebraska	Lincoln	55	57	59	60	60	63	69	76	71	67	66	59	55	64
	North Platte	53	63	63	64	62	64	72	78	74	72	70	62	58	68
North Dakota	Bismarck	65	52	58	56	57	58	61	73	69	62	59	49	48	59
	Devils Lake	55	53	60	59	60	59	62	71	67	59	56	44	45	58
	Williston	43	51	59	60	63	66	66	78	75	65	60	48	48	63
South Dakota	Huron	62	55	62	60	62	65	68	76	72	66	61	52	49	63
	Rapid City	53	58	62	63	62	61	66	73	73	69	66	58	54	64
Wyoming	Cheyenne	63	65	66	64	61	59	68	70	68	69	69	65	63	66
	Lander	57	66	70	71	66	65	74	76	75	72	67	61	62	69
	Sheridan	52	56	61	62	61	61	67	76	74	67	60	53	52	64

Table 5 – MEAN RELATIVE HUMIDITY (%)

State	Station	Years	January				April				July				October				Annual			
			1 A.M.	7 A.M.	1 P.M.	7 P.M.	1 A.M.	7 A.M.	1 P.M.	7 P.M.	1 A.M.	7 A.M.	1 P.M.	7 P.M.	1 A.M.	7 A.M.	1 P.M.	7 P.M.	1 A.M.	7 A.M.	1 P.M.	7 P.M.
Colorado	Denver	20	60	60	44	49	60	67	40	39	57	67	32	34	56	62	34	35	59	64	38	40
Iowa	Des Moines	19	78	79	71	73	71	79	54	54	78	85	56	56	71	80	52	55	77	82	61	62
	Sioux City	66	76	77	68	71	74	77	52	52	79	80	52	51	74	79	52	56	77	79	58	60
Kansas	Concordia	72	73	78	63	68	68	77	50	50	68	77	47	48	67	78	48	56	70	78	54	57
	Dodge City	67	74	79	56	62	69	76	47	47	67	76	41	44	69	78	46	52	71	78	48	52
	Topeka	18	75	78	64	67	72	79	53	53	76	81	51	50	73	80	50	54	75	81	56	58
Missouri	Kansas City	66	74	66	37	66	68	74	53	54	72	76	49	53	67	76	51	55	71	77	55	59
	St. Louis	65	77	77	65	68	72	73	54	58	74	73	50	55	74	76	52	58	75	76	57	61
	Springfield	68	80	82	68	72	74	77	56	57	84	82	57	60	78	82	54	61	80	81	60	63
Montana	Havre	50	76	82	71	78	65	79	47	44	57	74	38	35	67	79	50	54	69	79	54	55
	Helena	66	70	68	64	64	64	69	48	43	56	64	37	33	68	71	53	51	67	69	52	49
Nebraska	Lincoln	14	78	79	67	72	75	81	54	54	76	82	50	50	72	78	47	56	77	81	57	61
	North Platte	15	80	83	61	62	73	82	50	47	74	84	50	47	75	84	47	51	77	84	54	54
North Dakota	Bismarck	55	76	74	67	70	76	79	50	51	79	81	48	48	74	81	51	57	77	79	56	59
	Devils Lake	22	--	76	72	75	--	82	56	54	--	86	53	53	--	83	57	60	--	82	62	63
	Williston	43	74	74	67	69	68	76	49	47	71	77	45	41	70	79	53	53	73	77	55	55
South Dakota	Huron	67	78	76	72	72	76	80	54	51	79	81	52	49	75	81	52	56	79	80	60	59
	Rapid City	9	71	71	60	66	66	71	48	47	64	70	42	40	60	64	42	46	67	70	50	52
Wyoming	Cheyenne	67	61	58	48	52	68	72	47	49	65	70	36	41	64	65	39	47	65	66	44	48
	Sheridan	18	70	73	61	65	70	77	48	46	63	73	37	35	66	72	44	47	69	75	50	51

Time is Eastern Standard (75th Meridian), subtract 1 hour for Central (90th M.), 2 hours for Mountain (105th M.)
Based on records through 1959, except in a few instances, taken from "Normals, Means, and Extremes" table in U. S. Weather Bureau Publications, Local Climatological Data.

Figure 20 indicates the number and approximate location of tornadoes that were observed in the basin during the period, 1916 to 1961. Figure 20 shows also the mean annual number of days with thunderstorms, in all parts of the basin.

ICE COVER ON STREAMS

As might be expected in so large an area, extending over so great a range of latitude and with such varied topography, conditions of ice cover on streams vary extensively over the Missouri Basin. In the mountainous areas, formation of ice cover on flowing streams is inhibited by steep stream slopes and higher velocities of flow. In the more southerly portions of the basin, periods of subfreezing temperatures generally are not severe enough or long enough for formation of heavy ice cover. The heaviest and most protracted ice cover normally occurs on streams in the Dakotas and, to a somewhat lesser extent, in Nebraska and northwestern Iowa.

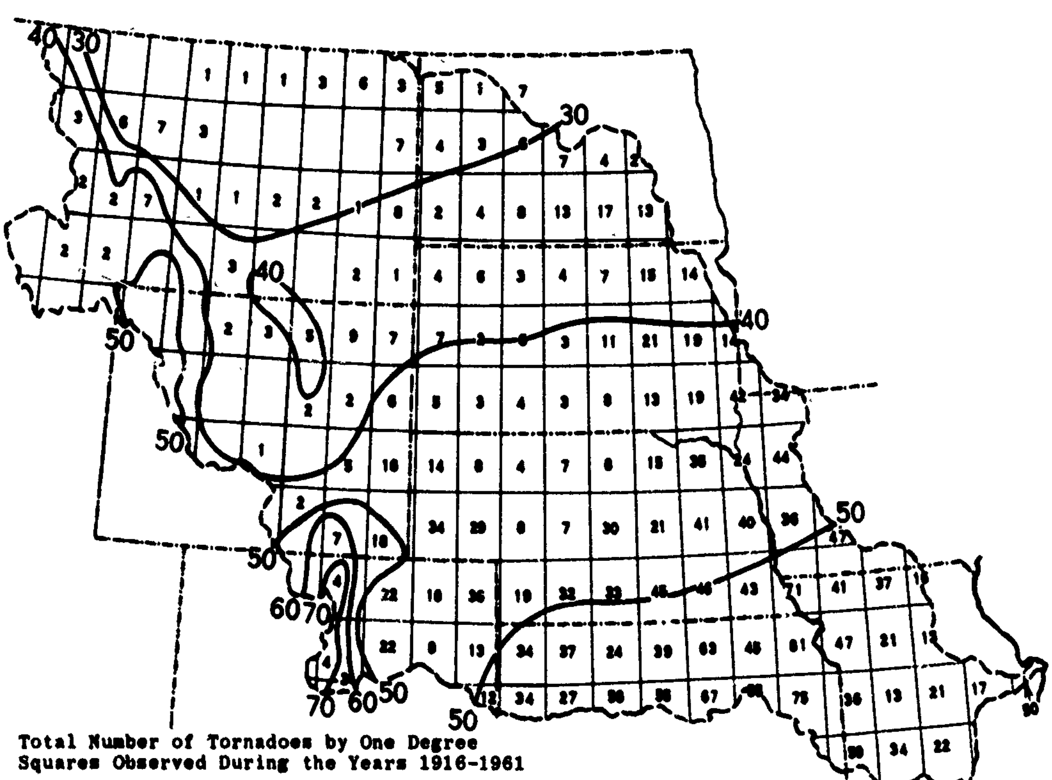
During severe winters, ice cover on streams in the Dakotas has reached thicknesses of up to 4 feet. In this area, thicknesses of as much as 2 feet are common even during comparatively mild winters. Ice thicknesses normally are substantially less in the more southerly parts of the basin. Obviously, throughout the basin, there are substantial variations from year to year in the extent and thickness of the ice cover.

Ice has formed on streams as early in the fall as October 10. The average date of ice cover formation, however, varies with locality from about November 20 to about January 20. The ice cover has been known to persist as late as May 1, but the average date of ice breakup varies with locality from about February 1 to about April 10. Plate 7 illustrates the duration of ice cover in the Missouri Basin, indicating the number of days, on the average, that streams are frozen, based on available records.

Disappearance of the winter ice cover in any locality may extend over days and even weeks. Normally, it occurs earlier on streams than on lakes, since lake ice cover must be melted whereas most stream ice cover is broken up mechanically and carried downstream as streamflows increase. When weather is such that stream ice cover breaks up in a downstream direction, rather than in the upstream direction which is normal, ice jams are likely to occur. Historically, ice-jam flooding, which occurs as streamflows are backed up by severe ice jams, has been a periodic problem in the Missouri Basin.

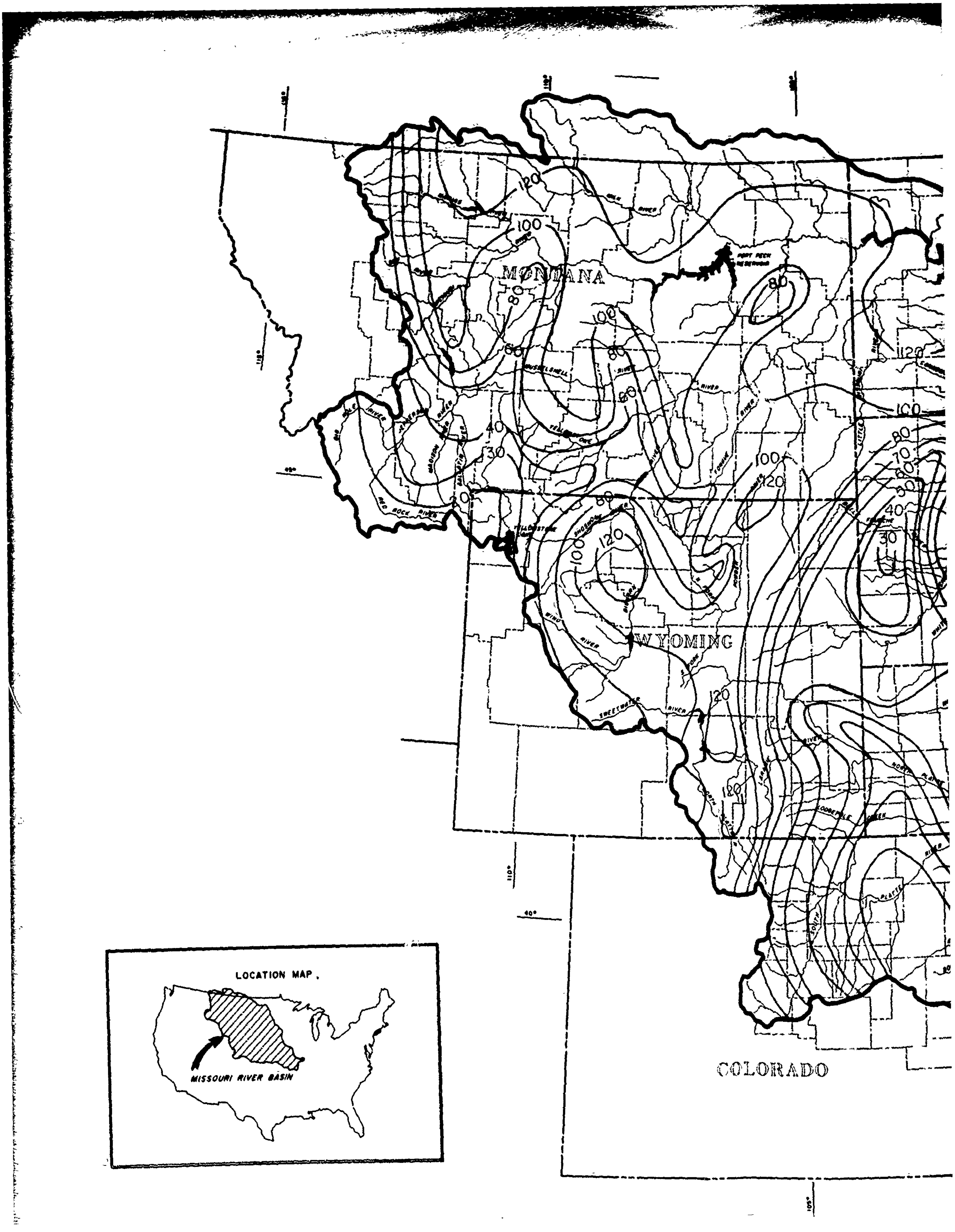
FIGURE 20

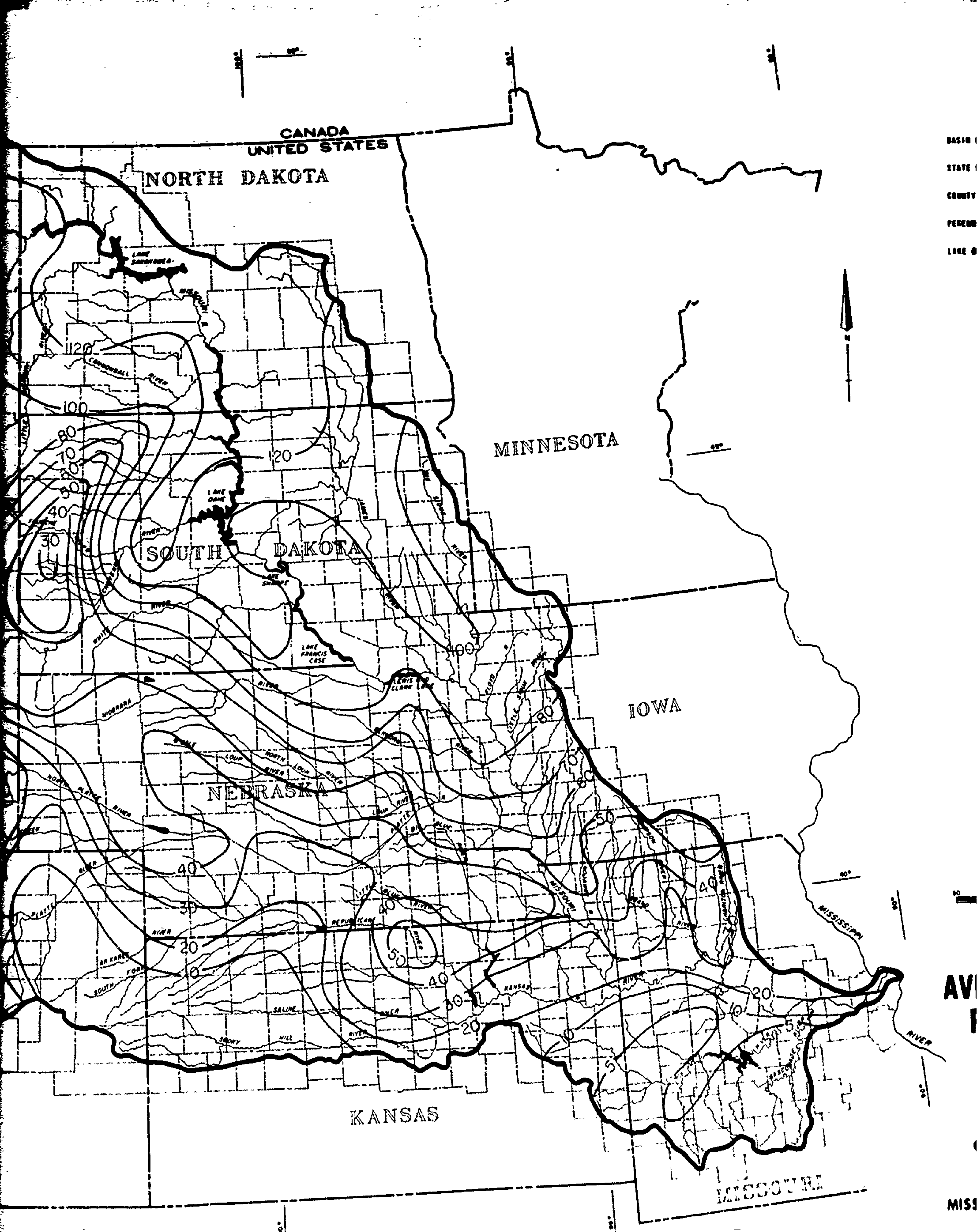
TOTAL NUMBER OF TORNADOES AND MEAN ANNUAL NUMBER OF DAYS WITH THUNDERSTORMS



Total Number of Tornadoes by One Degree Squares Observed During the Years 1916-1961

Thunderstorm Data, Mean Annual Isopleths, Based on Period 1896-1964


MONTANA
WYOMING
COLORADO
LOCATION MAP.
MISSOURI RIVER BASIN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KANSAS
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LAKE SHARPE
LAKE FRANCIS CASE
CANNONBALL RIVER
NIOBRARA
NORTH PLATTE RIVER
LOUP RIVER
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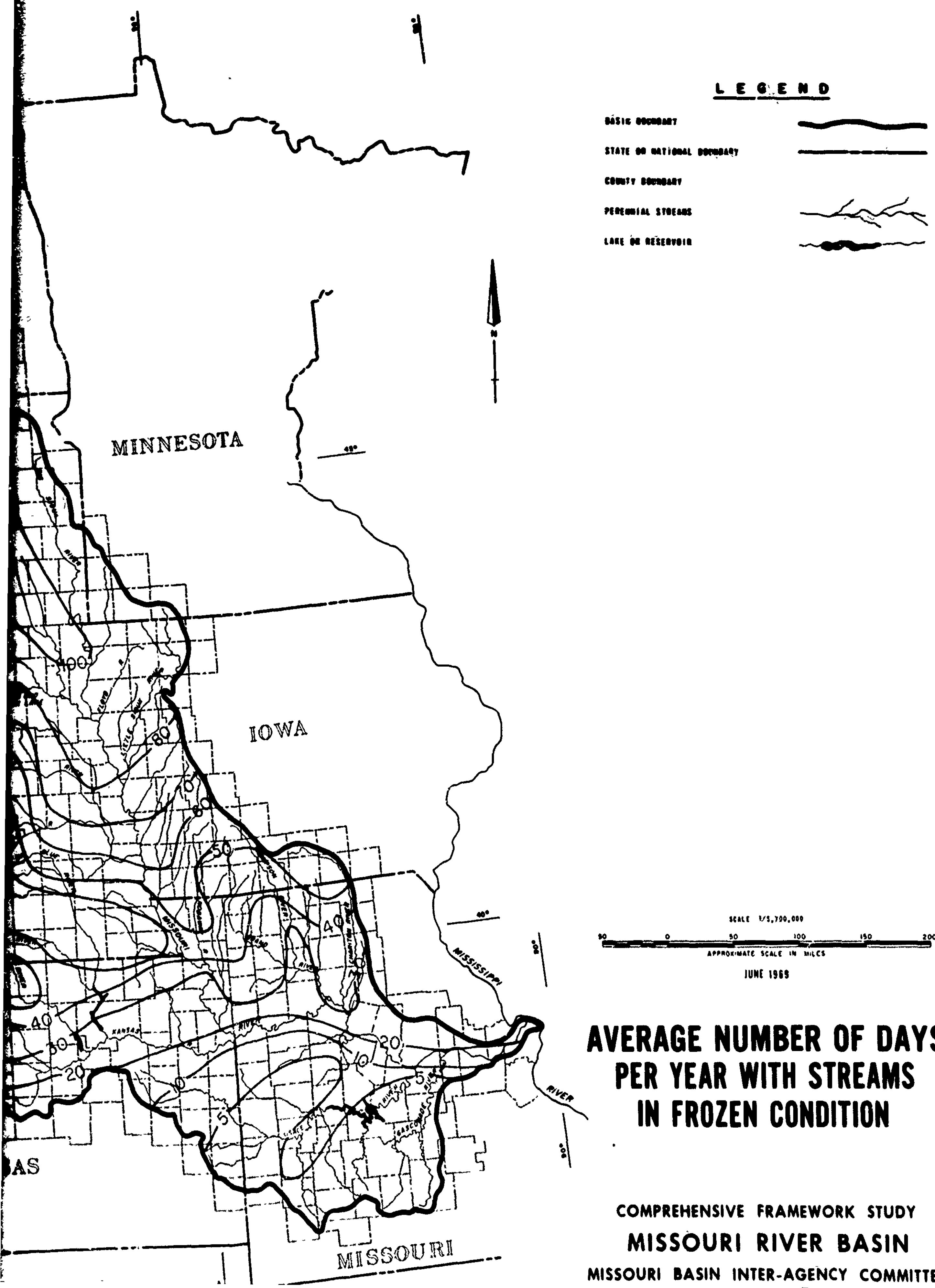


AVERAGE NUMBER OF DAYS PER YEAR WITH STREAMS IN FROZEN CONDITION

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

CHAPTER 4

EVAPORATION, EVAPOTRANSPIRATION, AND INFILTRATION

A major part of the water that falls as precipitation over the Missouri River Basin never appears as runoff in the basin streams but is lost through the processes of evaporation, evapotranspiration, and infiltration. These phenomena, accordingly, require careful consideration in evaluation of available water supply and in planning for water resources development.

EVAPORATION

Pan Evaporation

Evaporation measurements are made by use of a standard evaporation pan of water fitted with a device for accurately measuring the lowering of the water surface as evaporation occurs. Pan evaporation data have been collected at numerous locations in the Missouri Basin. Using these data for the 10-year period from 1946 through 1955 and similar data from other areas of the Nation, the Weather Bureau conducted studies of pan evaporation and developed Technical Paper No. 37, "Evaporation Maps for the United States," by Kohler, Nordenson, and Baker. Since the 10-year record used for development of those maps is comparatively short and since additional evaporation data are available for the Missouri Basin, consideration was given in connection with this framework study to the possible effect of using a longer period of record.

Representative pan stations throughout the Missouri Basin having a period of record in excess of 15 years were selected for this study. The study results showed average annual pan evaporation amounts only slightly higher, about 3 percent higher on the average, than the average annual amounts shown by Technical Paper No. 37. Departures of this magnitude are not significant, and the evaporation amounts shown for the Missouri Basin in Technical Paper No. 37 accordingly were considered suitable for use in the framework study.

Average annual pan evanporation in the basin generally increases from the northeast to the south and to the west. Amounts range from about 41 inches in the northeastern part of the basin in North Dakota to about 55 inches east of the northern Rocky Mountain area, to about 65 inches east of the southern Rocky Mountain area, and to over 90 inches in west central Kansas. Amounts decrease again in the mountains to less than 35 inches in southwestern Montana and to less than 45 inches in central Colorado.

Gross Evaporation from Lakes and Reservoirs

Pan-evaporation data are not directly applicable in estimating evaporation from lakes and reservoirs, for evaporation from an open pan normally occurs at a faster rate than does evaporation from a large body of water in the same locality. Pan-evaporation data, however, do provide an index to the evaporative powers of the atmosphere, and lake and reservoir evaporation rates may be estimated by application of appropriate coefficients to the pan-evaporation data.

Studies by the Weather Bureau as presented in Weather Bureau Technical Paper No. 37 also included development of lake and reservoir evaporation rates from the available pan-evaporation data. Average annual gross lake and reservoir evaporation rates presented therein were reviewed and were also determined to be suitable for use in the framework study. Plate 8, which shows average annual gross evaporation from lakes and reservoirs in the Missouri Basin, was developed from data in Technical Paper No. 37.

Net Evaporation from Lakes and Reservoirs

Of greater significance than gross evaporation alone, in connection with studies of potential reservoirs, is net evaporation, derived by subtracting effective rainfall from the gross evaporation value. Effective rainfall, which offsets part of the evaporation loss, is defined as rainfall over the potential reservoir water surface less that portion of such rainfall that formerly escaped from the reservoir site as runoff and is already reflected in runoff records. Net evaporation represents the overall depleting effect of the reservoir on the water supply at the site and is equal to gross evaporation from the reservoir water surface, a water loss, plus runoff that would have occurred from the land inundated by the reservoir, a water loss, minus precipitation over the reservoir water surface, a water gain.

Using the gross evaporation values shown by plate 8, precipitation amounts shown by normal annual precipitation maps for the period 1931 through 1960 as published by the U.S. Weather Bureau in the National Atlas for the United States, and appropriate runoff data, reservoir and lake net evaporation rates for the Missouri Basin have been estimated. These are shown by plate 9, Average Annual Net Lake Evaporation in Inches.

Seasonal Distribution of Net Evaporation

Planning studies frequently require determination of net evaporation on a seasonal basis. For this purpose an analysis was made at several representative locations in the Missouri Basin, of all available concurrent pan-evaporation and precipitation data. Results of this analysis are represented in plate 10, Average Monthly Lake Evaporation Minus Precipitation – In Percent of Average Annual.

In the analysis the assumption was made that reservoir and lake evaporation would follow a monthly distribution pattern similar to that for pan evaporation. This assumption is valid for comparatively shallow reservoirs and lakes. For deep reservoirs and lakes, however, where water surface temperatures lag air temperatures significantly, special studies of the monthly distribution of average annual evaporation will be necessary.

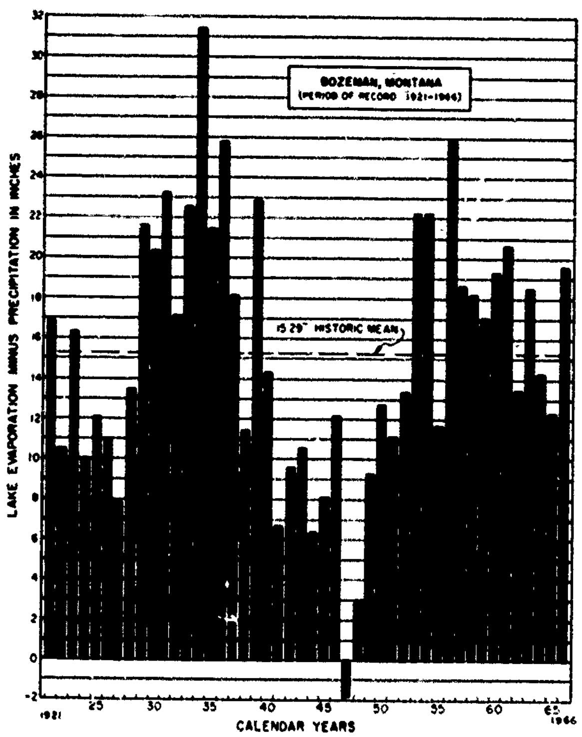
Runoff was not considered in the analysis because concurrent runoff data at the locations shown were not available. It is considered, however, that the monthly distribution pattern shown by plate 10 for average annual gross evaporation minus precipitation may be adopted for monthly distribution of net evaporation in all but the most detailed studies.

Variability of Annual Evaporation

The effect of evaporation on water resource developments varies greatly from year to year. Utilizing mean annual evaporation to estimate water losses is normally not satisfactory in planning studies because of the tendency for high evaporation to occur during drought years. This is demonstrated by figure 21 where annual lake evaporation minus precipitation for Bozeman, Mont., is shown to be several times greater during the drought of the 1930's than during the wetter decades of the 1920's and the 1940's.

Probability relationships for annual and multi-annual reservoir and lake evaporation also are frequently required in planning studies. The analysis of gross lake evaporation minus precipitation at representative locations in the Missouri Basin, described in the immediately preceding paragraphs, accordingly was extended to development of annual and multi-annual probability curves of reservoir and lake evaporation minus precipitation. Annual values were ranked and plotted on arithmetic probability paper by a standard formula. Probability curves were then fitted to the data by computation of means and standard deviations for each set of data.

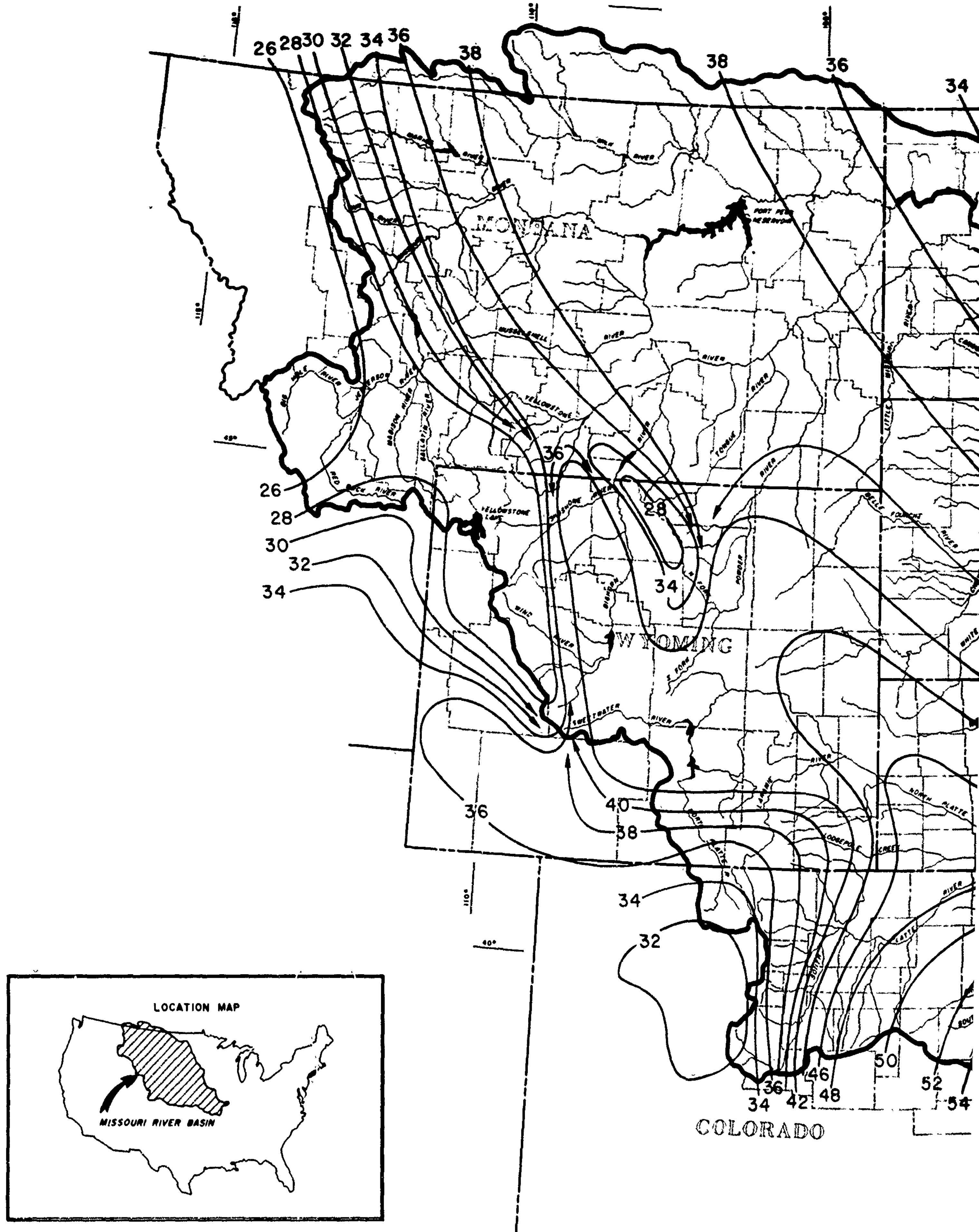
FIGURE 21
ANNUAL LAKE EVAPORATION MINUS PRECIPITATION



EVAPOTRANSPIRATION

Evapotranspiration, commonly called consumptive use, is defined as the sum of evaporation from plant and soil surfaces and transpiration from plants and is usually expressed in terms of depth (volume per unit area). Crop consumptive use is equal to evapotranspiration plus water required for plant tissue, but the two are usually considered the same. Predictions or estimates of evapotranspiration are basic parameters for the engineer or agronomist involved in planning and developing water resources. Estimates of evapotranspiration are also used in assessing the disposition of water in an irrigation project, evaluating the irrigation water-management efficiency, and projecting drainage requirements.

Reliable rational equations are available for estimating evapotranspiration when basic meteorological



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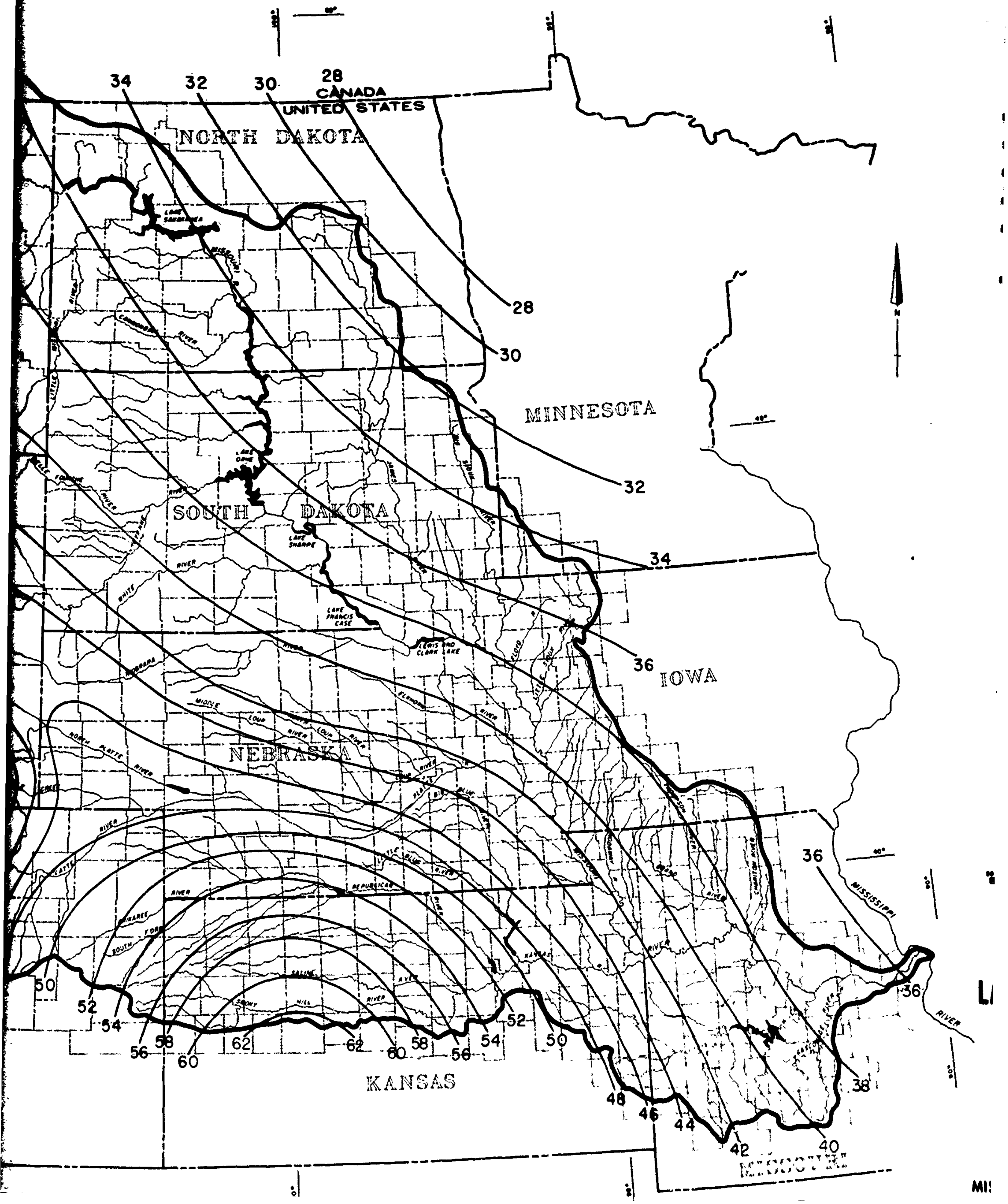
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
KANSAS
LAKE SAKAKAWEA
LAKE OAHE
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
CANNONBALL RIVER
WHITE RIVER
NIOBRARA RIVER
NORTH PLATTE RIVER
MIDDLE LOUP RIVER
NORTH LOUP RIVER
ELKHORN RIVER
REPUBLICAN RIVER
SMOKY HILL RIVER
SALINE
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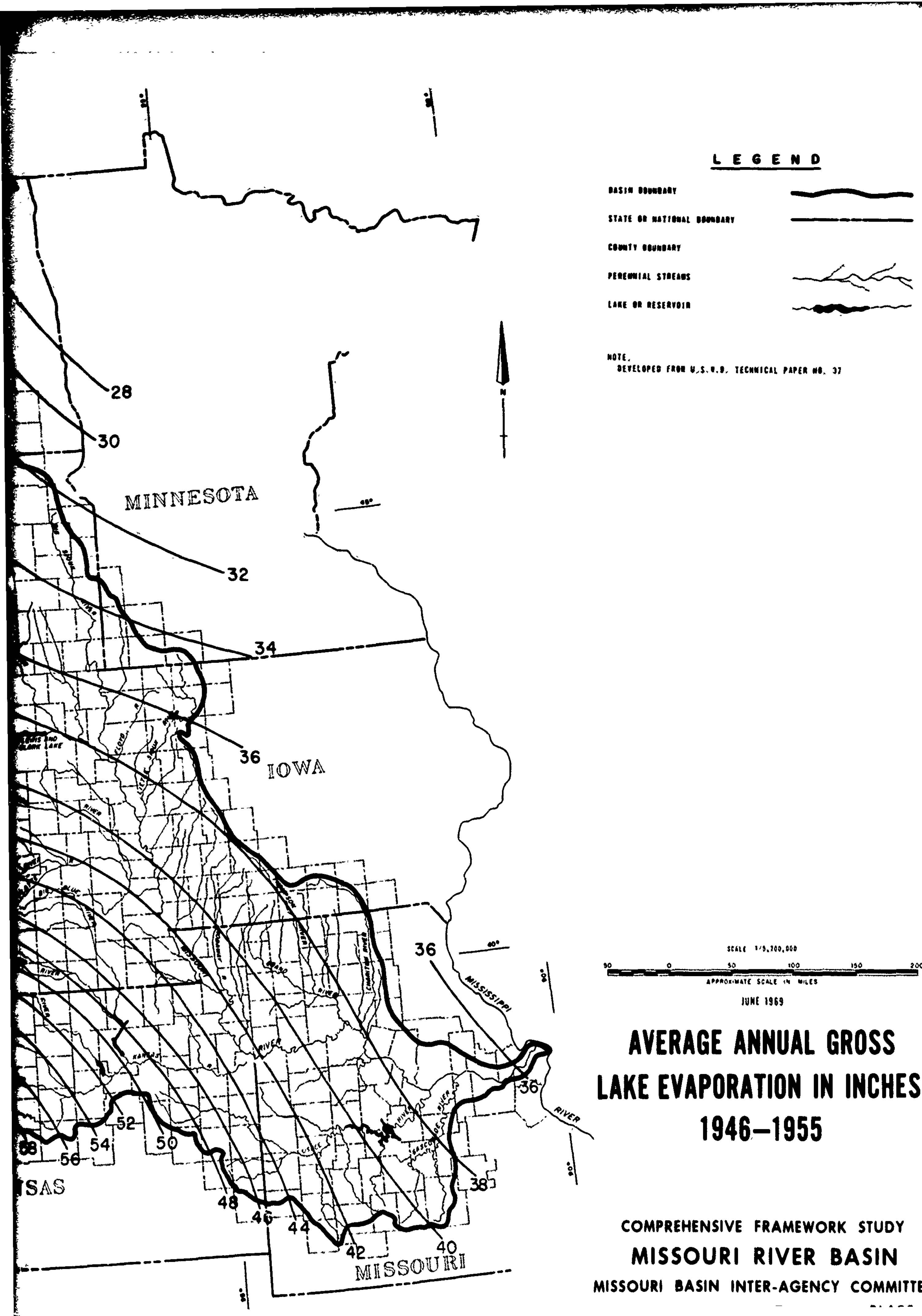
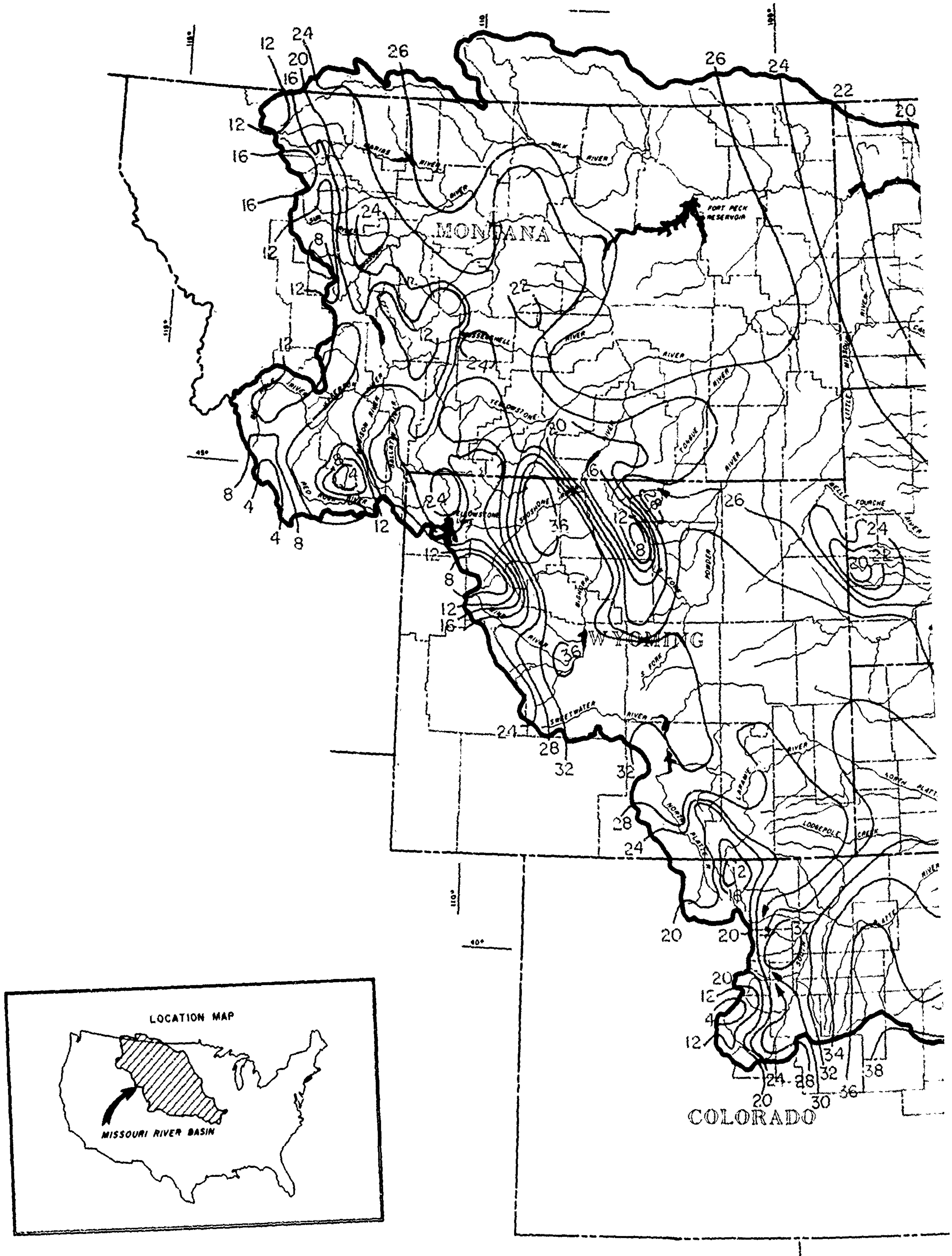


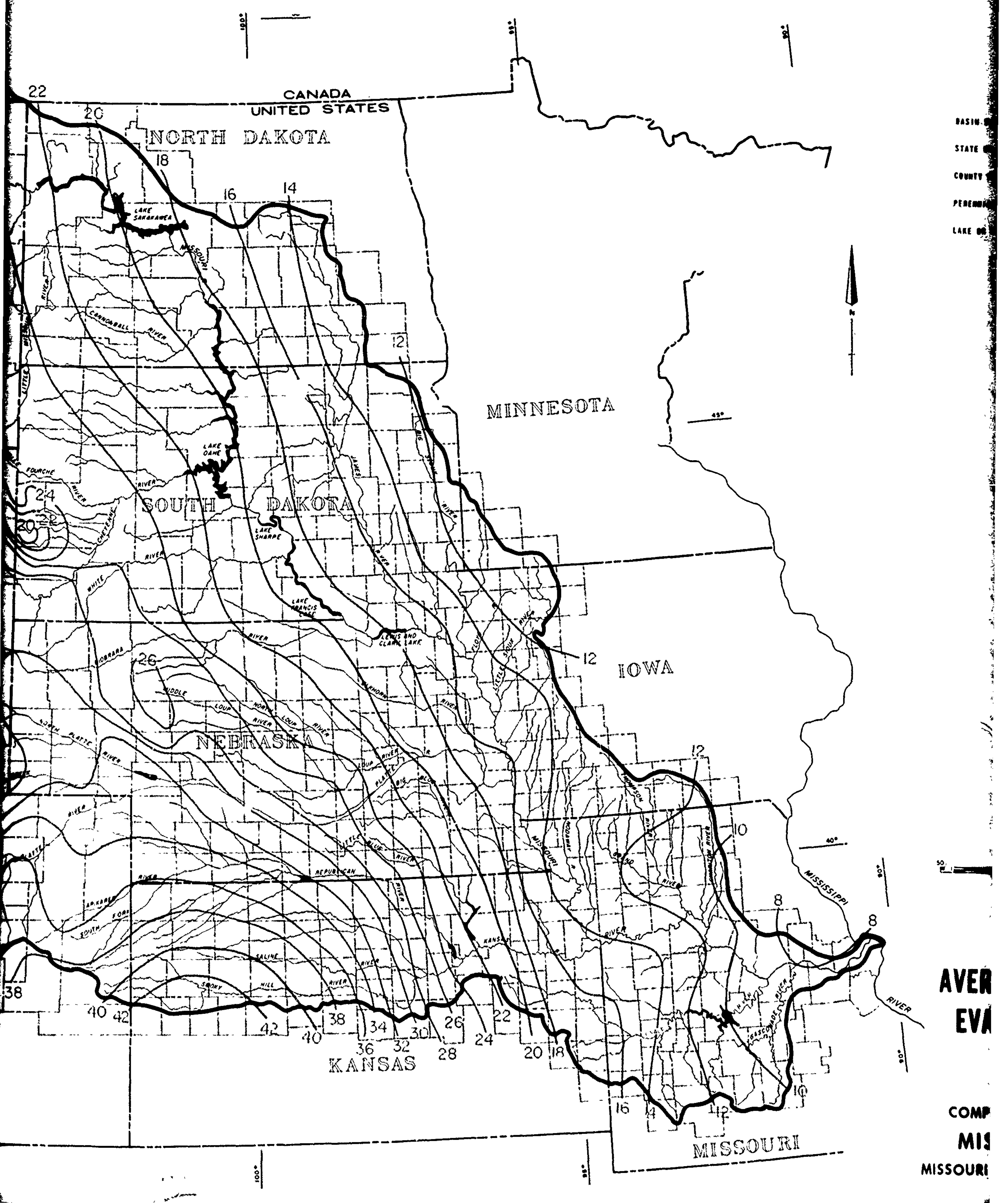
AVERAGE ANNUAL GROSS LAKE EVAPORATION IN INCHES 1946–1955

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE


MONTANA
WYOMING
COLORADO
FORT PECK RESERVOIR
YELLOWSTONE
SWEETWATER RIVER
LODGEPOLE CREEK
LOCATION MAP
MISSOURI RIVER BASIN



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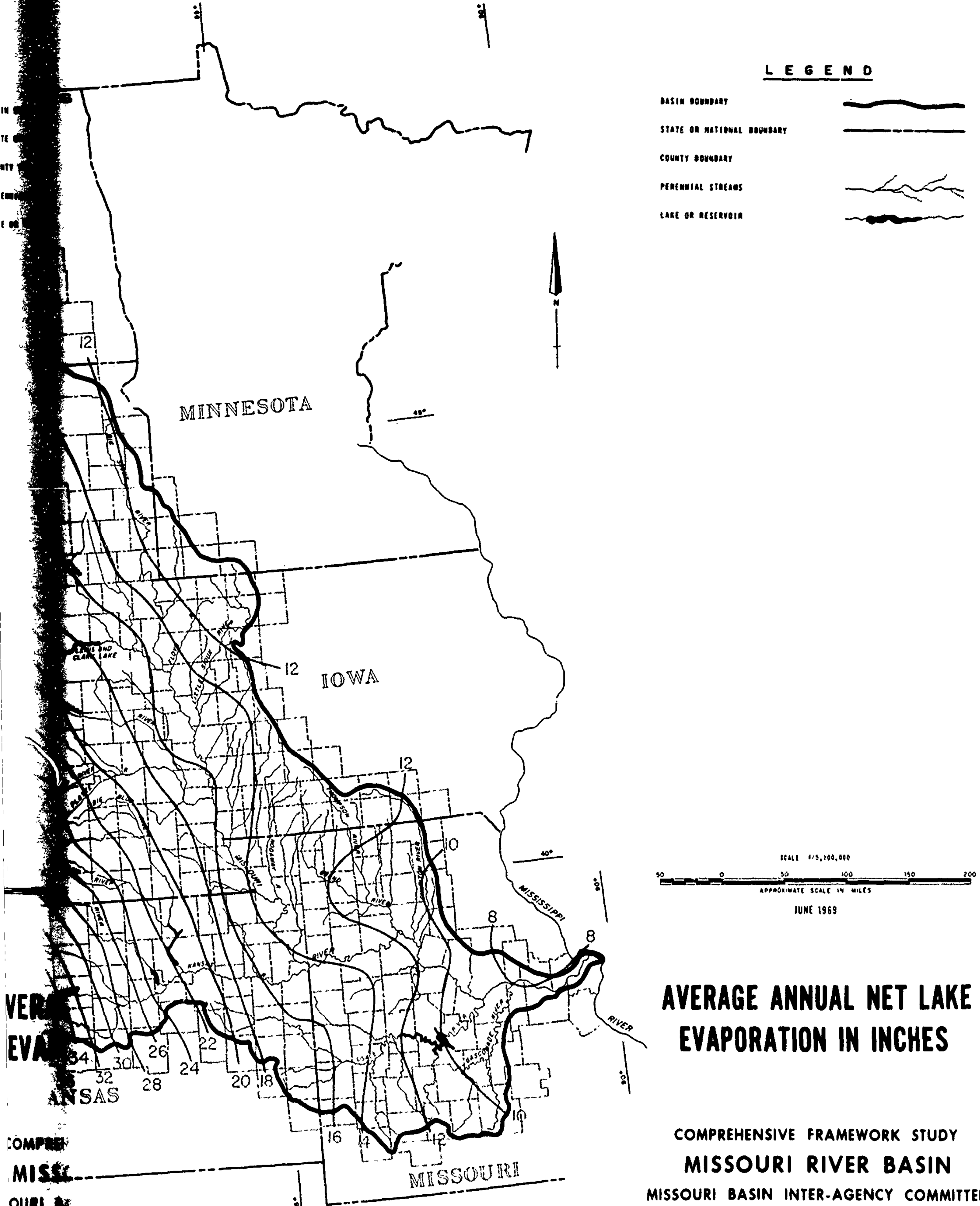


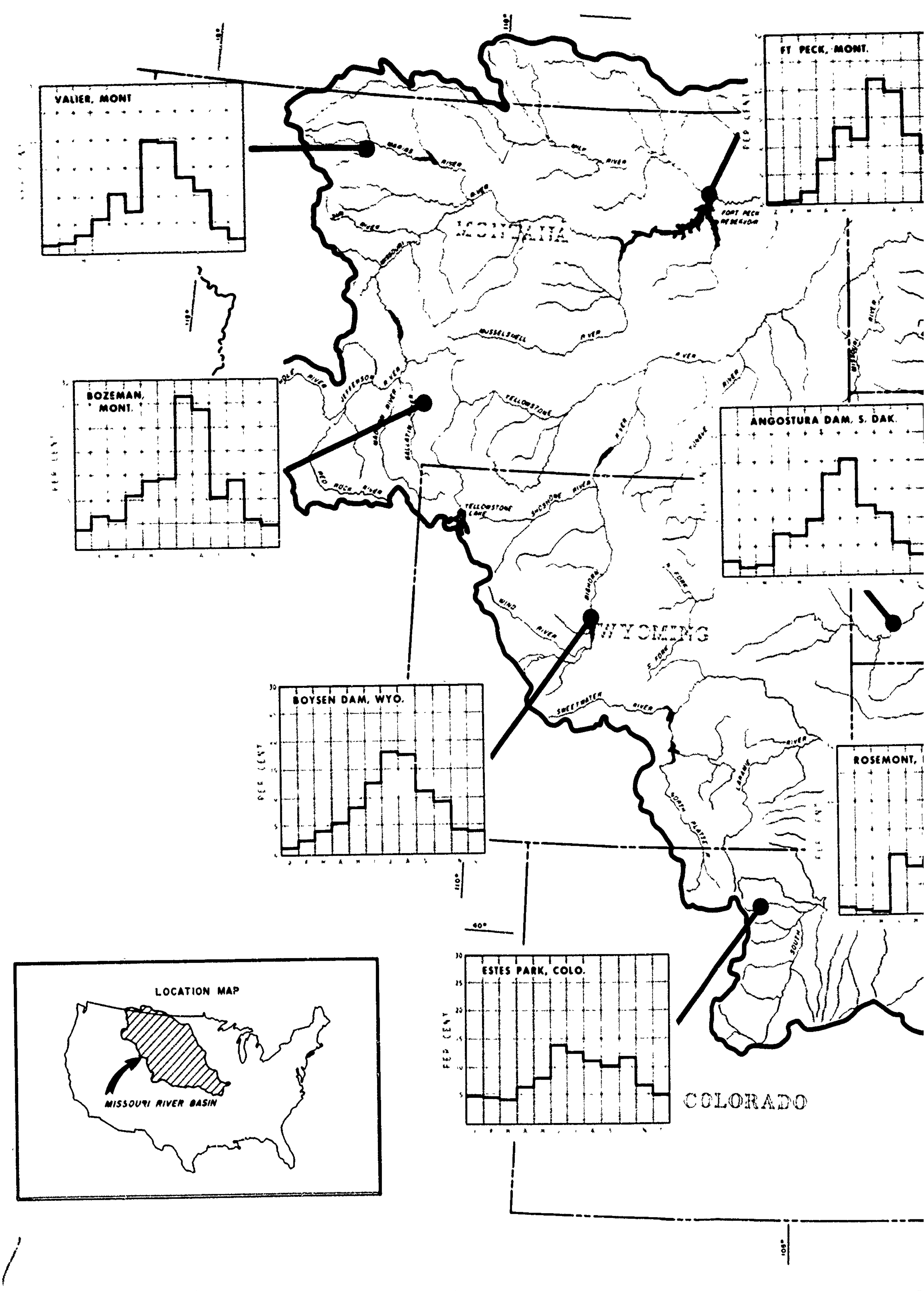
AVERAGE ANNUAL NET LAKE EVAPORATION IN INCHES

COMPREHENSIVE FRAMEWORK STUDY

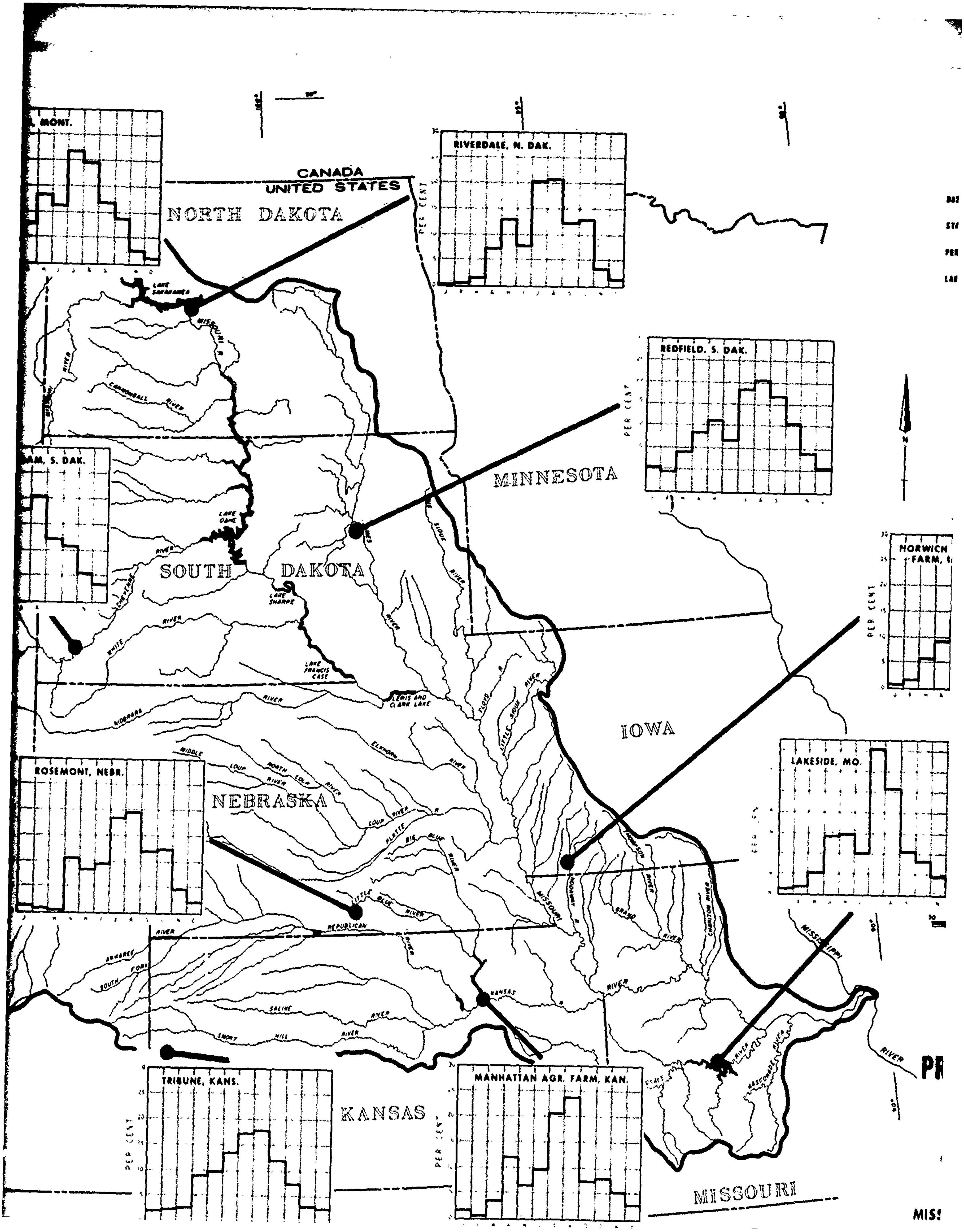
MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

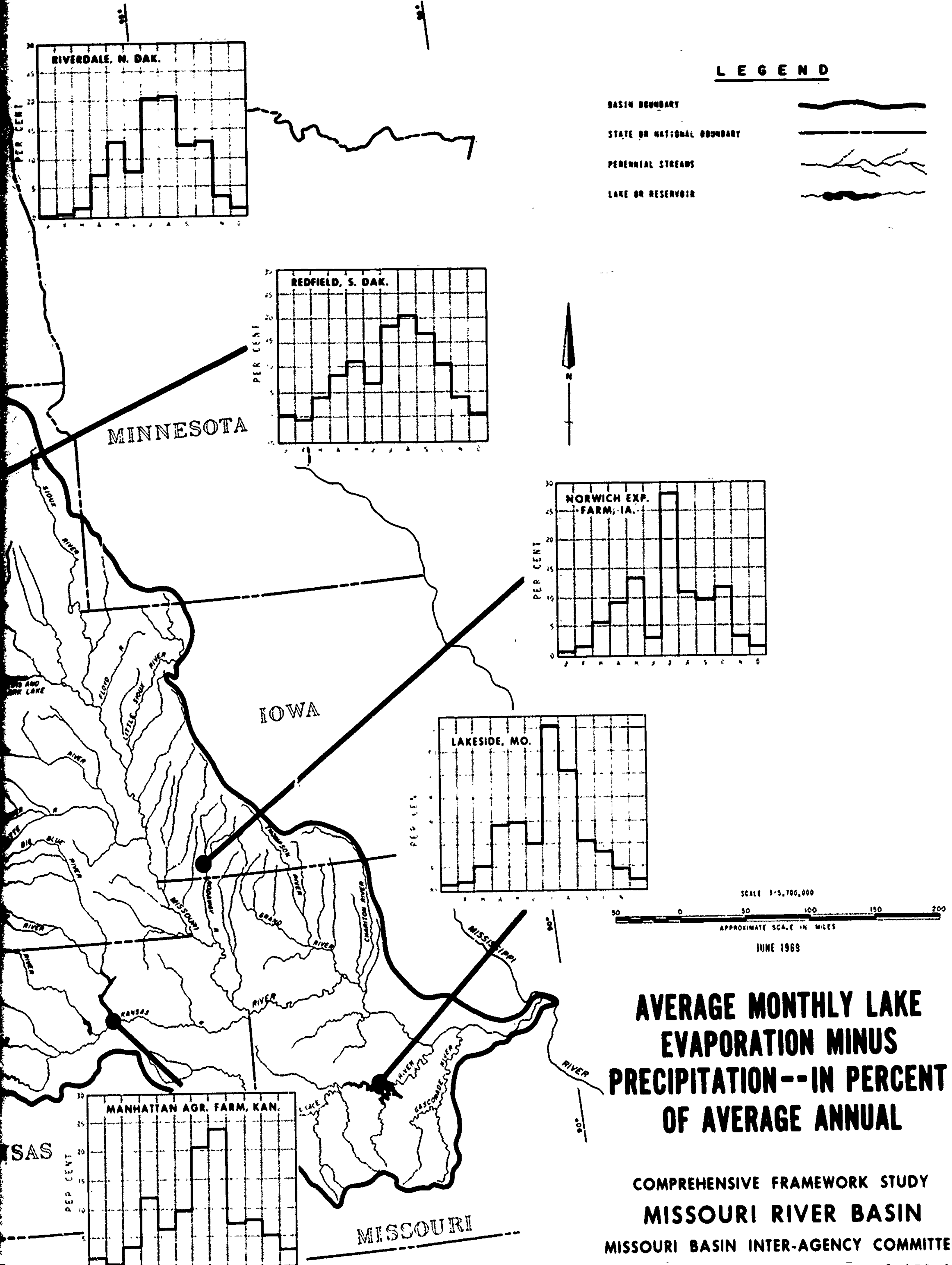
PLATE 9



VALIER, MONT
FT. PECK, MONT.
BOZEMAN, MONT.
ANGOSTURA DAM, S. DAK.
BOYSEN DAM, WYO.
ROSEMONT,
ESTES PARK, COLO.
PER CENT
MONTANA
WYOMING
COLORADO
MUSSELSHELL RIVER
YELLOWSTONE
JEFFERSON RIVER
GALLATIN R.
MADISON RIVER
RED ROCK RIVER
YELLOWSTONE LAKE
SHOSHONE RIVER
BIGHORN
WIND RIVER
SWEETWATER RIVER
LARAMIE
NORTH PLATTE R.
FORT PECK RESERVOIR
MILK RIVER
MARIAS RIVER
MISSOURI
LOCATION MAP
MISSOURI RIVER BASIN
110°
40°
105°



CANADA
UNITED STATES
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
IOWA
NEBRASKA
KANSAS
MISSOURI
MONT.
RIVERDALE, N. DAK.
REDFIELD, S. DAK.
NORWICH FARM,
LAKESIDE, MO.
ROSEMONT, NEBR.
TRIBUNE, KANS.
MANHATTAN AGR. FARM, KAN.
PER CENT
LAKE SAKAKAWEA
MISSOURI R.
CANNONBALL RIVER
LAKE OAHE
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
CHEYENNE RIVER
WHITE RIVER
NIOBRARA RIVER
ELKHORN RIVER
MIDDLE LOUP
NORTH LOUP RIVER
LOUP RIVER
PLATTE R.
BIG BLUE RIVER
LITTLE BLUE RIVER
REPUBLICAN RIVER
ARIKAREE
SOUTH FORK
SALINE RIVER
SMOKY HILL RIVER
KANSAS R.
JAMES
BIG SIOUX RIVER
FLOYD R.
LITTLE SIOUX RIVER
NODAWAY R.
GRAND RIVER
CHARITON RIVER
MISSOURI
OSAGE
GASCONADE RIVER
MISSISSIPPI RIVER
MISS



AVERAGE MONTHLY LAKE EVAPORATION MINUS PRECIPITATION--IN PERCENT OF AVERAGE ANNUAL

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

parameters such as net radiation, vapor pressure and temperature gradients, wind speed at a prescribed elevation above the crop or over a standard surface, and soil heat flux are available. When information on these parameters is not available, which is the usual case, recourse is made to empirical methods. Numerous equations, both empirical and partially based on theory, have been developed for estimating potential evapotranspiration. Estimates from these methods are generally accepted as being of suitable accuracy for planning and developing water resources. Probably the most widely used methods at this time are the Blaney-Criddle method and the Soil Conservation Service adaptation of the Blaney-Criddle method. A more recent method, nearly developed for general usage, is the Jensen-Haise solar radiation method. In general terms, these methods utilize climatic data to estimate a climatic index. Then coefficients, reflecting the stage of growth of individual crops and their actual water requirement in relationship to the climatic index, are used to estimate the consumptive use requirements for selected crops.

During preliminary phases of this investigation, consideration was given to a careful study of evapotranspiration in the Missouri River Basin. While desirable, after considering the information already available from previous isolated studies and their sufficiency for framework planning, it was decided this contemplated study was unwarranted for this investigation. As a result, where estimates of evapotranspiration have been required, use has been made of the earlier isolated studies and, if needed, the accepted empirical methods.

Knowledge of consumptive uses is important in the case of a large irrigation project, and especially for river systems as a whole. However, of equal and perhaps more importance in the case of an individual farm or project is the efficiency with which the water is conveyed, distributed, and applied. The losses incidental to application on the farm and the conveyance system losses and operational waste may in many instances exceed the water required by the growing crops. In actual operation, the amount of loss is to a great extent a matter of economics. In areas where water is not plentiful and high-value crops are grown, the use of pipe or lined conveyance systems and costly land preparation or sprinkler systems can be afforded to reduce losses to a minimum. A part of the "losses" may be consumed nonbeneficially by nonproductive areas adjacent to the irrigated land or in drainage channels. Usually most of the "loss" eventually returns to a surface stream or drain and is referred to as return flow.

In planning irrigation projects, two consumptive use values are developed. One composed of monthly or seasonal values is used with an adjustment for effective precipitation and anticipated "losses" mentioned above to determine the total water requirement for appraising the adequacy of the total water supply and determining reservoir storage requirements. The other, a peak use rate, is used for sizing the canal and lateral system. For general information on the variation of consumptive use in the Missouri Basin, two tables are presented. Table 6 shows estimated monthly potential evapotranspiration in inches for 5 years at eight different locations. Table 7 shows peak period estimated average potential evapotranspiration values for 7- and 14-day periods for 12 years at one of the locations, Rapid City, S. Dak.

INFILTRATION

The capacity of soils in the Missouri Basin to absorb rainfall varies over an extremely wide range. However, a great deal of infiltration data, from various sources, is available in the basin and accordingly, for the comprehensive framework study. A special effort was made, however, to collect and summarize the available data that do exist.

Generalized Soil Groupings

During the late forties through the mid-fifties, thousands of undisturbed soil samples were taken throughout the basin. By use of the Uhland Core sampling method, 3½-inch undisturbed soil cores were brought into laboratories and tested. The final rates of percolation were determined after thorough wetting of the core.

For the framework study, the basin was divided into six broad soil groupings, as shown on plate 11. The usual range of final infiltration rates, in inches per hour, is shown for each grouping. These rates are based upon the physical soil characteristics only. They include the combined effects of surface texture, water intake, and soil permeability. The effects of land use, cover, management, slope, erosion, etc., are not considered in these generalized groupings. Therefore, the map should not be used as a direct hydrologic tool to obtain infiltration rates for precipitation and runoff studies.

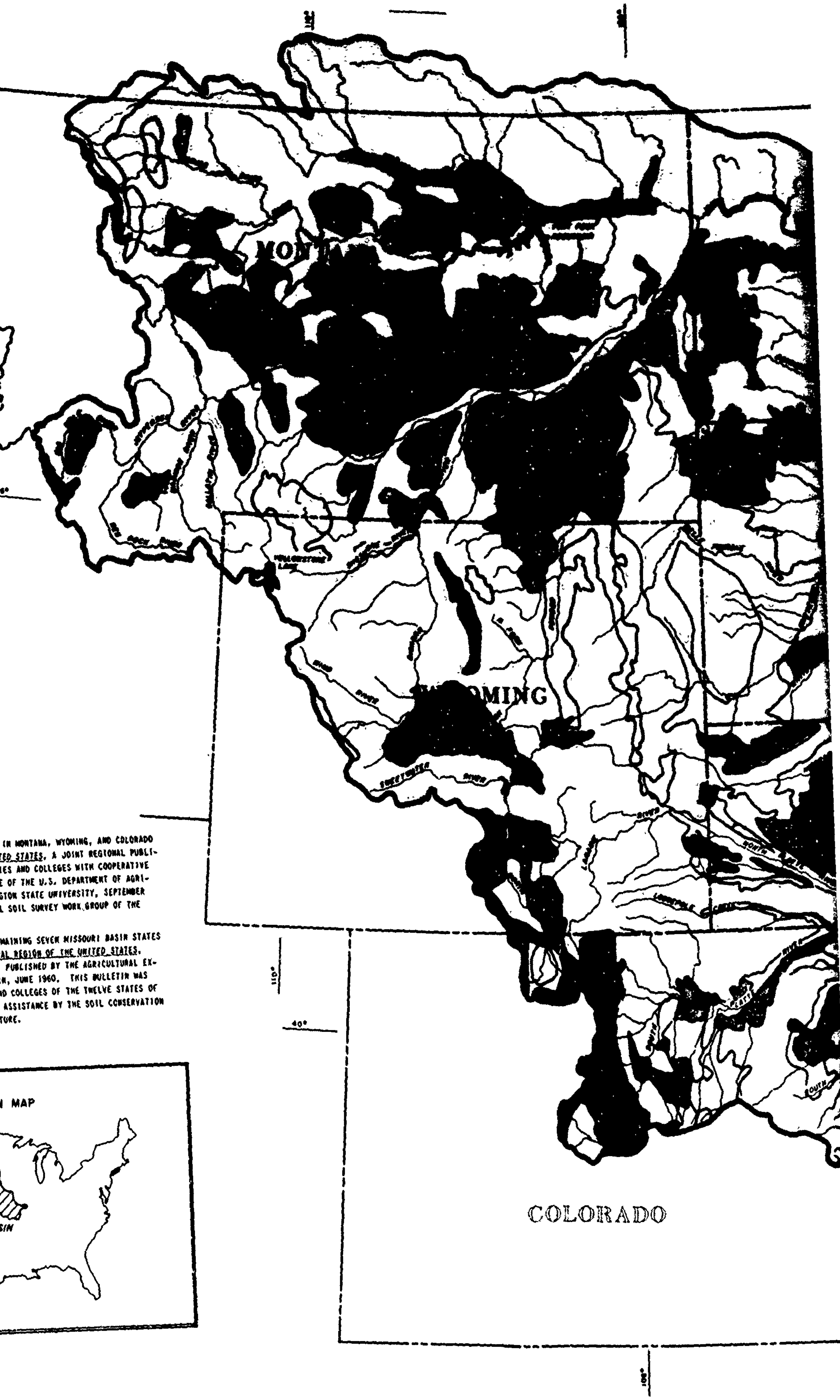
Combined into Group 1 are those areas of relatively impermeable soils with infiltration rates of less than .05 inches per hour. Only a comparatively small part of the basin is in this group. It includes the Badlands of North Dakota, South Dakota, and Montana, where soils are thin on steep slopes with numerous gullies and where most of the area is barren or has only a thin stand of grass cover. It includes also the high Alpine areas of the Rocky Mountains, where little true soil has developed and where the principal vegetation is a thin stand of moss and lichens.

Combined into Group 2 are those areas having soils with infiltration rates ranging from 0.05 to 0.20 inches per hour. Areas in this group exist in each of the basin States except North Dakota. In Missouri, Kansas, Iowa,

Table 6 – MONTHLY POTENTIAL EVAPOTRANSPIRATION IN INCHES

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
LANDER, WYOMING												
1963	0.	.81	1.27	2.02	4.25	5.73	7.33	5.74	4.09	2.45	.73	.01
1964	.06	.15	.72	2.04	3.74	4.75	8.35	6.22	3.68	1.99	.58	.20
1965	.41	.26	.42	2.27	3.05	4.89	6.94	6.05	2.23	2.28	.69	.26
1966	.16	.31	1.42	2.01	4.75	5.43	7.66	5.94	3.64	1.67	.65	.18
1967	.31	.50	1.46	2.17	3.24	4.06	6.88	6.33	4.08	2.11	.45	0.
Means	.19	.41	1.06	2.10	3.81	4.97	7.43	6.06	3.55	2.10	.62	.13
GREAT FALLS, MONTANA												
1963	0.	.56	1.14	1.66	3.18	4.19	6.44	5.54	3.23	1.57	.45	.06
1964	.18	.40	.43	1.57	3.11	4.54	7.10	4.35	1.93	1.57	.26	0.
1965	.08	.22	.03	1.69	2.64	3.97	5.94	4.53	1.03	1.44	.33	.15
1966	0.	.23	.98	1.25	3.43	3.88	6.09	4.23	3.06	1.00	.20	.13
1967	.13	.38	.46	1.17	3.23	4.18	7.89	6.67	3.78	1.44	.45	.03
Means	.08	.36	.61	1.47	3.12	4.15	6.69	5.07	2.61	1.40	.34	.08
GLASGOW, MONTANA												
1963	0.	.13	1.23	1.59	3.35	5.26	7.91	6.66	3.83	1.82	.40	0.
1964	.05	.33	.36	2.06	3.48	5.18	8.93	5.73	2.74	1.74	.23	0.
1965	0.	0.	0.	1.64	3.42	5.45	7.59	6.10	1.76	1.87	.22	.08
1966	0.	0.	.95	1.59	3.93	5.34	6.61	5.25	3.53	1.32	.14	0.
1967	0.	0.	.20	1.55	2.87	4.66	8.28	6.61	3.42	1.43	.35	0.
Means	.01	.09	.55	1.69	3.41	5.18	7.86	6.07	3.06	1.64	.27	.02
BISMARCK, NORTH DAKOTA												
1963	0.	0.	1.10	1.63	3.45	5.90	6.76	5.64	2.93	1.92	.40	0.
1964	0.	.07	.18	1.89	3.96	4.25	6.49	4.57	2.32	1.40	.14	0.
1965	0.	0.	0.	1.24	3.12	4.52	6.04	4.88	1.29	1.63	.30	.07
1966	0.	0.	.82	1.20	3.42	5.17	6.24	4.19	2.81	1.26	.03	0.
1967	0.	0.	.52	1.23	3.39	4.63	7.53	5.89	3.43	1.12	.24	0.
Means	0.	.01	.52	1.44	3.47	4.89	6.61	5.04	2.56	1.47	.22	.01
RAPID CITY, SOUTH DAKOTA												
1963	0.	.38	1.39	1.83	3.82	5.74	6.67	5.97	3.46	2.34	.66	.06
1964	.25	.31	.62	1.90	3.68	4.75	7.05	5.24	3.16	1.76	.43	0.
1965	.15	.22	.05	1.92	3.07	4.33	5.93	4.96	1.67	1.88	.49	.28
1966	0.	0.	.92	1.27	3.46	4.64	6.40	4.13	2.86	1.36	.41	.16
1967	.25	.36	.95	1.95	2.92	3.58	6.17	5.43	3.27	1.74	.56	.06
Means	.13	.26	.79	1.78	3.39	4.61	6.44	5.15	2.89	1.82	.51	.11
OMAHA, NEBRASKA												
1963	0.	.17	1.22	2.38	3.89	6.94	7.05	5.65	3.74	3.23	.89	0.
1964	.27	.38	.80	2.19	5.39	6.02	7.76	4.89	3.16	1.92	.56	.02
1965	0.	0.	.21	2.21	4.94	5.82	6.51	5.71	2.17	2.60	.74	.38
1966	0.	.24	1.54	1.73	4.75	6.15	7.54	5.80	3.33	2.04	.63	.13
1967	.05	.12	1.38	3.10	3.27	5.54	7.31	6.31	3.45	1.55	.61	.15
Means	.06	.18	1.03	2.32	4.45	6.10	7.23	5.67	3.17	2.27	.69	.14
MANHATTAN, KANSAS												
1963	.03	.79	2.02	3.63	4.52	7.88	8.36	7.19	5.52	4.03	1.34	.27
1964	.80	.89	1.80	3.13	6.53	7.66	9.74	6.74	4.82	2.97	1.06	.43
1965	.55	.71	1.12	3.27	5.22	5.68	7.09	5.98	3.34	2.95	1.17	.70
1966	.37	.76	2.46	2.20	5.71	5.73	8.88	6.29	3.77	2.71	1.10	.46
1967	.51	.79	1.75	3.21	4.06	5.61	6.39	6.59	3.60	2.12	.92	.43
Means	.45	.79	1.83	3.09	5.21	6.51	8.09	6.56	4.21	2.96	1.12	.46
COLUMBIA, MISSOURI												
1963	0.	.34	1.69	2.88	4.83	7.25	7.56	6.10	4.43	3.42	.92	.02
1964	.52	.53	1.17	2.89	5.34	5.85	7.50	6.30	4.14	2.26	.96	.29
1965	.32	.51	.69	2.90	5.84	5.75	6.39	5.37	3.55	2.16	.91	.55
1966	.14	.46	1.61	1.89	4.36	5.57	7.49	5.44	3.29	2.16	.98	.35
1967	40	.48	1.56	3.00	3.85	5.76	7.44	6.24	3.84	1.92	.80	.34
Means	.28	.46	1.34	2.71	4.84	6.04	7.27	5.89	3.85	2.38	.91	.31

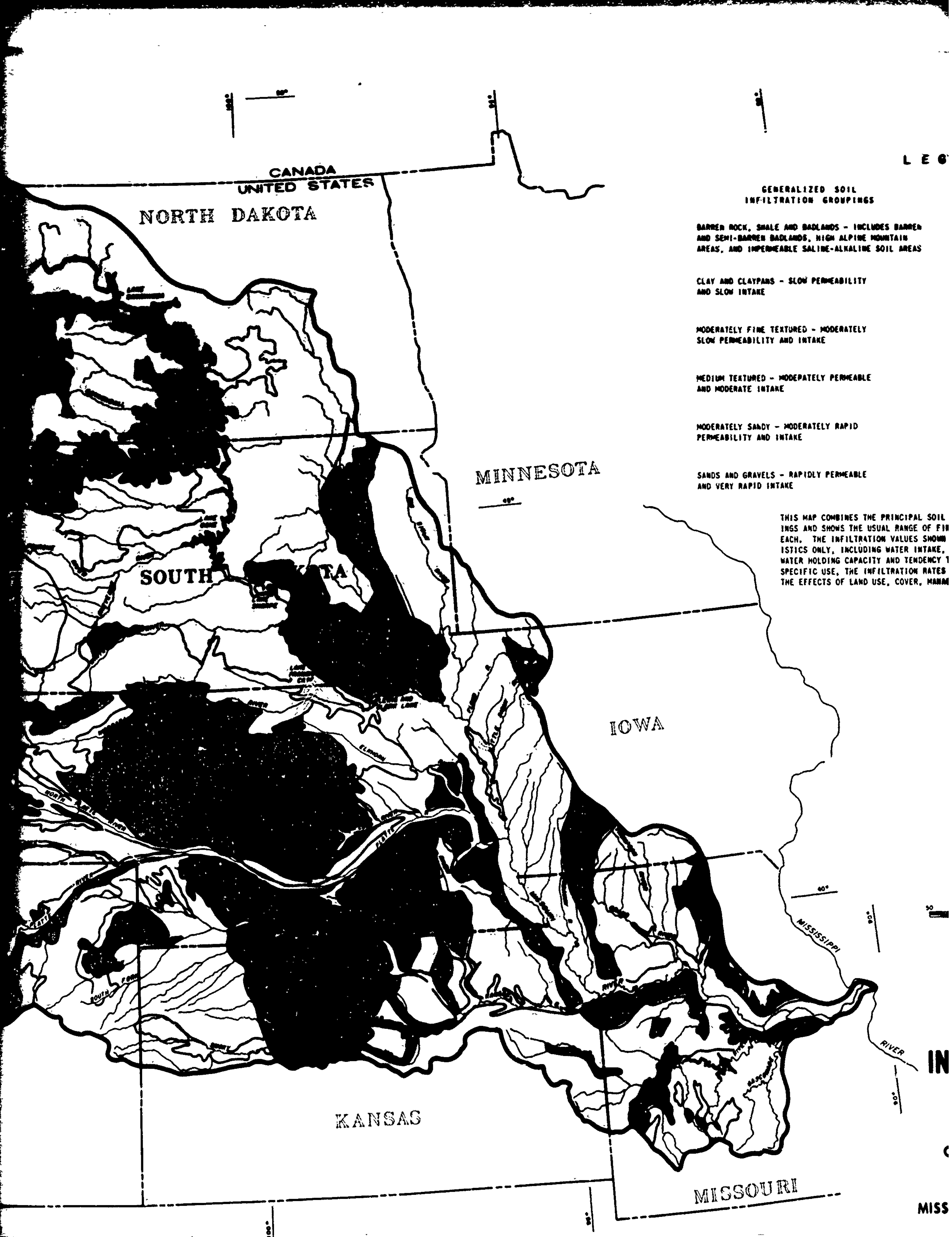
and Nebraska, areas in this group are characterized by deep silty clay and clay loam soils with a slowly permeable, compact, claypan subsoil. Average slopes are in the 4 to 7 percent range. Much of the area is in cultivated crops. Poor soil structure and poor soil tilth, along with clean cultivation, aggravate the problem of water intake and infiltration into the soil. In Montana, Wyoming, and South Dakota, areas in this group for the

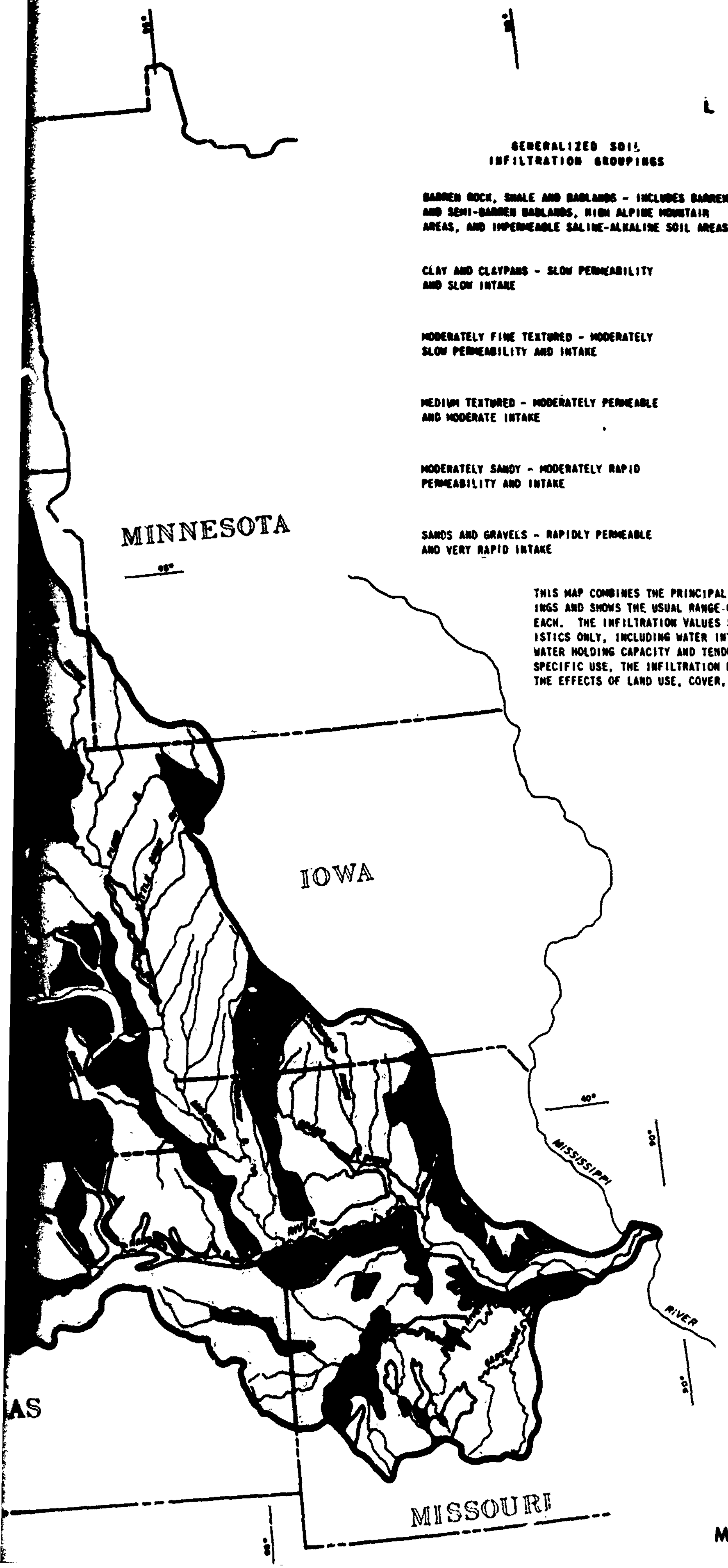


THE DELINEATION OF THE SOIL GROUPINGS IN MONTANA, WYOMING, AND COLORADO WERE DERIVED FROM SOILS OF THE WESTERN UNITED STATES, A JOINT REGIONAL PUBLICATION BY THE WESTERN LAND GRANT UNIVERSITIES AND COLLEGES WITH COOPERATIVE ASSISTANCE BY THE SOIL CONSERVA[illegible] SERVICE OF THE U.S. DEPARTMENT OF AGRICULTURE. THIS REPORT, PUBLISHE[illegible] WASHINGTON STATE UNIVERSITY, SEPTEMBER 1964, WAS SPONSORED BY THE WESTERN REGIONAL SOIL SURVEY WORK GROUP OF THE WESTERN SOIL AND WATER RESEARCH COMMITTEE.

SOIL DELINEATIONS AND DATA FOR THE REMAINING SEVEN MISSOURI BASIN STATES WERE SECURED FROM SOILS OF THE NORTH CENTRAL REGION OF THE UNITED STATES, NORTH CENTRAL REGIONAL PUBLICATION NO. 76, PUBLISHED BY THE AGRICULTURAL EXPERIMENT STATION -- UNIVERSITY OF WISCONSIN, JUNE 1960. THIS BULLETIN WAS COMPILED BY THE LAND GRANT UNIVERSITIES AND COLLEGES OF THE TWELVE STATES OF THE NORTH CENTRAL REGION WITH COOPERATIVE ASSISTANCE BY THE SOIL CONSERVATION SERVICE OF THE U.S. DEPARTMENT OF AGRICULTURE.

LOCATION MAP


LEG
GENERALIZED SOIL INFILTRATION GROUPINGS
BARREN ROCK, SHALE AND BADLANDS - INCLUDES BARREN AND SEMI-BARREN BADLANDS, HIGH ALPINE MOUNTAIN AREAS, AND IMPERMEABLE SALINE-ALKALINE SOIL AREAS
CLAY AND CLAYPANS - SLOW PERMEABILITY AND SLOW INTAKE
MODERATELY FINE TEXTURED - MODERATELY SLOW PERMEABILITY AND INTAKE
MEDIUM TEXTURED - MODERATELY PERMEABLE AND MODERATE INTAKE
MODERATELY SANDY - MODERATELY RAPID PERMEABILITY AND INTAKE
SANDS AND GRAVELS - RAPIDLY PERMEABLE AND VERY RAPID INTAKE
THIS MAP COMBINES THE PRINCIPAL SOIL
INGS AND SHOWS THE USUAL RANGE OF FI
EACH. THE INFILTRATION VALUES SHOWN
ISTICS ONLY, INCLUDING WATER INTAKE,
WATER HOLDING CAPACITY AND TENDENCY T
SPECIFIC USE, THE INFILTRATION RATES
THE EFFECTS OF LAND USE, COVER, MANA
CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
KANSAS
MISSOURI
MISSISSIPPI
RIVER
ELKHORN
IN
MISS



LEGEND

GENERALIZED SOIL INFILTRATION GROUPINGS	INFILTRATION RATE	
BARREN ROCK, SHALE AND BADLANDS - INCLUDES BARREN AND SEMI-BARREN BADLANDS, HIGH ALPINE MOUNTAIN AREAS, AND IMPERMEABLE SALINE-ALKALINE SOIL AREAS	LESS THAN .05	
CLAY AND CLAYPANS - SLOW PERMEABILITY AND SLOW INTAKE	.05 - .20	2
MODERATELY FINE TEXTURED - MODERATELY SLOW PERMEABILITY AND INTAKE	.20 - .60	
MEDIUM TEXTURED - MODERATELY PERMEABLE AND MODERATE INTAKE	.60 - 2.00	4
MODERATELY SANDY - MODERATELY RAPID PERMEABILITY AND INTAKE	2.00 - 6.3	5
SANDS AND GRAVELS - RAPIDLY PERMEABLE AND VERY RAPID INTAKE	OVER 6.3	

THIS MAP COMBINES THE PRINCIPAL SOIL ASSOCIATIONS INTO SIX BROAD SOIL GROUPINGS AND SHOWS THE USUAL RANGE OF FINAL INFILTRATION RATES OCCURRING IN EACH. THE INFILTRATION VALUES SHOWN ARE BASED ON PHYSICAL SOIL CHARACTERISTICS ONLY, INCLUDING WATER INTAKE, SURFACE TEXTURE, SOIL PERMEABILITY, WATER HOLDING CAPACITY AND TENDENCY TO SEAL UNDER RAINDROP ACTION. FOR SPECIFIC USE, THE INFILTRATION RATES SHOWN WOULD HAVE TO BE ADJUSTED FOR THE EFFECTS OF LAND USE, COVER, MANAGEMENT, SLOPE, EROSION, ETC.

N

APPROXIMATE SCALE IN MILES: 50 0 50 100 150 200

JUNE 1969

GENERALIZED SOIL INFILTRATION GROUPINGS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 11

most part have moderately deep soils formed from the Pierre and Fox Hills shales. Much of the area has fair stands of mid and short grasses, and some of the deeper soils are in crops.

Table 7 – PEAK PERIOD POTENTIAL EVAPO-TRANSPIRATION IN INCHES PER DAY, RAPID CITY, SOUTH DAKOTA

Year	7-day Period		14-day Period	
	July	August	July	August
1955	0.30	0.28	0.28	0.25
1956	0.29	0.23	0.26	0.21
1957	0.28	0.26	0.27	0.25
1958	0.22	0.28	0.20	0.26
1959	0.29	0.25	0.27	0.25
1960	0.29	0.27	0.27	0.24
1961	0.25	0.29	0.25	0.25
1962	0.23	0.25	0.20	0.23
1963	0.24	0.22	0.24	0.21
1964	0.27	0.27	0.26	0.24
1965	0.22	0.23	0.21	0.21
1966	0.24	0.19	0.23	0.18

Areas in Group 3 have infiltration rates ranging from 0.20 to 0.60 inches per hour, and they exist in all of the basin states. Soils are deep to moderately deep silt loams, clay loams, and silty clay loams. They have a moderately slow permeability and a relatively high water storage capacity. Except in the foothills areas of Colorado, Wyoming, and Montana, a large part of the area in Group 3 is in cultivation.

Areas in Group 4 have infiltration rates ranging from 0.60 to 2.0 inches per hour. The aggregate area in Group 4 is larger by far than in any other of the six groups. Soils are deep, medium textured, and moderately permeable, and they are dominantly in cropland with some pasture. Before cultivation started, almost 100 years ago, these soils had a good granular structure and a good water intake rate. As a result of continuous cultivation, erosion losses, and poor crop residue management, the surface soil ' ave lost much of their former ability to take in water. On freshly plowed fields the surface layer puddles and seals over immediately following rains of more than about 1/4 inch. If a good stubble-mulch is maintained or the surface is otherwise kept open, infiltration into these soils can be increased.

Areas in Group 5 have infiltration rates ranging from 2.0 to 6.3 inches per hour. They consist primarily of the alluvial soils of stream floodplains and other areas of moderately sandy soils with moderately rapid permeability. In western Nebraska and northeastern Colorado, the Group 5 areas include some of the most valuable irrigated land in the Missouri Basin.

Areas in Group 6 have infiltration rates in excess of 6.3 inches per hour. The sandhills of Nebraska comprise the greater part of the Group 6 area. Soils are deep, sandy, and rapidly permeable. About 90 percent of the area has native, bluestem vegetation. The area produces little surface runoff and is considered to be one of the greatest ground-water recharge areas in the Nation.

The six broad soil groupings described are delineated on plate 11 of this appendix. It should be understood that within each of the six delineated areas, small areas with different soil types and different infiltration characteristics exist.

Infiltrometer Field-Plot Test Data

Field infiltrometer test data, made with various types of infiltrometers or rainfall simulators, were furnished by the Soil Conservation Service, the Forest Service, the Agricultural Research Service, and the Bureau of Reclamation. The test data furnished show infiltration rates ranging from 0.04 to 9.7 inches per hour.

Infiltration Data from Hydrograph and Storm Analyses

Infiltration data obtained from hydrograph analyses and storm studies were furnished by the Bureau of Reclamation and the Corps of Engineers. Most of the data are for areas above stream gaging stations although some are for areas above other locations such as damsites, reservoirs, and mouths of streams. The data show infiltration rates ranging from 0.01 to 1.32 inches per hour.

CHAPTER 5

SEDIMENT

INTRODUCTION

The Missouri River Basin covers a very large and diverse area varying from flat, essentially non-draining land to high mountains; from highly erodible soil to rock; and from subhumid to semiarid climate. Within these diversities, there are areas of more or less localized characteristics; thus, it is not possible to develop simple formulae nor an overall relationship for sediment yields within this basin. Sediment yields, representing all sediment carried by the streams, in tons per square mile per year, range from near zero in streams draining the mountainous areas to 10,000 or more in streams entrenched in the more erodible soils of the central Missouri Basin.

It has been necessary to analyze the basin, area by area, considering the availability of suspended sediment sampling data, physiographic and geologic information, soils, topography, climate, runoff, vegetation, land use, upland erosion, channel erosion, and knowledge of sediment transport and delivery. The magnitude of the task precluded any analysis on a relatively localized basis. Data on sediment sampling and reservoir sedimentation surveys were assembled, generalized soil maps and physiographic and geologic maps were consulted, and runoff data considered. With these as a basis, and from technical knowledge of the area, it was possible to develop generalized maps of sediment yield. In some areas, data from field reconnaissances were available to aid in the analyses.

The sediment yield estimates apply only to drainages in excess of 100 square miles. For smaller areas a single erosion feature may be predominant, while in the larger areas the local features usually will be integrated to produce a reasonable average. It must be recognized also that the generalized estimates cannot always be definitive even for the larger areas. They are considered to be adequate for preliminary planning, but the available information from which they were developed is, in most instances, inadequate to delineate the variations which occur even within reasonably large drainages. Prior to the final design of any project, the sediment yield estimate should be refined by a field reconnaissance of the drainage, review of the local geology, physiography, and soils, and the collection of at least enough suspended sediment discharge data to provide some comparison with established stations.

SEDIMENT YIELD CHARACTERISTICS

Sediment yield estimates have been made in terms of tons per year per square mile of drainage. For most purposes it will be necessary to convert these values to terms of acre-feet or other volume unit, the most commonly used conversion value being 65 pounds per cubic foot (dry weight) or 1,416 tons per acre-foot. This value is reasonably adequate for sediments derived from average soils; however, the actual volume-weight ratio for sediments deposited in reservoirs will vary from as low as 30 pounds per cubic foot (650 tons per acre-foot) for thixotropic deposits of Bentonitic clays such as found in the White River Basin to 85 to 90 pounds per cubic foot (2,200 tons to 2,300 tons per acre-foot) for predominantly sandy deposits. These values will also vary with the reservoir operation; i.e., deposits containing a moderate to high proportion of clay and silt size sediments will attain a higher density if exposed to air frequently or for long periods of time than will similar deposits if continuously submerged.

The sediment yield from a given area is dependent primarily on ten factors: Geology, topography, soils, sheet erosion, upland erosion, channel erosion, climate, runoff, ground cover, and land use.

Geology is concerned with the development of the earth mantle; whether hard rock, weathered rock, immature or partially formed soils, or fully developed soils. Hard rock, of course, produces essentially no sediment yield. Weathered rock, immature soils, glacial moraine deposits, and alluvial deposits are increasingly susceptible to erosion, while weathered shale, friable fine sands, and deep aeolian deposits have an extremely high sediment yield potential.

Topography– The obvious factor involved in the effect of topography on sediment yield is the degree of slope, whether the land surface is level, gently sloping, rolling, hilly, or steeply sloping, for it is the slope that largely governs the velocity and the erosive power of the runoff. In order to induce a major sediment yield, however, it is also necessary for the topography to be such that the eroded sediments are transported into defined water courses. For example, even a deeply eroded hillside may not add appreciably to the downstream sediment yield if the eroded materials are deposited on a valley floor rather than moved into the stream network.

Soils– In general, soils containing a high proportion of clay-size materials are difficult to erode, particularly if the total mixture is sufficiently well graded to form a relatively dense material. Well consolidated soils and soils containing rock fragments also tend to erode slowly. On the other hand, friable and sandy soils erode readily. Soils with the greatest erosion potential appear to be those in which there is a very small range of grain sizes, such as the loess deposits in western Iowa, and the weathered shale. The inclusion of bentonite and of soluble salts in soils and alluvial materials increases the erosion potential.

Sheet Erosion– The impact of raindrops and of snow-melt runoff on land surface everywhere causes erosion. The sediment thus detached is transported away by runoff in the form of sheet flow or in small rills. Because of the total area thus affected the quantity of sediment is large. Sheet erosion is the major cause of sediment production in the Missouri Basin.

Upland Erosion– Upland erosion, evidenced by rills or channels on the hillsides, may produce a very high sediment yield locally and provide serious problems in soil conservation. To be effective in downstream sediment yield, however, it is necessary that the hillside erosion be associated with a reasonably well developed drainage network. If the hillside erosion features drain onto a flat alluvial plain, only a small portion of the eroded material will be moved into stream channels.

Channel Erosion– This feature includes gully erosion as well as erosion of mature stream channels. In the Soldier River of western Iowa, as an example, a very high sediment yield results from the head cutting of the parent stream and its tributaries into the deep loess. Material from pronounced hillside erosion appears to deposit on the narrow alluvial plains rather than to enter the stream channel. In more mature streams, sediment production is usually a result of eroding channel banks.

Climate– There are several climatic factors affecting land erosion; i.e., total rainfall, rainfall intensity and duration, freezing and thawing cycles, and proportion of precipitation falling as snow. In general, erosion is least with a humid climate which encourages vegetation, with low intensity storms, and with snow fall. An arid climate with sparse vegetation, and high intensity storms is conducive to erosion, although it may be restricted by the infrequency of storm occurrences.

Runoff– High intensity runoff has a high potential for both erosion of the land and transport of the eroded materials. It is most often associated with the high intensity storms and sparse ground cover typical of arid or semiarid areas; thus, its effect may be limited by infrequent occurrences.

Ground Cover– In an area which is completely covered by vegetation, litter, or rock fragments, rainfall has little opportunity to either reach erodible material readily or run off with sufficient intensity to transport sediments. Conversely, an unprotected area may be susceptible to both erosion and transport.

Land Use– To a certain degree, ground cover and land use are associated factors; however, the variation between cultivated and unbroken land is important as is the distinction between row-crops and small-grain and between lightly grazed or heavily grazed pasture. Soil conservation practices may decrease downstream yield, particularly if the drainage net is so developed that eroded materials are introduced directly into flow channels or if channel controls are constructed in head-cutting areas.

DETERMINATIONS OF SEDIMENT YIELD

The sediment yield to be anticipated at a project site is, of course, most accurately determined if a long period record of sediment discharge has been obtained at the site. Such records are seldom available, however, for it is seldom that the probability of the future justification of a project can be adequately established to permit the operation of a sediment discharge station for the 10-year to 20-year period required to develop a reasonable value of average annual sediment yield. In some cases, a station may be operated during a 2- or 3-year planning period. The record thus obtained is, of itself, inadequate, but it is valuable as a reference in combination with other available information.

In many areas there will be sediment discharge records for other locations on the stream in question or for other streams in the same general area. Even the records for streams in the same major drainage may be helpful. In utilizing such records, however, it must be recognized that the area contributing to any given station may be composed of segments having different sediment yield characteristics. For any rational evaluation of the station data it is necessary to balance an estimated yield from each of these areas against the integrated yield at the station. On this basis, areas draining to the project in question may be compared for assistance in determining sediment yields. Sediment yields at all available sediment sampling stations throughout the Missouri Basin are listed in table 8.

Except for those rare instances of an adequate record at a desired site, there is no adequate substitute for a field reconnaissance by competent personnel in determining sediment yield in an area as diverse as the Missouri Basin. For preliminary planning purposes, maps of estimated ranges of sediment yield for drainages in excess of 100 square miles have been prepared. They were developed on the basis of available sediment discharge data, reservoir sedimentation survey data, soil maps, geologic and physiographic maps, and technical knowledge. This was supplemented, in some areas, by information from detailed field reconnaissances made for projects currently under investigation. Yield values were determined as a range for example, 500 to 1,000 tons per square mile per year, since local variations make it impractical to develop specific values for generalized areas. These maps are shown as figures 22 through 29.

No general yield values have been developed for application to drainage areas of less than 100 square miles. For such areas, local conditions frequently vary to such an extent that the inclusion or exclusion of a single-tributary area might result in a radically different sediment yield. For areas of 10 square miles or less, the stage of development of various erosion features is extremely important; for example, an active, head-cutting gully might produce extremely high sediment yields while a mature gully in the same area might produce only a moderate yield. A field reconnaissance of such areas is the only rational method of developing sediment yield values.

SEDIMENT YIELD VALUES FOR PROJECT PLANNING

For preliminary planning of projects involving drainages of 100 square miles or more, the values developed for the subbasin reports should be adequate. It must be recognized that the importance of local variation is in an inverse ratio to the size of the drainage; thus, it is recommended that the higher values of the yield range be tentatively used for the relatively small drainages. As the size of the drainage increases, the median or even the lesser values of the range might be appropriate.

For final planning, except for very large drainage areas of several thousand square miles, a field reconnaissance is recommended. Specific yield values can be assigned to various segments of the drainage and weighted by proportionate areas. The use of topographic, physiographic, and soils maps is helpful in this process.

EFFECTS OF WATER CONTROL PROJECTS ON SEDIMENT YIELD

In order to analyze the effects of water control projects on sediment production, it is necessary to analyze the process of sediment erosion and transport. When the soil surface is disturbed by rainfall, only a small portion of the disturbed material will be removed from a given area. The remainder will be moved only a short distance to lodge in an adjacent furrow or against a clump of grass, a fence post, or other object. The material moved from the area will be collected in small rills or channels, but when it is discharged into a larger channel with a lesser slope and lower velocity of flow a large proportion of that material will be deposited as a debris fan, or may aggrade the bed over a long reach. The remainder will be moved to the next larger channel where a proportion will be deposited, and this process continues until the material remaining in transport reaches a stream where the flow is adequate to maintain an average balance between the material introduced and the material transported. The debris fans and channel deposits, in turn, may be eroded later by larger flows in the channels in which they were deposited.

Material eroded from hillside rills may in some cases be almost immediately introduced into a flow system, or it may be more or less permanently deposited on a flat valley floor. Fine-grained material eroded from gullies would normally be expected to remain in a flow system, but it may go through the process of deposition and re-erosion, depending on particle size distribution.

Investigations of erosion and sediment transport have indicated that the sediment yield at the lower end of a drainage of less than 1 square mile may be as much as 50 percent to 75 percent of the material eroded. In the case of severe gullying it may be even larger. This proportion decreases as the size of the drainage increases until, with drainages of [illegible]0 square miles or more, the average yield approaches 10 percent.

The effect of projects for conservation, irrigation, flood control, or similar purposes will thus depend largely upon the nature of the project, the character of the drainage, and the area of the drainage involved. Experimental projects have demonstrated that the application of soil conservation practices on drainages of up to 1 square mile, with only a moderately developed drainage net, can reduce the sediment yield by as much as 85 percent. With increasing size of the drainage, however, the effect of soil conservation on sediment yield at a downstream point decreases rapidly. Much of the sediment previously eroded from the land surface will remain available for continued movement from the debris fans and flow channels for long periods of time and additional erosion may be induced. While there is no question as to the value of conservation practices to the land on which they are applied, it is unwise to assume

Table 8 – SUSPENDED SEDIMENT DISCHARGE

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Upper Missouri Subbasin								
0185	Beaverhead River at Blaine, Mont.	3,619		1963-64	2	33,600		9
0255	Big Hole River near Melrose, Mont.	2,476		1957, 61-64	5	26,900		11
0265	Jefferson River near Twin Bridges, Mont.	7,632		1958-59 1961-62	4	93,700		12
0545	Missouri River at Toston, Mont.	14,669		1950-53	4	396,000		27
0711	Little Prickly Pear Cr. at Sieben Ranch near Wolf Cr., Mont.	270		1963	1	1,420		5.3[1]
0713	Little Prickly Pear Creek at Wolf Creek, Mont.	381		1963	1	2,690		7.1[1]
0995	Marias River near Shelby, Mont.	3,242		1950-51	2	1,000,000[2]		310[2]
1080	Teton River near Dutton, Mont.	1,308		1955-57	3	92,100[2]		.70[2]
1150	Missouri River at Power Plant Ferry, Mont.		13,000[3]	1949-51 1958-63	9	5,829,000		448
1276	Musselshell River near Mosby, Mont.	5,941		1949-50 1963-65	3	431,000[2]		73[2]
1740	Willow Creek near Glasgow, Mont.	538		1954-63	10	892,000		1,660
1745	Milk River at Nashua, Mont.		18,300[3]	1949-58 1961-63	12	1,505,000		82
1770	Missouri River at Wolf Point, Mont.	24,734[4]		1949-63	15	3,995,000		162
1855	Missouri River at Culbertson, Mont.	34,000[4]		1948-51[5] 1959-63	9	5,354,000		207

[1] Yields for 1964-65 were much higher, but were affected by highway construction.
[2] Yield affected by diversions to offstream reservoir(s).
[3] Approximate.
[4] Drainage Area below Fort Peck Reservoir.
[5] At Snowden, Mont. in 1948 and 1949.

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Yellowstone Subbasin								
	Butcher Creek near Luther, Mont.	9		1960-62	3	120[1]		13
	Butcher Creek near Roscoe, Mont.			1960-62	3	1,100[1]		44
	Butcher Creek near Fishtail, Mont.			1960-62	3	1,900[1]		58
2043	Butcher Creek near Absarokee, Mont.	39.6		1960-62	3	3,000[1]		76
2077	North Fork Bluewater Creek, near Bridger, Mont.	7.5		1961-63	3	250[1]		34
2078	Bluewater Creek near Bridger, Mont.	27.5		1960-63	4	2,300[1]		84
2078.5	Bluewater Creek at Sanford Ranch near Bridger, Mont.	43.9		1961-63	3	5,000[1]		115
2078.7	Bluewater Creek near Fromberg, Mont.	46.6		1961-63	3	6,500[1]		140
2079	Bluewater Creek at Fromberg, Mont.	53.2		1960-63	4	20,000[1]		380
2280	Wind River at Riverton, Wyo.	2,309		1949-56	8	448,000	470,000	204
2350	Beaver Creek near Arapaho, Wyo.	354		1951-53	3	124,000	130,000[10]	367[10]
2355	Little Wind River near Riverton, Wyo.	1,904		1949-53 1956	6	244,000	220,000	116
2360	Kirby Draw near Riverton, Wyo.	182		1951-53	3	4,500		25
2390	Muskrat Creek near Shoshoni, Wyo.	733		1950-58 1960-63	13	194,000	160,000	220
2445	Fivemile Creek near Pavillion, Wyo.	118		1949-58 1961-63	13	34,000[2]	37,000[2]	314[2]

[1] Computed on basis of twice weekly samples.
[2] Not representative of natural yield because of development of upstream controls. Estimated delivery of 70,000 tons per year, or 600 tons per square mile per year prior to control and 6,000 tons per year, or 50 tons per square mile per year under present conditions.
[10] Approximate.

Table 8 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Yellowstone Subbasin (Continued)								
2500	Fivemile Creek near Riverton, Wyo.	356		1950-58	13	660,000[3]	660,000[3]	
				1960-63				
2530	Fivemile Creek near Shoshoni, Wyo.	418		1949-63	15	1,080,000[4]	1,100,000[4]	
2555	Poison Creek near Shoshoni, Wyo.	500		1949-53	6	13,900	20,000[10]	40[10]
				1956				
2570	Badwater Creek near Bonneville, Wyo.	808		1948-53	15	239,000	227,000	281
				1955-63				
2575	Muddy Creek near Pavillion, Wyo.	267		1949-53				
				1955-58	12	150,000[5]	140,000	524[5]
				1961-63				
2580	Muddy Creek near Shoshoni, Wyo.	332		1949-63	15	286,000[6]	300,000[6]	
2585	Dry Cottonwood Creek near Bonneville, Wyo.	165		1951-53	3	94,000		570
2595	Bighorn River at Thermopolis, Wyo.	8,020		1947-51	5	4,700,000		580
		319[7]		1952	1	239,000		750
2670	Gooseberry Creek at Neiber, Wyo.	361		1952	1	271,000		750
2685	Fifteen Mile Creek near Worland, Wyo.	518		1951-63	13	583,000	600,000	1,160
2690	Bighorn River near Manderson, Wyo.	11,020		1947-51	5	7,560,000		695
		3,319[7]		1952-53	3	1,730,000		500
				1956				
2765	Greybull River at Meeteetse, Wyo.	681		1955-56	2	162,000		238
2780	Dry Creek at Greybull, Wyo.	433		1952-53	2	97,000		224
2795	Bighorn River at Kane, Wyo.	15,846		1947-51	5	10,680,000		674
		8,145[7]		1952-63	12	4,020,000	4,300,000[8]	528
2855	Sage Creek near Lovell, Wyo.	381		1951-53	3	200,000		525
2862	Shoshone River at Kane, Wyo.	2,989		1960-63	4	1,543,000[9]		516[9]
2947	Bighorn River at Bighorn, Mont.	22,885		1948-51	4	11,100,000		485
		15,184[7]		1952-54				
				1956-58	10	5,300,000	5,700,000	375
				1960-63				
3085	Tongue River at Miles City, Mont.	5,379		1947-51	5	568,000	420,000	78[10]
3090	Yellowstone River at Miles City, Mont.	48,253		1949-51	3	16,583,000		343
3095	Middle Fork Powder River above Kaycee, Wyo.	450		1949-53	5	53,000	60,000[10]	133[10]
3125	Powder River near Kaycee, Wyo.	980		1950-53	4	214,000	240,000[10]	245[10]
3130	South Fork Powder River near Kaycee, Wyo.	1,150		1951-53	3	1,115,000	1,800,000[10]	1,560[10]
3135	Powder River at Sussex, Wyo.	3,090		1950-53	4	2,690,000	3,500,000[10]	1,130[10]
3165	Crazy Woman Creek near Arvada, Wyo.	956		1950-53	4	150,000	175,000[10]	180[10]
3170	Powder River at Arvada, Wyo.	6,050		1947-57	11	4,850,000	5,500,000	910
3240	Clear Creek near Arvada, Wyo.	1,110		1950-53	4	120,000	150,000[10]	135[10]
3265	Powder River near Locate, Mont.	13,189		1950-53	4	5,000,000	7,000,000	530[10]
3295	Yellowstone River near Sidney, Mont.	69,103		1938-63	26	27,380,000	20,982,000	304

3 Not representative of natural yield because of irrigation return flow. Estimated 200,000 T/yr. under present conditions.
4 Not representative of natural yield because of irrigation return flow. Estimated 250,000 T/yr. under present conditions.
5 Not representative of natural yield because of development of upstream controls. Estimated delivery of 60,000 tons per year or 225 tons per square mile per year under present conditions.
6 Not representative of natural yield because of irrigation return flow.
7 Contributing area below Boysen Reservoir.
8 Estimated yield for standard period under conditions of upstream control as of 1963.
9 Not representative of natural yield owing to storage in Buffalo Bill Reservoir and irrigation developments.
10 Approximate.

Table 8 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area: Gross Sq. Mi.	Drainage Area: Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Western Dakota Subbasin								
3340	Little Missouri River near Alzada, Mont.	904		1949-51	3	130,000	150,000[1]	165[1]
3355	Little Missouri River at Marmarth, N. D.	4,570		1953-54	2	1,460,000	1,800,000[1]	395[1]
3360	Little Missouri River at Medora, N. D.	6,190		1946-51	6	3,620,000	3,000,000[1]	485[1]
3370	Little Missouri River near Watford City, N. D.	8,490		1948-63	16	5,850,000	5,850,000	689
3395	Knife River near Golden Valley, N. D.	1,230		1947-49	3	151,000	100,000[1]	81[1]
3405	Knife River at Hazen, N. D.	2,350		1948-63	16	150,000	150,000	64
3430	Heart River near S. Heart, N. D.	315		1947-51	5	26,300	17,000[1]	54[1]
3455	Heart River near Richardton, N. D.	1,240		1947-52	6	324,000	200,000[1]	238[1]
3490	Heart River at Mandan, N. D.	1,600[5]		1950-54	5	1,020,000		673
				1955-63	9	559,000		350
3510	Cannonball River near New Leipzig, N. D.	1,140		1947-50	4	336,000	200,000[1]	175[1]
3525	Cedar Creek near Pretty Rock, N. D.	1,340		1947-49	3	49,100	45,000[1]	34[1]
3540	Cannonball River at Breien, N. D.	4,100		1949-51 1960-63	7	625,000	456,000	113
3550	N. Fork Grand River, Haley, N. D.	509		1962-63	2	9,530	29,010	57
3575	Grand River at Shadehill, S. D.	3,120		1946-50	5	605,000	---[2]	
3580	Grand River at Wakpala, S. D.	2,390		1951 1958-63	7	451,000[6]	920,000	384
3590	Moreau River at Bixby, S. D.	1,570		1949-51	3	476,000		200[1]
3595	Moreau River near Faith, S. D.	2,660		1947-49	3	649,000	450,000[1]	200[1]
3605	Moreau River, Whitehorse, S. D.	5,223[4] 4,880		1948-51 1958-63	10	2,651,000	3,140,000	606
3860	Lance Creek at Spencer, Wyo.	2,070		1951-54	4	830,000	800,000[1]	385[1]
3940	Beaver Creek near Newcastle, Wyo.	1,320		1950-57	8	139,000	200,000	150
4000	Hat Creek near Edgemont, S. D.	1,044		1951-54	4	112,000		100[1]
4005	Cheyenne River near Hot Springs, S. D.	8,710		1946-63	18	1,707,000	1,662,000	191
4015	Cheyenne River below Angostura Dam, S. D.		9,100[3]	1952-53 1955-63	11	1,230		
4265	Belle Fourche River below Moorcroft, Wyo.	1,730		1950-51	2	43,000		60[1]
4370	Belle Fourche River near Sturgis, S. D.	5,870		1956-58	3	653,000		200[1]
4395	Cheyenne River, Eagle Butte, S. D.	24,500		1948-51 1958-63	10	7,952,000	7,772,000	317
4415	Bad River, Fort Pierre, S. D.	3,107		1948-63	16	4,225,000	4,225,000	1,350
4460	White River near Ogala, S. D.	2,200		1947-52	6	267,000	190,000	86
4470	White River near Kadoka, S. D.	5,000		1950-54	5	7,463,000	7,500,000	1,500
4505	So. Fk. White River below White River, S. D.	1,570		1951-54 1956-58	7	204,000	190,000	120
4520	White River, Oacoma, S. D.	10,200		1940-63	23	13,000,000	12,000,000	1,177
4535	Ponca Creek at Anoka, Nebr.	410		1951-52	2	200,000	150,000[1]	370[1]

[1] Approximate: available data are insufficient to permit a reliable estimate of yield.
[2] Shadehill Reservoir closed June 30, 1950. Natural yield for period 1948-63 probably did not exceed 350,000 tons per year.
[3] Outflow from reservoir.
[4] At Promise, S. D. prior to 1959.
[5] Below Heart Butte Dam.
[6] Additional record by Corps of Engineers.
[7] Subsequent to storage in Shadehill Reservoir.

Eastern Dakota Subbasin								
4855	Big Sioux River at Akron, Iowa	5,600[2]		1941-51	11	1,114,200	932,000[1]	167

[1] 1941-1960, since stream discharge records not available subsequent to 1960.
[2] Based on field reconnaissance.

Table 8 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Platte-Niobrara Subbasin								
4565	Niobrara River near Hay Springs, Nebr.			1953-55	3	7,650[1]		
4575	Niobrara River near Gordon, Nebr.	4,290		1948-50 1954-55	5	88,600[2]	85,000	
4590	Niobrara River near Cody, Nebr.			1948-54	7	536,200[2]	550,000	
4615	Niobrara River near Sparks, Nebr.	8,090		1948-50	3	930,400[2]	900,000	
4630	Niobrara River at Meadville, Nebr.			1951-52	2	1,850,000[2]	1,500,000	
4635	Long Pine Creek near Riverview, Nebr.	390		1948-51	4	167,000	150,000	385
6379.1	Rock Cr. at Atlantic City, Wyo.	21.3		1958-63	6	1,560[3]		
6430	Bates Cr. near Alcova, Wyo.	393		1957-58	2	100,200		
6435	No. Platte River near Goose Egg, Wyo.		10,745	1951-53 1957-58	5	314,200[4]		
6450	No. Platte River below Casper, Wyo.		11,733	1948-52	5	527,000[4]		
6500	No. Platte River near Douglas, Wyo.		13,180	1948-52	5	699,000[4]		
6540	No. Platte River near Cassa, Wyo.		14,621	1948-53	6	919,000[4]		
6560	No. Platte River below Guernsey Res., Wyo.		15,021	1948-53	6	57,400[4]		
6700	Laramie River near Uva, Wyo.		3,818	1953-57	5	14,900[4]		
7100	So. Platte R. at Littleton, Colo.	3,069		1942-48	7	384,000[7]		125
7120	Cherry Cr. near Franktown, Colo.	169		1942-45 1947-48	6	39,100[7]		231
7125	Cherry Cr. near Melvin, Colo.	360		1942-48	7	260,000[7]		722
7180	Clear Cr. below Idaho Springs, Colo.	264		1953-55	3	33,000		
7185	No. Clear Cr. near Blackhawk, Colo.	55.8		1953-55	3	2,300		
7205	So. Platte R. near Henderson, Colo.	4,713		1942-44 1946-48	6	1,129,000[7]		299
7570	So. Platte R. at Sublette, Colo.	12,170		1944-48	5	729,000[7]		60
7580	Kiowa Cr. at Elbert, Colo.	28.6		1957-64	8	740		
7581	West Kiowa Cr. at Elbert, Colo.	35.9		1963-64	2	800		
7582	Kiowa Cr. at Kiowa, Colo.	111		1957-64	8	1,710		
7590	Bijou Cr. near Wiggins, Colo.	1,314		1951-55	5	953,000		
7595	So. Platte R. at Fort Morgan, Colo.	14,810		1944-48	5	1,827,000[7]		124
7600	So. Platte R. at Balzac, Colo.	16,852		1942-48	7	1,328,000[7]		79
7710	Wood River near Riverdale, Nebr.	379		1948-51	4	37,900	40,000[6]	105
7755	Middle Loup River at Dunning, Nebr.	1,760		1947-52 1954	7	300,000[5]	300,000[6]	170
7840	South Loup R. at St. Michael, Nebr.	2,560		1946-53	8	800,000	600,000[6]	234
7850	Middle Loup R. at St. Paul, Nebr.	7,720		1946-53	8	2,640,000	2,400,000[6]	311
7905	North Loup River near St. Paul, Nebr.	4,460		1946-53	8	1,220,000	1,250,000[6]	280
7935	Beaver Cr. at Loretto, Nebr.	311		1947-50	4	71,700		227
8035	Salt Cr. at Lincoln, Nebr.	710		1951-54	4	2,250,000[6]	1,500,000[6]	2,110
8055	Platte R. near Ashland, Nebr.	85,500		1940-51 1953-63	23	14,963,000	15,227,000[6]	178

[1] Stream flow unusually low in this period.
[2] Yield affected by storage in Box Butte Reservoir and by large noncontributing areas.
[3] Affected by storage in Rock Creek Reservoir, and by mining operations, since October 1961.
[4] Sediment discharge greatly affected by storage and diversions.
[5] Total sediment load about 500,000 tons per year, (285 T/Y/Sq. Mi.).
[6] Partly estimated.
[7] Records considered poor to fair.

Table 8 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Middle Missouri Subbasin								
6005	Floyd River at James, Iowa	882		1955-56	2	45,065	236,000	268
6020	West Fork ditch at Holly Springs, Iowa	399		1958-63	6	403,000	444,000	1,112
6024	Monona-Harrison ditch near Turin, Iowa	4,460		1940-51	12[1]	5,313,000		
6075	Little Sioux River near Turin, Iowa	4,460		1940-51	12[1]	2,120,000		1,777
		3,526		1960-63	4	3,103,000		880
6072	Maple River, Mapleton, Iowa	669		1940-51	12	1,936,000	1,775,000	2,690
6066	Little Sioux River, Correctionville, Iowa	2,500		1950-62	13	687,000	610,400	244
6067	Little Sioux River, Kennebec, Iowa	2,738		1940-57	18	2,368,000	1,969,806	719
6085	Soldier River, Pisgah, Iowa	407		1941-51	11	4,189,000	3,960,000	9,500
6095	Boyer River, Logan, Iowa	871		1945-51	7	7,378,000	4,720,000	5,430
8100	Nishnabotna River, Hamburg, Iowa	2,800		1940-51	12	13,950,000	10,200,000	3,650
8140	Turkey Creek, Seneca, Kans.	276		1950-54	5	1,004,000	670,000	2,425
8150	Nemaha River, Falls City, Nebr.	1,340		1950-63	14	5,862,000	6,140,000	4,580
8090	Davids Creek, Hamlin, Iowa	26		1953-66	14	41,600		1,560
8080	Mule Creek, Malvern, Iowa	10.6		1955-59				
				1962				
				1964-66	9	23,900		2,257
8095	E. Nishnabotna River, Red Oak, Iowa	894		1964-66	3	2,832,000		3,168

[1] Prior to January 1958, part or all of the flow of the Little Sioux River was diverted into the Monona-Harrison ditch above Turin.

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Kansas Subbasin								
8215	Arikaree River at Haigler, Nebr.	1,460	1,330	1948-51	4	159,000		120
8270	S. Fork Republican River near Colo.-Kansas State Line		1,860	1949-50	1[1]			
8275	S. Fork Republican River near Benkleman, Nebr.	2,580	700[2]	1962-63	2	110,300		158
8285	Republican River, Stratton, Nebr.	7,940	...[3]	1951	1	3,220,000		
				1953-54	2	50,000		
8295	Republican River at Trenton, Nebr.	8,100	...[3]	1947-49	3	1,593,000		
				1950[4]	1	749,000		
8325	Frenchman Creek near Enders, Nebr.	1,300	820	1947[5]	1	29,000		35
8380	Red Willow Creek near Red Willow, Nebr.	710	400	1950-53	4[6]	344,000		860
8390	Medicine Creek at Maywood, Nebr.	207	82	1951-58	8[7]	30,100		367
8395	Brushy Creek near Maywood, Nebr.	130	72	1951-58	8[7]	67,000		930
8400	Fox Creek at Curtis, Nebr.	77[8]		1951-58	8[7]	72,700		944
8405	Dry Creek near Curtis, Nebr.	20[8]		1951-58	8[7]	59,000		2,950
8410	Medicine Creek above Harry Strunk				6			
	Lake, Nebr.			1951-58	3	533,000		
8415	Mitchell Creek above Harry Strunk				5[9]			
	Lake, Nebr.	53[8]		1952-57	16	31,700		598
8430	Medicine Creek at Cambridge, Nebr.	1,070	680	1947-49	3	2,673,000		3,920
				1952-56	5[9]	28,244		
8445	Republican River near Orleans, Nebr.	15,400	...[10]	1948-63	15	1,966,000		...[10]
8450	Sappa Creek near Oberlin, Kans.	1,040		1963	1	11,670		11
8452	Sappa Creek near Beaver City, Nebr.	1,500		1948-51	4	379,000		253
8465	Beaver Creek at Cedar Bluffs, Kans.	1,710		1962-63	2	57,700		33
8470	Beaver Creek near Beaver City, Nebr.	2,060		1951-53	3	122,000		59
8475	Sappa Creek near Stanford, Nebr.	3,840		1948-53	6	448,000		117

[1] 1949 Record - affected by Bonny Reservoir after July 1950.
[2] 1850 Sq. Mi. controlled by Bonny Reservoir.
[3] A large, unspecified portion of the drainage is non-contributing.
[4] Modified by Bonny Reservoir after July 1950.
[5] Partly estimated.
[6] 1950 records estimated for Oct. to Dec.
[7] 1951 records estimated for Oct. to Dec.
[8] Approximate.
[9] Affected by storage in Harry Strunk Lake after Aug. 8, 1949.
[10] Affected by Harry Strunk Lake (1950), Bonny Reservoir (1951), Enders Reservoir (1951), Swanson Reservoir (1954) and Red Willow Reservoir (1962).

Table 8 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Kansas Subbasin (Continued)								
8480	Prairie Dog Creek at Norton, Kans.	721[11]		1948-52	5	311,000		432
8495	Republican River below Harlan County Dam, Nebr.	20,750	10	1953-63	11	14,280		1,428
8505	Republican River at Bloomington, Nebr.	20,800	---[12]	1948-52	5	5,739,000		
				1953 & 1962-63	3	293,000		
8530	Republican River near Guide Rock, Nebr.	22,060	---[13]	1961-63	3	328,000		
8535	Republican River near Hardy, Nebr.	22,400	---[14]	1961-63	3	478,000		
8540	White Rock Creek at Lovewell, Kans.	342	342[15]	1950-53	4	640,000		1,870
8560	Republican River at Concordia, Kans.	23,540	---[14]	1961-63	3	964,000		
8566	Republican River at Clay Center, Kans.	24,570	---[16]	1948-52	5	10,123,000		
			---[14]	1953	1	805,000		
			---[14]	1958-63	6	1,620,000		
8625	Smoky Hill River at Ellis, Kans.	5,630	5,630	1948-50	3	611,000		109
8633	Big Creek near Ogallah, Kans.	297	297	1956-59 & 1962	5	135,000		455
8645	Smoky Hill River at Ellsworth, Kans.	7,580	---[17]	1948-63	16	1,060,000		
8660	Smoky Hill River at Lindsborg, Kans.	8,110	253[18]	1952-63	12	168,400		666
8669	Saline River near Wakeeney, Kans.	696	696	1956-59	4	154,000		221
8670	Saline River near Russell, Kans.	1,502	1,502	1947-51	5	904,000		602
8675	Paradise Creek near Paradise, Kans.	212	212	1947-51	5	245,000		1,150
8685	Wolf Creek near Sylvan Grove, Kans.	261	261	1948-50	3	115,000		441
8695	Saline River at Tescott, Kans.	2,820	2,820	1960-63	4	920,000		326
8705	Smoky Hill River at New Cambria, Kans.	11,730	---[19]	1963	1	141,000		
8718	N. Fork Solomon River at Kirwin, Kans.	1,360	1,360[20]	1950-51	2	1,570,000		1,150
8725	N. Fork Solomon River at Downs, Kans.	2,390	1,030[21]	1962-63	2	430,000		418
8735	S. Fork Solomon River near Alton, Kans.	1,720	1,720[22]	1947-51	5	1,180,000		754
8740	S. Fork Solomon River at Osborne, Kans.	2,024	...[22]	1962-63	2	227,000		
8760	Solomon River at Beloit, Kans.	5,530	...[23]	1949-52	4	3,660,000		662
8776	Smoky Hill River at Enterprise, Kans.	19,200	8,783[24]	1958-63	6	4,330,000		493
8810	Big Blue River near Crete, Nebr.	2,716	2,716	1962-	1	535,940		197
8820	Big Blue River at Barnston, Nebr.	4,420	4,420	1960-63	4	1,886,000		427
8830	Little Blue River near Deweese, Nebr.	1,140	1,140	1957-61	5	513,000		495
8845	Little Blue River at Waterville, Kans.	3,330	3,330	1960-63	4	2,426,000		729
8860	Big Blue River at Randolph, Kans.	9,100	9,100	1943-61	19	9,160,000		1,008
8875	Kansas River at Wamego, Kans.	55,240		1958-63	6	13,276,000		
8880	Vermillion Creek near Wamego, Kans.	243	243	1959-63	5	336,200		1,380
8905	Delaware River at Valley Falls, Kans.	922	922	1949-54	6	3,441,000		3,730
8925	Kansas River at Bonner Springs, Kans.	59,890		1948-63	16	32,825,000		

[11] 684 sq. mi. after October 1, 1961.
[12] Affected by five major upstream reservoirs - Harlan County Reservoir, 13 1/2 miles upstream, closed in 1952.
[13] 1/4 mile below Courtland Diversion Dam.
[14] Affected by Harlan County Dam and by Courtland Diversion.
[15] Oct. 1949 - Jan. 1950 estimated.
[16] Affected by upstream reservoirs.
[17] Cedar Bluffs Reservoir closed Nov. 1950.
[18] Net drainage below Kanopolis Reservoir (closed 1948).
[19] Affected by Kanopolis Reservoir.
[20] Kirwin Reservoir closed 1955.
[21] Drainage below Kirwin Reservoir.
[22] Webster Reservoir closed 1956
[23] This station subsequently affected by Kirwin and Webster Reservoirs.
[24] Area below Kirwin, Webster and Kanopolis Reservoirs.

Table 8 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Lower Missouri Subbasin								
8930	Missouri River at Kansas City, Mo.	489,200		1949-63	15	149,510,000		308
9090	Missouri River at Boonville, Mo.	505,700		1949-51	3	349,899,000		
9345	Missouri River at Hermann, Mo.	528,200		1949-63	15	155,936,000		295
8970	E. Fork Big Creek, Bethany, Mo.	95		1949-59	11	60,900	84,156	886
8975	Grand River, Gallatin, Mo.	2,250		1948-51	4	4,051,500	4,669,000	2,075
8980	Thompson River, Davis City, Iowa	701		1950-54	5	1,094,500	1,012,000	1,444
8995	Thompson River, Trenton, Mo.	1,670		1943-51	9	7,964,600	6,210,000	3,718
9040	Chariton River, Centerville, Iowa	708		1950-54	5	276,100	357,800	505
9035	Honey Creek, Russell, Iowa	13.2		1953-62	10	4,440		343
9125	110-Mile Creek, Quenemo, Kans.	321		1949-54	6	447,380	341,313	1,063
9150	Big Bull Creek, Hillsdale, Kans.	147		1949-53	5	179,200		938
9175	Marmaton River, Fort Scott, Kans.	411		1950-54	5	223,560	187,550	456
9190	Sac River, Stockton, Mo.	1,160		1950-54	5	209,920	165,413	142
9195	Cedar Creek, Pleasant View, Mo.	420		1950-53	4	118,150	92,300	220
9205	Osage River, Osceola, Mo.	8,220		1943-51	9	5,404,400	3,104,000	378
9215	Pomme de Terre River, Hermitage, Mo.	635		1943-51	9	402,400	191,000	292
9220	South Grand River, Browningtion, Mo.	1,660		1943-51	9	1,605,200	817,600	493
9335	Gasconade River, Jerome, Mo.	2,840		1943-51	9	934,800	386,900	136

that such work will immediately reduce the sediment yield appreciably from areas in excess of about 10 square miles unless it includes channel installations to control severe channel erosion or gully head-cutting.

In the case of structures controlling only channel bank erosion or channel degradation, the effect on downstream yield from areas in excess of 10 square miles will probably not be appreciable. If these structures are ponding or detention works, they may reduce the yield somewhat for a year or more, but not for an extended period. If, however, they actually control a severe head-cutting condition, they may significantly reduce the yield from moderately sized drainages; perhaps up to about 50 square miles. With larger drainages it becomes increasingly difficult to control all of the erosion areas, and the effect on downstream yield decreases. Analysis of the individual areas of a given drainage is, of course, required for a rational estimate of the problem.

Reservoir projects will reduce the sediment yield by varying degrees, both in time and quantity, depending upon their size in relation to the water inflow, sediment yield at the point of their location, and the proportion of the sediment-producing area of the drainage actually controlled. Small reservoirs or detention ponds, individually, may have a limited life and moderate trap efficiency; on the other hand, the great number of stock ponds in range country has caused a considerable reduction of sediment yield. Although they usually have a short life, they are continually replaced or rebuilt. Farm ponds in humid areas have a similar effect.

Larger reservoirs, currently, are generally designed with sediment storage capacity to retain essentially all the inflowing sediment for a period of 100 years. At the end of this period the sediment will encroach on storage provided for other purposes, but will continue to be retained; thus, it is practical to assume that the drainage above the reservoir will no longer contribute to the sediment yield downstream.

This reduction in yield will be tempered by degradation of the channel downstream, depending on characteristics of the channel and of the controlled project releases. This is normally a process of decreasing intensity, however, and should be treated as a total volume expected to be removed before the channel again stabilizes rather than as a continuous yield. Rarely, characteristics of the area might be such that downstream channel degradation could trigger tributary head-cutting, but such an event should be predictable and considered in project design. It is also possible that regulation of the flow would reduce the total transport capacity of the stream so that sediment contributions from downstream tributaries could not be entirely transported through the system. This would result in reducing the net yield by aggradation of the channel. In most instances, however, it is probable that a readjustment of the channel characteristics would restore it to balance.

Irrigation projects which divert water from a stream also tend to reduce the downstream transport capacity. In extreme cases where a large proportion of the flow is diverted, aggradation of the stream with a consequent reduction in net downstream yield may occur. Land levelling for irrigation and better land management is effective in reducing erosion and sedimentation. Essentially, this reduces the grade and lowers the velocity of runoff.

FIGURE 22

UPPER MISSOURI RIVER TRIBUTARIES
SEDIMENT YIELD

FOR DRAINAGES IN EXCESS OF 100 SQUARE MILES

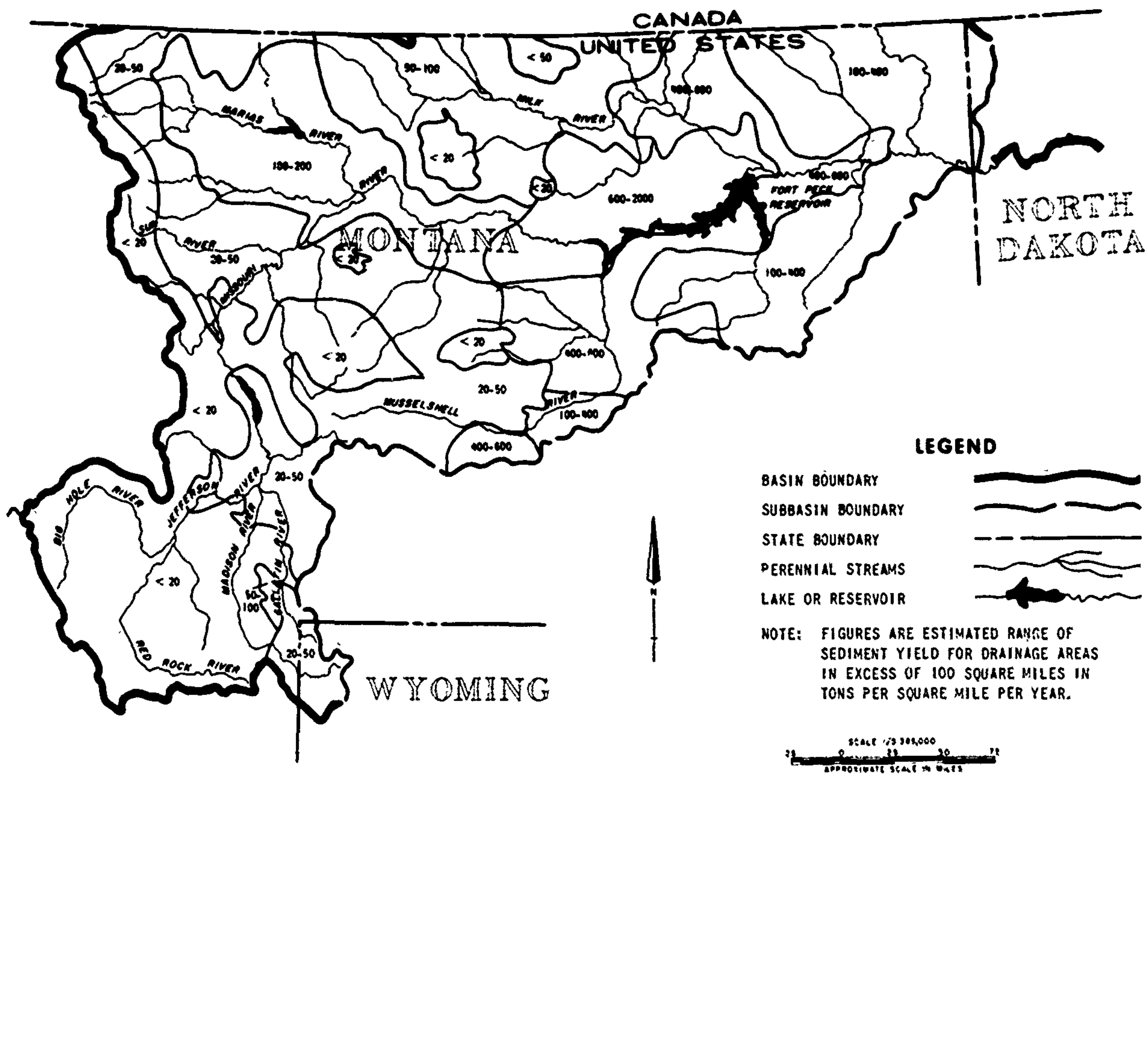


FIGURE 23

YELLOWSTONE RIVER

SEDIMENT YIELD

FOR DRAINAGES IN EXCESS OF 100 SQUARE MILES

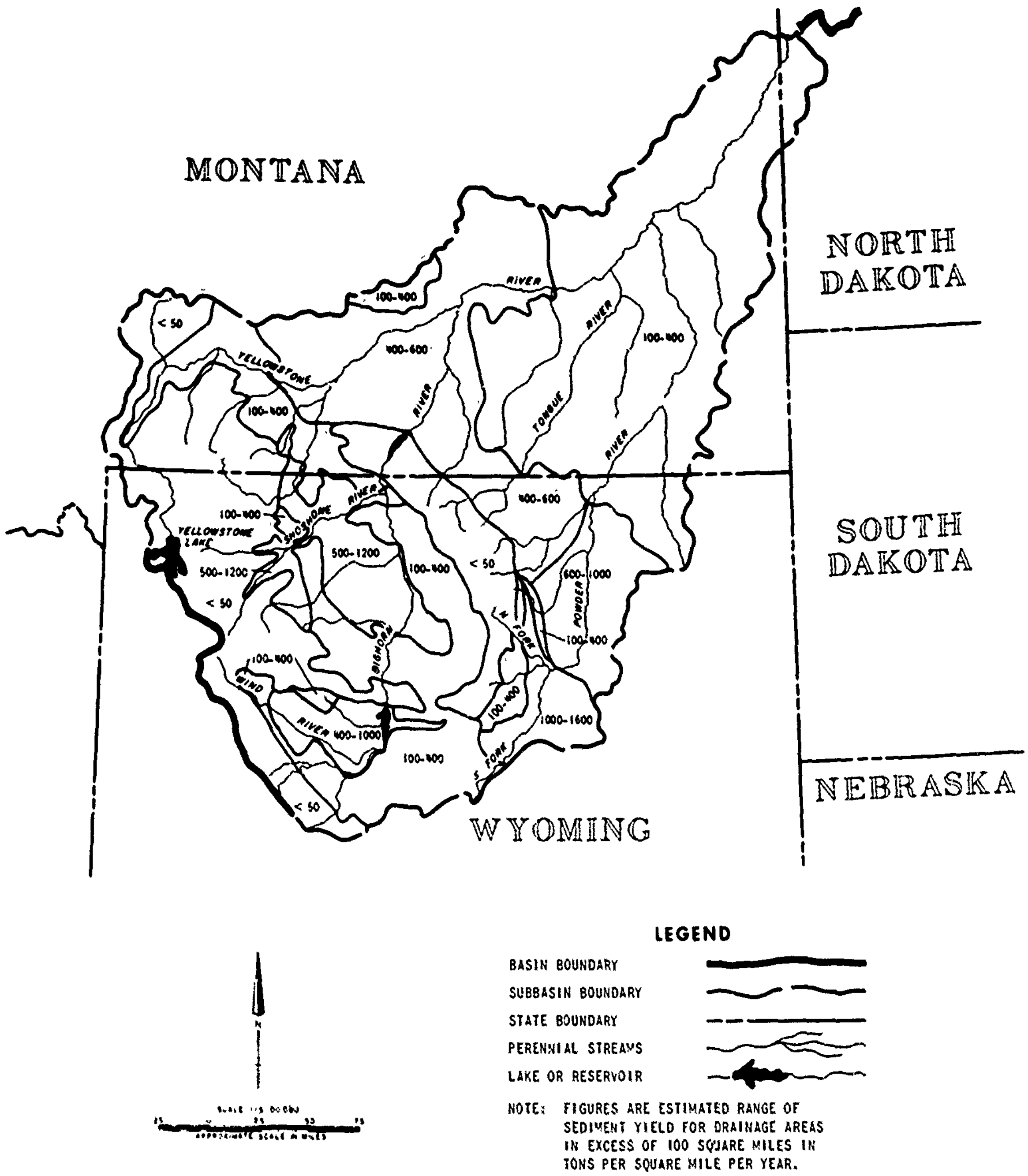


FIGURE 24

WESTERN DAKOTA TRIBUTARIES SEDIMENT YIELD

FOR DRAINAGES IN EXCESS OF 100 SQUARE MILES

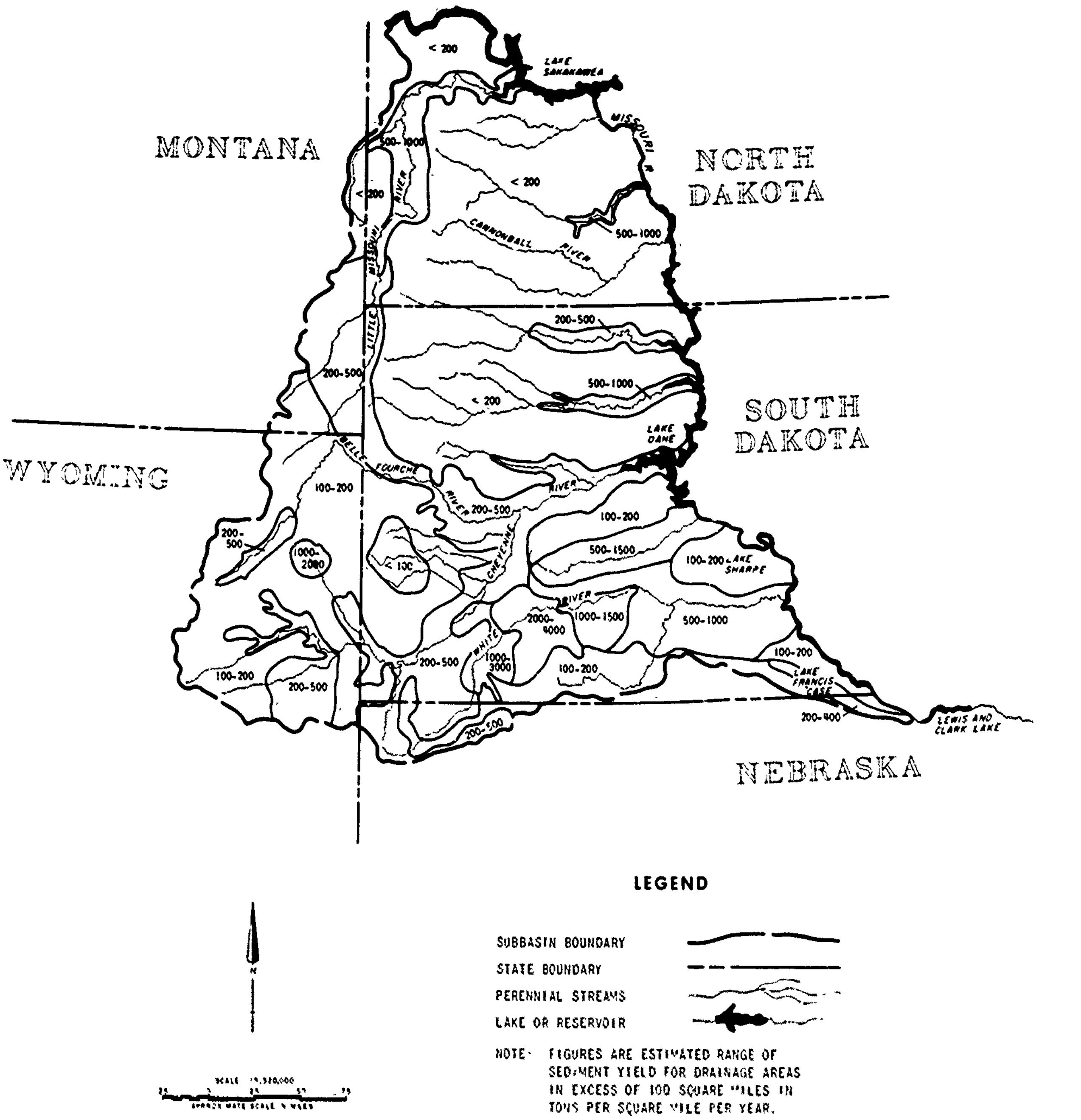


FIGURE 25

EASTERN DAKOTA TRIBUTARIES

SEDIMENT YIELD

FOR DRAINAGES IN EXCESS OF 100 SQUARE MILES

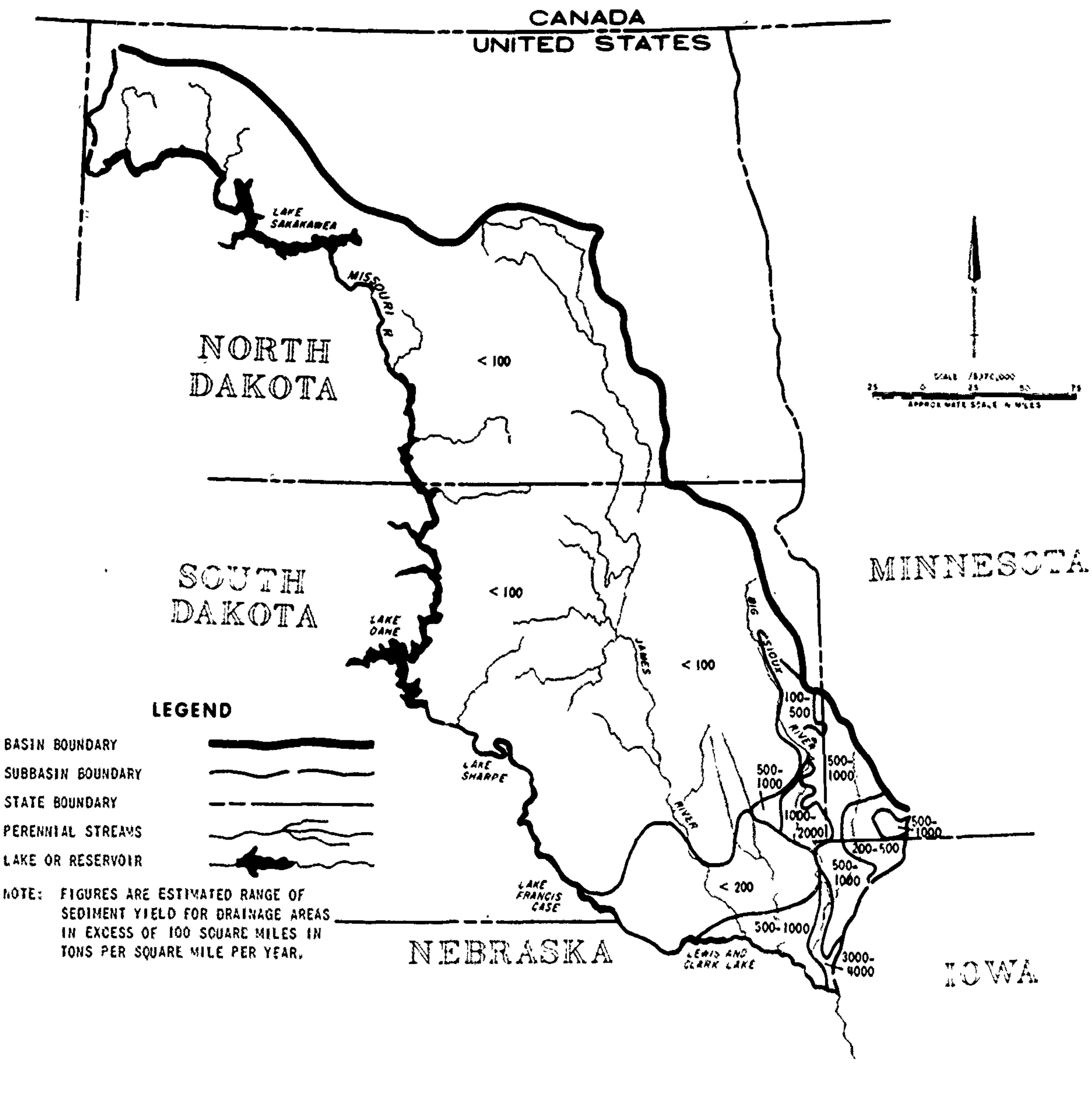


FIGURE 26

PLATTE-NIOBRARA RIVERS
SEDIMENT YIELD

FOR DRAINAGES IN EXCESS OF 100 SQUARE MILES

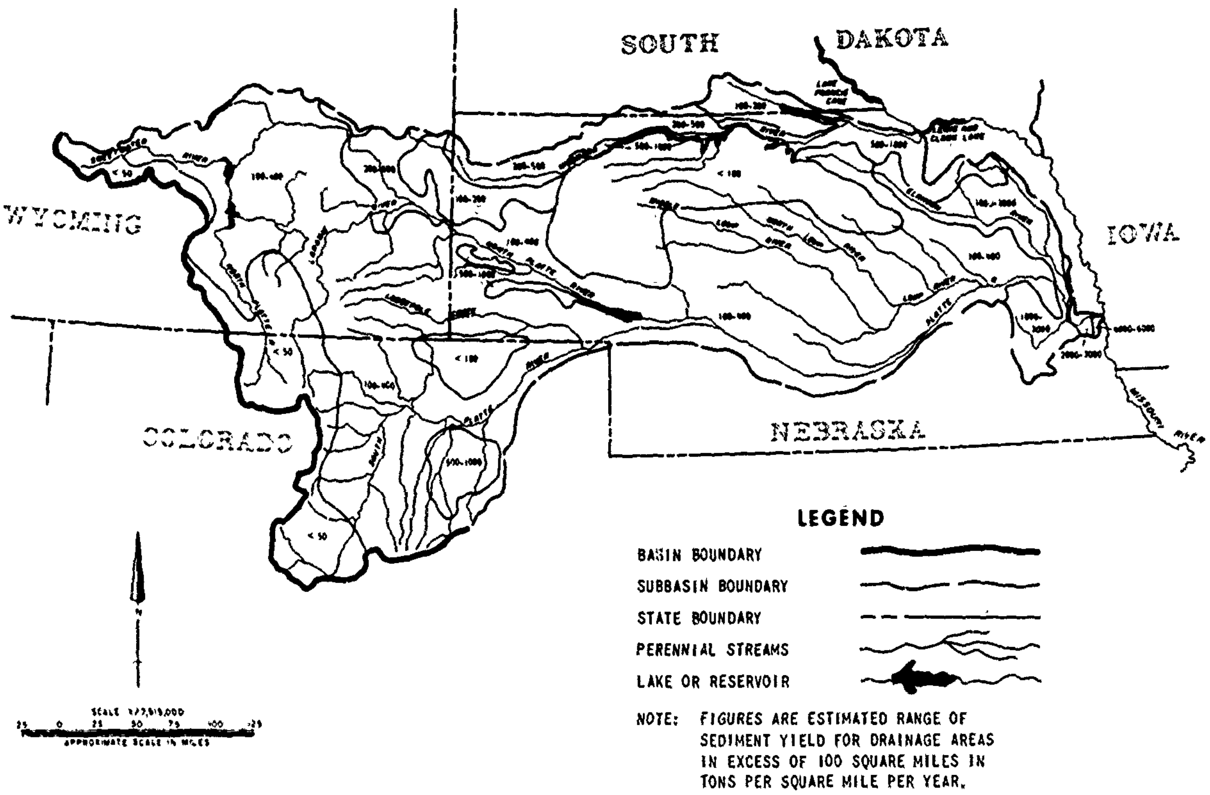


FIGURE 27

MIDDLE MISSOURI RIVER TRIBUTARIES
SEDIMENT YIELD

FOR DRAINAGES IN EXCESS OF 100 SQUARE MILES

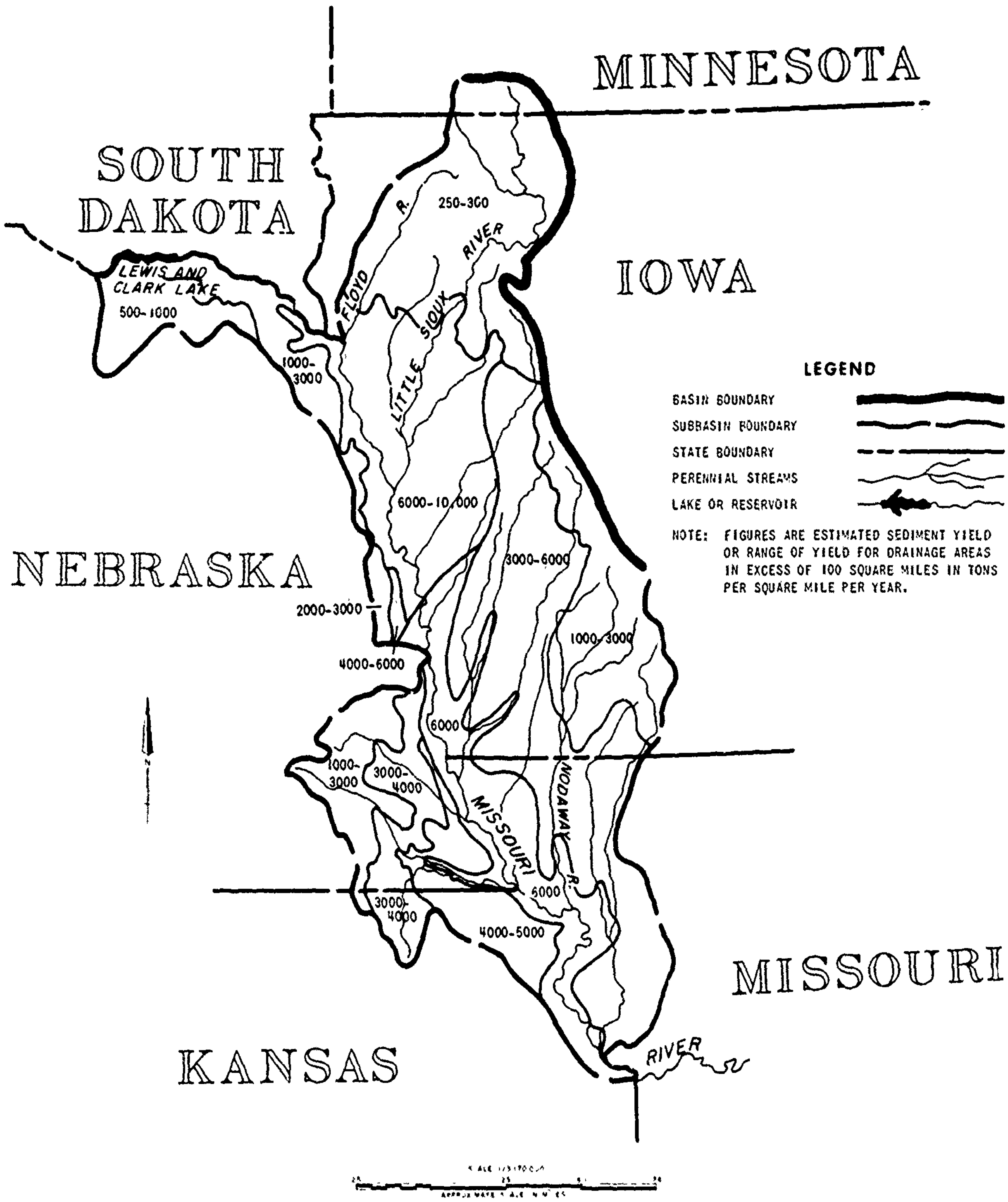
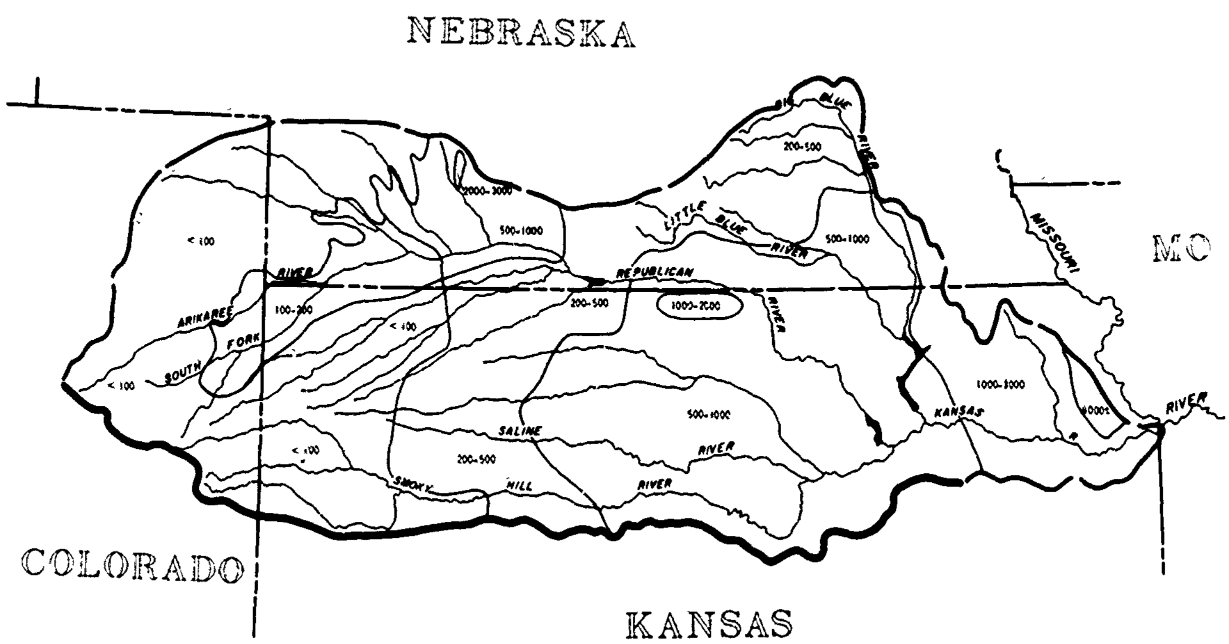


FIGURE 28

KANSAS RIVER

SEDIMENT YIELD

FOR DRAINAGES IN EXCESS OF 100 SQUARE MILES



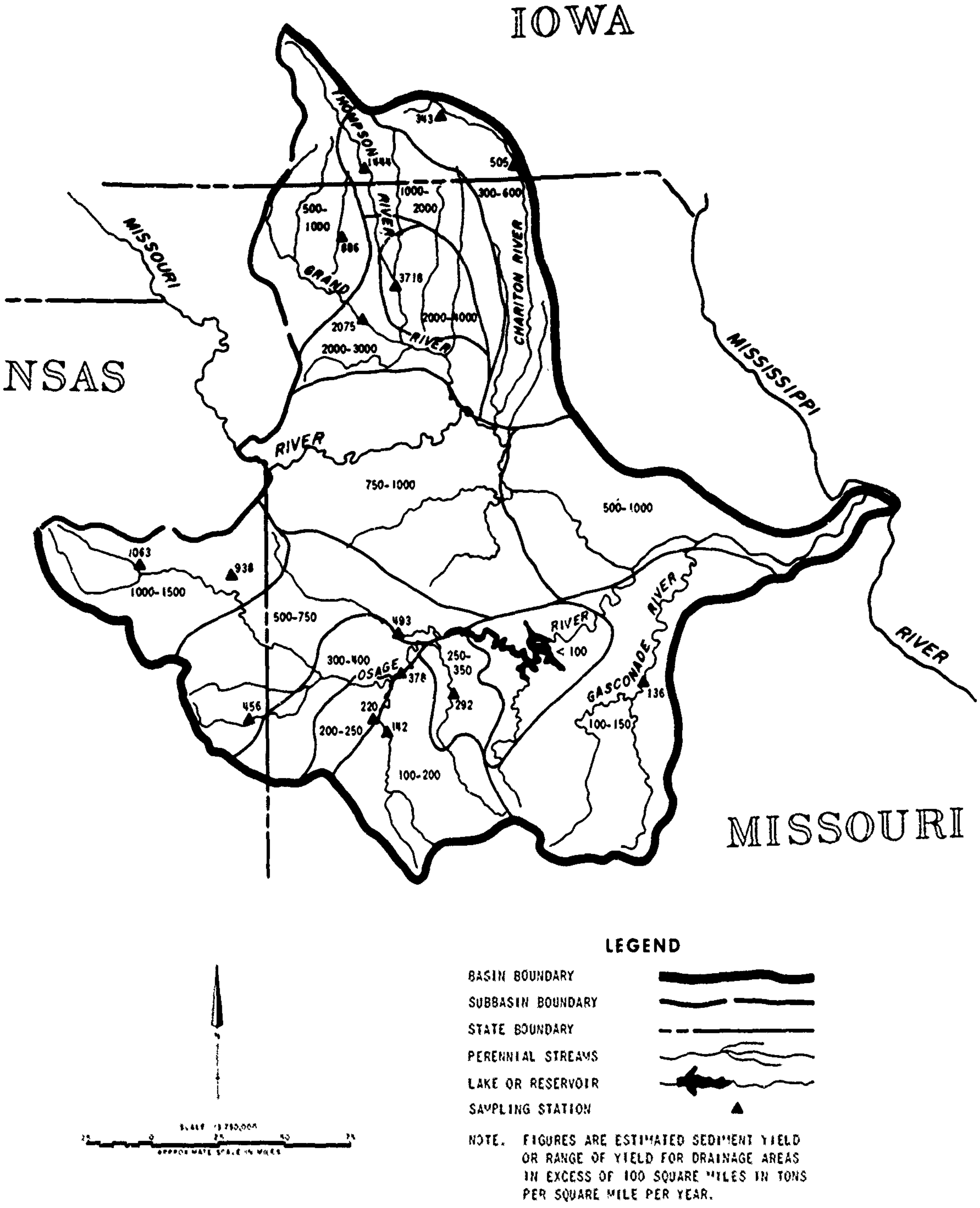
LEGEND

BASIN BOUNDARY
SUBBASIN BOUNDARY
STATE BOUNDARY
PERENNIAL STREAMS
LAKE OR RESERVOIR

NOTE: FIGURES ARE ESTIMATED RANGE OF SEDIMENT YIELD FOR DRAINAGE AREAS IN EXCESS OF 100 SQUARE MILES IN TONS PER SQUARE MILE PER YEAR.

FIGURE 29

LOWER MISSOURI RIVER TRIBUTARIES
SEDIMENT YIELD
FOR DRAINAGES IN EXCESS OF 100 SQUARE MILES



MISSOURI RIVER MAIN STEM SEDIMENT

In its natural state, the Missouri River transported a sediment load increasing from an average of 25 million tons per year in the vicinity of Fort Peck, Mont., to 150 million tons per year at Yankton, S. Dak., 175 million tons per year at Omaha, Nebr., and approximately 250 million tons per year at Hermann, Mo., near its confluence with the Mississippi River. With the construction of each of the main stem dams, beginning with the closure of the Fort Peck Dam in 1936, the sediment entering each of the respective reservoirs was trapped. The flow released from the reservoirs was clear and essentially free from sediment, and the downstream load was derived from downstream tributary contributions and from material eroded from the bed and banks of the river. Currently, the river from the head waters of the Fort Peck Reservoir to the Gavins Point Dam near Yankton, S. Dak., is almost fully controlled by the main stem dams. Beginning at Gavins Point, the lowermost dam, the main stem of the Missouri begins anew as a sediment free stream. It begins immediately to derive a new load from erosion of the bed and banks and from tributary streams, but, to date, the sediment transport in the river from the Gavins Point Dam to the mouth is but a small portion of its previous load.

It is impossible at this time to isolate the exact effects of the various factors involved in this reduction of transport. Erosion of the bed cannot be evaluated because the length of channel involved is such that lowering of the bed is too small to be measured even though the total quantity of material moved might be appreciable. The banks of the river below Sioux City are almost completely armored, although there has been an appreciable movement and deposition of bank material due to channel regulation works. A major factor in the reduction of sediment load carried by the Missouri River has been the fact that the decade during the 1950's approached drought conditions, and this, coupled with the requirement for withholding water to fill the reservoirs, reduced the flow to about one-half the normal average discharge. In addition, the flood flows from the upper Missouri River have been eliminated and discharges from Gavins Point have been reasonably constant.

There are two major tributaries to this downstream reach, the Platte River and the Kansas River. The Kansas is partially regulated by tributary reservoirs, but again it is impossible to assess the exact effect of these reservoirs on the sediment carried by the Missouri River. The mining of sand and gravel in the lower 15 miles of the Kansas River has lowered the low flow stage by about one-half foot per year since 1952, and this, coupled with flow regulation by upstream reservoirs has virtually eliminated contribution of sand-size and larger sediments from the Kansas River. The Kansas River contributes about a fourth of the sediment load presently carried by the Missouri River at Kansas City. The Platte River sediment load varies markedly from year to year, but, in the years since closure of the first main stem dam, has provided about half as much sediment to the Missouri River as in the Missouri above the mouth of the Platte River.

Analysis of the sediment transport in the Missouri River at Omaha shows that the load is composed of about 70 percent sand-size material whereas this fraction was only about 30 percent of the total prior to closure of the upstream dams and armoring of the channel bank below Sioux City, Ia. Subsequent to closure of the Fort Randall Dam in 1952, the total suspended load at Omaha has been relatively consistent at approximately 25 million tons per year, versus the long-term average of 175 million tons per year or the average of approximately 150 million tons per year during the period 1940-1954. Subsequent to 1953, there has been a relatively consistent increase in the transport of sand-size material from a low of 11 million tons per year to 20 million per year, a phenomenon which is difficult to explain on the basis of streamflow, although there has been a small but reasonably consistent increase in annual discharge during that period. It may be noted that total sediment load in 1940, a year when discharge was somewhat less than that during the period subsequent to 1954, was 139 million tons, with the sand-size load being about equal to the later period. It is dangerous to make comparisons on the basis of any one year; however, it appears that the sand load, in relation to annual discharge, has not been substantially affected by the upstream dams and that the reduction in transport is primarily a matter of reduction in silt- and clay-size sediments. There is some evidence that the finest sand fractions are being removed from the channel bed by a process of selective degradation; however, the available data are not yet conclusive.

With respect to the reaches of the river between the main stem dams, the current sources of sediment are erosion of the bed and banks and tributary contributions. Degradation of the channel below each dam is resulting in a progressive armoring of the bed, so that this source of sediment will be available for only a few more years except for those periods when reservoir releases considerably in excess of those generally made in the past may be necessary. Bank erosion is continuing in some areas between the Fort Peck and Garrison Dams and the Garrison and Oahe Dams; however, some bank protection works are being constructed in the latter reach. There is only a very short reach of open river between the Oahe and Big Bend Reservoirs and none between the Big Bend and Fort Randall Reservoirs. No appreciable bank erosion has been noted between the Fort Randall and Gavins Point pools. There has been no consistent change in tributary sediment contributions except that the load of the Heart River has been decreased substantially, apparently as a result of reservoirs reasonably close to the mouth.

Sediment discharges at selected locations on the Missouri River and major tributaries are listed in table 9.

Table 9 – ANNUAL SEDIMENT DISCHARGES – MISSOURI RIVER AND MAJOR TRIBUTARIES

	Missouri R. @ Snowden (or Culbertson)[1]			Yellowstone @ Sidney			Williston			Bismarck			Pierre		
Water Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year
1937		---			---			---			---			---	
38		---			---			---			---			---	
39		18.7		6.5	21.9	3.37	14.5	47.1	3.25		---			---	
1940		6.6		5.2	16.8	3.23	9.2	26.5	2.88		---			---	
41		4.0		7.3	53.7	7.36	10.6	61.4	5.79		---			---	
42	3.0	3.7	1.23	10.0	42.4	4.24	13.0	55.1	4.24		---			---	
43	5.2	11.0	2.12	13.3	54.8	4.12	18.5	73.0	3.95		---			---	
44	6.2	9.2	1.48	11.6	62.0	5.34	18.1	74.0	4.09		---			---	
45	5.1	6.2	1.22	9.4	28.0	2.98	14.6	38.6	2.64		---			---	
46	4.5	7.0	1.56	8.0	25.3	3.16	12.9	35.9	2.78		---			---	
47	8.1	12.8	1.58	11.0	37.5	3.40	19.5	63.9	3.28	21.0	94.2	4.49		---	
48	10.5	14.7	1.40	10.4	48.8	4.69	20.7	60.0	2.90	21.6	77.2	3.57	23.7	97.8	4.13
49	9.0	11.3	1.26	7.6	15.6	2.05	16.6	31.1	1.87	18.3	45.3	2.48	21.0	83.7	3.99
1950	6.4	8.8	1.38	9.3	23.8	2.56	16.2	38.1	2.35	17.4	52.6	3.02	22.3	119.4	5.35
51	8.8	10.8	1.23	9.8	20.7	2.12	18.9	36.4	1.93	20.1	47.1	2.34	21.2	70.5	3.33
52		---		9.5	24.1	2.54	21.0	48.6	2.31	22.8	69.5	3.05	26.5	116.8	4.40
53		---		6.8	16.5	2.43	15.8	31.7	2.01	16.5	41.2	2.50	18.6	76.4	4.11
54		---		6.8	10.2	1.50	16.6	26.3	1.58	16.7	15.8	0.95	17.1	29.3	1.71
55		---		6.5	17.2	2.64	18.4	31.8	1.73	13.9	10.8	0.78	14.6	16.8	1.15
56		---		8.6	13.5	1.57	15.6	23.7	1.52	14.9	9.9	0.66	16.1	18.1	1.12
57		---		9.9	25.9	2.62	15.4	32.3	2.10	11.3	5.4	0.48	12.1	26.9	2.22
58		---		7.4	13.8	1.87	12.2	14.4	1.18	12.7	5.8	0.46	12.6	13.7	1.09
59	5.7	3.4	0.60	7.8	16.0	2.05	13.6	16.1	1.18	13.4	5.3	0.40	13.7	3.0	0.22
1960	6.2	4.6	0.74	5.5	7.5	1.36	13.4	14.0	1.04	10.4	3.4	0.33	10.4	0.6	.06
61	6.0	1.8	0.30	4.3	7.1	1.65	10.3	10.8	1.05	11.7	4.1	0.35	12.4	0.7	.06
62	6.6	3.9	0.59	10.5	41.9	3.99	17.2	52.3	3.04	13.6	6.1	0.45	5.6	0.5	.09
63	4.4	4.1	0.93	9.6	33.1	3.45	13.8	35.1	2.54	10.4	3.8	0.37	13.3	0.3	.02
64	4.7	1.8	0.38	9.8	31.6	3.22	14.3	37.6	2.63	14.4	6.5	0.45		---	

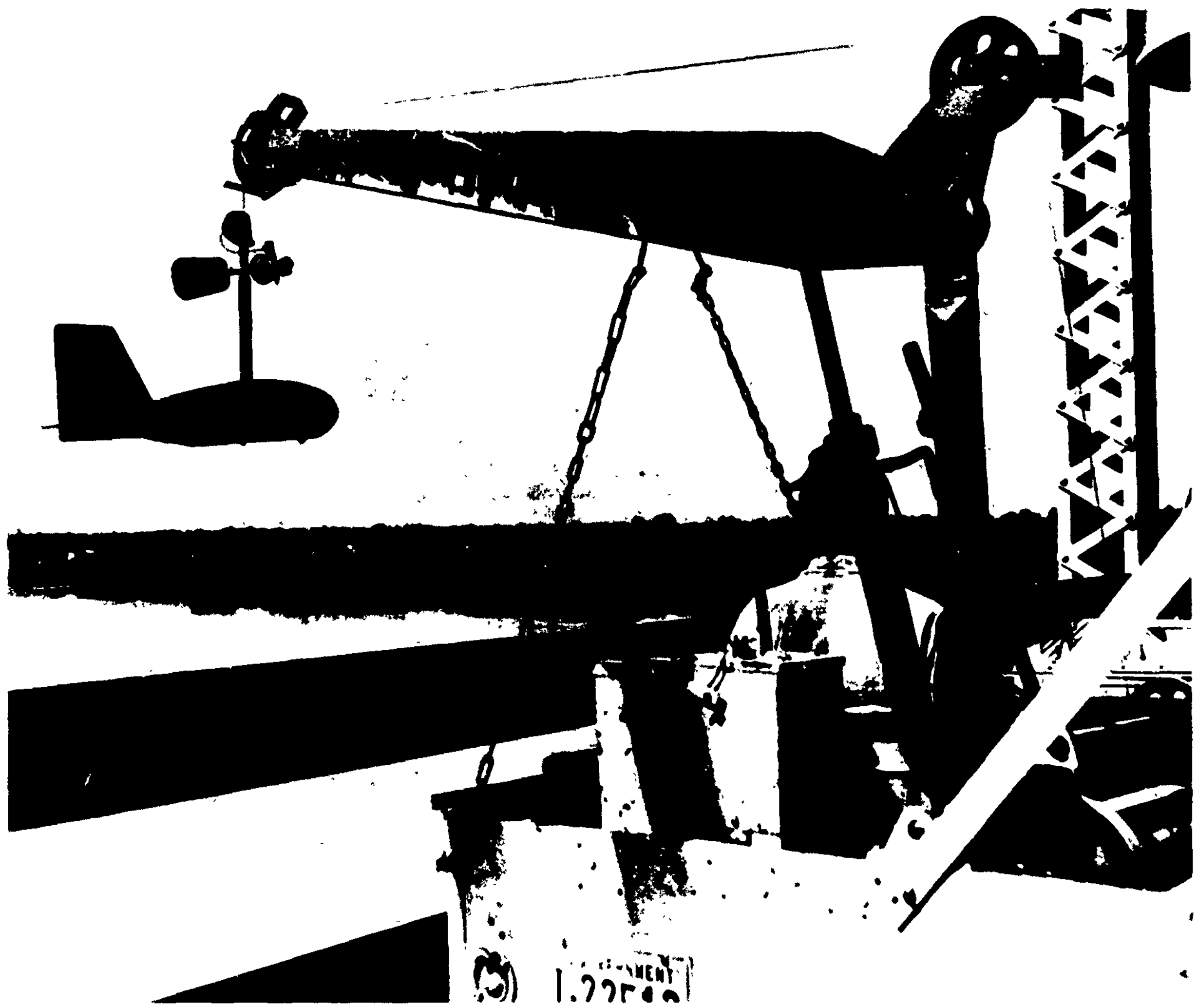
[1]See Table 15 for date of closure of main stem and major tributary reservoirs which may have affected sediment load at downstream stations.

Table 9 (Continued)

Water Year	Yankton			Sioux City			Omaha			Platte @ Louisville[1]			St. Joseph		
	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year
1937		---			---			---			---			---	
38		---			---			---			---			---	
39		---			---			---			---			---	
1940	10.9	49.7	4.56		---		11.8	78.3	6.64	2.0	9.4	4.70		---	
41	13.9	139.1	10.01		---		15.0	139.5	9.30	2.2	9.0	4.09		---	
42	20.1	201.3	10.01		---		22.8	230.4	10.11	3.7	13.1	3.54		---	
43	24.7	149.4	6.05		---		26.4	179.6	6.80	3.0	10.5	3.50		---	
44	26.1	230.3	8.82		---		30.1	251.7	8.36	4.2	26.5	6.31		---	
45	20.0	89.0	4.45		---		24.4	156.5	6.41	3.9	19.8	5.08		---	
46	17.1	92.3	5.40		---		18.2	109.1	5.99	2.8	7.5	2.68			
47	25.6	169.3	6.61		---		28.7	176.2	6.14	5.5	19.9	3.62		---	
48	25.7	138.2	5.38		---		28.4	150.1	5.29	3.7	8.9	2.41		---	
49	23.1	102.2	4.42		---		26.4	120.6	4.57	5.1	19.5	3.82	36.0	221.7	6.16
1950	25.0	147.4	5.90		---		27.4	159.6	5.82	4.4	19.0	4.32	34.5	251.3	7.28
51	24.0	108.1	4.50		---		31.2	219.5	7.04	6.1	38.3	6.28	43.8	332.3	7.59
52	31.0	174.9	5.64		---		35.7	158.0	4.43		---		46.7	223.6	4.79
53	21.2	58.3	2.75		---		24.1	80.5	3.34	---	7.2	---	29.1	101.4	3.48
54	16.8	26.8	1.60		---		19.2	37.3	1.94	3.3	8.5	2.58	23.3	74.3	3.19
55	16.2	8.9	.55	16.1	12.1	.75	17.2	25.5	1.48	2.4	4.2	1.75	20.5	41.1	2.00
56	17.0	4.4	.26	17.2	14.1	.82	17.5	23.3	1.33	2.1	5.3	2.52	20.1	37.4	1.86
57	13.7	1.7	.12	14.3	8.0	.56	14.8	28.0	1.89	3.3	16.6	5.03	19.1	53.6	2.81
58	14.3	1.3	.09	14.6	7.3	.50	15.1	19.1	1.26	4.5	17.9	3.98	23.4	63.4	2.71
59	14.5	1.6	.11	14.9	10.6	.71	15.6	28.8	1.85	3.8	15.0	3.95	23.3	75.9	3.26
1960	12.7	0.6	.05	15.5	14.1	.91	17.3	30.9	1.79	6.0	30.8	5.13	27.8	80.1	2.88
61	14.1	0.9	.06	15.1	6.5	.43	16.5	25.6	1.55	3.3	4.4	1.33	23.3	49.6	2.13
62	10.5	0.6	.06	14.5	12.4	.86	17.6	43.5	2.47	5.3	21.3	4.02	28.0	72.2	2.58
63	14.9	1.2	.08	15.4	7.0	.45	16.5	30.2	1.83	3.6	11.4	3.17	22.4	39.8	1.78
64	15.2	1.2	.08	15.8	8.0	.51	16.5	26.3	1.59	3.9	19.2	4.92	22.8	63.6	2.79

Water Year	Kansas @ Bonner Springs			Kansas City			Hermann		
	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year	Annual Flow in Million AF	Annual Sediment Discharge in Million Tons	Tons Per AF Per Year
1937		---			---			---	
38		---			---			---	
39		---			---			---	
1940		---			---			---	
41		---			---			---	
42		---			---			---	
43		---			---			---	
44		---			---			---	
45		---			---			---	
46		---			---			---	
47		---			---			---	
48	5.1	16.9	3.31		---			---	
49	8.3	58.4	7.04	45.4	283.0	6.23	67.1	328.4	4.89
1950	6.9	54.4	7.88	42.4	292.1	6.89	66.8	297.2	4.45
51	21.2	173.9	8.20	65.8	493.9	7.51	100.9	423.4	4.20
52	6.3	22.1	3.51	52.5	242.8	4.62	74.9	255.9	3.42
53	1.2	1.8	1.50	31.2	103.5	3.32	40.0	94.6	2.37
54	2.0	12.0	6.00	26.4	73.2	2.77	29.6	68.9	2.33
55	1.3	4.1	3.15	22.9	45.3	1.98	34.2	65.8	1.92
56	1.0	2.2	2.20	21.5	83.1	3.87	25.5	42.0	1.65
57	3.6	19.2	5.33	23.1	66.3	2.87	34.0	66.8	1.96
58	6.8	29.3	4.31	31.9	102.9	3.23	53.2	149.3	2.81
59	5.0	19.7	3.94	30.0	100.8	3.36	41.3	99.1	2.40
1960	7.7	36.1	4.69	37.5	109.3	2.91	57.5	122.1	2.12
61	6.7	28.7	4.28	31.9	86.2	2.70	57.3	124.2	2.17
62	8.5	42.8	5.04	39.3	111.1	2.83	61.5	135.8	2.21
63	2.7	3.5	1.30	25.8	49.4	1.91	32.6	65.5	2.01
64	2.3	3.8	1.65	25.9	75.8	2.93	34.4	101.9	2.96

[1] 1940-51, near Ashland.



CHAPTER 6

SURFACE WATER AVAILABILITY

COMPILATION OF HISTORIC RUNOFF DATA

Records of Streamflow

The first streamflow measurement recorded in the Missouri River Basin was a flood measurement on Clear Creek at Golden, Colo., in June 1876. The first streamgaging station in the basin was established by the State of Colorado on the Cache la Poudre River near Fort Collins. This station was equipped with a water-stage recorder in 1884, it has continued in operation since that time, and it is believed to be the oldest recording station in the United States. The longest continuous record of streamflow in the Missouri River Basin, however, is for the Osage River near Bagnell, Mo., where records are available since 1880. Measurements of streamflow in the basin by the U. S. Geological Survey were begun in 1889 in Montana. The work was expanded to Nebraska in 1891, to Kansas and Wyoming in 1895, to Colorado in 1897, to North Dakota, South Dakota and Missouri in 1903, and to Iowa in 1917.

Despite a slow and erratic start, collection of streamflow records in the Missouri Basin expanded with agricultural and industrial development to a network of about 900 active streamflow stations in the mid-1960's when the comprehensive framework study was begun. At that time, records were available for about 1,800 stations, about half of which were then in operation and about half of which had been discontinued. Periods of record ranged from less than 5 years to more than 80 years and averaged about 25 years. Records for the entire network were available primarily in the annual water-supply papers published by the U. S. Geological Survey.

Selection of Streamflow Stations for Data Analysis

Because of their great volume, analysis of all of the streamflow records available in the basin, as a part of the framework study was impracticable, and it was necessary to select a manageable portion of the records for this purpose. In all, records of 483 stations within the basin and of 57 peripheral stations adjacent to the basin on the south and east were selected for detailed analysis. Selection was based on several criteria, including length of record, degree of streamflow control exerted by existing reservoir projects and streamflow diversions, attainment of representative areal coverage, and study data needs of the several Federal agencies and states involved in the framework study.

In general, records were selected for analysis only if the period of record exceeded 10 years, but records for a shorter period were included in some cases to obtain proper areal coverage or to provide more detailed data for small areas. To the extent practicable, records were selected for gaging stations relatively unaffected by man-made controls such as reservoirs or levees; but in some areas, water resources development has already progressed to the point that unaffected records are not available. In such areas, preference was given to records for gaging stations with development effects that had been relatively constant throughout the period of record and records for stations with variable development effects were selected for analysis only where better records were not available. Also, in some cases where major upstream reservoirs were constructed, streamflow records were split into two parts for analysis, before and after reservoir construction. Locations of the 540 streamgaging stations whose records were selected for analysis are shown on plate 12.

Streamflow Data Processing

In connection with previous streamflow studies, the U. S. Geological Survey had established a procedure for processing daily streamflow records by electronic computers to obtain statistical summaries of high flows, low flows, and flow durations. The procedure involved punching IBM cards for daily discharges for each day of record for each of the 540 stations selected for analysis. In total, about 14,000 station years of data were punched, transferred to magnetic tape, and processed by computers to obtain station summaries and tabulated similar to table 10 for Little Beaver Creek near

Table 10 – EXAMPLE OF STREAMFLOW TABULATIONS

Little Beaver Creek near Marmarth, N. Dak. (06-3350.00)

Location–Lat 46°16', long 103°58', in NE¼ sec. 7, T. 132 N., R. 106 W., on left bank 150 ft upstream from concreted ford, three-quarters of a mile downstream from Corral Creek, 3 miles southwest of Marmarth; and 5 miles upstream from mouth.
Drainage area–615 sq mi, approximately.
Average discharge–25 years, 39.8 cfs.
Remarks–Records of chemical analyses for the period December 1949 to September 1951 and suspended sediment loads for the period August 1952 to September 1954 are published in reports of Geological Survey.

	Duration Table of Daily Discharge																																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Year	Class and Number of Days																																			CFS-Days
1939	178	9	8	12	5	8	4	9	16	21	22	17	13	6	10	4	6	2	3	2	3	2	1	1		3										10382.9
1940	186	7	5	8	9	3	7	3	13	14	26	16	22	6	5	12	5	4	6	1	2	4	2													5812.3
1941	118	19	13	3	22	11	32	5	25	22	13	10	22	9	13	8	6	1	4	1	3	3			2											6728.7
1942	28			2	12	15	35	15	58	37	13	7	38	21	8	28	16	3	7	4	3	8	1	4	2											15083.2
1943	23				2		24	37	90	27	24	32	29	12	14	7	5	3	8	5	4	7	2	2	2	1	4	1								26781.6
1944	40	9	6			5	43	5	48	68	12	11	15	18	37	10	8	4	5	1	1	3	5	2	3		2	5								38998.7
1945	39	37	16	4	9	5	23	4	17	45	21	23	29	19	24	11	7	10	3	4	3	1	4	2	1	2	2									17445.3
1946	54	4	4	5	3	2	34	13	62	63	12	21	19	9	17	20	4	7	2	2	1	3		2	1	1										9766.7
1947				2	8	9	7	9	40	53	37	22	42	20	25	18	12	9	11	3	13	6	5	7	4	1	1		1							33803.2
1948		11	8	11	2	2	15	6	63	61	22	20	34	22	29	13	7	5	6	6	3	6	3	6	3	2										21372.8
1949	92	10	10	8	20	7	23	22	28	27	19	14	16	15	8	5	5	4	5	3	8	5	5		4		1	1								19958 6
1950	37	16	18	10	9	6	15	9	28	54	27	13	14	23	16	13	9	9	9	3	6	11	3	2	3		1	1								23566.7
1951	25	5	6	10	20	9	29	37	67	58	26	16	16	4	11	4	4	3	6	1	3	1	1	2	1											7108.1
1952	68	48	11	4	8	3	23	18	47	36	11	21	13	5	14	8	2	5	3	1	4	2	2		1	1	3	2		2						43228.1
1953	23			1	16	10	46	34	58	26	34	27	20	10	18	8	5	6	6	6	4	4		2	1											9893.0
1954	7	5	7	12	20	14	11	29	91	64	8	15	30	13	15	7	3	3	6		1	2	1		1											5501.6
1955	64	21	24	21	10	13	49	25	13	21	11	22	17	4	12	12	7	5	6	2	2	2	1	1												5633.5
1956	226	4	8	11	4	5	8	7	18	23	12	7	7	8	4	4	3	3	3		1															1697.4
1957	127	15	11	24	10	10	33	15	16	21	14	14	11	3	12	12	5	2	3		4		1	1	1											5730 4
1958	137	17	11	34	17	23	22	22	6	13	6	5	10	7	7	9	8	4	4	1	2															3041.0
1959	191	2	16	32	1	2	3	3	6	18	16	5	4	16	12	14	3	4	4	1	3	1	2	3	3											11254.5
1960	141	10	9	25	16	7	13	14	22	27	26	15	3	9	4	11	5		2		1	1	2		1		2									9391.9
1961	256	7	9	21	3	3	8	4	21	8	3	1	5	2	7		4	1		1	1															1149.8
1962	134	9	5	6	4	15	12	13	21	18	8	16	19	10	17	13	11	9	3	3	6	9	4	1	2											12185.2
1963	10	6	9	14	12	19	43	34	10	29	17	12	17	11	23	18	9	22	20	10	6	7	4	2	1											17474.4

Class	CFS	Total	Accum	Percent	Class	CFS	Total	Accum	Percent	Class	CFS	Total	Accum	Percent	Class	CFS	Total	Accum	Percent
	.0	2204	9131	100.0	09	3.0	854	3876	42.4	18	100	135	535	5.9	27	3000	10	13	.1
1	.1	271	6927	75.9	10	5.0	440	3022	33.1	19	150	61	400	4.4	28	5000	1	3	.0
2	.2	214	6656	72.9	11	7.0	382	2582	28.3	20	200	88	339	3.7	29	7000	2	2	.0
3	.3	280	6442	70 6	12	10.0	465	2200	24.1	21	300	88	251	2.7	30				.0
4	.5	242	6162	67.5	13	15.0	282	1735	19.0	22	500	46	163	1.8	31				.0
5	.7	206	5920	64.8	14	20.0	362	1453	15.9	23	700	40	117	1.3	32				.0
6	1.0	562	5714	62.6	15	30 0	269	1091	11.9	24	1000	37	77	.8	33				.0
7	1.5	392	5152	56.4	16	50.0	159	822	9.0	25	1500	11	40	.4	34				.0
8	2.0	884	4760	52.1	17	70.0	128	663	7.3	26	2000	16	29	.3	35				

Table 10 (Continued)

Year	Highest Mean Discharge, in CFS, for the Following Number of Consecutive Days in Year Ending September 30												
	1	3	7	15	30	60	90	120	150	183	274	Annual	Peak
1939	1840.0	1410 0	764.0	368.0	188 0	96.3	78.1	85.2	68.9	56.7	37.9	28.4	5500
1940	616.0	341.0	159.0	143.0	102.0	81.4	56.7	43.3	35.1	30.5	21.2	15.9	1130
1941	1250.0	902.0	515.0	252.0	129.0	67.6	49.4	49.9	41.1	34.8	24.3	18.4	2670
1942	1200 0	957.0	609.0	316.0	188.0	123.0	120.0	101.0	82.0	68.9	52.9	41.3	2440
1943	3000 0	2180.0	1160.0	571.0	292.0	279.0	190.0	188.0	168 0	142.0	97.1	73.4	4000
1944	4660.0	4260.0	3180.0	1580.0	808.0	415.0	409.0	319.0	256.0	211.0	141.0	107 0	9260
1945	2100.0	1900.0	1400.0	808.0	439.0	233.0	174.0	137.0	113.0	93.0	63.1	47.8	2700
1946	1840.0	898 0	439.0	293.0	212.0	125.0	86.0	66.7	61.4	51.0	34.6	26.8	3700
1947	5000.0	2600.0	1360 0	752.0	596.0	342.0	242.0	213.0	191.0	165.0	117.0	92.6	a5000
1948	1870.0	1100.0	796.0	456.0	251.0	157.0	120.0	136.0	126.0	113.0	77.2	58 4	6700
1949	3000.0	2330 0	1520.0	945.0	578 0	318.0	217.0	164.0	131.0	108 0	72 6	54.7	3300
1950	3800 0	1990.0	1440 0	944.0	547.0	328 0	242.0	190.0	154.0	127.0	84 8	64 6	4600
1951	1050.0	832.0	394.0	198.0	101.0	66.2	48.1	40.1	33.2	36.7	25.0	19 5	2230
1952	9090.0	7430.0	4910.0	2690 0	1390.0	701.0	469.0	353.0	284.0	233.0	157.0	118.0	12700
1953	1040.0	582.0	530.0	310 0	165.0	107.0	74.9	65.8	56.1	52.5	36 8	27.1	2170
1954	1100.0	509 0	226.0	108.0	58 8	30 0	28.5	22.5	22.0	23.5	19.1	15.1	4820
1955	706.0	357.0	239.0	129.0	88.3	55.5	41.5	42.6	36.7	30.1	20.5	15 4	2990
1956	214.0	127.0	65.7	31.9	18.7	11.1	12.6	10 0	11.0	9.3	6.2	4.64	1070
1957	1180.0	705.0	324.0	153.0	80 8	53 3	47.3	39.4	33.5	29.7	20.8	15.7	11200
1958	297.0	182.0	113.0	71.0	58 0	41.5	27.8	23.5	19.5	16.1	11.1	8.33	1180
1959	1350.0	1170.0	1010.0	605.0	329.0	174.0	117.0	92.1	73.8	60.5	41.0	30 8	1290
1960	2400 0	1910.0	1060.0	516.0	263.0	134.0	94.8	76.6	61.3	50.3	34.2	25.6	3900
1961	266.0	127.0	54.9	51.1	26 2	13.1	8.7	6.6	6.4	5 5	4.2	3.15	614
1962	1280 0	608.0	446.0	254.0	158.0	145.0	107.0	82.5	76.7	65.4	44.5	33.4	2270
1963	1320.0	875.0	422 0	213.0	198 0	133.0	134.0	111.0	110 0	91.2	63.3	47.9	2140

a Maximum daily.

Year	Lowest Mean Discharge, in CFS, for the Following Number of Consecutive Days in Year Beginning April 1										
	1	3	7	14	30	60	90	120	150	183	274
1939	.0	.0	.0	.0	.0	.0	.0	.4	1.4	1.3	14.4
1940	.0	.0	.0	.0	.0	.0	0	.0	.2	.3	1.7
1941	.0	.0	.0	.0	.2	.8	1.2	1.8	6.6	21.8	30.4
1942	.0	.0	.0	.0	.2	2.0	2.2	2.7	3 4	4.0	17.1
1943	.0	.0	.0	.0	.0	.1	.5	1.0	1.7	1.7	9 8
1944	.1	.1	.1	.1	.1	.2	1.5	2.7	3.6	4.1	51.7
1945	.0	.0	.0	.0	.0	.4	.8	1.9	2.1	1.8	6 4
1946	.0	.0	.0	.0	.8	2.9	11.6	16.0	22.8	19.3	41.0
1947	1.0	1.0	1.4	1.9	2.4	2.9	3.1	3.2	3.2	3.9	33.1
1948	.0	.0	.0	.0	.0	.0	.2	1.1	1.5	1 3	26 6
1949	.0	.0	.0	.0	.0	.1	.3	1.0	2 3	1 9	2.3
1950	.0	.0	.0	.0	.5	1.1	1.3	1.5	1.7	2.1	4 8
1951	.0	.0	.0	.0	.1	.2	.3	3.2	3.1	3.8	18 3
1952	.0	.0	.0	.0	.0	.0	.6	.7	.7	1.0	2.3
1953	.5	.5	.5	.6	1.3	1.8	2.3	2.9	3.1	6 8	11.8
1954	.0	.0	.0	.0	.1	.3	.6	.8	.8	1.6	10.1
1955	.0	.0	.0	.0	.0	.0	.0	.0	.0	0	3.4
1956	.0	.0	.0	.0	.0	.0	.2	3	3	.3	2 9
1957	.0	.0	.0	.0	.0	.2	.4	.7	.7	.8	4.6
1958	.0	.0	.0	.0	.0	.0	.0	.0	1	.1	6.5
1959	.0	.0	.0	.0	.0	.0	.2	1.3	1.2	2.0	3.1
1960	.0	.0	.0	.0	.0	.0	0	0	0	0	8
1961	.0	.0	.0	.0	.0	.0	.0	.0	1.4	4 3	3.5
1962	.0	.0	.0	.1	.5	.8	8	1.1	1.4	1 8	35 5

Marmarth, N. Dak. Similar printouts were prepared for each of the 540 stations and were bound in separate volumes, one volume for each subbasin, to form a background data source for subsequent studies.

Flow-Duration Relationships

The flow-duration tabulations show, for each water year, the number of days with discharges within each of some 20 to 35 class intervals of streamflow. The selected class interval limits are listed in a separate tabulation, along with the total number of occurrences in each class interval, the accumulated total, and the percent of time during the period of record that the lowest discharge in each class was either equalled or exceeded. Table 10, compiled from computer printouts, contains a sample duration table of daily discharge.

High-Flow-Sequence Tabulations

Streamflow records were also processed by computer to obtain, for each station, a high-flow-sequence tabulation showing the highest mean discharge for periods of 1, 3, 7, 15, 30, 60, 90, 120, 150, 183, and 274 consecutive days in each water year. The maximum instantaneous also is presented for each year where available, as is the mean annual discharge for the water year. A sample high-flow-sequence tabulation, for Little Beaver Creek near Marmarth, N. Dak., is also shown in table 10.

Low-Flow-Sequence Tabulations

Also obtained by computer were low-flow-sequence tabulations showing the lowest mean discharge for periods of 1, 3, 7, 14, 30, 60, 90, 120, 150, 183, and 274 consecutive days in each climatic year. The year beginning April 1 was used for processing low-flow data because a general flow recession usually begins in the summer months and may persist through the winter months. If the water year ending September 30 were used, a single low-flow period might be reported as two separate events. A sample low-flow-sequence tabulation, for Little Beaver Creek near Marmarth, N. Dak., is also shown in table 10.

Mean Annual Runoff

Runoff which enters Missouri River Basin streams varies widely from place to place and from year to year. In large parts of the northern and western plains area, average annual runoff is less than one inch. In contrast, average annual runoff approaches 15 inches in the southeastern part of the basin, and it exceeds 20 inches in some areas along the mountainous western rim of the basin.

Generalized estimates of mean annual runoff in the Missouri River Basin are presented on plate 13. These estimates were based on average annual runoff for the period of record at the streamgaging stations selected for detailed analysis, supplemented by data from other stations in some areas. Actual data for preparation of the map were taken from the latest available U. S. Geological Survey Surface Water Records Report for each basin state, which was generally for the 1964 water year at the time these studies were made. Drainage areas above each gaging station also were obtained from these same publications.

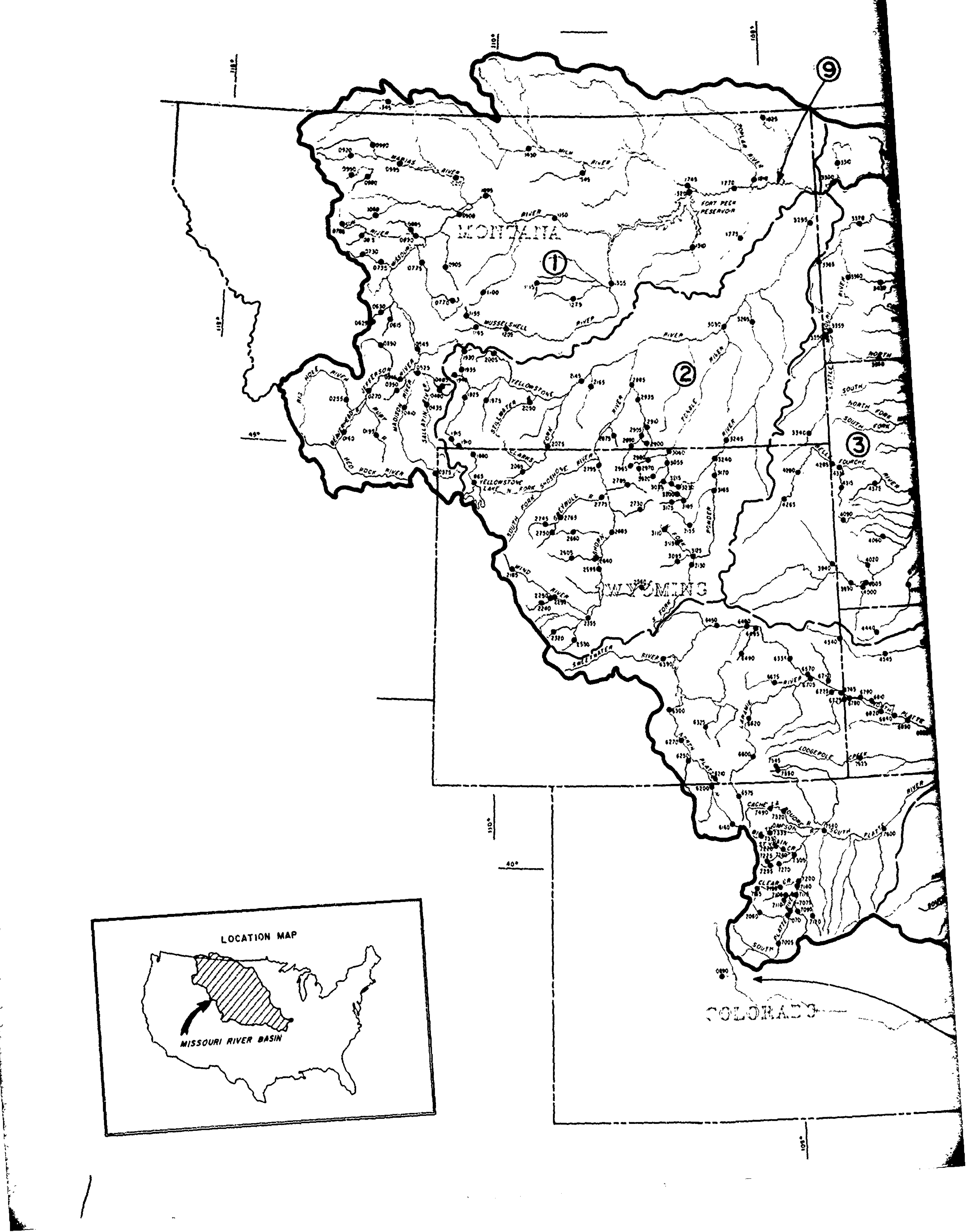
Streamflow records at the stations used varied in length from about 10 years to over 50 years. In order to reconcile these differences in period of record, about 30 so-called pivot stations with periods generally in excess of 40 years were selected. Historical mean annual runoff values at all other stations were compared with runoff values during common periods at appropriate pivot stations and were then adjusted for consistency with the pivot station records.

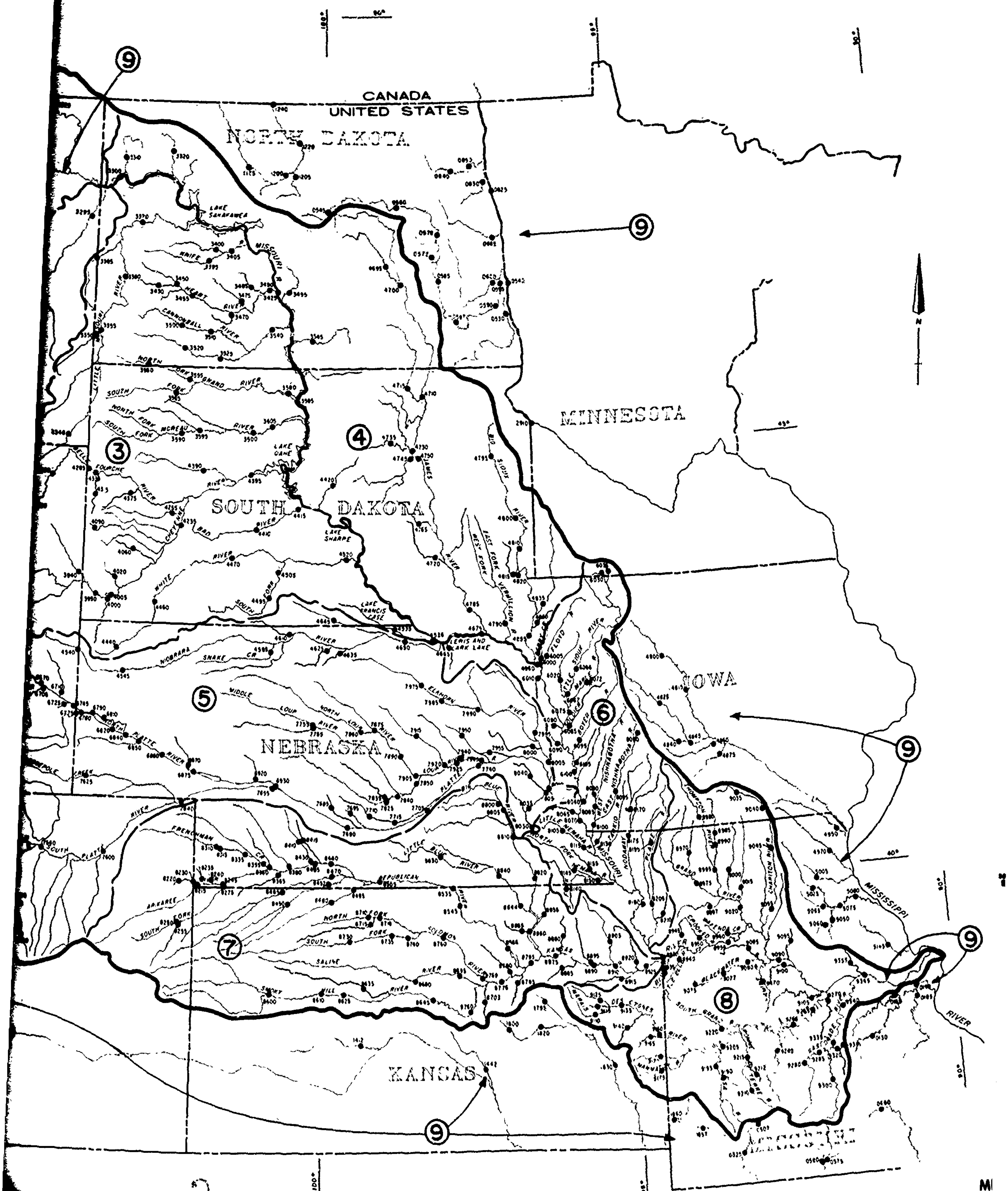
In construction of the mean annual runoff map, major emphasis was given to runoff data for small-area gaging stations. Therefore, the map as constructed represents runoff from the land surface into small streams and does not recognize losses that occur due to evaporation, evapotranspiration, bank infiltration, and consumptive use as these flows move downstream. Therefore, runoff values shown by the map for the larger basins are somewhat higher than values obtained by consideration of gaging stations for the larger areas.

FLOODS

Periodic heavy runoff, at rates high enough to produce flooding is characteristic of almost all parts of the Missouri Basin, even those where average annual rainfall amounts are least. Flood runoff constitutes a significant portion of the basin's surface water supply and the magnitude of flood flows is a significant factor in design of water resources development projects.

Floods in the Missouri Basin may be the result of intense or prolonged rainfall, melting of the winter's snow cover, or a combination of these phenomena. Rainfall floods are the most frequent. Flash flooding, caused by local cloudburst-type rainfall, is experienced in all parts of the basin during the summer months. General floods, caused by prolonged rainstorms of greater areal extent, are most frequent in the spring and summer months in the more humid lower portion of the basin, but they occur also in the hilly and mountainous areas of the western basin in late spring and early summer. Floods resulting from melt of the plains snow


MONTANA
WYOMING
COLORADO
LOCATION MAP
MISSOURI RIVER BASIN
MARIAS RIVER
MILK RIVER
MUSSELSHELL RIVER
FORT PECK RESERVOIR
YELLOWSTONE
STILLWATER
CLARKS FORK
SHOSHONE RIVER
YELLOWSTONE LAKE
RED ROCK RIVER
BIG HOLE RIVER
JEFFERSON RIVER
MADISON RIVER
GALLATIN RIVER
WIND RIVER
SWEETWATER RIVER
LARAMIE RIVER
LODGEPOLE CREEK
SOUTH PLATTE RIVER
CACHE LA POUDRE R.
CLEAR CR.
TONGUE RIVER
POWDER RIVER
BELLE FOURCHE RIVER


CANADA
UNITED STATES
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
MINNESOTA
IOWA
MISSOURI
MISSISSIPPI
RIVER
LAKE SAKAKAWEA
LAKE OAHE
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
KNIFE
HEART
CANNONBALL
GRAND RIVER
MOREAU
CHEYENNE
BAD
WHITE
JAMES
BIG SIOUX
VERMILLION
NIOBRARA
SNAKE CR
ELKHORN
LOUP
PLATTE RIVER
SOUTH PLATTE
LITTLE BLUE RIVER
REPUBLICAN
FRENCHMAN
SOLOMON
SALINE
SMOKY HILL
KANSAS
GRAND
OSAGE
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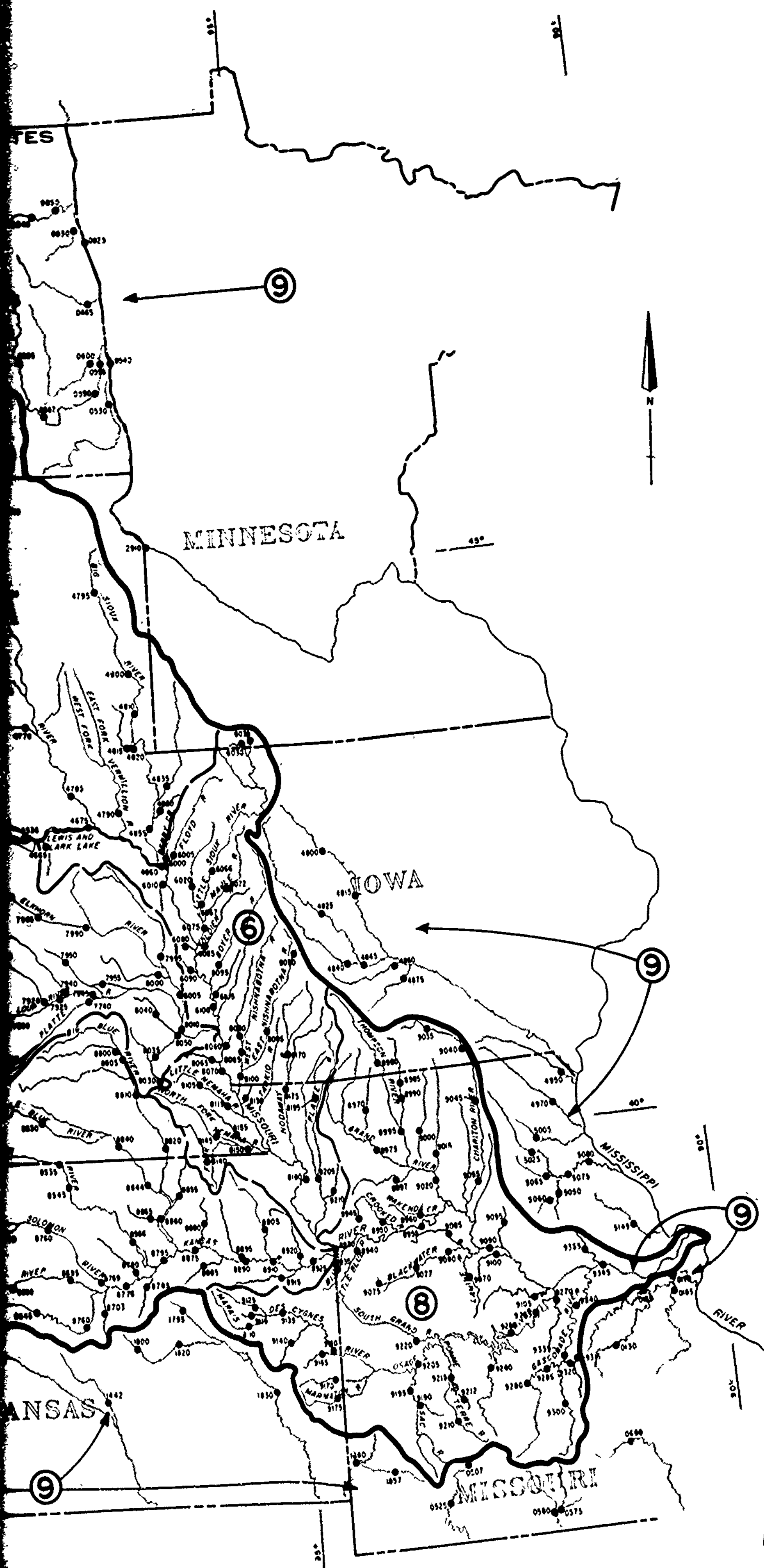


LEGEND

PERENNIAL STREAMS

LAKE OR RESERVOIR

GAGING STATION

SUBBASINS

UPPER MISSOURI RIVER TRIBUTARIES	①
YELLOWSTONE RIVER	②
WESTERN DAKOTA TRIBUTARIES	③
EASTERN DAKOTA TRIBUTARIES	④
PLATTE-NIOBRARA RIVERS	⑤
MIDDLE MISSOURI RIVER TRIBUTARIES	⑥
KANSAS RIVER	⑦
LOWER MISSOURI RIVER TRIBUTARIES	⑧
MISSOURI RIVER MAIN STEM, AND AREAS IN UPPER AND LOWER MISSISSIPPI AND HUDSON BAY BASINS	⑨

NUMBERS SHOWN ARE THE LAST FOUR DIGITS OF THE USGS GAGING STATION INDEX NUMBERS.

STREAMFLOW STATIONS FOR WHICH RECORDS WERE ANALYZED FOR USE IN THE MISSOURI RIVER BASIN FRAMEWORK STUDY

SCALE 1:5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

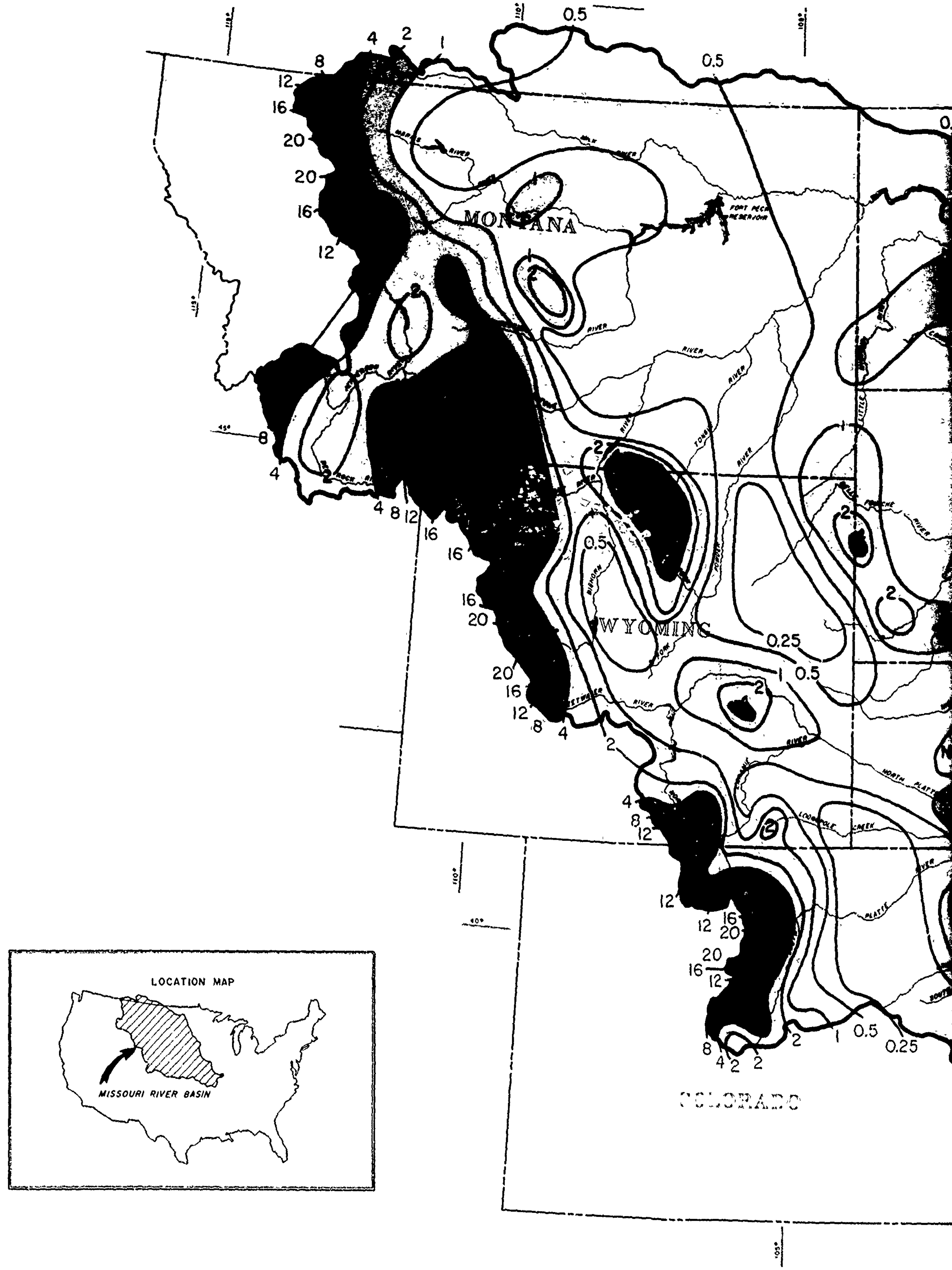
LOCATION OF STREAMFLOW GAGING STATIONS SELECTED FOR DETAILED ANALYSES

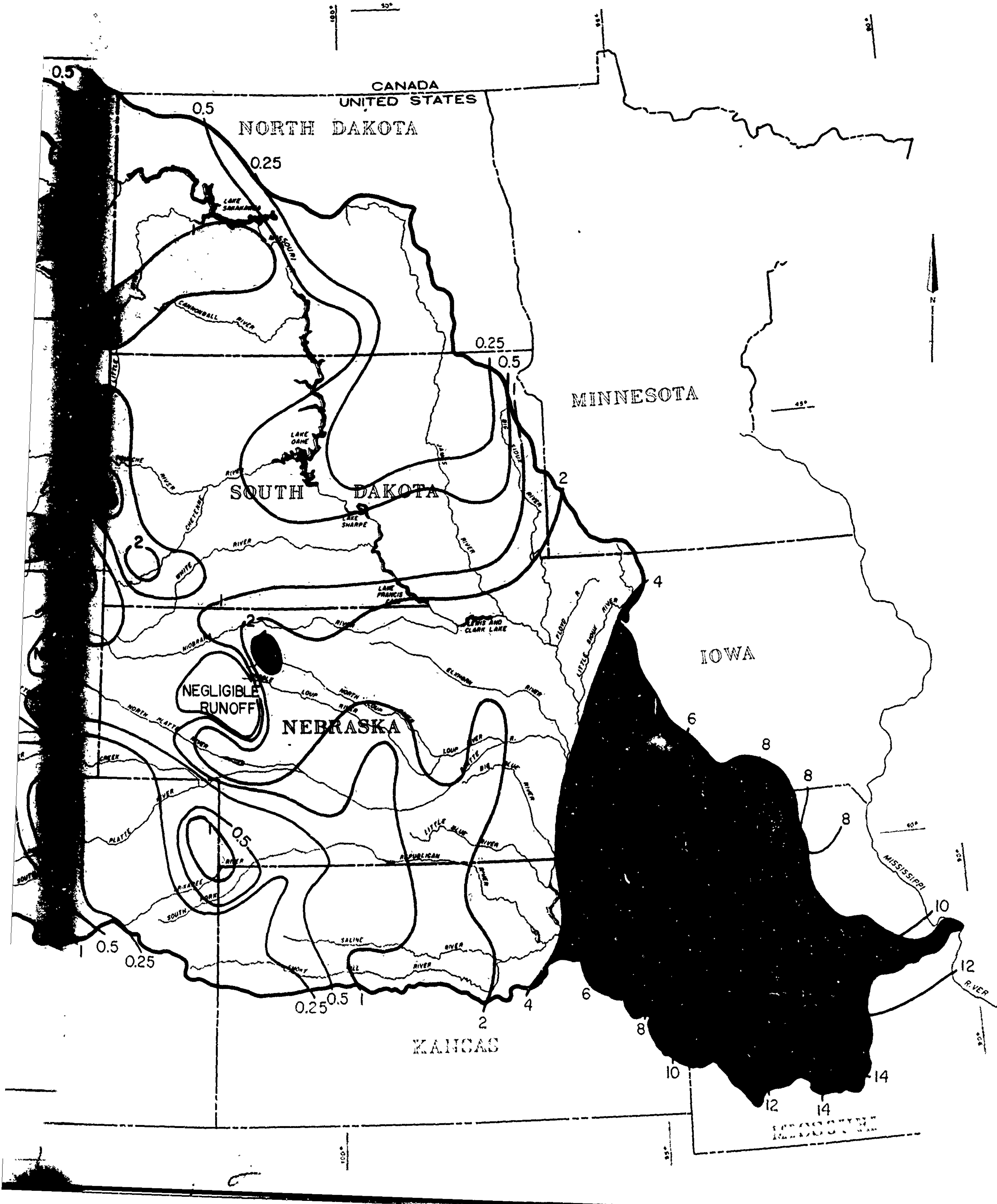
COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 12


MONTANA
WYOMING
COLORADO
LOCATION MAP
MISSOURI RIVER BASIN
FORT PECK RESERVOIR
NORTH PLATTE
LODGEPOLE CREEK
0.25
0.5
1
2
4
8
12
16
20



AREAS
1 INCH

AREAS
INCHES

AREAS
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LAKE

NOTE:
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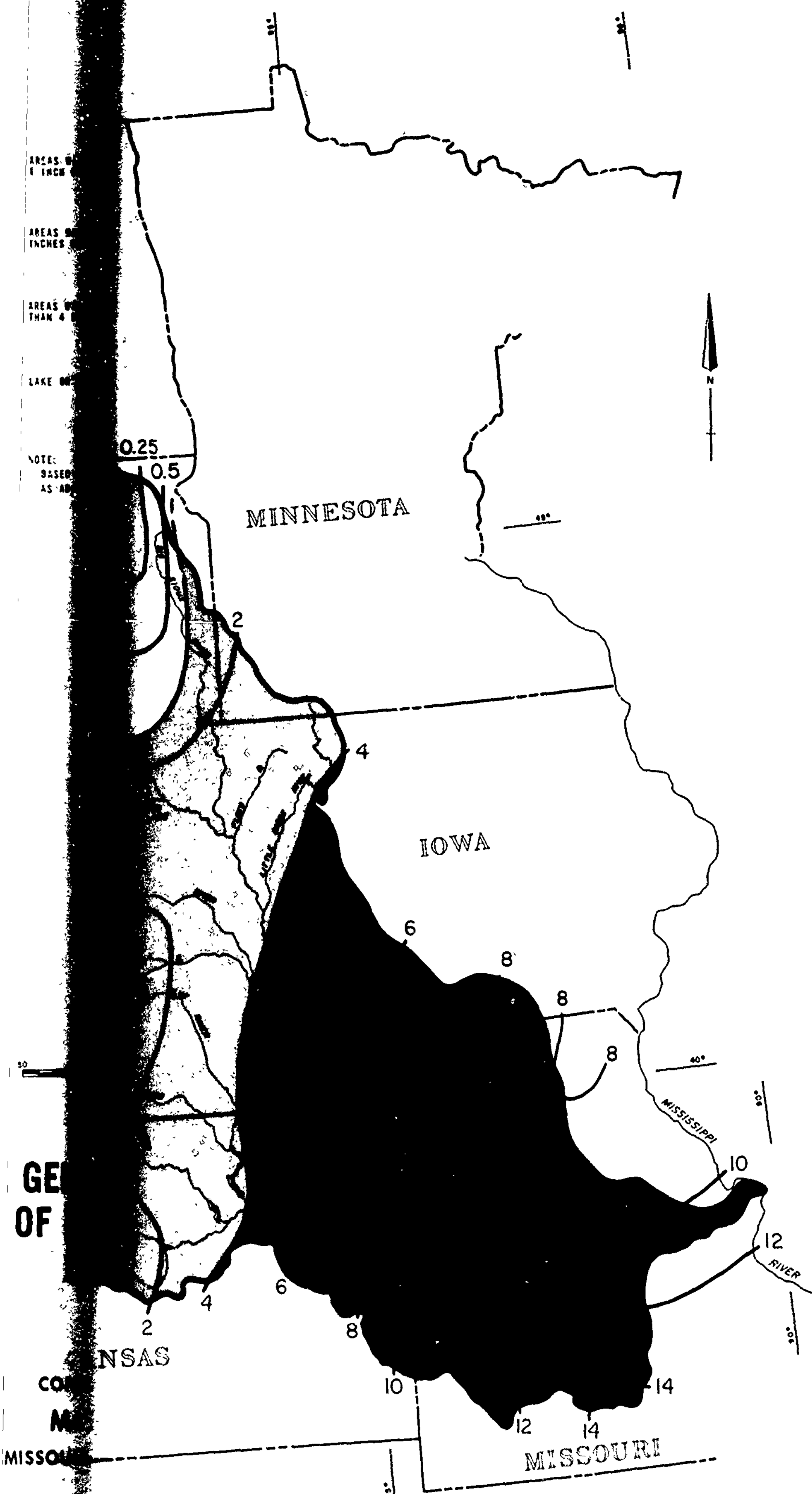


LEGEND

AREAS WITH LESS THAN 1 INCH OF RUNOFF

AREAS WITH 1 TO 4 INCHES OF RUNOFF

AREAS WITH GREATER THAN 4 INCHES OF RUNOFF

LAKE OR RESERVOIR

NOTE
BASED ON PERIOD OF RECORD FOR EACH STATION AS ADJUSTED TO LONG RECORD STATION DATA

SCALE 1:5,700,000
50 0 50 100 150 200
APPROXIMATE SCALE IN MILES

JUNE 1969

GENERALIZED ESTIMATES OF MEAN ANNUAL RUNOFF IN INCHES

COMPREHENSIVE FRAMEWORK STUDY
MISSOURI RIVER BASIN
MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 13

cover are most frequent in the plains area of the upper and middle basin. General floods due to melting of the mountain snow accumulation alone are uncommon, but mountain snowmelt becomes a major factor when heavy rainstorms occur during the snowmelt period.

Flood-Producing Storms

The amount of precipitation, either rain or snow, that any particular locality within the Missouri Basin may experience during a storm or series of storms is a function of the atmospheric moisture present and the rate and duration of vertical lifting of the air mass. The basin experiences all of the storm mechanisms recognized as lifting processes – frontal lifting, lifting due to convergence associated with a low pressure center or a pressure trough, upslope and orographic lifting in the mountainous areas, air mass convective instability, and squall lines. The primary source of moisture for all storms is the Gulf of Mexico.

Flood-producing storms in the Missouri River Basin may be classified synoptically into three types. In storms of the first type, the basin is under the influence of a cool, high-pressure area of modified maritime polar or continental polar air. Moist tropical air from the Gulf of Mexico is brought into the basin by circulation of a low-pressure area in the southwestern portion of the United States. Overrunning of the cool high pressure by the moist air mass together with the westward upslope of the basin produce sufficient lift to cause precipitation. Moisture content of the tropical air mass and the velocity and duration of the moist air inflow determine the amount and intensity of the rainfall or snowfall produced.

In storms of the second type, a persistent pressure trough oriented in an approximate north-south direction between the Pacific Ocean and the Rocky Mountains produces a southerly flow of air on the east side of the trough. Moisture is brought into the basin at the same time from the Gulf of Mexico, or in rare cases, from the Pacific Ocean west of Mexico. Storms of this type occur during the summer when the Bermuda high is strong enough to penetrate the south-central part of the United States and cause stagnation of the western trough for several days. The persistence of this pattern causes a continual inflow of unstable air which eventually results in numerous, locally intense thunderstorms.

Storms of the third type are caused by migratory frontal systems moving into the basin from the west. If maritime tropical air is present or if the front stagnates until tropical air is transported into the basin from the Gulf of Mexico, precipitation results. Precipitation may occur on either side of the cold front and is often intensified by the movement of a stable cyclone wave south of the area of occurring precipitation. Storms of the third type are more frequent than storms of the other two types. They occur most frequently during the winter, and precipitation is in the form of snow.

Because of the significance of flood flows in design of water-resources development projects, hydrometeorological investigation of some 160 flood-producing storms in the Missouri Basin has been accomplished, involving compilation of published and unofficial precipitation data, preparation of mass curves of rainfall, and derivation of rainfall depth duration relationships. Locations of and pertinent data for representative major rainfall storms that have occurred are shown by figure 30. It is interesting to note that the storm which centered near Holt, Mo., during the period of June 18-23, 1947, established a world record for rainfall intensity when 12 inches of rain fell in 42 minutes at Holt.

Major flood-producing storms in which precipitation was primarily in the form of snowfall also have occurred in the Missouri River Basin. One of the more notable was that associated with the floods of April 1952 on the Missouri River, the Mississippi River, and the Red River of the North. The water equivalent pattern of the snow cover over the Missouri Basin plains area, as determined by a survey during March 17-20, 1952, is shown by figure 31. Rapid melting of this snow pack and associated ice jams resulted in the maximum flood of record along the Missouri River from Williston, North Dakota, to just above the mouth of the Kansas River.

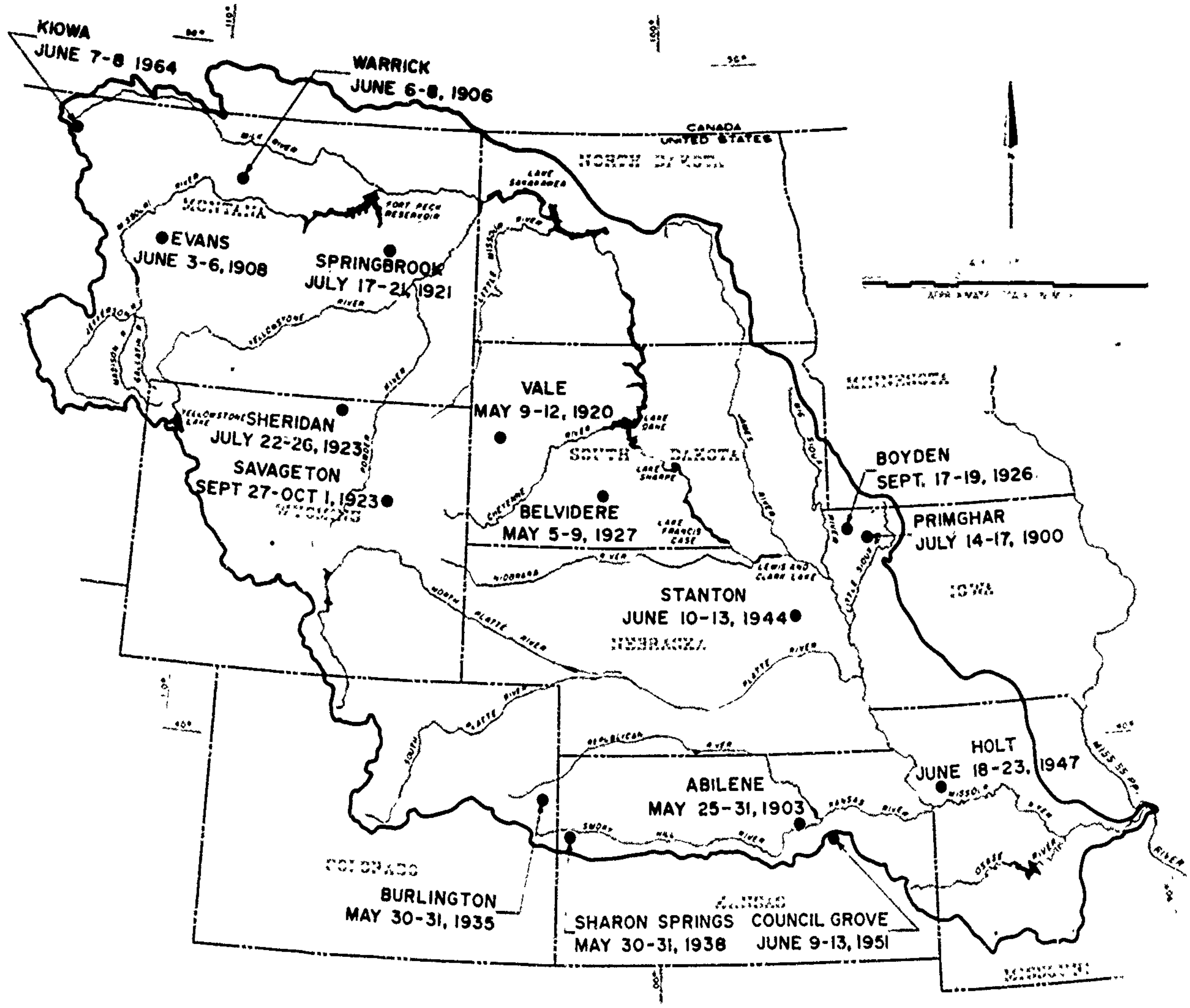
Floods of Record

Description of the many major floods that have occurred in the Missouri Basin is beyond the scope of this appendix. Publications exist in which such material is presented. Among these are annual flood reports prepared by the Corps of Engineers, U. S. Geological Survey Water Supply Papers summarizing flood events for specific years, and special reports prepared by these agencies, the U. S. Weather Bureau and other Federal agencies, and the states involved.

Some flood events, however, have been so notable as to warrant specific mention. The 1881 flood in the upper Missouri River Basin and the 1844 and 1903 floods in the lower basin produced crest stages and peak discharges which, at some locations, have not since been exceeded. The 1927 flood on the Missouri River, resulting from a combination of mountain snowmelt in the upper basin and heavy rainfall in the central and lower basin, is notable because of its great flood volume. The 1950 and 1952 early spring floods were outstanding examples of major floods caused almost entirely by melting of the plains snow cover. Intense rainstorms of relatively short duration caused the great 1935 flood on the upper Republican River, the severely damaging 1965 flood in northeastern Colorado, and, in conjunction with residual mountain snowmelt, the severe 1964 floods in northwestern Montana. The 1951 floods in eastern

FIGURE 30

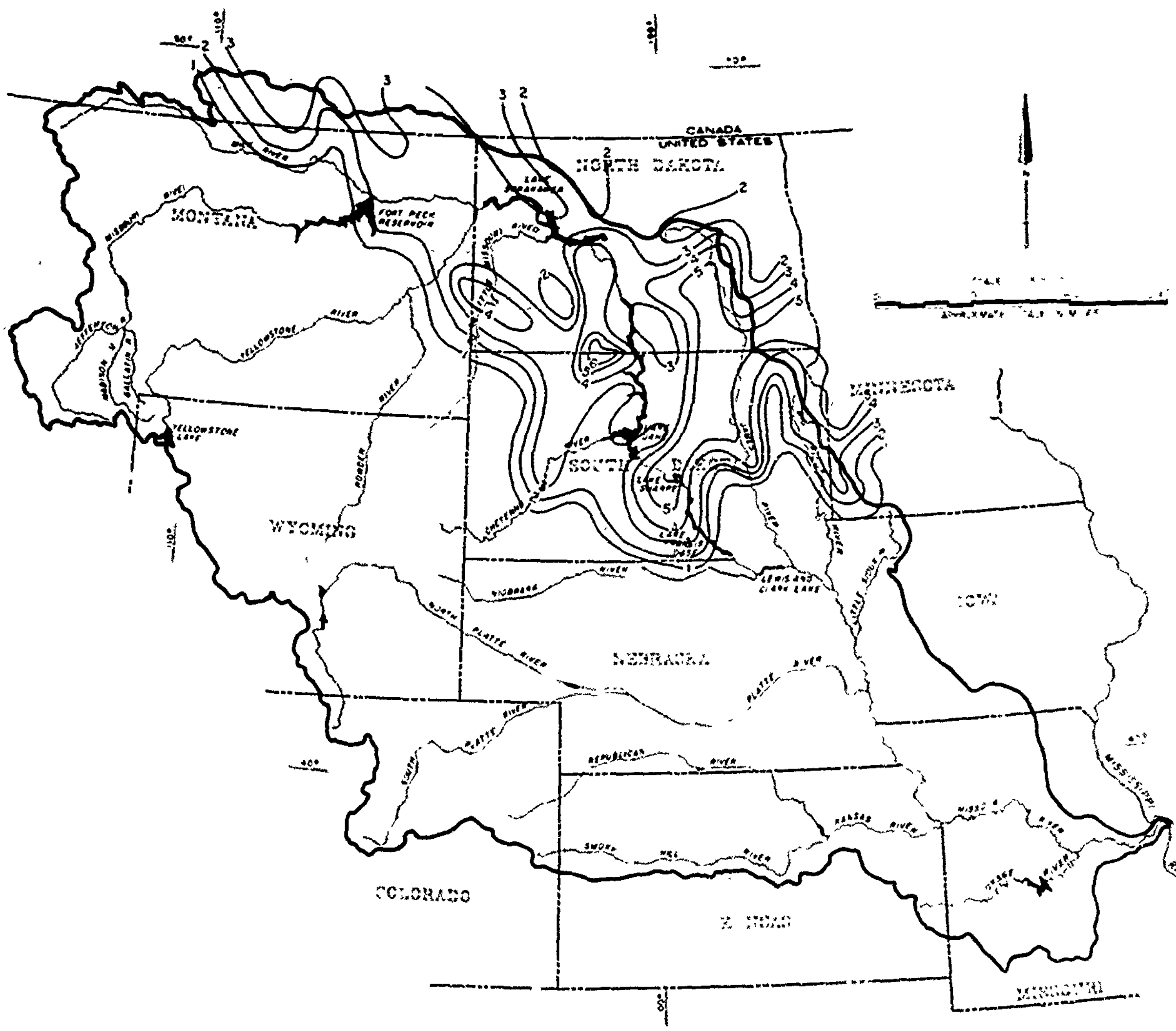
LOCATION AND PERTINENT DATA FOR MAJOR HISTORICAL STORMS



Date	Approximate Location	Maximum Point Rainfall Inches	Total Storm Duration Hours	Area of Total Storm Sq. Mi.	Average Rainfall Total Storm Inches	Average Rainfall in Inches 6 Hours 1,000 Sq. Miles	6 Hours 10,000 Sq. Miles	24 Hours 1,000 Sq. Miles	24 Hours 10,000 Sq. Miles
July 14-17, 1900	Primghar, Iowa	13.6	78	100,000	3.9	4.5	2.5	9.1	5.7
May 25-31, 1903	Abilene, Kansas	16.8	168	136,000	4.8	3.8	1.9	7.3	3.7
June 6-8, 1906	Warrick, Mont.	13.3	54	40,000	3.6	3.5	1.7	6.7	3.4
June 3-6, 1908	Evans, Mont.	8.0	72	20,000	3.8	1.6	1.1	5.3	3.4
May 9-12, 1920	Vale, S. Dak.	6.4	78	54,000	3.0	1.2	0.8	3.8	2.4
June 17-21, 1921	Springbrook, Mont.	15.1	108	52,600	4.2	7.4	3.0	11.3	5.6
July 22-26, 1923	Sheridan, Wyo.	5.6	84	9,000	2.8	2.6	-	2.8	-
Sept 27-Oct 1, 1923	Savageton, Wyo.	17.1	108	95,000	3.8	3.7	1.6	6.6	3.0
Sept 17-19, 1926	Boyden, Iowa	24.0	54	63,000	3.5	7.5	3.0	10.6	5.5
May 5-9, 1927	Belvidere, S. Dak.	7.2	108	150,000	3.2	2.4	1.1	3.7	2.8
May 30-31, 1935	Burlington, Colo.	24.0	24	6,300	3.8	5.8	-	7.2	-
May 30-31, 1938	Sharon Springs, Kans.	10.0	30	14,000	3.4	5.9	2.9	5.1	3.8
June 10-13, 1944	Stanton, Nebr.	17.3	78	16,000	4.6	7.8	2.2	9.3	3.5
June 18-23, 1947	Holt, Mo.	17.6	120	306,000	1.8	5.6	2.6	5.6	3.0
July 9-13, 1951	Council Grove, Kans.	18.5	108	57,000	6.0	4.0	2.9	6.6	4.8
June 7-8, 1964	Kiowa, Mont.	16.0	36	8,000	8.4	4.3	-	11.5	-

FIGURE 31

WATER EQUIVALENT OF PLAINS SNOW COVER IN INCHES 17-20 MARCH 1952



Kansas and in Missouri were outstanding examples of floods resulting from a prolonged series of rainstorms.

Travel Time of Flood Peaks

In connection with analyses of streamflow on the Missouri River as well as on tributary streams, time of water travel is a significant factor. The approximate travel time of a flood wave from various locations in the basin to the mouth of the Missouri River is shown by plate 14. The travel times shown are based on bankfull conditions and on the assumption that the flood wave will be passed through any reservoir in the basin as it occurs. Substantial deviations from the travel times shown by this plate may occur if flows are significantly greater or significantly less than bankfull. The approximate travel times shown are based on data obtained through observation of actual flood events or, where such data were not available, on information furnished by the Weather Bureau, the Bureau of Reclamation, and the Corps of Engineers concerning channel characteristics.

Record Peak Flows

Peak flows of record in cubic feet per second per square mile of drainage area at streamgaging stations and other selected sites throughout the Missouri Basin are shown by plate 15. For a given size of drainage area there is an obviously wide range of peak flow. Variations in precipitation, topography, and soil are the primary factors responsible for this.

DROUGHTS AND LOW FLOWS

A drought is an extended period of deficient precipitation and runoff. However, it has no universally accepted quantitative definition. As stated in U. S. Weather Bureau Research Paper No. 45, "Meteorological Drought," by Wayne C. Palmer, 1965, "Drought means various things to various people, depending on their specific interest. To the farmer, drought means a shortage of moisture in the root zone of his crops. To the hydrologist, it suggests below average water levels in streams, lakes, reservoirs, and the like. To the economist it means a water shortage which adversely affects the established economy. Each has a concern which depends on the effects of a fairly prolonged weather anomaly."

Historical precipitation and runoff records for the Missouri Basin show that the basin is subject to a wide variety of drought conditions, ranging from short-term drought in small areas to long-term, widespread droughts such as plagued the entire basin in the 1930's. No attempt has been made in this appendix to establish arbitrary criteria by which drought severity might be judged. Rather, in the drought and low-flow studies in connection with the comprehensive framework plan, emphasis has been placed on determination of the probabilities of recurrence of historical drought periods and of the ability of resultant low streamflows to meet water requirements for water-quality control, municipal and industrial water supply, irrigation, and other water uses.

Subnormal Precipitation

All parts of the Missouri Basin have experienced numerous periods of subnormal precipitation. This is illustrated graphically on plate 5, presented previously in Chapter 3, which shows the adjusted average precipitation over each subbasin, over the Missouri Basin above Sioux City, Ia., and over the entire Missouri Basin for each year of the period of record.

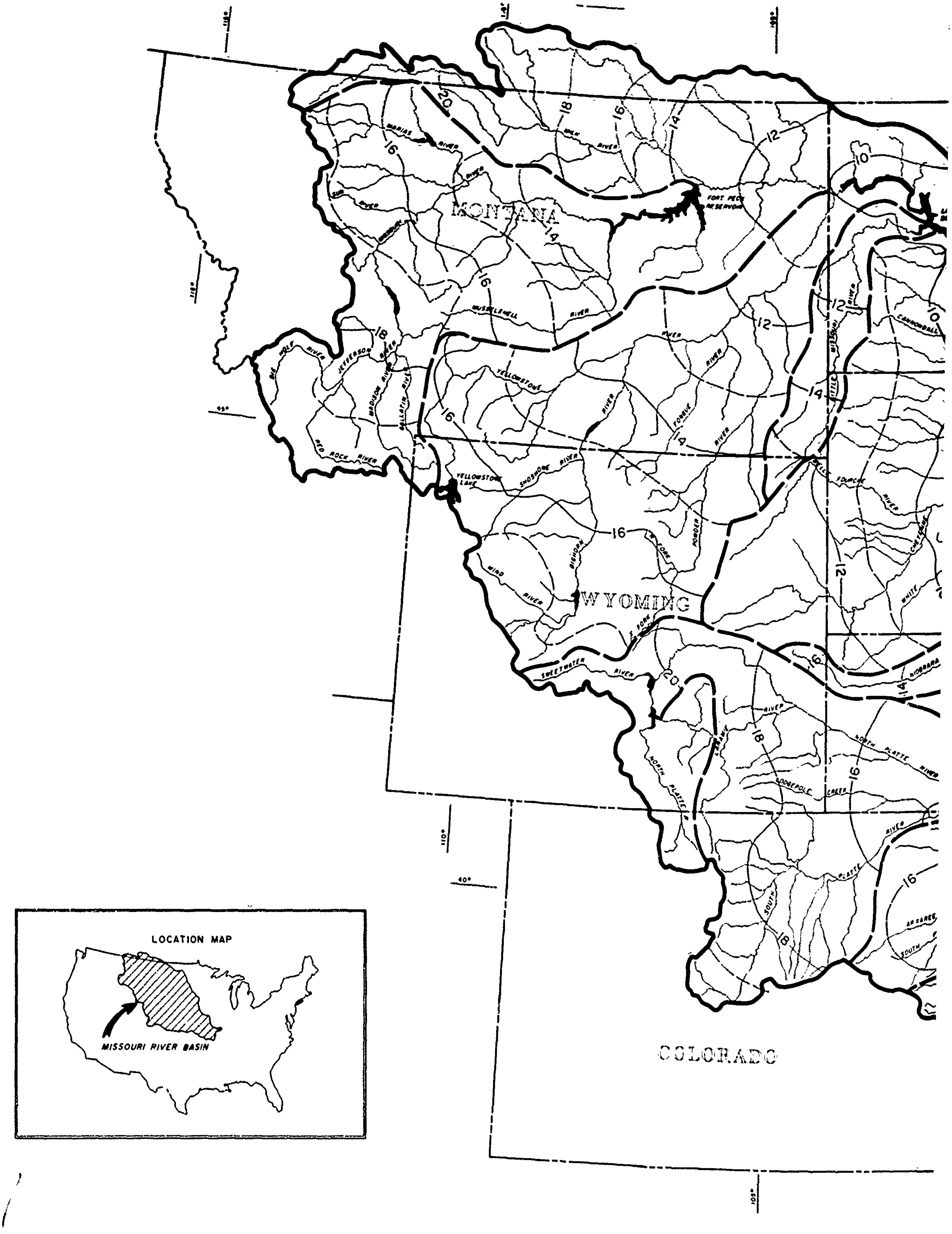
The severity of rainfall deficiency, of course, varies over the basin. Table 11 shows for each subbasin or part of a subbasin the minimum average precipitation experienced over the area in any one year and the minimum average annual precipitation experienced over the area in any period of 5 consecutive years. The 1-year minimum shown for the entire Missouri Basin is 68 percent of the long-term average annual precipitation. The 1-year minimums for the subbasin areas vary from 46 percent to 66 percent of the long-term average annual precipitation amounts. The 5-year minimum shown for the entire basin is 81 percent of the long-term average, and the 5-year minimums for the subbasins vary from 67 percent to 81 percent of the long-term averages.

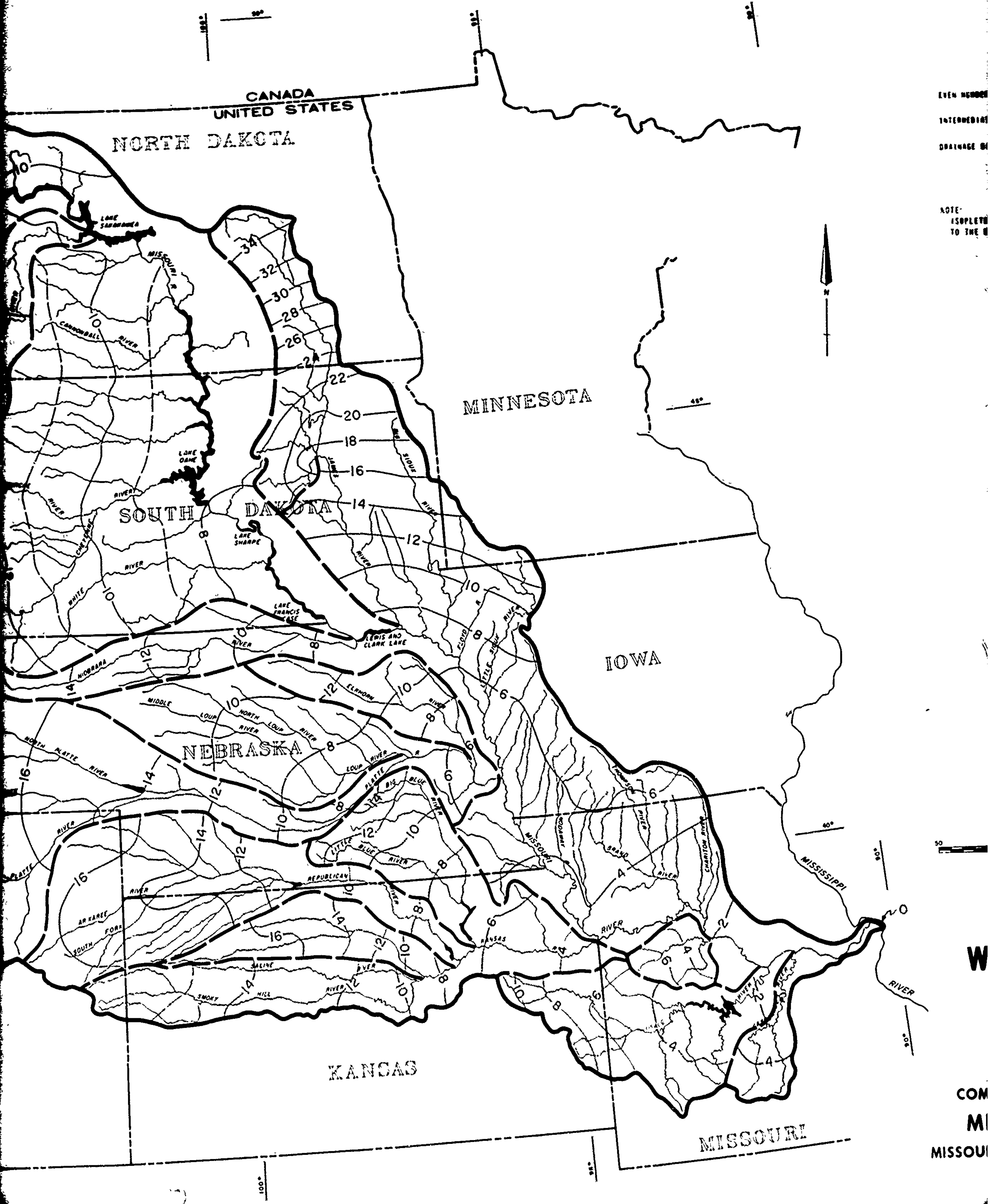
Table 11 – MINIMUM ANNUAL AND MINIMUM 5-YEAR AVERAGE VALUES OF PRECIPITATION OVER THE MISSOURI BASIN AND OVER ITS SUBBASINS

Subbasin or Basin Area	Minimum Average Precipitation in Inches over Basin or Subbasin Area Shown			
	1-Year	Year	5-Year Average	Period
Upper Missouri	8.6	1872	11.6	1933-37
Yellowstone	8.8	1872	12.8	1933-37
Western Dakota	8.8	1936	13.3	1933-37
Eastern Dakota	11.1	1864	15.5	1932-36
Platte-Niobrara				
East of 102° Longitude	12.4	1864	15.4	1860-64
West of 102° Longitude	9.6	1876	13.1	1873-77
Middle Missouri	13.3	1843	22.3	1839-43
Kansas				
East of 99° Longitude	13.0	1843	21.4	1933-37
West of 99° Longitude	11.2	1894	15.0	1952-56
Lower Missouri	24.7	1901	29.8	1952-56
Missouri Basin above Sioux City, Ia.	10.4	1936	12.8	1933-37
Total Missouri Basin	13.5	1936	16.1	1933-37

The extended drought of the 1930's was the most critical of record in the Missouri Basin and, for the basin as a whole, rainfall deficiency during the period from 1930 to 1939 was the most critical of record. Individual subbasins, however, have had more critical periods of rainfall deficiency. In the Platte-Niobrara Subbasin west of 102° longitude, rainfall deficiency was most critical during the period 1873-1882. In the Middle Missouri Subbasin, it was most critical during the period 1838-1847.

In planning to meet water requirements, it is necessary to consider inclusion of carryover storage in reservoirs to compensate for periods of deficient precipitation and runoff. Since precipitation records in the


MONTANA
WYOMING
COLORADO
FORT PECK RESERVOIR
MUSSELSHELL RIVER
YELLOWSTONE
YELLOWSTONE LAKE
SHOSHONE RIVER
JEFFERSON RIVER
MADISON RIVER
GALLATIN RIVER
RED ROCK RIVER
WIND RIVER
BIGHORN
POWDER RIVER
SWEETWATER RIVER
NORTH PLATTE RIVER
LARAMIE
LODGEPOLE CREEK
SOUTH PLATTE RIVER
BELLE FOURCHE RIVER
CHEYENNE
WHITE
NIOBRARA
CANNONBALL
LITTLE MISSOURI RIVER
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
UNITED STATES
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
IOWA
NEBRASKA
KANSAS
MISSOURI
LAKE SAKAKAWEA
MISSOURI R.
CANNONBALL RIVER
LAKE OAHE
CHEYENNE RIVER
WHITE RIVER
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
JAMES RIVER
BIG SIOUX RIVER
FLOYD R.
LITTLE SIOUX RIVER
NIOBRARA RIVER
ELKHORN RIVER
MIDDLE LOUP
NORTH LOUP RIVER
LOUP RIVER
NORTH PLATTE RIVER
PLATTE RIVER
PLATTE R.
BIG BLUE RIVER
LITTLE BLUE RIVER
REPUBLICAN RIVER
ARIKAREE
SOUTH FORK
SALINE RIVER
SMOKY HILL RIVER
KANSAS
MISSOURI RIVER
NODAWAY
GRAND RIVER
CHARITON RIVER
MISSISSIPPI RIVER
N
40°
45°
100°
95°
90°
34
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14
12
10
8
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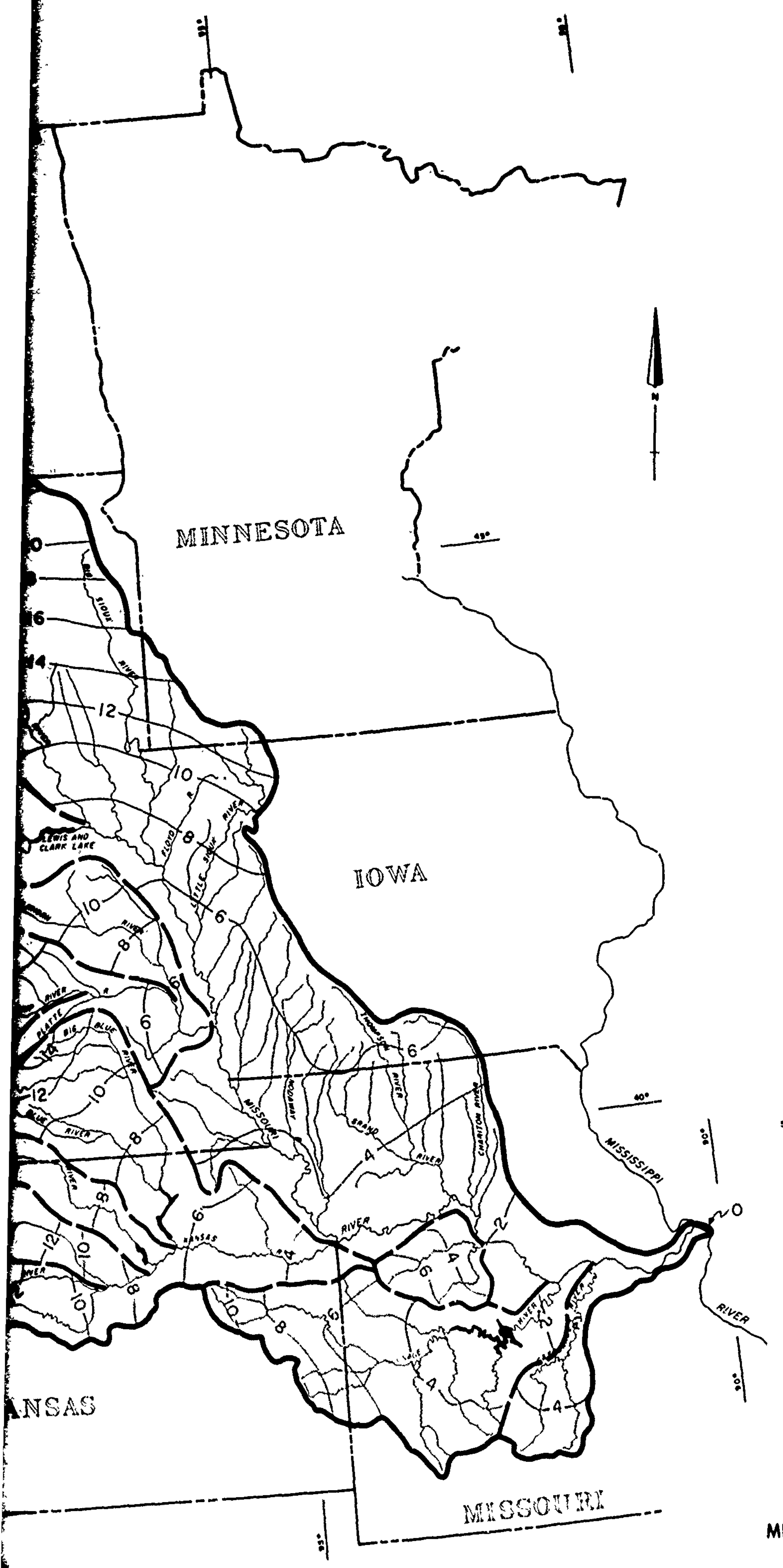


L E G E N D

EVEN NUMBER OF DAYS AS INDICATED —8—

INTERMEDIATE ONE-DAY INTERVALS

DRAINAGE DIVIDES

NOTE.
ISOPLETHS REPRESENT AVERAGE BANKFULL TRAVEL TIME TO THE MOUTH OF THE MISSOURI RIVER IN DAYS

SCALE 1:5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

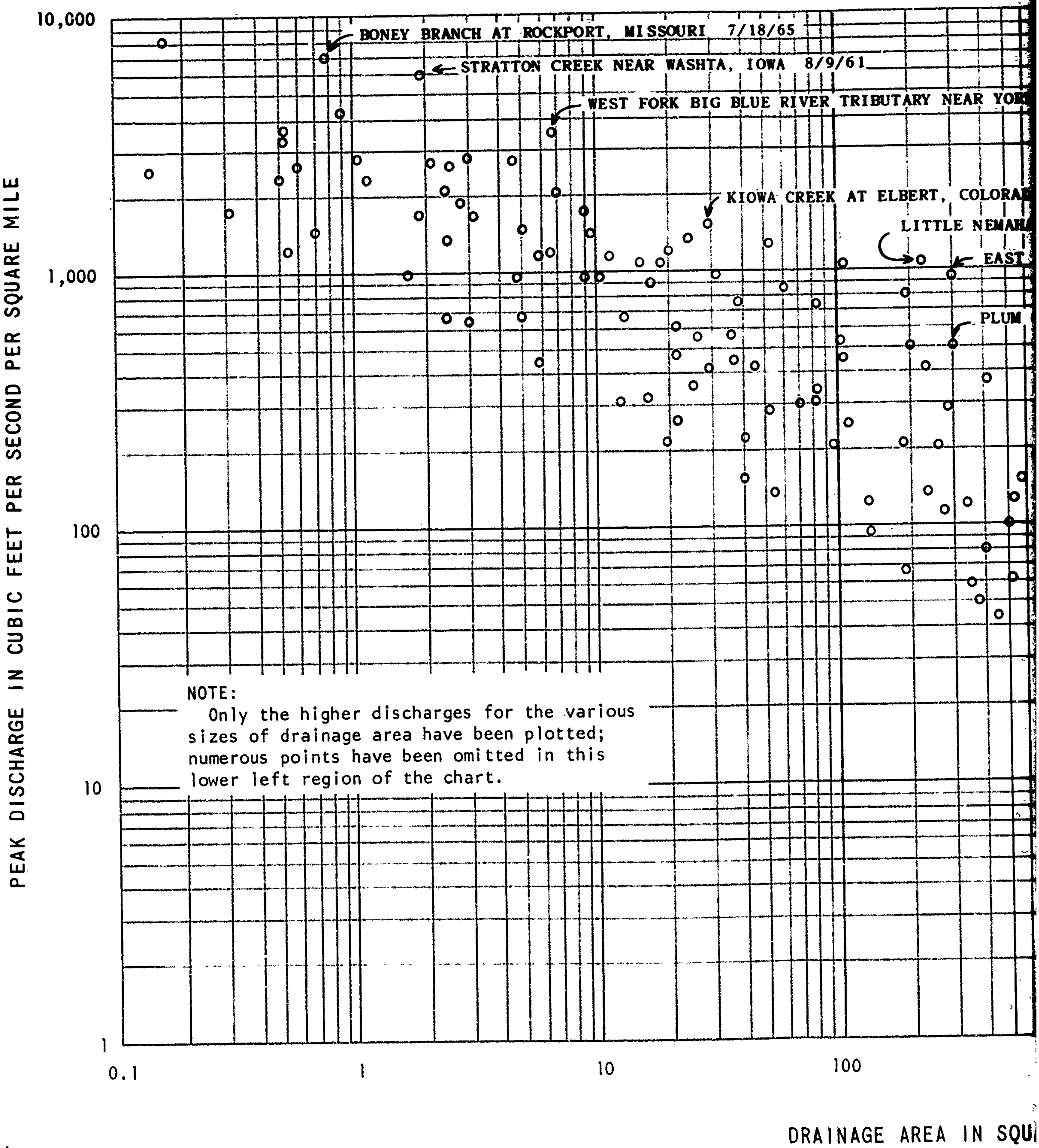
WATER TRAVEL TIME IN DAYS

COMPREHENSIVE FRAMEWORK STUDY

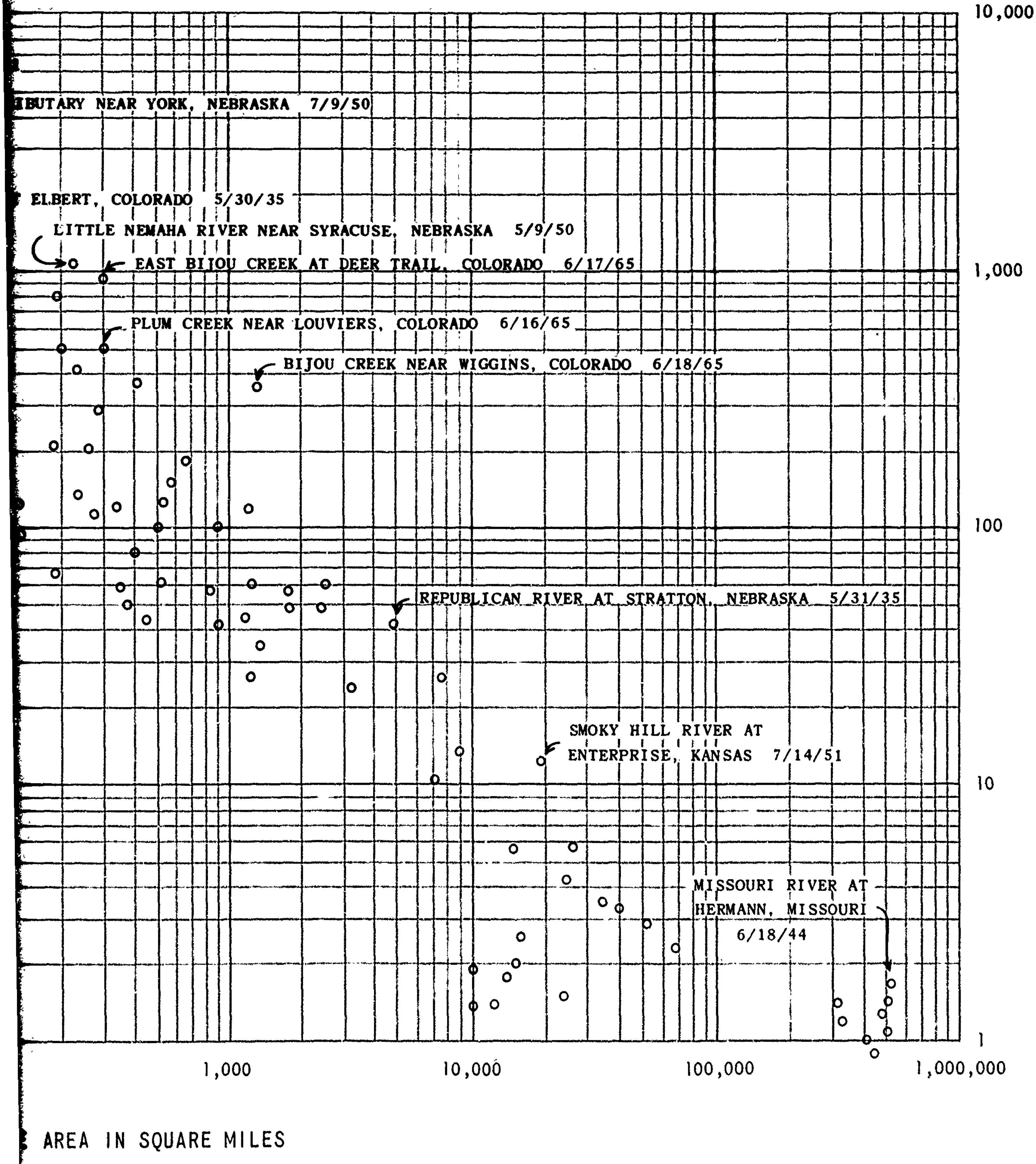
MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

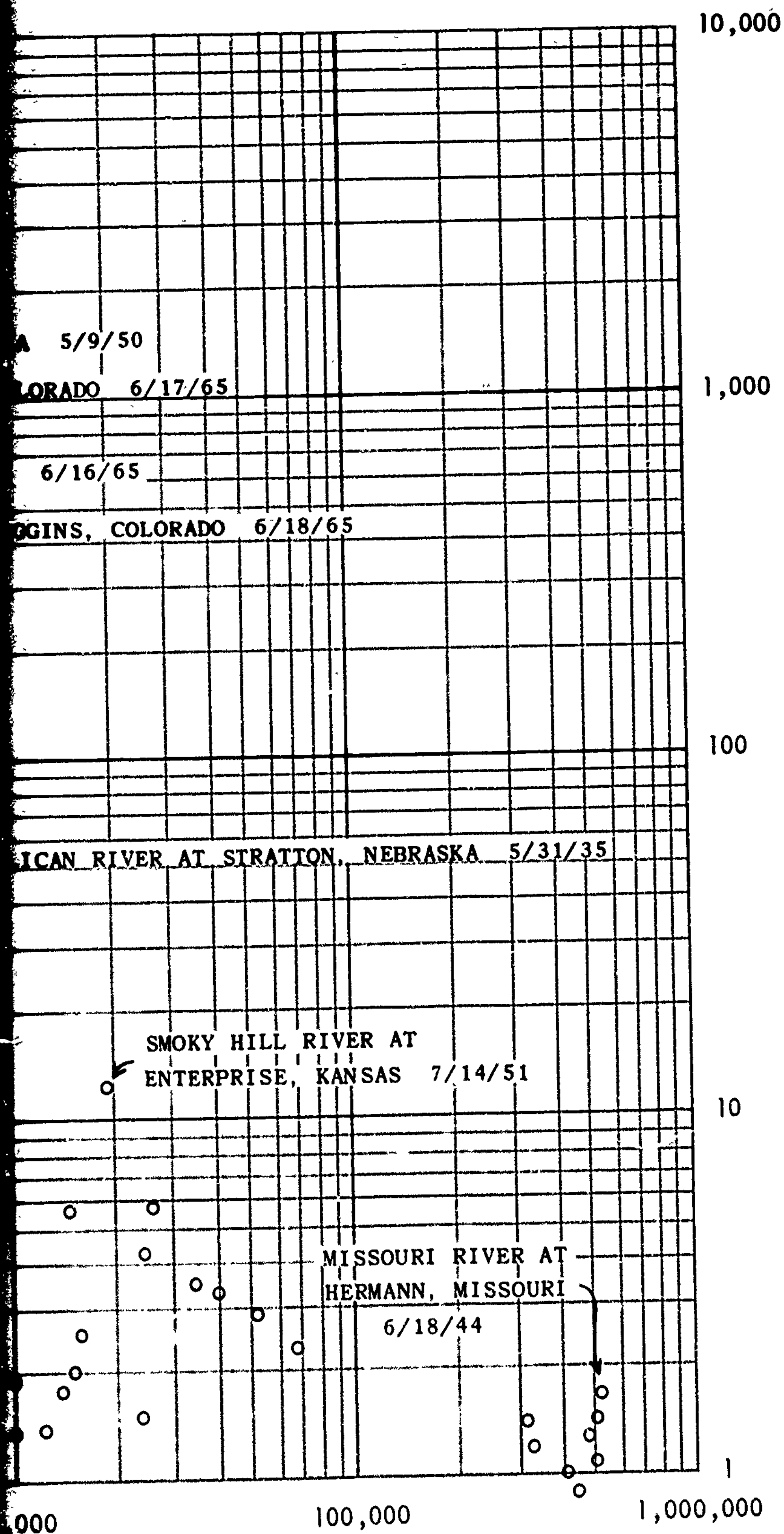
PLATE 14



BONEY BRANCH AT ROCKPORT, MISSOURI 7/18/65
STRATTON CREEK NEAR WASHTA, IOWA 8/9/61
WEST FORK BIG BLUE RIVER TRIBUTARY NEAR YOR
KIOWA CREEK AT ELBERT, COLORA
LITTLE NEMAHA
EAST
PLUM
NOTE:
Only the higher discharges for the various sizes of drainage area have been plotted; numerous points have been omitted in this lower left region of the chart.
10,000
1,000
100
10
1
0.1
1
10
100
PEAK DISCHARGE IN CUBIC FEET PER SECOND PER SQUARE MILE
DRAINAGE AREA IN SQU



IBUTARY NEAR YORK, NEBRASKA 7/9/50
ELBERT, COLORADO 5/30/35
LITTLE NEMAHA RIVER NEAR SYRACUSE, NEBRASKA 5/9/50
EAST BIJOU CREEK AT DEER TRAIL, COLORADO 6/17/65
PLUM CREEK NEAR LOUVIERS, COLORADO 6/16/65
BIJOU CREEK NEAR WIGGINS, COLORADO 6/18/65
REPUBLICAN RIVER AT STRATTON, NEBRASKA 5/31/35
SMOKY HILL RIVER AT
ENTERPRISE, KANSAS 7/14/51
MISSOURI RIVER AT
HERMANN, MISSOURI
6/18/44
10,000
1,000
100
10
1
1,000
10,000
100,000
1,000,000
AREA IN SQUARE MILES



RELATION OF UNIT DISCHARGE TO DRAINAGE AREA FOR SELECTED FLOODS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 15

Missouri Basin are generally available for much longer periods than are streamflow records, evaluation of the probability of recurrence of past drought periods has been based on precipitation data. Figure 32 shows pertinent data and sample curves of multi-annual precipitation probabilities that have been developed for the total Missouri Basin area. Similar curves have been developed for each of the individual subbasins, and for the basin area above Sioux City, Ia.

From the multi-annual precipitation probability curves, the probabilities of specific amounts of precipitation in one year or in periods of 2, 3, 5, or 10 consecutive years can be determined. As shown by these curves, the minimum observed precipitation over a period of 5 consecutive years, in the entire Missouri Basin and in each of its subbasins, has a recurrence interval as shown in table 12. Based on this study, it may be concluded that the minimum 5-year precipitation which has been observed in each of the subbasins except the Platte-Niobrara and the Middle Missouri represents a greater precipitation deficiency than might logically be expected in a period of record of about 100 years. This is particularly true for the Missouri Basin above Sioux City and for the total Missouri Basin where the minimum 5-year precipitation experienced in about the past 100 years has an estimated recurrence interval of several thousand years.

Table 12 – RECURRENCE INTERVAL FOR MINIMUM OBSERVED 5-YEAR PRECIPITATION MISSOURI BASIN AND ITS SUBBASINS

Subbasin or Basin Area	Recurrence Interval[1] In Years		
Upper Missouri	(122)	400	(1,280)
Yellowstone	(74)	200	(550)
Western Dakota	(80)	222	(590)
Eastern Dakota	(82)	217	(560)
Platte-Niobrara			
East of 102° Longitude	(360)	1250	(4,500)
West of 102° Longitude	(25)	50	(100)
Middle Missouri	(48)	100	(220)
Kansas			
East of 99° Longitude	(103)	213	(740)
West of 99° Longitude	(119)	333	(920)
Lower Missouri	(117)	250	(890)
Missouri Basin above Sioux City	(700)	3846	(20,500)
Total Missouri Basin	(460)	2222	(10,600)

[1] In the recurrence-interval column, the middle value is the estimated recurrence interval in years. The values in parentheses are the 90-percent confidence limits.

Subnormal Runoff

Subnormal precipitation, of course, is primarily responsible for subnormal runoff. The severity of subnormal runoff conditions, however, is influenced also by high temperatures, high winds, low humidity, and type of land use.

Since systematic streamgaging over the entire Missouri River Basin began, in about 1928, there have been two periods of extended and severely subnormal runoff. These occurred in the 1930's and in the 1950's. Subnormal runoff in the 1930's was of longer duration and of greater areal extent than that which occurred in the 1950's Subnormal runoff in the 1950's, however, particularly during the period from 1952 to 1956, was of major severity in Colorado, Kansas, Missouri, and Iowa.

STREAMFLOW VOLUME-FREQUENCY ANALYSES

Hydrologic frequency estimates are required in many phases of planning, design, and operation of water resources development projects in order to adequately appraise the representativeness of past flood and drought periods and to estimate the magnitude of future hydrologic events that water resource projects may experience. High-flow volume-frequency data are used in connection with establishment of flood-control storage volumes and in connection with selection of design floods for levee and channel-improvement projects. Low-flow volume-frequency data frequently are useful in connection with establishment of conservation storage volumes. Two separate types of streamflow frequency analyses were made. One involved the computation of volume-frequency curve statistics from actual station records and the plotting and construction of the resulting curves by a computer-fed plotter. The second involved the development of generalized relations, based on correlations between frequency curve statistics and basin characteristics, for subsequent use in developing frequency estimates at any location in the basin, gaged or ungaged.

Data Available for Analysis

As previously indicated, daily streamflow records of 540 streamgaging stations in and near the Missouri River Basin were placed on IBM cards and magnetic tapes. Although these daily streamflow records were readily available for analysis, a number of the stations were excluded from the streamflow frequency studies because their records were of a duration too short to permit reliable projection, their records were affected too greatly by upstream control, or their drainage areas were larger than desired for the study.

High-Flow Volume-Frequency Curves from Station Data

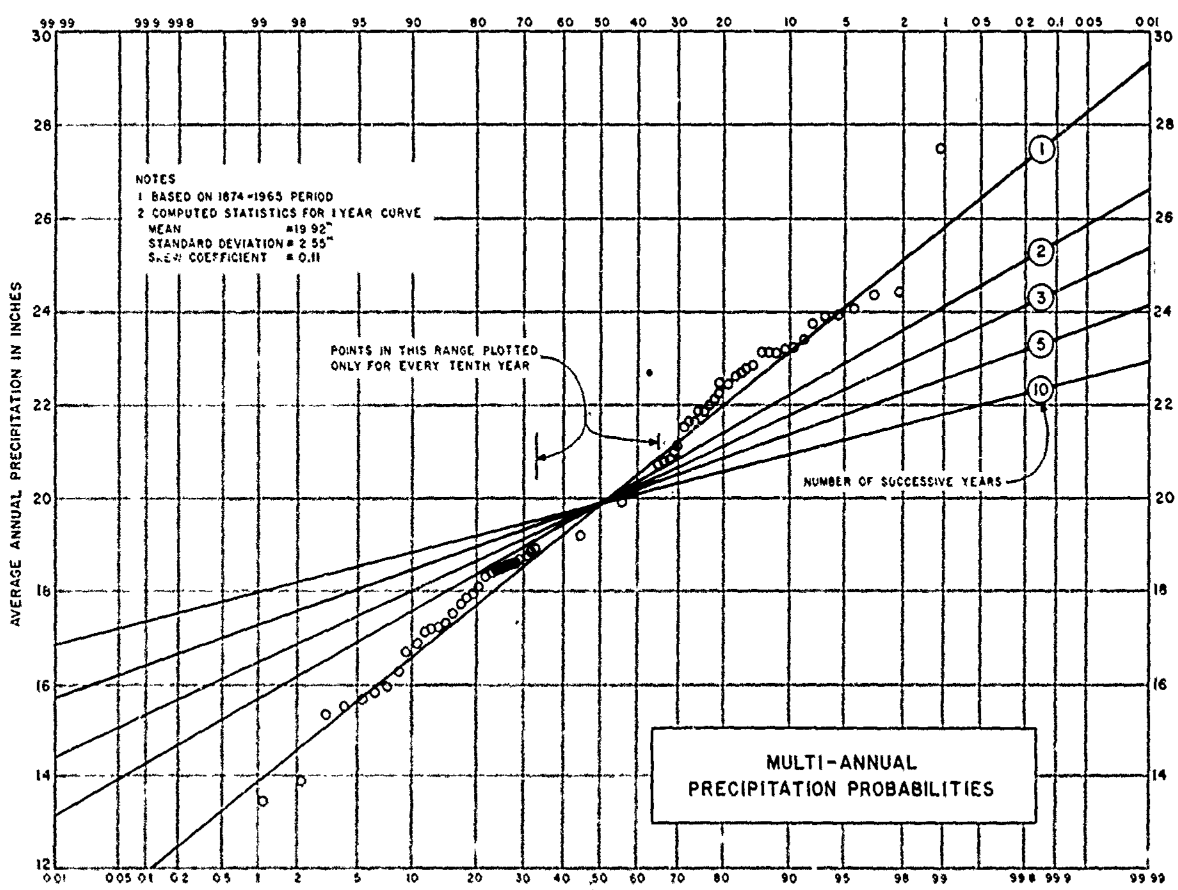
High-flow volume-frequency curves were plotted for about 475 of the 540 stations for which daily records

FIGURE 32

AVERAGE ANNUAL PRECIPITATION AND MULTI-ANNUAL PROBABILITIES

YEAR	0	1	2	3	4	5	6	7	8	9
1870					19.34	24.41	22.80	21.54	22.17	21.87
1880	19.48	23.40	18.70	21.04	22.49	21.06	18.11	19.62	19.22	17.88
1890	16.69	23.21	21.99	17.20	15.95	18.41	22.33	19.74	20.08	19.50
1900	19.85	13.83	21.87	21.62	18.92	23.18	22.46	18.85	23.24	22.66
1910	15.70	18.96	20.77	18.86	18.98	27.56	20.04	16.29	19.89	18.60
1920	20.70	19.19	20.46	24.06	18.78	[illegible]	18.61	23.95	20.23	20.77
1930	18.63	17.18	19.17	17.25	13.94	19.0[illegible]	13.52	16.88	20.05	15.83
1940	17.58	23.75	23.17	18.37	23.90	20.79	22.70	20.84	19.71	20.06
1950	19.29	24.40	15.57	18.54	17.26	17.97	15.33	22.83	19.13	18.86
1960	17.74	19.99	21.63	18.48	19.06	23.18				

AVERAGE ANNUAL PRECIPITATION



had been placed on IBM cards. These curves were plotted and drawn for eight time periods, ranging from the instantaneous peak flow to the annual volume, utilizing actual station data without adjustment or generalization. Sample curves for the Yellowstone River near Sidney, Mont., are shown on figure 33. The points were plotted and the curves were drawn by a CALCOMP Plotter, utilizing an on-line RCA 301 computer. The points plotted for each period for each station were based on the formula:

$$\text{Exceedence Frequency per 100 Years} = \frac{M}{N+1}$$

where: N = Number of years of record
M = Order of magnitude (rank) of event

The frequency curves drawn through the plotted points were based on fitting the Pearson Type III function by use of moments of flow logarithms in accordance with the procedure developed by L. R. Beard, Hydrologic Engineering Center, Sacramento District, Corps of Engineers. The first two moments (mean logarithm and standard deviation) were based on data from each individual station. The third moment (skew) was based on average skew coefficients developed by the Washington District, Corps of Engineers, as follows:

Periods	*Skew Coefficient*
Instantaneous	0
1 day	-.04
3 days	-.12
10 days	-.23
30 days	-.32
90 days	-.37
1 year	-.40

Curves for the 475 stations are presented in a series of working papers, one for each subbasin, entitled, "High-Flow Volume-Frequency Curves for Selected Durations."

Generalized High-Flow Volume-Frequency Analyses

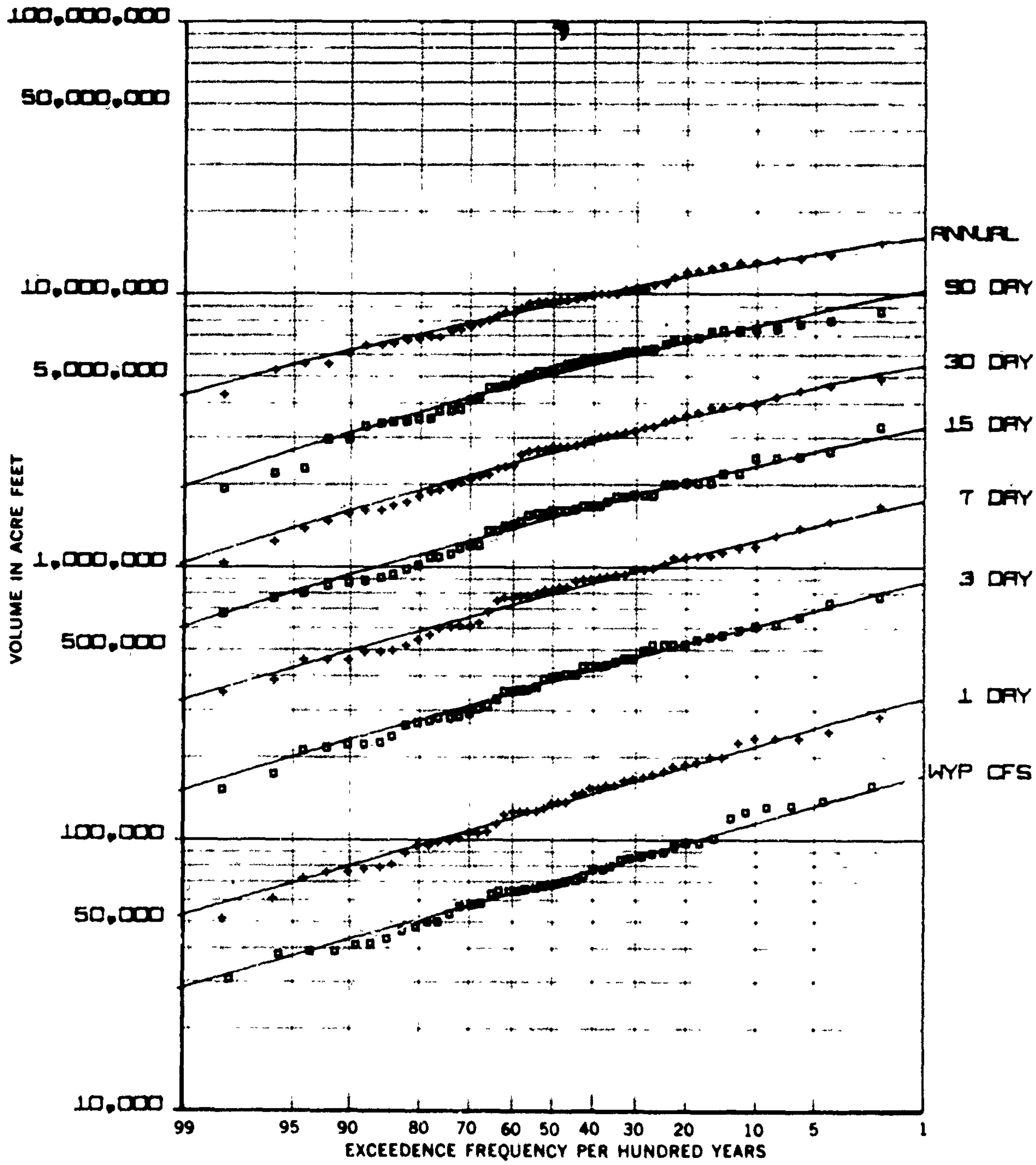
Even among the streamflow stations selected for frequency analyses, the periods of record vary in length to an extent sufficient to produce significant variations in the reliability of streamflow volume-frequency relationships based upon individual station flow records alone. The reliability of these relationships, however, can be improved by generalization techniques, and these generalization techniques can be used also to develop volume-frequency relationships at ungaged locations. In the analyses performed for the comprehensive framework study, generalization techniques have been used as proposed by L. R. Beard in his publication, "Statistical Methods in Hydrology."

High-flow volume-frequency analyses were performed for each subbasin. The steps involved in the generalization procedure utilized are described briefly in the following subparagraphs.

a. In each subbasin, the streamflow stations selected for frequency analyses were divided into so-called pivot stations and satellite stations. Pivot stations were selected on the basis of length of record, reliability of record, and geographic location.
b. For each station, for each year of record, discharges were determined in cubic feet per second for the water year peak discharge and in mean cubic feet per second for the maximum 1-, 3-, 7-, 15-, 30-, and 90-day discharges and the annual discharge.
c. For each station logarithms were computed for each of the above discharge values.
d. From the array of logarithms of annual maximum discharge values for each of the eight specified periods of time at each station, the mean logarithm, the standard deviation of the logarithms, and the skew coefficient were computed for each station. These three statistics defined the computed cumulative frequency curve for each period at each station.
e. Computed values of the mean logarithm and standard deviation at satellite stations were adjusted by comparison with corresponding values at pivot stations.
f. For each station, those drainage basin and climatic characteristics affecting streamflow analysis which were to be correlated with the adjusted mean logarithms and standard deviations were selected and their values were determined.
g. Multiple correlations between the selected drainage basin characteristics and the adjusted mean logarithms, and standard deviations were performed to establish regression equations for use in computing means and standard deviations for the generalized high-flow volume-frequency curves.
h. Runoff coefficients and frequency indices for use in the regression equations were determined.
i. Appropriate skew coefficients for each duration were determined. Pending completion of a regional skew study for the Missouri Basin, the skew coefficients proposed by the Washington District, Corps of Engineers, and listed previously were used.

The climatic and drainage basin characteristics which exert some influence on high-flow volumes are numerous and varied. The more significant factors involved are contributing drainage area, mainstream length, valley slope, basin altitude, distance to drainage area centroid,

FIGURE 33
HIGH-FLOW VOLUME-FREQUENCY CURVE



YELLOWSTONE RIVER NR SIDNEY, MONT.

1912-1963 06-3295.00

infiltration capacity, normal summer precipitation, normal winter precipitation, rainfall intensity, drainage area shape, water equivalent of plains snow cover, water equivalent of snow cover above 5,000 feet elevation and above 8,000 feet elevation, and percent of total drainage area above each of these elevations.

Each of these factors was considered in analyses of streamflow in connection with each subbasin to which it was applicable. The significance of each varies from subbasin to subbasin. Some are of greater significance in connection with evaluation of mean logarithms of annual maximum flows; others are of greater significance in connection with evaluation of the standard deviation of these logarithms. Table 13 shows for each subbasin the drainage basin and climatic characteristics of greatest significance in connection with evaluation of the means and standard deviation of the logarithms of annual maximum flows.

Low-Flow Volume-Frequency Curves from Station Data

Low-flow volume-frequency curves were prepared for 50 streamgaging stations in the Lower Missouri Subbasin. Curves were drawn for periods of 1, 3, 7, 14, 30, and 90 consecutive days and 1 year.

The exceedence frequency of the points plotted for each period at each station was determined by the same formula used for high flows:

$$\text{Exceedence Frequency per 100 years} = \frac{M}{N+1}$$

Where: N = Number of years of record
M = Order of magnitude (rank) of event

The frequency curves drawn through the plotted points were based on fitting the Pearson Type III function by use of moments of logarithms of the annual minimum flow values in accordance with the procedure developed by L. R. Beard. The first two moments (mean logarithm and standard deviation) were based on data from each individual station with the exception that, for those cases where the low-flow series contained zero flow, a small increment of 0.1 cubic foot per second was substituted for each zero value. The third moment, skew, was based on smoothed average skew coefficients, weighted for length of record from the individual station data for the subbasin, excluding from the computations those durations for each station where more than one-fourth of the annual minimum flow values were

Table 13 – DRAINAGE BASIN AND CLIMATIC CHARACTERISTICS AFFECTING STREAMFLOW ANALYSES

I. Factors Closely Related to Mean Logarithms of Annual Maximum Flows for Eight Durations

Subbasin	Contributing Drainage Area	Basin Altitude	Basin Shape	Rainfall Intensity	Normal Summer Precipitation	Normal Winter Precipitation
Upper Missouri	x	x				
Yellowstone	x	x			x	x
Western Dakota	x	x				
Eastern Dakota	x	x			x	
Platte-Niobrara	x		x			x
Middle Missouri	x			x		
Kansas	x				x	
Lower Missouri	x				x	x

II. Factors Closely Related to Standard Deviation of Logarithms of Annual Maximum Flows for Eight Durations

Subbasin	Contributing Drainage Area	Basin Altitude	Basin Shape	Rainfall Intensity	Water Course Length	Normal Summer Precipitation	Normal Winter Precipitation	Infiltration	Valley Slope
Upper Missouri		x							x
Yellowstone		x		x			x		
Western Dakota		x	x						x
Eastern Dakota		x	x				x		
Platte-Niobrara		x	x					x	
Middle Missouri				x	x			x	
Kansas						x		x	
Lower Missouri	x	x		x				x	

zero. Annual frequency curves were plotted with zero skew. Skew coefficients used are shown as follows:

Periods	*Skew Coefficient*
1 day	-.40
3 day	-.32
7 day	-.25
14 day	-.20
30 day	-.14
90 day	-.05
Annual	zero

For those stations and periods where zero flows were experienced during a significant number of the years of record the arbitrary assignment of a mean flow value of 0.1 cfs introduced considerable bias in the computed curve. In those cases, a curve eye-fitted to the plotted points, ignoring the points representing the arbitrary assigned values of 0.1 cubic foot per second was used in lieu of the computed curve. This eye-fit curve was not extended downward below the lowest non-zero value. Computed volume frequency curves were plotted by a Benson-Lehner Delta Card Plotter, utilizing an online RCA 301 computer. Sample curves for the Grand River near Gallatin, Mo., are shown on figure 34.

The curves in figure 34 and other curves of this nature were used to determine preliminary values of reservoir storage requirements for water supply and water quality control in the Lower Missouri Subbasin. Since these curves were without respect to season, however, the effect of the phase relationship of water supply and water demand could not be dependably determined. Accordingly, low-flow volume-frequency curves were prepared only for this one subbasin and dependence on such curves was abandoned in favor of a computer study of reservoir conservation storage requirements.

Computer Study of Reservoir Conservation Storage Requirements

The most widespread water requirements investigated during the comprehensive framework study were those for water supply and water quality control. Early estimates indicated that supplemental flows might be needed at up to several thousand locations throughout the Missouri Basin. Subsequent screening to omit locations where flows were obviously sufficient to meet demands without storage, or insufficient to meet demands even with maximum development of potential storage sites, reduced the number of locations to about 500.

Determination of reservoir storage requirements to meet these demands was accomplished by utilizing the services of the Hydrologic Engineering Center, Sacramento District, Corps of Engineers. The Center modified one of its existing computer programs (23-J2-L245) to conduct monthly reservoir regulation studies of individual potential reservoirs for a specified base period and to recycle as necessary to determine the optimum amount of storage required to meet specified demands under specified shortage conditions.

These studies were conducted for a 40-year base period, generally 1927-1966, utilizing streamflow data from long-record stations in the area, with missing monthly flow data determined by multiple-correlation analyses in accordance with the Center's computer program 23-67, Monthly Streamflow Simulation. Inflows to each potential reservoir were determined by consideration of drainage area and mean annual runoff at the dam site, as compared to the same factors at the most appropriate gaging station.

A generalized area capacity curve was developed for the Missouri River Basin by consideration of area capacity curves for existing and planned reservoirs in the basin. The equation of the curve used in these studies was

$$A = 0.35\ S_t^{0.81}$$

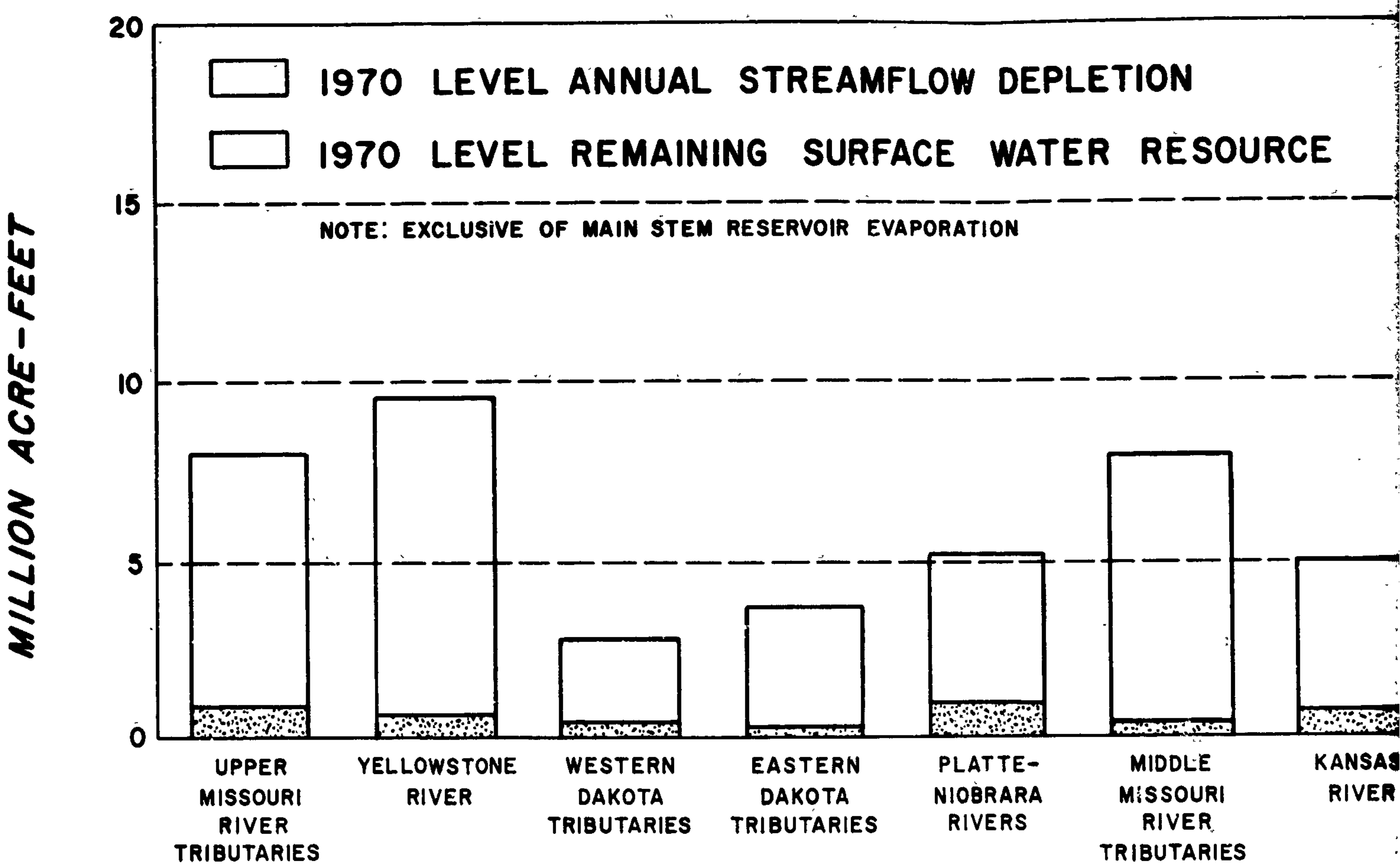
A = surface area of reservoir in acres

S_t = reservoir storage in acre-feet

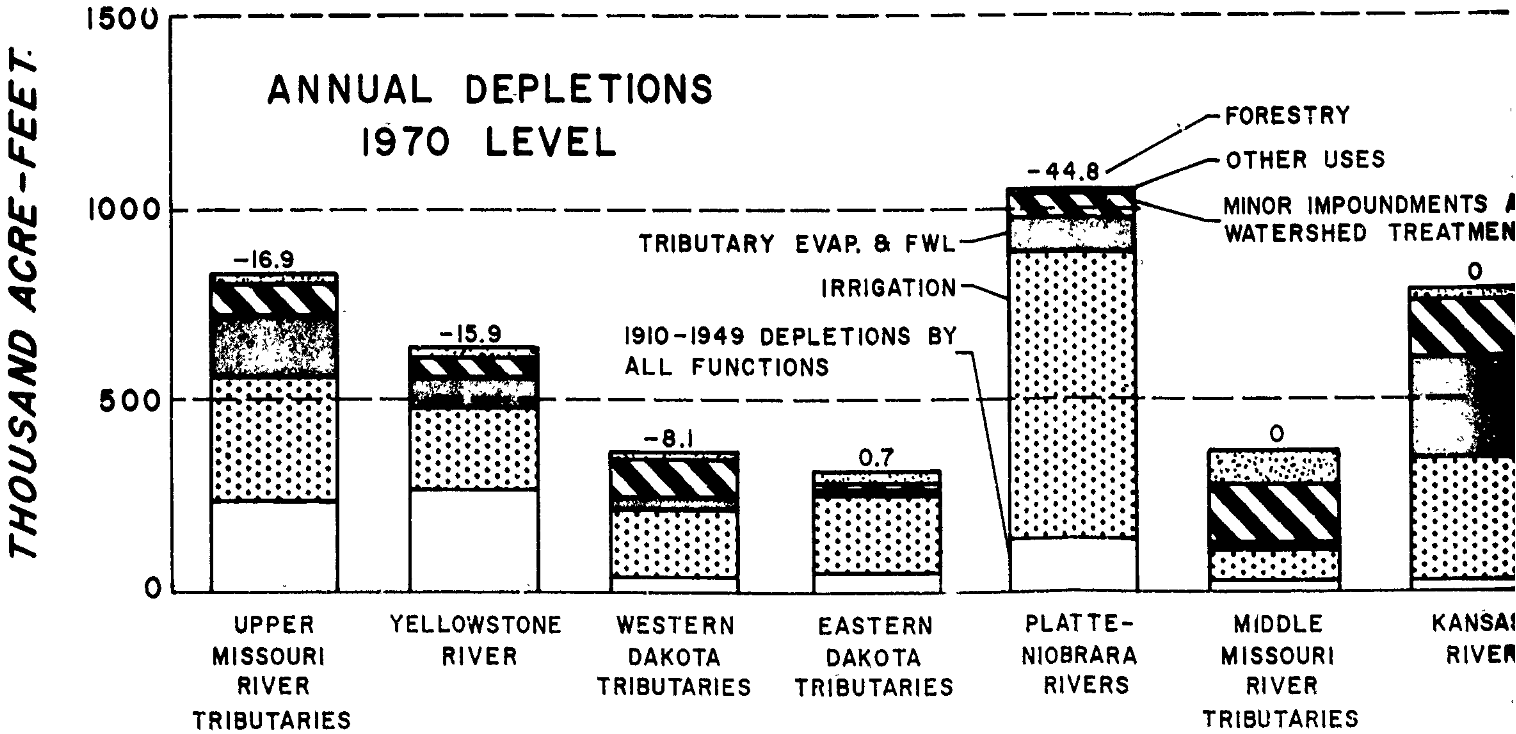
Although this curve may not be strictly applicable to any particular reservoir it is adequate for determining reservoir evaporation in framework planning studies. Evaporation estimates were based on USWB Technical Paper No. 37, "Evaporation Maps for the United States," by Kohler, Nordinson and Baker, 1959, modified as described in chapter 4 to recognize average monthly precipitation on the reservoir surface and average monthly runoff from the land area covered by the reservoir.

A 100-year sediment storage allowance was provided in each reservoir and was assumed to form a dead-storage pool. These sediment allowances were determined from generalized relations developed essentially as discussed in chapter 5 of this appendix.

The computer program which utilized these physical data took the computed monthly inflows and ran a sequential monthly reservoir regulation study for the 40-year base period to determine the storage required to meet the specified monthly water quality control and water supply demands under specified shortage conditions. Shortage index criteria proposed by L. R. Beard in the publication, "Estimating Long-Term Requirements and Firm Yield of Rivers," were adopted. Beard's shortage index is defined as the sum of squares of the annual shortages expressed as a ratio to the annual demand, converted to a 100-year base. A shortage index of 0.25 was adopted for these studies. This index represents one annual shortage of 50 percent in a 100-year period, 25 annual shortages of 10 percent, or

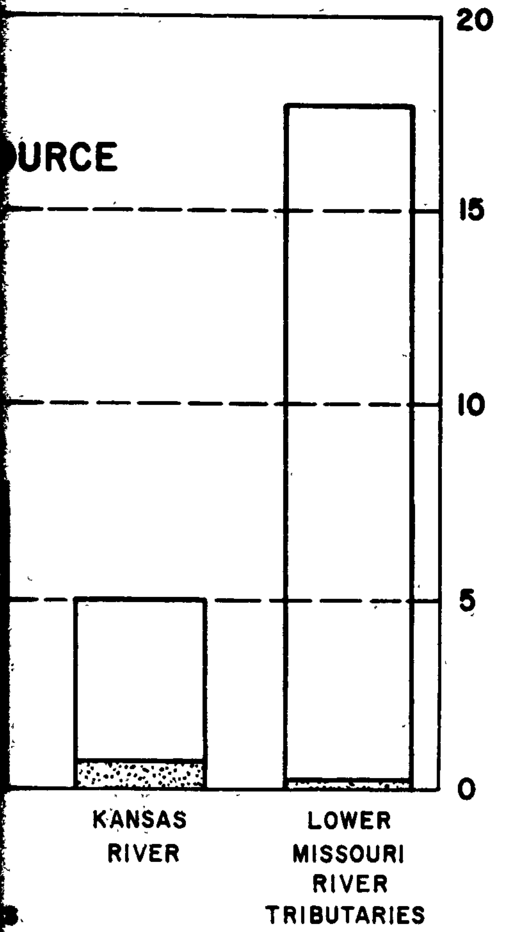


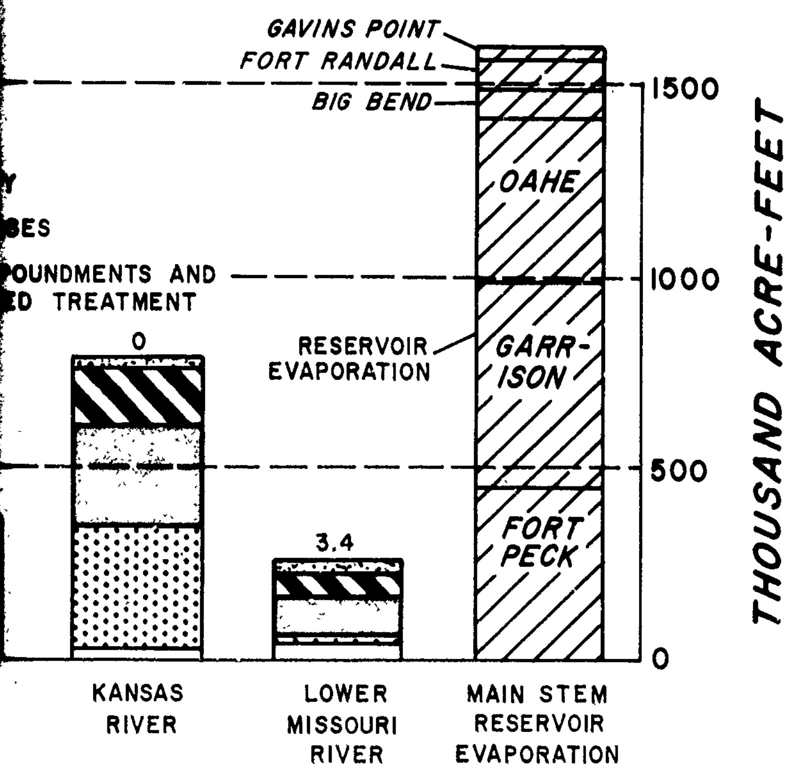
1970 LEVEL ANNUAL STREAMFLOW DEPLETION
1970 LEVEL REMAINING SURFACE WATER RESOURCE
NOTE: EXCLUSIVE OF MAIN STEM RESERVOIR EVAPORATION
MILLION ACRE-FEET
20
15
10
5
0
UPPER MISSOURI RIVER TRIBUTARIES
YELLOWSTONE RIVER
WESTERN DAKOTA TRIBUTARIES
EASTERN DAKOTA TRIBUTARIES
PLATTE-NIOBRARA RIVERS
MIDDLE MISSOURI RIVER TRIBUTARIES
KANSAS RIVER



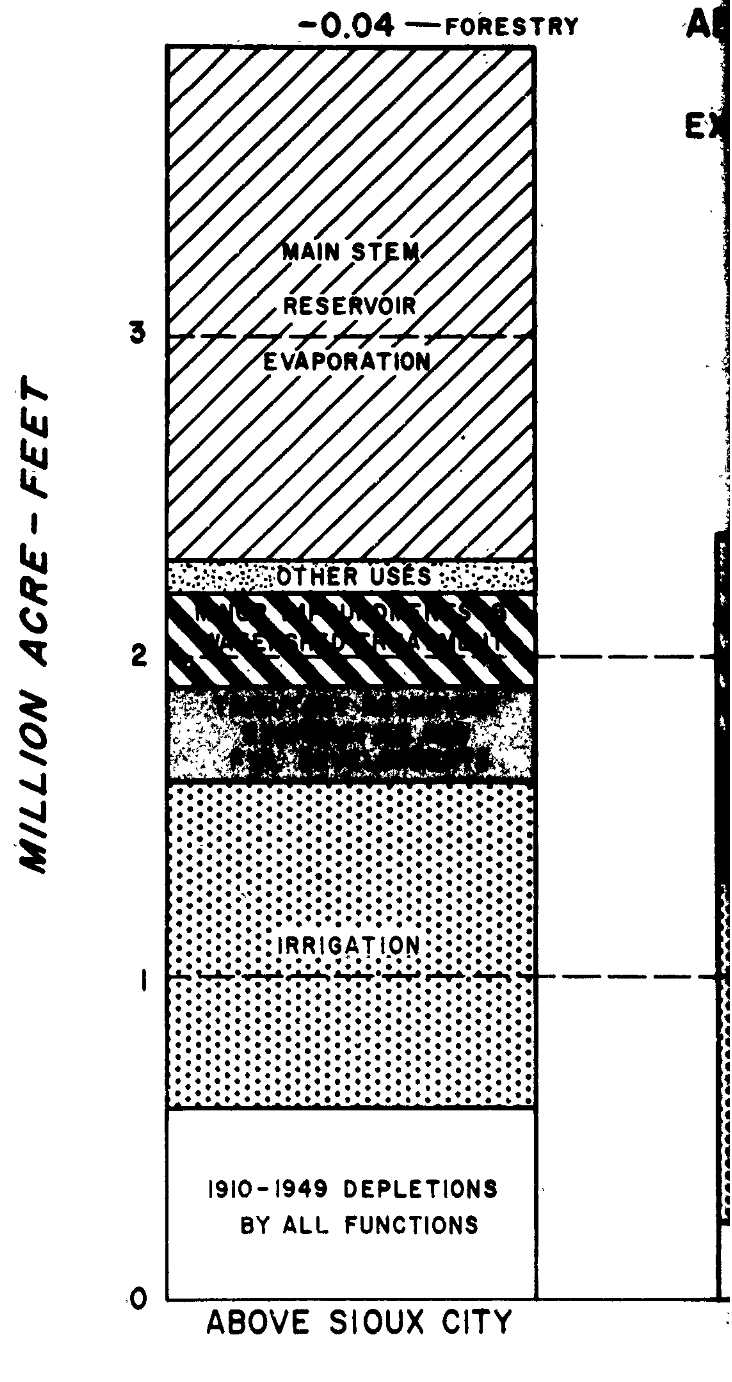
ANNUAL DEPLETIONS
1970 LEVEL
THOUSAND ACRE-FEET
1500
1000
500
0
FORESTRY
OTHER USES
MINOR IMPOUNDMENTS
WATERSHED TREATMEN
TRIBUTARY EVAP. & FWL
IRRIGATION
1910-1949 DEPLETIONS BY ALL FUNCTIONS
-16.9
-15.9
-8.1
0.7
-44.8
0
0
UPPER MISSOURI RIVER TRIBUTARIES
YELLOWSTONE RIVER
WESTERN DAKOTA TRIBUTARIES
EASTERN DAKOTA TRIBUTARIES
PLATTE-NIOBRARA RIVERS
MIDDLE MISSOURI RIVER TRIBUTARIES
KANSAS RIVER

URCE



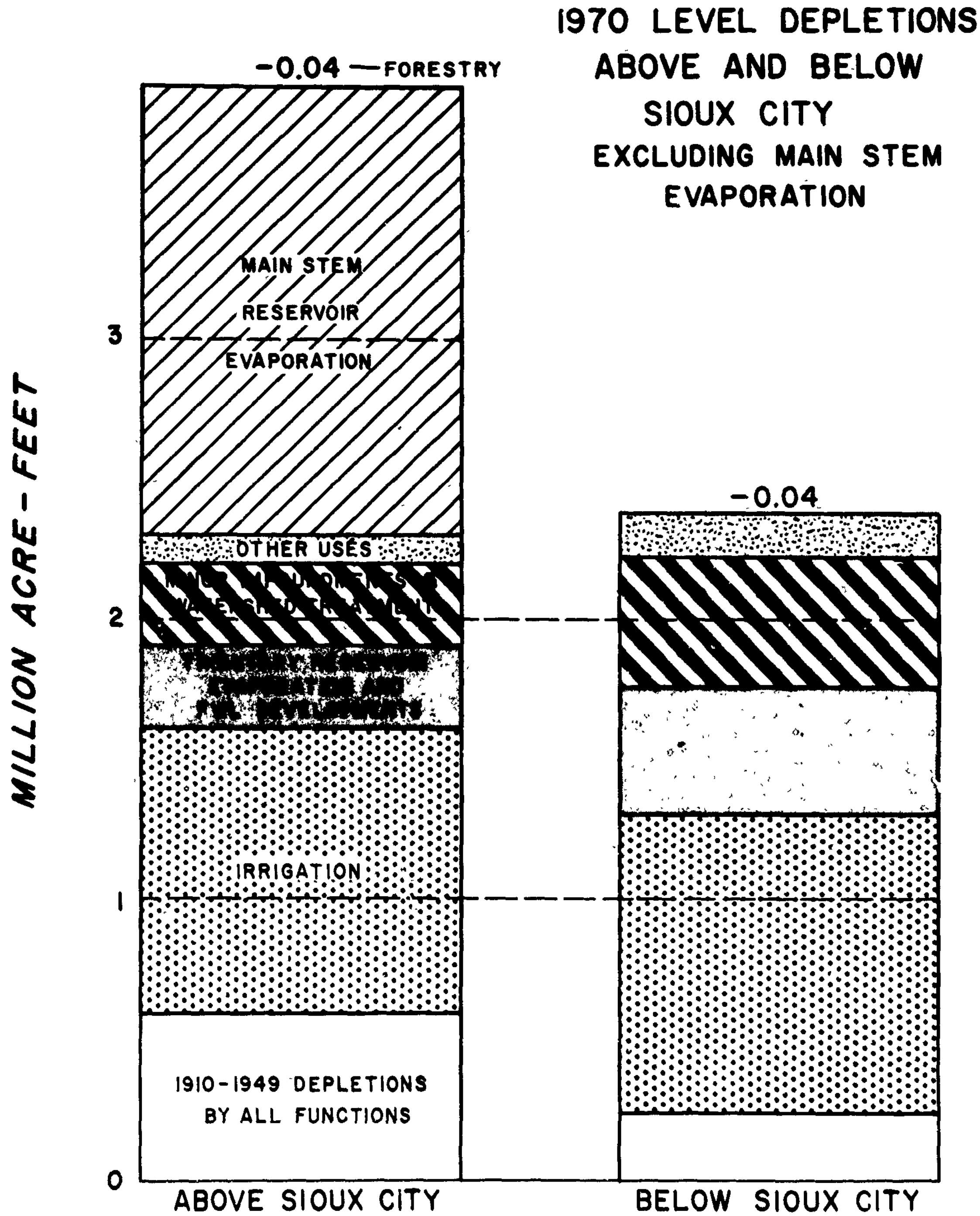


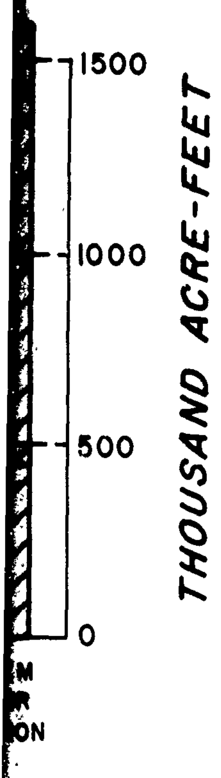
1970
A
EX



POST 1910 ANNUAL STREA
AND REMAINING SURFACE
FOR 1970 LEVEL OF D

COMPREHENSIVE FRAME
MISSOURI RIVE





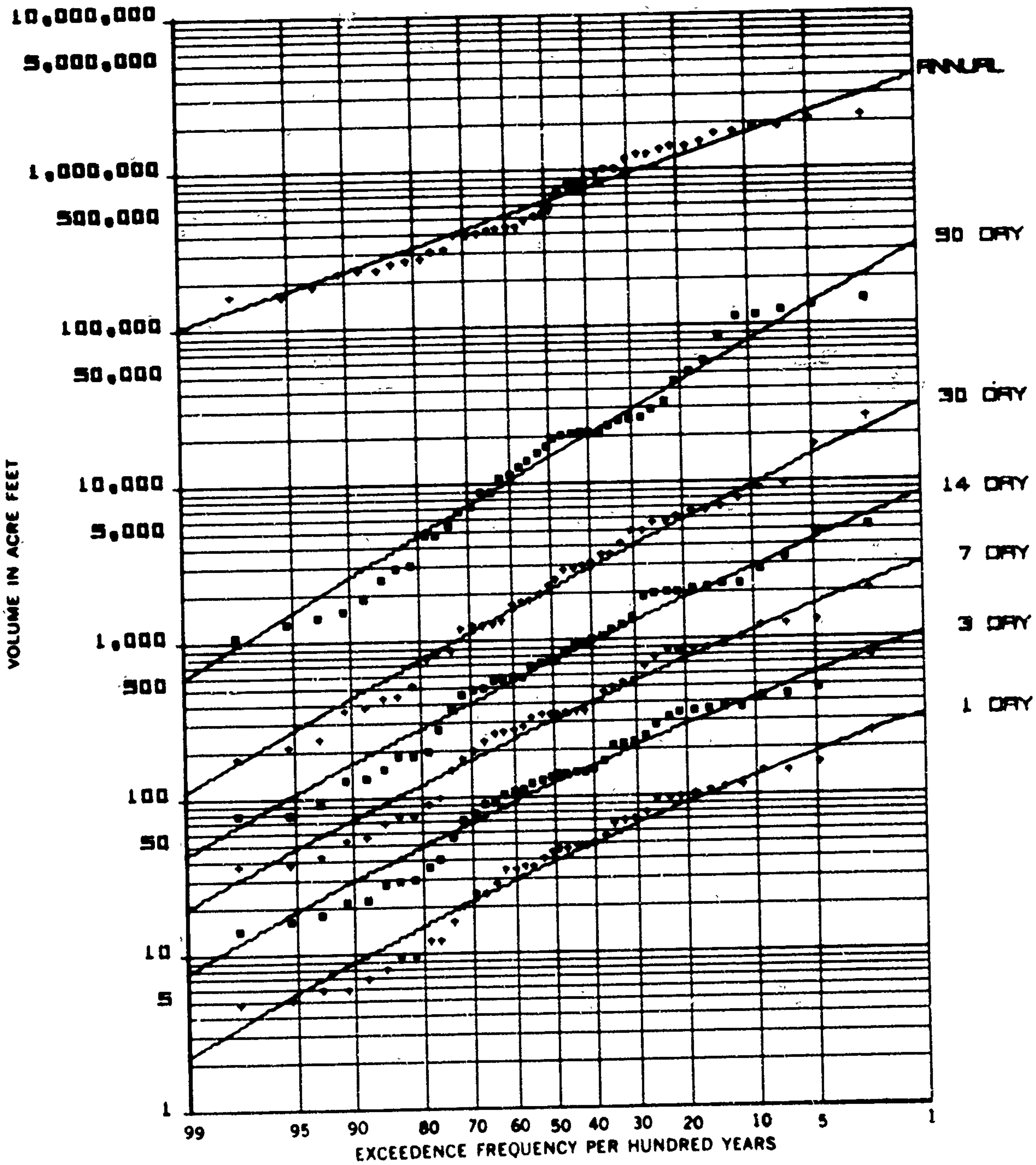
POST 1910 ANNUAL STREAMFLOW DEPLETIONS AND REMAINING SURFACE WATER RESOURCE, FOR 1970 LEVEL OF DEVELOPMENT

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

FIGURE 34
LOW-FLOW VOLUME-FREQUENCY CURVES



GRAND RIVER NR GALLATIN, MO.

1921-1962 06-8975.00

any combination of annual shortages for which the sum of squares of the shortages totaled 0.25 in 100 years or 0.10 in the 40-year base period used. If only water supply demands or only water quality control demands existed at a given location the computer recycled as necessary to determine the storage required to meet the 0.25 shortage index criteria. If demands for both purposes existed, the computer program gave priority to water supply demands, then determined the storage necessary to meet water quality control demands with a 0.25 shortage index. If in this computation the water supply shortage index was equal to or less than 0.25 the storage indicated was considered acceptable and the computer proceeded to the next station. If the water supply shortage index exceeded 0.25 the computer recycled adding storage as necessary to lower the shortage index for water supply demands to 0.25. This sometimes resulted in lowering the shortage index for water quality control to less than 0.25 and, therefore, future refinements in the program are indicated to be desirable. These probably will use a buffer zone concept to compute storages required to meet the desired shortage index for each function. However, the studies accomplished are believed to be satisfactory for framework planning particularly since the problem of a shortage index for water quality control or water supply of less than 0.25 occurred at only a half dozen or so stations.

Results of the computer study are summarized in table 14. Locations where the computer study indicated the demand could be met by the natural streamflow without regulation have been omitted from this table.

HISTORIC STREAMFLOW ADJUSTED FOR 1970 DEVELOPMENT

Prior to 1865, streamflow in the Missouri Basin was largely unused except for transportation by water. At about that time, the early settlers and homesteaders, their numbers swollen by uprooted Civil War survivors, started irrigation and mining ventures and began filing for water-use permits in substantial numbers. Some additional irrigation development was induced by establishment of Indian reservations.

By 1898, streamflow depletions in the Missouri Basin averaged about 3 million acre-feet annually. By 1910, they averaged about 5.6 million acre-feet annually. Between 1910 and 1949, water use increased at a slower rate, with depletions reaching an average annual level of 6.9 million acre-feet in 1949. Since 1949, with accelerated Federal water resources development, water use has increased much more rapidly. It is estimated that, during the period from 1949 to 1970, depletions will have increased by 4.9 million acre-feet, on an average annual basis.

Streamflow records, of course, reflect the constantly changing levels of water resources development and streamflow depletion. To be useful as an accurate measure of surface water-supply availability, historic streamflow data must be adjusted to a common level of water resources development and water use and a corresponding common level of streamflow depletion. Accordingly, available streamflow data have been adjusted to the level of water-resources development that it is anticipated will be reached by 1970 and the level of streamflow depletion that it is estimated will be reached at that level of development. Year 1970 conditions were selected for this purpose because the level of water resources development in 1970 could be anticipated with reasonable accuracy at the time these studies were initiated in 1964, and because it was considered desirable to have the estimates of water availability current at the time the comprehensive framework studies were scheduled to be completed.

Assumed 1970 Level of Water Resources Development

Water resources development projects originally assumed to be in operation in 1970 included all projects existing at the time these studies were initiated in 1964, all projects under construction at that time, and those additional projects which the constructing agency then anticipated would be funded for construction by 1970. Major reservoirs in this category, and their approximate total storage capacity, are:

Chatfield Reservoir, Colorado	235,000 acre-feet;
Clinton Reservoir, Kansas	397,200 acre-feet;
Grove Reservoir, Kansas	157,000 acre-feet;
Round Mound Reservoir, Kansas	176,000 acre-feet;
Rathbun Reservoir, Iowa	551,700 acre-feet;
Melvern Reservoir, Kansas	363,000 acre-feet;
Fort Scott Reservoir, Kansas	235,500 acre-feet;
Stockton Reservoir, Missouri	1,674,000 acre-feet;
Kaysinger Bluff Reservoir, Missouri	5,209,000 acre-feet;

Additional smaller reservoirs and small irrigation projects also fall into this same category, but only those with the more significant regulation or depletion effects have been listed. All of the major water resources development projects included in the assumed 1970 level of development are listed in table 15.

Table 14 – RESERVOIR STORAGE REQUIREMENTS FOR WATER QUALITY AND M&I DEMANDS

Name of Town With Demand	Name of Stream	Drainage Area: Between Damsite and Town Sq. Mi.	Drainage Area: At Potential Damsite Sq. Mi.	100-Yr. Sediment Storage in AF	Maximum Monthly Water Quality Demand CFS	Maximum Monthly Surface M&I Demand CFS	Average Annual Inflow at Potential Damsite 1927-1966 CFS	Active Conservation Storage AF	Average Annual Evaporation 1927-1966 AF	Shortage Index: Water Quality	Shortage Index: M&I Water Supply	Water Quality: Number of Years With Shortages 1927-1966	Water Quality: Number of Months With Shortages 1927-1966
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Upper Missouri													
White Sulphur Springs, Mont.	S. Fork Smith R.	0	200	2,000	1.86	0.82	262.10	140	277	0.260	0.062	5	8
Harlowton, Mont.	Musselshell R.	995	130	3,900	2.12		12.83	560	505	0.241		5	13
Roundup, Mont.	Musselshell R.	0	4023	120,000	4.10		79.53	10,930	11,602	0.249		3	5
Big Sandy, Mont.	Big Sandy Creek	37	68	680	1.14		2.82	1,810	356	0.254		3	10
Havre, Mont.	Milk River	1856	985	19,800	74.73	3.47	16.52	2,960	2,773	0.041	0.262	5	11
Havre, Mont.	Milk River	1466	1378	27,560	74.73	3.47	89.55	1,900	3,495	0.047	0.250	5	12
Chinook, Mont.	Milk River	0	9656	193,120	2.85	1.84				0.107	0.013	4	7
Harlem, Mont.	Thirty Mile Creek	0	675	13,500	1.41	0.56	28.19	5,470	2,241	0.146	0.255	2	6
Helena, Mont.	Ten Mile Creek	0	102	1,020	36.38	9.15	229.36	[illegible]	530	0.249	0.013	11	24
Browning, Mont.	Cutbank Creek	0	30	300	2.95		13.37	450	165	0.251		3	8
Circle, Mont.	Redwater River	367	180	9,000	1.24		4.90	5,190	1,656	0.247		5	13
Scobey, Mont.	Poplar River	1500	144	7,200	2.10		6.00	560	1,114	0.251		12	25
Poplar, Mont.	Poplar River	3030	144	7,200	1.92		6.00	680	1,154	0.259		11	19
Plentywood, Mont.	Big Muddy Creek	1200	288	14,400	2.58		12.00	1,730	1,993	0.253		11	27
Yellowstone													
Alexander, N.D.	Lonesome Creek	0	15	300	0.33		1.04	180	105	[illegible]		4	12
Lander, Wyo.	Popo Agie	0	89	1,335	5.91	3.01	32.16	255	415	0.244	0.000	5	3
Pavillion, Wyo.	Pavillion	0	1	50	0.26		0.43	13	32	0.319		10	20
Shoshoni, Wyo.	Poison Creek	0	500	10,000	1.05		28.90	1,470	2,044	0.245		11	23
Tensleep, Wyo.	Tensleep Creek	0	153	2,470	0.43		19.05	160	636	0.262		5	13
Frannie, Wyo.	Sage Creek	0	200	12,000	0.23		16.02	910	2,261	0.253		5	12
Deaver, Wyo.	Polecat Creek	0	15	900	0.17		1.72	150	299	0.266		7	15
Cowley, Wyo.	Sage Creek	0	220	1,200	7.44	4.90	23.93	2,870	602	0.251	0.157	8	15
Acme, Wyo.	Goose Creek	0	405	6,690	85.55	36.90	179.30	14,690	3,006	0.251	0.000	5	11
Edgerton, Wyo.	Salt Creek	0	300	27,000	0.60		17.34	5,210	4,513	0.257		4	[illegible]
Midwest, Wyo.	Salt Creek	0	300	27,000	1.04		17.34	5,940	4,832	0.255		4	10
Linch, Wyo.[4]	Meadow Creek	0	40	2,000	0.71		2.31	3,540	753	0.254		3	8
Buffalo, Wyo.	Clear Creek	0	120	2,400	3.70	1.02	49.38	330	656	0.253	0.066	5	15
Baker, Mont.	Sandstone Creek	0	40	800	3.46		4.63	2,360	433	0.249		4	12
Plevna, Mont.	Sandstone Creek	0	140	2,000	0.39		14.57	330	401	0.229		6	14
Western Dakota 3													
Ekalaka, Mont.	L. Beaver Creek	4	20	600	0.88		1.12	1,530	245	0.247		2	5
Wibaux, Mont.	Beaver Creek	52	300	12,000	0.91		16.93	2,770	1,436	0.231		2	7
Watford City, N.D.	Cherry Creek	12	150	4,500	2.26		6.80	1,690	691	0.247		6	16
Arnegard, N.D.	Timber Creek	0	10	100	0.32		0.39	550	90	0.260		2	7
Keene, N.D.	Tobacco Gardon Creek	0	10	400	0.14		0.33	260	125	0.234		2	7
Kildeer, N.D.	Spring Creek	4	20	400	0.41		1.44	130	95	0.295		8	22
Hebron, N.D.	Br. of Knife River	0	40	1,200	1.59		2.59	1,700	343	0.246		4	10
Center, N.D.	Sq. Butte Creek	0	50	1,500	0.57		3.23	420	268	0.253		5	14
Belfield, N.D.	Heart River	4	20	400	1.27		1.96	950	174	0.263		2	3
Dickinson, N.D.	Heart River	20	380	15,200	16.35	4.94	37.57	18,420	2,568	0.147	0.242	3	7
New England, N.D.	Cannonball River	0	200	4,000	1.30		11.98	540	564	0.245		7	23
Flasher, N.D.	Louise Creek	6	90	3,600	0.62		3.50	920	547	0.231		6	14
Scranton, N.D.	Buffalo Creek	1	20	400	0.42		1.40	510	135	0.253		5	15
Hettinger, N.D.[4]	Flat Creek	0	32	640	2.24		2.00	10,040	626	0.250		3	11
McLaughlin, S.D.	Oak Creek	0	90	3,600	1.16		4.07	1,330	578	0.249		7	18
Buffalo, S.D.	S.F. Grand River	0	148	2,960	0.77		6.26	230	429	0.236		7	17
Bison, S.D.	Thunder Butte Creek	0	40	1,200	0.45		1.94	1,630	401	0.249		2	7
Edgemont, S.D.	Cheyenne River	45	1,500	45,000	3.04		45.69	8,450	5,305	0.247		2	5
Gregory, S.D.	Ponca Creek	0	50	1,500	2.55		3.60	1,600	442	0.250		4	13
Belle Fourche, S.D.	Belle Fourche River	0	3,300	99,000	8.12		77.71	13,910	9,783	0.248		1	5
Eastern Dakota													
Napoleon, N.D.	Unnamed	0	12	125	1.69		3.51	6,585	490	0.254		2	7
Wishek, N.D.	S. Br. Beaver Creek	0	32	320	2.01		4.61	7,410	559	0.251		2	7
Linton, N.D.	Beaver Creek	117	500	20,000	3.14		177.74	1,850	1,658	0.247		7	18
Herreid, S.D.	Spring Creek	270	70	2,800	0.97		24.80	410	349	0.247		9	22
Selby, S.D.	Unnamed	0	22	645	1.24		6.14	1,695	234	0.245		2	7
Platte, S.D.	Platte Creek	0	260	10,400	1.83		15.86	5,080	1,191	0.255		2	7
Lake Andes, S.D.	Unnamed	174	42	840	1.72		2.55	2,610	323	0.247		2	7
Wagner, S.D.	Choteau Creek	0	404	8,080	2.48		30.11	4,240	390	0.246		2	7
Fessenden, N.D.	Unnamed	4	162	1,620	1.16		3.93	5,940	603	0.253		2	6
New Rockford, N.D.	James River	150	360	3,600	3.39		8.79	12,210	1,114	0.250		2	6
New Rockford, N.D.	James River	348	162	1,620	3.39		3.93	15,320	1,028	0.245		2	6
Jamestown, N.D.[4]	James River	1000	1600	16,000	34.56		39.19	152,850	6,951	0.243		2	7
LaMoure, N.D.	James River	2200	192	3,840	1.66		4.72	760	457	0.250		6	12
Edgely, N.D.[4]	Maple Creek	0	72	720	1.25		1.56	6,620	496	0.248		2	7
Britton, S.D.[4]	Unnamed	0	56	560	2.24		1.20	35,220	844	0.240		2	7
Groton, S.D.	Unnamed	10	225	2,280	1.65		4.93	3,530	504	0.245		2	7
Redfield, S.D.	Turtle Creek	0	1540	30,800	6.52		16.22	36,630	3,721	0.250		2	7
Woonsocket, S.D.[4]	Unnamed Canal	13	20	200	1.30		0.95	6,670	393	0.252		2	7
Menno, S.D.[4]	Unnamed	0	9	90	1.05		0.92	5,580	327	0.252		2	7
Scotland, S.D.	Dawson Creek	36	45	450	1.69		6.09	1,900	233	0.256		2	7
Howard, S.D.	W.F. Vermillion R.	10	85	850	1.98		2.06	2,170	269	0.247		2	7
Salem, S.D.	W.F. Vermillion R.	70	80	800	1.95		7.23	330	151	0.236		10	24
Marion, S.D.	W.F. Vermillion R.	270	80	1,600	1.11		7.23	150	210	0.269		9	20
Lennox, S.D.	Long Creek	0	66	665	2.21		8.10	745	165	0.260		5	13
Centerville, S.D.	Vermillion River	100	1400	42,000	1.17		128.09	1,730	3,013	0.250		[illegible]	9
Viborg, S.D.	Frog Creek	0	15	350	0.93		2.15	430	107	0.268		2	7
Vermillion, S.D.	Vermillion River	280	1400	42,000	11.32		85.36	4,510	3,143	0.252		6	19
Watertown, S.D.	Big Sioux River	120	510	10,200	23.03	4.86	61.00	16,030	1,749	0.248	0.000	7	13
Clear Lake, S.D.	Hidewood Creek	37	48	490	1.86		11.48	820	156	0.245		4	11
Fateline, S.D.	Big Sioux River	2000	180	3,600	0.96		39.70	530	499	0.232		2	7
Volga, S.D.	Unnamed	0	36	720	0.94		4.50	293	134	0.234		5	14
Brookings, S.D.	Six Mile Creek	2250	126	2,550	19.63		27.44	1,310	402	0.243		5	14
Flandreau, S.D.	Big Sioux River	2500	128	6,375	3.83		27.44	135	621	0.252		3	6
Dell Rapids, S.D.	Big Sioux River	3000	128	6,375	3.73		22.42	165	623	0.243		2	1
Colton, S.D.	Unnamed	0	15	450	0.96		1.32	1,865	210	0.256		2	4
Hartford, S.D.	Unnamed	0	23	340	1.11		2.45	1,170	215	0.252		2	7
Jasper, Ia.	Split Rock Creek	60	16	480	1.09		2.28	60	32	0.262		5	20
Canton, S.D.	Big Sioux River	0	4100	287,000	4.67		652.35	7,000	14,470	0.247		4	8
Luverne, S.D.	Rock River	140	55	1,650	4.90		7.41	150	216	0.247		8	21
Adrian, S.D.	Kanaranzi Creek	0	60	1,800	2.00		8.27	355	246	0.240		5	18
Hills, Minn.	Mud Creek	0	21	1,350	0.93		3.71	223	193	0.260		7	19
Beresford, S.D.	W. Brule Creek	0	95	4,750	2.94		17.56	2,630	640	0.253		4	32
Parshall, N.D.	E. Fk. Shell Creek	17	71	1,420	1.70		2.72	250	226	0.251		4	22
Powers Lake, N.D.	White Earth Creek	40	12	120	0.80		0.46	240	43	0.248		9	26
Platte-Niobrara													
Hartville, Wyo.[4]	Unnamed	0	4	120	0.28		0.29	61,290	1,590	0.271		1	5
Laramie, Wyo.	Laramie River	700	371	7,420	23.42	5.69	75.86	4,310	1,335	0.252	[illegible]	1	15
Wheatland, Wyo.	Wheatland Creek	55	500	15,000	3.27		11.55	12,760	[illegible]	0.243		2	7
Chugwater, Wyo.	Chugwater Creek	80	300	9,000	0.45		10.37	1,020	1,300	0.244		2	[illegible]
Dalton, Nebr.	Deep Holes Creek	0	1	35	0.54		[illegible]	890	[illegible]	0.271		1	27
Longview, Colo.[4]	Unnamed	0	4	45	0.83	0.23	0.71	11,770	377	0.243	0.055	4	31
Buffalo Creek, Colo.	Buffalo Creek	4	32	320	10.29		3.47	4,390	145	0.243		[illegible]	[illegible]
Englewood, Colo.	S. Platte	401	3018	60,360	117.15	52.40	193.1[illegible]	144,17[illegible]	[illegible]	[illegible]	0.311	[illegible]	[illegible]
Golden, Colo.	Clear Creek	0	414	4,140	131.66	[illegible]	216.41	20,360	[illegible]	[illegible]	[illegible]	[illegible]	7
Arvada, Colo.	Clear Creek	0	520	5,200	67.50	[illegible]	[illegible]	4,395	[illegible]	[illegible]	[illegible]	[illegible]	4
Louisville, Colo.	Unnamed	6	45	450	2.83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 14 (Continued)

Name of Town With Demand	Name of Stream	Drainage Area: Between Damsite and Town Sq. Mi.	Drainage Area: At Potential Damsite Sq. Mi.	100-Yr. Sediment Storage in AF	Maximum Monthly Water Quality Demand[1] CFS	Maximum Monthly Surface M&I Demand[2] CFS	Average Annual Inflow at Potential Damsite 1927-1966 CFS	Active Conservation Storage AF	Average Annual Evaporation 1927-1966 AF	Shortage Index: Water Quality	Shortage Index: M&I Water Supply	Water Quality: Number of Years With Shortages 1927-1966	Water Quality: Number of Months With Shortages 1927-1966
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Platte-Niobrara (Cont'd)													
Fimball, Nebr.[4]	Lodge Pole Creek	15	1,464	29,280	8.45		6.83	661,330	17,598	0.250		1	5
Ogallala, Nebr.	So. Platte	19,784	3,640	36,400	145.01	29.40	279.53	24,230	5,617	0.252	0.000	7	21
Grand Island, Nebr	No. Channel Platte	40,852	18,649	559,440	352.48		649.64	64,280	39,705	0.250		2	8
Broken Bow, Nebr.	Mud Creek	10	70	2,100	4.53		6.27	5,860	1,262	0.250		2	11
Elgin, Nebr.[4]	N. Cedar Creek	2	20	600	0.99		1.33	50,690	1,666	0.247		2	6
Tilden, Nebr.[4]	Giles Creek	2	15	1,500	1.54		1.64	170,220	4,446	0.248		2	6
Wausa, Nebr.[4]	No. Fork Elkhorn	7	7	875	0.82		0.48	239,685	5,993	0.249		2	8
Humphrey, Nebr.[4]	Tracy Creek	2	8	1,120	0.85		0.52	315,210	7,834	0.249		2	8
Randolph, Nebr.[4]	Logan Creek	0	11	1,540	1.19		0.76	415,850	10,261	0.251		3	8
Wayne, Nebr.[4]	So. Logan Creek	52	78	16,380	7.33		6.43	135,900	5,800	0.249		2	6
Rushville, Nebr.	Rush Creek	0	25	500	1.25		2.45	110	142	0.240		3	7
Middle Missouri													
Papillion, Nebr.	West Papio Creek	67	16	3,800	3.16		4	310	329	0.254		4	7
Syracuse, Nebr.	L. Nemaha River	154	55	8,250	1.23		16	270	591	0.243		1	1
Pawnee City, Nebr.	Turkey Creek	126	45	11,250	1.31		15	1,040	786	0.256		2	9
Troy, Kansas	Peters Creek	0	6	2,100	1.02		3	970	244	0.254		4	12
Sheldon, Ia.	Floyd River	42	46	1,400	4.83		9	680	181	0.248		4	12
Sanborn, Ia.	L. Floyd River	3	15	500	1.25		4	120	69	0.255		9	22
Remsen, Ia.	Deep Creek	0	43	1,300	1.30		8	100	136	0.246		9	22
Hull & Sioux Center, Ia.	Unnamed	35	34	1,000	4.91		8	460	135	0.251		9	21
Lake Park, Ia.	Silver Creek	12	10	325	0.92	0.18	2	75	49	0.247		10	26
Iowa Great Lakes	Unnamed	46	24	750	6.15	1.63	6	1,110	153	0.250		13	30
So. Dist. Iowa Great Lakes	Unnamed	175	308	9,220	35.81		75	2,250	745	0.248		6	14
Ruthven, Ia.	Prairie Creek	0	5	200	1.16		1	300	52	0.244		6	16
Hartley, Ia.	Waterman Creek	0	24	750	4.00		6	810	133	0.253		9	24
Sutherland, Ia.[4]	Murray Creek	0	4	120	1.66		1	3,670	170	0.252		1	5
Primghar, Ia.	Dry Run Creek	0	6	180	1.09		1	260	47	0.257		9	20
Marcus, Ia.	W. Fk. L. Sioux	0	11	330	1.94		3	420	73	0.252		10	23
Odebolt, Ia.	Odebolt Creek	3	10	300	1.29		3	140	53	0.238		2	9
Denison, Ia.	Boyer & E. Boyer R.	183	328	98,400	173.95		102	110,230	7,009	0.251		5	17
Glenwood, Ia.	Keg Creek	73	108	54,000	32.00		37	7,040	2,995	0.248		3	11
Harlan, Ia.	W. Nishnabotna	251	143	42,900	37.65		53	1,640	2,350	0.249		9	21
Sidney, Ia.[4]	Unnamed	0	2	1,000	1.04		1	3,870	236	0.247		2	9
Audubon, Ia.[4]	Blue Grass Creek	0	13	2,000	7.32		5	14,230	720	0.250		2	11
Anita, Ia.	Turkey Creek	10	6	900	1.21		2	50	101	0.245		6	14
Griswold, Ia.	Baughmans Creek	0	12	3,600	1.41		5	590	330	0.249		2	5
Rockport, Mo.	Rock Creek	4	42	21,250	1.28		16	1,720	1,332	0.249		2	7
Mound City, Mo.	Davies Creek	0	11	5,500	1.22		5	620	449	0.253		2	8
Kansas (Big Blue Subdivision)													
Stromsburg, Nebr.	Prairie Creek	55	0	4,280	1.3		5.47	820	475	0.250		2	5
Osceola, Nebr.	Davis Creek	16	10	2,340	1.1		1.61	890	319	0.231		3	10
David City, Nebr.	No.Fk. Big Blue R.	103	12	6,800	2.8		10.27	870	668	0.252		4	9
Seward, Nebr.	Plum Creek	90	0	6,120	1.6		8.42	1,520	656	0.241		2	6
Aurora, Nebr.	Lincoln Creek	55	8	4,660	3.2		5.47	1,850	563	0.249		2	6
York, Nebr.	Beaver Creek	172	48	10,150	7.7		20.80	720	897	0.248		4	6
Ingleside, Nebr.	Pawnee Creek	16	3	1,600	2.4		2.17	620	232	0.248		2	8
Blue Hill, Nebr.	Dove Creek	4	0	585	0.8		0.68	935	140	0.251		4	13
Lawrence, Nebr.	Dry Creek	4	0	585	0.4		0.68	125	95	0.269		2	5
Greenleaf, Kans.[4]	Coon Creek	3	2	426	0.6		0.70	2,424	222	0.257		2	7
Barnes, Kans.	Camp Creek	7	1	826	0.3		1.65	874	176	0.237		2	6
Centralia, Kans.	Black Vermillion R.	3	7	426	0.8		0.84	924	141	0.251		2	8
Frankfort, Kans.	Little Timber Creek	14	0	1,430	0.6		4.10	550	215	0.257		3	9
Beattie, Kans.	Robidoux Creek	36	6	3,020	0.3		10.49	280	343	0.238		8	18
Lower Missouri													
Kearny, Mo.	Fishing River	0	50	3,440	1.3		29.08	600	378	0.261		5	12
Lawson, Mo.	Fishing River	0	70	4,820	1.8	0.5	40.72	960	502	0.256	0.1-9	5	12
Excelsior Springs[4], Mo.	Fishing River	0	20	1,380	14.9		11.63	124,160	2,645	0.250		5	13
Grain Valley, Mo.	Sni-A-Bar	0	60	4,140	1.0	0.2	33.71	1,090	160	0.205	0.174	1	3
Oak Grove, Mo	Sni-A-Bar	0	75	5,160	2.5	0.8	41.41	1,350	188	0.245	0.082	4	7
Mayview-Mines, Mo.	Tabo Creek	0	25	1,720	0.5	0.1	16.65	240	205	0.230	0.057	5	11
Mt. Ayr, Ia.	E. Fork Grand	0	60	12,400	2.1	0.6	24.69	1,830	1,039	0.251	0.134	1	4
Grant City, Mo.	Middle Fork Grand	0	50	10,350	1.0		22.83	1,350	887	0.250		4	[illegible]
Diagonal, Ia.	W. Fork Grand	0	80	16,600	0.5		34.41	1,390	1,269	0.246		2	6
Stanberry, Mo	Branch	0	40	8,250	1.7		18.11	1,350	786	0.248		3	7
Kellerton, Iowa	Lotts Creek	0	24	4,970	0.4		6.17	760	502	0.275		1	4
Maysville, Mo.	W. Fork Lost Creek	0	25	3,440	0.9	0.2	10.64	550	374	0.251	0.045	5	[illegible]
Ridgeway, Mo.	E. Fork Big Creek	0	50	6,900	0.5		25.26	740	631	0.251		3	7
Bethany, Mo.	Big Creek	0	400	55,000	4.0	1.2	200.21	4,530	3,492	0.248	0.246	3	6
Greenfield, Ia	Thompson River	0	30	6,200	2.8	0.4	14.54	450	566	0.257	0.012	8	21
Afton, Ia.	Twelve Mile	0	20	4,150	0.8	0.2	8.10	900	451	0.263	0.134	1	[illegible]
Leon, Ia.	Little River	0	30	10,300	2.4		15.43	2,110	925	0.251		1	4
Lathrop, Mo.	Little Platte	0	50	17,300	1.0		21.28	1,340	1,305	0.248		3	6
Cameron, Mo.	Shoal Creek	0	60	8,250	4.4	1.3	30.99	4,050	900	0.248	0.183	2	7
Milan, Mo	E. Locust Creek	0	40	5,520	2.0	0.6	25.19	1,190	562	0.244	0.136	3	8
Green City, Mo.	Yellow Creek	0	15	3,060	0.6	0.1	9.28	420	251	0.237	0.107	3	7
Sexton, Mo.	E. Fork Medicine	0	100	27,500	0.3		60.67	1,890	1,952	0.276		2	5
Meadville, Mo.	Parsons Creek	0	75	20,700	0.6		54.14	940	1,490	0.265		3	7
LaClede, Mo.	Turkey Creek	0	25	6,875	0.8		19.34	765	631	0.250		1	4
Bogard, Mo.	Big Creek	0	18	2,490	0.3	0.1	8.36	300	281	0.244	0.108	5	10
Chariton, Ia.	Chariton River	0	100	3,450	5.2	1.8	45.34	2,770	513	0.252	0.0[illegible]	1	4
Humeston, Ia.	Nine Mile Creek	0	12	415	0.8	0.2	8.33	815	132	0.250	0.134	1	4
Corydon, Ia.	Chariton River	0	100	3,450	2.1	0.6	45.34	1,180	421	0.255	0.095	1	5
Unionville, Mo.	N. Blackbird River	0	50	1,725	2.3	0.7	49.93	465	226	0.255	0.022	6	14
Bucklin, Mo.	Mussel Fork	0	150	5,175	4.7	0.2	83.71	495	500	0.248	0.011	8	17
LaPlata, Mo.	Long Branch	0	10	[illegible]	1.7	0.5	7.74	1,380	206	0.250	0.099	2	7
Ionia, Mo.	Flat Creek	0	14	385	0.3		9.02	85	22	0.244		5	9
Green Ridge, Mo.	Basin Fork	0	20	550	0.6		13.53	130	30	0.254		6	10
LaMonte, Mo.	Muddy Creek	0	100	2,750	1.8		81.18	320	108	0.246		7	9
Hughesville, Mo.	Heaths Creek	0	15	775	0.2		13.53	125	38	0.220		4	6
Leeton, Mo	Clear Creek	0	25	690	0.7		20.73	270	33	0.248		2	7
Kingsville, Mo.	S. Fork Blackwater	0	30	1,240	0.4		20.27	360	56	0.248		4	7
Holden, Mo.	Blackwater	0	50	2,070	4.5	1.3	34.78	4,280	175	0.252	0.000	1	[illegible]
Chilhowee, Mo.	E. Fk. Post Oak Creek	0	15	515	0.6		10.37	245	32	0.252		3	9
Warrensburg, Mo.	Blackwater	0	300	12,400	17.1		176.55	4,210	413	0.248		5	15
Higginsville, Mo	Davis Creek	0	75	3,880	0.3	1.1	47.53	750	145	0.250	0.113	3	6
Marshall, Mo	Salt Fork	0	200	13,800	3.7		122.22	1,600	385	0.250		5	9
Corder, Mo	Davis Creek	0	100	5,160	0.9	0.2	61.11	550	174	0.249	0.210	6	8
Alma, Mo	Davis Creek	0	100	5,160	0.7	0.2	61.11	540	174	0.246	0.210	6	8
Fayette, Mo.	Bonne Femme Creek	0	100		4.0	1.2	41.41	1,660	175	0.249	0.133	8	18
Bunceton, Mo	Petite Saline	0	30	825	1.0		19.35	135	41	0.240		13	17
New Bloomfield, Mo	Little Auxvasse Creek	0	20	825	1.0		15.02	85	40	0.261		7	9
Hallsville, Mo	Perche Creek	0	40	1,660	0.6		16.50	255	203	0.244		3	7
Allen, Kans	14 Mile Creek	0	20	1,660	0.2		7.96	1,870	425	0.262		2	6
Reading, Kans.	Duck Creek	0	40	3,300	0.3		17.40	2,200	620	0.252		2	6

Table 14 (Continued)

Name of Town with Demand (1)	Name of Stream (2)	Drainage Area Between Damsite and Town Sq. Mi. (3)	Drainage Area at Potential Damsite Sq. Mi. (4)	100-Yr. Sediment Storage in AF (5)	Maximum Monthly Water Quality Demand[1] CFS (6)	Maximum Monthly Surface M&I Demand[2] CFS (7)	Average Annual Inflow at Potential Damsite 1927-1966[3] CFS (8)	Active Conservation Storage AF (9)	Average Annual Evaporation 1927-1966[3] AF (10)	Shortage Index: Water Quality (11)	Shortage Index: M&I Water Suppl. (12)	Water Quality: Number of Years With Shortages 1927-1966 (13)	Water Quality: Number of Months With Shortages 1927-1966 (14)
Lower Missouri													
[illegible], Kans.	Salt Creek	0	65	[illegible]	[illegible]	1.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	6
[illegible], Kans.	110 Mile Creek	0	20	1,65[illegible]	[illegible]	[illegible]	7.91	3,3[illegible]	[illegible]	[illegible]	[illegible]	2	5
Harveyville, Kans.	Dragoon Creek	0	50	4,1[illegible]	0.3	0.1	22.40	2,670	735	0.240	0.107	2	5
Burlingame, Kans.	Dragoon Creek	0	150	12,450	0.6	2.0	67.50	7,230	1,[illegible]	[illegible]	0.197	2	6
Gardner, Kans.	Big Bull Creek	0	40	3,300	[illegible]	0.9	19.61	2,3[illegible]	[illegible]	[illegible]	[illegible]	4	9
Spring Hill, Kans.	Bull Creek	0	37	2,620	2.9	0.3	14.27	[illegible]	[illegible]	[illegible]	[illegible]	4	9
Blue Mound, Kans.	Little Osage	0	100	2,070	0.5	0.1	62.22	350	[illegible]	[illegible]	0.365	6	12
Moran, Kans.	Marmaton	0	20	415	1.0	0.3	142.34	[illegible]	32	[illegible]	[illegible]	12	21
[illegible], Kans.	James Basin	0	75	1,550	4.4		[illegible]	1,5[illegible]	[illegible]	[illegible]		9	21
[illegible], Mo.	Turnback Creek	0	40	830	2.4		35.09	[illegible]	[illegible]	[illegible]		7	14
Bolivar, Mo.	Pomme de Terre	0	250	5,150	3.9		117.33	[illegible]	[illegible]	[illegible]		6	12
Waverly, Kansas	Rock Creek	0	80	6,620	0.5		16.[illegible]	[illegible]	[illegible]	[illegible]		4	7
Williamsburg, Kans.	Tagua Creek	0	20	1,65[illegible]	0.4		6.55	715	310	[illegible]		3	6
Baldwin, Kans.	W. F. Davy Creek	0	25	2,070	4.3		3.57	14,200	1,230	[illegible]		2	6
Louisburg, Kans.	S. Wea Creek	0	25	1,035	1.2	0.2	8.57	2,995	[illegible]	[illegible]	[illegible]	2	5
Parker, Mo.	Sugar Creek	0	20	690	0.3	0.1	14.72	[illegible]	147	[illegible]	[illegible]	6	11
Mound City, Kans.	L. Sugar Creek	0	45	1,550	1.1	0.2	31.35	570	246	0.254	[illegible]	7	12
Butler, Mo.	Miami Creek	0	100	3,440	5.5	1.6	32.36	3,720	196	0.263	0.011	3	9
Hume, Mo	Duncan Creek	0	15	520	0.5		9.72	250	31	0.244		5	11
Liberal, Mo.	Dry Wood Creek	0	40	1,100	0.9		29.05	[illegible]	[illegible]	0.253		4	11
Arcadia, Kans	Cox Creek	0	40	1,100	0.7		27.05	320	[illegible]	[illegible]		4	11
Shelton, Mo.	Clear Creek Branch	0	10	275	0.6		6.41	305	[illegible]	[illegible]		3	11
Eldorado Springs, Mo.	Clear Creek	0	250	6,900	2.4		133.03	1,552	[illegible]	0.250		3	7
Appleton City, Mo.	Branch	0	35	955	3.4	0.9	22.43	2,9[illegible]	[illegible]	[illegible]	0.111	1	1
Humansville, Mo.	Brush Creek	0	20	415	2.2		9.73	1,015	52	0.252		3	10
Drexel, Mo.	N. Sugar Creek	0	30	1,240	[illegible]	0.2	12.74	[illegible]	[illegible]	[illegible]	[illegible]	2	7
Greenwood, Mo	Big Rock Creek	0	10	415	0.9	0.2	10.37	485	[illegible]	0.247	0.093	4	10
Pleasant Hill, Mo.	Big Creek	0	100	4,150	4.8	1.4	64.12	2,390	180	[illegible]	0.027	6	11
Blairstown, Mo.	Big Creek	0	400	16,500	0.4		249.73	1,630	440	0.249		4	6
Montrose Power, Mo.	Montrose Lake	0	175	7,250		82.5	114.03	[illegible],170	1,[illegible]63		[illegible]		
Montrose, Mo.	Bear Creek	0	10	415	1.2		10.37	495	37	0.240		5	14
Windsor, Mo.	S. Fk. Tebo Creek	0	15	520	2.2		121.77	150	31	0.259		[illegible]	7
Cole Camp, Mo.	Cole Camp Creek	0	15	310	2.5		121.77	150	23	[illegible]		6	12
Marshfield, Mo	Branch	0	35	730	6.5		63.96	[illegible]	57	0.247		9	22
Linn, Mo.	Cedar Creek	0	20	410	0.4		11.26	72	23	[illegible]		7	23
Auxvasse, Mo.	Branch	0	15	[illegible]	1.0		7.05	330	124	[illegible]		6	23
Fulton, Mo.	Auxvasse Creek	0	200	8300	15.6		94.70	5,370	973	[illegible]		6	15
Martinsburg, Mo.	Loutre River	0	150	6,200	0.5		70.52	370	[illegible]	0.244		3	7
Mansfield, Mo.	Gasconade River	0	30	410	2.8		26.42	320	34	0.249		7	22

[1] Monthly distribution for Dec., Jan., and Feb. is 20% of values shown, for Mar., Apr., May, Sept., Oct., and Nov. 40%; and 100% for June, July, and Aug.
[2] Monthly distribution for June, July, and Aug. is 100% of values shown, and 74% for all other months.
[3] Average annual inflow at the potential damsite, average annual evaporation, and number of years and months of water quality shortages were based on the [illegible] year period 1927-1934 and 1939-1966, inclusive.
[4] Inflow insufficient to support reservoir storage listed.

Table 15 – MAJOR PHYSICAL DEVELOPMENTS CONSIDERED AT 1970 DEVELOPMENT LEVEL

Subbasin	Major Reservoirs Affecting 1970 Flows: Name	Agency	Capacity (Acre-feet)	Year of Closure	Major Irrigation Projects Assumed Depleting By 1970: Name	Agency	Acres	Remarks
Upper Missouri	Clark Canyon	BR	257,000	1964	East Bench	BR	49,800	
	Kennison	BR	9,000	Future	West Bench	BR	6,800	1
	Tiber	BR	1,368,000	1956	Lower Marias	BR	0^2	1
	Ruby	Mont.	39,000	1938	Ruby R. Stor. Proj.	MSWB	34,000	
	Willow Creek	Mont.	17,000	1938	W. Cr. Stor. Proj.	MSWB	3,500	
	Hyalite	Mont.	8,000	1950	Middle Creek	MSWB	2,700	
	Deadman's Basin	Mont.	57,000	1941	Deadman's B. Proj.	MSWB	15,000	
	Canyon Ferry	BR	2,051,000	1954	Helena Valley	BR	13,000	
					Crow Creek	BR	5,000	
	Fort Peck	CE	19,100,000	1937				
					Broadwater-Mo.	MSWB	7,100	
Yellowstone	Bull Lake	BR	152,000	1938	Riverton	BR	60,000	
	Boysen	BR	952,000	1951	Hanover-Bluff	BR	6,500	
	Anchor	BR	17,000	1960	Owl Creek	BR	13,000	1
	Yellowtail	BR	1,375,000	1965	Lower Yellowstone	BR	44,300	
	Lodge Grass	BIA	23,000	1942	Crow Irrig. Proj.	BIA	30,600	
					Shoshone	BR	80,000	
					Buffalo Rapids	BR	21,000	
	Tongue River	Mont.	68,000	1936				
Western Dakota	Bowman-Haley	CE	73,900	1966				
	Cold Brook	CE	7,200	1952				
	Cottonwood Springs	CE	8,340	1969				
	Dickinson	BR	6,700	1950	Dickinson Unit	BR	400	
	Heart Butte	BR	226,000	1949	Heart River Unit	BR	4,000	
	Shadehill	BR	357,000	1951	Shadehill	BR	0^2	1
	Keyhole	BR	340,000	1952	Belle Fourche	BR	57,100	
	Angostura	BR	160,000	1949	Angostura Unit	BR	12,000	
	Pactola	BR	99,000	1956	Rapid Valley	BR	8,900	
Eastern Dakota	Jamestown	BR	221,000	1953	Fort Clark Unit	BR	2,000	

Table 15 (Continued)

Subbasin	Major Reservoirs Affecting 1970 Flows: Name	Agency	Capacity (Acre-feet)	Year of Closure	Major Irrigation Projects Assumed Depleting By 1970: Name	Agency	Acres	Remarks
Platte River	Cherry Creek	CE	96,000	1948				
	Chatfield	CE	235,000	Future				
	Kortes	BR	4,800	1951				
	Glendo	BR	795,000	1958	Glendo Unit	BR	32,000	
	McConaughy	CNPPID	1,948,000	1941	Tri-County	CNPPID	126,800	
	Sherman	BR	68,000	1962	Farwell-Sargent	BR	67,300	
	Davis Creek	BR	30,300	Future				
					Kendrick	BR	24,300	
					Colo.-Big Thompson	BR	720,000	Transbasin import[3]
	Salt Creek Storages	CE	49,600	1962-67				
Niobrara	Box Butte	BR	31,000	1946	Mirage Flats	BR	11,300	
	Merritt	BR	74,000	1964	Ainsworth Unit	BR	34,000	
Middle Missouri	Indian Creek	CE	8,600	Future				
Kansas	Kanopolis	CE	432,900	1946				
	Harlan County	CE	840,500	1951	Franklin	BR	18,200	
					Superior Courtland	BR	9,800	
	Tuttle Creek	CE	2,367,000	1959				
	Wilson	CE	776,000	1964				
	Milford	CE	1,160,000	1966				
	Perry	CE	770,000	1966				
	Clinton	CE	397,200	Future				
	Grove	CE	157,000	Future				
	Bonny	BR	170,000	1951	Armel	BR	800	
	Swanson Lake	BR	254,000	1953	Meeker-Driftwood	BR	16,400	
	Enders	BR	75,000	1951	Frenchman	BR	21,100	
	Harry Strunk	BR	89,000	1949	Cambridge	BR	15,600	
	Hugh Butler	BR	87,000	1962	Red Willow	BR	11,200	
	Norton	BR	135,000	1964	Almena	BR	5,400	
	Lovewell	BR	92,000	1957	Courtland-Scandia	BR	62,000	
	Cedar Bluff	BR	377,000	1951	Cedar Bluff	BR	6,600	
	Round Mound	BR	176,000	Future	Ellis	BR	[4]	1
	Kirwin	BR	315,000	1955	Kirwin	BR	11,500	
	Webster	BR	261,000	1956	Webster	BR	8,500	
	Waconda Lake	BR	976,000	1968	Glen Elder	BR	0[2]	1
Lower Missouri	Rathbun	CE	551,700	1967				
	Melvern	CE	363,000	Future				
	Pomona	CE	246,500	1962				
	Fort Scott	CE	235,500	Future				
	Stockton	CE	1,674,000	1968				
	Kaysinger Bluff	CE	5,209,000	Future				
	Pomme de Terre	CE	648,700	1960				
Main Stem Missouri River	Garrison	CE	24,400,000	1953				
	Oahe	CE	23,600,000	1958				
	Big Bend	CE	1,900,000	1963				
	Fort Randall	CE	5,700,000	1952				
	Gavins Point	CE	540,000	1955				

Irrigated acres include both new developments and old lands receiving supplemental water supplies.
Privately developed irrigation acreage is not shown, but depletions were accounted for in 1970 flow tabulations.
Major reservoirs in operation for many years have not been included, such as Buffalo Bill in Wyoming and Lake of the [illegible] Missouri.

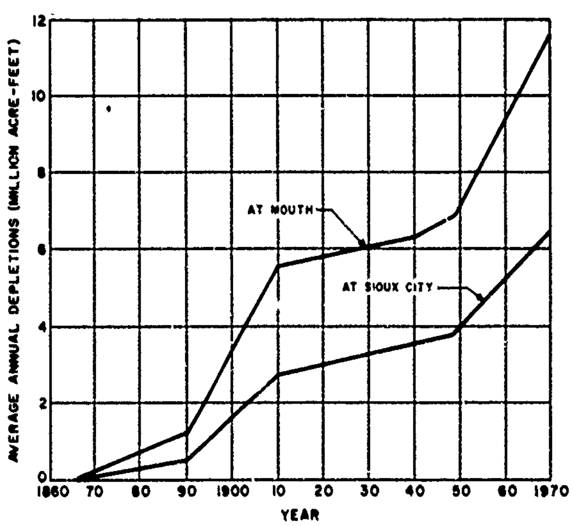
[1]No depletion before 1970.
[2]Irrigation acreage not firm but currently appears to be 72,700 on Lower Marias, 6,700 on Shadehill, and 21,[illegible]
[3]Other import projects are Moffat Tunnel, Roberts Tunnel, Grand River Ditch, Englewood, Homestake, [illegible] diverting 401,000 acre-feet from Colorado River Basin into the Denver area and 6,000 acre-feet into the [illegible] import averaging 135,000 acre-feet annually from St. Mary River to Milk River has been treated [illegible]
[4]M&I and Flood Control.

Streamflow Depletion, 1970 Development

Adequate information concerning both streamflow and water use are available only since 1910. Detailed studies of streamflow depletion, accordingly, were made for the period from 1910 to 1970. Streamflow depletion estimates were made for all types of water resources and related land resources development. Geographic distribution of the projects included in the assumed 1970 level of development necessitated individual depletion estimates in many of the smaller stream basins. The Missouri River subbasins, therefore, were divided into smaller areas, each comprising the area above some meaningful locality such as the mouth of a stream, a state boundary, or a major dam, and each relating to a specific streamgaging station. In all, some 110 smaller areas were analyzed. Together they comprise the entire Missouri River Basin.

As previously indicated, streamflow depletions in the Missouri River Basin in 1910 totaled 5.6 million acre-feet on an average annual basis. Depletions increased by 1.3 million acre-feet, on an average annual basis, during the period from 1910 to 1949, reaching a total of 6.9 million acre-feet. It is estimated that they will have increased by another 4.9 million acre-feet on an average annual basis by 1970, reaching a total of 11.7 million acre-feet. The historic growth of streamflow depletions in the basin, and the projected further growth to 1970, are illustrated by figure 35.

FIGURE 35
GROWTH OF STREAMFLOW DEPLETIONS



The increases in depletions during the period from 1910 to 1949 and during the period from 1949 to 1970, by subbasins and smaller stream basins and for selected locations along the main stem of the Missouri River, are summarized in table 16. Increased depletions during the period from 1910 to 1949, 1.3 million acre-feet, are broken down by geographical location only. Increased depletions during the period from 1949 to 1970, 4.9 million acre-feet, are broken down also by activities to which the increased depletions are attributable.

Plate 16 shows the increased depletions graphically, with the same breakdowns used in table 16 but in somewhat more detail with respect to the activities to which the depletions are attributable. Plate 16 shows also the surface water availability over and above the 1970 level of depletion.

The estimated increase of 4.9 million acre-feet in average annual depletions between 1949 and 1970 is due to the following activities:

Activity	*Millions of Acre-Feet*
Irrigation	2.1
Evaporation from Major Impoundments	1.8
Fish and Wildlife	0.1
Land Treatment	0.3
Minor Impoundments	0.4
Rural domestic water supply	0.1
Municipal and Industrial water supply	0.2
Forestry	0.1
TOTAL	4.9

The evaporation value in the preceding tabulation represents net evaporation from lakes and major reservoirs. On lakes and reservoirs that were in existence throughout the period of streamflow record, evaporation depletion was not estimated since streamflow records already reflect such evaporation.

Irrigation depletions were estimated in several ways. For almost all large irrigation projects, depletion estimates were readily extractable from available reservoir-operation and water-supply studies. For smaller projects for which such detailed studies were not available, depletion estimates were based on diversion requirements and return-flow allowances deemed applicable for the geographic area and irrigable area involved. For ground-water withdrawals from stream floodplain areas, net depletions were applied directly in the months pumping was accomplished. With withdrawals at some distance from a stream, where pumping affects only the stream base flow and only after considerable lag time, net annual depletions were applied to base flows by months uniformly throughout the year and were limited to the extent that base flows were available. With withdrawals remote from any stream, no streamflow depletions were charged since local aquifers rather than streamflow are depleted and, when the ground-water tables decline sufficiently, the aquifers will be lost as a source of water supply.

Table 16 – SUMMARY OF ESTIMATED AVERAGE ANNUAL DEPLETIONS IN THE MISSOURI BASIN

Area No.	Subbasin and General Area Description	Gaging Station[1]	Depletions: Total 1910 to 1970	Depletions: 1910 to 1949	Depletions: 1949 to 1970	1949 to 1970 by Function: Irrigation Farming	1949 to 1970 by Function: Large[2] Reservoir Evap.	1949 to 1970 by Function: Forestry[3] Practices	1949 to 1970 by Function: Watershed[4] Treatment and Ponds	Other Uses	Average Annual Flow After 1970
			(Thousand Acre-Feet)								
	UPPER MISSOURI										
1	Beaverhead River Basin	6-185	91.2	14.0	77.2	70.7	6.8	- 0.7	0.4		200
2	Ruby River Basin	6-230	40.6	40.9	- 0.3			- 0.3			130
3	Bighole River Basin	6-255	- 7.3		- 7.3			- 7.3			790
5	Jefferson River Valley Area	6-345	4.7		4.7	4.7					
6	Madison River Basin	6-410	- 1.6		- 1.6	7.6		- 9.4	0.2		1,170
7	Gallatin River Basin	6-525	24.1		24.1	28.0		- 4.3	0.4		650
9	Missouri Valley Area above Toston	6-545	70.1	45.0	25.1	25.1					
11	Smith and Dearborn Rivers Area		9.4	-25.0	34.4	23.0		10.0	1.4		
10	Sun River Basin	6-890	112.1	96.3	15.8	5.8	10.0	- 0.2	0.2		490
13	Marias-Teton River Basins	6-1095	135.7	34.0	101.7	53.7	40.0	- 1.1	9.1		
14	Arrow-Judith River Basins	6-1150	11.3		11.3	5.6		- 0.8	6.5		
15	Musselshell River Basin	6-1305	46.1	20.0	26.1	23.1		- 2.8	5.8		130
17	Missouri Valley Area to Fort Peck	6-1320	145.2	- 9.0	154.2	30.0	95.0		29.2		
	Evaporation from Fort Peck		441.0	441.0							
	Subtotal above Fort Peck Dam		1,122 6	657.2	465.4	277.3	151.8	-16.9	53.2		
35	Milk River Basin	6-1745	77.8		77.8	36.9	1.0		39.9		430
36	Poplar River Basin	6-1810	3.7		3.7	0.6			3.1		100
37	Missouri Valley Area to Williston	6-3300	40 2	16.0	24.2	12.0			12.2		
	Subtotal Fort Peck to Garrison		135.7	16.0	119.7	49.5	1.0		55.2	14.0	
	Total		1,258.3	673.2	585.1	326.8	152.8	-16.9	108 4	14.0[5]	7,276
	YELLOWSTONE										
18	Yellowstone River above Livingston	6-1925	6 8		6.8	8 0		- 1.3	0.1		2,500
19	Stillwater River Basin	6-2050	3.5		3.5	3.5					650
20	Clarks Fork River Basin	6-2085	4.3		4.3	4.7		- 1.8	1.4		720
21	Shields-Boulder-Rock Creek	6-2145	30.2	5.5	24.7	20.2		- 1.4	5.9		
22	Wind River Basin	6-2590	193.9	104.3	89.6	36.2	53.8	- 6.4	6.0		960
23	Greybull River Basin	6-2775	10.7	10 0	0.7			0.1	0 6		120
24	Bighorn Valley Area above Kane		28.1	0.3	27.8	21.3			6.5		
25	Shoshone River Basin	6-2850	112.9	36.2	76.7	76.3	0.9	- 1.6	1.1		510
26	Bighorn Valley Area to St. Xavier	6-2870	26.4		26.4		25.8	- 0.2	0.8		
28	Tongue River	6-3085	16.2	4.5	11.7	7.6	1.8	- 1.9	4.2		280
29	Yellowstone Valley to Miles City	6-3090	35.6	10.4	25.2	16.6		- 3.0	9.9	1.7	
30	Upper Powder River Basin	6-3170	13.4	3.5	9.9	3.0		- 0 6	7.5		185
31	Middle Powder River Basin	6-3245	4.3	1.2	3.1			1.1	2.0		
32	Lower Powder River Basin	6-3265	14.2	2.9	11.3	3.6		1.1	6.6		
33	Lower Yellowstone to Sidney	6-3295	105.1	80.3	24.8	12.1			12.7		
	Total		629.9	268.9	361.0	213.1	82.3	-15.9	65.3	16 2[6]	8,800
	WESTERN DAKOTA										
1	Little Missouri River Basin	6-3370	28.7	5.0	23.7	8.2		1.5	14.0		390
	Subtotal above Garrison Dam		28.7	5.0	23.7	8.2		1.5	14.0		
2	Knife River Basin	6-3405	5.2	0.9	4.3	1.9			2.4		110
3	Heart River Basin	6-3490	23.8	1.4	22.4	9.5	8.0	0.1	3.3	1.5	140
4	Cannonball River Basin	6-3540	9.4	1.2	8.2	4.2		0.1	3.9		140
5	Grand River Basin	6-3580	51.5	3.2	48.3	25.8	14.3	0.2	5.0	3.0	150
6	Moreau River Basin	6-3610	20.8	5.8	15.0	7.8			7.2		170
7	Upper Cheyenne River Basin	6-4015	75.8	4.2	71.6	47.4	9.7	0.1	14.4		40
8	Belle Fourche River Basin (Wyo.)	6-4285	1.8	0.4	1.4		7.0	-11.1	5.5		50
9	Lower Cheyenne Basin	6-4395	76.2	3.0	73.2	51.0	1.3		15.5	5.4	
	Subtotal Garrison to Oahe		264.5	20.1	244.4	147.6	40.3	-10.6	57.2	9.9	
10	Bad River Basin	6-4415	15.8	7.5	8.3	2.0		0.4	5.9		100
	Subtotal Oahe to Big Bend		15.8	7.5	8.3	2.0		0 4	5.9		
11	White River Basin	6-4520	56.5	14.3	42.2	19.4		0 6	22.2		
	Subtotal Big Bend to Ft. Randall		56.5	14.3	42.2	19.4		0.6	22.2		
	Total		365.5	46.9	318.6	177.2	40.3	- 8.1	99.3	9.9[7]	2,430
	EASTERN DAKOTA										
1	Missouri Valley Williston to Bismarck		78.5	9.4	69.1	54.0			4.7	10.4	
	Subtotal above Garrison Dam		68.1	9.4	58.7	54.0			4.7		
	Subtotal below Garrison Dam		10.4		10 4					10.4	
2	Missouri Valley Bismarck to Mobridge		16.7	6.3	10.4	5.1			3.2	2.1	
3	Missouri Valley Mobridge to Pierre		27.0	7.8	19.2	14.7			2.5	2.0	
	Subtotal Garrison to Oahe		54.1	14.1	40 0	19.8			5.7	14.5	
7	Missouri Valley Pierre to Sioux City		77.8	17.2	60 6	44.2		0.7	10.7	5.0	
	Subtotal of Oahe to Gavins Point			17.2	59.8	44.2		0 7	9.9	5.0	
4	James River Basin	6-4785	62.3	4 4	57.9	48.2	2.4		2.3	[illegible]	210
5	Vermillion River Basin	6-4790	12.3	0.6	11.7	10.2			0.5	1.0	80
6	Big Sioux River Basin	6-4855	40.9	3.6	37.3	27.0			2.9	7.4	580
	Total		315.5[9]	49.3	266.2	203.4	2.4	0.7	26.8	32.9[8]	3,235

[1] Location of gaging stations on plates 12 and 17.

[2] Includes IWL developments causing depletions during the period of record. They are generally insignificant, but exceptions are U-L Bend in Area 17 of Upper Missouri Subbasin and Area 1 of Eastern Dakota Subbasin associated with Garrison Diversion Unit. Neither is completed to date, but will evaporate 50 0 and 60.0 thousand A.F., respectively.

[3] Includes selective cutting, thinning, and management practices which increase runoff.

[4] Effects on all lands (Federal and private) from land treatment (contouring, terracing, drainage and water spreading), minor impoundments (farm ponds, dugouts, erosion control, fisheries, recreation ponds and small irrigation reservoirs of all agencies, groups and individuals), and upstream watershed structural measures.

[5] Rural domestic and livestock - 10.4 Mining – 0.1 M&I – 3.5

[6] Rural domestic and livestock - 7.5 Mining – 2.5 M&I - 4.5 Thermal power - 1.7

[7] Rural domestic and livestock 1.3 Mining – 1.4 M&I 7.2

[8] Rural domestic and livestock 22.5 Thermal power 10.4

[9] Evaporation from five main stem reservoirs in this reach will deplete another 1.1 million acre-feet.

Table 16 (Continued)

Area No.	Subbasin and General Area Description	Gaging Station	Depletions: Total 1910 to 1970	1910 to 1949	1949 to 1970	1949 to 1970 by Function: Irrigation Farming	Large[2] Reservoir Evap.	Forestry[3] Practices	Watershed[4] Treatment and Ponds	Other Uses	Average Annual Flow After 1970
			(Thousand Acre-Feet)								
	PLATTE-NIOBRARA										
1	North Platte Basin in Colorado	6-6200	21.9	1.2	20.7	18.4	3.3	- 1.3	0.3		250
2	Sweetwater-No. Platte above Alcova	6-6420	61.9	44.5	17.4	32.6	1.5	-21.3	3.4	1.2	
3	No. Platte-Wyo.-Alcova to Whalen	6-6570	34.0	3.0	31.0	3.1	20.9	- 3.5	3.8	6.7	
4	Laramie River Basin	6-6705	5.8	0.5	5.3	6.5		- 3.2	1.2	0.8	70
5	No. Platte Basin-Whalen to Lisco	6-6860	23.3	1.7	21.6	16.7			4.9		
6	Upper So.Platte abv So.Platte, Colo.	6-7075	- 2.2	2.3	- 4.5			- 5.2	0.7		240
7	Clear Creek Basin-Colorado	6-7200	- 8.8	0.6	- 9.4			0.1	0.5	-10.0[10]	70
8	St. Vrain River Basin-Colorado	6-7310	- 6.1	0.8	- 6.9	- 6.6		- 0.9	0.6		140
9	Big Thompson River Basin-Colo.	6-7440	-20.6	0.8	-21.4	-20.7		- 1.4	0.7		60
10	Cache LaPoudre-Colo., Wyo.	6-7525	-32.0[11]	2.2	-34.2	-28.0		- 7.2	1.0		80
11	So. Platte from So. Platte to Weldona	6-7585	45.4	1.1	44.3	40.1		- 1.3	4.3	-1.2	
12	So. Platte from Weldona to Julesburg	6-7640	22.8	2.2	20.6	13.0		0.4	7.2		
13	Middle Loup River Basin	6-7850	205.6	34.3	171.3	158.3	7.1		5.9		630
14	North Loup River Basin	6-7905	39.8	23.7	16.1	14.9			1.2		510
15	Loup and Cedar River Basins	6-7945	82.8	11.2	71.6	27.0			2.3	42.3	
16	Elkhorn River Basin	6-8005	64.2	7.4	56.8	56.0			0.8		740
17	Platte River Basin to Ashland	6-8010	365.1	2.8	362.3	324.0	59.1		20.2	-41.0	
	Total in Platte River Basin		902.9	140.3	762.6	655.3	91.9	-44.8	59.0	1.2[12]	3,172
18	Upper Niobrara Basin	6-4575	18.8	0.3	18.5	13.1	2.4		3.0		70
19	Snake River Basin	6-4595	100.2		100.2	100.2					80
20	Middle Niobrara Basin	6-4615	8.1		8.1	7.0			1.1		
21	Lower Niobrara Basin	6-4650	-30.4	0.3	-30.7	-33.5			2.8		
	Total in Niobrara Basin		96.7	0.6	96.1	86.8	2.4		6.9		1,030
	Total		999.6	140.9	858.7	742.1	94.3	-44.8	65.9	1.2	4,202
	MIDDLE MISSOURI										
1	Perry Creek Basin	6-6000	0.5		0.5				0.5		10
2	Floyd River Basin	6-6005	4.2	0.8	3.4	0.5			2.9		130
3	Little Sioux Basin	6-6067	15.9	2.3	13.6	1.3			12.3		550
4	Maple River Basin	6-6072	6.0	1.2	4.8	0.4			4.4		160
5	Soldier River Basin	6-6085	3.6	0.5	3.1	0.5			2.6		90
6	Boyer River Basin	6-6095	10.8	2.0	8.8	1.0			7.8		200
7	Mo. Valley S. C. to Omaha		41.2	4.1	37.1	15.7			21.4		
9	Mo. Valley Omaha to Neb. City (Excluding Platte Basin)		63.6	2.6	61.0	32.8	6.0		22.2		
10	Little Nemaha Basin	6-8115	16.7	0.6	16.1	7.3			8.8		210
11	Nishnabotna River Basin	6-8100	24.9	5.1	19.8	2.7			17.1		670
12	Nemaha River Basin	6-8150	26.9	1.8	25.1	11.6			13.5		450
13	Tarkio River Basin	6-8130	5.1	1.2	3.9				3.9		130
14	Nodaway River Basin	6-8175	9.4	3.7	5.7	0.9			4.8		370
15	Mo. Valley Neb.City to St. Joe.		26.5		26.5	1.0			25.5		
16	Platte Basin (Ia.-Mo.)	6-8205	11.3	3.1	8.2				8.2		550
18	Mo. Valley St. Joe. to K.C. (Excluding Kansas Basin)		14.5	3.1	11.4				11.4		
	Total		379.3	32.1	347.2	75.7	6.0		167.3	98.2[13]	7,670
	KANSAS RIVER										
1,2	South Fork Republican River Basin	6-8275	10.5		10.5	2.5	6.4		1.6		30
3	Arikaree River Basin		44.0		44.0	28.5	13.2		2.3		
4	Frenchman Creek Basin	6-8355	43.0		43.0	35.8	4.6		2.6		60
5	Red Willow-Medicine Creek Areas		81.4		81.4	64.3	9.3		7.8		
6	Beaver-Sappa-Prairie Dog Basins		100.9		100.9	43.7	45.0		12.2		
7	Lower Republican Basin		107.8		107.8	59.1	30.4		18.3		
8,9	Smoky Hill River Basin	6-8655	60.8	4.4	56.4	9.6	28.7		18.1		200
10	Saline River Basin	6-8695	40.6		40.6	0.7	22.0		17.9		240
11	North Fork Solomon River	6-8725	38.1	1.4	36.7	12.9	13.3		10.5		120
12	South Fork Solomon River	6-8740	26.4	0.5	25.9	9.2	7.5		9.2		120
13	Solomon River Basin	6-8769	35.8	1.5	34.3		24.4		9.9		550
14	Big Blue River Basin	6-8820	43.3	8.1	35.2	22.8			12.4		530
15	Little Blue River Basin	6-8840	20.2	4.0	16.2	11.7			4.5		250
16	Lower Blue River Basin		52.3	4.5	47.8	5.3	30.0		12.5		
17	Kansas River Basin		74.9	3.7	71.2	13.7	33.1		24.4		
	Total		795.6	28.1	767.5	319.8	267.9		164.2	15.6[14]	4,154
	LOWER MISSOURI										
6	Blue River Basin (Mo.)	6-8935	0.5		0.5	0.2			0.3		90
7	Little Blue Basin (Mo.)	6-8940	1.4		1.4				1.4		70
8	Crooked River Basin	6-8950	0.5		0.5				0.5		60
9	Mo. Valley K.C. to Waverly		9.2		9.2				9.2		
10	Wakenda Creek Basin	6-8960	.0		.0				.0		90
11	Grand River Basin	6-9020	43.4	23.9	19.5				19.5		2,600
12	Chariton River Basin	6-9055	16.3	1.1	15.2	0.4	11.9		2.9		770
13	Lamine River Basin	6-9070	1.9	0.7	1.2				1.2		320
14	Blackwater River Basin	6-9080	2.8	0.5	2.3				2.3		490
15	Mo. Valley Waverly to Boonville		9.8		9.8				9.8		
16-20	Osage River Basin		119.3	12.8	106.5	2.3	88.1		16.1		6,600
22	Gasconade River Basin	6-9335	5.3	0.8	4.5			3.4	1.1		1,700
23	Mo. Valley Boonville to Hermann		4.8	1.7	3.1				3.1		
	Total		260.0	41.5	218.5	2.9	100.0	3.4	67.4	44.8[15]	17,263

[2] Includes FWL developments causing depletions during the period of record. They are generally insignificant, but exceptions are U-L Bend in Area 12 of Upper Missouri Subbasin and Area 1 of Eastern Dakota Subbasin associated with Garrison Diversion Unit. Neither is completed to date, but will evaporate 50.0 and 60.0 thousand A.F., respectively.

[3] Includes selective cutting, thinning, and management practices which increase runoff.

[4] Effects on all lands (Federal and private) from: land treatment (contouring, terracing, drainage and water spreading), minor impoundments (farm ponds, dugouts, erosion control, fisheries, recreation ponds and small irrigation reservoirs of all agencies, groups and individuals), and upstream watershed structural measures.

[10] Municipal effluent from imported water.

[11] Negative depletions (accretions in Areas 7, 8, 9, and 10 are increased return flows from import.

[12] Rural domestic and livestock – 2.1; Mining – 4.2; M&I – 10.0 (effluent) and 1.2 consumed; hydropower diversion – 42.3 in Area 15 returns 41.0 in Area 17 for depletion of 1.3; thermal power – 2.4.

[13] Rural domestic and livestock – 60.0 Mining – 0.2 M&I – 38.0

[14] Rural domestic and livestock – 11.7 Mining – 0.2 M&I – 3.7

[15] Rural domestic and livestock – 10.1 Mining – 0.4 M&I – 34.3

Table 16 (Continued)

Main Stem Location	Depletions: Total 1910 to 1970	1910 to 1949	1949 to 1970	1949 to 1970 by Functions: Irrigation Farming	Large Reservoir Evap.	Forestry Practices	Watershed Treatment and Ponds	Other Uses
	(Thousand Acre-Feet)							
From Upper Missouri Tribs.	681.6	216.2	465.4	277.3	151.8	-16.9	53.2	
Evaporation at Fort Peck Res.	441.0[1]	441.0						
FORT PECK DAM	1,122.6	657.2	465.4	277.3	151.8	-16.9	53.2	
Fort Peck to Garrison Dam								
From Upper Missouri Tribs.	135.7	16.0	119.7	49.5	1.0	---	55.2	14.0
From Yellowstone Basin	629.9	268.9	361.0	213.1	82.3	-15.9	65.3	16.2
From Western Dakota Tribs.	28.7	5.0	23.7	8.2		1.5	14.0	---
From Eastern Dakota Tribs.	58.1	9.4	58.7	54.0		---	4.7	
Evaporation at Garrison Res.	345.0[1]		545.0		545.0	---	---	---
GARRISON DAM	2,530.0	956.5	1,573.5	602.1	780.1	-31.3	192.4	30.2
Garrison to Oahe Dam								
From Western Dakota Tribs.	264.5	20.1	244.4	147.6	40.3	-10.6	57.2	9.9
From Eastern Dakota Tribs.	54.1	14.1	40.0	19.8	---	---	5.7	14.5
Evaporation at Oahe Res.	420.0[1]		420.0		420.0			
OAHE DAM	3,268.6	990.7	2,277.9	769.5	1,240.4	-41.9	255.5	54.6
Oahe to Big Bend Dam								
From Western Dakota Tribs.	15.8	7.5	8.3	2.0	---	0.4	5.9	
Evaporation at Big Bend Res.	76.0[1]		76.0		76.0			
BIG BEND DAM	3,360.4	998.2	2,352.2	771.5	1,316.4	-41.5	261.2	54.6
Big Bend to Fort Randall Dam								
From Western Dakota Tribs.	56.5	14.3	42.2	19.4		0.6	22.2	
From Eastern Dakota Tribs.	52.4	11.4	41.0	29.5		0.7	7.4	3.4
Evaporation at Fort Randall Res.	77.0[1]		77.0		77.0			
FORT RANDALL DAM	3,546.3	1,023.9	2,522.4	820.4	1,393.4	-40.2	290.8	58.0
Fort Randall to Gavins Point								
From Eastern Dakota Tribs.	25.4	5.8	19.6	14.7			3.3	1.6
From Niobrara Basin	96.7	0.6	96.1	86.8	2.4		6.9	
Evaporation at Gavins Point Res.	27.0[1]		27.0		27.0			
GAVINS POINT DAM	3,695.4	1,030.3	2,665.1	921.9	1,422.8	-40.2	301.0	59.6
Gavins Point to Sioux City	115.5	8.6	106.9	85.4	2.4		5.7	13.4
SIOUX CITY, IOWA	3,810.9	1,038.9	2,772.0	1,007.3	1,425.2	-40.2	306.7	73.0
Sioux City to Omaha	82.2	10.9	71.3	19.4			51.9	
OMAHA, NEBRASKA	3,893.1	1,049.8	2,843.3	1,026.7	1,425.2	-40.2	358.6	73.0
Omaha to Nebraska City								
From Middle Missouri Tribs	63.6	2.6	61.0	32.8	6.0		22.2	
From Platte River Basin	902.9	140.3	762.6	655.3	91.9	-44.8	59.0	1.2
NEBRASKA CITY, NEBRASKA	4,859.6	1,192.7	3,666.9	1,714.8	1,523.1	-85.0	439.8	74.2
Nebraska City to Kansas City								
From Middle Missouri Tribs.	233.5	18.6	214.9	23.5			93.2	98.2
From Kansas River Basin	795.6	28.1	767.5	319.8	267.9		164.2	15.6
KANSAS CITY, MISSOURI	5,888.7	1,239.4	4,649.3	2,058.1	1,791.0	-85.0	697.2	188.0
Kansas City to Boonville	130.6	26.2	104.4	0.4	11.9		47.1	
BOONVILLE, MISSOURI	6,019.3	1,265.6	4,753.7	2,058.7	1,802.9	-85.0	744.3	188.0
Boonville to Hermann	129.4	15.3	114.1	2.3	88.1	3.4	20.3	44.8
HERMANN, MISSOURI	6,148.7	1,280.9	4,867.8	2,061.0	1,891.0	-81.6	764.6	232.8

[1] Estimated evaporation from Main Stem Reservoirs based on Operation Study PGOR-19A. These values were substantiated upon completion of an operation study conducted for comprehensive basin planning and using average annual tributary depletions shown herein.

Depletions by municipal and industrial water supply and rural domestic water supply were based on the increased usage for these purposes indicated by comparison of population and actual use rates in 1940 with 1970 projected population and 1970 projected use rates per person. Consumptive use of water for these purposes range from 20 to 30 percent of the gross water requirement. Depletions were applied uniformly throughout the year. Depletions for thermal power plants are included in the depletions for municipal and industrial water supply except where the power plant intakes had obvious non-urban locations.

Land treatment measures considered to have a significant effect on water supply include contour farming, terraces, waterspreading, farm ponds, and drainage improvements. Except for drainage improvements, these measures normally cause some depletion of streamflow in most watersheds in the Missouri Basin, with the magnitude of depletion influenced by the location, geology, soils, and climate of each watershed and the percentage of watershed area to which land and treatment measures are applied. Procedures used to estimate depletions are explained in the U. S. Department of Agriculture Technical Bulletin No. 1352, "Development of a Procedure for Estimating the Effects of Land and Watershed Treatment on Streamflow," a publication which was the result of a cooperative study by the Soil Conservation Service, the Agricultural Research Service, and the Bureau of Reclamation.

Small reservoirs usually operate on a cyclic pattern. Generally, they fill in late spring, are drawn down through the summer and fall months, and begin to refill after the winter period ends. They regulate natural flows by reducing high flows and increasing low flows. Normally, they deplete streamflows only to the extent of net evaporation losses.

Forestry depletions were estimated for reservoirs and stock ponds on lands administered by the U. S. Forest Service, and were limited to net evaporation losses. Forestry accretions were estimated for areas on which forest harvest has been accomplished or is planned during the period from 1949 to 1970. Past studies have shown that an average annual water yield of one acre-foot per acre is representative of forested central Rocky Mountain watersheds. Measurements at the Fraser Experimental Forest, as well as other Colorado studies, have shown that forest cutting increases water yields by 25 to 35 percent. An increase of 22.5 percent was used in the Missouri Basin studies to allow for the effect of regeneration of the earlier cuttings during the study period. Effects of construction, forest fires, and other changes were considered to be offset by reforestation and other forest improvement measures. The net effect of forest management on historical streamflow is an accretion, or negative depletion.

Streamflow Regulation, 1970 Development

Large reservoirs frequently are designed to draw down or refill over a period of years. Thus, in any specific year, they might reduce or increase natural streamflows by amounts varying over a substantial range. Since monthly operation studies are available for all large reservoirs, the effect of any reservoir on natural streamflow under conditions of 1970 development was readily determined by the difference between the planned 1970 release and the historic release for any specific month. For a reservoir not historically in operation, the effect was determined by the difference between the planned 1970 release and the natural streamflow.

Some reservoirs were in operation throughout the period of streamflow record, but past operations were not representative of those that will be necessary under 1970 conditions and demands. In such cases, new operation studies were made, and the monthly releases shown by the new studies were compared with historic monthly releases to determine the effect on streamflow under 1970 conditions of development.

Reservoirs that were constructed and began operation during the period of streamflow record required special consideration. In each such case, actual flows during the period the reservoir was in operation were modified to obtain flows as they would have been without the reservoir in operation. A new operation study consistent with 1970 release requirements then was made, beginning with an assumed full seasonal storage. The difference between the monthly releases shown by the new operation studies and the reconstituted natural flows was adopted as indicative of the regulating effect of the reservoir.

Remaining Surface-Water Supply, 1970 Development

Tabulations of remaining monthly streamflow volumes under conditions of 1970 development have been derived for 110 locations in the Missouri Basin. Plate 17 shows the locations for which these 1970 condition streamflow tabulations were derived. Table 17 is an example of the 1970 condition streamflow tabulation for Hamburg, Ia. All of the monthly tabulations are included in the working papers prepared by the Hydrologic Work Group.

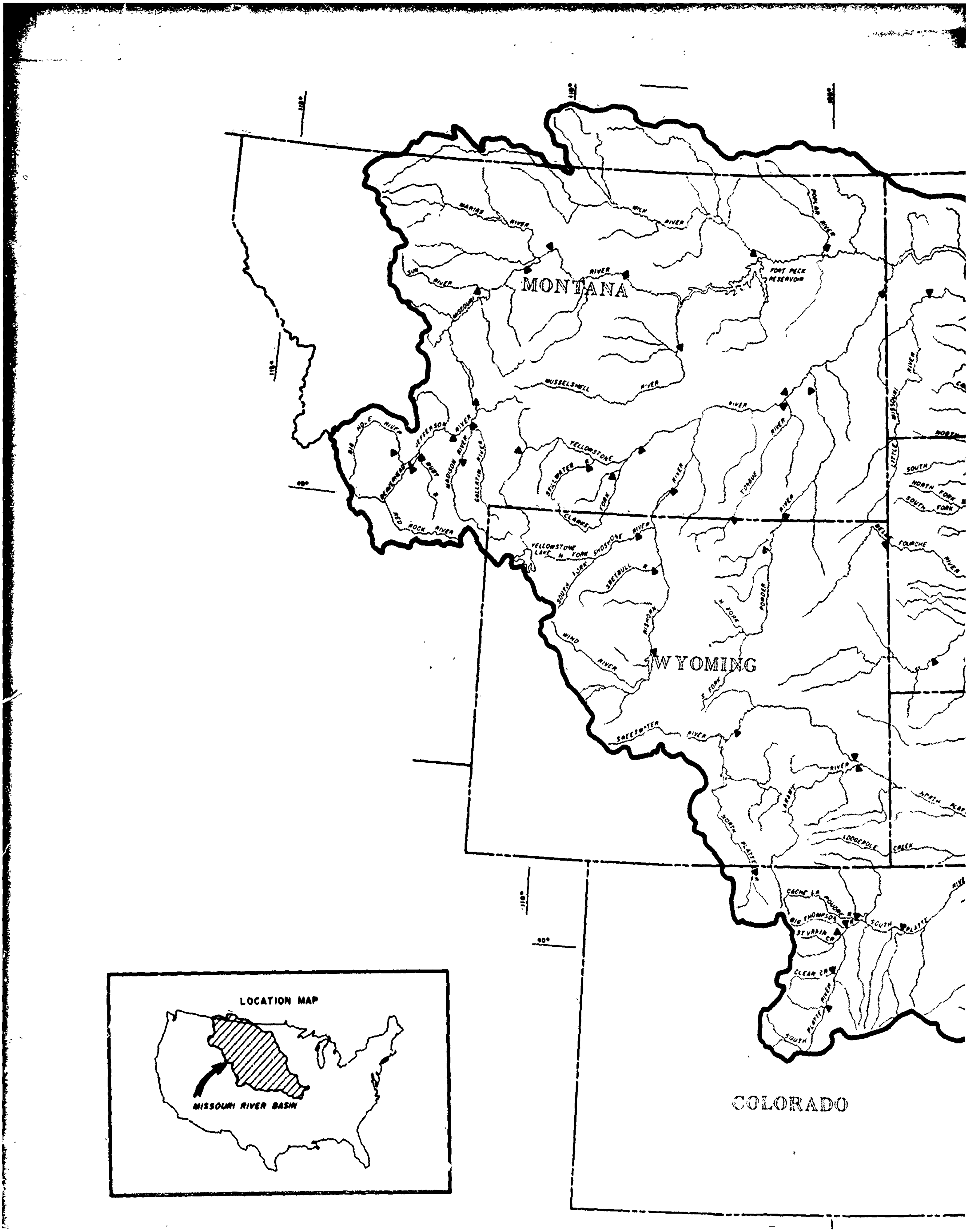
As previously indicated, the total annual volume of remaining surface water supply under 1970 conditions of development is shown for each subbasin on plate 16.

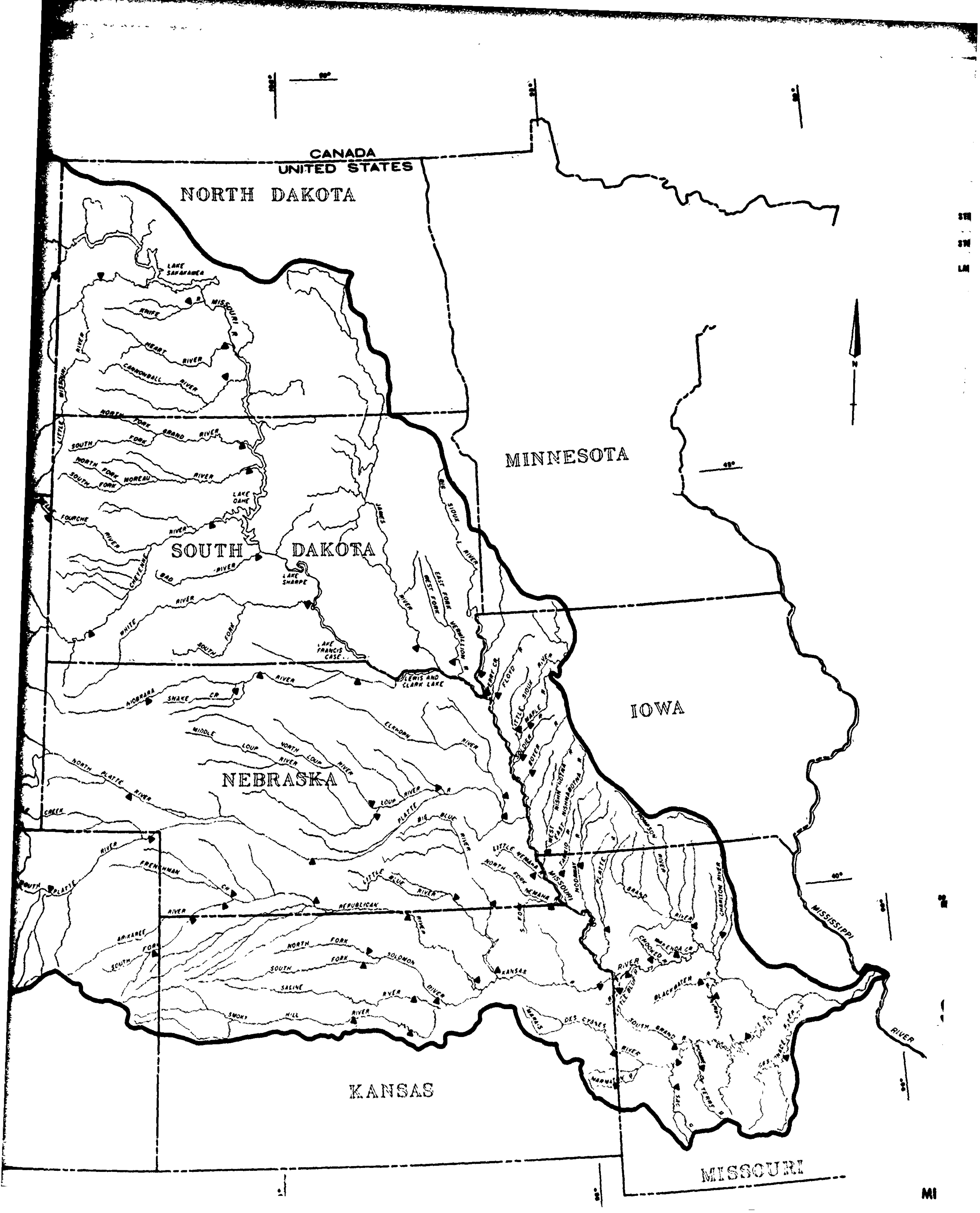
Table 17 – MONTHLY AND ANNUAL STREAMFLOWS FOR 1970 DEPLETION LEVEL NISHNABOTNA RIVER ABOVE HAMBURG, IOWA

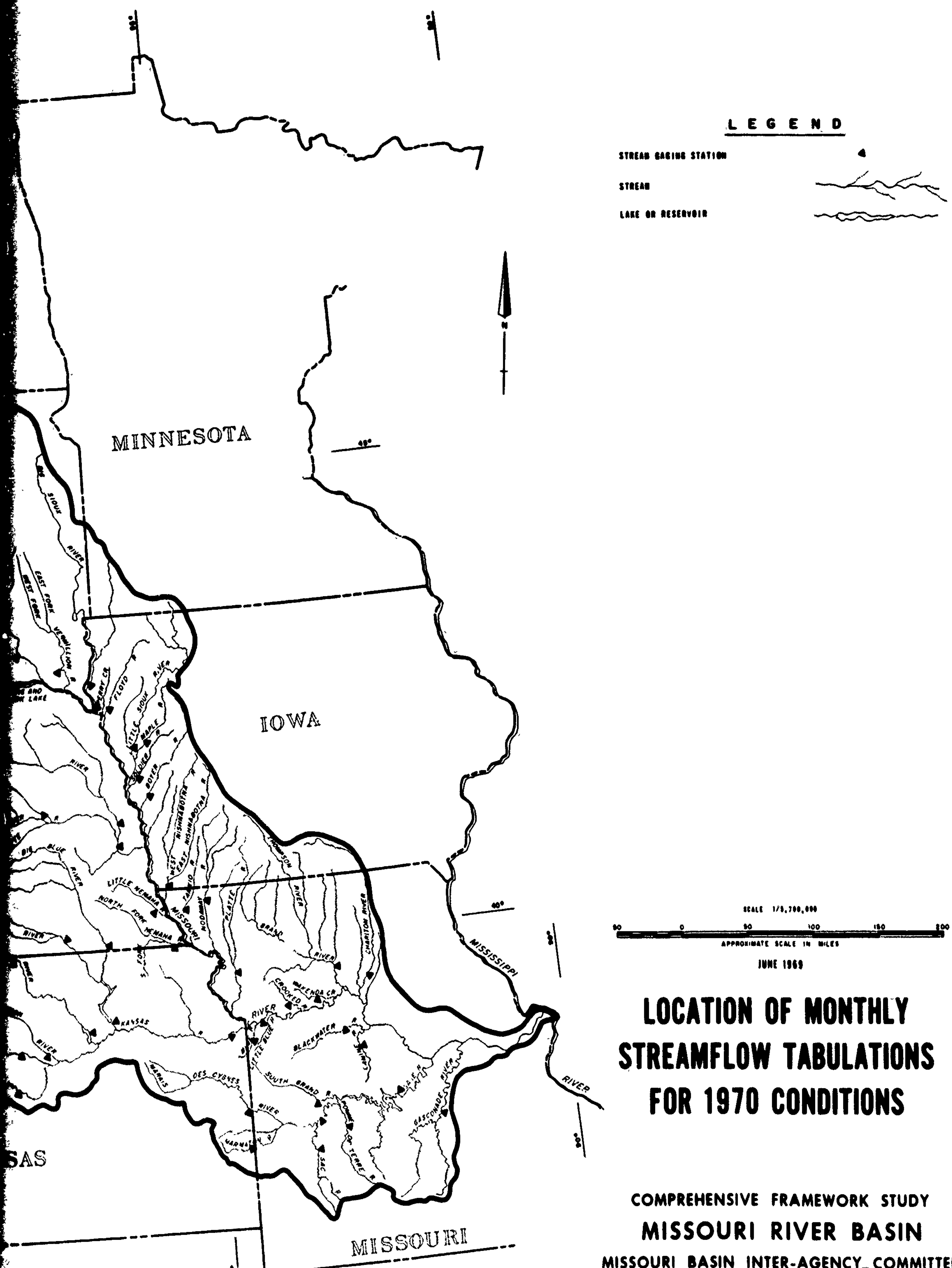
(Thousand Acre-Feet)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1920													
21													
22													
23													
24													
1925													
26													
27													
28													
29	23.9	53.3	67.6	26.1	24.0	253.8	127.8	78.7	63.7	118.4	23.6	20.9	881.8
1930	24.8	35.3	25.7	17.1	50.9	23.2	16.7	30.9	30.6	4.0	10.2	5.9	275.3
31	6.9	8.8	6.5	6.5	4.8	5.1	5.4	10.7	89.7	18.3	18.3	41.1	220.1
32	59.7	139.0	89.2	140.0	146.6	122.6	84.0	108.1	154.7	67.3	182.8	48.9	1,342.9
33	27.2	29.5	30.4	61.5	18.7	30.8	33.4	18.9	6.8	9.8	19.8	23.4	310.2
34	7.9	6.3	8.2	18.3	7.8	8.1	6.2	1.3	17.6	9.7	0	15.1	106.5
1935	12.0	17.1	6.9	30.8	23.1	28.9	3.5	10.0	72.2	12.8	12.5	5.3	235.1
36	10.3	18.6	5.6	3.9	29.7	233.5	19.4	20.0	32.7	0	0.9	91.6	466.2
37	16.9	5.6	8.1	6.1	129.9	150.5	22.2	45.6	18.3	22.0	21.4	2.4	449.0
38	2.4	2.6	1.7	1.9	2.3	6.5	9.0	23.0	26.4	25.8	41.8	73.7	217.1
39	6.9	8.6	4.5	4.4	18.0	189.3	8.6	2.5	50.0	71.3	63.3	4.2	431.6
1940	4.0	2.9	3.0	1.3	0	39.1	11.1	6.4	9.3	55.4	149.8	9.1	291.4
41	5.3	8.4	7.6	10.8	16.2	20.6	26.9	10.7	148.2	26.0	8.1	75.0	363.8
42	98.4	62.0	47.7	61.5	45.0	85.9	47.8	137.0	133.0	98.3	37.1	51.3	905.0
43	18.3	13.9	19.1	13.5	98.4	54.1	25.4	70.9	156.6	38.0	64.0	19.9	592.1
44	7.7	10.0	7.4	10.8	13.6	32.0	68.4	178.3	291.4	100.6	95.3	31.0	846.5
1945	35.4	20.7	11.8	16.1	37.6	148.6	145.8	333.0	277.4	130.5	104.4	32.5	1,293.8
46	24.5	21.1	17.6	65.8	125.1	106.6	37.3	61.6	99.2	33.1	74.3	119.3	785.5
47	98.8	65.4	39.2	32.4	42.5	65.6	162.2	122.1	976.8	176.5	51.8	22.1	1,855.4
48	20.2	26.5	21.0	17.8	91.3	250.9	63.2	36.2	13.3	55.5	35.2	24.5	655.6
49	9.9	18.1	15.6	84.1	65.4	290.2	46.1	42.7	118.7	43.6	18.3	17.4	770.1
1950	19.3	11.3	12.3	7.1	77.6	94.4	13.8	141.0	78.1	50.5	57.2	16.2	578.8
51	40.9	17.9	12.6	10.0	38.3	159.9	155.8	324.4	360.0	193.3	129.5	77.3	1,520.6
52	59.1	47.5	28.9	44.6	58.7	139.9	137.5	107.0	210.8	131.0	116.8	71.6	1,153.4
53	30.8	29.9	30.2	28.7	88.2	90.5	86.0	91.6	78.9	36.5	20.4	8.9	620.6
54	8.7	11.6	7.7	4.0	17.7	11.8	15.8	19.2	43.7	4.8	98.9	21.0	264.9
1955	33.1	15.4	12.8	10.9	24.0	116.8	44.3	22.4	23.8	33.5	4.8	4.8	346.6
56	3.5	4.1	2.5	3.2	2.1	6.8	4.3	11.1	5.9	42.2	36.1	38.6	160.4
57	8.8	14.2	6.6	3.1	9.4	11.9	24.2	42.2	174.7	25.7	11.5	19.0	351.3
58	17.8	26.0	27.5	18.9	57.7	68.7	36.1	23.0	16.4	289.2	122.2	136.8	840.3
59	36.7	23.7	14.9	11.0	48.5	98.4	64.2	274.1	141.4	75.3	62.8	30.2	881.2
1960	32.2	23.8	25.3	32.5	34.0	140.9	274.0	133.4	91.3	85.2	113.0	80.8	1,066.4
61	46.4	37.5	30.2	19.8	49.2	185.3	120.7	75.7	99.0	56.5	49.4	59.4	829.1
62	70.1	69.5	51.8	55.0	90.1	262.0	134.5	191.5	213.1	88.3	43.2	45.0	1,314.1
63	31.3	25.0	21.5	20.0	34.0	171.9	35.6	52.6	26.1	14.7	18.0	23.8	474.5
64													
1965													
66													
67													
68													
69													
1970													
Mean	27.4	26.6	20.8	25.7	46.3	105.9	60.5	81.6	124.3	64.1	54.8	39.1	677.1

Drainage area 2,806 sq. mi. USGS Sta. No. 8100


MONTANA
WYOMING
COLORADO
LOCATION MAP
MISSOURI RIVER BASIN
MARIAS RIVER
MILK RIVER
POPLAR RIVER
FORT PECK RESERVOIR
SUN RIVER
MISSOURI
MUSSELSHELL RIVER
YELLOWSTONE
JEFFERSON RIVER
MADISON RIVER
GALLATIN RIVER
RED ROCK RIVER
STILLWATER
CLARKS FORK
YELLOWSTONE LAKE
N FORK SHOSHONE RIVER
SOUTH FORK
GREYBULL R
BIGHORN
WIND RIVER
POWDER
TONGUE
SWEETWATER RIVER
NORTH PLATTE R
LARAMIE
LODGEPOLE CREEK
CACHE LA POUDRE R
BIG THOMPSON
ST VRAIN CR
CLEAR CR
SOUTH PLATTE RIVER
SOUTH PLATTE
BELLE FOURCHE RIVER
LITTLE MISSOURI RIVER
110°
40°


CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
KANSAS
MISSOURI
LAKE SAKAKAWEA
MISSOURI R.
KNIFE
HEART RIVER
CANNONBALL RIVER
LITTLE MISSOURI RIVER
NORTH FORK GRAND RIVER
SOUTH FORK
NORTH FORK MOREAU RIVER
SOUTH FORK
LAKE OAHE
CHEYENNE RIVER
BAD RIVER
LAKE SHARPE
WHITE RIVER
SOUTH FORK
LAKE FRANCIS CASE
JAMES RIVER
BIG SIOUX RIVER
VERMILLION R.
LEWIS AND CLARK LAKE
NIOBRARA RIVER
SNAKE CR.
ELKHORN RIVER
MIDDLE LOUP RIVER
NORTH LOUP RIVER
LOUP RIVER
NORTH PLATTE RIVER
SOUTH PLATTE RIVER
PLATTE
BIG BLUE RIVER
LITTLE BLUE RIVER
LITTLE NEMAHA
NORTH FORK NEMAHA
FRENCHMAN CR.
REPUBLICAN RIVER
ARIKAREE
SOUTH FORK
NORTH FORK SOLOMON
SOUTH FORK
SALINE RIVER
SMOKY HILL RIVER
KANSAS RIVER
FLOYD R.
LITTLE SIOUX RIVER
MAPLE R.
BOYER R.
NISHNABOTNA R.
GRAND RIVER
CHARITON RIVER
BLACKWATER
SOUTH GRAND R.
MARAIS DES CYGNES RIVER
OSAGE
MISSISSIPPI
RIVER



LOCATION OF MONTHLY STREAMFLOW TABULATIONS FOR 1970 CONDITIONS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

MISSOURI RIVER MAIN STEM RESERVOIR REGULATION

General

The Missouri River main stem reservoirs have been operating as a system for about 15 years. During this period the reservoirs have filled to normal operating levels while providing service to four primary and several secondary purposes. In serving these functions the system has completely regulated the flow of the Missouri River from Fort Peck, Mont., to Yankton, S. Dak.; has markedly affected streamflows on the lower Missouri River, and, to a lesser degree, on the Mississippi River. The actual operation, during a major portion of this period, has been atypical, since the reservoirs were in the process of filling. In addition, during the 1954-1962 interval, reservoir inflows were generally well below normal.

The Main Stem Reservoir System

The six Missouri River main stem dams are located in the reach from just above Yankton, S. Dak., to Glasgow, Mont., as shown on plate 17. The dams are earth fill with appropriately sized outlet works, spillways and power installations. The spillways have discharge capabilities ranging from 250,000 to 827,000 cfs and the outlet works have discharge capabilities ranging from zero (at Big Bend and Gavins Point) to 128,000 cfs at Fort Randall. Hydropower installations range in size from 100,000 kw to 595,000 kw, totaling 2,048,000 kw. Pertinent engineering data for the individual projects, and the system, are given on table 18.

The reservoirs contain an aggregate storage space of 75,240,000 acre-feet, somewhat greater than three times the average annual flow of the Missouri River at the lowermost dam. Functionally, the main stem reservoirs and powerplants operate as a hydraulically and electrically integrated system. All reservoirs except Big Bend have the storage divided into four zones, as listed in table 18 and described below.

Exclusive Flood Control Zone– The top zone of 4,840,000 acre-feet, 6% of the total storage, is reserved exclusively for flood control. Impoundments in this zone are evacuated as soon as downstream conditions permit, in the interest of having space available to control future floods, should they occur.

Annual Flood Control and Multiple-Use Zone– This zone, which lies immediately below the Exclusive Flood Control zone, contains 11,600,000 acre-feet, 15% of the total storage space. Reservoir regulation criteria are designed to empty this zone by 1 March of each year. The zone is then filled, to the extent inflows permit, in the March to July high-water season and then drawn down for multiple purposes during the low-flow season which extends from late summer through winter.

Carryover Multiple-Use Zone– This zone of 41,160,000 acre-feet, 55% of the total storage, provides a reserve of multiple-use storage for serving navigation, power, irrigation, and other conservation functions during prolonged low-flow periods of up to several years duration. In event of a recurrence of an extended drought period such as the 1930's, it would be necessary to empty this storage zone to maintain a satisfactory level of service to all functions.

Inactive Zone– This zone provides an assured minimum pool level for power, irrigation pump diversions, recreation, fish and wildlife purposes, and provides storage capacity for sediment accumulation. It contains 17,640,000 acre-feet, 24% of the total.

General Criteria for System Regulation

In the planning for, and the operation of, the main stem reservoirs, the general criteria and procedures have been:

a. To maintain adequate seasonal and year-around storage capacity available for flood control on the Missouri River.
b. To provide the water requirements of irrigation from flows before regulation of the remaining water available to supply other purposes.
c. To pattern the releases from the lower end of the main stem system to supply the varying seasonal requirements of water quality control, and navigation which provides adequate water levels for municipal water intakes.
d. With internal adjustments in the system and moderate adjustments in outflow from the system, to sustain the highest system power output consistent with the other primary functions of flood control, irrigation, and navigation.

Flood control operations of the main stem reservoirs are aimed at controlling floods on reaches of the Missouri River between reservoirs, and minimizing flood damages from Gavins Point Dam downstream to the mouth of the Missouri River. The main stem reservoirs are operated in conjunction with many tributary reservoirs and the lower river levees and local protection systems for control of floods on the Missouri River.

The principal functions of the main stem reservoirs in serving irrigation are to provide water from storage during periods of deficient flows, to reduce diversion

Table 18 – SUMMARY OF ENGINEERING DATA – MISSOURI RIVER MAIN STEM RESERVOIRS

ITEM NO.	SUBJECT	FORT PECK	GARRISON	OAHE
1	Location of Dam	Near Glasgow, Montana	Near Garrison, N. Dak.	Near Pierre, S. Dak.
2	River Mile – 1960 mileage	Mile 1771.5	Mile 1389.9	Mile 1072.3
3	Total & incremental Drainage Areas, square miles	57,500	181,400 (2) 123,900	243,490 (1) 62,090
4	Approximate length of full Reservoir (in Valley Miles)	134, ending near Zortman, Mont.	178, ending near Trenton, N. D.	231, ending near Bismarck, N. D.
5	Shoreline – Miles (3)	1520 (El. 2234)	1340 (El. 1837.5)	2250 (El. 1607.5)
6	Average total & incremental inflow in cfs	9,900	25,200 15,300	28,400 3,200
7	Max. Discharge of Record near Damsite in cfs	137,000 (June 1953)	348,000 (April 1952)	440,000 (April 1952)
8	Construction started – Cal. yr.	1933	1946	1948
9	In operation (4) Cal. yr.	1940	1955	1962
	DAM AND EMBANKMENT			
10	Top of Dam, Elev. ft. msl	2280.5	1875	1660
11	Length of Dam in feet	21,026 (excluding spillway)	11,300 (including spillway)	9,300 (excluding spillway)
12	Damming Height, feet (5)	220	180	200
13	Maximum Height, feet (5)	250.5	202	245
14	Max. Base width, total & w/o Berms, feet	3500;2700	3400;2050	3500;1500
15	Abutment Formations (Under Dam & embankment)	Bearpaw Shale and Glacial Till	Fort Union Clay-Shale	Pierre Shale
16	Type of fill	Hydraulic & rolled earth fill	Rolled earth fill	Rolled earth fill & shale berms
17	Fill quantity, cu. yds.	125,628,000	66,500,000	55,000,000 & 37,000,000
18	Volume of concrete (Cu. yds.)	1,200,000	1,500,000	1,045,000
19	Date of closure	24 June 1937	15 April 1953	3 August 1958
	SPILLWAY DATA			
20	Location	Right bank – remote	Left bank – adjacent	Right bank – remote
21	Crest Elevation, msl	2225	1825	1596.5
22	Width (including piers) in feet	820 gated	1336 gated	456 gated
23	No., Size and Type of Gates	16-40'x25' Vertical Lift Gates	28-40'x29' Tainter	8-50'x23.5' Tainter
24	Design Discharge Capacity, cfs	275,000 at elev. 2253.3	827,000 at elev. 185?.5	304,000 at elev. 164?.?
25	Discharge Capacity at Maximum Operating Pool, cfs	230,000	660,000	80,000
	RESERVOIR DATA (6)			
26	Max. Operating Pool Elev. & Area	2250 msl 247,000 acres	1854 msl 382,000 acres	1620 msl 376,000 acres
27	Max. Nor. Oper. Pool Elev. & Area	2246 msl 239,000 acres	1850 msl 368,000 acres	1617 msl 358,000 acres
28	Base Flood Control Elev. & Area	2234 msl 215,000 acres	1837.5 msl 323,000 acres	1607.5 msl 313,000 acres
29	Min. Oper. Pool Elev. & Area	2160 msl 93,000 acres	1775 msl 129,000 acres	1540 msl 119,000 acres
	Storage Allocation, Elev. & Cap.			
30	Exclusive Flood Control	2250-2246 1,000,000 a.f.	1854-1850 1,500,000 a.f. (11)	1620-1617 1,100,000 a.f.
31	Flood Control & Multiple use	2246-2234 2,700,000 a.f.	1850-1837.5 4,300,000 a.f. (11)	1617-1607.5 3,200,000 a.f.
32	Carryover Multiple use	2234-2160 11,100,000 a.f.	1837.5-1775 13,600,000 a.f. (11)	1607.5-1540 13,800,000 a.f.
33	Inactive	2160-2030 4,300,000 a.f.	1775-1673 5,000,000 a.f.	1540-1415 5,500,000 a.f.
34	Gross	2250-2030 19,100,000 a.f.	1854-1673 24,400,000 a.f. (11)	1620-1415 23,600,000 a.f.
35	Reservoir filling initiated	November 1937	December 1953	August 1958
36	Initially reached Min. Oper Pool	27 May 1942	7 August 1955	3 April 1962
37	Est. Annual Sediment Inflow	17,500 a.f.	38,100 a.f.	32,300 a.f.
	OUTLET WORKS DATA			
38	Location	Right bank	Right bank	Right bank
39	Number and size of conduits	2-24'8" dia. (Nos 3 & 4)	1-26' dia. and 2-22' dia.	6-19.75' dia. upstream; 18.25' dia. downstream
40	Length of Conduits in feet (8)	No. 3-6,615, No. 4-7,240	1529	3496 to 3659
41	No., size and type of service gates	1-28' dia. cylindrical gate 6 ports 7.6'x8.5' high (net opening) in each control shaft	1-18'x24.5', Tainter gate per conduit for fine regulation	1-13'x22' per conduit, vertical lift; 4 cable suspension and 2 hydraulic suspension (fine regulation)
42	Entrance Invert Elevation	2095	1671.9	1425
43	Avg. Discharge Cap. per conduit & total	Elev. 2250, 22,500 cfs-45,000 cfs	Elev. 1854, 32,700 cfs-98,000 cfs	Elev. 1620, 18,500 cfs-111,000 cfs
44	Present Tailwater Elev. (msl)	2033-2037 10,000-25,000 cfs	1676-1681 25,000-50,000 cfs	1424-1428 25,000-50,000 cfs
	POWER FACILITIES AND DATA			
45	Avg. Gross Head available in feet	205	154	185
46	Number and size of conduits	No. 1-24'8" dia.; No. 2-22'4" dia	5-29' dia., 24' penstocks	7-24' dia., imbedded penstocks
47	Length of conduits in feet (8)	No. 1-5,653; No. 2-6,355	1,829	From 3,280 to 4,005
48	Surge Tanks	PH#1: 3-40' dia.; PH#2: 2-65' dia	65' dia., 2 per penstock	70' dia., 2 per penstock
49	No., type and speed of turbines	5-Francis, PH#1-2-128.5, 1-164 rpm; PH#2-2-128.6 rpm	5-Francis, 90 rpm	7-Francis, 100 rpm
50	Disch. Cap. at Rated Head-cfs	PH#1 units 1&3 170', 2-140' 7,800 cfs, PH#2-2-170'-7,200 cfs	150' 37,800 cfs	185' 53,200 cfs
51	Generator Rating, kw	2-35,000; 1-15,000; 2-40,000	80,000	85,000
52	Plant capacity, kw	165,000	400,000	595,000
53	Dependable capacity, kw (9)	158,000	302,000	512,000
54	Average Energy – Million kwh	960	1,886	2,302
55	Initial Gen., First & Last Unit	July 1943 – June 1961	January 1956 – October 1960	April 1962 – June 1963

REMARKS

(1) Includes 4,280 square miles of non-contributing areas.

(2) Includes 1,350 square miles of non-contributing areas

(3) With pool at base of flood control.

(4) Storage first available for regulation of flows

(5) Damming height is height from low water to maximum operating pool. Maximum height is from average streambed to top of dam

(6) Based on completed system and latest available storage data

(7) River regulation is attained by flows over low-crested spillway and through turbines

Corps of Engineers, U.S. Army
Compiled by Missouri River Division

Table 18 (Continued)

BIG BEND	FORT RANDALL	GAVINS POINT	TOTAL	ITEM NO.
21 mi. upstream Chamberlain, S.D.	Near Lake Andes, S. Dak	Near Yankton, S. Dak.		1
Mile 987.4	Mile 880.0	Mile 811.1		2
249,330 *(8)* 5,840	263,480 *(8)* 14,150	279,480 *(8)* 16,006		3
80, ending near Pierre, S. D.	107, ending at Big Bend Dam	25, ending near Niobrara, Nebr.	755 miles	4
200 *(El. 1420)*	540 *(El. 1350)*	90 *(El. 1204.5)*	5,940 miles	5
	29,500 1,100	31,400 1,900		6
440,000 *(April 1952)*	447,000 *(April 1952)*	480,000 *(April 1952)*		7
1959	1946	1952		8
1964	1953	1955		9
1440	1395	1234		10
10,570 *(including spillway)*	10,700 *(including spillway)*	8,700 *(including spillway)*	71,596 feet	11
78	140	45	863 feet	12
95	165	74		13
1200;700	4300;1250	850;450		14
Pierre shale & Niobrara Chalk	Niobrara Chalk	Niobrara Chalk & Carlile shale		15
Rolled earth, shale, chalk fill	Rolled earth fill & chalk berms	Rolled earth & chalk fill		16
17,000,000	28,000,000 & 22,000,000	7,000,000	358,128,000 cu. yds.	17
540,000	961,000	308,000	5,554,000 cu. yds.	18
24 July 1963	20 July 1952	31 July 1955		19
Left bank - adjacent	Left bank - adjacent	Right bank - adjacent		20
1385	1346	1180		21
376 gated	1000 gated	664 gated		22
8-40'x38' Tainter	21-40'x29' Tainter	14-40'x30' Tainter		23
390,000 at elev. 1433.6	620,000 at elev. 1379.3	584,000 at elev. 1221.4		24
232,000	508,000	345,000		25
1423 msl 60,000 acres	1375 msl 102,000 acres	1210 msl 33,000 acres	1,200,000 acres	26
1420 msl 56,000 acres	1365 msl 95,000 acres	1208 msl 30,000 acres	1,146,000 acres	27
1420 msl 56,000 acres	1350 msl 80,000 acres	1204.5 msl 26,000 acres	1,013,000 acres	28
1415 msl 49,000 acres	1310 msl 36,000 acres	1195 msl 16,000 acres	442,000 acres	29
1423-1420 175,000 a.f.	1375-1365 1,000,000 a.f.	1210-1208 65,000 a.f.	4,840,000 a.f.	30
0	1365-1350 1,300,000 a.f.	1208-1204.5 100,000 a.f.	11,600,000 a.f.	31
1420-1415 260,000 a.f.	1350-1310 2,200,000 a.f.	1204.5-1195 200,000 a.f.	41,160,000 a.f.	32
1415-1345 1,465,000 a.f.	1310-1240 1,200,000 a.f.	1195-1160 175,000 a.f.	17,640,000 a.f.	33
1423-1345 1,900,000 a.f.	1375-1240 5,700,000 a.f.	1210-1160 540,000 a.f.	75,240,000 a.f.	34
November 1963	January 1953	August 1955		35
25 March 1964	24 November 1953	22 December 1955		36
4,400 a.f.	16,600 a.f.	2,500 a.f.	11,,400 a.f.	37
	Left bank			38
None *(7)*	4-22' diameter	None *(7)*		39
	1013			40
	2-11'x23' per conduit, vertical lift, cable suspension, also one vert. lift fine regulating gate at d.s. end of tunnel #10			41
1385 *(13)*	1229	1180 *(13)*		42
	Elev. 1375,32,000cfs-128,000cfs			43
1351-1352 *(12)* 25,000-50,000cfs	[illegible] 25,000-50,000 cfs	[illegible] 30,000-50,000 cfs		44
69	110	47	770 feet	45
None; direct intake	8-28' dia., 22' penstocks	None; direct intake		46
	1,074		55,083 feet	47
None	59' dia.; 2 per alternate penstock	None		
8-Fixed blade, 81.8 rpm	8-Francis, 85.7 rpm	3-Kaplan, 75 rpm	36 units	49
67' 103,000 cfs	112' 41,500 cfs	48' 33,300 cfs		50
58,500	40,000	33,333		51
468,000	320,000	100,000	2,048,000 kw	52
538,000	268,000	67,000	1,845,000 kw	53
907	1,503	608	8,166 kwh	54
October 1964 - July 1966	March 1954 - January 1956	September 1956 - January 1957	July 1963 - July 1966	55

REMARKS

(8) Length from upstream face of intake to downstream face of outlet or to spiral case.

(9) Based on 4th year of drought drawdown, with full power installation.(100 yr. Econ. life)

(10) Affected by Fort Randall pool elevation.

(11) Storage volumes are exclusive of Snake Creek arm

(12) Affected by Fort Randall pool elevation. Applicable to pool at elevation 1350

(13) Spillway Crest

pumping heads, and to provide flow regulation to offset the depleting effects of upstream tributary irrigation projects on the water supply available for lower river use. Actual operation of the reservoirs as far as irrigation service is concerned principally involves maintaining adequate pool levels and river flow rates to supply the irrigation pumping stations during the growing season.

Operation of the main stem reservoir system for navigation involves releasing water from the lowermost reservoirs of the system at sufficient rates for maintenance of adequate channel depths in the 730-mile, open-channel, Missouri River navigation project between Sioux City and the mouth of the Missouri during the navigation season. Ice conditions normally limit navigation releases to an 8-month season, from late March to late November In future years, some reduction in length of navigation seasons will be necessary occasionally in series of critically low flow years. Releases during the non-navigation season are made to maintain satisfactory water quality in the river, although these releases are substantially lower than those needed for navigation.

Hydroelectric power is produced by making essentially all releases through the powerplants, with the releases at the various projects being specially programmed for maximum power consistent with the other major functions. For example, during the non-navigation season when energy generation is lower at the downstream powerplants, due to seasonally lower water releases from the system, the upstream plants are operated at high load factors and the downstream plants are operated at low load factors, except for Gavins Point. Winter releases from the upstream plants which are excess to lower river water requirements are mostly recaptured in Oahe and Fort Randall, and saved to serve the lower river in the ensuing navigation season.

Although the service requirements for the various individual functions are not completely compatible, the amount of storage capacity provided and the flexibility available from complete integration of the six projects into a multiple-purpose system operation, provide for excellent service for all main functions. This integrated multiple-purpose operation of the Missouri River main stem reservoirs for the principal purposes of flood control, irrigation, navigation, water quality, and power generation also provides ample flows for municipal water supply and provides quite well for fish and wildlife and recreation activities. Also, special operations which make the reservoirs even more attractive for these latter purposes can often be worked into the over-all system operation program.

Historic Regulation of the System

To a degree, system regulations began in 1953 when Fort Randall and Garrison reservoirs were first regulated in conjunction with Fort Peck Reservoir. The degree of hydraulic and electrical integration of system operations gradually increased as additional reservoir space was provided, as power units came into service, and as storage levels in individual reservoirs increased. Regulation during this period was not typical of what may be expected in the future due to the occurrence of an abnormal 8-year drought period, the requirement for filling approximately 45 million acre-feet of storage space, the ever-changing nature of the storage space to be filled, the increasing numbers of power units in service, and the delay in development of irrigation diversions from the reservoirs.

During the interim period until the reservoirs were finally filled to normal operating levels in 1967, service to power and to navigation was below normal. Navigation seasons were generally shorter than the normal 8 months and firm power contracts were entered into at a somewhat slower rate than would have been desirable. Full service was provided to flood control during the initial fill period, since storage available for filling generally greatly exceeded the storage allocated to flood control and releases were at reduced levels in the interest of filling storage. The reservoirs have fulfilled only a small portion of their irrigation function since the proposed large Federal projects have not been placed in operation, however, private irrigators are accomplishing some irrigation by pumping from the river and reservoirs. Recreational usage of the reservoirs has increased each year and numerous special operations of individual reservoirs have been undertaken to enhance fish and wildlife developments. The accomplishments of the main stem reservoir system during the interim period of initial fill are summarized in table 19.

Regulation of the System Under 1970 Development Conditions

In order to evaluate the effects of the filled reservoir system during a long period of hydrologic record, a monthly reservoir regulation study has been conducted for the period 1898-1968. This study demonstrates the service that could be provided, and the downstream effects thereof, utilizing inflows to the system and to downstream reaches after depletion of streamflows by 1970-level projects. This 1970-level regulation study of the main stem reservoirs was based on the following conditions and objectives:

a. Historical streamflow, as obtained largely from USGS records, but utilizing estimates during some periods for which records are unavailable.
b. Streamflow depletions for the 1970-level of development, essentially in accordance with the average annual depletions listed in table 16, except as discussed below.

Table 19 – ACCOMPLISHMENTS OF MISSOURI RIVER MAIN STEM RESERVOIR SYSTEM

Calendar Year	Adjusted[1] Flow at Sioux City	Actual Flow at Sioux City	Actual System Storage at End of Year	Power Generation: Gross Energy	Power Generation: Max Hourly Peak	Power Generation: Fiscal Year Revenue	Navigation: Season Length	Navigation: Target Flow Levels 1,000	Navigation: Commercial Tonnage	Fiscal Year Flood Damages Prevented	Recreational Usage of Reservoirs
	(MAF)	(MAF)	(MAF)	(Billion KWH)	(MW)	($ Million)	(Months)	(cfs[2])	(Million Tons)	($ Million)	(Million Visitor Days)
1953	25.4	22.8	14.2	0.6	98[4]	2.0[4]	7	25-31-35	0.2	10.7	0.6[4]
54	19.1	17.3	14.6	0.8	196[4]	2.3[4]	7	25-31-35	0.3	0.0	1.1[4]
55	16.1	16.1	13.6	1.4	298[4]	4.3[4]	6-1/2	25-31-35	0.4	0.0	1.2
56	19.1	16.8	14.0	2.3	435	5.7[4]	7	25-31-35	0.3	0.7	1.6
57	21.8	14.4	20.0	3.0	666	8.9	6	25-31-35	0.3	8.2	2.1
58	16.6	14.6	20.9	3.6	669	11.5	7	25-31-35	0.6	0.0	2.4
59	20.1	14.8	24.4	3.8	723	12.4	7	25-31-35	0.8	10.2	2.8
1960	20.1	16.0	26.8	3.4	736	12.3	7-3/4	25-31-35	1.4	95.2	2.7
61	12.2	13.5	23.9	3.9	844	13.7	6-1/2	25-31-35	1.6	1.6	3.2
62	30.3	16.3	35.2	3.9	849	15.1	8	25-31-35	2.2	15.0	3.5
63	20.1	15.6	37.7	5.5	1266	17.6	8	25-31-35	2.3	10.9	3.2
64	23.7	16.0	43.1	6.2	1306	22.0	8	25-31-35	2.6	41.7	3.9
65	32.3	17.1	55.0	8.5	1622	26.2	8	28-34-38	2.3	35.4	4.4
66	19.1	19.7	51.7	8.6	1754	31.5	8	28-34-38	2.6	46.5	4.9
67	30.8[3]	19.4	58.9	9.7	1922	32.1	8	31-37-41	2.6	238.8	6.6
68	24.0[3]	20.4[3]	59.4	10.2	2001	37.0	8-1/3	31-37-41	2.3	8.1	7.1

[1] Adjusted to 1950 level of basin development

[2] Entry denotes target flow levels at Sioux City-Omaha, Nebraska City, and Kansas City in 1,000 cfs. Thus, 25-31-35 indicates target flows of 25,000 cfs at Sioux City and/or Omaha, 31,000 cfs at Nebraska City, and 35,000 cfs at Kansas City. From 1965 through 1968 the target levels represent the general level of service provided.

[3] Based on preliminary data.

[4] Estimated.

c. The loss of main stem reservoir storage by sedimentation at the current level (June 1969).

d. Maintenance of minimum releases to meet downstream requirements for water quality control and water supply.

e. The maintenance of the highest navigation streamflow rates at downstream control points as practical with the available water supply.

f. Maintenance of an adequate reserve of storage space in each reservoir to permit controlling of inflows to minimize damages during downstream flood situations.

g. Maintenance of release rates from each reservoir for maximum power generation consistent with the other purposes stated herein.

In order to conduct the study and evaluate the effects of reservoir regulations, the Missouri River was divided into specific reaches, defined by the main stem reservoirs and Missouri River navigation control points below the system. These reach boundaries are defined by the following specific locations:

1. Fort Peck Dam
2. Garrison Dam
3. Oahe Dam
4. Fort Randall Dam
5. Gavins Point Dam
6. Sioux City, Iowa
7. Omaha, Nebr.
8. Nebraska City, Nebr.
9. Kansas City, Mo.
10. Boonville, Mo.
11. Hermann, Mo.

Historical monthly inflows to each of the Missouri River reaches defined above were obtained from USGS records and USGS estimates (Water Adequacy Reports and GS Circular 108 dated March 1951). These were supplemented by Corps of Engineers' records at the main stem reservoirs and estimates for some periods at particular locations where USGS data were not available. These estimates were developed to be consistent with the USGS data available at upstream and downstream stations.

These historical inflows represent flows during a changing level of water resource development. During the early years of the 1898-1968 record period considered, water resource developments were few and depletions to the water supply were nominal or nonexistent. However, in the later years of the period, water resource developments and resulting streamflow depletions were essentially equal to those present at the 1970-level of development. In order to provide a consistent series of monthly flow records for the 1970-level, it was necessary to adjust the historical flows to represent flows that would have occurred had the 1970-level projects been in full operation for the entire period, 1898-1968. Since many of the adjustments were the average value for a particular month for the entire period, it was necessary to modify the adjustments to recognize the variation in water supply from year to year. This was accomplished by means of abbreviated reservoir regulation studies for each reach which considered several factors.

a. Amount of multiple-purpose reservoir storage in the reach in 1970 (exclusive of flood control storage and inactive storage).
b. Maintenance of specified minimum flows for water quality control and water supply.
c. Limitations on the maximum percentage of the reach inflow that could be depleted each month.

This abbreviated study resulted in a series of monthly depletion estimates, or streamflow adjustments, which averaged essentially the same as the average annual values listed in table 16, but varied month by month during the 1898-1968 period, depending on water supply and the above factors.

The 1970-level main stem reservoir regulation study was conducted several years after initiation of the 1970-level depletion study and after the Resources Development Work Group has rescheduled, based on later information, several of the projects. In order that the Missouri River main stem reservoir regulation study would be reasonably consistent with the project schedule envisioned by the Resources Development Work Group, several adjustments in the timing of the previously assumed project developments were made. This involved transferring the Garrison Diversion Initial Unit, Mid-State Division, North Loup Division, and Narrows Unit from the 1970 development level to the 1980 development level. Depletions by the other reservoir projects which the Resources Development Work Group rescheduled from 1970 to 1980 were relatively minor (reservoir evaporation only) and rescheduling of these projects was ignored for purposes of conducting the 1970 reservoir regulation study.

Monthly evaporation rates for the main stem reservoirs were obtained from the working paper on Evaporation by the Work Group on Hydrologic Analyses and Projections. The selected annual net evaporation (lake evaporation plus runoff minus precipitation) depths for normal climatic periods are as follows:

Fort Peck	27.5 inches
Garrison	20.0 inches
Oahe	20.0 inches
Big Bend	19.5 inches
Fort Randall	19.0 inches
Gavins Point	18.0 inches

For the extreme drought period of 1930-1941, detailed estimates of evaporation were made, considering wind velocity, humidity, temperature, and precipitation data actually observed in the vicinity of the reservoir areas during the drought period. Monthly distribution of the annual evaporation was based on an analysis of available reservoir surface temperature and precipitation data.

Storage space has been provided in certain USBR tributary reservoirs which will be regulated to replace annual flood control and multiple-use space in the main stem system. With this space available, it is possible to regulate individual main stem reservoirs at a higher level when an adequate water supply is available with no adverse effects on the system's flood control function. It was assumed in this study that 1,200,000 acre-feet of replacement storage space would be available in the year 1970, located primarily in Canyon Ferry and Tiber reservoirs. The availability of this replacement storage space effectively increases the system storage at the base of the annual flood control and multiple-use zone by a corresponding amount or, under the 1970 conditions, from 58,800,000 acre-feet to 60,000,000 acre-feet.

The nameplate ratings of power installations at each plant as used in this study were as follow:

Fort Peck	165,000 kw
Garrison	400,000 kw
Oahe	595,000 kw
Big Bend	468,000 kw
Fort Randall	320,000 kw
Gavins Point	100,000 kw
TOTAL	2,048,000 kw

The maximum peaking capabilities of the powerplants were limited to the greater of either (a) the maximum which has been actually experienced, or (b) 107.5 percent of the nameplate capacity, with the exception of Big Bend and Gavins Point. At Big Bend, a maximum capability of 115 percent of nameplate was assumed, while at Gavins Point the nameplate capacity was considered the maximum. Actual maximums assumed at each plant were as follow:

Fort Peck	205 megawatts
Garrison	460 megawatts
Oahe	660 megawatts
Big Bend	538 megawatts
Fort Randall	360 megawatts
Gavins Point	100 megawatts
TOTAL	2,323 megawatts

Maximum permissible mean daily release rates used for this study, on the basis of present information on non-damaging downstream channel capacities, were as follow:

	Daily Mean CFS During	
	Open Water	*Ice Cover*
Fort Peck	25,000	12,500
Garrison	75,000	30,000
Oahe	100,000	Powerplant Capacity
Big Bend	100,000	Powerplant Capacity
Fort Randall	100,000	15,000
Gavins Point	100,000	*

*15,000 cfs from Fort Randall plus intervening inflow.

No limitations were placed on daily powerplant peaking operations as a result of ice cover conditions, except at Gavins Point. Gavins Point peaking was limited to not more than 40 percent departure from the mean release or to 66 megawatts, whichever is greater, in order to avoid objectionable surges downstream. Minimum permissible mean daily release rates, selected for this study largely on the basis of water intake and power peaking requirements, were as follow:

Fort Peck	3,000 cfs
Garrison	6,000 cfs
Oahe	6,000 cfs
Big Bend	6,000 cfs
Fort Randall	3,000 cfs
Gavins Point	3,000 cfs

At all reservoirs above Fort Randall, selected minimum releases in the study were more than adequate to meet estimated water quality requirements in the affected downstream reaches. During the navigation season, the required releases from Fort Randall and Gavins Point were well in excess of those required for such purposes. During the non-navigation season, releases from Fort Randall in excess of the selected minimum were scheduled when necessary to maintain the variable minimum water quality control requirements at Sioux City, Omaha, or Kansas City, whichever was controlling at the time. The maximum water quality control flow requirements utilized were 3,000 cfs at Sioux City, 7,500 cfs at Omaha, and 9,000 cfs at Kansas City. Maximum requirements would be applicable for the summer months, June through September. During the winter period, December through February and the month of May, requirements were 60 percent of the maximum and during the remainder of the year 45 percent of the maximum. These requirements were established by consideration of current sewage treatment practices along the river and maintenance of satisfactory dissolved oxygen levels in the river and provide an interim level of water quality control. Projected requirements for the 1980, 2000, and 2020 levels of development differ from those used in the 1970 study and should not be considered to be a demand in lieu of providing effluent treatment which will meet the standards established for all water users.

The authorized 9-foot deep by 300-foot wide navigation channel on the Missouri River from Sioux City to the mouth is still under construction. Until this construction is completed and sufficient time elapses for the river to complete the work of forming the navigation channel, the exact magnitude of flows required for satisfactory navigation cannot be determined. Operating experience to date has indicated that increased flow levels are required to maintain similar loading depths as one progresses downstream in the navigation project. While no increase appears necessary between Sioux City and Omaha, the increase amounts to 6,000 cfs between Omaha and Nebraska City and 4,000 cfs between Nebraska City and Kansas City. The main stem reservoirs are currently being regulated to provide these increased flow levels at these locations and the 1970-level regulation study assumes the requirement will continue. As yet, no flow increase other than that which naturally occurs has been established for points below Kansas City. The 1970-level main stem reservoir regulation study utilized navigation flow rates of 25,000 to 31,000 cfs at Sioux City and Omaha, 27,000 to 37,000 cfs at Nebraska City, and 31,000 to 41,000 cfs at Kansas City, depending on the status of storage in the main stem reservoirs. Flows above these levels would benefit navigation by minimizing dredging and permitting greater loading depths. Regulation experience has also indicated that only a portion of the runoff which originates in the respective reaches below Gavins Point Dam can be effectively used in meeting downstream target flows; this factor was considered in the studies. Any deficiencies in the reach inflows below the required target increments must be supplied by reservoir releases.

The level of navigation flows to be maintained, between the minimums and the assumed maximum beneficial rates, was assumed to be a function of system storage on 1 March and on 1 July. Selected criteria allowed an increase or decrease in rates at these times. The length of the navigation season was established on the basis of total system storage at the end of each month during the period, March through June. Any required shortening of the season was made at the end of the season. In this manner, the season would always open on 1 April at the mouth of the Missouri River, but could be shortened to close before the 8-month, 1 December date. Shortening of the season, when necessary, was made by quarter-month increments. Flow levels during shortened seasons were always at the established minimums.

Additional rules relating to the length of the navigation season which were incorporated in the criteria were as follow:

a. At least 1 month's notice must be provided before the navigation season is lengthened. For example, if indications on 30 June are that the navigation releases should end on 31 July, the season will not be extended beyond 31 July, even though storage on this latter date would indicate an extension was possible.

b. At least 2 month's notice must be provided before the navigation season is shortened. For example, if, on 30 April, the table indicates that navigation releases should end on 31 July, the season will not be shortened prior to this date on the basis of storage on 31 May.

c. An exception to previously stated criteria concerning the ending date of the navigation season was that, if inflows and storage balance among the projects were such that the maintenance of a navigation season length of less than 8 months required system releases in excess of the minimum navigation level, the season was lengthened to the extent necessary to restore the required storage balance while maintaining minimum navigation flows.

The selected maximum releases for all projects above Gavins Point were assumed to provide effective flood control regulation through their immediate downstream reaches. At Gavins Point, the flood control function of the system was recognized by limiting releases throughout the entire record period to the levels which were considered necessary for flood control purposes. During the navigation season, this flood potential was defined by the antecedent precipitation index (API). For study purposes, this potential was converted into limiting flows at Sioux City, month by month, through the entire period of record.

Prior to 1 August, system releases in excess of those assumed to provide the maximum beneficial service to the navigation function were made only after it became apparent that sufficient storage had been accumulated in the annual flood control and multiple-use zone of the system to satisfy all conservation requirements to the succeeding 1 March. After 1 August, system releases in excess of those needed for navigation were made only when they appeared necessary to evacuate the annual flood control and multiple-use storage space prior to the succeeding 1 March. During the non-navigation season system releases were a function of system storage at the end of the navigation season during all years that an 8-month season was provided. These criteria resulted in non-navigation releases from Fort Randall approximating 20,000 cfs less than average flows maintained at Sioux City during the preceding navigation season. Since average navigation flow levels at Sioux City ranged from 25,000 to 35,000 cfs, non-navigation season flows at Sioux City following an 8-month navigation season ranged between 5,000 and 15,000 cfs. If it was necessary to reduce the length of the navigation season to less than 8 months, subsequent non-navigation season releases from Fort Randall were 3,000 cfs unless higher releases were required to supply water quality control requirements. Gavins Point passed the Fort Randall releases plus the incremental runoff between these two projects.

At the beginning of the study, storage in each reservoir was assumed to be at the base of the annual flood control zone. Regulation of the specific projects comprising the system was based on target storage levels for each of the projects and the system as a whole. These targets were utilized to maintain balanced system storage insofar as practical, and represent desirable storage levels on the following 1 March date, provided that, in their attainment, other criteria governing system regulation could be met. The system target storage level was defined as the succeeding 1 March storage level which would occur with the current navigation level provided subsequent inflows to the system were normal. The maximum system target was represented by storage at the base of the annual flood control and multiple-use space. Targets at Big Bend, Fort Randall, and Gavins Point were always at the base of their annual flood control and multiple-use space. Storage targets at the other projects were related to the system target. Targets were computed at the beginning of each monthly time period through the study and the difference between the actual storage and the target sotrage was used for scheduling releases above selected minimum values from the projects. During all years with 8-month navigation seasons, winter releases from both Fort Peck and Garrison were limited to 12,500 cfs and 30,000 cfs, respectively. These are the maximum winter releases that can assuredly be made under ice, although actual operations in some years have demonstrated that releases approaching powerplant capacity from both projects are possible for extended periods under stable ice conditions without causing flooding. With less than 8-month navigation seasons, winter releases from these two projects (above established minimums) were based on assumed power requirements. As a further means of increasing the winter power generation, the Fort Randall pool was drawn down to elevation 1320, some 30 feet below its normal level, starting 3 months before the end of the navigation season. Its refill during the winter months allowed greater releases and corresponding generation from the upstream projects than would have been possible if the drawdown had not occurred.

The generation of energy also affected the rate at which releases were made from specific projects other than Fort Randall and Gavins Point. Energy requirements could increase the level of powerplant releases at any of the upstream projects, subject to flow restrictions under ice. Specific energy targets for each period examined were developed from seasonal load curves furnished by the Bureau of Reclamation, these targets being dependent on the navigation flow level being maintained and, when a season of less than 8 months occurred or was anticipated, the targets were dependent on the length of the navigation season.

Conclusions, resulting from an analysis of this study, are as follow:

a. The study demonstrates that the reservoir system with the assigned flood control storage capacities was fully effective for flood control for all runoff conditions experienced during the 1898-1968 period, as adjusted to the 1970 level of basin development. A reserve of exclusive flood control storage space was maintained at all times while maximum releases were limited to less than 25,000 cfs from Fort Peck and less than 75,000 cfs from Garrison. Sioux City flows were at all times at or below the level permitted by the downstream flood potential, and storage was evacuated to near or below the base of flood control (with allowance for replacement storage space) prior to the spring flood season of each year.

b. Sufficient releases were maintained from the reservoirs to meet any requirements for irrigation at or below the projects. The effects of 1970 irrigation projects on inflows to the system and releases from the system were considered throughout the study. No large-scale irrigation projects utilizing water directly from the reservoirs were in operation.

c. Navigation flows of 25,000 to 35,000 cfs at Sioux City were maintained for full 8-month navigation seasons, 23 March through 22 November, for 66 years of the 71-year study. As a result of drought conditions in the 1930's, navigation seasons of less than 8 months' duration with navigation flows at minimum rates (25,000 cfs at Sioux City) occurred for 5 years of the study. The minimum length of the navigation season was 6-3/4 months. The distribution of navigation season lengths through the 1898-1968 period is shown by the following tabulation:

Season Length, Months	*Years Experienced*
8.00	66
7.75	1
7.25	1
7.00	1
6.75	2
TOTAL	71

d. Water quality requirements on the Missouri River were met throughout the study period. During all years with full 8-month navigation seasons, and in all years during the navigation season, releases for other purposes exceeded these requirements. However, during non-navigation periods following periods when less than an 8-month navigation season had been provided, these water quality requirements established the system releases. This occurred in 5 out of 71 years.

e. The nameplate output and the December peaking capability at the end of the fourth year of the drought of the 1930's (December 1933) are as follow:

	Nameplate Rating (1,000 kw)	*December 1933 Capability (1,000 kw)*
Fort Peck	165	185
Garrison	400	399
Oahe	595	526
Big Bend	468	538
Fort Randall	320	277
Gavins Point	100	66
System Total	2048	1991

f. Average annual energy generation for the entire period and the generation for the fourth year of the drought (1933) are summarized as follow:

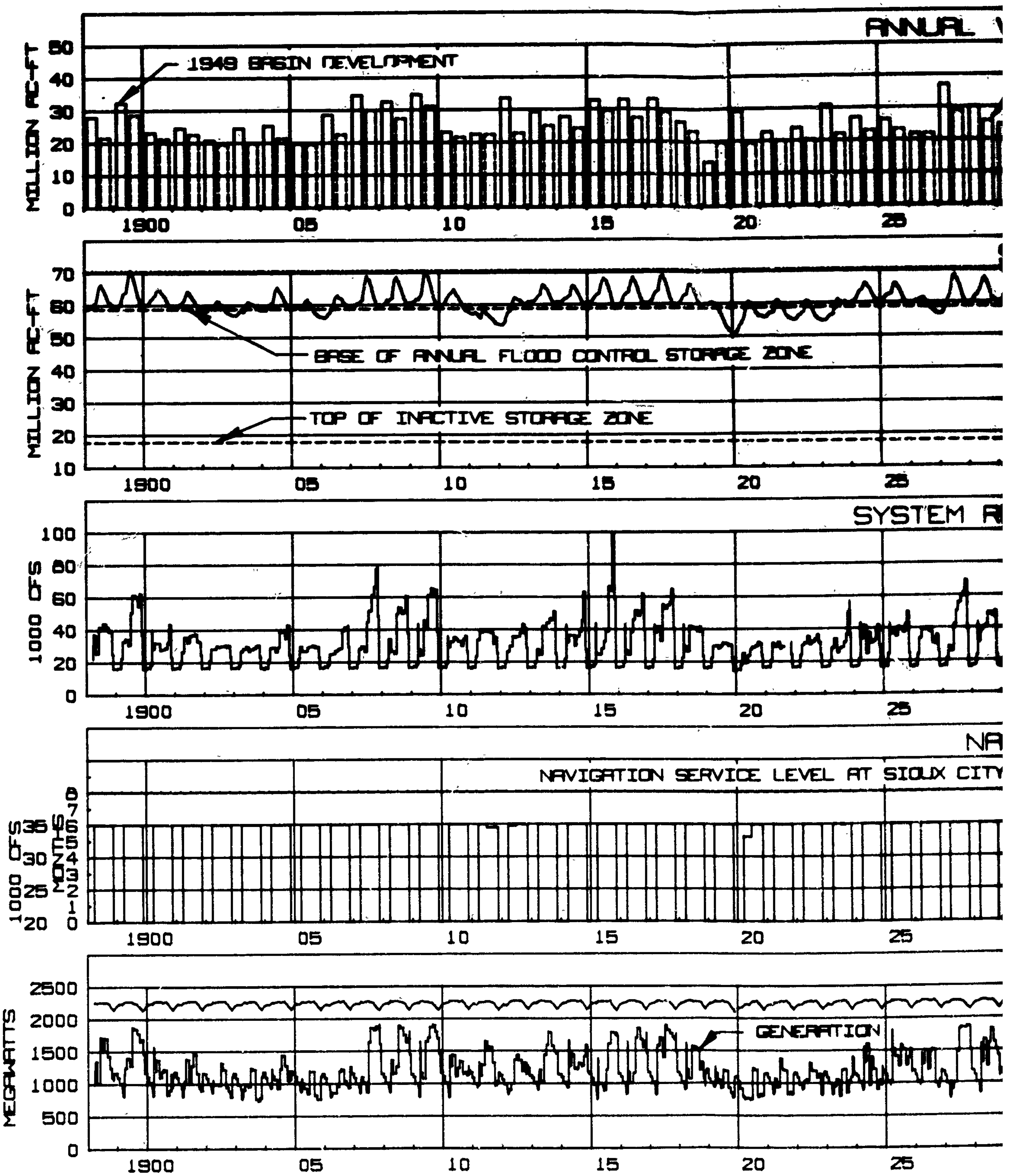
	Average Annual Generation (Million kwh)	*1933 Energy (Million kwh)*
Fort Peck	1008.2	738.5
Garrison	2312.8	2001.9
Oahe	2647.1	2093.8
Big Bend	1001.7	889.8
Fort Randall	1614.3	1449.9
Gavins Point	646.3	599.5
System Total	9230.4	7773.4

g. The average monthly distribution of system energy and peaking capability for the entire record period and for the fourth year of the drought (1933) are as follow:

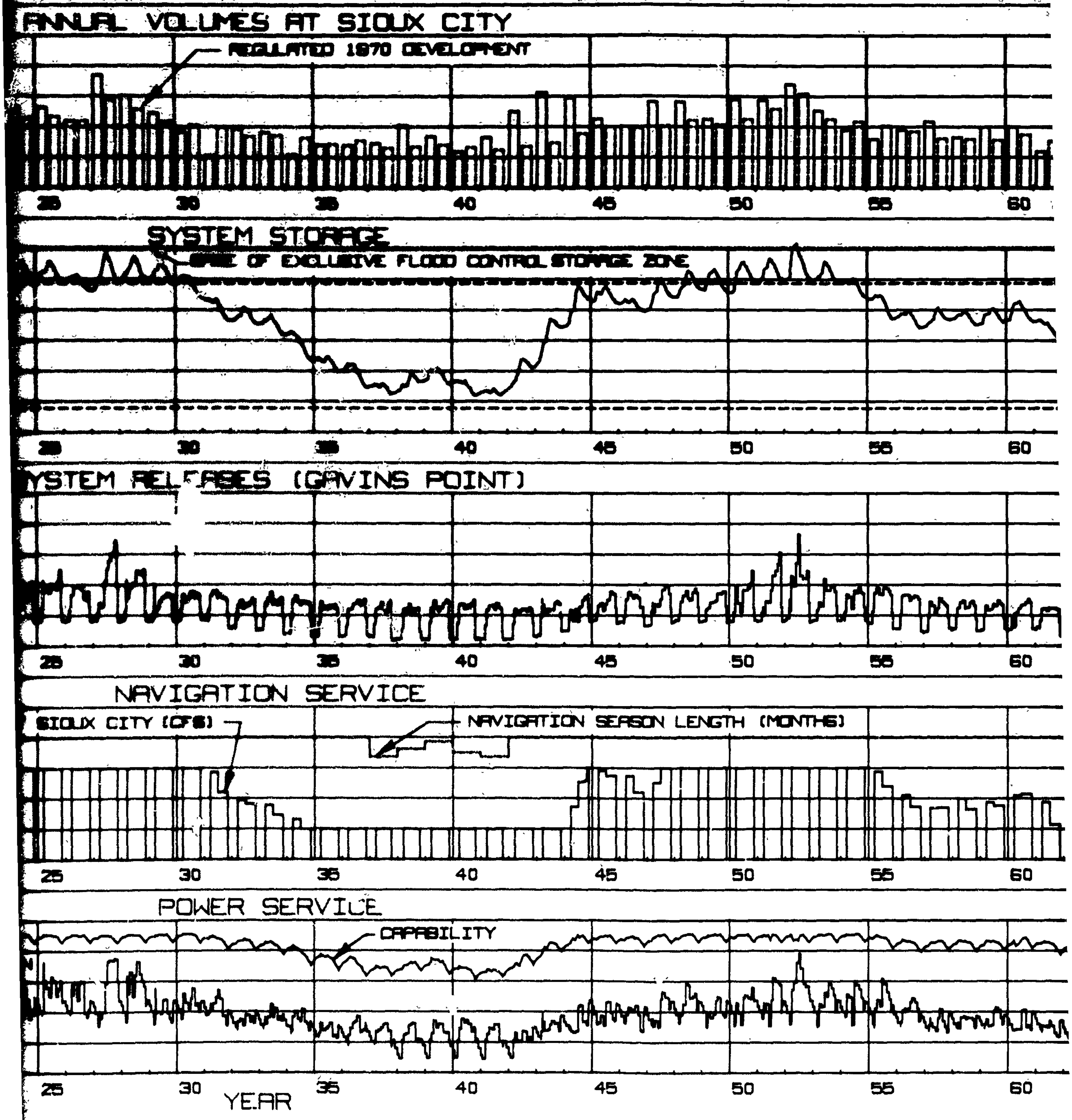
Month	Average 1898-1968		1933	
	Generation (Million kwh)	Peaking Capability (mw)	Generation (Million kwh)	Peaking Capability (mw)
16-31 March	358	2178	329	2148
April	723	2181	581	2137
May	773	2182	679	2140
June	742	2189	808	2132
July	922	2187	673	2104
August	958	2185	782	2085
September	800	2151	624	2055
October	803	2104	680	2006
1-15 November	367	2072	306	1969
16-30 November	390	2062	337	1940
December	778	2113	643	1991
January	720	2139	579	2025
February	596	2146	516	2042
1-15 March	300	2148	236	2053
	9230		7773	

Salient features of this study are shown in graphical form on plate 18. These include a comparison of the annual volumes at Sioux City at the approximate 1949-level of water resource development, uncontrolled by the main stem reservoirs, and the controlled annual volumes at this location. System storage at the 1970-level is shown through the 1898-1968 period indicating an essentially filled system with the exception of the severe drought period of the 1930's, when storage levels approached the minimum carry-over levels, and the moderate drought of the late 1950's and early 1960's when a significant decrease in storage levels occurred. System releases (Gavins Point outflows) reflect the cycle between navigation and non-navigation releases and also indicate the years when high releases were required to evacuate storage for flood control purposes. The graph showing service provided the navigation function illustrates the essentially full service which was provided with the exception of the drought periods referenced previously when the service level (as indexed to average navigation season flows at Sioux City) was reduced and, in the case of the 1930 drought, the season length reduced in five of the drought years. The graph of power service illustrates the level provided through the record period, the reduction in energy generation which accompanied the two drought periods, and the significant reduction in capability which occurred as a result of the 1930 drought. While masked at many ti .es due to releases required for other purposes, the energy load curve assumed for these studies can also be discerned from the seasonal pattern of energy generation. Criteria for firm power sales from the main stem reservoir system are nominally based on the peaking capability at the end of the fourth year of the drought of the 1930's (December 1933) and on average annual energy generation. Capability in excess of firm power sales would be available for disposal as peaking power.

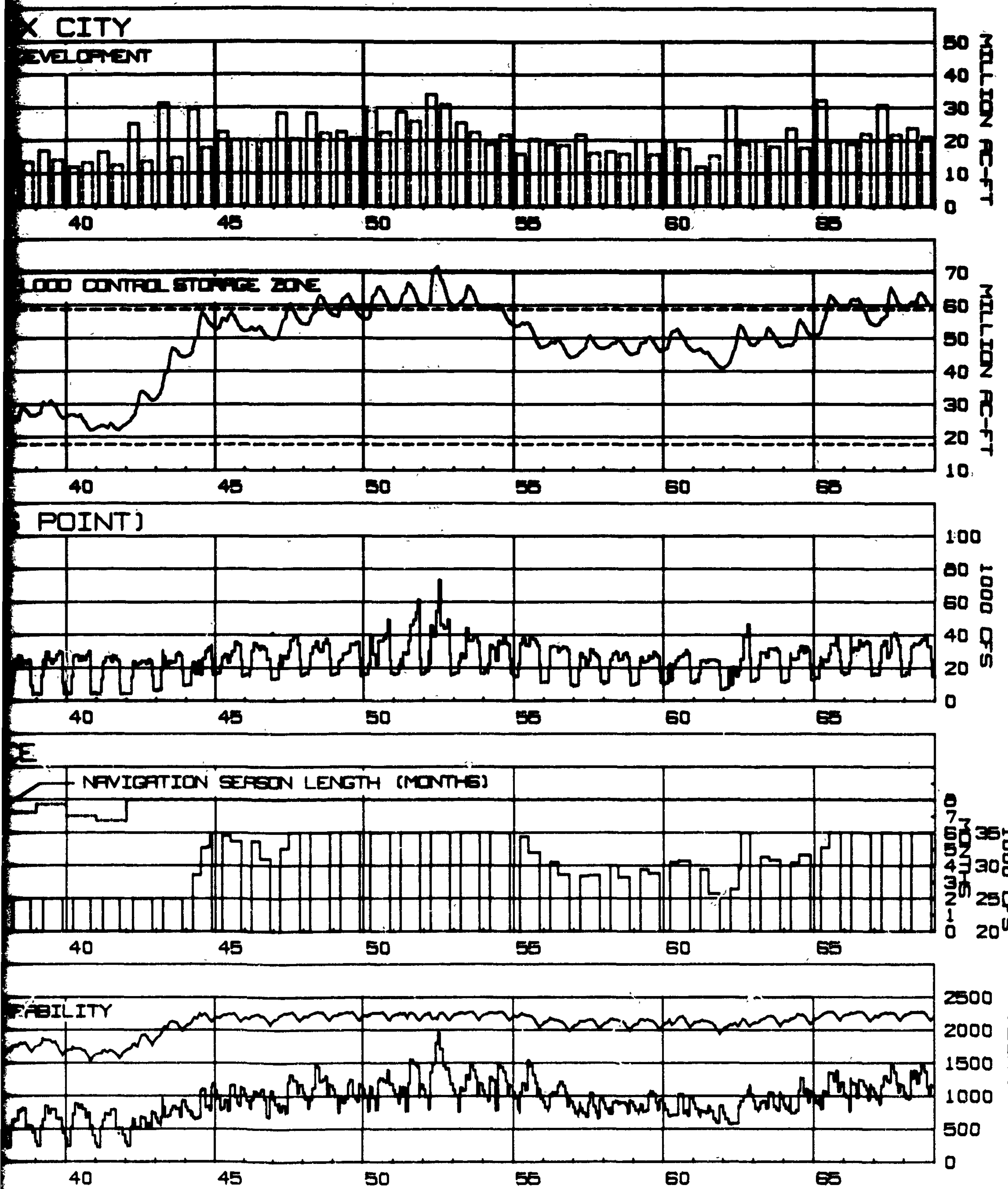
Detailed results of this study, month by month through the 1898-1968 record period, and summarizations of these and other elements of the study are on file in the Reservoir Control Center, Missouri River Division, Corps of Engineers.



MISSOURI RIVER MAIN STEM RESERVO



SERVOIR OPERATIONS FOR 1970 LEVEL OF DEVELOPM



NS FOR 1970 LEVEL OF DEVELOPMENT

PLATE 18

CHAPTER 7

GROUND-WATER AVAILABILITY

SIGNIFICANCE OF GROUND WATER

Compared to a mighty river serving as an artery of commerce, or even to a babbling brook in a sylvan setting, ground water is quite unspectacular. Filling openings in the rocks beneath the land surface, it is almost everywhere hidden from view. Only in the few places where it erupts in geysers or flows from springs does it attract attention. Results of its use, however, often may be spectacular. Great satisfaction may be derived from the sight of lush crops irrigated with water from wells, or from the knowledge that a community's ground-water supply will be dependable even through protracted periods of drought.

Despite its unimposing nature, ground water has played and will continue to play an important role in the economic development of the Missouri Basin. Its widespread occurrence in quantities sufficient for domestic and livestock needs has enabled agriculture to expand into areas remote from perennial streams. Its great abundance locally has permitted municipal, industrial, and irrigation development in many places where supplies of surface water were inadequate for these purposes. Except for ground water, which provides a base flow, many surface streams would flow only after runoff-producing precipitation. Ground water is less likely to be contaminated than is surface water, its chemical quality and temperature are more uniform, and it is practically free of sediment. Protected from the elements, it constitutes a water supply equally reliable throughout all seasons of the year.

HYDROLOGIC PRINCIPLES

Terminology

Of the water beneath the land surface, only that in permanent or virtually permanent zones of saturation is called ground water. Soil moisture and water in other ordinarily nonsaturated zones are not included. In a few localities, the top of a saturated zone may coincide with the land surface; but in most places, water-saturated rocks can be reached only by digging or drilling down to them.

Any saturated material through which water moves fast enough so that water can be produced from wells is termed an aquifer. Saturated rocks through which water moves so slowly that they are not capable of yielding water to wells and which retard the movement of ground water from one aquifer to another are called aquitards. Aquitards may contribute to the available water supply by very slow drainage into adjacent aquifers from which water is being withdrawn. Saturated rocks through which there is practically no ground-water movement are called aquicludes. Aquicludes yield practically no water to wells, they yield practically none to adjacent aquifers, and they constitute effective barriers against movement of ground water from one aquifer to another.

If not overlain by an aquiclude, the uppermost aquifer at a given locality is referred to as a water-table aquifer, and the water in it is said to occur under water-table conditions. In a well that taps such an aquifer, the water level coincides with the water table at the well site. Aquifers that are overlain and underlain by aquitards or aquicludes contain water that is confined under pressure and are referred to as artesian aquifers. If the pressure is great enough, water will flow from the top of a well tapping an artesian aquifer. When the first wells were drilled into the Dakota Sandstone beneath the James River valley in eastern South Dakota, natural pressure was sufficient to produce flowing wells throughout the area. With the drilling of each new well the natural pressure has progressively decreased and water levels have dropped. Pump lifts of 100 feet or more are now required, in many locations, to raise the water to the land surface.

Some of the water contained by rocks is connate; it has been in the rocks since they were first formed. Some is the result of downward transfer of moisture from the land surface. Much of the water now in the rocks has entered them since their formation; and in most places, the uppermost ground water is at least partly water that was recently on the land surface. Transfer of water from the land surface to the zone of saturation is referred to as recharge. It is natural recharge if it is due to natural infiltration of precipitation and influent seepage from streams. It is artificial recharge if due, accidentally or intentionally, to the results of man's distribution and use of water.

Relative Capacity of Aquifers

Unconsolidated coarse-grained sediments such as well sorted sand and sandy gravel have the greatest capacity for both storing and transmitting water; and, accordingly, they make the most productive aquifers. The tremendous storage and transmitting capacity of unconsolidated deposits of sand and sandy gravel is demonstrated by the several thousand irrigation wells, each commonly yielding 700 to 1,500 gallons per minute, in south-central Nebraska. Consolidated coarse-grained sediments such as sandstone and conglomerate also may be good aquifers if the intergranular spaces are only partly filled with the cementing material.

Unconsolidated fine-grained sediments such as silt and clay and their consolidated equivalents such as siltstone, shale, and mudstone may have a storage capacity as great as that of the coarse-grained sediments, but they transmit water much less readily. Accordingly, they ordinarily are not good aquifers.

When newly formed, most carbonate rocks had practically no capacity to store and transmit water. Some have been transformed into important aquifers, however, as a result of recrystallization, development of fracture systems, and solution activity. Limestone aquifers generally have rather small storage capacities but great capacities to transmit water. Big Spring near Toston, Mont., with a fairly constant flow of about 27,000 gallons per minute, is believed to issue from an extensive solution channel in the Madison Limestone. Success in obtaining a water supply from a limestone aquifer ordinarily depends on whether the drill intersects one or more solution channels or open fractures. Dolomite, also a carbonate rock, may have a moderately high capacity to store water and to yield it to wells.

Few metamorphic or igneous rocks can store or transmit large quantities of water. Most are fractured to some degree, however, and in some places may yield enough water for domestic needs. Success in obtaining water from these rocks depends on the degree of openness and the number of water-filled fractures that are penetrated in drilling. Failure to obtain adequate supplies of water from these rocks is fairly common.

Ground-Water Movement and Discharge

All water in the zone of saturation is moving toward points of discharge at the land surface. Direction of movement is the same as the direction of decreasing head. The rate of movement is very slow, generally ranging from a small fraction of an inch per day to no more than a few feet per day. Natural discharge of ground water occurs continuously. Flowing springs and gains in the fair-weather flow of streams are visual evidence of natural ground-water discharge. Less apparent is the extraction of ground water by plant roots where the water table is near the land surface. Practically all ground-water discharge occurs in valley areas. Where valley bottoms are broad and flat and the water table is within a few feet of the land surface, discharge through evapotranspiration may greatly exceed ground-water discharge into stream channels.

Ground-Water Recharge

Basinwide, the principal source of ground-water recharge is precipitation that infiltrates the ground at or near the point where the precipitation falls. In any locality, intensity and amount of precipitation, absorptive capacity of the soil, vegetation, and topographic characteristics are all factors that influence the amount of recharge from this source. Seepage from stream channels is another source of ground-water recharge. Also, in floodplain areas, the quantity of recharge resulting from temporary flooding may greatly exceed that resulting from precipitation over the same area during several months or even years.

Some ground-water recharge is artificial, resulting from works or actions of man, and it may be either unintentional or deliberate. Seepage from canals and reservoirs, blockage of natural ground-water outlets by reservoir impoundments, leakage from water-distribution systems, and outflow from septic tanks are all examples of unintentional ground-water recharge. Such recharge has occurred in nearly all areas irrigated with diverted streamflow; in fact, the water table in some irrigated areas has risen enough to cause waterlogging. An outstanding example of unintentional recharge exists in Gosper and Phelps counties, Nebraska, where seepage from the water-distribution system of the Central Nebraska Public Power and Irrigation District has caused a water-table rise of more than 60 feet under parts of the area.

Deliberate recharge of aquifers is practiced at only a few localities in the Missouri Basin. Some areas adjacent to streams are flooded, by pumping from the streams during periods of high flow which exceeds the demands of downstream users, in order to add to ground-water storage beneath the land. Later, when all streamflow is needed to supply downstream users, the water added to ground-water storage can be salvaged by pumping from wells. An artificial recharge project under construction at Lincoln, Nebr., will provide for injection of water into the underlying Dakota Sandstone, during the cooler months of the year, thereby creating a supply that can be pumped during hot weather to help meet peak demands. Water injected into the sandstone will be from the city's main supply, which is conveyed by pipeline from a well field on the Platte River 30 miles to the northeast. Another type of artificial recharge is under consideration for the well field itself. It will involve diversion of Platte River flows into man-made recharge ponds within and adjacent to the well field, thus lessening dependence on infiltration from the river for maintenance of the supply.

Experiments now underway near Burlington, Colo., involve killing vegetation and spreading a 1-inch layer of gravel over the experimental area to induce greater recharge from precipitation. The gravel mulch prevents rapid runoff and decreases evaporation losses. Preliminary results of these experiments indicate that ground-water recharge from precipitation can be increased several-fold in this way.

A tremendous quantity of water flows out of the Missouri River Basin each year. Additional opportunities exist, accordingly, for spreading floodwaters or other surplus waters to induce greater ground-water recharge. While the cost of diverting streamflow to sites where artificial recharge is practicable has largely limited such development to date, some conjunctive-use operations for surface and ground waters already exist. One large irrigation system of this type has been authorized for development to overcome current ground-water depletions and to stabilize the ground-water level for continued use for all purposes.

Discharge-Recharge Balance

Under natural conditions, with no pumping from wells and no artificial recharge, the average annual recharge balances the average annual discharge of ground water. Short-term rates of discharge and recharge, however, are rarely the same, since discharge is continuous whereas recharge is intermittent. This imbalance is reflected in short-term fluctuations in the water table and in the quantity of ground water in storage. The annual range of natural water-table fluctuation may be only a few inches in broad intervalley areas where the depth to water ordinarily is substantial, but it may be several feet in valley areas where the water table is nearer to the land surface and where rates of both natural discharge and natural recharge ordinarily are greatest.

Pumping from wells affects the natural long-term balance between discharge and recharge of ground water. When the quantity of water pumped is small, the effect is virtually negligible unless the quantity of ground water in storage also is small. When annual pumpage is large, however, lowering of the water table is the inevitable result. The commensurate decrease in the volume of ground water in storage is progressive unless a new balance between discharge and recharge can be established through decreasing the rate of natural discharge, increasing the rate of recharge, or both. Where a good hydraulic connection exists between a stream with a perennial strong flow and an aquifer with the capacity to transmit water rapidly, for example, pumping from wells close to the stream may induce a compensatory increase in the rate of seepage from the stream such that even large-scale pumping will not create a significant imbalance between discharge and recharge.

In many areas, however, the withdrawal rate from wells is so great that establishment of a new balance between discharge and recharge is not possible. This situation is already developing in some of the High Plains area where withdrawals for irrigation greatly exceed the combined effects of increased recharge and decreased natural discharge. Curtailment of withdrawals is the only feasible solution, and this is the natural economic result as the cost of withdrawals increases with depletion of the ground-water supply.

GENERAL AVAILABILITY OF GROUND WATER

Data Available

Springs and seeps, streams that continue to flow in dry weather, waterlogged soils, and stands of lush vegetation in a generally arid area are clues to the presence of ground water at shallow depth. They afford little or no indication, however, of the areal extent and thickness of the saturated rocks or of their capacity to transmit water to wells. Furthermore, an area may be underlain by thick water-bearing rocks with a surficial evidence thereof.

In some parts of the Missouri River Basin enough testholes and wells have been drilled so that subsurface conditions to depths of a few hundred feet are known in considerable detail. Information concerning the occurrence of ground water in the shallower rocks throughout the Kansas portion of the basin, most of the Missouri and Colorado portions, much of the Nebraska portion, and the southeastern Wyoming portion is presented in published reports. For the rest of the basin, detailed information concerning sources of supply shallower than 500 feet is available only for scattered areas or point locations. Considerable information on artesian aquifers at somewhat greater depths also has been published, principally for South Dakota but also for many localities in Montana, North Dakota, and Wyoming. The published reports vary in the amount of detail they contain. Some are of a reconnaissance nature, merely describing the geology and occurrence of ground water as deduced from observations of rock outcrops and an inventory of wells. Others contain extensive detailed information. Those describing ground-water resources most completely contain estimates of ground-water volumes based on systematic test drilling, evaluation of hydraulic properties based on aquifer tests and other data, records of pumpage and of water-level fluctuations during periods of several years, and estimates of aquifer response to projected water-supply developments. Few of the reports contain factual information concerning the water-supply potential of aquifers not already tapped by wells.

In nearly all of the basin states, most of the available data concerning ground water has been collected during studies financed jointly by the U. S. Geological Survey and cooperating state agencies. Exceptions are Missouri, where most of the studies were made by the Missouri Division of Geology and Water Resources, and South Dakota, where many were made by the South Dakota Geological Survey prior to initiation of a Federal-State cooperative program in 1959. Many areal studies have been made by the U. S. Geological Survey in Colorado, Wyoming, Montana, the Dakotas, Nebraska, and Kansas as part of the Department of the Interior's program for development of the Missouri River Basin.

Estimates of ground-water availability presented later have been based, to the extent practicable, on the specific ground-water data that exist. In unstudied areas, they have been based on the best geologic and hydrologic data available. In some areas, the experienced geohydrologist may infer the ground-water potential with reasonable accuracy by integrating observed surficial evidence of saturated rocks with a knowledge of the lithic characteristics and structure of rock strata and an understanding of subsurface hydrology. In other areas, however, surficial evidence of saturated rock is lacking and data on subsurface conditions are so meager that the best current evaluations of ground-water resources must be regarded as highly tentative.

Ground Water Available to Wells

The quantity of water available to wells varies widely, in accordance with the hydraulic character of the underlying rocks. The estimated quantities available to wells throughout the Missouri Basin and the depth to water level for areas where water-depth data are available are shown by the map on plate 19.

This map shows areas where properly located and properly constructed wells generally are capable of yielding water at rates within certain specified limits. The water would be of a chemical quality satisfactory for most ordinary uses, since local areas in which large yields of salty or otherwise highly mineralized ground water may be available have been excluded from the map designations. The map does not indicate the total quantity of water that may be obtained at any specific locality or from any specific aquifer. Such determinations generally can be made only on the basis of special investigations.

The map indicates depths to water level only in areas where water-level data are available and the estimated yield per well exceeds 50 gallons per minute. In artesian areas, with favorable topographic conditions, wells may flow.

Ground Water in Storage

Approximate quantities of ground water in storage in selected areas of the Missouri Basin have been estimated from values of aquifer thickness, areal extent, and average storage coefficient, the latter being the volume of water that an aquifer releases or takes into storage per unit of surface area per unit of change in head. These estimated quantities are shown by the map on plate 20.

The quantities of water in storage in these areas are not necessarily proportional to the quantities of water that can be withdrawn. In some situations, as pointed out previously, withdrawals from an aquifer may cause a reduction in natural discharge or an increase in recharge, or both, and eventually a far greater quantity of water can be withdrawn than the amount that can be stored in an aquifer at one time. In other situations, the total quantity that can be withdrawn may be substantially less than the quantity in storage because the rate of yield to wells will progressively decline to the point that further withdrawals will become economically impracticable before storage is exhausted.

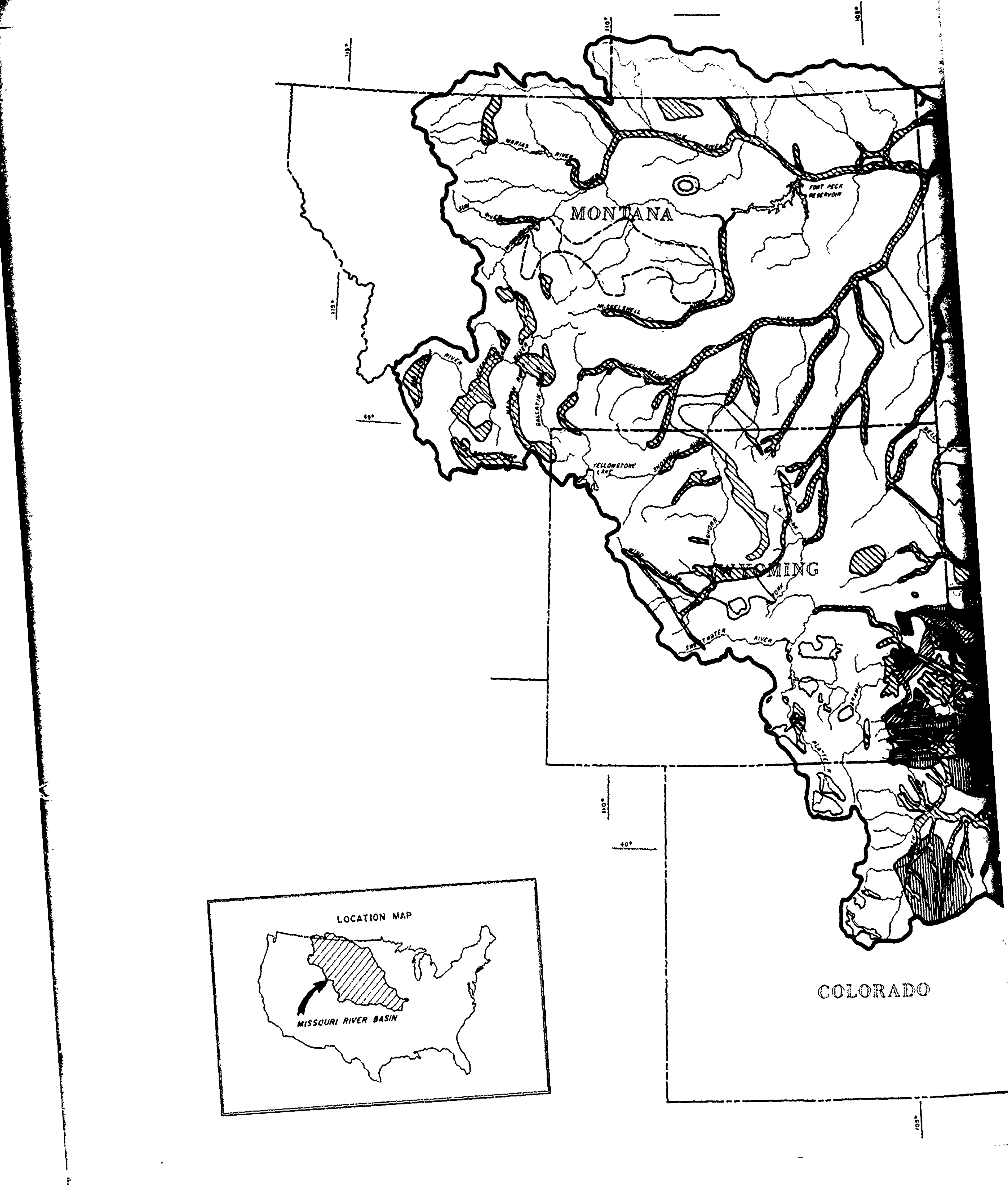
ANALYSIS OF PRESENTLY USED AQUIFERS

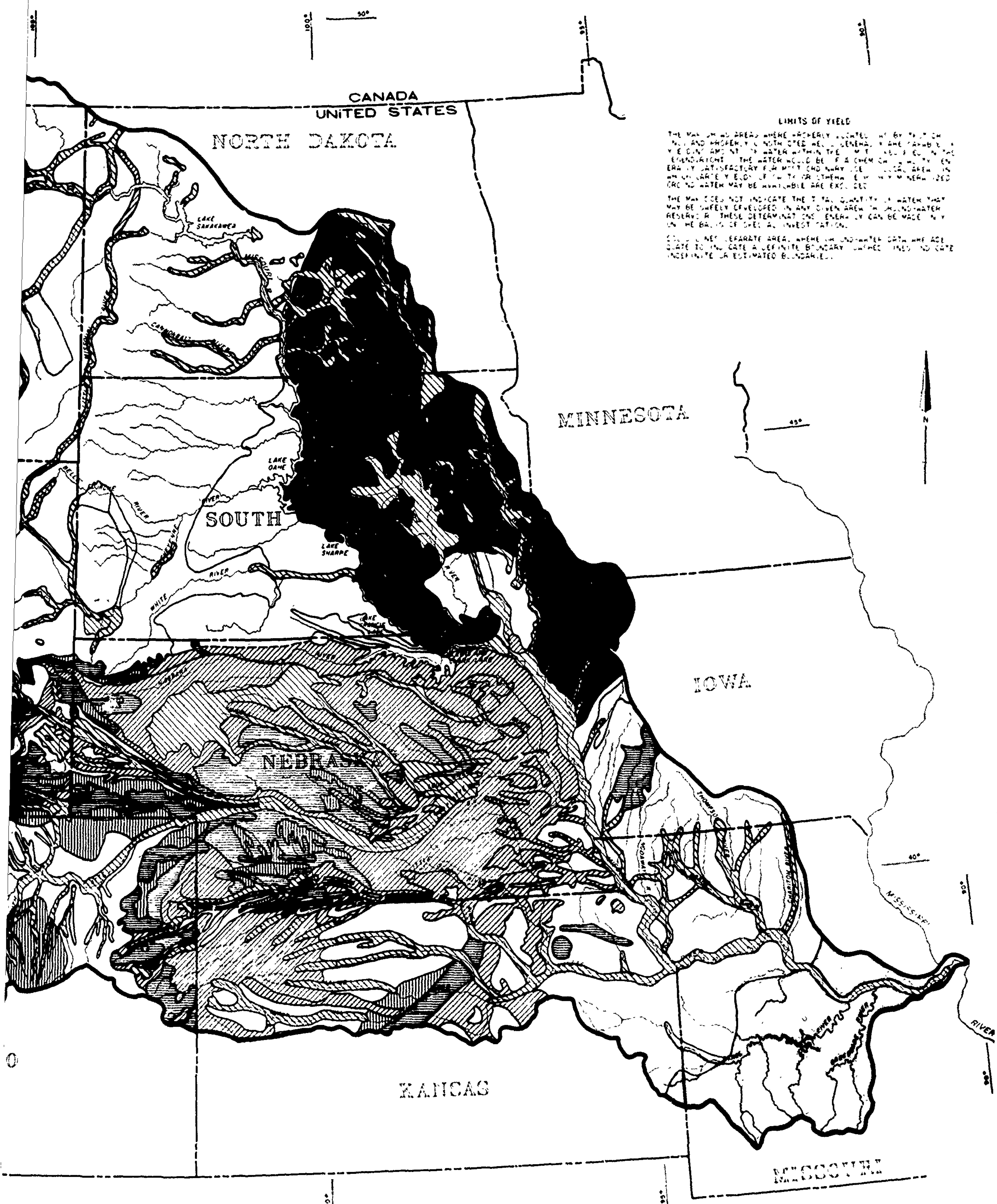
Generally, an aquifer may be regarded as important or potentially important if it contains water of good quality, if it yields water freely to wells or is capable of doing so, and if it currently has a significant quantity of water in storage. In some cases, however, aquifers without all these characteristics may be important for other reasons. An aquifer with only a meager quantity of water of marginal quality, for example, may be of great importance in an area where no better source of supply exists. Conversely, an aquifer with all these characteristics may be unimportant if its depth below the land surface is so great that the cost of water withdrawal makes such withdrawal economically impracticable.

The following descriptions of the more important water-bearing stratified rocks begin with the geologically youngest and conclude with the geologically oldest. This order is the same as that in which rocks ordinarily are penetrated during drilling at any specific site. A brief statement concerning the water-yield potential of extruded igneous rocks is included. Estimates of the quantity of water in storage are presented for many aquifers capable of yielding water to wells at rates of 300 gallons per minute or more.

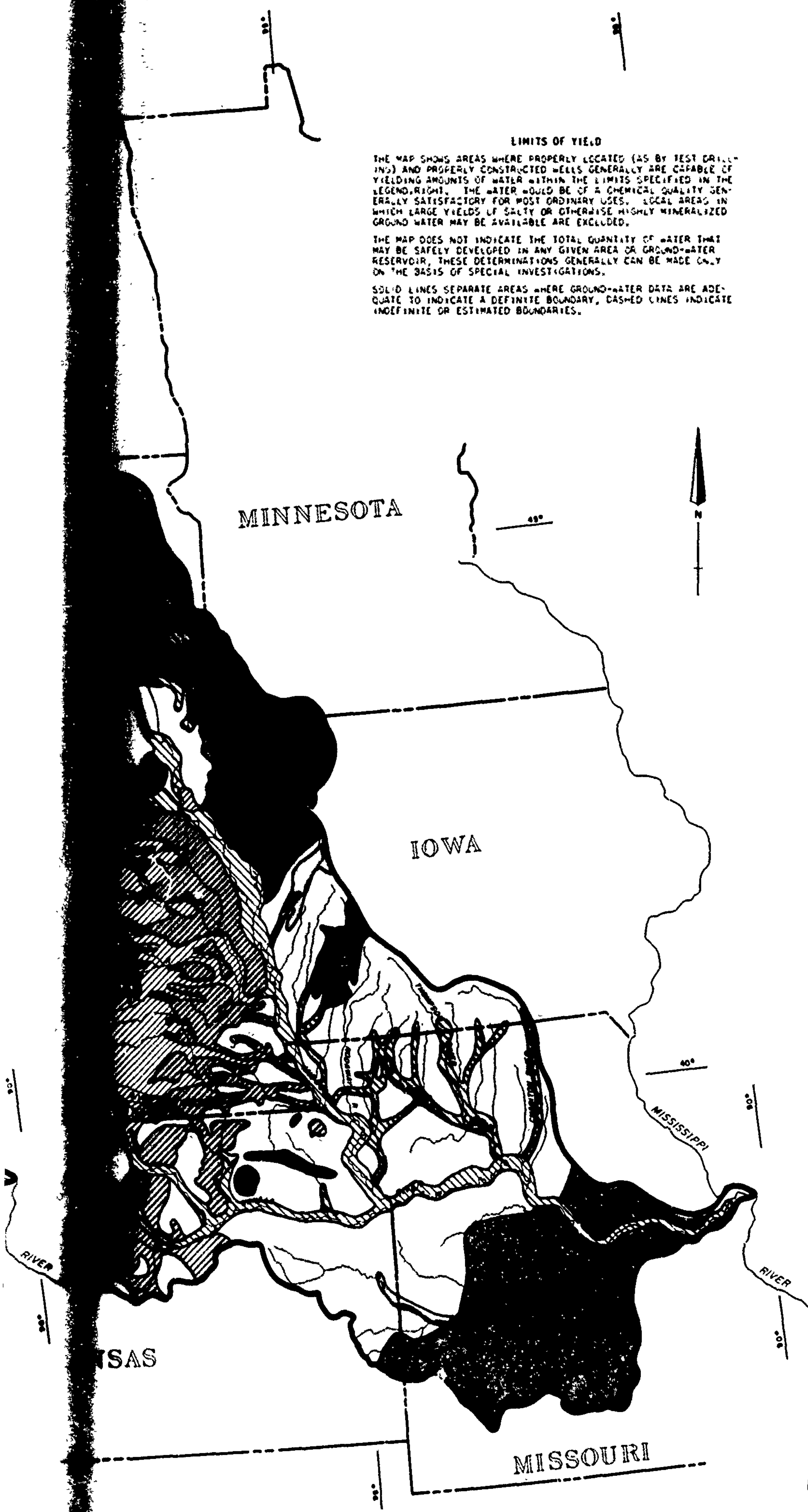
Rocks of Quatenary Age

Unconsolidated deposits of Quaternary age provide more than half of the water withdrawn from wells in the Missouri River Basin. These deposits are tapped by wells


MONTANA
WYOMING
COLORADO
MARIAS RIVER
FORT PECK RESERVOIR
MUSSELSHELL
GALLATIN
YELLOWSTONE LAKE
SWEETWATER RIVER
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
UNITED STATES
NORTH DAKOTA
LAKE SAKAKAWEA
CANNONBALL RIVER
MINNESOTA
LAKE OAHE
SOUTH
LAKE SHARPE
WHITE RIVER
IOWA
NEBRASKA
KANSAS
MISSOURI
LIMITS OF YIELD



LIMITS OF YIELD

THE MAP SHOWS AREAS WHERE PROPERLY LOCATED (AS BY TEST DRILLING) AND PROPERLY CONSTRUCTED WELLS GENERALLY ARE CAPABLE OF YIELDING AMOUNTS OF WATER WITHIN THE LIMITS SPECIFIED IN THE LEGEND, RIGHT. THE WATER WOULD BE OF A CHEMICAL QUALITY GENERALLY SATISFACTORY FOR MOST ORDINARY USES. LOCAL AREAS IN WHICH LARGE YIELDS OF SALTY OR OTHERWISE HIGHLY MINERALIZED GROUND WATER MAY BE AVAILABLE ARE EXCLUDED.

THE MAP DOES NOT INDICATE THE TOTAL QUANTITY OF WATER THAT MAY BE SAFELY DEVELOPED IN ANY GIVEN AREA OR GROUND-WATER RESERVOIR, THESE DETERMINATIONS GENERALLY CAN BE MADE ONLY ON THE BASIS OF SPECIAL INVESTIGATIONS.

SOLID LINES SEPARATE AREAS WHERE GROUND-WATER DATA ARE ADEQUATE TO INDICATE A DEFINITE BOUNDARY, DASHED LINES INDICATE INDEFINITE OR ESTIMATED BOUNDARIES.

LEGEND

BASIN BOUNDARY

STATE OR NATIONAL BOUNDARY

PERENNIAL STREAMS

LAKE OR RESERVOIR

QUANTITY GENERALLY AVAILABLE PER WELL

MORE THAN 500 GALLONS PER MINUTE

50 - 500 GALLONS PER MINUTE

50 - 500 GALLONS PER MINUTE COMMON, SOME WELLS MAY YIELD MORE THAN 500 GALLONS PER MINUTE.

LESS THAN 50 GALLONS PER MINUTE

LESS THAN 50 GALLONS PER MINUTE COMMON, SOME WELLS MAY YIELD MORE THAN 50 GALLONS PER MINUTE.

DEPTH TO WATER LEVEL

DESIGNATED ONLY IN AREAS WHERE WATER-LEVEL DATA ARE AVAILABLE AND YIELD IS MORE THAN 50 GALLONS PER MINUTE PER WELL. IN ARTESIAN AREAS, WITH FAVORABLE TOPOGRAPHIC SITUATION, WELLS MAY FLOW.

LESS THAN 50 FEET

50 - 100 FEET

100 - 200 FEET

MORE THAN 200 FEET

SCALE 1/5,000,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

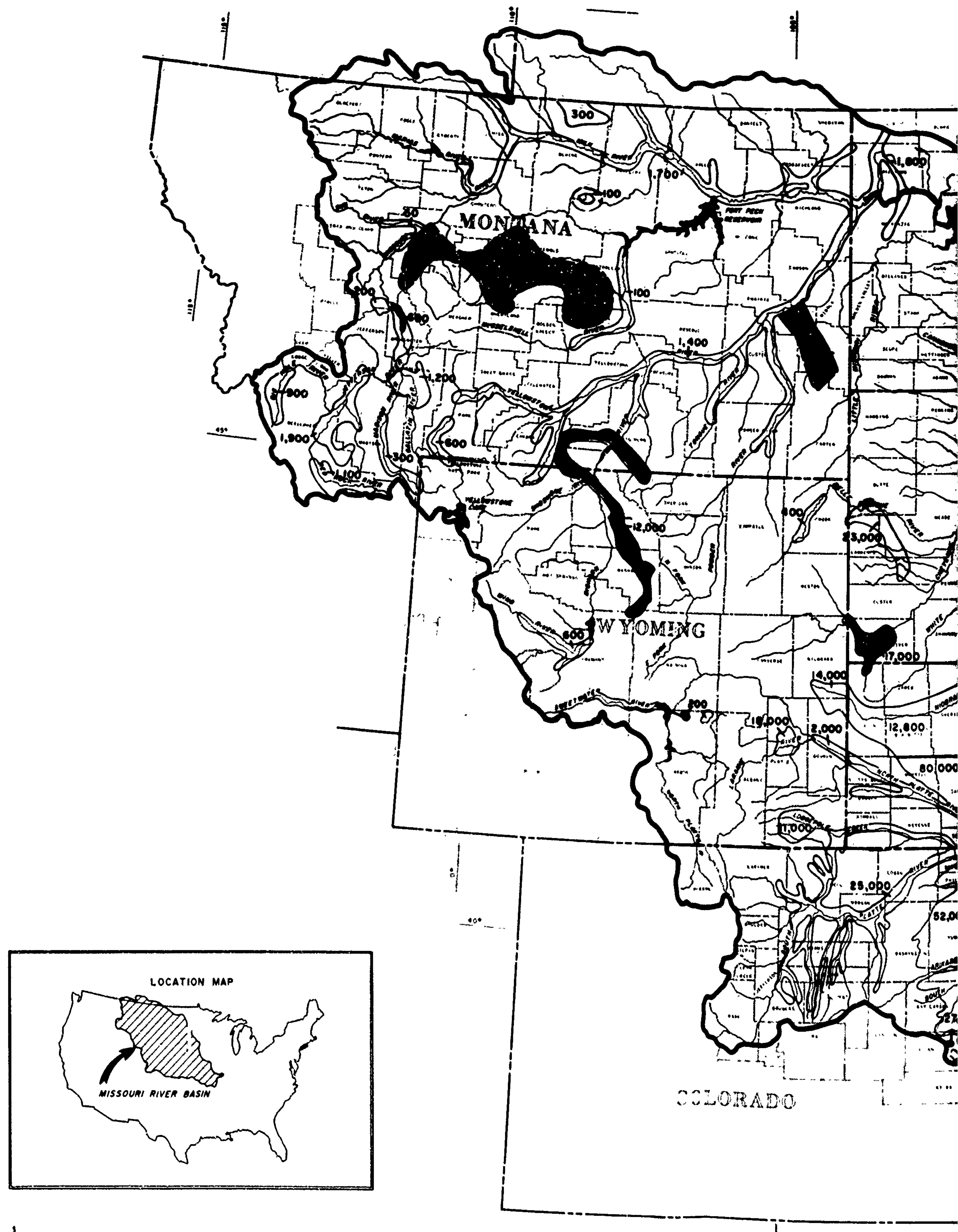
GENERAL AVAILABILITY OF GROUND WATER AND DEPTH TO WATER LEVEL

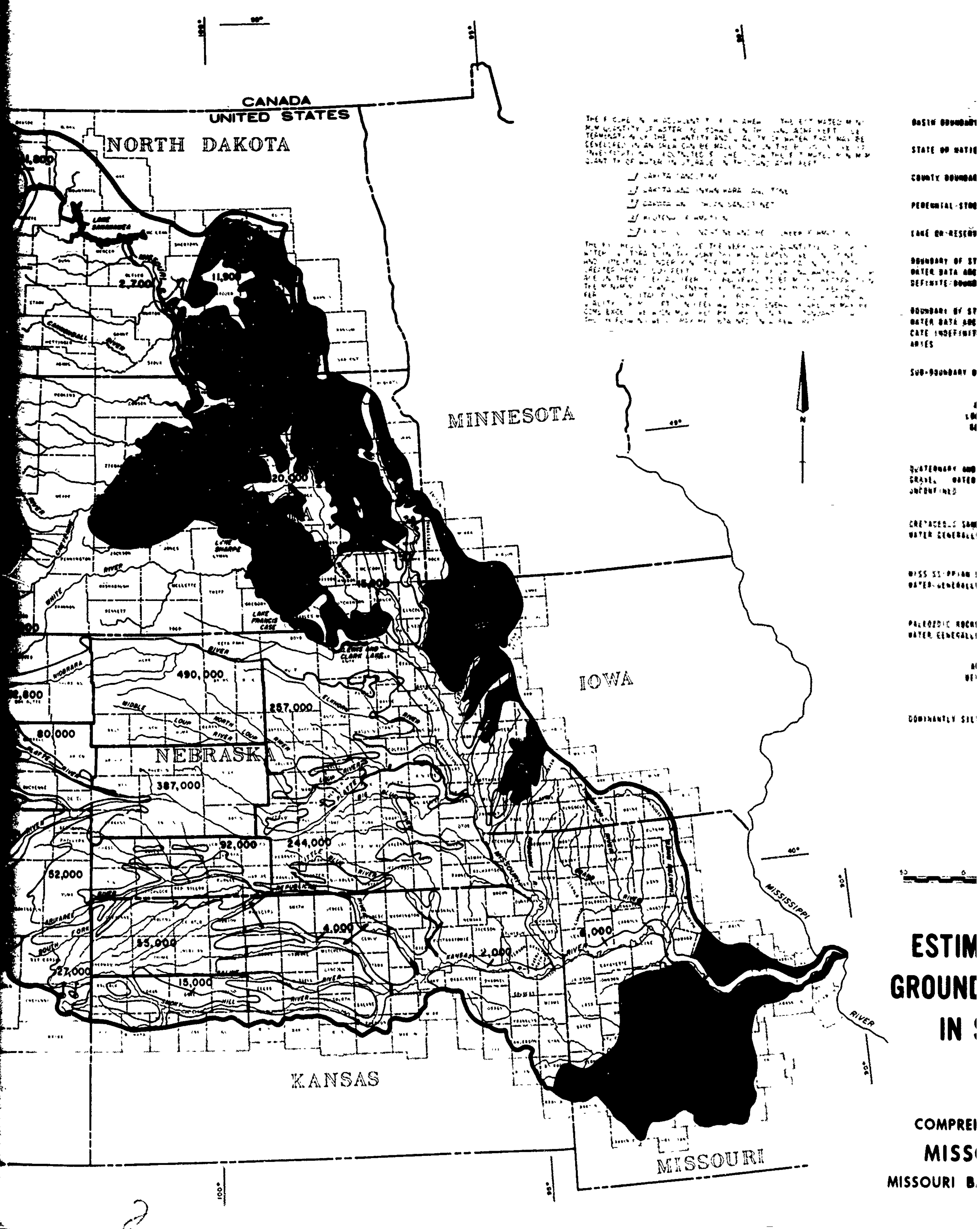
COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

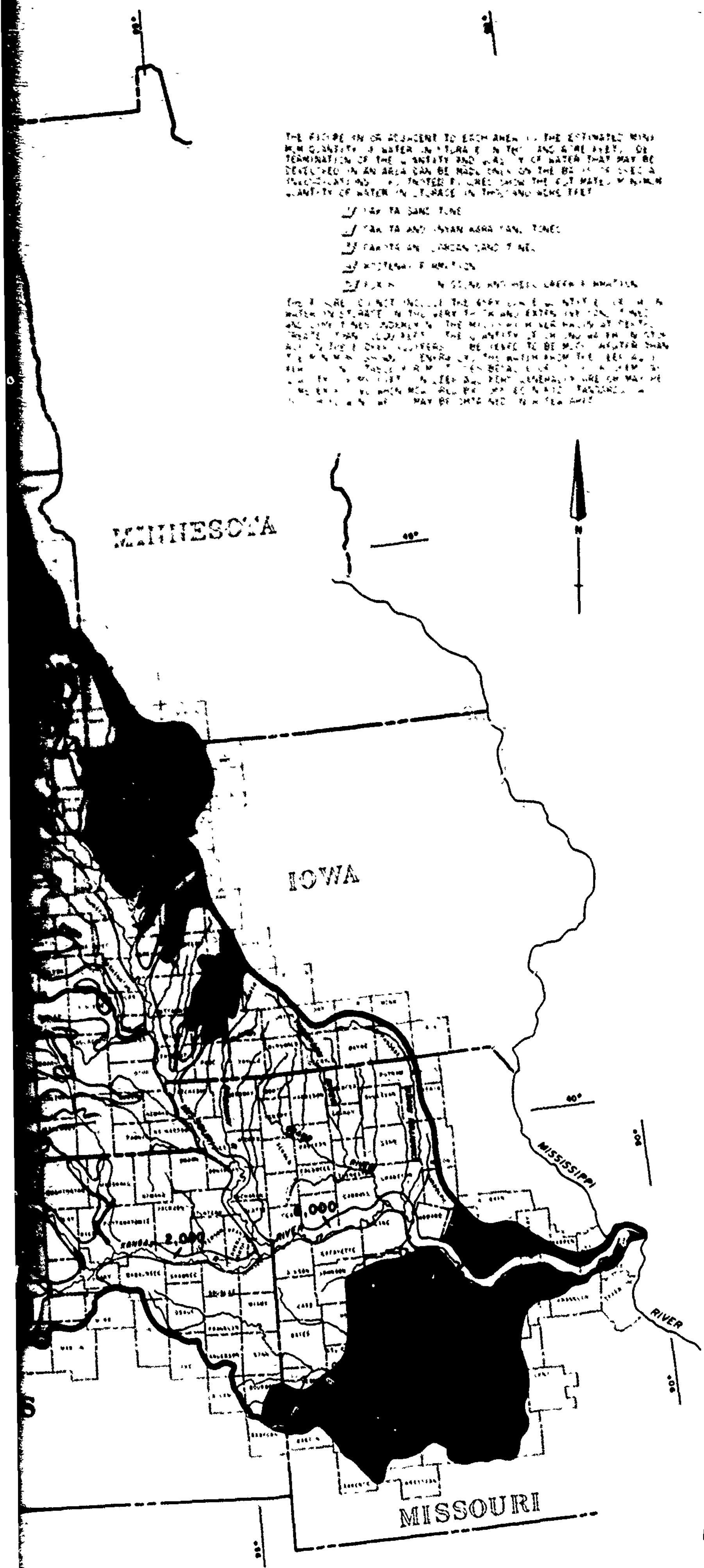
MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 19


MONTANA
WYOMING
COLORADO
300
1,700
100
1,800
100
1,400
1,200
1,900
1,900
1,100
600
300
12,000
800
23,000
17,000
14,000
600
800
18,000
2,000
12,800
80,000
11,000
25,000
52,000
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
IOWA
NEBRASKA
KANSAS
MISSOURI
MISSISSIPPI
RIVER
11,900
2,700
20,000
490,000
257,000
80,000
387,000
92,000
244,000
52,000
4,000
55,000
27,000
15,000
2,000
6,000
ESTIM
GROUND
IN
COMPRE
MISS
MISSOURI B



LEGEND

BASIN BOUNDARY

STATE OR NATIONAL BOUNDARY

COUNTY BOUNDARY

PERENNIAL STREAMS

LAKE OR RESERVOIR

BOUNDARY OF STORAGE UNIT, GROUND WATER DATA ARE ADEQUATE TO INDICATE DEFINITE BOUNDARIES.

BOUNDARY OF STORAGE UNIT, GROUND WATER DATA ARE INADEQUATE AND INDICATE INDEFINITE OR ESTIMATED BOUNDARIES

SUB-BOUNDARY OF STORAGE UNIT

AREAS WHERE PROPERLY CONSTRUCTED AND LOCATED WELLS, LESS THAN 1000 FEET DEEP, GENERALLY ARE CAPABLE OF YIELDING MORE THAN 300 GALLONS PER MINUTE

QUATERNARY AND TERTIARY SAND AND/OR GRAVEL. WATER MAY BE CONFINED OR UNCONFINED.

CRETACEOUS SANDSTONE, WATER GENERALLY CONFINED.

MISSISSIPPIAN LIMESTONE, WATER GENERALLY CONFINED.

PALEOZOIC ROCKS, UNDIFFERENTIATED, WATER GENERALLY CONFINED.

AREAS WHERE WELLS LESS THAN 1000 FEET DEEP GENERALLY WILL YIELD LESS THAN 300 GALLONS PER MINUTE.

DOMINANTLY SILT, CLAY AND SHALE.

SCALE 1:5,200,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

ESTIMATED QUANTITY OF GROUND WATER IN STORAGE IN SELECTED AREAS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 20

in each of the basin states, but their current importance and their potential for further development vary from state to state and from place to place within individual states. Probably not more than 25 per cent of the total volume of Quaternary deposits is capable of yielding water freely to wells. Colorado, Kansas, and Nebraska are well endowed with deposits with a high yield capability, and great quantities of water have been withdrawn from them annually for many years.

Quaternary deposits include the alluvium beneath present-day stream valleys, the alluvium filling ancient stream valleys, wind-deposited silt and sand, and a variety of sediments derived from rock debris left behind by melting glaciers. In the following descriptions, deposits in the glaciated part of the basin are covered first, followed by those in the nonglaciated part of the basin.

Throughout nearly all of the glaciated area, the Quaternary deposits consist mostly of glacial till, an unsorted mixture of clayey rock flour and larger rock fragments ranging in size from silt and fine sand to cobbles and boulders. Saturated till usually will yield some water to wells, but the rate of yield generally is small and the water may be highly mineralized. Scattered within the till are thin and areally small bodies of stratified sand and sandy gravel capable of yielding enough water for rural domestic and livestock needs. Many farm wells derive water from this source. Because of their generally small volume, such aquifers usually are not capable of sustaining high yields, and many wells tapping them are likely to become dry during extended drought periods.

Thicker and more extensive bodies of stratified sand and sandy gravel also occur within the glaciated area. These are of three types. The first consists of permeable sediments that filled or partly filled preglacial stream valleys. The second consists of similar deposits that filled or partly filled melt-water channels and other depressions in the land surface that existed between glaciations. The third consists of similar deposits in melt-water channels and other depressions formed during the waning phase of the last glaciation. The first two types usually are buried beneath layers of glacial till; the third type usually is the uppermost Quaternary deposit.

The buried valleys of the ancestral Missouri River and some of its ancestral tributaries in northern Montana constitute an important aquifer of the first type. Estimated storage here is about 1,700,000 acre-feet. The buried valleys of the ancestral Yellowstone River and some of its ancestral tributaries in southeastern Montana and northwestern North Dakota, generally underlying the modern Yellowstone River, constitute another important aquifer of this type, with an estimated 1,200,000 acre-feet of water in storage. Nearby, in northwestern North Dakota, the buried valley of the ancestral Little Missouri River constitutes another important aquifer of this type. Water storage is estimated at about 800,000 acre-feet. Test drilling indicates that the preglacial valley was as much as 400 feet below the present land surface.

Right-bank tributaries of the Missouri River in South Dakota formerly flowed in valleys that continued eastward beyond the present Missouri River into what is now the glaciated area. In at least two places, the sediments filling these ancient valleys constitute important aquifers. One of these, in north-central South Dakota east of the present mouth of the Grand River, has an estimated 3,100,000 acre-feet of water in storage. The other, in southeastern South Dakota near present Lake Andes, has an estimated 3,000,000 acre-feet of water in storage.

Other aquifers of significance in filled pre-glacial valleys exist in the glaciated portions of Nebraska, Kansas, and Missouri. In Nebraska and Kansas, moderately large supplies of water are obtained from wells tapping these aquifers. In Missouri, these aquifers are the principal source of fresh-water supplies in the glaciated area.

Aquifers in stratified sand and sandy gravel deposits of the second type, in filled or partly filled drainage ways developed by melt water from one or more of the earlier glaciers, exist in south-central North Dakota and in eastern South Dakota. The most significant of these, in Hand, Spink, Beadle, and Sanborn Counties, South Dakota, is estimated to contain 20 million acre-feet of water.

The Big Sioux River valley in South Dakota is an example of stratified sand and sandy gravel deposits of the third type, in filled or partly filled drainage ways cut by melt water from the last ice sheet. Here the valley was cut to depth somewhat below the present floodplain and then was partly filled with glacier-derived sediments. These sediments are estimated to be able to store an estimated 7,900,000 acre-feet of water.

For most of its length below Great Falls, Mont., the present-day Missouri River is either within or close to the glaciated part of the basin. Only in some reaches is its valley underlain by deposits of sand and gravel thick enough to be important as aquifers. Those in eastern Montana and western North Dakota, underlain by the filled valleys of the ancestral Missouri and Yellowstone rivers, have already been described. Other reaches underlain by alluvial aquifers of significance are between Garrison Dam and the upper end of Oahe Reservoir and between the mouth of the Niobrara River and the mouth of the Missouri River. Aquifers in the former reach store an estimated 200,000 acre-feet of water. Those in the latter reach store an estimated 11 million acre-feet of water above Kansas City and another 6 million acre-feet below Kansas City.

The valley of the Big Blue River from northern Seward County in Nebraska to the junction of the Blue

River and the Kansas River at Manhattan, Kans., and the Kansas River valley from that point to the river's mouth are also just within or close to the glaciated part of the Missouri basin. In Nebraska, moderately large yields are obtained from wells in areas where the alluvial deposits of the Big Blue River valley are underlain by similar deposits filling an underlying earlier valley; but where only the alluvium of the Big Blue River valley is present, well yields are much smaller. In Kansas, the alluvium of the Big Blue River valley is thicker and generally capable of yielding 300 gallons per minute to wells. Even greater yields from wells, as much as 1,500 gallons per minute, are common in the Kansas River valley. Ground water in the alluvium of the valleys bordering the glaciated area in Kansas is estimated at 1,500,000 acre-feet.

Where the valleys of the Elkhorn and Platte rivers are within the glaciated part of eastern Nebraska, the deposits of sand and gravel underlying them promise to become increasingly important as sources of water supply. Average daily pumpage in 1966 from the Lincoln city well field near Ashland, Nebr. in the Platte River valley was 27 million gallons. Another large supply has been developed recently by the Omaha Municipal Utilities District in the Platte River valley about 20 miles downstream from the Lincoln city well field.

Quaternary deposits outside the glaciated portion of the Missouri Basin are especially important sources of ground-water supply now and will become even more important in the future. Deposits along the edge of the glaciated area probably consist partly of glacier-derived sediments and partly of sediments derived from non-glaciated areas; those elsewhere consist entirely of sediments derived from the nonglaciated areas. Wind-deposited sand of Quaternary age, especially in Nebraska, is important to the water-supply picture in that the sand absorbs water readily and transmits it to underlying coarser-textured deposits.

Several intermontane basins that contain substantial thicknesses of water-bearing Quaternary deposits exist in southwestern Montana. In the Gallatin River valley — Three Forks area, in the vicinity of Bozeman, alluvial deposits and underlying older rocks are estimated to contain 1,200,000 acre-feet of water. An estimated 600,000 acre-feet of water is stored beneath the Townsend valley with another 200,000 acre-feet beneath the Helena valley. The aggregate quantity of water beneath other intermontane valleys in southwestern Montana approaches 5 million acre-feet. The thicker alluvium in all of these valleys is capable of yielding 1,000 gallons per minute, or more, to wells that are properly designed and constructed. Streamflow into the valleys and runoff from the relatively impermeable rocks forming the surrounding slopes combine to afford generally ample sources of replenishment.

In that part of Wyoming within the Missouri Basin, the only intermontane basin known to contain areally extensive Quaternary alluvial deposits is the Laramie basin in Albany County. The maximum thickness of the deposits is about 45 feet and the rocks immediately under the alluvium are nearly impermeable, so large supplies of water cannot be developed from conventional wells. However, radial collectors or infiltration galleries located where seepage from either the Laramie or Little Laramie rivers could be induced would probably provide a fairly large supply.

Long stretches of several stream valleys in that large part of the Missouri Basin between the mountains and the glaciated part of the basin contain alluvial deposits generally capable of yielding moderately large to large quantities of water to wells, 300 gallons per minute or more. These deposits underlie not only the floodplains but also terrace remnants bordering the floodplains. The more important stream-valley alluvial deposits in the area between the mountains and the glaciated portion of the basin are listed in table 20. It should be noted that the valleys of the Platte River, the Loup River, and other streams in east-central Nebraska are not included in this table. The alluvium beneath these valleys is not restricted to the valleys themselves but is a continuation of and virtually indistinguishable from an extensive sheetlike complex of unconsolidated fluvial deposits extending beneath the adjacent uplands. Descriptions of these stream valleys are included with a subsequent description of the sheetlike deposit.

The Quaternary deposits underlying the valleys of the South Platte River and its tributaries are the most highly developed of the aquifers listed in table 20. A large percentage of the water pumped from wells is used for irrigation, and most of the rest is used to meet municipal needs. In the valley of the South Platte River itself, a high rate of recharge due to application of surface water for irrigation so nearly balances current withdrawals plus natural discharge that the quantity of water in storage remains nearly constant. In some of the tributary valleys, however, withdrawals have caused significant reductions in storage. About three-fifths of the wells in the South Platte River valley yield between 300 and 1,000 gallons per minute. Most of the remainder yield more, but only a few yield in excess of 2,000 gallons per minute.

The most important Quaternary deposits of sand and gravel in the Missouri Basin underlie an area of 22,500 square miles in eastern Nebraska and northern Kansas. Their existence is due to creation of a sediment trap when glaciers blocked eastward-flowing streams, ponding their flow until it spilled over interstream divides. The sand and gravel deposits, together with interlayered and overlying fine-grained sediments, accumulated to a thickness exceeding 400 feet in places, enough so that not only the preglacial valleys but also many of the preglacial divides were buried.

Table 20 – GROUND-WATER STORAGE IN STREAM-VALLEY ALLUVIAL DEPOSITS NON-GLACIATED AND NON-MOUNTAINOUS PORTION OF THE MISSOURI BASIN

Valley	Location	Estimated Water in Storage (Acre-Feet)
Sun River	Northwestern Cascade County, Montana	50,000
Missouri River	Central Cascade County, Montana	
Musselshell River	Western Musselshell County, Montana, to junction with the Missouri River	100,000
Yellowstone River	Central Park County, Montana, to border of glaciated area at Intake, Montana	
Clark Fork	Northern Park County, Wyoming, to junction with Yellowstone River	
Rock Creek	Central Carbon County, Montana, to junction with Clark Fork	1,400,000
Bighorn River	Central Big Horn County, Montana, to junction with Yellowstone River	
Tongue River	Southern Rosebud County, Montana, to junction with Yellowstone River	
Powder River	Central Powder River County, Montana, to junction with Yellowstone River	
Wind and Popo Agie Rivers	Central Fremont County, Wyoming	600,000
Sweetwater River	Southeastern Fremont and southwestern Natrona Counties, Wyoming	200,000
Belle Fourche River	Southwestern Crook County, Wyoming	50,000
North Platte River	Eastern Platte County, Wyoming, to central Lincoln County, Nebraska	10,000,000
Pumpkin Creek	Banner and Morrill Counties, Nebraska	
South Platte River & Tributaries, NE Colorado	Northwestern Douglas County, Colorado, to central Lincoln County, Nebraska	28,000,000
Lodgepole Creek	Eastern Laramie County, Wyoming, to Sedgwick County, Colorado	
Republican River	Southwestern Dundy County, Nebraska, to junction with Smoky Hill River	
South Fork of Republican River	Southwestern Cheyenne County, Kansas, to junction with Republican River	3,000,000
Frenchman Creek	Southeastern Chase County, Nebraska, to junction with Republican River	
Prairie Dog Creek	Central Norton County, Kansas, to junction with Republican River	
Smoky Hill River	Western Wallace County, Kansas, to junction with Republican River	1,300,000
Saline River	Northeastern Trego County, Kansas, to junction with Smoky Hill River	
South Fork Solomon River	Western Graham County, Kansas, to junction with North Fork Solomon River	
North Fork Solomon River	Southwestern Norton County, Kansas, to junction with South Fork Solomon River	800,000
Solomon River	Western Mitchell County, Kansas, to junction with Smoky Hill River	
Kansas River	Northern Geary County, Kansas, to mouth of Blue River	150,000

The valley of the Platte River and the valley of the Loup River, its tributary, are broad and shallow incisions into this extensive deposit. Each river is hydraulically continuous with the zone of saturation in the deposits beneath the valley floor and that zone is continuous with the zone of saturation beneath the adjacent upland plains. The dry-weather flow of several smaller streams is maintained by seepage from the zone of saturation.

Because these Quaternary deposits mantle an ancient land surface of moderate relief, their thickness and the thickness of the zone of saturation are not uniform. The thickness of moderately to highly permeable sediments within the zone of saturation also differs. Consequently, yields obtainable from wells vary. Yields greater than 1,000 gallons per minute are the general rule; and in some places, yields greater than 2,000 gallons per minute are common. In a few places, however, yields are less than 1,000 gallons per minute. Water in storage in this huge reservoir is estimated to be between 230 million and 250 million acre-feet. In 1964, when precipitation over this area was about normal, total pumpage was about 1,800,000 acre-feet. This amounts to less than 1 per cent of the total storage.

In the Platte River valley, the water table is within a few feet of the land surface and the soils generally are moderately to highly permeable. Prior to development of irrigation, precipitation was the principal source of recharge and evapotranspiration accounted for most of the discharge. Depending upon its stage, the river either drained water from or added water to the zone of saturation. Now that pumping withdrawals lower the water table, less ground water is discharged by evapotranspiration, recharge by infiltrating precipitation is augmented by infiltrating irrigation water, and storage space is created for additional seepage from the river. The net depletion by pumping, accordingly, is not as great as the total quantity of water withdrawn. For example, the Conservation and Survey Division of the University of Nebraska has estimated that pumpage in Hall County, Nebraska, largely in the Platte River valley, amounted to 1,400,000 acre-feet through 1967 whereas storage had been depleted by only 200,000 acre-feet.

In the upland part of the area underlain by these deposits, the water table generally is more than 70 feet below the land surface and the soils are finer textured and less permeable than in the valley. Before irrigation, precipitation was the only source of recharge, and the average rate was less than in the valley. Natural discharge occurred only as the result of evapotranspiration and seepage into stream channels. Pump irrigation in this situation could not effect any significant increase in recharge nor salvage of natural discharge. Accordingly, it has resulted in depletion of storage roughly commensurate with the total amount of pumpage. Water-level declines greater than 10 feet have been experienced in an area of over 600 square miles. As depletion progresses, the amount of decline in the water table and the areal extent of the decline will both increase. Although the water-level decline has required deepening of several shallow wells and lowering of pumps in some others, the quantity of water in storage has been only modestly reduced since pumping began.

Rocks of Tertiary Age

The Ogallala Formation of Tertiary age is the second most important source of ground water in the Missouri River Basin. Several of the older Tertiary formations also are sources of ground water, but none rival the Ogallala Formation.

An areally extensive unit, the Ogallala Formation underlies much of central and western Nebraska, much of western Kansas, a large area in northeastern Colorado, and comparatively small areas in southwestern Wyoming and south-central South Dakota. Like the sheetlike Quaternary deposits in Nebraska and Kansas, it consists in large part of fluvial deposits derived from the western mountains. Although mostly sand and gravel, these deposits tend to be somewhat more compact than those of Quaternary age, and some beds are moderately-to-well cemented.

An estimated 600,000 acre-feet of water is withdrawn annually from the Ogallala Formation in eastern Colorado, western Nebraska, and western Kansas. Well yields ranging from 300 to 1,000 gallons per minute are the general rule, but some of the more favorably situated wells yield as much as 1,500 gallons per minute and a few yield more than 2,000 gallons per minute. In those areas where withdrawals are concentrated, water levels have begun to decline. Although the decline is not at an alarming rate, it does indicate that the supply is subject to eventual depletion. Quantities of water stored in the Ogallala Formation are conservatively estimated at 80 million acre-feet in Colorado, 70 million acre-feet in Kansas, 500 million acre-feet in Nebraska, and 30 million acre-feet in Wyoming.

The Browns Park (lower) and North Park (upper) formations, of about the same age as the Ogallala Formation, are important aquifers in parts of Carbon County, Wyoming. Tapped mainly by domestic and stock wells, these formations are capable of moderate to large yields in some places, as demonstrated by a few irrigation wells deriving water from them.

A rock sequence consisting of the Arikaree (lower) and Hemingford (upper) groups of Tertiary age constitutes an important aquifer in parts of western Nebraska and southeastern Wyoming. A few of the wells tapping these rocks yield as much as 1,000 gallons per minute, but most yield considerably less. For a large yield to be obtained, the thickness of water-bearing material tapped must be 200 feet or more.

Sediments comparable in age to the Arikaree-Hemingford-Ogallala sequence constitute part of the fill in intermontane basins of southwestern Montana. They exist also as remnants of a formerly extensive sheetlike deposit, the Flaxville Gravel, in northeastern Montana. Where these deposits are both moderately permeable and saturated, they are important local sources of water supply. Deposits in the intermontane basins have the greater potential because they are likely to be fully saturated and are so situated that they are readily recharged. Although the Flaxville Gravel remnants tend to be well drained, some of the larger ones store considerable water, with yields of as much as 1,200 gallons per minute to wells.

Older rocks of Tertiary age generally yield no water or only enough for domestic and livestock use. Moreover, much of the water is highly mineralized and therefore limited in its usefulness. The White River Group, which underlies most of western Nebraska and the adjoining parts of South Dakota, Wyoming, and Colorado, is notably poor as a source of water supply. However, where locally riddled by openings caused by piping or fracturing, water is transmitted freely to wells. The Wind River, Wasatch, and Fort Union formations, all older than the White River Group, are important sources of small supplies of water in a small part of northwestern South Dakota, much of western North Dakota, and large areas in Montana and Wyoming. Hundreds of farm wells tap one or another of these rock units or their equivalents where they are within economical drilling depth. Some of the water from the Fort Union Formation is derived from open fractures in beds of lignite. In an area around Denver, Colo. many wells derive water from the Denver Formation or the upper part of the Dawson Arkose, both of which are approximate equivalents of the Fort Union Formation. Although yields usually are less than 20 gallons per minute, total withdrawals are significantly large.

Rocks of Mesozoic Age

None of the rock units of Mesozoic age have the capacity to produce water in such large quantities as do the valley-fill and sheetlike deposits of Quaternary age or the Ogallala-Arikaree sequence of Tertiary age. However, several of them are important as reliable sources of supply for domestic and livestock use throughout much of the large area where these rocks crop out and even in some places where they are buried beneath several hundred feet of younger rocks.

A complex of water-bearing formations constituting the uppermost rocks of Mesozoic age underlies much of northwestern South Dakota, western North Dakota, eastern Montana, eastern Wyoming, the southwestern part of the Nebraska panhandle, and that part of Colorado extending from Weld County southward to the basin boundary. The most extensive of these formations is the Fox Hills Sandstone which extends throughout nearly all of the area. It is overlain in the northern part of the area by the Hell Creek Formation, in the central part by the Lance Formation, and in the southern part by the Laramie and Arapahoe formations. Where these formations are not buried beneath water-bearing younger rocks, they are the principal source of supply to wells. They are tapped by thousands of domestic and livestock wells and in some places by public supply and industrial supply wells. Yields greater than 150 gallons per minute are the exception, and most wells yield considerably less.

In rather large areas of the Missouri Basin, particularly in Montana, Wyoming, South Dakota, and Colorado, the upper part of one or another of the thick shales in the sequence of Mesozoic rocks is at or close to the land surface. Since the shales are either aquitards or aquicludes, even small supplies of ground water are generally unavailable except by drilling through them, and they may be as much as 1,500 to 2,000 feet thick.

In several places in the western part of the Missouri River Basin and in the vicinity of the Black Hills, one or more of the generally deeper-lying aquifers within the Mesozoic sequence have been upwarped by mountain-building forces and are within much easier reach by drilling. They are recharged where exposed on the flanks of the domelike uplifts. Important among these aquifers are the Judith River Formation, the Eagle Sandstone, and the Telegraph Creek Formation in central Montana; the Fall River and Lakota formations in northeastern Wyoming and western South Dakota; the Cloverly Formation in central Wyoming; the Kootenai Formation in central Montana; the Ellis, Swift, and Sundance formations in southwestern South Dakota, much of Wyoming, and south-central Montana; the Nuggett Sandstone in northwestern Wyoming; and the Chugwater Formation in Wyoming and south-central Montana. Although small yields to individual wells are the general rule, the capacity of these aquifers to produce water remains to be tested.

Even though they yield water at low rates, several other Mesozoic formations in the western part of the basin are locally important as sources of supply because they are the only accessible aquifers. In the eastern part of the basin, two Mesozoic rock units are important as aquifers. One is the Niobrara Formation which, in combination with the Codell Sandstone Member of the Carlile Shale, underlies a large area in eastern South Dakota. The other is the Dakota Formation, which underlies an area extending from eastern North Dakota to central Kansas. The former is the source of supply for many farm wells and, since withdrawals have not yet caused any significant lowering of the water level, it is likely that many more small-yield wells can be drilled into it before depletion becomes a matter of concern. The latter, first discovered in the 1880's as a source of artesian supplies, is also tapped by a multitude of small-diameter wells. Some flow at rates greater than 100 gallons per minute, but most flow at much smaller rates or must be pumped. Total current discharge of water from the Dakota Formation may exceed 50 million gallons per day.

Where they outcrop around the Black Hills and for a short distance downdip from their outcrop, the Fall River and Lakota formations are tapped by many wells. The water commonly is under sufficient artesian pressure to flow or to rise within a few feet of the land surface. Most wells yield less than 15 gallons per minute, but a few yield as much as 150 gallons per minute.

In recent years, many wells have been drilled into the Kootenai Formation in the Judith Basin area in Montana. In a large part of the area, the water is under enough artesian pressure to make the wells flow. It is estimated that 300,000 acre-feet of water still is stored in this aquifer within economical drilling depth.

Rocks of Paleozoic Age

Aquifers included within the thick sequence of Paleozoic rocks are sources of water supply not only in the several areas where these rocks are exposed but also in some areas where they are deeply buried beneath younger rocks not capable of yielding needed quantities of water. Thousands of domestic and stock wells and many municipal and industrial wells with moderately large to large yields tap one or another of these aquifers in the area of eastern Kansas, southeastern Nebraska, southwestern Iowa, and all of Missouri within the Missouri Basin. They also are sources of supply in and for short distances downdip from their outcrop in several of the mountainous areas, including the Black Hills, and at scattered locations in the plains area, where they are deeply buried. Several large springs issue from Paleozoic rocks in central Montana, north-central Wyoming, southwestern South Dakota, and south-central Missouri.

In descending order, the most important of the Paleozoic aquifers are the Minnekahta Limestone; a complex composed of the Quadrant and Tensleep sandstones, the upper part of the Amsden Formation, and the Minnelusa, Hartville, and Fountain formations; the Heath Formation; the Kibbey Sandstone; and the correlative Madison, Pahasapa, and Guernsey limestones.

The Minnekahta Limestone usually is not considered to be an aquifer. At several locations in western South Dakota and eastern Wyoming, however, flowing wells tapping it have yields ranging from 10 to as much as 5,000 gallons per minute. Probably, the productivity here is due to upward movement of water from underlying rocks along faults and other fractures.

The complex including the Quadrant and Tensleep sandstones underlies much of southern and eastern Montana, western North Dakota, much of Wyoming, western South Dakota, northeastern Colorado, and probably parts of western Nebraska and western Kansas. In most places, however, overlying aquifers are capable of supplying current water demands or the complex is too deeply buried to warrant its exploration as a source of water supply. The principal outcrops of this complex are in Montana and Wyoming, and on all sides of the Black Hills uplift. Conditions for recharge from precipitation and stream seepage are favorable in most of the outcrop areas; and downdip from the outcrops, the sandstone layers of this complex generally contain water under high pressure and are capable of yielding moderately large quantities of water to flowing wells.

The Heath Formation and the Kibbey Sandstone are tapped by several wells, some flowing, in central Montana. However, the full extent or the potential of these aquifers as sources of water supply is not known.

The correlative Madison-Pahasapa-Guernsey limestones constitute an aquifer that has been tapped by wells at scattered locations in Montana, Wyoming, western North Dakota, and western South Dakota. It is known to underlie northwestern Nebraska and part of Colorado, and it may extend into western Kansas. It outcrops in mountainous areas where conditions for recharge are frequently favorable. Downdip from the outcrops, water is under high enough pressure for wells to flow. Several wells in western South Dakota, for example, some more than 4,000 feet deep, flow more than 100 gallons per minute. Moderately large yields from scattered wells in Wyoming and Montana indicate a potential for much greater development of this aquifer in these states.

Upper Paleozoic rocks also crop out or are near the surface in the southeastern part of the Missouri Basin, where they are tapped by many farm wells. Apparently, none of these aquifers are capable of yielding supplies greater than those needed for domestic and stock use.

The lower Paleozoic rocks are known to contain important aquifers in the Black Hills area and in the Ozark area in the southeastern part of the basin. In the Black Hills area, these rocks are known to contain a large volume of water under high artesian pressure. Some water from these rocks is used for domestic and stock supplies, but most of the water from this source is too saline for most uses. In the southeastern part of the basin, the lower Paleozoic rocks outcrop on the flanks of the Ozark uplift in Missouri, and they underlie much of northwestern Missouri, extending also into Iowa and into eastern Kansas and Nebraska. Aquifers in these rocks are used extensively as a source of water supply for farm wells and for many wells supplying municipalities and industries. An estimated 352 million acre-feet of water is stored by Paleozoic aquifers in this part of the basin.

The lateral extent, the overall storage capacity, and the yield capability of the deeply buried Paleozoic rocks are not known. If information on all aquifers encountered during drilling of oil tests and other exploratory holes were made part of the public record, a sound basis for estimating the quantities of water that could be withdrawn from these rocks would be provided. Water from deep sources is generally warmer and more highly mineralized than that from shallower sources. However, desalinization of water from deep sources may eventually prove to be a feasible solution to some water-supply problems.

Rocks of Pre-Paleozoic Age

Despite their almost complete lack of primary intergranular porosity, the metamorphic and igneous rocks of pre-Paleozoic age are tapped by a large number of wells in those areas where younger rocks have been removed by erosion. Their capacity to store and transmit water generally is due entirely to the existence of a system of interconnected open fractures. In many cases, well yields vary seasonally, since the fractures tend to fill during rainy periods and to drain between such periods. Usually, wells in these rocks can sustain only small yields. They are important, however, because in areas where these rocks are exposed no other sources of ground water are available.

Few wells derive water from pre-Paleozoic rocks where these are overlain by sedimentary rocks. The possibility of obtaining water from weathered granite underlying the sedimentary sequence, however, should not be overlooked. Secondary porosity and permeability, developed during the weathering process, may have rendered this rock capable of small to moderate yields to wells.

Extruded Igneous Rocks

The occurrence of water in extruded igneous rocks, whatever their geologic age, is generally similar to its occurrence in the pre-Paleozoic rocks. Springs issuing from rhyolite of Tertiary age in Yellowstone National Park provide a noteworthy exception. At least seven springs in the park flow at rates greater than 500 gallons per minute, and a hundred or more other springs have smaller flows. Much of the spring water has a temperature higher than 150°F.

GROUND-WATER WITHDRAWALS

An accurate computation of annual ground-water pumpage in the Missouri River Basin would require an inventory of all large-yield wells, periodic measurement of yield rates, and recording of pumping periods. So tremendous an effort would be required that no such computation has been attempted for the framework study.

To obtain some measure of the quantity of ground water pumped annually and to determine the rate of increase in the use of ground water, each District office of the Water Resources Division of the U. S. Geological Survey was requested to estimate annual pumpage, by counties or groups of counties, for three different 5-year periods. Summarized by states, these estimates are shown in table 21.

Table 21 – USE OF GROUND-WATER RESOURCES

State (Missouri Basin Portion)	Annual Pumpage in Acre-Feet 1951-55	1956-60	1961-65
Colorado	578,300	563,300	731,100
Iowa	54,600	87,100	87,100
Kansas	423,000	538,000	956,000
Missouri	89,900	101,900	109,700
Montana	100,500	103,700	117,500
Nebraska	794,200	1,548,000	1,780,000
North Dakota	5,100	10,600	17,900
South Dakota	68,100	79,300	94,600
Wyoming	101,000	114,500	118,000
Missouri Basin	2,214,700	3,146,400	4,011,900

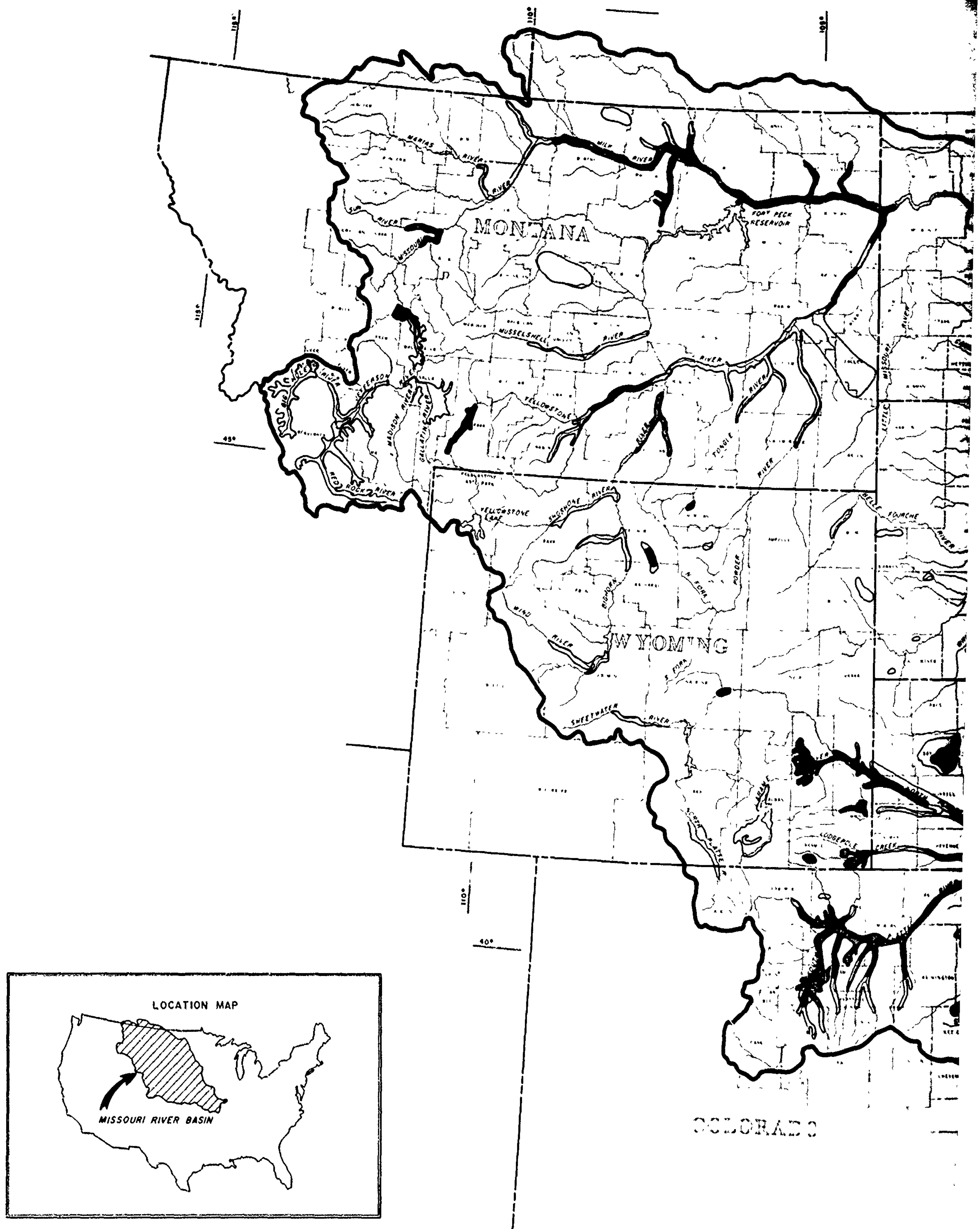
If the values in table 21 are approximately correct and the rate of increase during the 15-year period is projected, a reasonable estimate of average annual pumpage at the 1970 stage of development is about 5.3 million acre-feet. The approximate current distribution of withdrawals, expressed in acre-feet per square mile of aquifer extent, is shown by plate 21.

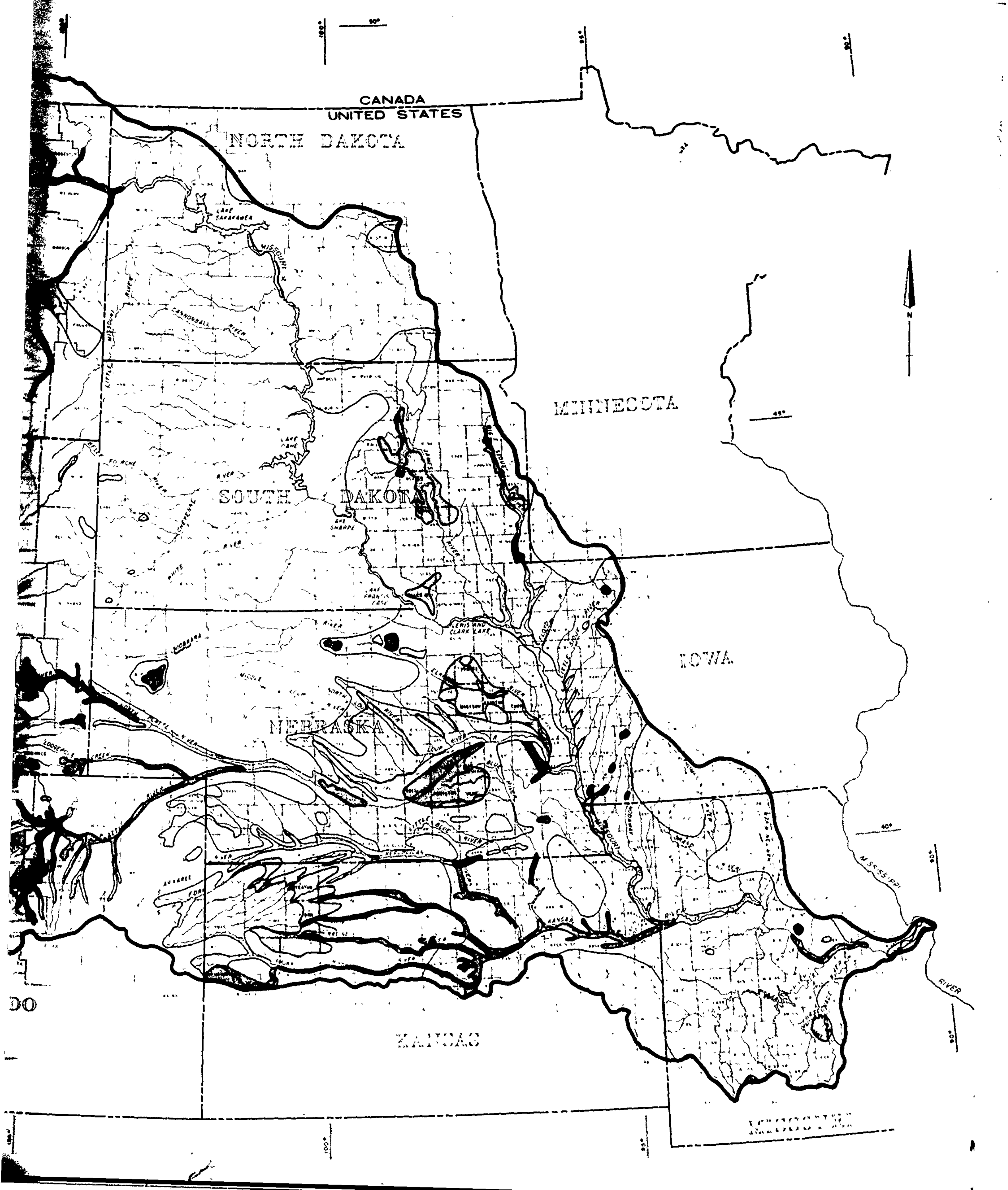
CHANGES IN GROUND-WATER LEVELS

In some localities, difficulties in meeting municipal demands from ground-water sources already have been experienced. Many long-time irrigators in upland areas are beginning to be concerned about evidences of progressive water-level decline. As use of ground-water resources continues to increase, concern over the adequacy of supplies will increase. Areas of the Missouri Basin in which marked water-level declines already have occurred are shown by plate 22. This plate shows also areas of pressure-surface decline and areas of marked water-table rise caused by seepage from canals and applied irrigation water.

Concern has been expressed in several parts of the basin that ground-water withdrawals will cause a reduction in the base flow of streams. Such concern is justified only if pumping from wells intercepts water otherwise destined to be discharged into a stream or causes an ordinarily effluent stream to become influent. Evapotranspiration, in areas of shallow water table, accounts for such a large fraction of total natural ground-water discharge that ground-water withdrawals are much more likely to effect a decrease in discharge to the atmosphere than to streamflow. Furthermore, because ground-water movement is so slow, heavy withdrawals are more likely to result in a local lowering of water levels than in a significant lessening of the hydraulic gradient toward a natural discharge area several miles distant. Generally speaking, streamflow is likely to be most affected by pumping from wells in localities where sites of large withdrawals are close to streams.

Despite the large total ground-water withdrawals to date, the quantity of ground water now in storage probably is nearly as great, and in some localities even greater, than when the first well was dug. Seepage from streams, particularly at times of high flow or flood stage, has replaced much ground water pumped in valley areas, and seepage of water diverted for irrigation has added water to storage. A notable example of the latter is the large mound of water beneath a part of the area supplied irrigation water by the Central Nebraska Public Power and Irrigation District in Nebraska. Less well documented is the buildup of the water table beneath terrace lands in the Platte River valley due to recharge from irrigation beginning late in the last century.


MONTANA
WYOMING
MILK RIVER
MARIAS RIVER
FORT PECK RESERVOIR
MUSSELSHELL RIVER
YELLOWSTONE RIVER
JEFFERSON RIVER
MADISON RIVER
GALLATIN RIVER
RED ROCK RIVER
TONGUE RIVER
YELLOWSTONE LAKE
SHOSHONE RIVER
BIGHORN RIVER
POWDER RIVER
WIND RIVER
SWEETWATER RIVER
BELLE FOURCHE RIVER
LODGEPOLE CREEK
LOCATION MAP
MISSOURI RIVER BASIN


CANADA
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LAKE OAHE
BELLE FOURCHE RIVER
CHEYENNE RIVER
WHITE RIVER
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
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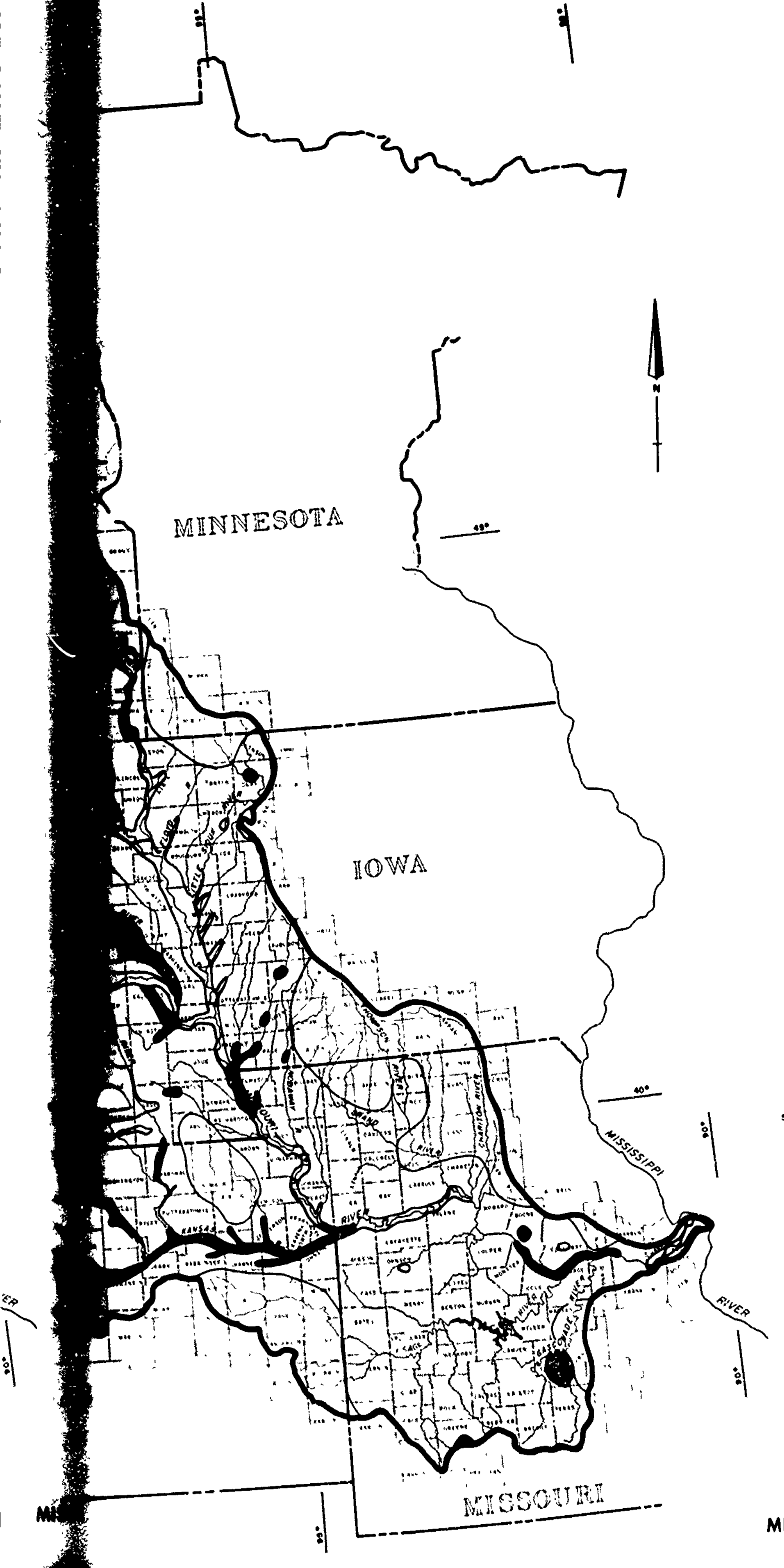


LEGEND

BASIN BOUNDARY	
STATE OR NATIONAL BOUNDARY	
COUNTY BOUNDARY	
PERENNIAL STREAMS	
LAKE OR RESERVOIR	

AVERAGE ANNUAL PUMPAGE IN ACRE-FEET PER SQUARE MILE.

- LESS THAN - 1
- 1 - 3
- 4 - 10
- 11 - 50
- 51 - 100
- 101 - 200
- MORE THAN 200

WITHDRAWALS FOR IRRIGATION CONSTITUTE THE GREATEST SINGLE USE OF GROUND WATER AND EXCEED ALL OTHER USES COMBINED AS THE QUANTITIES PUMPED FOR IRRIGATION DEPEND IN LARGE MEASURE ON THE AMOUNTS AND DISTRIBUTION OF PRECIPITATION BEFORE AND AT CRITICAL TIMES DURING THE GROWING SEASON. TOTAL WITHDRAWALS VARY WIDELY FROM YEAR TO YEAR. MAP IS BASED ON INFORMATION FURNISHED BY DISTRICT OFFICES OF WATER RESOURCES DIVISION OF U. S. GEOLOGICAL SURVEY

SCALE 1:5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

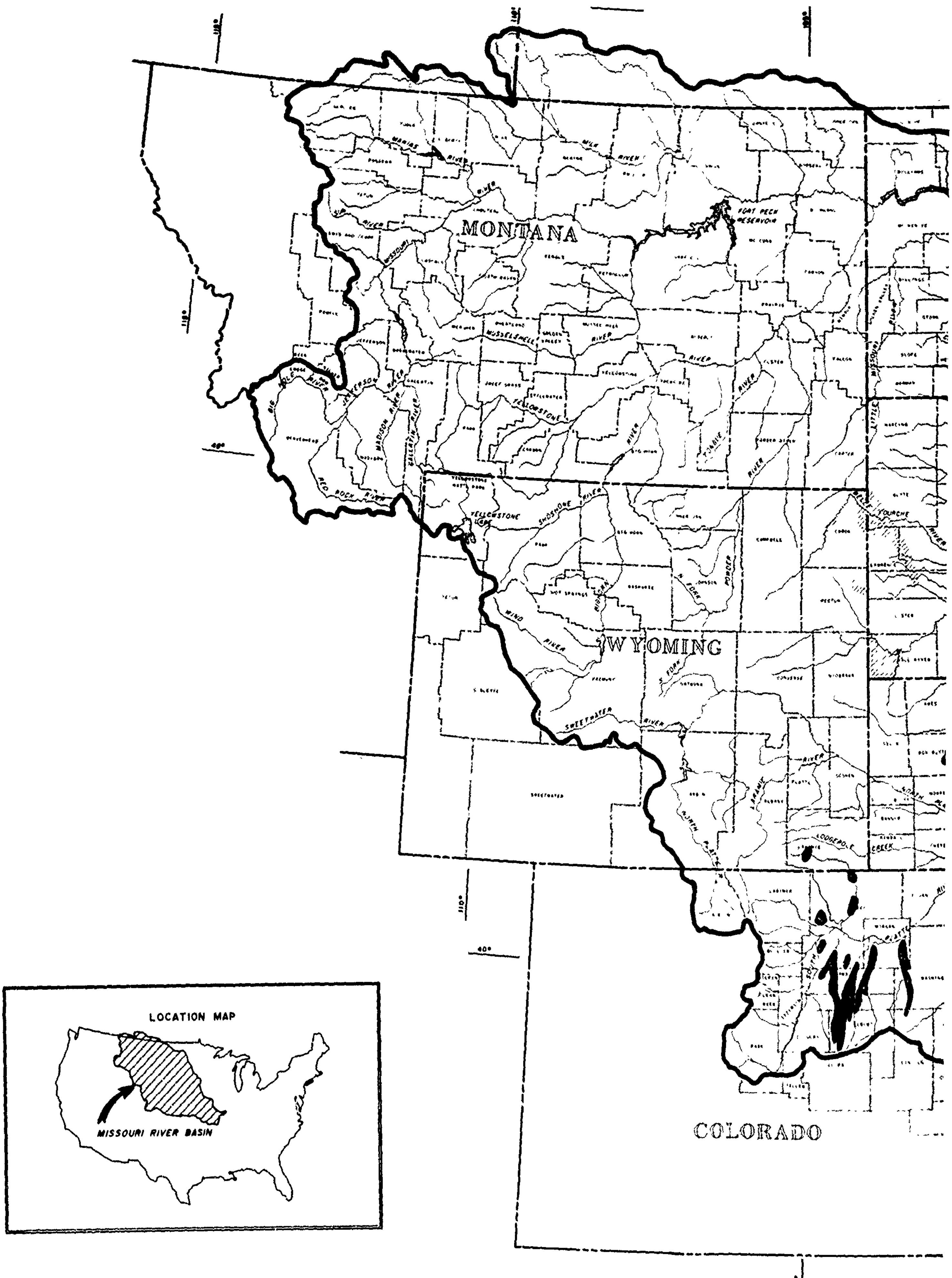
AVERAGE ANNUAL GROUND-WATER PUMPAGE AS OF 1965

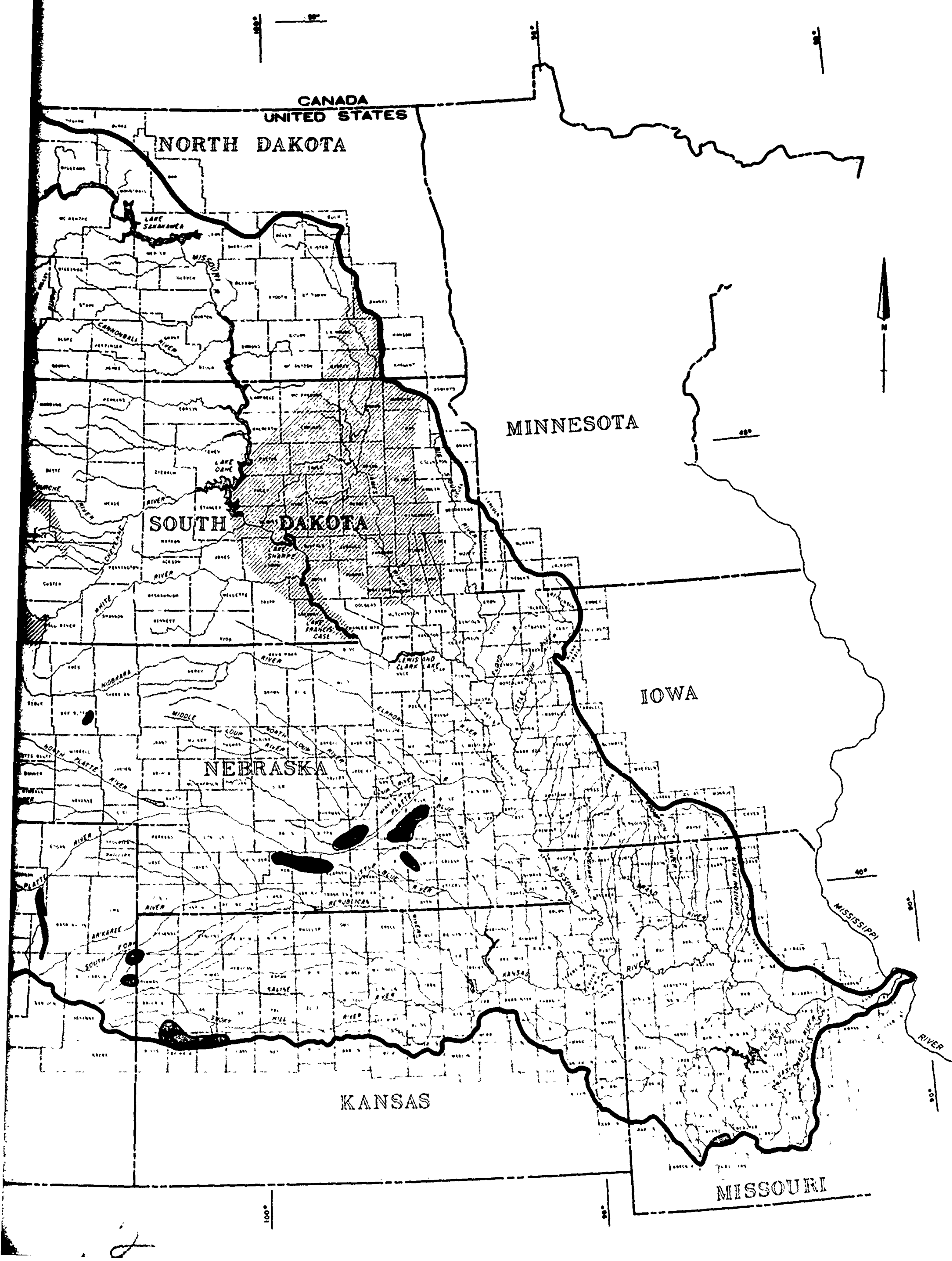
COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 21


MONTANA
WYOMING
COLORADO
FORT PECK RESERVOIR
YELLOWSTONE LAKE
LOCATION MAP
MISSOURI RIVER BASIN



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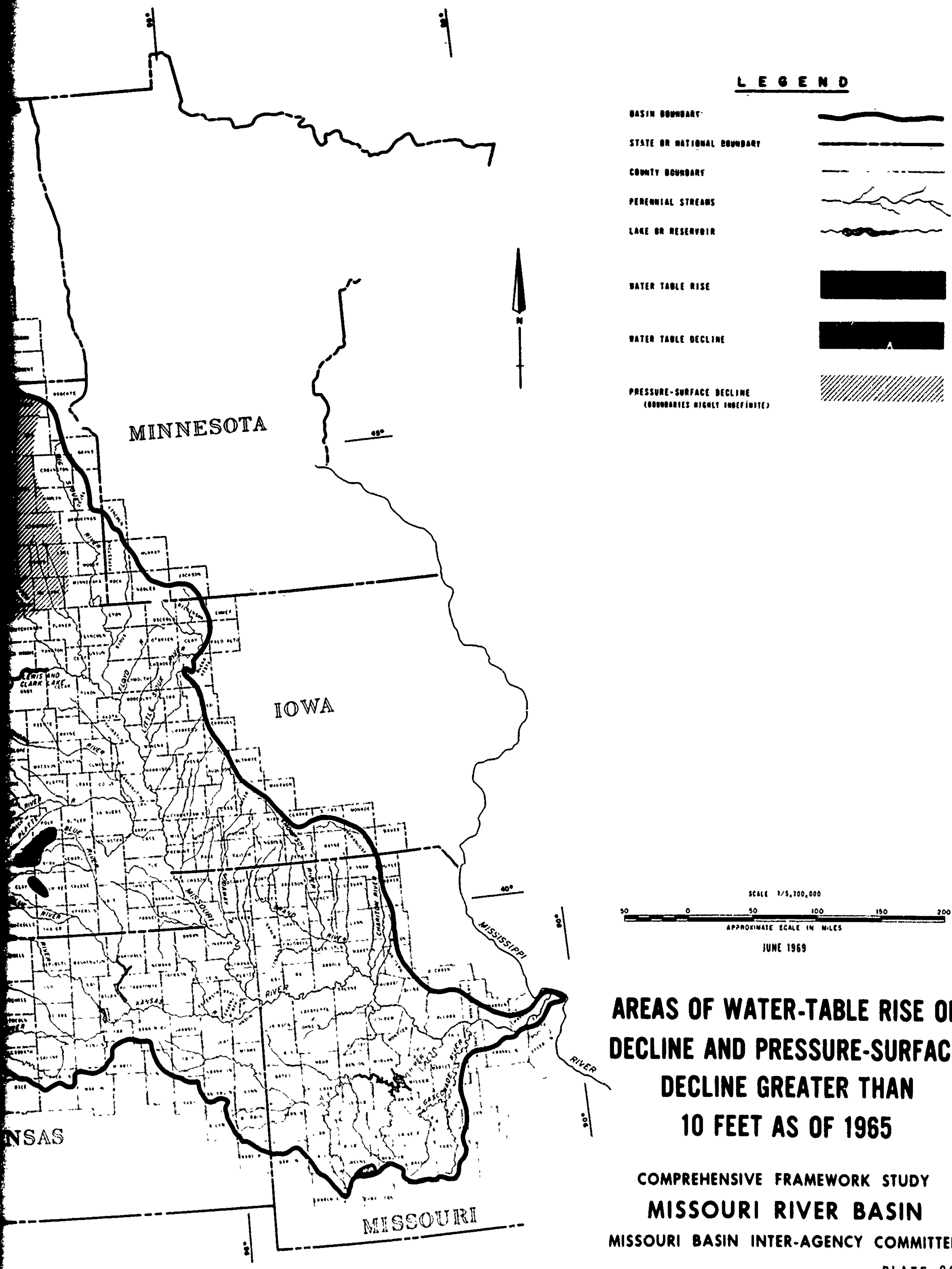


AREAS OF WATER-TABLE RISE OR DECLINE AND PRESSURE-SURFACE DECLINE GREATER THAN 10 FEET AS OF 1965

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 22

CHAPTER 8

WATER QUALITY

WATER QUALITY AND ENVIRONMENT

The quality of either surface water or ground water is largely the product of the environment in which the water exists. Pure water is practically unknown in nature. The substances which determine water's chemical and physical characteristics and which define its quality have many sources. Since water is a solvent, it dissolves and carries in solution certain materials derived from the soils and rocks over which it flows or through which it percolates. Since flowing water has the capacity to carry other materials in suspension, flowing streams transport sediments and wastes brought to them by overland runoff. The quantities of these materials that affect water quality often are increased by man's use of the land and by man-made wastes.

SIGNIFICANCE OF WATER QUALITY

Quality of water is vitally important in planning for water resources development, for it is quality that determines the suitability of an available water supply for an intended use. Water quality characteristics are numerous and varied, and quality requirements vary with intended use. Water suitable for one specific use may be entirely unsuitable for another. It is not enough, therefore, to determine that water is available. It must be determined also that the available supply is suitable for the use intended.

Each use of water alters its quality, sometimes significantly. Where water supply is limited, therefore, planning must include determination of the effect of intended uses on the suitability of the supply to continue to meet already existing uses.

WATER QUALITY CRITERIA

A rather complete discussion of criteria by which water quality may be judged appears in the "Report of the Committee on Water Quality Criteria," April 1, 1968, published by the Federal Water Pollution Control Administration, U. S. Department of the Interior. A discussion of criteria specifically applicable to drinking water appears in the "Public Health Service Drinking Water Standards, 1962", published by the U. S. Department of Health, Education and Welfare.

Water quality criteria for the Missouri Basin comprehensive framework study were adopted to judge the suitability of available supplies for a specific purpose or group of purposes. These criteria are considered subsequently in this appendix in connection with hydrologic analyses of framework plans developed for 1980, 2000, and 2020. The states of the basin have adopted water quality standards for the protection and enhancement of water quality. The general range of these values and those used in the framework study are as shown.

Measure	Maximum or Minimum Limit	Unit	Range of State Values	Framework Study Values
Dissolved Oxygen	Minimum	mg/l		
Cold-water fisheries			6 or 7	7
Warm-water fisheries			5	5
Domestic			3 or 4	
Industrial			3	
Total Dissolved Solids	Maximum	mg/l		500 to 1,500
Domestic			500 to 1,000	
Agriculture			700 to 1,500	
Temperature increase	Maximum	Degree F.		5
Cold-water fisheries			0 to 5	
Warm-water fisheries			0 to 10	

SUBSTANCES THAT AFFECT WATER QUALITY

Substances that affect the quality of water in the Missouri Basin are numerous. The more common and the more significant of these are described briefly in the following paragraphs, and their effects in connection with the various uses of water are discussed.

Total Dissolved Solids

Dissolved solids are salts in solution. Most commonly in the Missouri Basin, these are carbonates, bicarbonates, chlorides, sulfates, and phosphates of calcium, magnesium, sodium, and potassium, with traces of other chemicals. Water quality is affected more significantly by the specific chemicals present than by the total quantity of dissolved solids. Nevertheless, there is an upper limit for total dissolved solids concentration beyond which water becomes unpalatable, has undesirable physiological effects on both people and animals, adversely affects aquatic life through osmosis, is unsuitable for irrigation use, damages industrial equipment through scaling and corrosion, and adversely affects the taste and color of finished food products when such water is used for processing.

Sulfates

Sulfates in water are derived naturally from the dissolving action of water on gypsum and other common minerals. They are also among the wastes discharged from certain industrial processes. Some sulfates are relatively insoluble, but the sulfates of sodium, potassium, and ammonium are highly soluble. In sufficient concentration, sulfates make water unpalatable and such water may have a laxative effect on new users. In concentrations which vary with the specific sulfate compounds, waters containing them may be harmful to aquatic life. Sulfates in irrigation water in high concentrations may cause precipitation of calcium and may in themselves be harmful to plants. Sulfates increase the corrosive action of water on concrete and they form hard, adherent scales on heat-transfer equipment.

Chlorides

Chlorides most often affecting water quality are those of sodium, calcium, and magnesium. Natural sources of chlorides are leaching from soil and rock formations and erosion of soluble chloride salt deposits. Chlorides used in agriculture and industry are also often the source of chlorides in water. Brine associated with oilfield operations is a particularly significant industrial source. Chlorides in concentrations which do not make water unpalatable generally are not harmful to people except where certain diseases are already present. The effect of chlorides on aquatic life is highly variable, with some species of fresh-water fish being harmed by relatively minor concentrations while others are able to tolerate relatively high concentrations. Chlorides in irrigation water generally are more harmful to plants than are sulfates. The specific chlorides present, however, particularly with regard to sodium, are more significant in irrigation than are the concentrations in chlorides. Most industrial processes can tolerate only relatively low chloride concentrations, but the tolerance varies widely from industry to industry.

Calcium and Magnesium

Calcium and magnesium are the elements most often responsible for so-called hardness in water, although other elements also cause hardness. Sources are both natural, when water comes into contact with soil and rock formations containing the salts of these elements, and man-made, when industrial wastes containing these elements are disposed of in streams. Water with reasonable concentrations of these substances probably is not harmful to people or to animals.

The salts that produce hardness in domestic water supplies, however, affect the quality of foods cooked in such water, cause excessive soap consumption, and result in excessive formation of scale in heating equipment, in pipes, and on utensils. Excessive amounts of these sales also are harmful in many industrial processes.

Nitrates

Nitrates are utilized by plants as nutrients. Since they are produced by aerobic stabilization of organic nitrogen, they may occur in undesirable concentrations in surface waters containing organic wastes that have undergone natural purification or aerobic treatment processes. They also may occur in undesirable concentrations in ground waters or surface waters as the result of leaching from waste-treatment facilities and feedlots, or as the result of application of fertilizers in agricultural areas. Water containing excessive concentrations of nitrates has undesirable physiological effects on humans, particularly infants. Excess concentrations of nitrates also make water unsatisfactory for use in many industrial processes, and are in part responsible for nuisance aquatic weed growth which may cause taste and odor problems.

Other Chemical Substances

Other chemical substances, less common and less widespread, also affect water quality. Fluorides, found in ground water in some areas of the basin, are believed to be beneficial in low concentrations. Permissible upper limits of from 0.8 to 1.7 mg/l have been recommended in the USPHS Drinking Water Standards depending on the annual average of maximum daily air temperatures for the locale. As concentrations increase above these recommended limits, various physiological effects are evidenced with the level of toxicity to humans being about 180 mg/l. Neither fluorides, iron, nor managanese, in the concentrations normally found in the basin, adversely affect the use of water for irrigation. Water containing boron in higher concentrations, over 30 milligrams per liter, has undesirable physiological effects on people. Ingestion of large amounts of boron can affect the central nervous system, and protracted ingestion may result in a clinical syndrome known as borism. While boron is an element essential for plant growth, even concentrations as low as 1 milligram per liter may be injurious to some plants, since boron tends to accumulate in the soil with continued application of such water. Most other chemical substances affect such a limited portion of the basin's water supply or occur in such limited concentrations that they are not of major significance as determinants of water quality.

Sediment

The sediment content of water is primarily the result of the natural process of erosion. This process, however, is accelerated by some agricultural practices, by some construction activities, and by some industrial and municipal activities. Sediment constitutes the greater part of the suspended solids in most streams. Settleable solids may be of value in water treatment processes, but high concentrations increase the cost of treatment. An excess of settleable solids in natural streams and lakes may blanket the bottoms to such an extent that fish-spawning grounds are destroyed and food organisms are smothered. Sediment is generally undesirable in water for municipal or industrial use. It is generally undesirable also in waters used for recreational activities of a body-contact nature. In reservoirs, sediment deposition causes a depletion of reservoir storage capacity.

Radioactive Material

Radioactive material may be introduced into surface waters from both natural and man-made sources. Radioactive contamination of water to any degree is undesirable, regardless of the water use. Although radioactive contamination has not been a problem in the Missouri Basin to the present time, problems may develop in the future.

Microbiological Organisms

Bacteria have been used as indicators of the sanitary quality of water since 1880 when E. coli and similar organisms were shown to be normal inhabitants of fecal discharges. This group includes organisms that vary in biochemical and serological characteristics and in their natural sources and habitats, such as feces, soil, water, and vegetation.

Because the sanitary significance of the various members of the coliform group derives from their natural sources, differentiation of fecal from nonfecal organisms is important in the evaluation of raw water quality. Fecal coliforms are characteristically inhabitants of the intestines of warmblooded animals. Members of other coliform subgroups may be found in soil, on plants and insects, in old sewage, and in waters polluted some time in the past.

The objective of using the coliform group as an indicator of the sanitary quality of water is to evaluate the disease-producing potential of the water. To estimate the probability of pathogens being contributed from feces, the coliform and fecal coliform content must be quantified.

Fecal coliform organisms may be considered as indicators of recent fecal pollution. It is necessary to consider all fecal coliform organisms as indicative of dangerous contamination. Moreover, no satisfactory method is currently available for differentiating between fecal organisms of human and animal origin. However some diseases can be transmitted to man from animals and consequently fecal organisms from animal origin are of importance also.

In general, the presence of fecal coliform organisms indicates recent and possibly dangerous pollution. The presence of other coliform organisms suggests less recent pollution or contributions from other sources of nonfecal origin.

In the past, the coliform test has been the principal criterion of the suitability of raw water sources for public water supply. The increase in chlorination of sewage treatment plant effluents distorts this criterion by reducing coliform concentrations without removing many other substances which the water treatment plant is not well equipped to remove. It is essential that raw water sources be judged as to suitability by measures and criteria including, but not solely based on, the coliform organism concentrations.

Municipal Sewage

Municipal sewage is a diluted mixture of the many wastes from the household, commercial, and industrial activities of the community. Organic matter is normally the principal ingredient of municipal wastes insofar as effect on water quality is concerned. Where extensive industrial activity is present, however, the volume and great variety of industrial wastes also may have a major effect on water quality. That portion of municipal wastes attributable to widespread use of hard detergents and other household chemicals has a particular effect on water quality since these wastes are not removed by conventional sewage-treatment processes. The newer biodegradable detergents are removed in the secondary biological sewage treatment process.

Agricultural Wastes

Agricultural activities contribute many types of waste to the basin's streams. The most apparent effect of agricultural wastes on water quality is the increase in sediment over that produced under natural conditions.

Other effects, however, are also significant. Natural runoff from agricultural areas leaches agricultural chemicals, including fertilizers and pesticides, from the soil. Fertilizers washed into streams increase available nutrients and cause undesirable growth of aquatic plants. Pesticides and herbicides washed into the streams build up toxic concentrations which affect the biota of the receiving waters.

Surface runoff from barnyards and feedlots carries organic materials and large numbers of bacteria into the receiving streams. Limited available data indicate that, following each rise in stream turbidity, there is usually a measurable decrease in oxygen concentrations and a considerable increase in coliform organisms in the receiving streams. The current practice of feeding large numbers of cattle in small, confined areas is increasing the pollution problems caused by agricultural wastes. It is estimated that gross organic waste load from animal feedlots in the year 2020 will have a population equivalent nearly eight times as large as the human population at that time.

Irrigation practices also adversely affect water quality. The consumptive use of water by evapotranspiration increases the salt concentrations in irrigation return flows. In some areas, the increase in total dissolved solids may be great enough to limit the usefulness of the return flows.

OTHER CHARACTERISTICS THAT AFFECT WATER QUALITY

Color

Color in water may be of natural mineral or vegetable origin or may be the result of man's activities. Soluble organic or inorganic industrial wastes, agricultural drainage, and growth of algae or other aquatic organisms all may have an effect on the color of water. Color is objectionable in municipal water supply and is undesirable in water used for certain industrial processes. The principal effect of color in water, however, is aesthetic.

Taste and Odor

Disagreeable taste and odor in water are associated with the presence of any of a great variety of objectionable substances, particularly living microscopic organisms or decaying vegetation, including weeds, bacteria, fungi, antinomycetes and algae, decaying organic matter, sewage, and industrial waste products. Problems of taste and odor are very complex because the senses of taste and smell are intimately related and their responses are often difficult to differentiate clearly. In addition, it is frequently difficult and sometimes impossible to identify the specific cause of a taste or odor, because many substances can produce what appears to be the same effect or because mixtures of substances may be involved. Odor and taste problems may be aggravated by the impounding of water or by the settlement of suspended solids, resulting in trapping of decaying matter on lake or stream bottoms.

Waters free of taste and odor nuisances are desirable for drinking and domestic use, industry, irrigation, fish propagation, and recreation. Objectionable taste and odor are particularly undesirable in water used for drinking, domestic purposes, beverages, dairying, distilling, brewing, and food-processing industries.

Turbidity

Turbidity of a water sample is measured by the extent to which the intensity of light passing through it is reduced by suspended matter. Turbidity of water is attributable to suspended and colloidal matter, the effect of which is to disturb clearness and diminish the penetration of light. Turbidity may be caused by microorganisms or organic detritus, silica, or other mineral substances, including zinc, iron and manganese compounds, clay, silt, sawdust, fibers, or other materials. These causative agents may be the result of natural erosion processes or they may be the result of domestic sewage disposal or disposal of wastes from various industries such as mining, dredging, logging, and others.

Temperature

Temperature of water varies with seasonal changes in the temperature of the air and may also be affected by discharges from hot or cold springs, releases from water impoundments, and discharge of industrial wastes. Water temperature is critical in certain industrial processes. Sudden changes in temperature are of particular concern in propagation of fish and other aquatic life. Certain water-temperature conditions may result in algal blooms and taste and odor problems.

Sludge Deposits

Sludge deposits formed by the settling of organic material in streams smother beneficial organisms and inhibit the spawning of fish. Anaerobic decomposition of the sludge deposits robs the streams of oxygen. Floating material, lifted by the gas produced in decomposition, causes odor problems and is unsightly.

Floating Material

Floating debris, oil, and scum are not only aesthetically undesirable, but these materials also clog water-intake screens, interfere with water-treatment processes, impede stream reaeration, impart undesirable taste and odor, and necessitate extraordinary treatment before beneficial use may be made of the water in which they appear. They may also be evidence of putrefying organic deposits on the stream bed.

AVAILABILITY OF DATA ON WATER QUALITY

Surface Water

The U.S. Geological Survey, in cooperation with the basin states, has conducted investigations of the quality of surface waters in the Missouri River Basin. It began publishing annual records of chemical quality, suspended sediment, and water temperature, for surface waters, in 1941. More recently, some of the basin states have become more active in this field. The state of Kansas, for example, has participated since 1961 in an expanded cooperative quality-sampling network which now consists of 77 stations, of which seven are sampled daily, 64 are sampled monthly, and six are sampled quarterly. Five stations are equipped with continuous conductivity meters. In addition, Kansas conducts intensive investigations in individual stream basins, commonly involving 50 to 100 sampling stations, in order to better evaluate the quality characteristics of the water resources of those basins; and it is conducting a special investigation to evaluate the quantity and quality of irrigation return flow. As other examples, Wyoming participates in a cooperative program to investigate the quality of both surface-water and ground-water supplies, and Montana is expanding its investigations of surface-water quality.

The U. S. Public Health Service started a surveillance program in 1956 with the active participation of local agencies. The program has been maintained after the administrative reorganization by the Federal Water Pollution Control Administration. By 1969, 18 stations were in operation in the Missouri Basin with limited analyses for chemical, physical, bacteriological, radiological, and biological parameters being made. Starting in 1969 an additional 37 stations were initiated, including 32 by transfer of funds from the U.S.G.S. Considerable intensive field work has been performed recently by the FWPCA in specific areas. The FWPCA data are available through the computerized "STORET" storage and retrieval system.

The State Water Pollution Control agencies conduct intensive individual stream investigations and surveillance programs commonly involving 50 to 100 sampling stations, in order to better evaluate quality characteristics of the water resources of those basins. In addition, many local water and waste water treatment facilities perform stream and/or effluent quality analyses.

In spite of these activities, the amount of data available concerning quality of surface waters in the Missouri River Basin is somewhat less than desirable. More sampling stations and a reliable method to transmit the available data are needed to provide better coverage. Records at existing stations are not available for a period long enough to define accurately the changing quality of water. Data concerning the biological quality of surface waters are particularly deficient.

Ground Water

The ground-water resources of many areas in the Missouri Basin have been investigated in connection with numerous Federal and State programs, but most investigations to date have been, in large part, of a reconnaissance nature only. Usually, more than a cursory examination of chemical quality was made only where the groundwaters involved were determined to be adequate in quantity for domestic supplies or irrigation. Often, investigations were concerned primarily with the quantity of ground water available, with quality a secondary consideration. In many instances, quality investigations were limited to determinations of specific conductance. Generally, investigations for determination of changes that may have occurred in quality since development of specific ground-water supplies have not been made unless problems developed because of excessive pumping.

Some improvement is being made in the development of data on water quality. For the most part, however, the amount of data currently available concerning ground-water quality is less than desirable.

EXISTING QUALITY OF SURFACE WATER

Presentation of Quality Data

The vast size of the Missouri Basin and the consequent range that exists in the parameters of water quality make impracticable, within the space limitations inherent in a report appendix of this nature, a detailed presentation of all of the available data concerning quality of surface waters. Basin-wide graphic presentation of data pertaining to all of the parameters of surface-water quality is impracticable because of the limitations that exist in the data available. Further, some of the parameters of water quality are primarily of local, rather than basin-wide, significance. Accordingly, it has been concluded that map presentation of data on existing surface-water quality should be limited to five parameters of basin-wide significance, two primarily indicators of the suitability of water for irrigation and other three primarily indicators of the suitability of water for domestic or industrial use. Available data concerning other parameters of surface-water quality are described in subsequent text discussion of surface-water quality in each of the subbasins into which the Missouri Basin was divided in connection with the comprehensive framework study.

Basin-Wide Maps of Surface-Water Quality

Basin-wide maps of surface-water quality have been prepared for the parameters of total-dissolved-solids concentration, specific conductance, sodium-adsorption ratio, sulfates concentration, and chlorides concentration. The maps are somewhat generalized and in small areas, local quality characteristics may vary slightly from those shown. The maps are described in greater detail below.

Plate 23 shows total-dissolved-solids concentrations in surface waters. The significance of total dissolved solids has been discussed in previous paragraphs. The concentration of total dissolved solids is one indicator of the suitability of water for domestic or industrial use. It is also of value as an indicator of the suitability of water for irrigation use.

Plate 24 shows the specific conductance of surface waters. Specific conductance is a measure of the ability of water to transmit a small electric current. The more dissolved solids in water that can transmit electric current, the greater the specific conductance of the water. Specific conductance is approximately proportional to the concentration of total dissolved solids but varies with the nature of the dissolved solids. The factor to convert specific conductance in micromhos to total dissolved solids in milligrams per liter ranges from about 0.50 to about 1.00 for ordinary concentrations of dissolved solids. Water containing mostly bicarbonates or chlorides tends toward the lower factor while water containing mostly sulfates or silica tends toward and sometimes exceeds the upper factor. Data concerning specific conductance is most useful in connection with determination of the suitability of water for irrigation. By itself, it provides an approximation of the concentration of total dissolved solids. When the concentration of total dissolved solids is also known, specific conductance provides a clue to the nature of the salts involved.

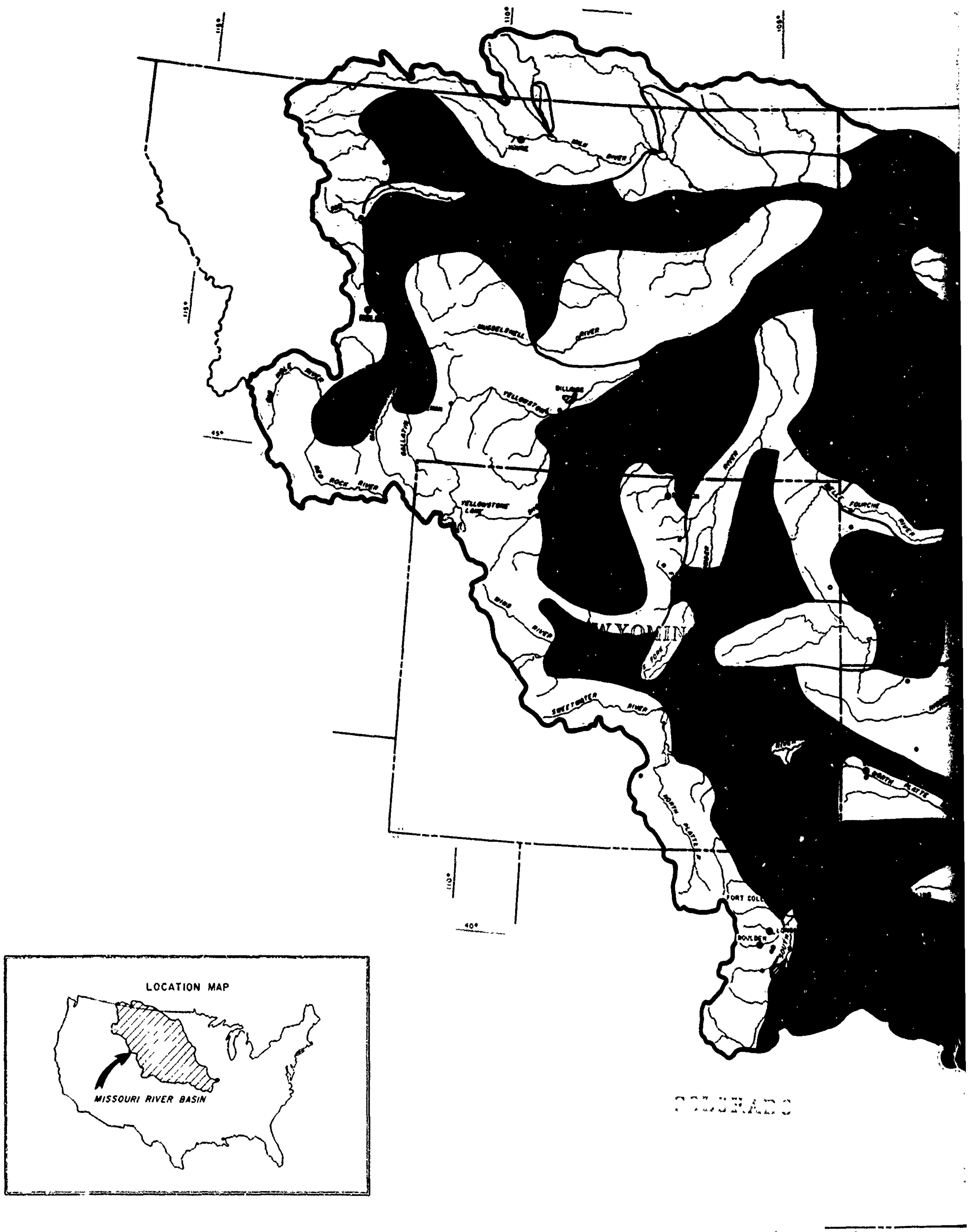
Plate 25 shows the sodium-adsorption ratio for surface waters. The sodium-adsorption ratio expresses the relative activity of sodium ions in exchange reaction with soil, and is an index of the sodium or alkali hazard to soil if the water involved is used for irrigation. Soils high in exchangeable sodium take water slowly, crust when dry, become sticky when wet, and are generally undesirable for agriculture. This condition can be developed or aggravated by irrigation with waters having a high sodium-adsorption ratio and can be prevented or reversed by irrigation with waters having a low sodium-adsorption ratio. In judging the suitability of water for irrigation, the sodium-adsorption ratio should be used in conjunction with specific conductance, for a higher sodium-adsorption ratio is tolerable in waters with a low specific conductance than in waters with a high specific conductance.

Plates 26 and 27 show the respective sulfate and chloride concentrations in surface waters. Aside from the significance of these constituents as discussed in previous paragraphs, the presence of one or both is an indicator of the suitability of water for domestic or industrial use.

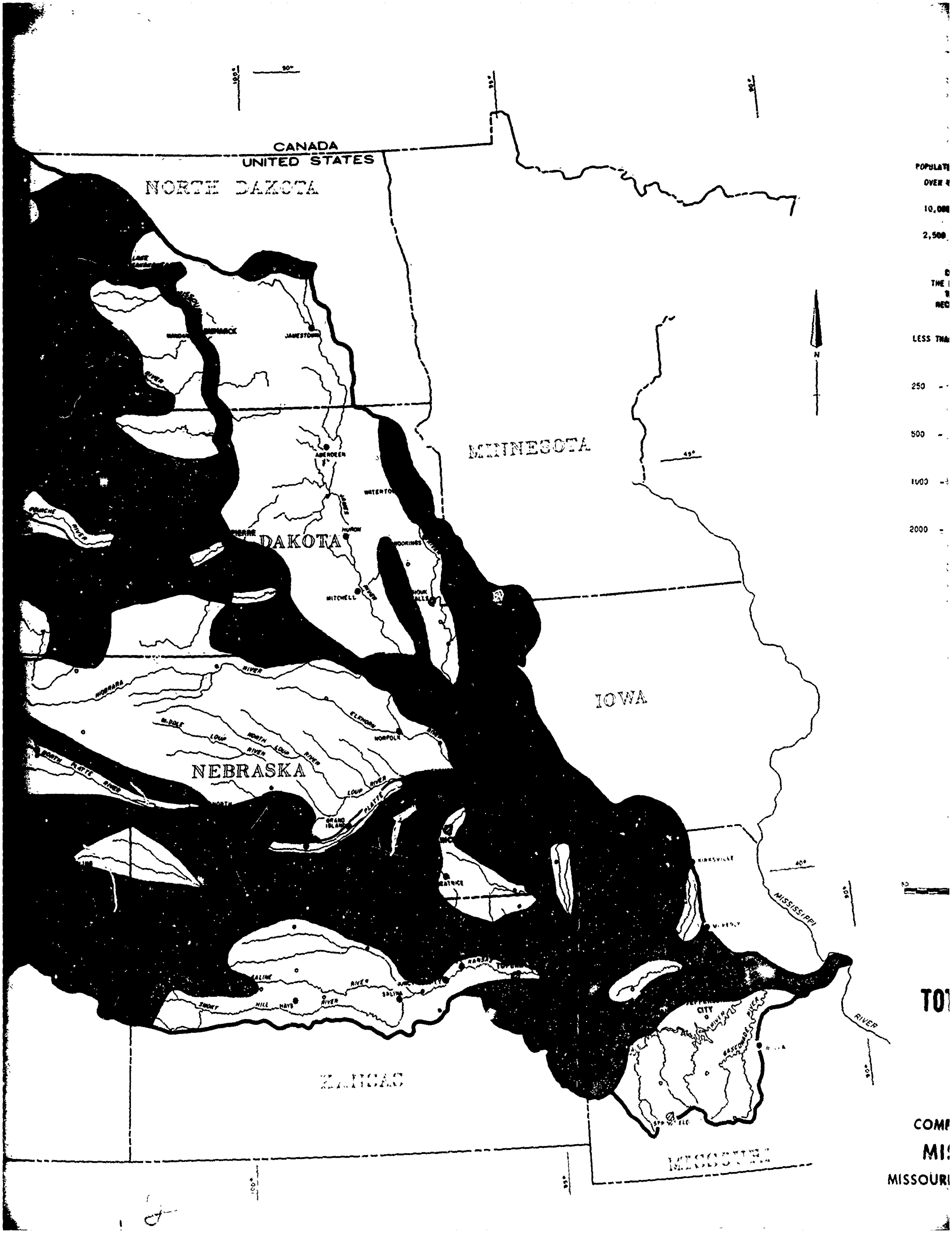
Upper Missouri Subbasin

The headwaters of most of the upper Missouri River tributaries are in the Rocky Mountains. The streams originating in and flowing through the mountainous area generally have stable flows sustained by snowmelt and, in many instances, by regulated storage. These streams run clear except during spring runoff or occasional isolated rainstorms. Except in the mountainous areas, much of the Upper Missouri Subbasin is semi-arid with precipitation usually ranging between 10 and 20 inches per year, much of it falling in the form of snow.

Streams in the mountainous areas tend to be low in dissolved solids and relatively free of mineral salts. The quality of surface waters is generally good throughout the subbasin. Physical, biological, and chemical parameters of quality are generally within limits which make the water suitable for most uses. Most of the area, when judged by stream-bottom organisms, exhibits favorable ecological conditions. Regulated storage has greatly reduced the amount of natural sediment in many streams of the subbasin.



LOCATION MAP
MISSOURI RIVER BASIN
MILK RIVER
HAVRE
MUSSELSHELL RIVER
YELLOWSTONE
BILLINGS
BIG HOLE RIVER
RED ROCK RIVER
GALLATIN
YELLOWSTONE LAKE
WIND RIVER
SWEETWATER RIVER
NORTH PLATTE R
NORTH PLATTE
BELLE FOURCHE RIVER
BOULDER
110°
45°
40°
105°



CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
DAKOTA
IOWA
NEBRASKA
MISSISSIPPI
RIVER
JAMESTOWN
ABERDEEN
PIERRE
HURON
MITCHELL
NORFOLK
GRAND ISLAND
BEATRICE
KIRKSVILLE
SALINA
HAYS
JEFFERSON CITY
N
POPULATI
OVER
10,000
2,500
LESS THA
250
500
1000
2000
TOT
COMP
MI
MISSOURI

LEGEND

POPULATED PLACES

OVER 49,999 POP. (1960)

10,000 TO 49,999 POP. (1960)

2,500 TO 10,000 POP. (1960)

AREAS WHERE SURFACE WATER HAS DISSOLVED-SOLIDS CONCENTRATIONS IN MILLIGRAMS PER LITER (MG/L) IN THE RANGES SHOWN BELOW. ALTHOUGH VALUES ARE EXTENDED THROUGH EXISTING RESERVOIRS, THESE VALUES DO NOT NECESSARILY REPRESENT THOSE FOR THE IMPOUNDED WATER.

LESS THAN 200 MG/L

250 - 500 MG/L

500 - 1000 MG/L

1000 - 2000 MG/L

2000 - 4000 MG/L

SCALE 1/5,000,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

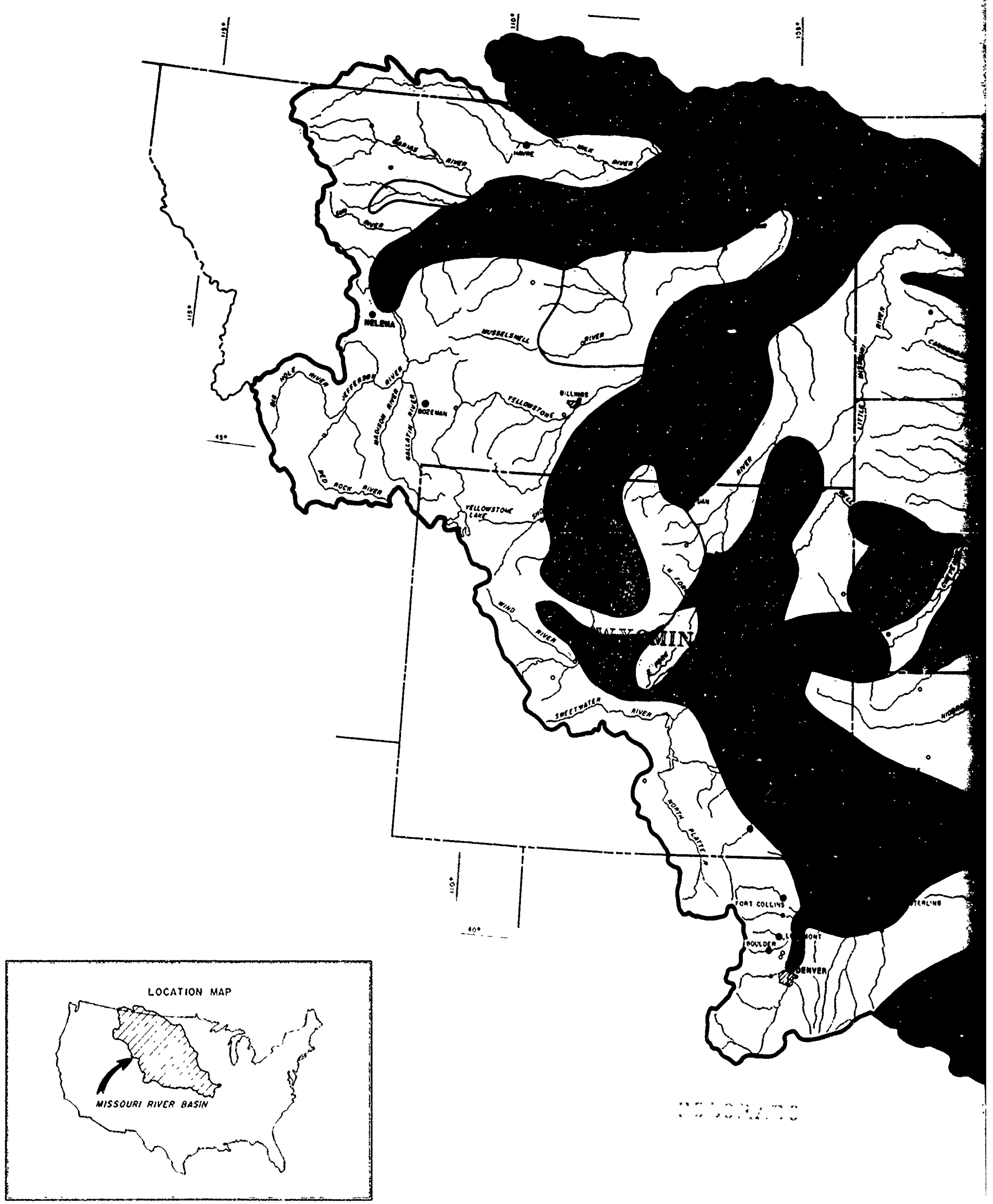
TOTAL DISSOLVED SOLIDS IN SURFACE WATER

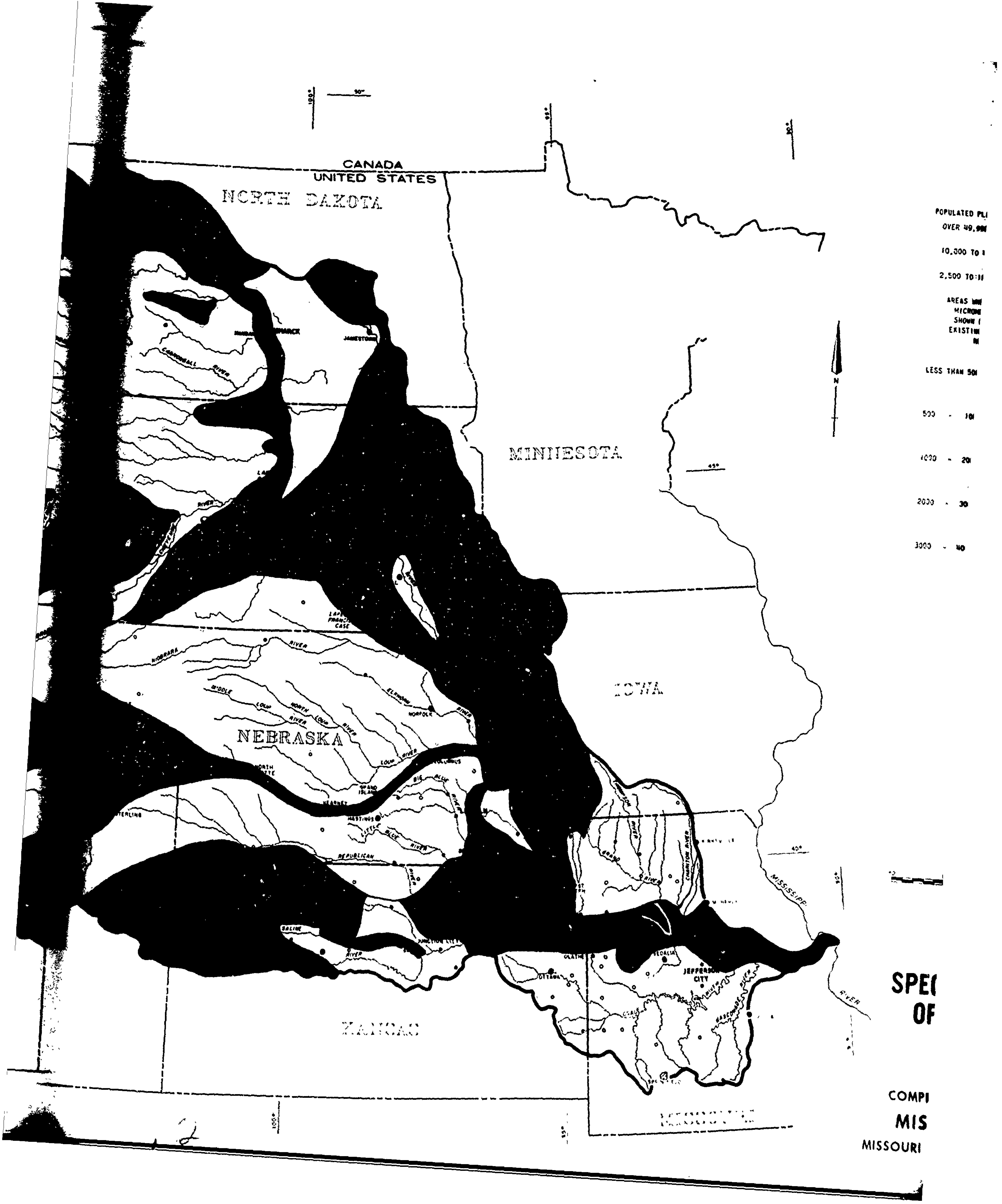
COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

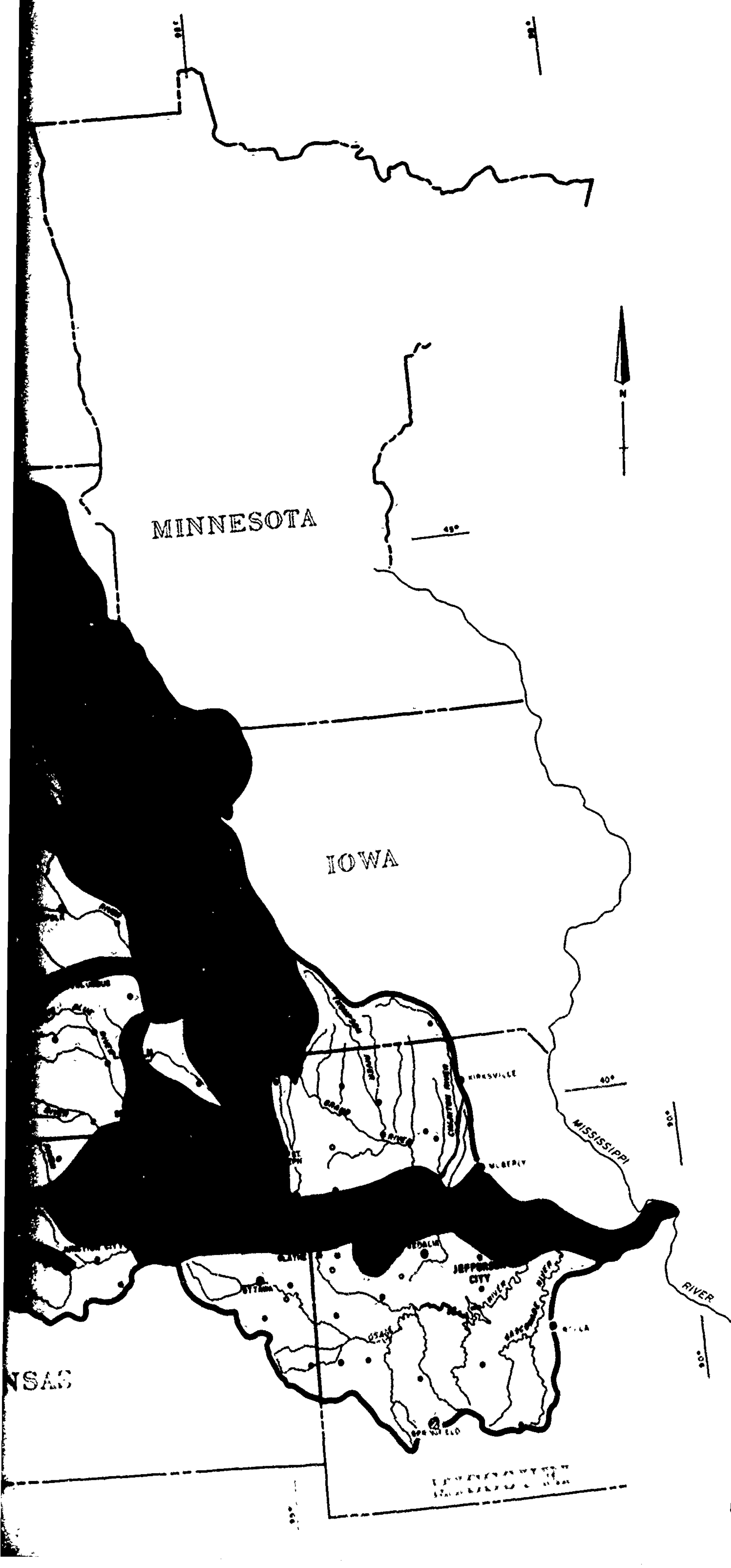
MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 23


HELENA
BOZEMAN
BILLINGS
HAVRE
MILK RIVER
MUSSELSHELL RIVER
YELLOWSTONE
BIG HOLE RIVER
JEFFERSON RIVER
MADISON RIVER
GALLATIN RIVER
RED ROCK RIVER
YELLOWSTONE LAKE
WIND RIVER
SWEETWATER RIVER
NORTH PLATTE R.
FORT COLLINS
BOULDER
DENVER
45°
40°
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
IOWA
NEBRASKA
CANNONBALL RIVER
JAMESTOWN
NIOBRARA RIVER
ELKHORN RIVER
NORFOLK
MIDDLE LOUP RIVER
NORTH LOUP RIVER
LOUP RIVER
BIG BLUE RIVER
HASTINGS
LITTLE BLUE RIVER
REPUBLICAN
SALINE
JUNCTION CITY
OLATHE
OTTAWA
SEDALIA
JEFFERSON CITY
GASCONADE RIVER
CHARITON RIVER
GRAND RIVER
MISSISSIPPI RIVER



LEGEND

POPULATED PLACES
- OVER 49,999 POP. (1960)
- 10,000 TO 49,999 POP. (1960)
- 2,500 TO 10,000 POP. (1960)

AREAS WHERE SURFACE WATER HAS SPECIFIC CONDUCTANCE IN MICROMHOS PER CENTIMETER AT 25°C WITHIN THE RANGES SHOWN BELOW. ALTHOUGH VALUES ARE EXTENDED THROUGH EXISTING RESERVOIRS, THESE VALUES DO NOT NECESSARILY REPRESENT THOSE FOR THE IMPOUNDED WATER.

LESS THAN 500 MICROMHOS/CM

500 - 1000 MICROMHOS/CM

1000 - 2000 MICROMHOS/CM

2000 - 3000 MICROMHOS/CM

3000 - 4000 MICROMHOS/CM

JUNE 1969

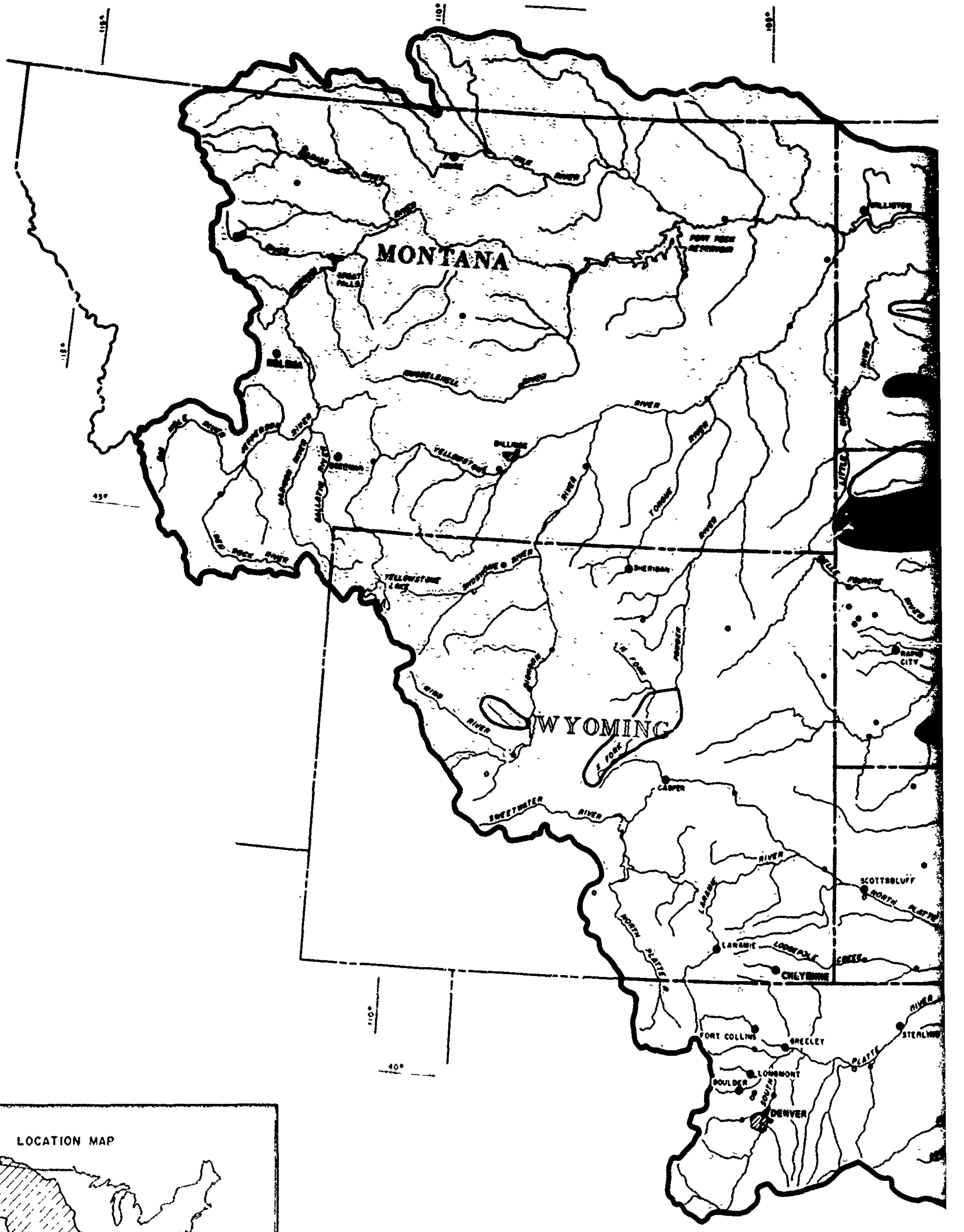
SPECIFIC CONDUCTANCE OF SURFACE WATER

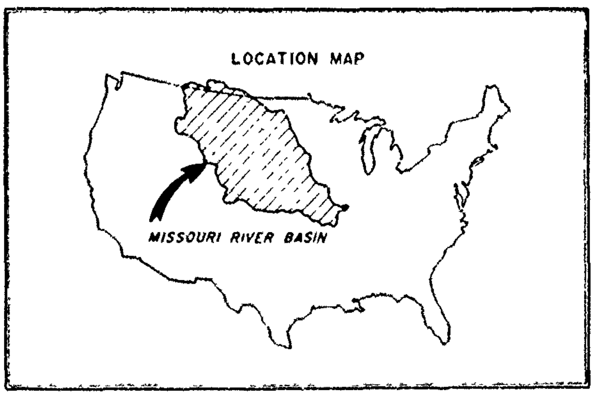
COMPREHENSIVE FRAMEWORK STUDY

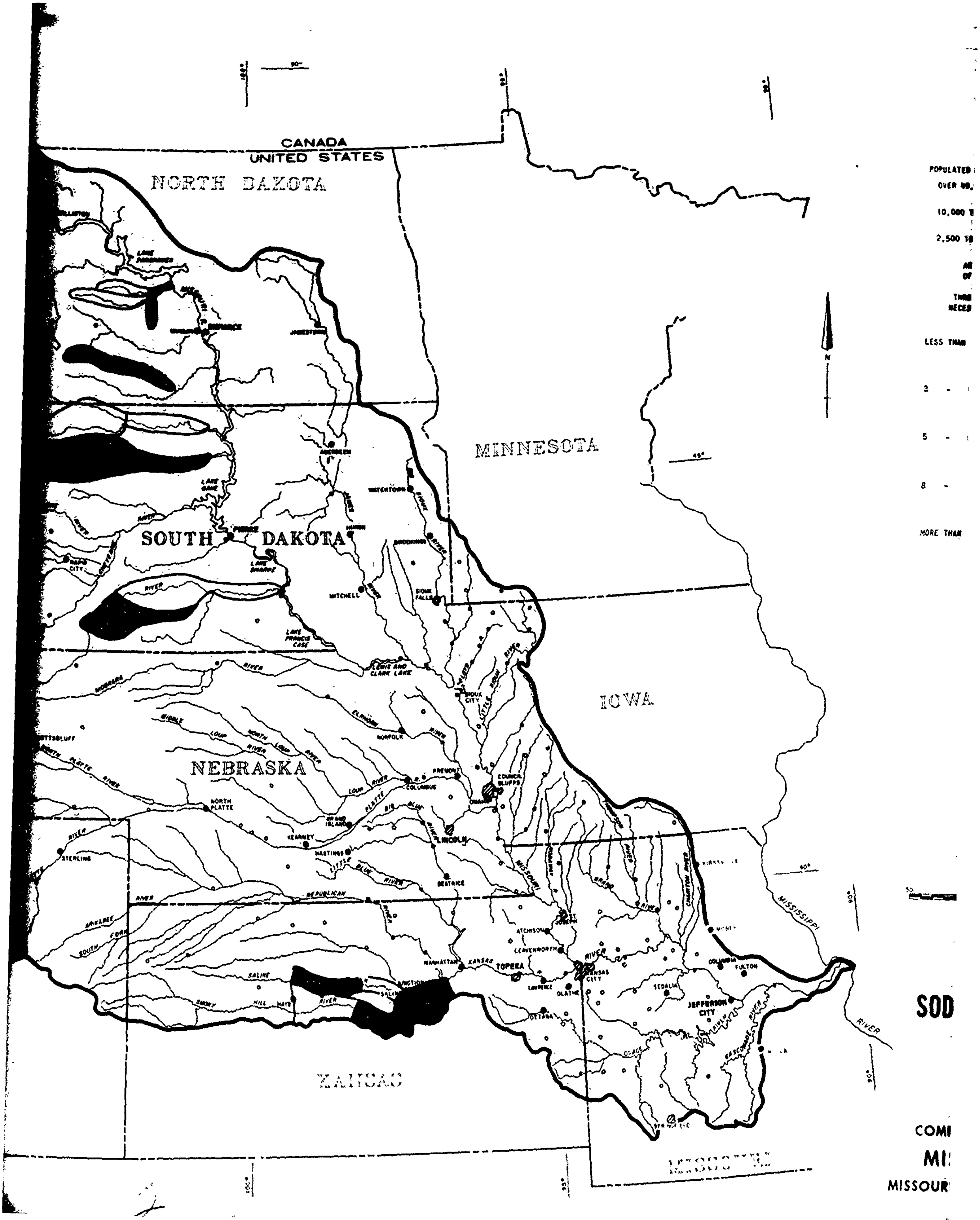
MISSOURI RIVER BASIN

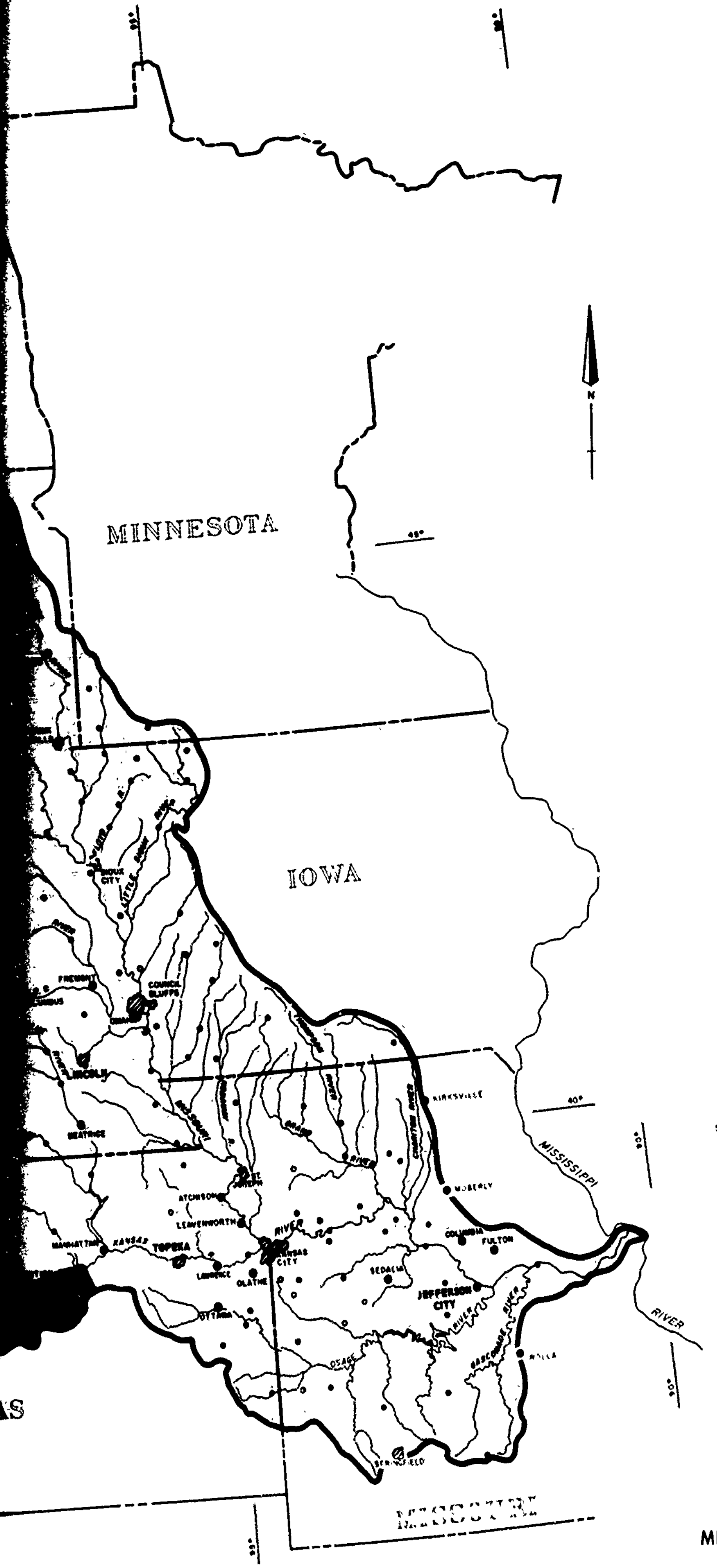
MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 24


MONTANA
WYOMING
COLORADO
GREAT FALLS
MUSSELSHELL RIVER
YELLOWSTONE RIVER
BILLINGS
RED ROCK RIVER
YELLOWSTONE LAKE
SHOSHONE RIVER
SHERIDAN
WIND RIVER
SWEETWATER RIVER
CASPER
RAPID CITY
SCOTTSBLUFF
NORTH PLATTE
NORTH PLATTE R.
LARAMIE
LODGEPOLE CREEK
CHEYENNE
FORT COLLINS
GREELEY
LONGMONT
BOULDER
DENVER
PLATTE
RIVER


LOCATION MAP
MISSOURI RIVER BASIN


CANADA
UNITED STATES
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
MINNESOTA
IOWA
MISSOURI
BISMARCK
JAMESTOWN
ABERDEEN
WATERTOWN
HURON
PIERRE
BROOKINGS
MITCHELL
SIOUX FALLS
RAPID CITY
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
SIOUX CITY
NORFOLK
FREMONT
COLUMBUS
COUNCIL BLUFFS
OMAHA
LINCOLN
NORTH PLATTE
GRAND ISLAND
KEARNEY
HASTINGS
BEATRICE
SCOTTSBLUFF
STERLING
ATCHISON
LEAVENWORTH
MANHATTAN
TOPEKA
LAWRENCE
OLATHE
KANSAS CITY
OTTAWA
SEDALIA
COLUMBIA
FULTON
JEFFERSON CITY
NIOBRARA RIVER
NORTH PLATTE RIVER
LOUP RIVER
PLATTE
ELKHORN
BIG BLUE RIVER
LITTLE BLUE RIVER
REPUBLICAN RIVER
SALINE
SMOKY HILL
GRAND RIVER
CHARITON RIVER
OSAGE
GASCONADE RIVER
MISSISSIPPI RIVER
POPULATED
OVER 40,
10,000
2,500
LESS THAN
MORE THAN
N
SOD
COMI
MI
MISSOUR



LEGEND

POPULATED PLACES

OVER 49,999 POP. (1960)

10,000 TO 49,999 POP. (1960)

2,500 TO 10,000 POP. (1960)

AREAS WHERE THE SODIUM-ADSORPTION RATIO (SAR) OF SURFACE WATER HAS VALUES WITHIN THE RANGES SHOWN BELOW. ALTHOUGH VALUES ARE EXTENDED THROUGH EXISTING RESERVOIRS, THESE VALUES DO NOT NECESSARILY REPRESENT THOSE FOR THE IMPOUNDED WATER.

LESS THAN 3

3 - 5

5 - 8

8 - 10

MORE THAN 10

SCALE 1:5,000,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

SODIUM-ADSORPTION RATIO OF SURFACE WATER

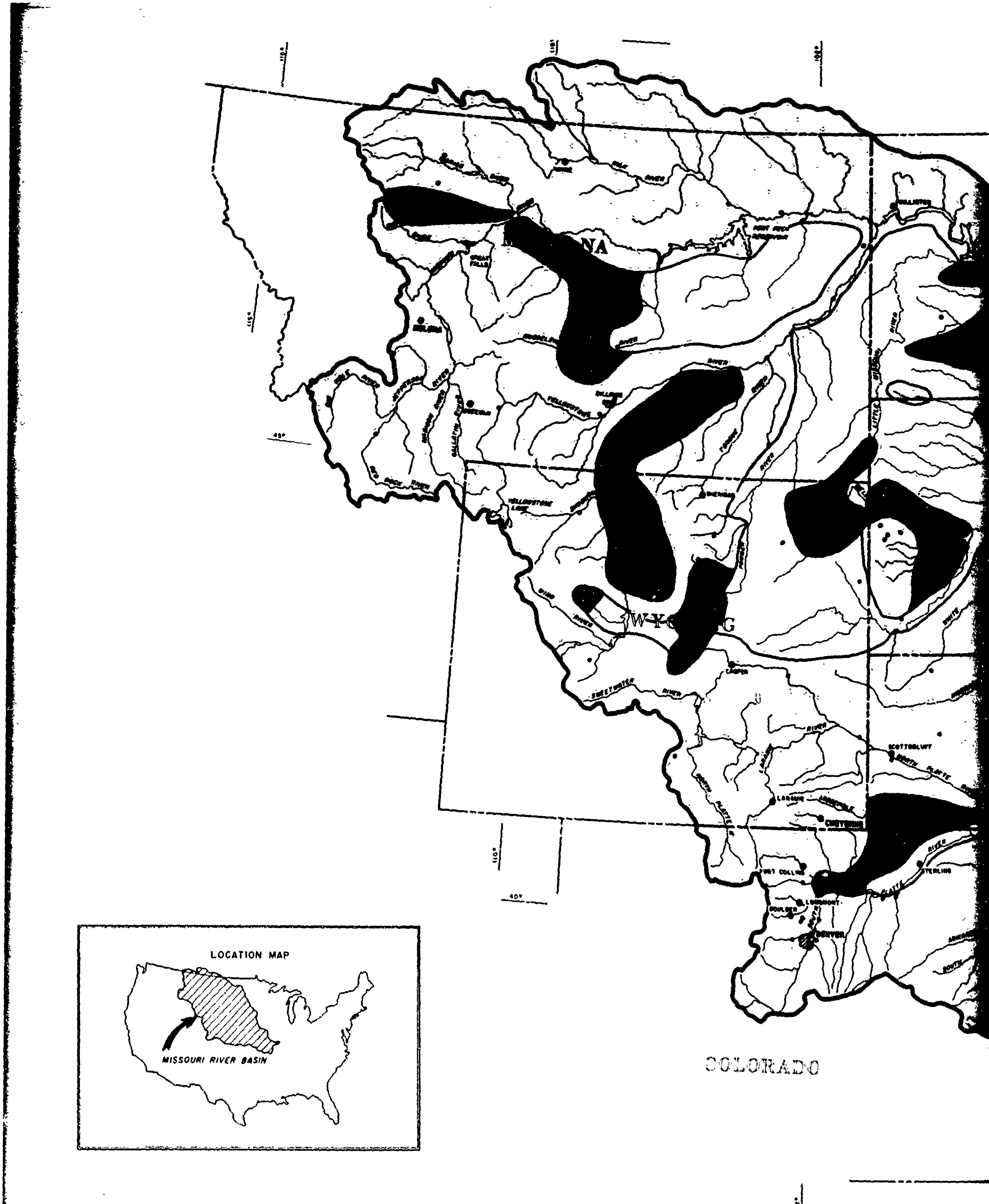
COMPREHENSIVE FRAMEWORK STUDY

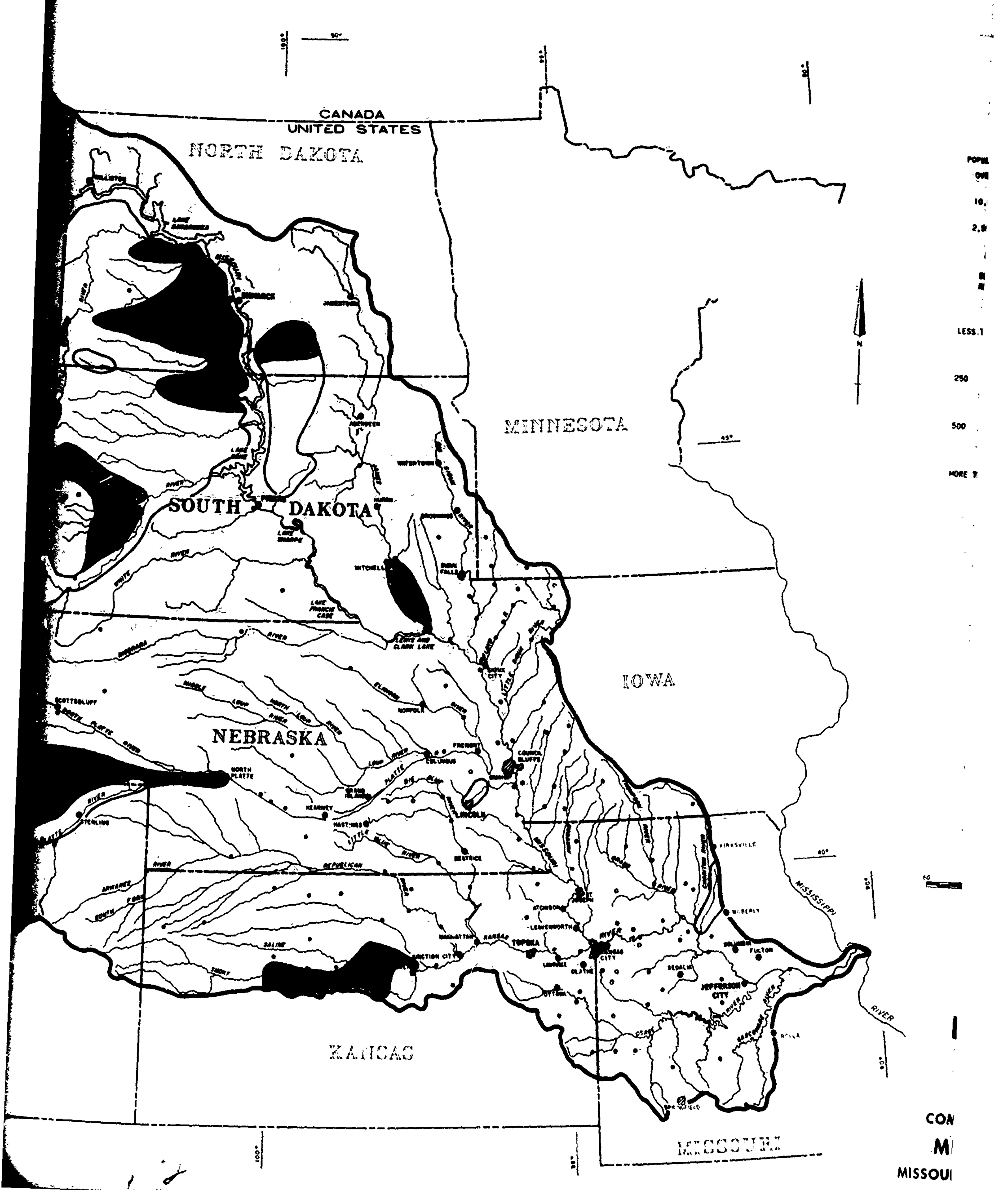
MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 25

3


LOCATION MAP
MISSOURI RIVER BASIN
COLORADO


CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
KANSAS
MISSOURI
BISMARCK
JAMESTOWN
ABERDEEN
WATERTOWN
PIERRE
HURON
BROOKINGS
MITCHELL
SIOUX FALLS
LAKE SHARPE
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
SIOUX CITY
NORFOLK
FREMONT
COLUMBUS
COUNCIL BLUFFS
LINCOLN
SCOTTSBLUFF
NORTH PLATTE
KEARNEY
GRAND ISLAND
HASTINGS
BEATRICE
STERLING
KIRKSVILLE
ST JOSEPH
ATCHISON
LEAVENWORTH
MANHATTAN
TOPEKA
JUNCTION CITY
KANSAS CITY
LAWRENCE
OLATHE
OTTAWA
SEDALIA
JEFFERSON CITY
COLUMBIA
FULTON
MOBERLY
ROLLA
WHITE RIVER
NIOBRARA
ELKHORN
LOUP RIVER
NORTH LOUP RIVER
SOUTH PLATTE RIVER
PLATTE
REPUBLICAN
KANSAS
SALINE
SMOKY
ARKANSAS
MISSOURI
GRAND RIVER
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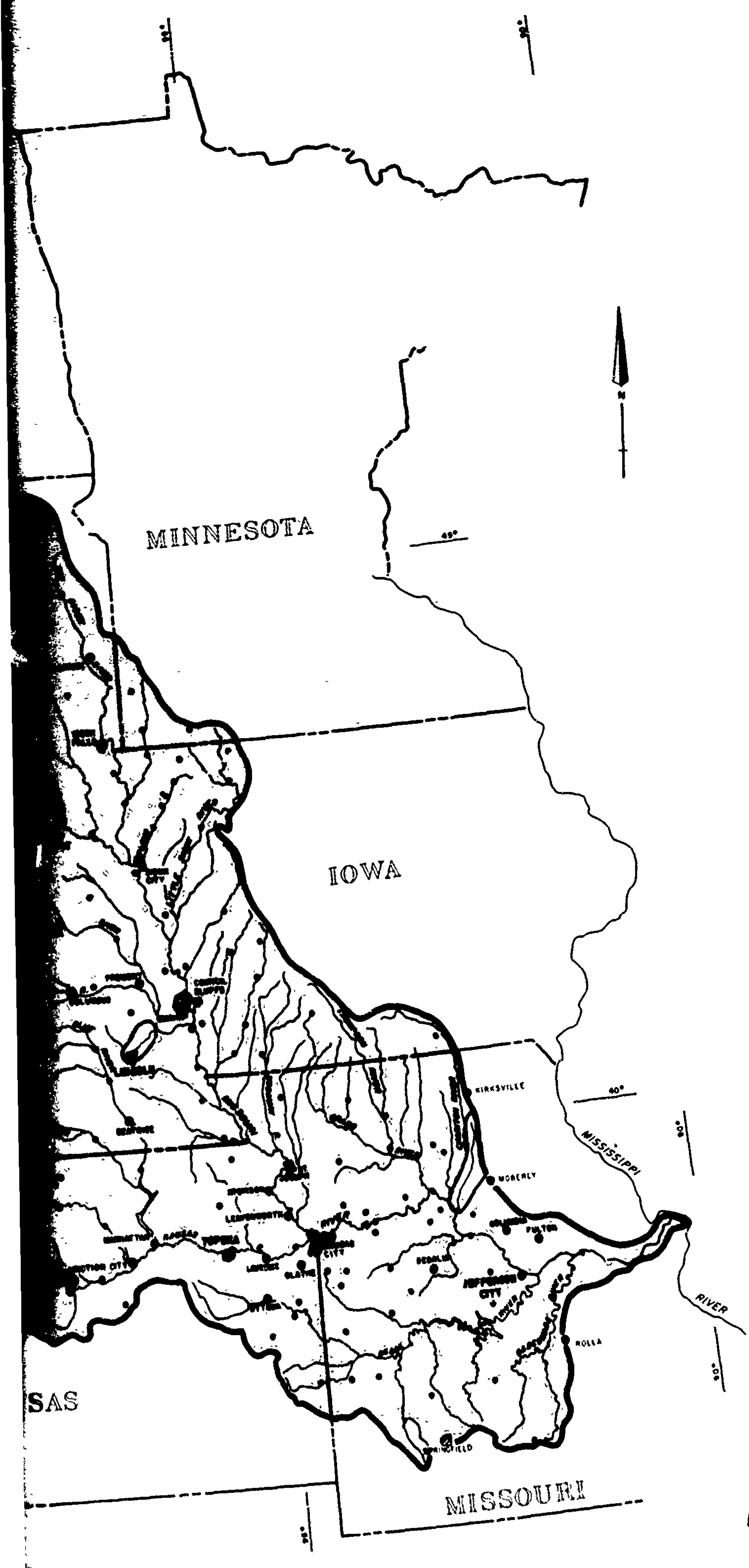


LEGEND

POPULATED PLACES

OVER 49,999 POP. (1960)

10,000 TO 49,999 POP. (1960)

2,500 TO 10,000 POP. (1960)

AREAS WHERE SURFACE WATER HAS SULFATE CONCENTRATIONS IN MILLIGRAMS PER LITER (MG/L) IN THE RANGES SHOWN BELOW. ALTHOUGH VALUES ARE EXTENDED THROUGH EXISTING RESERVOIRS, THESE VALUES DO NOT NECESSARILY REPRESENT THOSE FOR THE IMPOUNDED WATER.

LESS THAN 250 MG/L

250 - 500 MG/L

500 - 1000 MG/L

MORE THAN 1000 MG/L

SCALE 1:5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

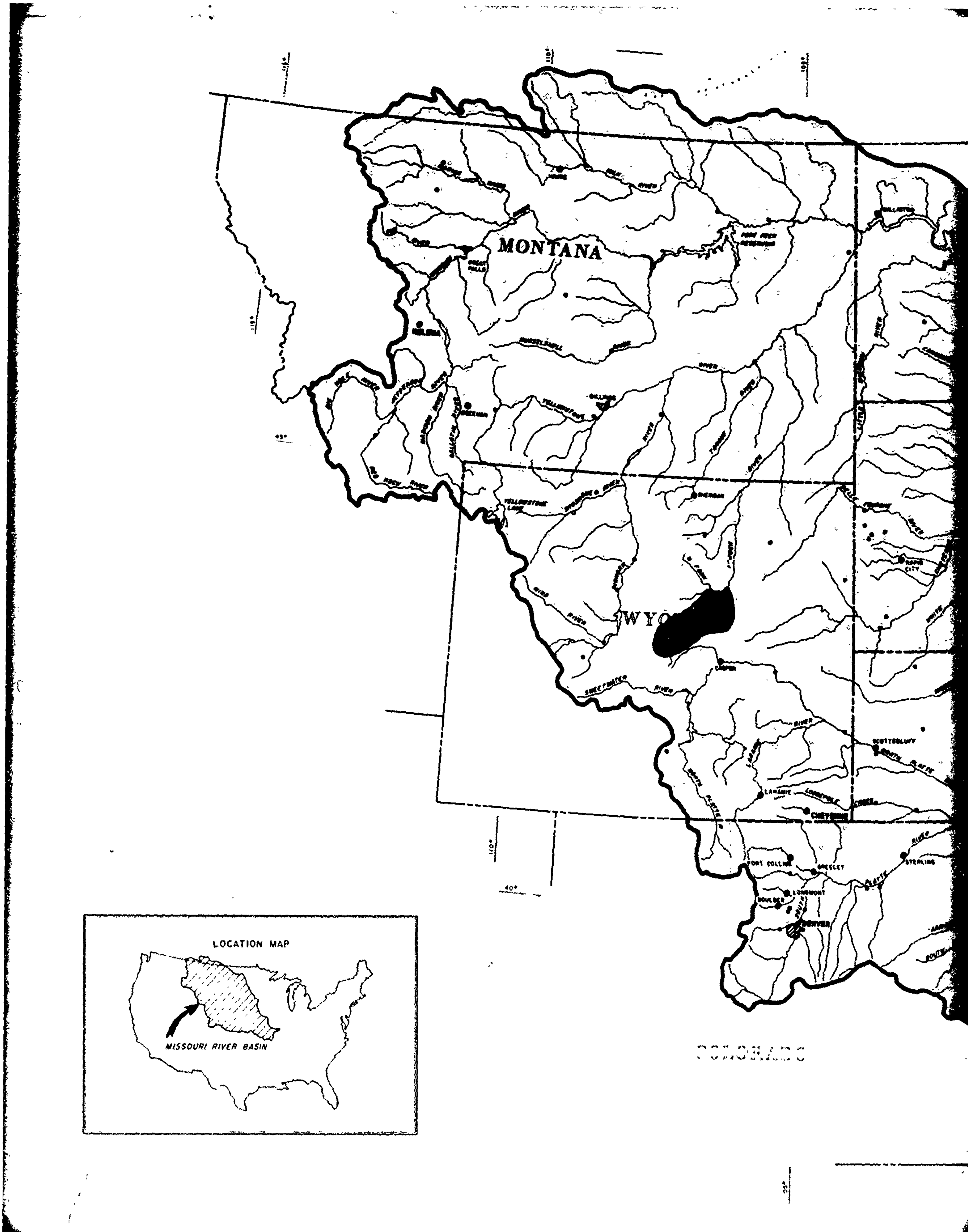
SULFATES IN SURFACE WATER

COMPREHENSIVE FRAMEWORK STUDY

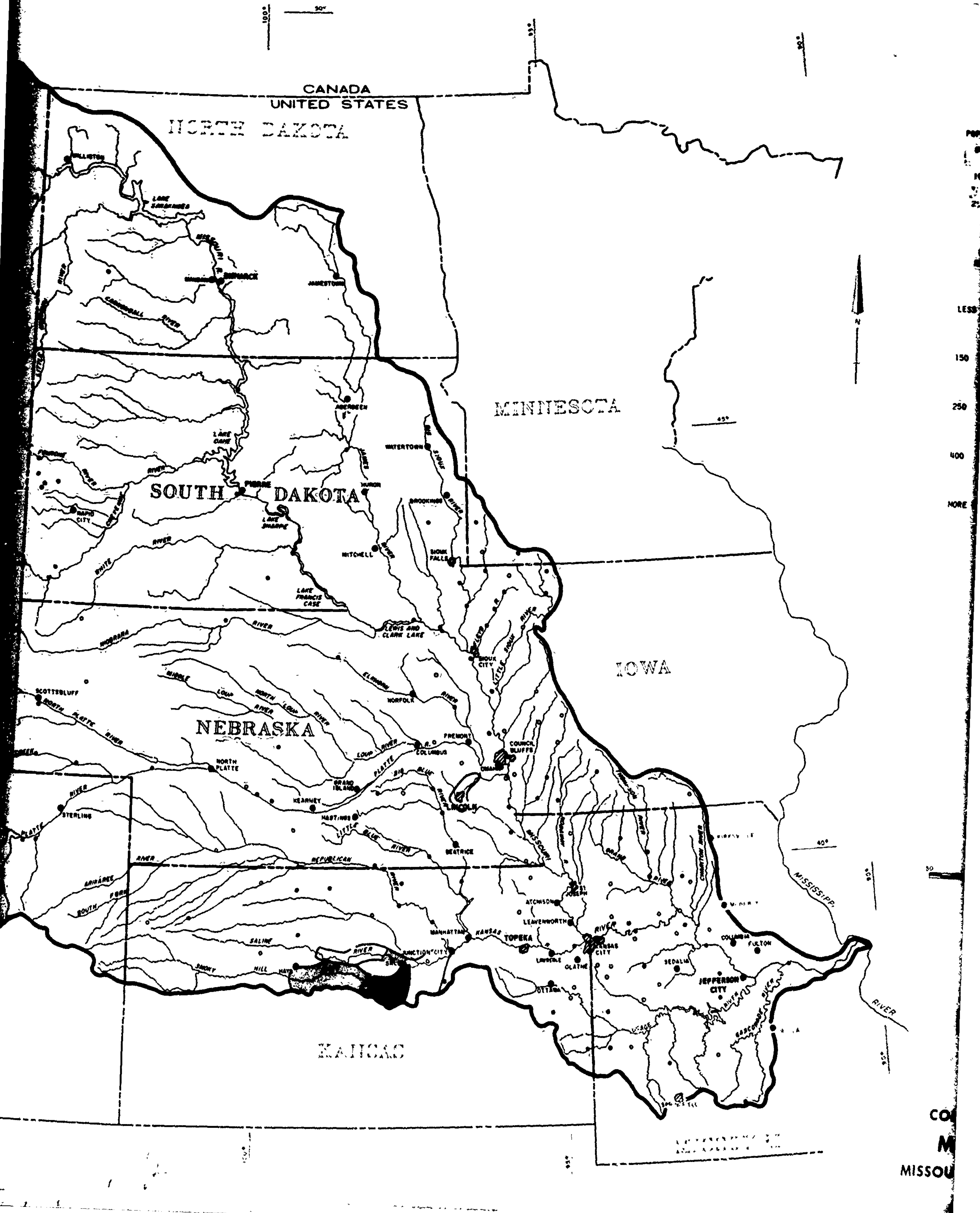
MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 26



MONTANA
WYO
LOCATION MAP
MISSOURI RIVER BASIN
GREAT FALLS
HELENA
BOZEMAN
BILLINGS
SHERIDAN
CASPER
YELLOWSTONE LAKE
SWEETWATER RIVER
SCOTTSBLUFF
LARAMIE
CHEYENNE
FORT COLLINS
GREELEY
LONGMONT
BOULDER
DENVER
STERLING
RAPID CITY
WILLISTON
FORT PECK RESERVOIR
MUSSELSHELL RIVER
YELLOWSTONE RIVER


CANADA
UNITED STATES
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
KANSAS
BISMARCK
JAMESTOWN
ABERDEEN
WATERTOWN
HURON
PIERRE
BROOKINGS
MITCHELL
SIOUX FALLS
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
SIOUX CITY
SCOTTSBLUFF
NORFOLK
FREMONT
COLUMBUS
COUNCIL BLUFFS
OMAHA
NORTH PLATTE
GRAND ISLAND
KEARNEY
HASTINGS
LINCOLN
STERLING
BEATRICE
ATCHISON
LEAVENWORTH
MANHATTAN
TOPEKA
JUNCTION CITY
KANSAS CITY
LAWRENCE
OLATHE
OTTAWA
SEDALIA
COLUMBIA
FULTON
JEFFERSON CITY
MISSISSIPPI
RIVER
LESS
150
250
400
MORE
MISSOU

L E G E N D

POPULATED PLACES

OVER 49,999 POP (1960)

10,000 TO 49,999 POP. (1960)

2,500 TO 10,000 POP. (1960)

AREAS WHERE SURFACE WATER HAS SULFATE CONCENTRATIONS IN MILLIGRAMS PER LITER (MG/L) IN THE RANGES SHOWN BELOW. ALTHOUGH VALUES ARE EXTENDED THROUGH EXISTING RESERVOIRS, THESE VALUES ARE NOT NECESSARILY REPRESENTATIVE OF THE IMPOUNDED WATER.

LESS THAN 150 MG/L

150 - 250 MG/L

250 - 400 MG/L

400 - 600 MG/L

MORE THAN 600 MG/L

APPROXIMATE SCALE IN MILES

50 0 50 100 150 200

JUNE 1969

CHLORIDES IN SURFACE WATER

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 27

Although the quality of surface waters is generally good, some pollution problems do exist, both localized and basin-wide. They involve the undesirable physiological effects on aquatic life and the aesthetic degradation which result from oxygen depletion, turbidity, and floating solids associated with municipal wastes, irrigation return flows, feedlot runoff, mining, and some other industrial activities. Turbidity problems usually are of a temporary nature, with the streams eventually returning to normal; but when channels are dredged, unstable conditions may persist for some time.

Pollution problems exist as a result of the discharge of inadequately treated municipal and industrial organic wastes in the Milk River below Havre, Chinook, Harlem, and Glasgow, Mont; in the Poplar River below Scobey, Mont; and in the Gallatin River below Bozeman, Mont. Increased sediment loads and increased mineral concentrations resulting from irrigation return flows are indicated in the lower Gallatin River and in the Milk River. Excessive turbidity resulting from other agricultural practices is in evidence in the Sun River. The Milk River above Chinook is only one illustration of undesirable stream conditions caused by runoff from cattle feedlots.

Yellowstone Subbasin

The topography of the Yellowstone Subbasin is characterized by mountain ranges and rugged hills. Great variations in elevation contribute to a substantial range of climatic conditions. In the upper, or mountainous, portions of the subbasin, streams are generally cold, clear, and low in suspended and dissolved solids. After the streams emerge from the mountainous areas, however, they flow through an area of badlands and plains. The waters become warmer and accumulate greater quantities of suspended and dissolved solids. Erosion is active here because the limited and erratic precipitation supports only a sparse vegetative cover for the soils. Soils derived from soft sedimentary rock are prevalent, and they contain appreciable amounts of the more soluble mineral salts, particularly sulfates of calcium, magnesium, potassium, and sodium. Precipitation and applied irrigation water dissolve these salts, and runoff and irrigation return flows transport them to the stream channels.

Dissolved solids concentrations, however, are generally within a range which imposes few restrictions on use of surface waters. Above the mouth of the Bighorn River, the Yellowstone River has a calcium-bicarbonate water with less than 250 milligrams per liter of dissolved solids. The Wind River has a calcium-bicarbonate water with low concentrations of dissolved solids in its upper reaches; but farther downstream, this changes to a calcium-sulfate water with a greater concentration of dissolved solids, reaching 500 milligrams per liter at Boysen Dam. Within the Bighorn River, the water changes to a sodium-sulfate type and the dissolved-solids concentration is further increased, reaching 700 milligrams per liter at the river's mouth. Downstream from the mouth of the Bighorn River, the Yellowstone River and its principal tributaries have a sodium-sulfate water with total dissolved solids in the 250-500 milligrams per liter range.

Although the chemical quality of the surface waters is good and although new treatment plants now control pollution in some previous problem areas, localized pollution problems still exist. Wastes from sugar beet processing, oil refining, and meat packing have adversely affected reaches of the Yellowstone River below Livingston, below Billings, and below Sidney, Mont. Packing-plant wastes at Riverton and beet-refining wastes below Worland have adversely affected the Bighorn River.

Irrigation, feedlots, over-grazing of range land, and new industrial development are also large contributors to stream pollution in this subbasin. The problems involved are complex and satisfactory solutions are not yet apparent.

Western Dakota Subbasin

The Western Dakota Subbasin, an area of some 50,000 square miles, is drained by the Little Missouri, Cheyenne, Grand, and White Rivers and some lesser streams. Most of the streams rise at relatively low elevations. High flows occur when the plains snow melts during the spring and after infrequent periods of excessive rainfall at other times. Annual precipitation averages about 18 inches, but annual runoff averages less than 1 inch. Except in the Black Hills area, most streams are intermittent. They traverse areas with rocks and soils that contain many soluble salts. Much of the area is readily erodible, and sediment concentrations in the subbasin streams are comparatively high.

Water quality in most of the streams is poor, primarily because of the natural conditions described. Salts leached from the land cause the water in many of the subbasin streams to be highly mineralized. An exception is the Black Hills area, where the natural chemical quality of the water is good but mining and smelter operations have seriously degraded the natural quality of some streams.

The Little Missouri, Moreau, and Cheyenne rivers and the upper reaches of the Heart, Cannonball, and Grand rivers have sodium-sulfate waters with total dissolved solids in the 1,000 to 2,000 milligrams per liter range. The Knife River and the lower reaches of the Heart, Cannonball, and Grand rivers have dissolved solids concentrations in the 500 to 1,000 milligrams per liter range.

The Cheyenne River traverses a diversified area surrounding the Black Hills, where exposed rocks belong to the Cretaceous Age. Total dissolved solids range from 1,000 to 2,000 milligrams per liter in the waters of the main stem and lesser tributaries and from 2,000 to 4,000 milligrams per liter in the Belle Fourche River, principal tributary of the Cheyenne River, where the water is of a calcium-sulfate type. Ground-water accretions and runoff from the shale hills contribute to the mineralization where the Belle Fourche River skirts the Wyoming extension of the Black Hills downstream from Keyhole Dam. Return flows from irrigation and wastes from mining operations contribute highly mineralized water.

Pollution problems caused by organic loadings are evident or are suspected in the Little Missouri River below Marmarth, N. Dak.; in the Belle Fourche River below Spearfish, Nisland, Deadwood, Lead, and Vale, S. Dak.; in the Cheyenne River below Hot Springs, Custer, and Keystone, S. Dak.; and in the White River below Harrison, Nebr.

Waste discharges from mining and processing of gold, uranium, and beryllium in the Black Hills contribute additional dissolved solids and cause color and turbidity, all of which interfere with fish propagation and adversely affect the aesthetic quality of the streams. One stream system has been reduced to a virtual biological desert and there is some question whether parts of it can ever be reclaimed. Irrigation return flows have become a problem in some areas because of the dissolved solids carried by return flows to receiving streams.

Eastern Dakota Subbasin

The Eastern Dakota Subbasin is drained by the James River, the Big Sioux River, and several lesser streams. In some of the area drainage is poorly developed. Lakes, ponds, and marshes are common. In many tributaries flows are intermittent with long periods of little or no flow.

Available data indicate that the chemical quality of the water is good in the headwaters reaches of the subbasin streams but becomes of poorer quality as the waters move downstream. The James River and the Big Sioux River in its upper reaches have a predominately sodium-calcium-bicarbonate type of water with total dissolved solids in the 250 to 500 milligrams per liter range. In the lower reaches of the Big Sioux River the water has slightly more sulfate than bicarbonate, and total dissolved solids are in the 500 to 1,000 milligrams per liter range.

The bacterial quality of the surface waters in this subbasin is generally poor. However, there are relatively few restraints on usage. Most communities and rural homes use ground water for their water supply. Ground water is usually more mineralized but of better physical and bacterial quality than are most available surface waters.

The high bacterial densities in surface waters are due to the generally small streamflow, cattle feeding and pasturing operations, and municipal waste discharges. Receiving streams generally do not have sustained flows sufficient to properly dilute the wastes from these operations. The situation will improve with provision of higher degrees of treatment for these wastes. It is doubtful, however, that the low, erratic streamflow can adequately assimilate even properly treated wastes.

Localized pollution problems exist on the James River below Oakes and Ellendale, N. Dak., and below Warner, Brentford, Melette, Ashton, Frankfort, Dolan, Artesian, Mount Vernon, Mitchell, Bridgewater, Menno, and Lesterville, S. Dak.; and on the Big Sioux River below Watertown, Flandreau, Colman, Dell Rapids, Sioux Falls, Corson, and Hudson, S. Dak., and below Hawarden, Akron, Doon, Ashton, George, and Sibley, Ia. Treated organic wastes discharged from packing plants on the Big Sioux River result in the principal industrial pollution problem in the subbasin.

Platte-Niobrara Subbasin

The Platte and Niobrara rivers drain an area of about 102,000 square miles in Colorado, Wyoming, South Dakota, and Nebraska. The subbasin includes portions of the eastern slope and foothills of the Rocky Mountains, the high plains, the Sand Hills of northern Nebraska, and the broad, flat valleys of the Great Plains rising to gently sloping uplands. About two-thirds of the land in this subbasin is classified as pasture and range land; about 29 percent is cropland.

One of the major problems of the subbasin is the imbalance in distribution of precipitation and runoff. Except for the high-mountain areas, the western portion of the subbasin has very deficient rainfall. Ground water is heavily relied upon for municipal, industrial, and agricultural water supplies.

The chemical quality of surface waters in the subbasin is generally good. Successive reuse for irrigation, however, may present problems in some areas. Increasing use of fertilizers has caused appreciable concentrations of inorganic plant foods in the streams and impoundments of the middle and lower portions of the subbasin. High bacterial densities and severe oxygen depletion are widespread.

The headwaters of the North Platte River system generally have a calcium-carbonate water with total dissolved solids of less than 250 milligrams per liter. An increase in sulfate is caused by return flows from irrigation in the North Park area of Colorado and the area in Wyoming upstream from Seminoe Reservoir. Additional sulfate is contributed by return flows from the irrigated area downstream from Alcova Reservoir. Precipitation of bicarbonate occurs in the Seminoe, Pathfinder, and Alcova reservoirs. Analyses at Capser, Wyo., show a preponderance of calcium sulfate, with total dissolved solids near 400 milligrams per liter. Mineralization is increased again by return flows from irrigated lands below Guernsey Reservoir in the Wheatland-Torrington-Scottsbluff area. Calcium and sodium sulfates are the principal salts, and the total-dissolved-solids concentration is in the 250 to 1,000 milligrams per liter range.

High concentrations of dissolved solids exist in several tributaries of the North Platte River above Casper. These are Medicine Bow River, Bates Creek, Poison Spider Creek, Oregon Trail Drain, and Casper Creek. Tributary flows are generally of better mineral quality downstream from Casper. Although there is appreciable seasonal variation, salinity generally is relatively low.

The North Platte River is substantially free of oxygen-consuming wastes above Casper, Wyo., and is in good condition from this standpoint as far downstream as Torrington, Wyo. The Laramie River, a tributary of the North Platte River, experiences oxygen depletion at times of low flow because of effluent from the oxidation ponds at Laramie. Below Torrington, poultry and meat packers, mining industry, sugar mills, and several communities discharge inadequately treated wastes into the North Platte River, which adversely affects water quality.

Headwaters of the South Platte River in Colorado have a comparatively low mineral content of the calcium-bicarbonate type. Below Denver, with irrigation return flows from the Longmont-Fort Collins Greeley area, the water of the South Platte River changes to a sulfate type and total dissolved solids increase to a concentration in the 1,000 to 2,000 milligrams per liter range. Downstream from Greeley, irrigation return flows further increase this mineralization. At Julesburg, Colo., the total-dissolved-solids concentration averages about 1,500 milligrams per liter with a predominance of calcium and sodium sulfate.

The South Platte River below Denver and several of its major tributaries, including the Cache la Poudre River, the Big Thompson River, St. Vrain Creek, and Boulder Creek, sometimes contain little or no dissolved oxygen. The pollution effects of wastes from municipal sewers and sugar beet refineries exceed the assimilation capacities of the streams, and the oxygen reserves are sometimes exhausted, to the detriment of fish and other aquatic life.

Severe bacterial pollution also exists in the South Platte River and in many of its tributaries below Denver. In the upper reaches of these streams, uncontrolled or untreated wastes from many resort areas are discharged. In metropolitan Denver, the large population and many industries contribute to the bacterial concentration. Below Denver, runoff from agricultural land and feedlots together with effluents from sugar-beet refineries, meat-packing plants, and fruit and vegetable canneries add to the bacterial loading. Coliform densities greatly exceed all commonly accepted standards for recreational use of water.

Sludge deposits formed from settleable solids in the South Platte River have destroyed desirable aquatic plants and animals. They also interfere with development or use of riverside recreational areas. Pollution in the South Platte River also has affected shallow ground-water supplies and thus created a hazard to public health.

Downstream from the junction of the North Platte and South Platte rivers, the main stem of the Platte River has water of a calcium-sodium-sulfate type with total-dissolved-solids concentrations in the 250 to 500 milligrams per liter range. Between Lexington and Columbus, Nebr., the concentration increases to the 500 to 1,000 milligrams per liter range. Below the mouth of the Loup River near Columbus, after dilution by the less highly mineralized waters of the Loup River, the total-dissolved-solids concentration drops again to the 250 to 500 milligrams per liter range.

Bacterial pollution exists in the main stem of the Platte River throughout its length because of municipal and industrial wastes and runoff from cattle feedlots. Some progress has been made in the construction of remedial works and improvement of industrial operations, but much remains to be accomplished before suitable bacterial quality can be achieved.

The Loup and Elkhorn river systems, both tributary to the Platte River in Nebraska, discharge water of a calcium-bicarbonate type with concentrations of total dissolved solids less than 250 milligrams per liter. Pollution in these river systems has caused depletion of dissolved oxygen, high bacterial densities, and deposits which have resulted in deterioration of aesthetic values along the streams.

The Niobrara River also discharges a calcium-bicarbonate type of water with a concentration of total dissolved solids less than 250 milligrams per liter. The entire Niobrara River Basin is a rural area without large towns or large industrial operations. In 1967, only five towns with populations between 500 and 3,000 discharged effluent from primary treatment plants to the river. Only two small industrial plants were without waste treatment. Pollution through runoff from grazing lands and cultivated lands is not severe. Pollution levels in the streams of this river basin accordingly are low. The upper portion of the Niobrara River in Nebraska is designated as a trout stream.

Middle Missouri Subbasin

Cropland accounts for more than three-fourths of the land use in the Middle Missouri Subbasin. Most of the streams are comparatively small, many are intermittent, and water shortages are common.

The chemical quality of the subbasin streams has not been surveyed extensively. Because the streams drain agricultural areas primarily, it is possible that runoff could cause high concentrations of nitrates, phosphates, and insecticides. Normally, however, the concentrations of inorganic salts are considered to be low.

All of the subbasin streams carry heavy loads of suspended sediment, and turbidity is high most of the time. All have experienced undesirably low levels of dissolved oxygen as the result of inadequately treated wastes, low flows, and warm water temperatures. Low dissolved-oxygen levels also are experienced after heavy runoff has produced high levels of stream turbidity.

Kansas Subbasin

The Kansas Subbasin covers an area of about 60,000 square miles. About 60 percent is in northern Kansas, about 24 percent is in southern Nebraska, and about 16 percent is in northeastern Colorado. Most of the subbasin area is devoted to agriculture. There is substantial industrial development, however, in the lower part of the subbasin.

The quality of surface waters in the subbasin is affected by mineral constituents which are of natural, industrial, and agricultural origin and by organic wastes of both municipal and industrial origin. The basin landscape is largely the product of geologic processes, and the natural mineral constituents of surface waters are closely related to the subbasin's geology. The Kansas River Basin can be divided into four general geologic regions for purposes of characterization of surface-water quality.

Quaternary deposits form the surface in much of the basin. The Pleistocene loess and the soils of the Quaternary system developed on the loess are primarily calcareous, and they supply much of the calcium bicarbonate that is found in surface runoff. Alluvium and terrace deposits are relatively small in quantity, and their effect on the composition of surface waters, therefore, is probably slight.

Rocks of the Tertiary system are found primarily in the western third of the basin. Water draining areas where the Ogallala formation of the Tertiary system is exposed is relatively high in silica and is of the calcium-bicarbonate type. Since streamflow is maintained almost entirely by direct runoff, it is of low mineralization.

Rocks of Cretaceous age predominate in the middle third of the basin. A significant stratigraphic unit in this area is the Dakota Formation, which contains zones of a highly saline nature. Drainage from the Dakota Formation probably supplies most of the dissolved solids, particularly chlorides, appearing in the lower reaches of the Solomon, Saline, and Smoky Hill rivers.

Surface rocks of the west half of the eastern third of the basin are primarily of Permian age. They include a series of shales, limestones, and sandstones, all of which contain relatively large amount of gypsum. This region contributes significant amounts of calcium, sulfate, and carbonate and some chloride to the tributary river systems.

Surface rocks in the easternmost portion of the basin are primarily of Pennsylvanian age, but there are fewer bedrock outcrops north of the Kansas River because of loess deposits and because of the till mantle left by quaternary glaciation. Significant amounts of calcium and carbonate enter the tributary river systems in this area. Relatively little chloride originates here.

The surface exposures of the various geological formations run north and south, while most of the basin streams flow in an easterly direction. Accordingly, as the streams receive runoff from the successive formations they traverse, the chemical quality of their water changes.

In the extreme western portions of the Saline, Solomon, and Smoky Hill rivers, where runoff is from areas of Tertiary and Pleistocene deposits, waters are bicarbonate in character and of good quality except that they are usually very hard. The concentration of total dissolved solids generally ranges from 250 to 500 milligrams per liter. In the Smoky Hill River drainage west of Cedar Bluff Reservoir, calcium-sulfate water is encountered, probably derived from sulfurous concretions where the stream channels are cut into bedrock. Eastward of Cedar Bluff Reservoir on the Smoky Hill River and Webster and Kirwin reservoirs in the Solomon River Basin, the common minerals encountered in surface waters are calcium, magnesium, sulfate, and chloride. In the lower reaches of the Smoky Hill, Saline, and Solomon rivers, the Dakota Sandstone is a principal contributor of dissolved minerals, mainly sodium and chloride. Surface waters here are highly mineralized during periods of low flow, with concentrations of total dissolved solids ranging from 1,000 to 2,000 milligrams per liter. Water quality in the lower Smoky Hill River Basin will be influenced in the future by operation of Glen Elder, Wilson, and Kanopolis reservoirs and by irrigation development below these reservoirs.

The Republican River and the Big Blue River now have water low in mineralization, with the concentration of total dissolved solids generally below 500 milligrams per liter, and classified as of excellent chemical quality. Extensive irrigation development in the basins of both streams may effect marked changes in the chemical quality of these waters in the future.

The effect of the Dakota Formation on the chemical composition of streamflows is also apparent in the Kansas River. Higher precipitation and runoff in the lower Kansas Subbasin and the better quality of the lower subbasin tributaries result in good chemical quality in the Kansas River. At the mouth of the Kansas River, the water is of a calcium-bicarbonate type with a prevalent concentration of total dissolved solids near 300 milligrams per liter. On occasion, however, the concentrations may fluctuate as much as 100 to 400 milligrams per liter above this prevalent value.

Future problems of high mineralization in the Kansas River may occur, primarily as the result of inflow from the Smoky Hill and Saline rivers. Industrial wastes also will increase mineral concentrations in this stream.

Livestock wastes, silt, nutrients, pesticides, and the waste products of man's activities also affect water quality in this subbasin. Some towns and cities provide inadequate treatment for sanitary sewage. In Kansas, however, the state plan for water quality control and pollution abatement calls for correction of these situations by 1971. Pollution by industrial wastes should be under control by 1972, by which time most of such wastes are scheduled to be treated in municipal treatment plants or in plants constructed especially to handle these specific wastes.

Lower Missouri Subbasin

Streams in the Lower Missouri Subbasin drain an area of about 43,400 square miles, of which about 84 percent is in Missouri, about 10 percent is in Kansas, and about 6 percent is in Iowa. The Missouri River flows eastward through the middle of the subbasin, from Kansas City to St. Louis, Mo. The major tributaries in this subbasin are the Grand and the Chariton rivers north of the Missouri River and the Osage-Marais de Cygnes and Gasconade rivers south of the Missouri River.

Little is known about the chemical quality of streamflow in the Grand, Osage, and Gasconade rivers. Waters in these streams are of a calcium-bicarbonate type with concentrations of total dissolved solids averaging less than 250 milligrams per liter. In the Little Chariton River, calcium sulfate is dominant and the concentration of total dissolved solids is about 1,000 milligrams per liter.

Throughout the subbasin, overland runoff contributes large amounts of silt and organic material to the streams. Most communities provide good secondary treatment of municipal wastes, but base-flow characteristics of the streams are such that flows generally are inadequate to assimilate the treated wastes without quality degradation. In several reaches of the Osage-Marais de Cygnes, Grand, Chariton, and Blue rivers, dissolved-oxygen levels during periods of low flow drop below values desirable for propagation of aquatic life.

Bacterial contamination of the subbasin streams has not been fully evaluated. Many streams, however, have high concentrations of coliform organisms, and localized problems occur in recreational areas on the Lake of the Ozarks, all of which represent potential hazards to public health.

Missouri River Main Stem

The headwaters of the Missouri River tend to be low in dissolved solids and relatively free of mineral salts. As a result, water in the main stem of the Missouri River in its extreme upper reaches rarely exceeds 500 milligrams per liter in dissolved solids. It is of a calcium-bicarbonate type. Below Fort Peck Reservoir, it changes to a calcium-bicarbonate-sulfate type, reflecting the geology and arid climate of the intervening tributary area and the precipitation of some of the calcium bicarbonate in the Fort Peck Reservoir. Chemical quality is generally good in the remainder of the river.

Pollution problems exist in the Missouri River, as a result of the discharge of inadequately treated municipal and industrial organic wastes below all large communities. The problem is particularly acute below Great Falls, Mont., Sioux City, Ia., Omaha, Nebr., St. Joseph, Mo., and Kansas City, Mo. This pollution reduces recreational and aesthetic values of the stream, and interferes with some aspects of commercial fishing.

Sporadic taste and odor problems exist in the Missouri River between Sioux City, Ia., and the mouth near St. Louis, Mo. The causes of these problems have not been fully determined.

The Missouri River between Sioux City, Ia., and Kansas City, Mo., is extremely high in coliform densities. This seems to be related primarily to overland runoff rather than waste discharges. However, municipal wastes are definitely a contributing factor to high bacterial concentrations below Sioux City, Ia., Omaha, Nebr., St. Joseph, Mo., and Kansas City, Mo.

Low dissolved-oxygen levels are sometimes experienced in the middle Missouri River following rainstorms when heavy runoff causes major increases in turbidity. The depressed levels do not persist throughout the subsequent rise in streamflow, oxygen levels quickly return to normal, and they tend to approach the saturation point. Evidence indicates that these oxygen deficiencies are the result of organic loadings equal to between 20 and 30 times the known municipal and industrial loads, and that overland runoff is primarily responsible.

EXISTING QUALITY OF GROUND WATER

Presentation of Quality Data

The vast size of the Missouri Basin and the consequent range that exists in the parameters of water quality also make impracticable a detailed presentation of all of the available data concerning quality of ground water. It has been concluded that basinwide graphic presentation of data on existing ground-water quality should be limited to the same five parameters that were used for graphic presentation of surface-water quality. In addition, there is included a discussion of the significance of geology to the quality of ground water and a description of some of the ground-water problems encountered in the Missouri River Basin.

Significance of Geology to the Chemical Quality of Ground Water

Ground water in the Missouri River Basin varies in quality. Although nearly all geologic formations yield some water, relatively few yield water of good quality in large quantities.

The chemical quality of water from metamorphic and igneous rocks is generally very good. Exceptions exist where salts have been concentrated in recharge water by evaporation and where connate water has migrated into fractures in the rocks.

Water recovered from sedimentary rocks varies in chemical quality between the saturated brines found in some deeply buried marine rocks to water with total-dissolved-solids concentrations less than 100 milligrams per liter found in certain limestones and near-surface sandstones. Considering all the water in sedimentary deposits, brine and other saline waters are far more abundant than fresh water. In general, salinity increases with depth.

Aeolian deposits are commonly composed of relatively inert minerals which have little effect on the chemical character of infiltrating water. As a consequence, most ground water originating in dune sand is of good quality. Water originating in loess is somewhat more mineralized since calcium carbonate usually is present in loess below the zone of weathering.

Chemical quality of water from glacial deposits varies. In those deposits overlain by thick beds of glacial till, ground water is almost stagnant and may contain appreciable amounts of dissolved material from underlying marine deposits. Where glacial deposits are subject to circulation, however, the quality of ground water is generally good.

Ground water in most valley alluvium is derived from local recharge and from lateral inflow from nearby streams and aquifers. The chemical quality of ground water in the alluvium is controlled to a large extent by vegetation culture and rock types on the valley floor and along side streams. The alluvium along many streams contains ground water with relatively high concentrations of sulfate derived from nearby rocks that are rich in gypsum. Where ground water use is high and alluvium aquifers are subject to recharge from streams, ground-water quality is controlled in part by the quality of the water in the stream.

The effects of irrigation on quality of ground water vary widely, depending upon the amount of return flow, soil conditions, and the initial concentrations of dissolved minerals in the applied water. It also depends upon the ratio between the amount of return flow that enters the ground and the amount that discharges into surface streams.

Salts contained in water applied for irrigation are not removed by the soil or the growing plants. Generally, the return flows from irrigation carry to the surface streams or to ground water most of the dissolved minerals contained in the applied water plus additional minerals leached from the soils through which the irrigation waters have passed.

Basin-Wide Maps of Ground-Water Quality

Basin-wide maps of ground-water quality have been prepared for the parameters of total-dissolved-solids concentration, specific conductance, sodium-adsorption ratio, sulfates concentration, and chlorides concentration. These parameters have the same significance in connection with ground water as was previously described in connection with surface waters. Data on these maps are limited to areas where properly located and properly constructed wells are capable of yielding 300 gallons or more of water per minute. The maps are described in greater detail below.

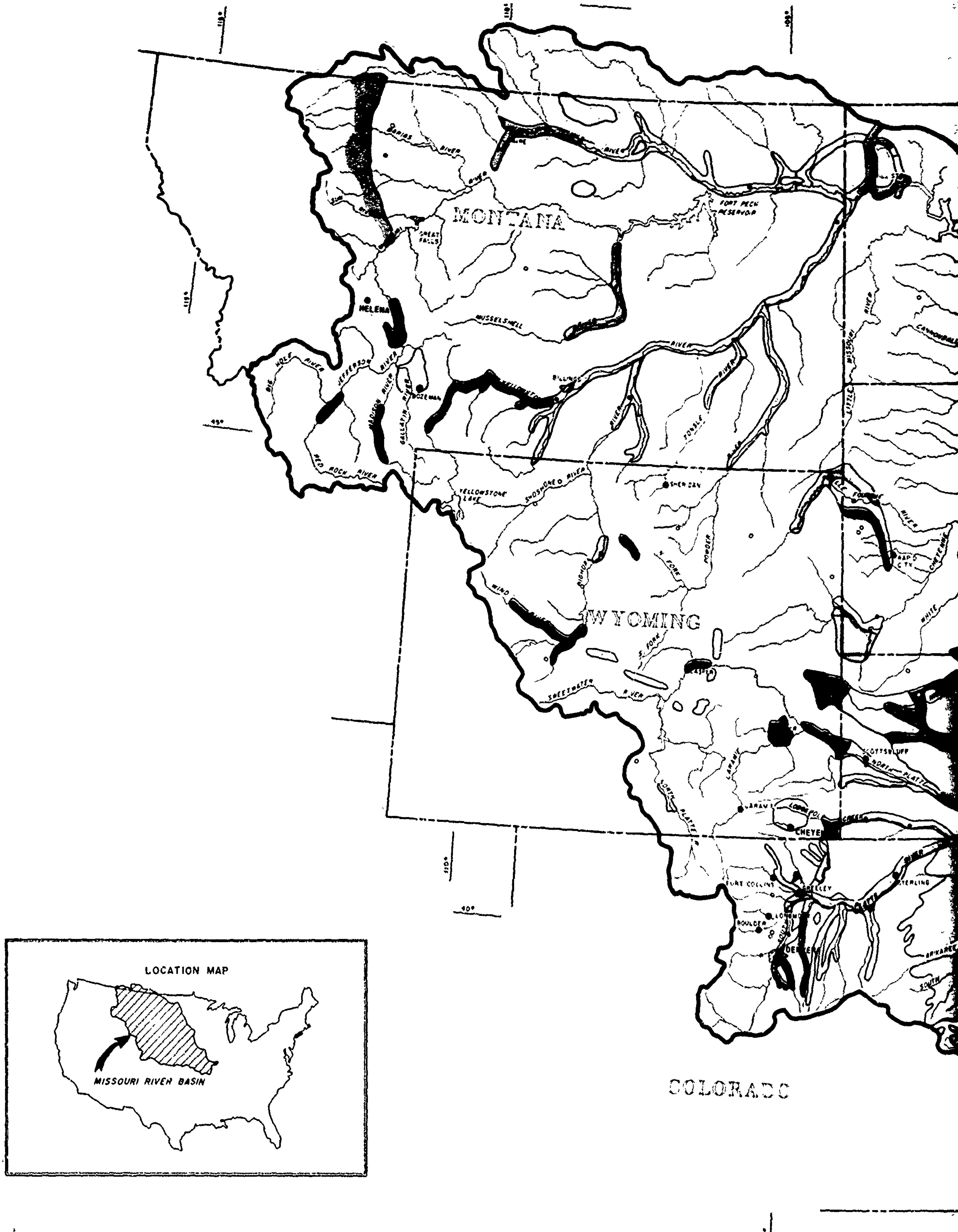
Plate 28 shows total-dissolved-solids concentrations in ground waters. These concentrations vary from less than 250 to more than 4,000 milligrams per liter.

Plate 29 shows the specific conductance of ground waters. Specific conductance ranges from less than 500 to more than 4,000 micromhos, a range somewhat parallel, as might be expected, to the range of total dissolved solids.

Plate 30 shows the sodium-adsorption ratio for ground waters. It ranges from less than three for most of the basin to more than ten in only three small areas. Water with a sodium-adsorption ratio of ten or less is considered to have a low sodium hazard. With the exception of the three small areas mentioned, therefore, ground water in the basin has a low sodium hazard.

Plate 31 shows the sulfate concentration in ground waters. It varies from less than 250 to more than 1,000 milligrams per liter. A large part of the basin, however, has ground water with sulfate concentrations less than 500 milligrams per liter. It will be noted from comparison with plate 28 that total-dissolved-solids concentrations are shown in some areas where sulfate concentrations are not shown. This is because some analyses of ground water were limited to measurement of total dissolved solids and did not include measurement of individual ions.

Plate 32 shows the chloride concentration in ground waters. Chloride in ground water is generally low throughout the basin, ranging from less than 150 milligrams per liter in most of the basin's ground water to more than 600 milligrams per liter in only a few small areas. The bulk of the water has a chloride concentration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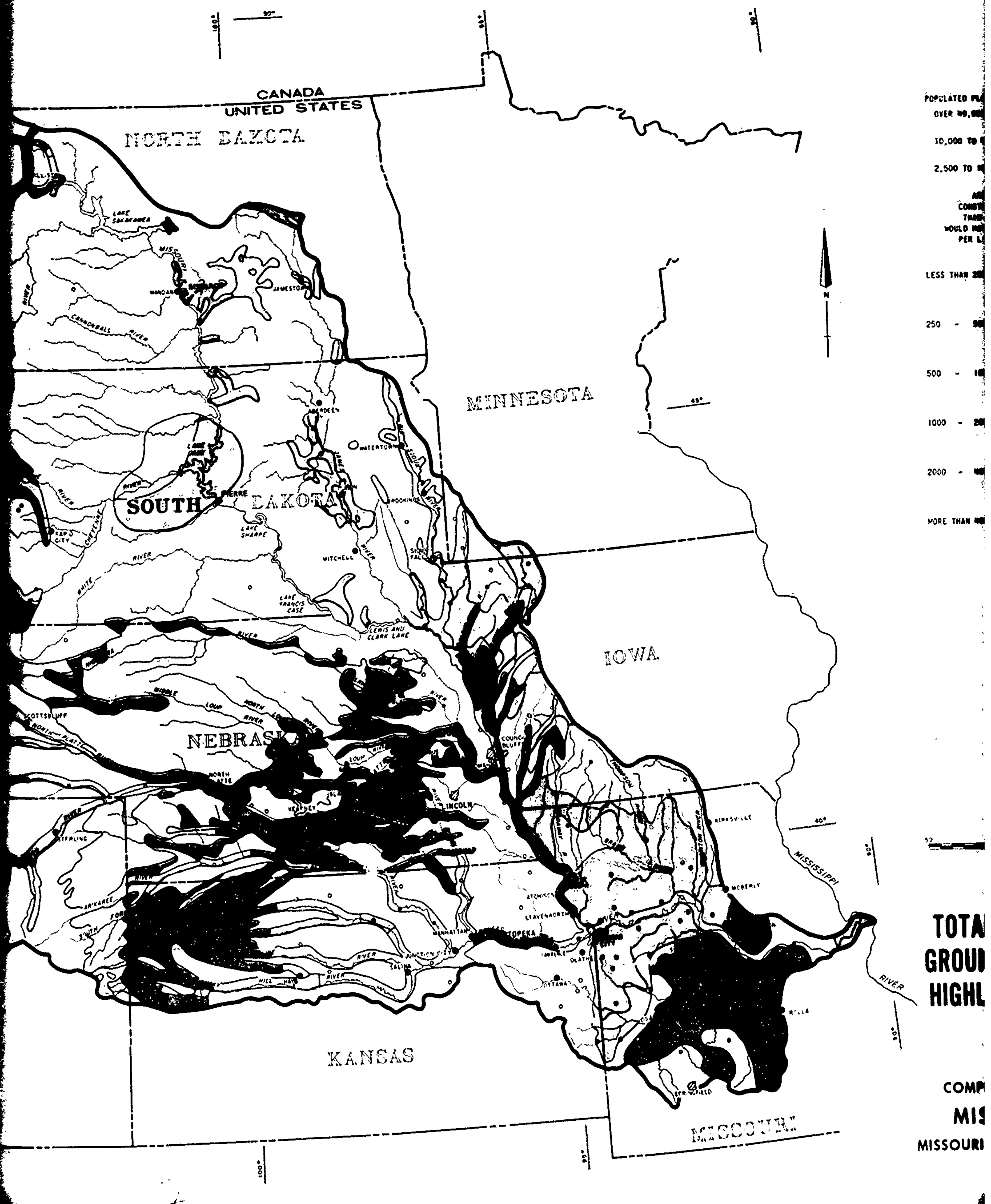
MADISON RIVER
GALLATIN RIVER
RED ROCK RIVER
YELLOWSTONE LAKE
SHOSHONE RIVER
SHERIDAN
SWEETWATER RIVER
SCOTTSBLUFF
NORTH PLATTE
STERLING
GREELEY
FORT COLLINS
BOULDER
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
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LEWIS AND CLARK LAKE
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NORTH PLATTE
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NORTH LOUP RIVER
COUNCIL BLUFFS
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KEARNEY
STERLING
SOUTH FORK
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KIRKSVILLE
MOBERLY
MISSISSIPPI RIVER
ATCHISON
LEAVENWORTH
TOPEKA
MANHATTAN
JUNCTION CITY
SALINA
OLATHE
OTTAWA
ROLLA
SPRINGFIELD
POPULATED PLA
OVER 49,0
10,000 TO
2,500 TO
LESS THAN 2
250 -
500 -
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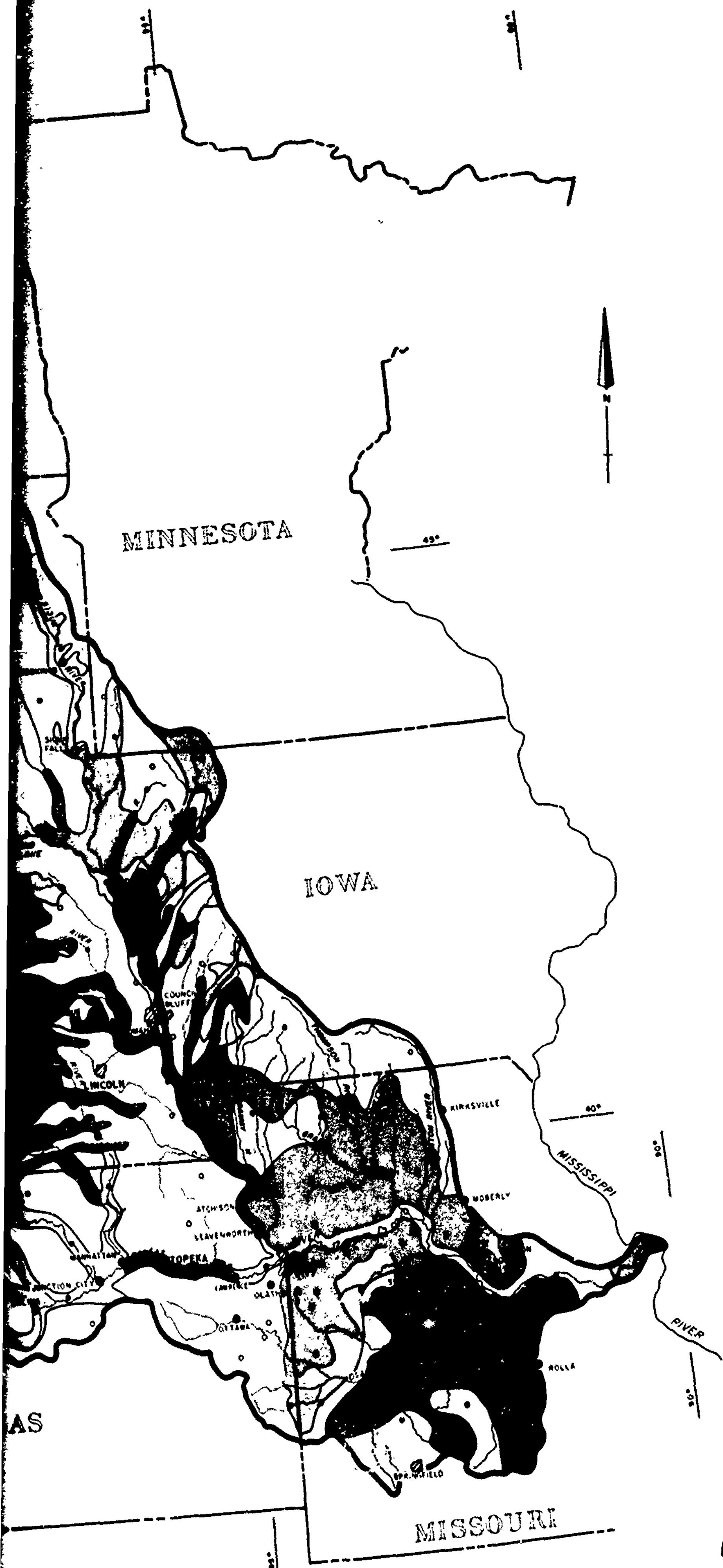


LEGEND

POPULATED PLACES

OVER 49,999 POP. (1960)

10,000 TO 49,999 POP (1960)

2,500 TO 10,000 POP (1960)

AREAS WHERE PROPERLY LOCATED AND PROPERLY CONSTRUCTED WELLS ARE CAPABLE OF YIELDING MORE THAN 300 GALLONS PER MINUTE (GPM). THE WATER WOULD HAVE A DISSOLVED SOLIDS CONTENT, IN MILLIGRAMS PER LITER (MG L), WITHIN THE LIMITS SHOWN BELOW.

LESS THAN 250 MG L

250 - 500 MG L

500 - 1000 MG L

1000 - 2000 MG L

2000 - 4000 MG L

MORE THAN 4000 MG L

APPROXIMATE SCALE IN MILES

JUNE 1969

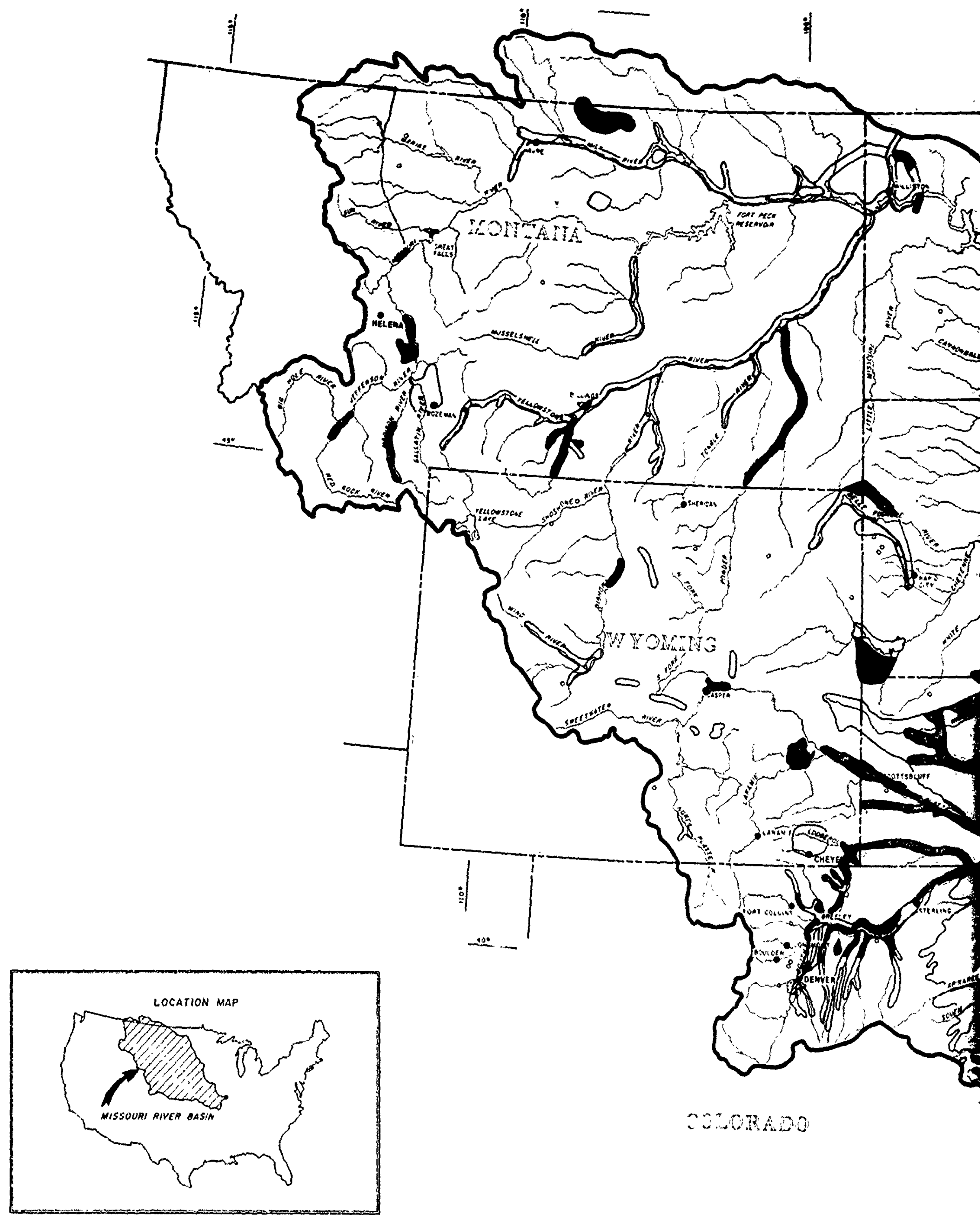
TOTAL DISSOLVED SOLIDS IN GROUND WATER OF THE MORE HIGHLY DEVELOPED AQUIFERS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 28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FORT PECK RESERVOIR
MILK RIVER
MARIAS RIVER
SUN RIVER
MUSSELSHELL RIVER
YELLOWSTONE RIVER
BIG HOLE RIVER
JEFFERSON RIVER
MADISON RIVER
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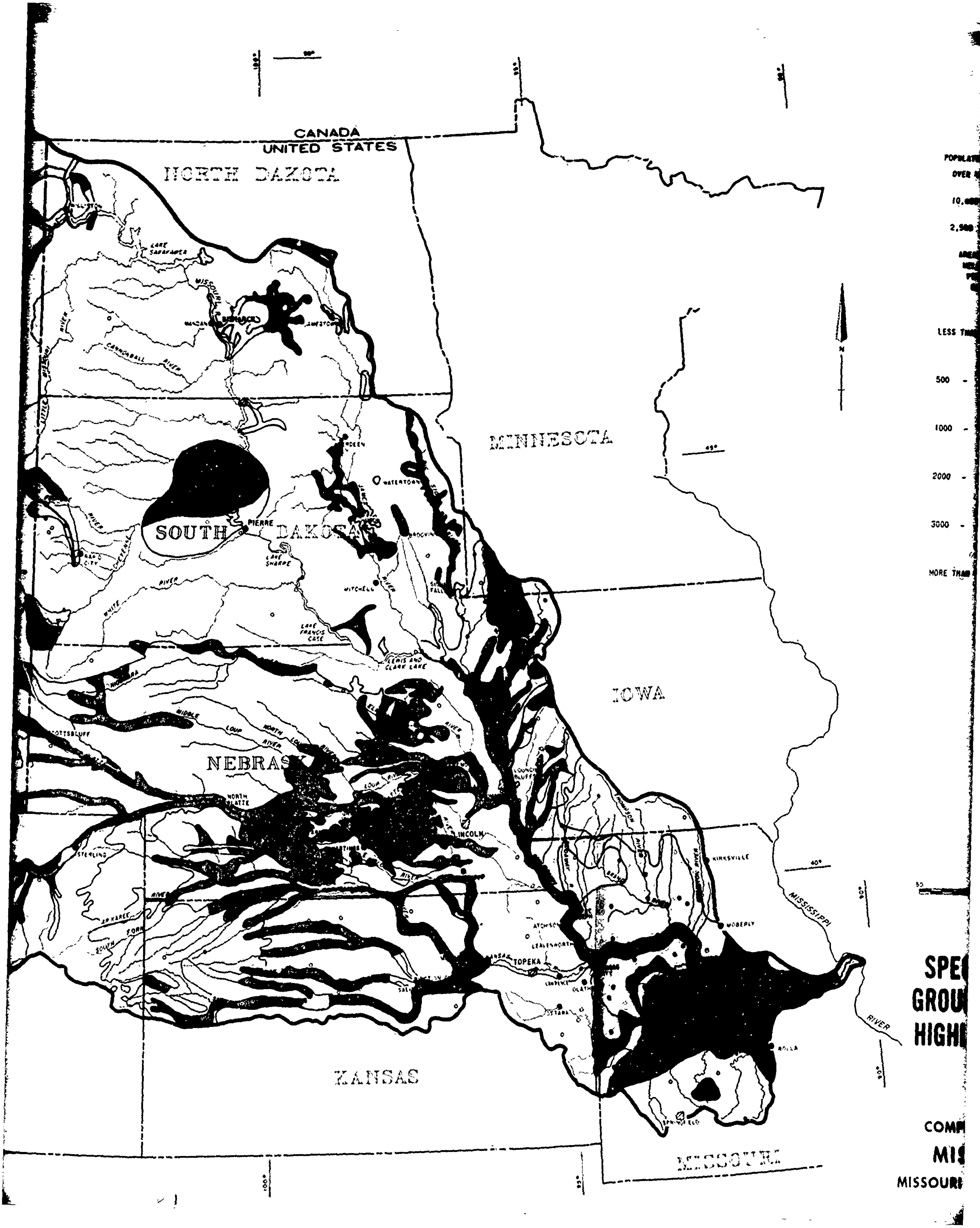
YELLOWSTONE LAKE
SHOSHONE RIVER
SHERIDAN
TONGUE RIVER
POWDER RIVER
WIND RIVER
SWEETWATER RIVER
CASPER
SCOTTSBLUFF
FORT COLLINS
GREELEY
BOULDER
DENVER
STERLING
LOCATION MAP
MISSOURI RIVER BASIN


CANADA
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TOPEKA
MISSOURI
KIRKSVILLE
MOBERLY
ROLLA
MISSISSIPPI
RIVER
500
1000
2000
3000

L E G E N D

POPULATED PLACES

OVER 49,999 POP. (1960)

10,000 TO 49,999 POP. (1960)

2,500 TO 10,000 POP. (1960)

AREAS WHERE PROPERLY LOCATED AND PROPERLY CONSTRUCTED WELLS ARE CAPABLE OF YIELDING MORE THAN 300 GALLONS PER MINUTE (GPM). THE WATER WOULD HAVE A SPECIFIC CONDUCTANCE IN MICROMHOS PER CENTIMETER AT 25°C WITHIN THE LIMITS SHOWN BELOW.

LESS THAN 500 MICROMHOS/CM.

500 - 1000 MICROMHOS/CM.

1000 - 2000 MICROMHOS/CM.

2000 - 3000 MICROMHOS/CM.

3000 - 4000 MICROMHOS/CM.

MORE THAN 4000 MICROMHOS/CM.

SCALE 1:5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

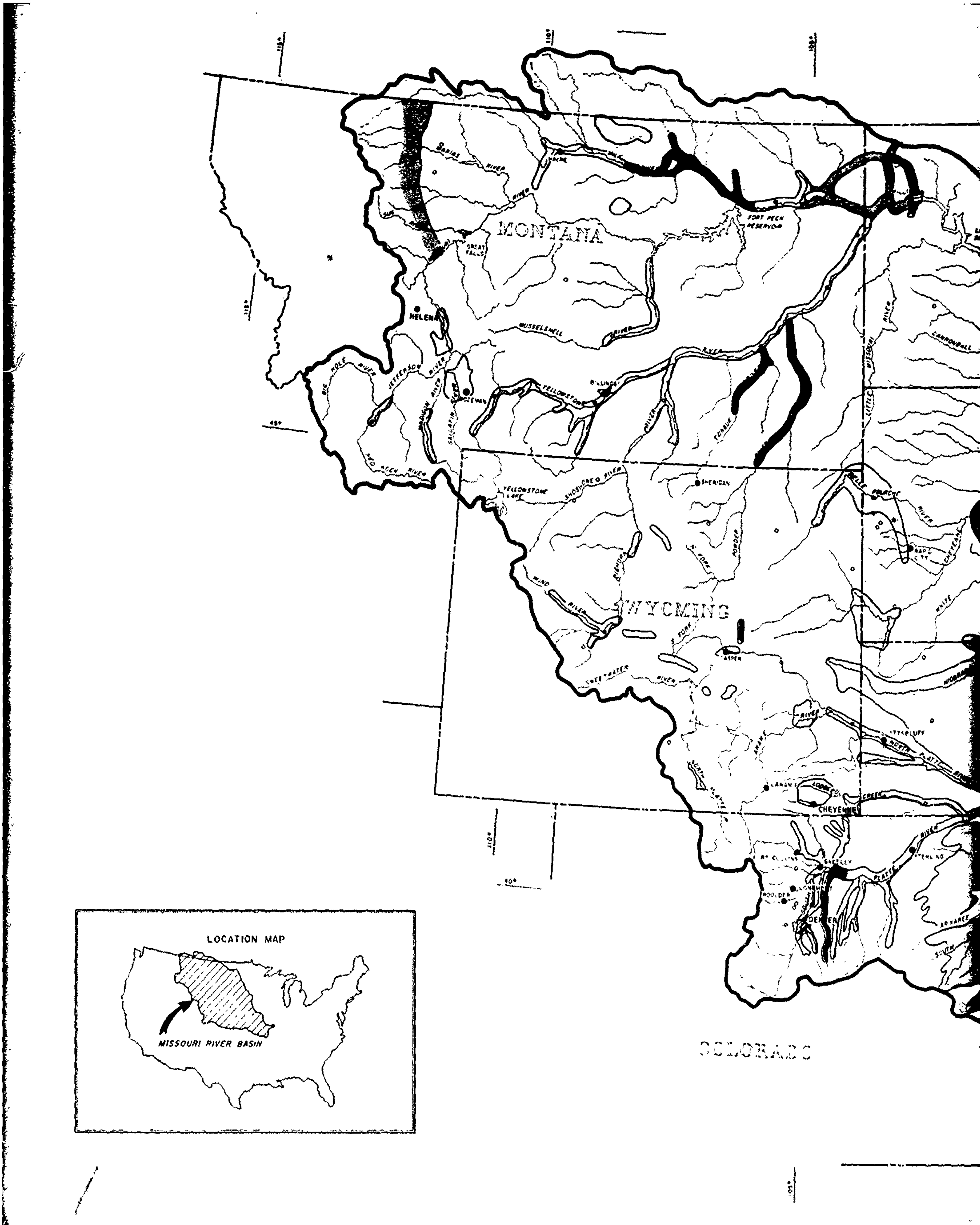
SPECIFIC CONDUCTANCE OF GROUND WATER OF THE MORE HIGHLY DEVELOPED AQUIFERS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 29



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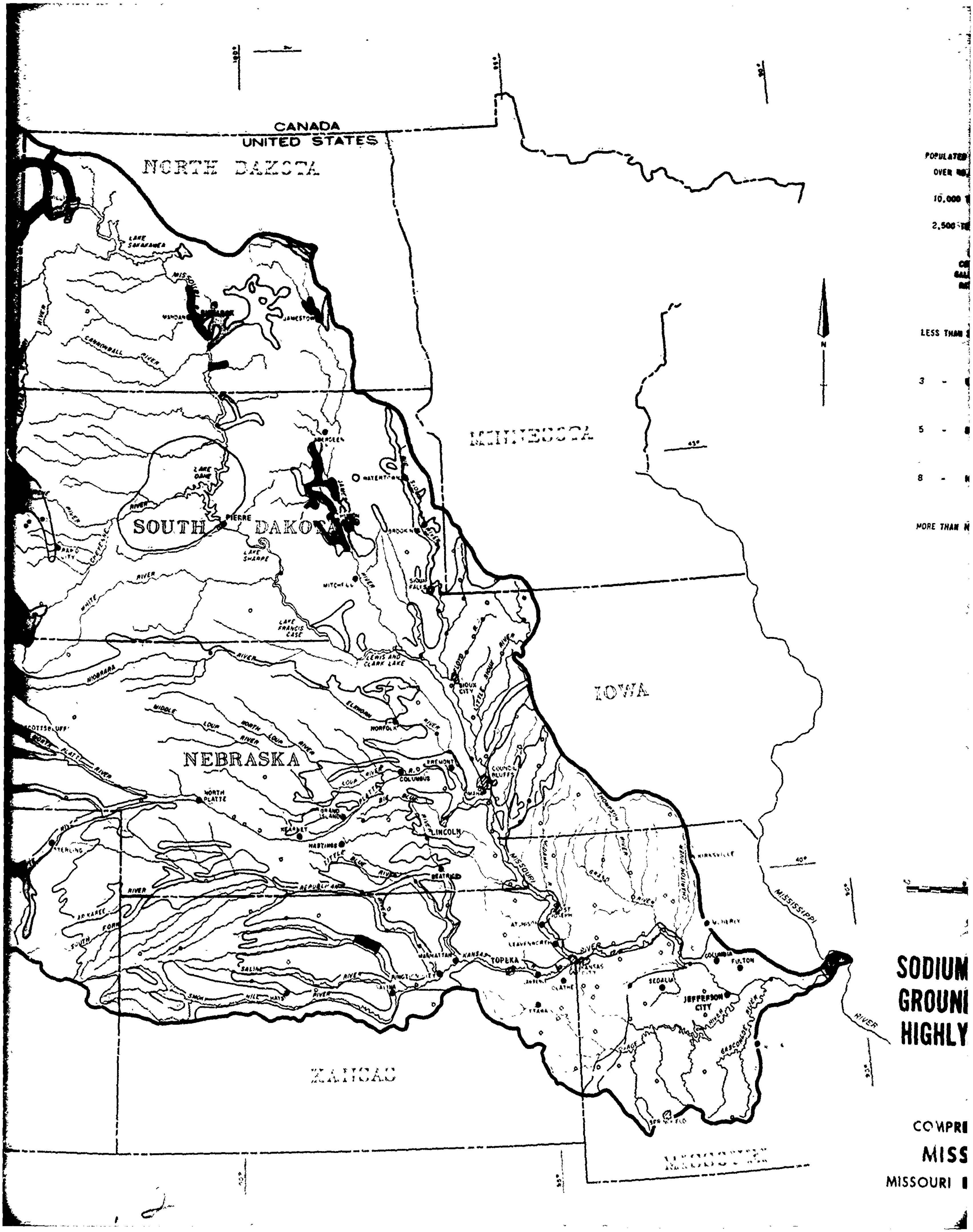
FORT PECK RESERVOIR
MUSSELSHELL
YELLOWSTONE
JEFFERSON
SHOSHONE RIVER
YELLOWSTONE LAKE
SHERIDAN
CASPER
CHEYENNE
DENVER
GREELEY
BOULDER
CANNONBALL
LOCATION MAP
MISSOURI RIVER BASIN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WHITE RIVER
MITCHELL
SIOUX FALLS
LAKE FRANCIS CASE
LEWIS AND CLARK LAKE
NIOBRARA RIVER
SIOUX CITY
LITTLE SIOUX RIVER
ELKHORN RIVER
NORFOLK
MIDDLE LOUP RIVER
NORTH LOUP RIVER
SCOTTSBLUFF
NORTH PLATTE RIVER
NORTH PLATTE
COLUMBUS
FREMONT
COUNCIL BLUFFS
GRAND ISLAND
KEARNEY
HASTINGS
LINCOLN
LITTLE BLUE RIVER
BEATRICE
STERLING
REPUBLICAN
SOUTH FORK
SALINE RIVER
SMOKY HILL RIVER
HAYS
SALINA
JUNCTION CITY
MANHATTAN
KANSAS
TOPEKA
LEAVENWORTH
ATCHISON
ST. JOSEPH
KANSAS CITY
OLATHE
MISSOURI
GRAND RIVER
CHARITON RIVER
KIRKSVILLE
MISSISSIPPI RIVER
COLUMBIA
FULTON
SEDALIA
JEFFERSON CITY
OSAGE
GASCONADE RIVER
SPRINGFIELD
POPULATED
10,000
2,500
LESS THAN
3 -
5 -
8 -
MORE THAN
SODIUM
GROUN
HIGHLY
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MISSOURI

LEGEND

POPULATED PLACES

- OVER 49,999 POP. (1960)
- 10,000 TO 49,999 POP. (1960)
- 2,500 TO 10,000 POP. (1960)

AREAS WHERE PROPERLY LOCATED AND PROPERLY CONSTRUCTED WELLS ARE CAPABLE OF YIELDING 300 GALLONS PER MINUTE (GPM). THE SODIUM-ADSORPTION RATIO WOULD BE WITHIN THE LIMITS SHOWN BELOW.

LESS THAN 3

3 - 5

5 - 8

8 - 10

MORE THAN 10

SCALE 1:1,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

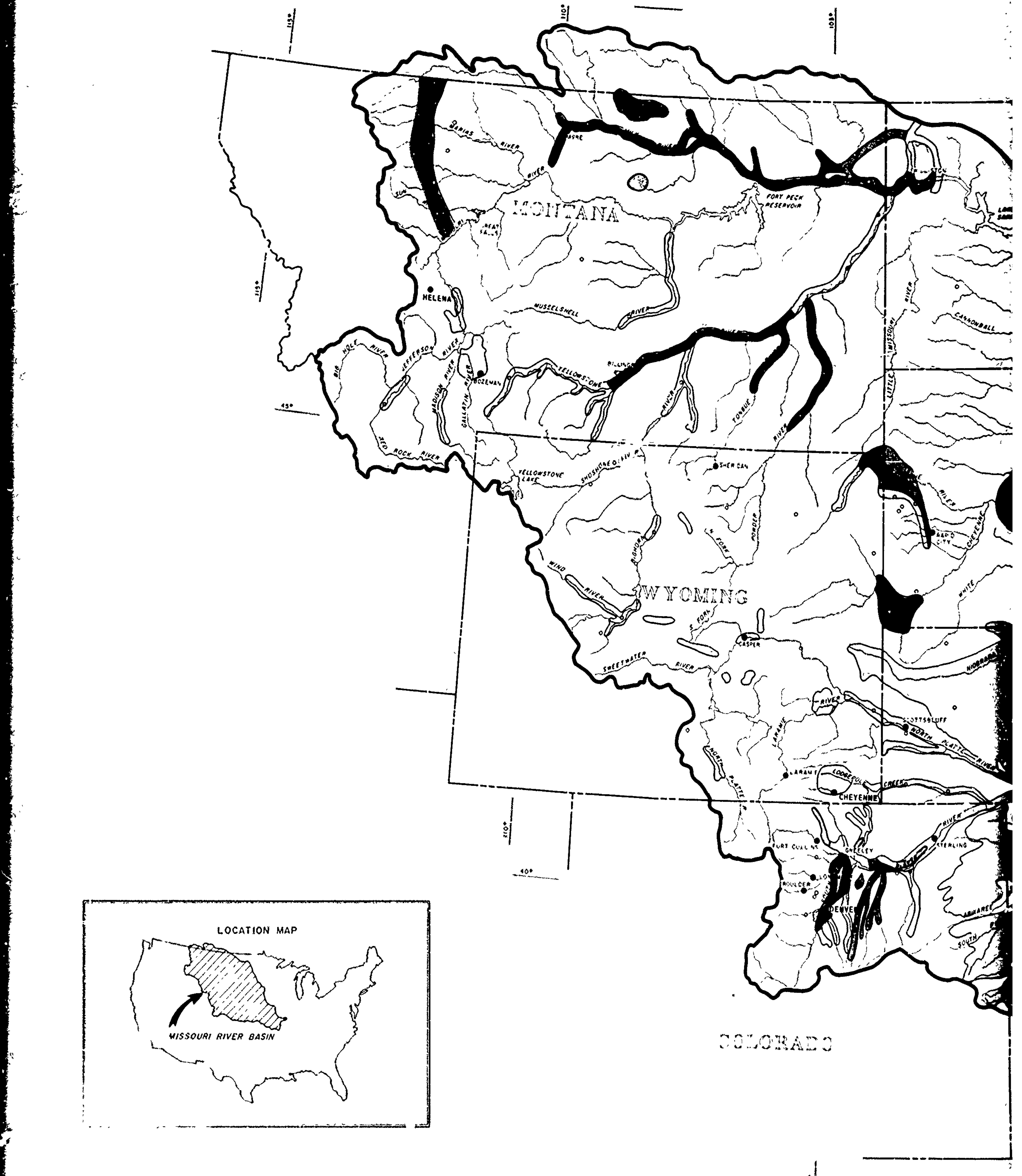
SODIUM-ADSORPTION RATIO OF GROUND WATER OF THE MORE HIGHLY DEVELOPED AQUIFERS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 30



MONTANA
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COLORADO
HELENA
BOZEMAN
BILLINGS
GREAT FALLS
FORT PECK RESERVOIR
MARIAS RIVER
SUN RIVER
MUSSELSHELL RIVER
YELLOWSTONE RIVER
JEFFERSON RIVER
MADISON RIVER
GALLATIN RIVER
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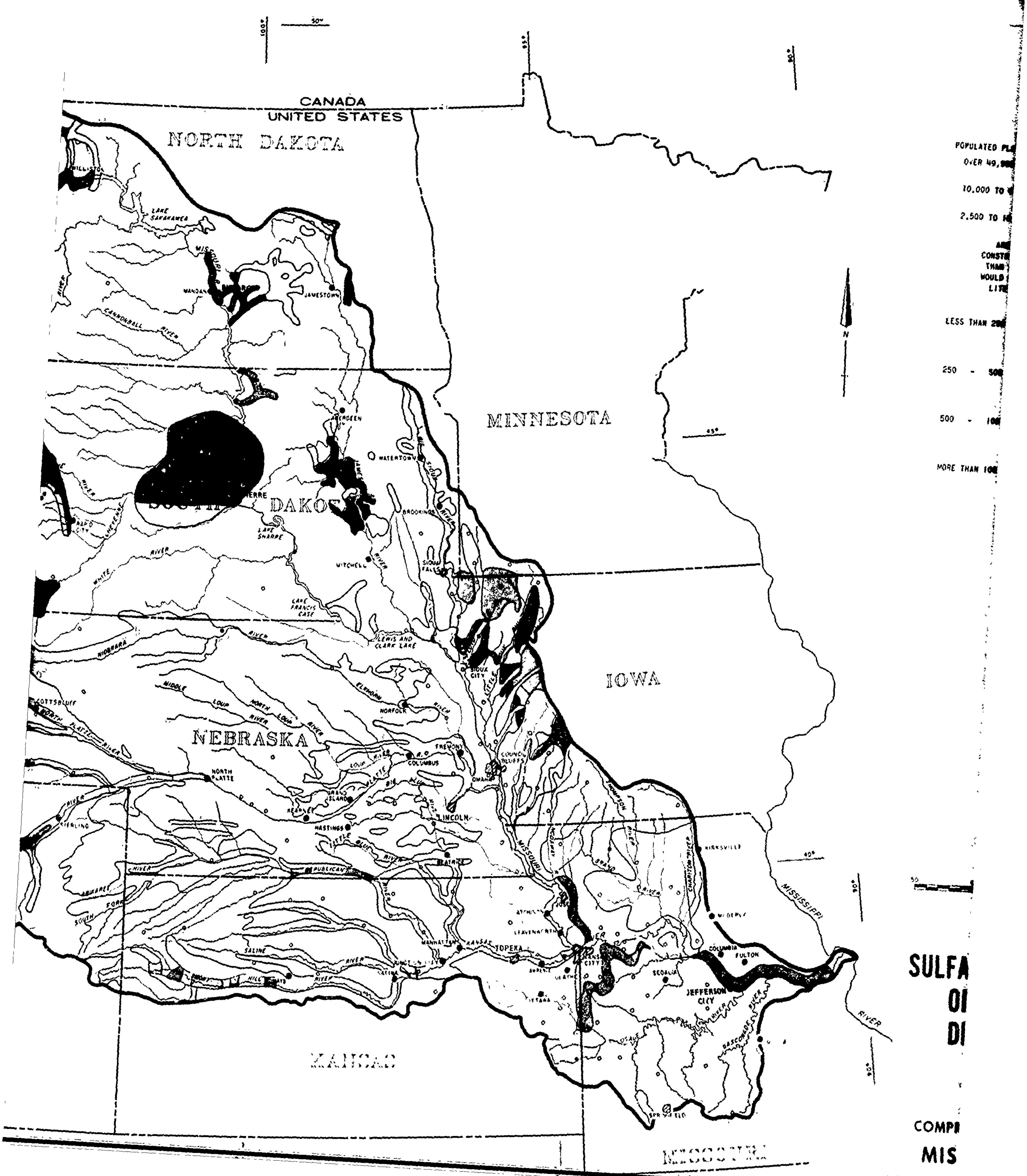
RED ROCK RIVER
YELLOWSTONE LAKE
SHOSHONE RIVER
BIGHORN RIVER
WIND RIVER
TONGUE RIVER
POWDER RIVER
SHERIDAN
CASPER
SWEETWATER RIVER
NORTH PLATTE RIVER
LARAMIE
CHEYENNE
LODGEPOLE CREEK
SCOTTSBLUFF
FORT COLLINS
GREELEY
BOULDER
DENVER
STERLING
CANNONBALL
LITTLE MISSOURI RIVER
RAPID CITY
CHEYENNE
WHITE
NIOBRARA
LOCATION MAP
MISSOURI RIVER BASIN
45°
40°
110°
115°
105°



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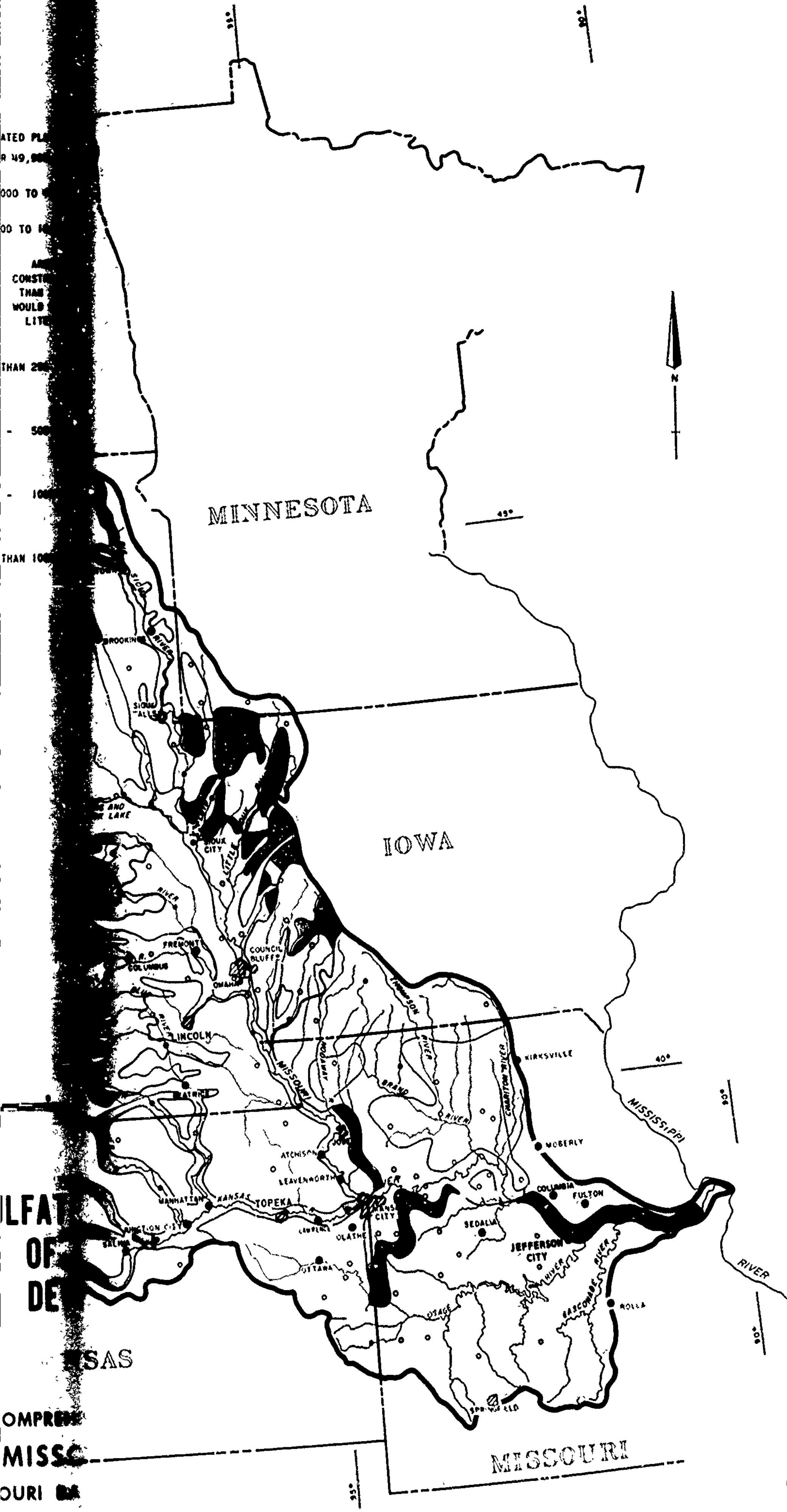


LEGEND

POPULATED PLACES

- OVER 49,999 POP. (1960)
- 10,000 TO 49,999 POP. (1960)
- 2,500 TO 10,000 POP. (1960)

AREAS WHERE PROPERLY LOCATED AND PROPERLY CONSTRUCTED WELLS ARE CAPABLE OF YIELDING MORE THAN 300 GALLONS PER MINUTE (GPM). THE WATER WOULD HAVE A SULFATE CONTENT, IN MILLIGRAMS PER LITER (MG/L), WITHIN THE LIMITS SHOWN BELOW.

- LESS THAN 250 MG/L
- 250 - 500 MG/L
- 500 - 1000 MG/L
- MORE THAN 1000 MG/L

SCALE 1:5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

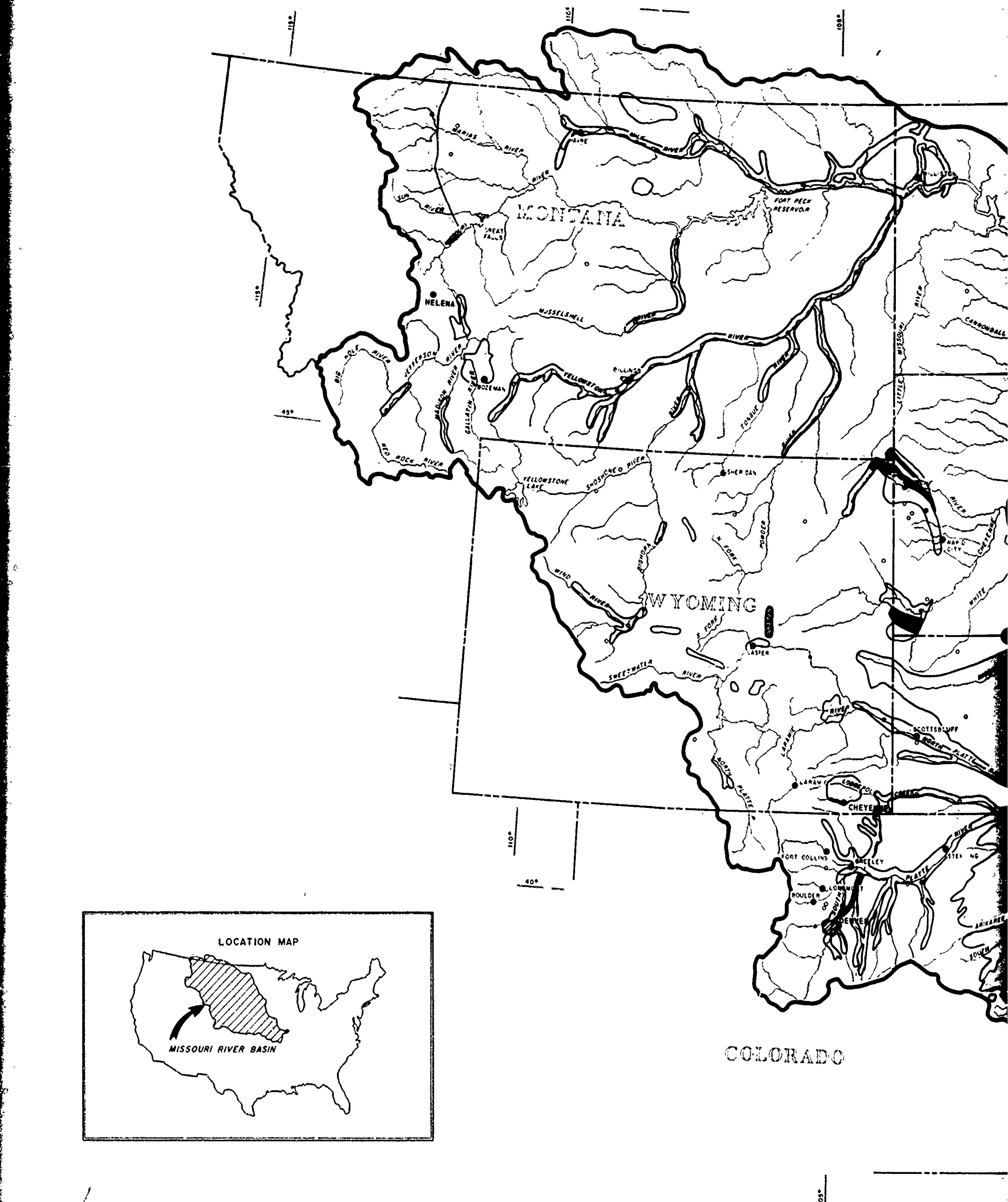
SULFATES IN GROUND WATER OF THE MORE HIGHLY DEVELOPED AQUIFERS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 31


MONTANA
WYOMING
COLORADO
HELENA
BOZEMAN
BILLINGS
GREAT FALLS
FORT PECK RESERVOIR
MILK RIVER
MARIAS RIVER
SUN RIVER
MUSSELSHELL
YELLOWSTONE
JEFFERSON RIVER
BIG HOLE RIVER
MADISON RIVER
GALLATIN RIVER
RED ROCK RIVER
YELLOWSTONE LAKE
SHOSHONE RIVER
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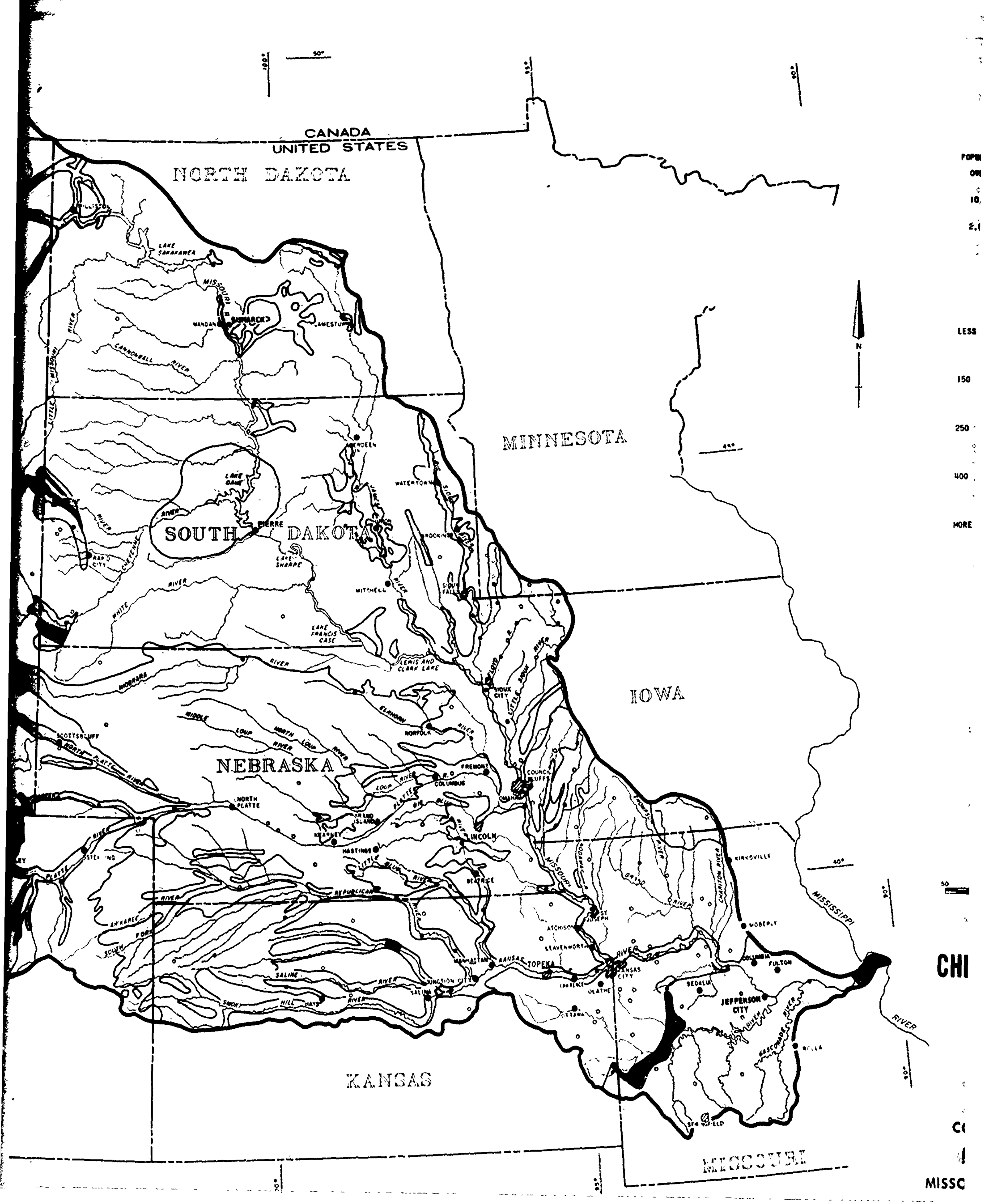
CASPER
SWEETWATER RIVER
NORTH PLATTE
LARAMIE
CHEYENNE
SCOTTSBLUFF
NORTH PLATTE
FORT COLLINS
GREELEY
BOULDER
DENVER
SOUTH PLATTE
PLATTE
LITTLE MISSOURI RIVER
CANNONBALL
CHEYENNE
WHITE
45°
40°
110°
LOCATION MAP
MISSOURI RIVER BASIN



CANADA
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LEWIS AND CLARK LAKE
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NORTH LOUP RIVER
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NORTH PLATTE RIVER
FREMONT
COUNCIL BLUFFS
COLUMBUS
LOUP RIVER
PLATTE
OMAHA
NORTH PLATTE
GRAND ISLAND
KEARNEY
LINCOLN
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SMOKY HILL RIVER
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JEFFERSON CITY
GASCONADE RIVER
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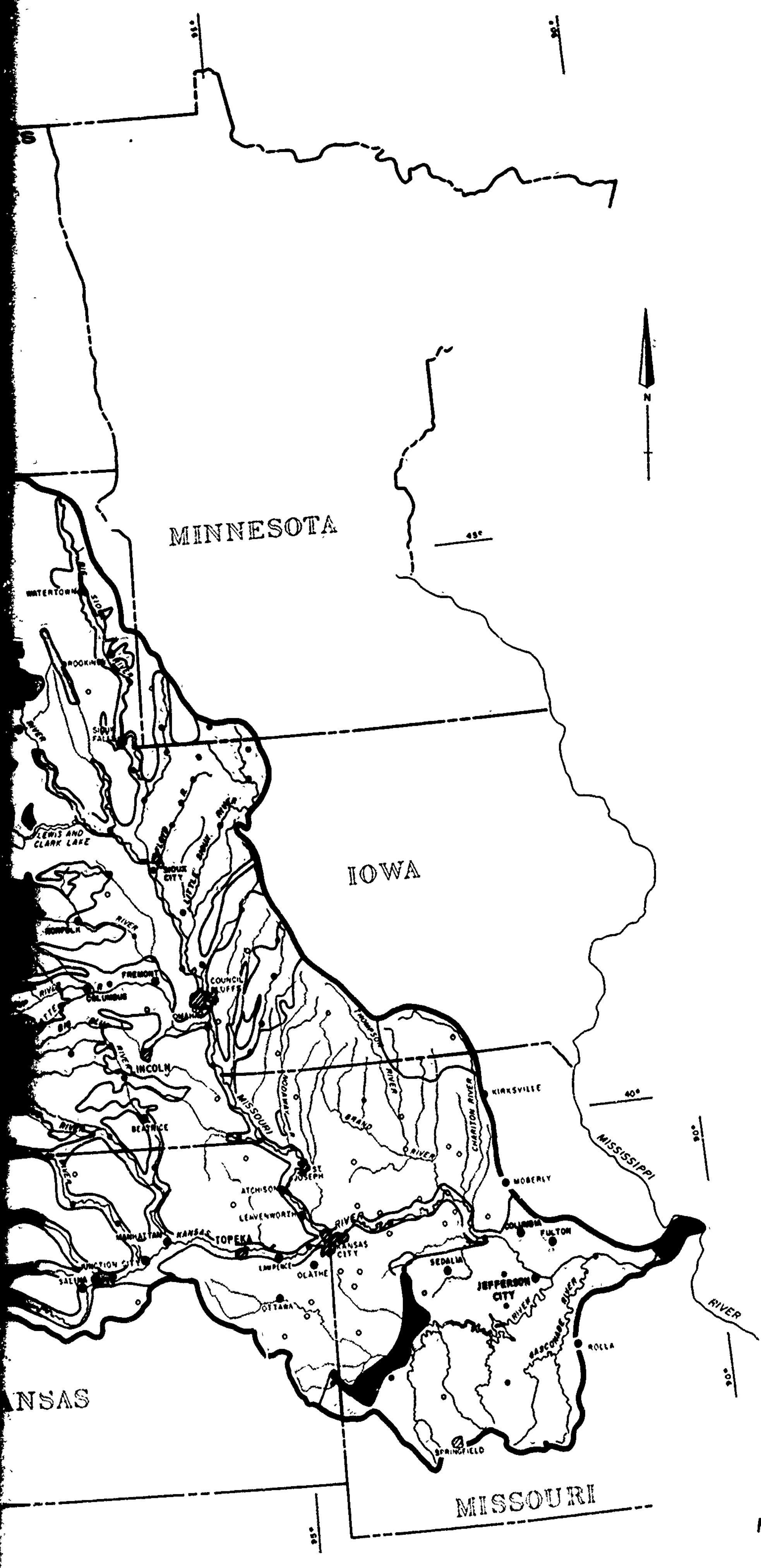


LEGEND

POPULATED PLACES

OVER 49,999 POP. (1960)

10,000 TO 49,999 POP. (1960)

2,500 TO 10,000 POP. (1960)

AREAS WHERE PROPERLY LOCATED AND PROPERLY CONSTRUCTED WELLS ARE CAPABLE OF YIELDING MORE THAN 300 GALLONS PER MINUTE (GPM). THE WATER WOULD HAVE A CHLORIDE CONTENT, IN MILLIGRAMS PER LITER (MG/L), WITHIN THE LIMITS SHOWN BELOW.

LESS THAN 150 MG/L

150 - 250 MG/L

250 - 400 MG/L

400 - 600 MG/L

MORE THAN 600 MG/L

SCALE 1:5,700,000

50 0 50 100 150 200

APPROXIMATE SCALE IN MILES

JUNE 1969

CHLORIDES IN GROUND WATER OF THE MORE HIGHLY DEVELOPED AQUIFERS

COMPREHENSIVE FRAMEWORK STUDY

MISSOURI RIVER BASIN

MISSOURI BASIN INTER-AGENCY COMMITTEE

PLATE 32

well below 250 milligrams per liter. As previously explained in connection with sulfates, chloride concentrations are not shown for some areas where total-dissolved-solids concentrations were shown.

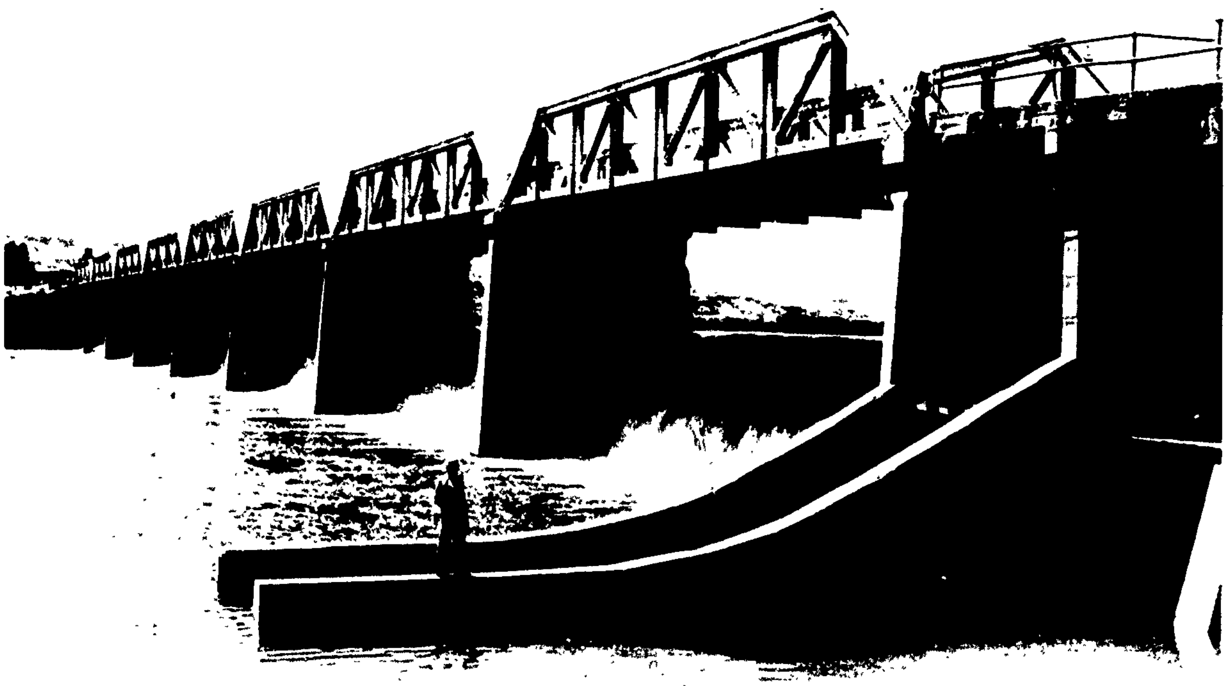
Local Ground-Water Problems

The following examples illustrate some local problems with ground-water supplies in the Missouri Basin. In some cases, they may be typical of other similar small areas, while in other cases they may be unique. They do not cover all of the varied local ground-water problems in the basin.

In the Eastern Dakota Subbasin, where most communities and rural homes use ground water as a source of domestic supply, high fluoride content exists in some localities and nitrates are above the levels recommended for use. Webster, S. Dak., in this subbasin, has been selected by the Office of Saline Water as the site for a pilot plant to evaluate the performance of the electrodialysis process in treating hard, high sulfate, brackish water.

Well water at Eagle Butte in western South Dakota is highly mineralized. It is also quite hot.

The shallow valley-fill aquifer along the South Platte River between Denver and the downstream town of Brighton, Colo., contains over 1,000 wells for public and private water supply and irrigation. Withdrawals from the aquifer are balanced by recharge directly from the South Platte River and by waters diverted from the river for irrigation. Much of the aquifer has become contaminated with sewage containing detergents. Local areas have been contaminated by hydrocarbons, pesticides, herbicides, and other chemicals. Defective deep wells may permit the contamination of deeper aquifers which are now considered potable.



CHAPTER 9

HYDROLOGIC ANALYSES OF POTENTIAL FRAMEWORK PLANS FOR 1980, 2000, AND 2020

SCOPE OF ANALYSIS

Potential framework plans for each of the eight Missouri River subbasins were reviewed by the Work Group on Hydrologic Analyses and Projections to ascertain that the potential developments were consistent with the surface-water and ground-water resources available in each subbasin, to estimate the effect of the potential developments on the available water supply, and to compile estimates of water depletion, by type of water use, attributable to the potential developments. Close coordination was maintained during this review with the Work Group on Water and Related Land Resources Development so that adjustments in planned developments and depletion estimates could be effected as necessary.

In comparing water availability with requirements of the potential developments, it has been assumed that future water supplies would be increased to some extent through precipitation management, improvements in forestry management, and importations to the basin, and decreased through exportations from the basin. Consideration was given also to a possible further increase in water supplies through evaporation-reduction operations on lakes and reservoir surfaces, but no specific increase in water supply from this source has been assumed. These sources of additional water supply are discussed later in this chapter.

Results of the hydrologic analyses are presented in subsequent brief discussions, separately for each subbasin, of the adequacy of available supplies to meet the water requirements of the framework plans and in a series of tables showing, for each subbasin and for the Missouri Basin as a whole, estimated depletions attributable to the framework plans. The hydrologic analyses included studies of the effect of the framework plans on water quality. The results of the quality studies, however, are included in the Appendix by the Work Group on Plan of Development and Management of Water and Related Land Resources.

WEATHER MODIFICATION

Status

Recent scientific and technical advances in weather modification have been so significant that weather elements no longer should be regarded as entirely uncontrollable inputs into engineering, agricultural, and economic activities. In the words of Dr. Earl G. Droessler, National Science Foundation: "Weather modification can never again be approached only as a scientific problem * * *. It is now, and will be in the future, an element in the resources planning of the nation and the world."

Research is actively underway in the Missouri Basin to develop methods for beneficial modification of three weather elements important to the region's economy. These elements are snow, rain, and hail. Lightning suppression by weather modification, in the interest of forest-fire prevention, is also under study near Missoula, Mont. Modification of snow, rain, and hail involves adding proper quantities of minute particles to clouds to change cloud composition and to help form more raindrops or snowflakes. Commonly called cloud seeding, this is usually accomplished by burning silver iodide mixtures.

Much progress has been made in increasing precipitation, not only in the Missouri Basin but in other parts of the Nation as well and throughout the world. That cloud seeding can increase precipitation on the order of 10 to 20 percent has been recognized by the National Academy of Sciences - National Research Council, the National Science Foundation, and the American Meteorology Society.

What is now known and what is continually being learned gives ample reason to believe that reliable, efficient weather-modification techniques, capable of significantly increasing precipitation and water supplies in the Missouri Basin, could be developed by 1980. By as early as 1975, routine operational seeding of winter storms over the basin's mountainous areas could be feasible. A capability to increase snowfall in these areas by an average of about 15 percent may be anticipated. By the mid-1970's, capabilities should be available for increasing rainfall by 1 to 2 inches during the spring and summer months from convective clouds over the plains area of the basin.

It is generally agreed that large-scale, routine operations should await greater knowledge of cloud seeding methods and criteria, which, with adequate effort and support, can be obtained in the next few years. Among several weather-modification research programs, the U. S. Bureau of Reclamation's Atmospheric Water Resources Program particularly is directed toward providing soon the applicable scientific knowledge and engineering systems that can make practical modification of precipitation a reality. Knowledge concerning hail and lightning suppression and evidence of success in this field are less apparent. There are preliminary indications, from an experiment sponsored by the National Science Foundation in South Dakota, that effective reduction in hailfall damage and effective augmentation of precipitation may result simultaneously from one seeding operation.

Research and Development

The entire Federal program for weather modification research totalled about $11 million in Fiscal Year 1968. Of this total, about $7 million was allotted specifically to precipitation modification, with $5.1 million directed to the U. S. Bureau of Reclamation, $1.1 million to the National Science Foundation, and $690,000 to the Environmental Science Services Administration. Recommendations have been made that these research efforts be continued and significantly expanded.

Weather modification research also includes consideration of fog and cloud modification and modification of severe storms such as hurricanes and cyclones, in addition to the precipitation management and hail and lightning suppression previously mentioned. Other Federal agencies involved in the research effort are the Department of Agriculture, the Department of Defense, the National Aeronautics and Space Administration, and the Federal Aviation Administration.

Two major field efforts for snowfall enhancement research are in progress in the Missouri Basin. The University of Wyoming is engaged in development of seeding techniques aimed at increasing snowfall from mountain-cap clouds at the Elk Mountain experiment site in southern Wyoming. Montana State University is evaluating the effects of seeding on precipitation in the Bangtail Ridge area near Bozeman, Mont., and in a large downwind area extending eastward.

Other major winter seeding experiments are in progress just west of the Missouri River Basin in the mountains near Steamboat Springs and Climax, Colo. An operational seeding project aimed at augmenting streamflow into Hungry Horse Reservoir during years of low runoff has been underway since 1966. The University of Wyoming in 1968 began a limited seeding experiment on the western side of the Wind River Range. Findings of these activities and of other research have led to initiation of a large pilot-type research project in the adjoining Upper Colorado River Basin as the last step in the operational development sequence outlined in the Department of the Interior's report, "Plan to Develop Technology for Increasing Water Yield from Atmospheric Sources." This project is designed to give water resource planners firm answers by 1973 on how much additional water could be expected and what costs would be involved if full-scale winter seeding operations were undertaken.

An estimated 1.87 million acre-feet average annual water augmentation for $1 to $3 per acre-foot is currently forecast for the upper Colorado River Basin. A similar pilot project is planned for the western Missouri Basin mountains beginning in 1970 or 1971.

The South Dakota School of Mines and Technology is conducting a comprehensive field program in western South Dakota involving development of techniques for increasing rainfall from summer cumulus clouds. Also included in this program are hail-suppression research and coordination and evaluation of commercial seeding operations in the western Dakotas. An increase in precipitation of about 10 percent resulting from seeding of individual convective clouds on days with isolated showers, associated with southwesterly winds has been indicated. Increases resulting from seeding of individual clouds associated with other wind directions appear less likely.

A pilot research project involving seeding of groups of cumulus clouds and convective storms was initiated in this same area during 1968. The scientific and technical operation problems associated with increasing rainfall primarily for crop production, and the environmental aspects involved, are more complex than those associated with seeding winter storms over mountainous areas primarily to augment streamflow. More time and further studies will be required in connection with precipitation augmentation in the northern plains, but necessary developments should be accomplished and sufficiently firm answers should be available in time to permit initial operations to begin in mid-1970's.

In connection with the introduction of precipitation augmentation and other weather modifications into the water resources and agricultural fields, all possible undesirable side effects must be considered so that steps may be taken to minimize them. The need for careful study, monitoring, and evaluation of social-cultural impacts, economic effects, and effects on natural species and regimes is well recognized. Investigations to resolve possible problems in these areas, and in the areas of legal implication and hydrological change, will be important parts of weather modification research and development in the Missouri River Basin.

Missouri River Basin Precipitation Management Potential

The current technological forecast in connection with precipitation augmentation is for a 15 percent increase in mountain snowfall to be attainable by about 1975. Based on temperature and wind criteria involved, the best operational target areas would be located in the high country above 8500-foot elevation. For seeding most efficiently to produce more water, the best target areas should also be in areas of highest water yield. In the Missouri Basin, an area of more than 14,000 square miles in the Upper Missouri, Yellowstone, and Platte-Niobrara subbasins meets both criteria. Here the natural snowpack averages 13 inches of water content on April 1, and the annual runoff is 10 inches or greater.

Assuming that the forecasted 15 percent increase in snowfall would produce a 15 percent increase in the April 1 snowpack and its water content, and assuming an 85 percent runoff yield from the additional snow, the potential increase in average annual basin streamflow amounts to 1,270,000 acre-feet.

Production costs for the additional water produced, after equipment and procedures are fully developed, should be in the range of $1 to $3 per acre-foot in the Western mountainous portions of the Missouri River Basin. Since the areas involved are in the stream headwaters, retention and control of the additional runoff, for flexibility of use, would be possible, often with existing storage facilities.

Precipitation in the Black Hills area could be increased both as additional snowfall during the winter and as additional rainfall from spring and summer clouds. The runoff-augmentation potential is less than in the high mountain areas, but the potential increase in streamflow to be realized is estimated at about 20,000 acre-feet.

Unit production costs also would be higher than in the high mountain areas, ranging up to $4 per acre-foot. Routine seeding of convective clouds over the Black Hills would yield from 1 to 1.5 inches of additional summer rainfall, mostly for crop, pasture, and forest growth.

Streamflow Augmentation Assumed in Analyses

In the hydrologic analyses of the framework plans, increased runoff through precipitation management has been assumed only from the high mountain target areas previously described. It has been assumed further that the previously indicated augmentation potential of these areas would be fully realized in 2020, with only portions of the full potential realized by 1980 and 2000. The assumed cumulative increases in runoff from this source are as shown below.

Basin	Total Drainage Area (Sq. Mi.)	Target Area (Sq. Mi.)	Estimated Cumulative Runoff Within Target Area 1980	2000	2020
			(1,000 Acre-Feet)		
North Platte River	37,400	2,905	70	145	295
South Platte River	24,000	3,255	24	73	243
Upper Missouri River	82,800	2,168	20	79	196
Yellowstone River	70,600	6,130	89	267	536
Missouri Basin		14,458	203	564	1,270

FOREST MANAGEMENT

Observation of the effects of improved forest management has demonstrated that, in some areas of the Missouri River Basin, altering and improving forest cover to induce added runoff and to reduce evapotranspiration can significantly increase water supply in these areas. Timely harvesting, proper thinning, intensive protection, and accelerated tree planting all can contribute to significantly increased runoff from forest areas in locations and at altitudes where normal precipitation exceeds 20 inches annually and where normal runoff is already substantial.

Only a relatively small part of all of the basin's forests, however, is so situated that water yield can be significantly increased by improved management practices. In the hydrologic analyses of the framework plans, increased runoff from this source has been assumed for less than 10 percent of the basin's forest lands. Estimated cumulative increases, by subbasins, are shown below.

Subbasin	Total Forest Area	Area Susceptible to Water Yield Increase	Estimated Cumulative Increase in Forest Water Yield 1970	1980	2000	2020
	(1,000 Acres)		(1,000 AF)			
Upper Missouri	7,211	310	17	30	59	88
Yellowstone	7,037	1,228	16	61	152	161
Western Dakota	2,424	75	8	8	16	16
Eastern Dakota	160	0	0	0	0	0
Platte-Niobrara	5,128	1,107	45	104	258	258
Middle Missouri	1,036	0	0	0	0	0
Kansas	520	0	0	0	0	0
Lower Missouri	6,857	0	0	0	0	0
Missouri Basin	30,373	2,820	86	203	485	523

EVAPORATION REDUCTION

Evaporation losses from the water surface areas of the Missouri River Basin constitute nearly one-third of the fresh-water evaporation losses in the 17 Western States. From those lakes and reservoirs of the basin over 500 acres in size, evaporation losses amount to 4.3 million acre-feet annually. Based on a national average per capita consumptive use rate of 147 gallons per day, or about one-sixth acre-foot per year, this evaporation loss, if it were conserved, could supply the water needs of nearly 26 million people. This is more than three times the present population of all the states lying wholly or partially within the Missouri Basin. A saving of even a portion of this great water loss would have a significant effect on the basin's water supply and on its economy.

No generalization can be made concerning the potential of evaporation-reduction operations in the Missouri River Basin as a whole. Climatic conditions vary over a wide range. Evaporation rates vary from about 2 feet per year in the Upper Missouri Subbasin to over 4 feet per year in the Kansas Subbasin. Evaporation-reduction operations would be practical only in certain areas. Each lake or reservoir would have to be evaluated individually to determine its suitability for such operations. Each evaluation would require a complete study of the climatology and hydrology of the local area as well as a determination of the value of the water saved in relation to its potential use for irrigation, power generation, municipal needs, or other purposes.

Currently available data indicate that by 1980, with full scale treatment of all reservoirs in the basin in the size range of 500 to 50,000 acre-feet, approximately 500,000 acre-feet of water could be saved annually at an estimated cost of $8.90 per acre-foot. At present, evaporation reduction shows greatest promise in areas where the bulk of the total annual evaporation occurs during a relatively short, hot, and dry period during which evaporation-reduction operations could be conducted to effect the greatest water savings at least cost. This type of situation does prevail in large areas of the Missouri Basin, and evaporation-reduction operations in these areas may prove feasible at some time in the future. The extent and rate of possible development are too uncertain at this time, however, to warrant the assumption of an increased water supply from this source in the hydrologic analyses of the framework plans.

WATER IMPORTS AND EXPORTS

The usable water supply within the Missouri Basin has been augmented historically by the importation of water from adjoining basins. While a small percentage of the total basin water supply, the importations represent significant contributions to those areas where the available runoff is insufficient to meet local demands. Currently facilities for such importations are in operation bringing an average of 407,000 acre-feet of water per year into the South Platte River system from the Colorado River Basin, and 135,000 acre-feet into the Milk River from the St. Mary River, although the annual quantities vary as governed by the granted rights or decrees. The South Platte importations are regulated by rights granted by the states of Colorado and Wyoming and as permitted within their share of Colorado River water recognized under the Upper Colorado River Compact. The Milk River importation is governed by the International Water Treaty with Canada consummated in 1910.

Increasing quantities of water imports to the South Platte River system from the Colorado River were estimated for 1980, 2000, and 2020 under the rights already granted, and within the stipulated shares of Colorado River Basin water under the Upper Colorado River Compact. It is possible that the importations to the Missouri Basin within either state may be greater than estimated in the plan, but the amounts included were limited to those permitted under currently granted rights. The importation from the St. Mary River could be increased under the provisions of the International Treaty with Canada, but were estimated as not increasing in the plan due to the high cost of the added physical works.

Currently there is no exportation of water from the basin; however, the authorized Garrison Diversion Unit now under construction will divert water from the Missouri River Basin to the Souris-Red-Rainy River Basins. Water rights for this diversion have been granted by the state of North Dakota for full development and it was estimated in the framework plan that the Garrison Diversion Unit would be fully developed by 2020. The quantities of water so exported were estimated as a net depletion to the Missouri Basin, although the net exportation may be decreased by rediversion of project return flows back to the Missouri Basin under the ultimate plan of development.

The Milk River originates in the United States, flows into Canada, then back into the United States and is tributary to the Missouri River below Fort Peck Dam. Canada is entitled to use of water from the Milk River in Canada and it was estimated that future Canadian depletions would be 45,000 acre-feet by the year 2000. The 45,000 acre-feet of Canadian depletion has been considered an export from the Missouri Basin in the United States.

Estimated and projected average annual water importations and exportations by subbasins are as follows

Subbasin	Average Annual Water Importation 1970	1980	2000	2020	Average Annual Water Exportation 1970	1980	2000	2020
	(Cumulative – 1,000 Acre-feet)							
Upper Missouri	135	135	135	135	0	0	45	45
Eastern Dakota	0	0	0	0	0	411	1087	2000
Platte-Niobrara	407	512	744	744	0	0	0	0
Missouri Basin	542	647	879	879	0	411	1132	2045

UNIT WATER-USE REQUIREMENTS

Unit water-use requirements were adopted to develop overall water requirements of the framework plans. These are discussed in the following paragraphs.

Irrigation Water Supply

Current rates of irrigation diversion were used in estimating future irrigation demands. Irrigation in the Missouri Basin currently requires annual farm deliveries as shown below. These amounts do not include evaporation and transpiration losses from reservoirs, canals, laterals, and seepage areas.

Subbasin	*Average Annual Farm Delivery of Irrigation Water*
	(Acre-Feet Per Acre)
Upper Missouri	1.8
Yellowstone	2.0
Western Dakota	1.8
Eastern Dakota	1.5
Platte-Niorbrara	1.9
Middle Missouri	1.0
Kansas	2.0
Lower Missouri	1.0

Municipal and Rural Domestic Water Supply

In cities with population in excess of 10,000, inventories were made to determine current average water use, and these amounts were then adjusted to reflect anticipated increases in future demands. For communities with population less than 10,000, unit values for municipal water use were selected to reflect the significance of lawn sprinkling and garden irrigation in some areas. This was done by determination of a precipitation effectiveness index line, the location of which roughly approximates that of the line of 22-inch average annual precipitation, and using higher unit values west of the precipitation effectiveness index line where average annual rainfall values are less. In rural areas, unit values for domestic water use were selected to reflect the greater water use in rural homes with pressurized water systems than in those without such systems.

Unit values used to develop municipal and industrial and rural domestic water supply requirements are shown below.

Location	*Gallons per Capita per Day*
Communities of 2,500 to 10,000 Population	
East of Precipitation Effectiveness Index Line	125
West of Precipitation Effectiveness Index Line	150
Communities of Less than 2,500 Population	
East of Precipitation Effectiveness Index Line	80
West of Precipitation Effectiveness Index Line	120
Rural Homes	
With Pressurized Systems	50
Without Pressurized Systems	10

Industrial and Mineral Water Supply

Some industries obtain required water supplies from municipal water-supply systems. In such cases, water requirements in the future were considered as part of future municipal requirements. Other industries were inventoried to determine current average water requirements, and these values were then adjusted to reflect anticipated changes in future requirements.

Thermal Power Water Supply

The principal water demand of steam-electric generator plants is for condenser cooling purposes. Unit values used to develop thermal power water supply requirements were 550 gallons per minute per megawatt for fossil fuel and 650 gallons per minute per megawatt for nuclear fuel, both rates being for a flow-through system with a cooling-water temperature rise of 18°F. The amount of streamflow diversions and depletions will be dependent on the type of cooling provided, whether it be flow-through, pond, or tower.

Livestock Water Supply

Unit values used to develop livestock water-supply requirements, based on current average livestock use rates, are shown below.

Livestock	*Water Supply Requirement per Head* (*Gallons per Day*)
Milk Cows	30.0
Beef Cattle	12.0
Hogs	4.0
Sheep	1.8
Turkeys	0.18
Chickens	0.06

Fish and Wildlife, Recreation, and Water Quality Control

Unit requirement criteria were not established for those uses which were found to vary with the type of development, stream hydraulics, climatic factors, and at times multiple service of a common facility. The individual requirements were variously recognized in the planning but are not always defined as specific functional withdrawals, depletions, or streamflow demands. Single-purpose recreation and fish and wildlife storage impoundments and storage regulation impoundments for streamflow augmentation are included in the plan and the depletions are included in the large reservoir, small reservoir, and minor ponds evaporation estimates. Streamflow demands for water quality control to accommodate effluent residuals, after the prescribed level of treatment, were estimated for specific stream reaches.

Streamflow demands were generally met for quality control as dictated by temperature and dissolved-oxygen criteria for a satisfactory quality-of-flow fishery habitat. In most cases these water demands also will provide a satisfactory streamflow regimen for the fishery. However, in some stream reaches, meeting this quality criteria does not necessarily provide a satisfactory streamflow for fishery. While specific streamflow criteria were not developed, obvious potential conflicts were usually resolved. Future detailed studies should include consideration of streamflow requirements for the fishery.

ADEQUACY OF WATER SUPPLY TO MEET PLAN REQUIREMENTS

During the initial phases of water resources development planning in each of the subbasins, water-use plans were developed on the basis of generalized hydrologic information without a detailed appraisal of the adequacy of the water supply to meet the demands of the planned improvements. After development of preliminary plans, more detailed appraisals were made for each subbasin, and development plans were scaled down where necessary to be consistent with the available water supply.

These more detailed hydrologic analyses demonstrated that, generally, surface-water supplies as regulated by reservoirs will be sufficient to meet requirements of the final framework plans. However, these appraisals of water adequacy were based on comparisons of average annual water requirements and the average annual water supply for each subbasin as a whole, or for large portions of a subbasin. In some basins there may well be problems of water availability for planned uses at specific locations and problems of severe shortages in some months and years.

Ground-water supplies also will be generally sufficient to meet requirements of the final framework plans. In many cases, ground-water withdrawals will be reflected rather quickly in streamflow depletions as aquifers are recharged rapidly from streamflow. In other cases, ground-water withdrawals will result in streamflow depletions only after an appreciable time lag. In some cases, however, ground-water withdrawals represent use of a non-replenishable or only very slowly replenishable resource; and in some such cases, sometime after 2020, reduction in ground-water withdrawals will become necessary. The estimates of the effects of ground-water depletion on surface-water flows, while taking into account available data, were based largely on judgment. Additional studies are needed to confirm these estimates.

All instances involving full use of available surface-water supplies or possible non-replenishable depletion of ground-water supplies are associated with the use of these supplies for irrigation. Except for some relatively small local areas, there appears to be no question, in any of the tributary subbasins, of the adequacy of both surface-water supplies and ground-water supplies for purposes other than irrigation.

Depletions caused by the developments included in the framework plans, however, will appreciably reduce power generation by the Missouri River main stem plants and will require frequent curtailment or interruption of the navigation season on the Missouri River.

Results of the hydrologic analyses of the framework plans are summarized briefly, by subbasins, in the following paragraphs. The effects of the framework plan developments on Missouri River main stem reservoir regulation and on water uses along the Missouri River also are summarized in succeeding paragraphs. These effects are based on the framework plans to meet projected needs by 1980, 2000, and 2020 and do not recognize any possible budgetary restrictions or changes in economic projections.

Upper Missouri Subbasin

The framework plan for the Upper Missouri Subbasin is aimed at intensifying and improving the economic efficiency of the subbasin's agricultural base, and preservation, development, and management of the subbasin's outstanding environmental attributes with a view to development of a significant recreation industry.

Major water-use components of the framework plan for the Upper Missouri Subbasin by the year 2020 are as follows:

Multiple-purpose reservoir storage in 15 large[1] and 77 small reservoirs	2,952,000 af
Single-purpose reservoir storage	99,000 af
Public systems irrigation development	495,000 acres
Private irrigation development	
From surface water	0 acres
From ground water	55,000 acres
Streamflow withdrawals for municipal, industrial, mineral, and rural domestic use	58,000 af
Streamflow withdrawals for thermal powerplant cooling	455,000 af
Streamflow withdrawals by land conservation practices	43,000 af
Streamflow withdrawals for wetlands and fish and wildlife	93,000 af

[1]Total storage in excess of 25,000 acre-feet in each large reservoir.

The water supply in this subbasin, after depletion by the 1970-level developments, totals about 7,276,000 acre-feet. The listed features of the framework plan, and other lesser developments, are expected to deplete the 1970 water supply of the subbasin by 990,000 acre-feet, as shown in table 23. Therefore, net depletions by the proposed 2020 developments in the framework plan will reduce the 1970 water supply by 14%. The available surface-water supply is adequate to serve the planned developments and still provide average annual flows of about 6.3 million acre-feet for regulation by the downstream Missouri River reservoirs.

The planned development of irrigation in the Milk River valley and in the area between the Missouri River and the Milk River, however, will require diversion of about 150,000 acre-feet annually from the Missouri River near Virgelle, Mont.

Ground-water developments proposed within the Upper Missouri Subbasin are mostly small, scattered, and confined largely to alluvial areas adjacent to streams. Net withdrawals of ground water generally will be equivalent to stream depletions because of relatively rapid recharge from streamflow, and 90 percent of all ground water extracted is considered as an immediate stream depletion. Since ground-water developments as proposed are limited in size, it is considered that sufficient water is available. Depletions to ground water are estimated to be 10 percent of all withdrawals to account for those areas which are not immediately related to the drainage pattern and where recharge is not fully effective.

Yellowstone Subbasin

The framework plan for the Yellowstone Subbasin is aimed at increasing agricultural production and processing of agricultural products, at development of greater industrial utilization of the subbasin's coal supplies, and at preservation, development, and management of the subbasin's environmental attributes with a view to expansion of the subbasin's recreation and tourist industry.

Major water-use components of the framework plan for the Yellowstone Subbasin by the year 2020 are as follows:

Multiple-purpose reservoir storage in 8 large and 69 small reservoirs	2,110,000 af
Single-purpose reservoir storage	3,000 af
Public systems irrigation development	139,000 acres
Private irrigation development	
From surface water	469,000 acres
From ground water	29,000 acres
Streamflow withdrawals for municipal, industrial, mineral, and rural domestic use	1,078,000 af
Streamflow withdrawals for thermal powerplant cooling	778,000 af
Streamflow withdrawals by land conservation practices	17,000 af
Streamflow withdrawals for wetlands and fish and wildlife	49,000 af

The water supply in this subbasin, after depletion by the 1970-level developments, totals about 8,800,000 acre-feet. The listed features of the framework plan, and other lesser developments, are expected to deplete the 1970 water supply of the subbasin by 1,500,000 acre-feet, as shown in table 24. Therefore, net depletions by the proposed 2020 developments in the framework plan will reduce the 1970 water supply by 17%.

Ground-water irrigation developments proposed within the Yellowstone Subbasin are comparatively small and are confined for the most part to stream bottomlands where withdrawals will be quickly recharged and will constitute a direct stream depletion.

Some of the withdrawals from ground water in isolated upland areas for irrigation and livestock, and for municipal use in small towns, may not be so directly related to drainage and will result in minor depletions to ground water. It is estimated that 90 percent of all pumped quantities will result in stream depletion and the remainder will be a depletion to ground-water storage. Sufficient ground water is available for developments of the size contemplated.

The surface-water supply of the Yellowstone Subbasin is generally adequate; however, that of the Wind River portion of the subbasin appears to be sufficient for development of only about 75,000 acres of additional irrigation. Moreover, the availability of additional storage sites in this portion of the subbasin with the potential capacity to serve more than 75,000 acres of additional irrigation appears questionable. It is considered that irrigation of 45,000 acres more than currently irrigated could be accomplished rather readily and that irrigation of the remaining 30,000 additional acres could be accomplished by utilizing the remaining streamflow and storage potentials of the Wind River portion of the subbasin.

Additional storage planned for the Yellowstone Subbasin appears to be near the minimum required to serve the planned developments.

Western Dakota Subbasin

The framework plan for the Western Dakota Subbasin is aimed primarily at enhancing the economy of the subbasin in ways most consistent with the natural attributes of the several portions of the subbasin. One objective is enhancement and stabilization of agricultural production in the plains portion of the subbasin. Another is enhancement and stabilization of the subbasin's mining industry through development to permit industrial utilization of the subbasin's great lignite deposits in southwestern North Dakota. A third is environmental enhancement to promote and stabilize the recreation and tourist industry, most significant in the Black Hills portion of the subbasin. The subbasin plan here is essentially the result of blending objectives, in the best interest of economic enhancement, rather than a compromise among objectives.

Major water-use components of the framework plan for the Western Dakota Subbasin by the year 2020 are as follows:

Multiple-purpose reservoir storage in 7 large and 64 small reservoirs	2,823,000 af
Single-purpose reservoir storage	4,000 af
Public systems irrigation development	136,000 acres
Private irrigation development	
From surface water	507,000 acres
From ground water	119,000 acres
Streamflow withdrawals for municipal, industrial, mineral, and rural domestic use	27,000 af
Streamflow withdrawals for thermal powerplant cooling	302,000 af
Streamflow withdrawals by land conservation practices	112,000 af
Streamflow withdrawals for wetlands and fish and wildlife	0 af

The water supply in this subbasin, after depletion by the 1970-level developments, totals about 2,430,000 acre-feet. The listed features of the framework plan, and other lesser developments, are expected to deplete the 1970 water supply of the subbasin by 1,265,000 acre-feet, as shown in table 25. Therefore, net depletions by the proposed 2020 developments in the framework plan will be 52 percent of the 1970 water supply.

Surface waters of this subbasin are comprised of a number of individual rivers flowing into the Missouri River. Each river contributes a share of water but its individual development will require significant storage capacity to reach the proposed degree of development. As noted in the table, seven additional major reservoirs and 64 other significant impoundments strategically located on the individual basins and altogether providing about 2.8 million acre-feet of new storage, are required to attain the proposed water-use development. Each river basin also lends itself to construction of minor ponds and small watershed developments which improve, but also deplete, water resources.

Ground-water supplies throughout most of the subbasin area may be obtained but there are several problems in their utilization. The alluvial materials comprising lands adjoining the streams are mostly fine grained and will not support withdrawal rates generally required for irrigation. Wells in upland areas will provide only small to medium yields which will be adequate for some water uses but probably will not supply water at sustained irrigation rates. The planned annual net extraction from ground water in these areas of 82,600 acre-feet is possible, but costs may be high because of small yields.

In the Little Missouri Basin a substantial ground-water reservoir exists under the upland area of McKenzie County. Underflow from this area now contributes to the Missouri River. Recharge of the area will be relatively good because of sandy soils and favorable drainage pattern. Substantial irrigation may be developed, and proposed net ground-water extractions of 73,400 acre-feet annually can be easily made.

Ground-water depletions were estimated to be 10 percent mined and 90 percent subject to eventual stream depletion after 2020 in the McKenzie County ground-water area, and 20 percent mined with 80 percent eventually becoming a stream depletion in the remaining areas of the subbasin where ground-water extractions are contemplated.

Eastern Dakota Subbasin

The framework plan for the Eastern Dakota Subbasin also is aimed primarily at enhancing the economy of the subbasin in ways most consistent with its natural attributes. One objective is enhancement and stabilization of agriculture, the subbasin's principal industry. Another is environmental enhancement to promote and stabilize the recreation and tourist industry. Here also, the subbasin plan is essentially the result of blending objectives, in the best interest of economic enhancement, rather than a compromise among objectives.

Major water-use components of the framework plan for the Eastern Dakota Subbasin by the year 2020 are as follows:

Multiple-purpose reservoir storage in 20 large and 108 small reservoirs	2,704,000 af
Single-purpose reservoir storage	327,000 af
Public systems irrigation development	918,000 acres
Private irrigation development	
From surface water	367,000 acres
From ground water	442,000 acres
Streamflow withdrawals for municipal, industrial, mineral, and rural domestic use	95,000 af
Streamflow withdrawals for thermal powerplant cooling	684,000 af
Streamflow withdrawals by land conservation practices	71,000 af
Streamflow withdrawals for wetlands and fish and wildlife	149,000 af

The water supply in this subbasin, after depletion by the 1970-level developments, totals about 3,235,000 acre-feet. Total depletions assigned to this subbasin of 4.4 million acre-feet are listed in table 26. Approximately 2.0 million acre-feet of these depletions result from diverting water from the Garrison Reservoir through this subbasin to the Souris and Red Rivers. Of the remaining depletions of 2.4 million acre-feet in this subbasin, 0.6 million acre-feet are served from the Garrison Reservoir and 1.3 million acre-feet by diversions from the Oahe Reservoir and other Federal irrigation units. Inclusion of private irrigation directly from the Missouri River, return flow to the Missouri River, and James River return flow leaves about 0.4 million acre-feet which represent depletions to this subbasin's water supply. Therefore, the 2020 developments that utilize water supplies which originate in the subbasin will deplete the subbasin's water supply by 12%.

Existing ground-water resources of the subbasin and streamflows originating in the subbasin are adequate to meet the requirements of development planned to be served from these sources.

In the upper portion of the James River Basin and in the basins of the minor Eastern Dakota tributaries, stream base flows are very low and ground-water withdrawals will not be fully reflected as streamflow depletions. The rate of non-renewable ground-water depletion will reach 215,000 acre-feet for the subbasin as a whole by 2020.

Platte-Niobrara Subbasin

The Platte-Niobrara Subbasin is composed basically of four river systems, all different with respect to climate, water supply, and economic development. The four are the South Platte River system, located mostly in Colorado; the North Platte River system, located mostly in Wyoming; the Lower Platte River system in Nebraska; and the Niobrara River system, entirely separate from the Platte River and its tributaries, located mostly in Nebraska along the Nebraska-South Dakota state line. The framework plan for the Platte-Niobrara Subbasin has somewhat different aims within the four areas drained by these four river systems.

In the drainage area of the South Platte River system, which contains the large and rapidly growing Denver metropolitan area and where both natural and imported water supplies are already fully appropriated, plan objectives are support for the continued economic growth of Denver and other urban areas. These objectives are maintenance of the irrigated rural economy at its present level, adequate water supply for other segments of the agricultural rural economy, a reasonable degree of flood protection for the high value flood plains in both urban and rural areas, and maintenance of environmental quality at the highest practical level. In the drainage area of the North Platte River system, in the absence of any urban development comparable to that in the Denver metropolitan area, plan objectives are primarily maintenance of the irrigated rural economy, adequate water supply for other segments of the agricultural rural economy, and maintenance of environmental quality. In the drainage area of the Lower Platte River system, where both surface water and ground water are more abundant than in the North Platte and South Platte drainage areas, the principal objectives are enhancement of the agricultural economy and improvement and maintenance of environmental quality. In the drainage area of the Niobrara River system, a rather sparsely populated agricultural area which makes only limited use of its available water supply, the objectives of enhancement of the agricultural economy and environmental enhancement both are emphasized.

In all areas of the subbasin, plan objectives have been dictated by quite apparent area requirements. Emphasis has been on best meeting these requirements, and there has been little or no need for compromise among objectives.

Major water-use components of the framework plan for the Platte-Niobrara Subbasin by the year 2020 are as follows:

Multiple-purpose reservoir storage in 39 large and 397 small reservoirs	7,961,000 af
Single-purpose reservoir storage	1,059,000 af
Public systems irrigation development	437,000 acres
Private irrigation development	
From surface water	192,000 acres
From ground water	1,732,000 acres
Streamflow withdrawals for municipal, industrial, mineral, and rural domestic use	946,000 af
Streamflow withdrawals for thermal powerplant cooling	-253,000 af[1]
Streamflow withdrawals by land conservation practices	123,000 af
Streamflow withdrawals for wetlands and fish and wildlife	8,000 af

[1]Negative depletion (accretion) due to less flow-through powerplant cooling in 2020 than in 1970.

The water supply in this subbasin, after depletion by the 1970-level developments, totals about 4,202,000 acre-feet. The listed features of the framework plan, the residual effects of pre-1970 ground-water pumping, and other lesser developments, are expected to deplete the 1970 water supply of the subbasin by 2,594,000 acre-feet, as shown in tables 27 through 31. Therefore, net depletions by the proposed 2020 developments in the framework plan, including the residual effects of pre-1970 ground-water pumping, will deplete the 1970 water supply by 62%. The overall effect of ground-water pumping on streamflow totals about 500,000 acre-feet by 2020. About half of these depletions are due to existing ground-water developments and the remainder to framework plan developments.

The effect of ground-water development on streamflow is expected to vary widely among the individual stream basins within the Platte-Niobrara Subbasin. Because of this variation, depletion factors ranging from zero to 100 percent were applied in different parts of the subbasin.

The South Platte River drainage presents a highly used surface-water system which has attained almost maximum development and a ground-water system which in many areas is largely sustained by recharge from ditch-irrigation systems. In most of the drainage basin in Colorado, ground water is closely related to surface-irrigation systems and extractions are replenished from surface applications and by recharge from precipitation. Without the surface irrigation, many well systems would not sustain ground-water withdrawals on a permanent basis.

Much the same situation exists in most of the North Platte drainage. Throughout Wyoming, sustained ground-water removal generally results in depletions to streamflow. In the Nebraska reach west of North Platte, however, it is believed that aquifers in some localities may be adequate to allow ground-water withdrawals independent of surface conditions. Depletions to the ground-water aquifers shown for both the North and South Platte drainages are primarily restricted to Nebraska; ground-water pumping elsewhere is assumed to result in direct stream depletion.

Additional developments in the North and South Platte drainages are dependent on water to become available from external sources such as imports, weather modification, forest management, and retirement of presently irrigated land which will free water for other uses. If such water becomes available, large amounts of new storage space are required to impound and utilize it. Adequate storage appears to be provided in framework plans to fully use all current and future water supplies.

The Sandhills region of north-central and northwestern Nebraska, which is drained primarily by the Loup and Niobrara rivers, is underlain by a thick sequence of saturated permeable rocks. An estimated 12 million acre-feet of water infiltrates the sandy soil annually, and about 80 percent of this amount is returned to the atmosphere by evapotranspiration. A very substantial potential exists in this region for salvage of water without appreciable depletion of streamflow. Controlled ground-water pumpage could be utilized to lower ground-water levels in order to substantially reduce evapotranspiration rates.

Elsewhere in the Loup River, Elkhorn River, and Niobrara River basins, the opportunity is extensive for either surface- or ground-water developments. Substantial water-bearing aquifers are available from which ground water may be used over a long period with only minor effects on flow of streams. Eventually, the withdrawals will be reflected in stream depletions, and it is estimated that the surface depletions will accelerate with time. A sliding-scale estimate was used wherein the stream depletion would be equivalent to 5, 10, and 15 percent, for successive 20-year periods, of the net ground water removed. Sufficient streamflow is available for all expansions planned to utilize surface waters.

The Lower Platte River area is known to present large opportunities for either ground-water or surface-water development. Removals of ground water are considered to be more directly related to streamflow than in the Loup, Elkhorn, and Niobrara drainages, but not dependent on surface replenishment. It is estimated that ground-water extractions will be possible on an extensive scale, but that such depletions to the ground-water aquifers will be reflected in diminished streamflow both sooner and in greater amounts than in the Loup, Elkhorn, and Niobrara drainage basins. In the Lower

Platte River area, a similar sliding scale was employed, but with depletion factors of 10, 30, and 50 percent for successive 20-year periods. The sliding-scale approach was used for two principal reasons. First, it permits an estimate of current stream depletion for ground-water developments undertaken in the past, and second, it allows a means of computing a probable streamflow which may be expected to occur even after ground-water removal ceases. An expected streamflow depletion, due to ground-water pumping, which is applicable to a period 20 years later (year 2040) has been listed in the depletions tables, but is shown separately as a lag.

In both the South Platte and the North Platte areas, natural runoff will be completely utilized and planned developments will be dependent upon imports and other "made" water. In fact, in the South Platte area, both natural runoff and "made" water will be almost completely utilized by 2020, and planned developments in this area, therefore, are the absolute limit that the available water supply will support. There will also be a very high percentage of depletion of streamflow in the Lower Platte area, greater than the indicated depletion percentage for the subbasin as a whole. Only in the Niobrara area will the percent depletion of streamflow be less than the indicated depletion percentage for the subbasin as a whole.

Although studies indicate that the expected future surface water supply in the South Platte area will be barely adequate for planned developments, the supply may actually fall short of requirements. It should be recognized that future consideration may need be given to the possibility of increasing water imports or restricting some water uses, or both. Similar action may be necessary also in the North Platte area.

The 1970 level of water imports into the Missouri River Basin, shown as 542,000 acre-feet in subsequent depletion tables, includes imports of 401,000 acre-feet into the South Platte area. It appears that this level of imports may be more nearly representative of 1965 conditions than 1970 conditions. A part of the increase in imports between 1970 and 1980 as indicated in subsequent tables, therefore, may actually have occurred by 1970.

Middle Missouri Subbasin

The framework plan for the Middle Missouri Subbasin is aimed primarily at continuation and enhancement of a balanced urban-rural economy. With four metropolitan areas of the subbasin located on the Missouri River and assured of an adequate water supply from that source, it is possible to plan for regulation of the subbasin water supply primarily for agricultural uses and for associated environmental enhancement for the benefit of both urban and rural areas of the subbasin.

Major water-use components of the framework plan for the Middle Missouri Subbasin by the year 2020 are as follows:

Multiple-purpose reservoir storage in 39 large and 513 small reservoirs	5,264,000 af
Single-purpose reservoir storage	1,298,000 af
Public systems irrigation development	27,000 acres
Private irrigation development	
From surface water	322,000 acres
From ground water	1,282,000 acres
Streamflow withdrawals for municipal, industrial, mineral, and rural domestic use	325,000 af
Streamflow withdrawals for thermal powerplant cooling	757,000 af
Streamflow withdrawals by land conservation practices	238,000 af
Streamflow withdrawals for wetlands and fish and wildlife	41,000 af

The water supply in this subbasin, after depletion by the 1970-level developments, and excluding the water supply available in the Missouri River, totals about 7,670,000 acre-feet. The listed features of the framework plan, and other lesser developments, are expected to deplete the 1970 water supply of the subbasin by 1,163,000 acre-feet, as shown in table 32. Therefore, net depletions by the proposed 2020 developments in the framework plan will reduce the 1970 water supply by 15%. The remaining depletions of about 1.3 million acre-feet represent depletions to the Missouri River itself.

Proposed ground-water developments for several stream basins in the western Iowa portion of the Middle Missouri Subbasin appear to be rather optimistic. Most of the available ground water is in alluvial deposits underlying the larger stream valleys. In most areas, however, the alluvial materials are of limited thickness, and generally they are fine grained. Expected yields of wells in the alluvial aquifers will range generally from a few gallons per minute to about 300 gallons per minute. In many areas, yields will be between 50 and 100 gallons per minute. Thus, many individual wells will be required to provide enough water for even relatively small irrigation systems, and in many localities irrigation from ground-water sources may therefore prove infeasible.

Areas of particular concern are the Perry Creek and Floyd River Basins in northwestern Iowa and the Platte River Basin of northwestern Missouri, not including the Little Platte River tributary basin. It appears that the ultimate area to be irrigated by ground water will be limited to not more than 10,000 acres in the Perry Creek and Floyd River Basins and to not more than 5,000 acres in the Platte River Basin.

Depletions to ground water in this subbasin were estimated, as in the Upper Missouri and Yellowstone subbasins, to be 10 percent of all withdrawals, with 90 percent being direct depletion to surface stream flow. This minor allowance for ground-water depletion is to recognize that some of the outlying areas are neither closely related to drainage nor possess full recharge capability and must therefore deplete the existing ground-water resource.

Surface water available is also sufficient for the developments planned in this subbasin.

Kansas Subbasin

The framework plan for the Kansas Subbasin is aimed at meeting the water and related land requirements of expanding urban-industrial developments, intensifying and stabilizing agricultural production as a continuing basis for the subbasin's rural economy, and enhancement of the subbasin's environmental qualities in support of both urban and rural future development. Emphasis has been on best meeting subbasin requirements, and there has been little or no need in plan development for compromise among objectives.

Major water-use components of the framework plan for the Kansas Subbasin by the year 2020 are as follows:

Multiple-purpose reservoir storage in 15 large and 1243 small reservoirs, and in reservoirs necessary to regulate water imported from the Platte River	6,341,000 af
Single-purpose reservoir storage	137,000 af
Public systems irrigation development	232,000 acres
Private irrigation development	
From surface water	87,000 acres
From ground water	1,898,000 acres
Streamflow withdrawals for municipal, industrial, mineral, and rural domestic use	78,000 af
Streamflow withdrawals for thermal powerplant cooling	20,000 af
Streamflow withdrawals by land conservation practices	88,000 af
Streamflow withdrawals for wetlands and fish and wildlife	22,000 af

The water supply in this subbasin, after depletion by the 1970-level developments, totals about 4,154,000 acre-feet. The listed features of the framework plan, and other lesser developments, are expected to deplete the 1970 water supply of the subbasin by 912,000 acre-feet, as shown in table 33. Therefore, net depletions by the proposed 2020 developments in the framework plan will reduce the 1970 water supply by 22%.

As of 1965, an estimated 1,449,000 acres, or some 85 percent, were irrigated from ground-water sources; an additional 254,000 acres were irrigated from surface waters, primarily from Federal multi-purpose storage reservoirs. By 2020, it is contemplated that over 78 percent of the total 3,920,000 acres to be irrigated will be supplied by ground water. However, this extensive future development will result in "mining" of the ground water in many areas. Also, the effect of such extensive ground-water withdrawals will have an appreciable effect on stream flow depletions, though varying considerably over the subbasin. Streamflow depletion factors applied in the various hydrologic planning subdivisions ranged from zero to 30 percent of the ground water consumptively used.

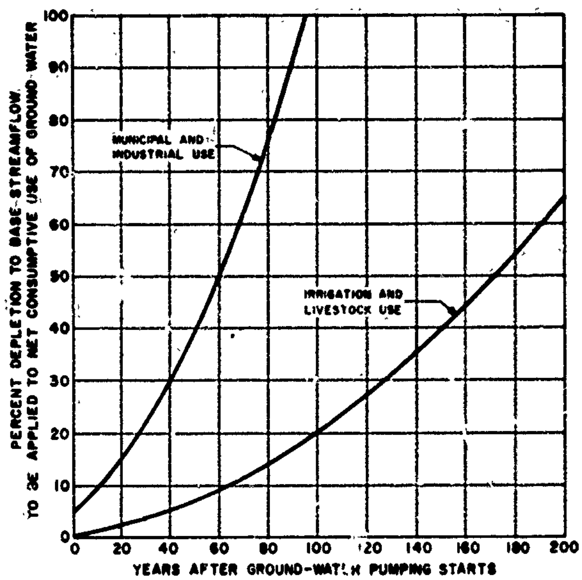
In the western portion of the subbasin, where many of the streams are intermittent, the ground-water levels generally are below stream levels. Here ground water extracted from the underlying aquifers has little discernible effect upon streamflow. The large amount of ground water stored beneath these uplands may be used until exhausted. However, once exhausted, it would require considerable time to replenish the aquifers from natural recharge.

In the uplands of the Blue River Basin, ground-water levels in the principal aquifers are generally below stream levels. Recharge to the aquifers from the streams is limited and areas of discharge from the aquifers generally are far distant from the recharge areas. Accordingly, pumping of ground water from the principal aquifers has a relatively limited effect on streamflows over extended periods of time. Withdrawals of ground water will be primarily from storage, and will de-water the aquifers until ultimately they will no longer provide water in usable and economical amounts.

In the remainder of the subbasin, streamflow depletions due to ground-water pumping were estimated on a sliding-percentage basis. Curves were developed to permit estimating of current streamflow depletions which would apply to pre-1970 developments and to estimate the expected depletions likely after the end of the planning period in 2020 (see figure 36). Note that the curve for irrigation- and livestock-water pumping is flatter, because it usually occurs at a considerable distance from the streams affected, and hence takes a longer time to show an effect. The municipal and industrial ground-water pumping curve is steeper, as these withdrawals are generally made closer to the affected streams, resulting in more rapid streamflow depletions.

Water appears to be available from which, in conjunction with planned storage, the surface diversions can be made. An import from the Platte River Basin is proposed which will bring in an average of 190,000 acre-feet annually by the year 2000 and increase to 500,000 acre-feet annually by 2020. The disposition of these

FIGURE 36
STREAMFLOW DEPLETION RATES
FROM GROUND-WATER PUMPING
KANSAS RIVER BASIN



amounts, in average annual units of 1,000 acre-feet, follows:

Year	Average Imports	Irrigation Depletion	Reservoir Evaporation Loss	Ground-Water Recharge	Stream Accretion
2000	190.0	105.0	37.5	23.0	24.5
2020	500.0	344.0	37.5	75.0	43.5

In the following depletion tables, delayed streamflow depletions are estimated for a 20-year period beyond 2020, the assumed plan completion date. These estimates are listed under streamflow depletions but are shown separately as a lag. The total amount for the Kansas Subbasin is 376,000 acre-feet.

Developments in the subbasin plan will cause ground-water depletions by 2020 amounting to 2,235,000 acre-feet above the 1970 level of depletion. Obviously, depletions at this rate cannot be continued indefinitely. Although the ground-water resources of the subbasin are considered great enough to permit the planned developments, cut-backs in the use of ground water will be necessary sometime after 2020.

It is considered that surface-water supplies are adequate for the planned developments, but that the planned imports are an essential component of the supply.

Lower Missouri Subbasin

The framework plan for the Lower Missouri Subbasin is aimed at meeting the water and related land requirements of the subbasin's extensive and growing urban-industrial development, intensifying and stabilizing agricultural production in the rural areas of the subbasin, and enhancement of the subbasin's environmental qualities in support of both urban and rural future development. Emphasis has been on best meeting subbasin requirements, and there has been only limited need for compromise between the objectives of national efficiency and regional economic and social enhancement on the one hand and the objective of environmental enhancement on the other.

Major water-use components of the framework plan for the Lower Missouri Subbasin by the year 2020 are as follows:

Multiple-purpose reservoir storage in 26 large and 979 small reservoirs	12,604,000 af
Single-purpose reservoir storage	658,000 af
Public systems irrigation development	0 acres
Private irrigation development	
From surface water	558,000 acres
From ground water	412,000 acres
Streamflow withdrawals for municipal, industrial, mineral, and rural domestic use	614,000 af
Streamflow withdrawals for thermal powerplant cooling	350,000 af
Streamflow withdrawals by land conservation practices	20,000 af
Streamflow withdrawals for wetlands and fish and wildlife	19,000 af

The water supply in this subbasin, after depletion by the 1970-level developments, totals about 17,263,000 acre-feet. The listed features of the framework plan, and other lesser developments, are expected to deplete the 1970 water supply of the subbasin by 1,588,000 acre-feet, as shown in table 34. Therefore, net depletions by the proposed 2020 developments in the framework plan will reduce the 1970 water supply by 9%.

Ground-water supplies in the Lower Missouri Subbasin generally are adequate for the ground-water developments included in the subbasin plan. A possible exception exists, however, in the Blackwater-Lamine Rivers drainage area where planned irrigation development may be somewhat greater than can be supported on a permanent basis by ground water in storage and available short-term streamflow. Potential ground-water developments in this area will require careful investigation. Throughout the subbasin, withdrawals of ground water usually will be reflected rather quickly in streamflow depletions because of the relatively rapid recharge from streamflow, and neither permanent ground-water depletions nor appreciable lag in streamflow depletion, because of ground-water use, are anticipated.

Surface water available also is sufficient for planned developments.

DEPLETIONS

Streamflow and ground-water depletions that will result from the water resource developments included in the framework plans have been estimated, by type of depletion, for each of the eight subbasins and for the Missouri Basin as a whole. These estimated depletions are listed in tables 22 through 34. The first four columns under the heading "Streamflow" represent estimated depletions to streamflow, including the effect that ground-water pumping is estimated to have on that streamflow. This ground-water pumping effect is very

Table 22 – AVERAGE ANNUAL DEPLETIONS MISSOURI BASIN

Type of Use	Total Through 1970	Average Annual Depletions in Thousand Acre-Feet[1]						
		Streamflow				Ground Water		
		1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	8141 (both cropland irrigation rows)	2117.6	5097.7	8789.6	790.1	1239.4	2269.5	4083.6
Cropland Irrigation – Supplemental		310.0	636.0	850.7	39.9	27.0	44.0	35.5
Irrigation Systems Rehabilitation	-5	-40.4	-106.1	-178.2				
Municipal and Rural Domestic Use	210	305.7	552.6	887.9	59.4	10.9	28.0	52.8
Industrial and Mineral	140	258.3	417.9	753.6	5.0	0.2	0.5	1.3
Thermal-Electric Power	37	84.9	314.1	556.0	2.3	1.2	3.4	4.9
Large Reservoir Evaporation	1818	392.1	753.3	1045.6				
Small Reservoir Evaporation	313	288.8	541.5	712.6				
Minor Ponds Evaporation	824	133.6	426.1	664.1				
Livestock	303	172.0	368.5	635.0	52.2	46.2	96.2	157.5
Watershed Treatment and Protection	340	154.1	422.1	711.2				
Wetlands and FWL Areas	200	144.6	236.4	380.0				
Exportations	0	410.6	1131.6	2044.8				
Forestry Management	-82	-116.9	-399.1	-436.6				
Importations	-542	-104.5	-337.0	-337.0				
Ground-water Recharge	0	...	...	...		0	-23.0	-75.0
Precipitation Management	0	-202.6	-563.4	-1270.0				
Conversion from Rural to Urban	0	-50.0	-80.0	-135.0				
Missouri Basin	11697	4257.9	9412.2	15674.3	948.9	1324.9	2418.6	4260.6

[1] Cumulative depletions above 1970 Level.
[2] Expected additional stream depletion 20 years later (2040) from ground-water pumping.

Table 23 – AVERAGE ANNUAL DEPLETIONS UPPER MISSOURI SUBBASIN

Type of Use	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
	1980	2000	2020	Lag[3]	1980	2000	2020
Cropland Irrigation – Full Service	263.0	512.2	671.2	0.3		2.6	4.5
Cropland Irrigation – Supplemental	43.0	116.0	150.5	0.1		1.0	1.5
Irrigation Systems Rehabilitation	0	0	0				
Municipal and Rural Domestic Use	11.4	24.0	30.7	1.3	2.4	2.9	3.5
Industrial and Mineral	0	0	0				
Thermal-Electric Power	4.4	19.1	45.4				
Large Reservoir Evaporation	31.7	70.0	77.6				
Small Reservoir Evaporation	8.0	17.7	34.5				
Minor Ponds Evaporation	4.1	14.8	24.1				
Livestock	11.5	24.2	42.2	0.2	0.6	1.3	2.2
Watershed Treatment and Protection	8.4	25.8	42.9				
Wetlands and FWL Areas	15.3	60.8	92.9				
Forestry Management	-13.0	-42.0	-70.5				
Importations	0	0	0				
Exportations[2]	0	45.0	45.0				
Precipitation Management	-19.6	-78.4	-196.0				
Total for Upper Missouri Subbasin	368.2	809.2	990.5	1.9	3.0	7.8	11.7

[1] Above 1970 Level of Depletion
[2] Upstream depletion of Milk River by Canada.
[3] Expected additional stream depletion 20 years later (2040) from ground-water pumping.

Table 24 – AVERAGE ANNUAL DEPLETIONS YELLOWSTONE SUBBASIN

	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
Type of Use	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	272.5	683.6	975.6	0.5	1.5	4.6	6.1
Cropland Irrigation – Supplemental	53.4	102.5	122.0				
Irrigation Systems Rehabilitation	-19.4	-44.5	-64.2				
Municipal and Rural Domestic Use	124.7	106.0	116.0	0.1	0.5	1.0	1.6
Industrial and Mineral	195.4	355.2	694.7				
Thermal-Electric Power	7.6	41.6	87.8				
Large Reservoir Evaporation	11.0	21.7	62.1				
Small Reservoir Evaporation	17.9	37.3	43.4				
Minor Ponds Evaporation	17.8	35.2	30.8				
Livestock	10.5	23.7	40.0	0.1	0.2	0.5	0.9
Watershed Treatment and Protection	4.5	10.4	16.8				
Wetlands and FWL Areas	11.2	26.9	49.0				
Forestry Management	-45.0	-136.0	-145.0				
Importations	0	0	0				
Exportations	0	0	0				
Precipitation Management	-89.0	-267.0	-536.0				
Total for Yellowstone Subbasin	573.1	996.6	1493.0	0.7	2.2	6.1	8.6

[1] Above 1970 Level of Depletions.
[2] Expected additional stream depletion 20 years later (2040) from ground-water pumping.

Table 25 – AVERAGE ANNUAL DEPLETIONS WESTERN DAKOTA SUBBASIN

	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
Type of Use	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	215.0	455.0	818.0	104.0	7.0	39.0	121.0
Cropland Irrigation – Supplemental	0	0	0				
Irrigation Systems Rehabilitation	1.0	2.0	5.0				
Municipal and Rural Domestic Use	3.0	6.0	9.0	12.0	4.0	8.0	15.0
Industrial and Mineral	0	0	0				
Thermal-Electric Power	15.0	30.0	53.0				
Large Reservoir Evaporation	1.0	28.0	30.0				
Small Reservoir Evaporation	75.0	143.0	186.0				
Minor Ponds Evaporation	3.0	10.0	15.0				
Livestock	13.0	26.0	45.0	16.2	6.0	12.0	20.0
Watershed Treatment and Protection	20.0	63.0	112.0				
Wetlands and FWL Areas	0	0	0				
Forestry Management	0	-8.0	-8.0				
Importations	0	0	0				
Exportations	0	0	0				
Precipitation Management	0	0	0				
Total for Western Dakota Subbasin	346.0	755.0	1265.0	132.2	17.0	59.0	156.0

[1] Above 1970 Level of Depletions.
[2] Expected additional stream depletion 20 years later (2040) from ground-water pumping.

Table 26 – AVERAGE ANNUAL DEPLETIONS EASTERN DAKOTA SUBBASIN

Type of Use[2]	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
	1980	2000	2020	Lag[4]	1980	2000	2020
Cropland Irrigation – Full Service	224.6	803.4	1910.6	15.4	49.4	102.3	211.6
Cropland Irrigation – Supplemental	0	0	0				
Irrigation Systems Rehabilitation	0	0	0				
Municipal and Rural Domestic Use	9.0	16.1	23.7	0.8	1.0	2.1	3.7
Industrial and Mineral	0	0	0				
Thermal-Electric Power	5.0	15.8	36.0				
Large Reservoir Evaporation	82.1	95.3	99.8				
Small Reservoir Evaporation	8.6	12.3	15.8				
Minor Ponds Evaporation	0	6.4	14.8				
Livestock	23.5	52.5	91.5				
Watershed Treatment and Protection	10.0	33.0	71.0				
Wetlands and FWL Areas	60.7	64.3	148.9				
Forestry Management	0	0	0				
Importations	0	0	0				
Exportations[3]	410.6	1086.6	1999.8				
Precipitation Management	0	0	0				
Total for Eastern Dakota Subbasin	834.1	2185.7	4411.9	16.2	50.4	104.4	215.3

1 Above 1970 Level of Depletions.
2 Accounts for both initial and ultimate stages of the Garrison Diversion Unit, Oahe Diversion Unit, other Federal and private irrigation units diverting from the Missouri River, and return flow to the Missouri River:

1980	2000	2020
776.0	2022.6	4047.4

3 Export to Souris and Red Rivers via Garrison Diversion Unit.
4 Expected additional stream depletion 20 years later (2040) from ground-water pumping.

Table 27 – AVERAGE ANNUAL DEPLETIONS PLATTE-NIOBRARA SUBBASIN

Type of Use	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	688.0	1112.3	1469.8	318.9	318.7	756.8	1355.0
Cropland Irrigation – Supplemental[3]	213.6	417.5	578.2	39.8	27.0	43.0	34.0
Irrigation Systems Rehabilitation	-22.0	-58.9	-110.2				
Municipal and Rural Domestic Use	110.6	283.5	453.3	31.5	0.4	8.9	20.2
Industrial and Mineral	54.5	48.5	33.2				
Thermal-Electric Power	15.4	61.6	99.1				
Large Reservoir Evaporation	77.1	176.3	342.5				
Small Reservoir Evaporation	31.0	77.3	109.4				
Minor Ponds Evaporation	5.6	60.6	111.8				
Livestock	31.5	62.5	98.4	21.1	26.5	54.5	87.6
Watershed Treatment and Protection	24.6	73.7	123.2				
Wetlands and FWL Areas	4.9	4.9	8.1				
Forestry Management	-58.9	-213.1	-213.1				
Importations	-104.5	-337.0	-337.0				
Exportations[4]	0	190.0	500.0				
Conversion from Rural to Urban	-50.0	-80.0	-135.0				
Precipitation Management	-94.0	-218.0	-538.0				
Total for Platte-Niobrara Subbasin	927.4	1661.7	2593.7	411.3	372.6	863.2	1496.8

1 Above 1970 Level of Depletions. Includes depletions in Tables 28, 29, 30, and 31.
2 Expected additional stream depletion 20 years later (2040) from ground-water pumping.
3 Includes future streamflow depletion from pre-1970 ground-water developments.
4 To Kansas Subbasin.

Table 28 – AVERAGE ANNUAL DEPLETIONS NORTH PLATTE RIVER

Type of Use	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	24.0	89.0	96.0	4.6	21.0	39.0	34.0
Cropland Irrigation – Supplemental	38.3	106.0	181.5	5.3	27.0	43.0	34.0
Irrigation Systems Rehabilitation	-4.4	-11.7	-21.9				
Municipal and Rural Domestic Use	7.3	12.0	20.1				
Industrial and Mineral	47.0	43.0	30.0				
Thermal-Electric Power	2.1	12.8	21.4				
Large Reservoir Evaporation	0	14.0	44.0				
Small Reservoir Evaporation	8.2	24.4	36.0				
Minor Ponds Evaporation	0	2.3	8.1				
Livestock	3.7	7.4	11.6	0.9	3.2	6.4	10.5
Watershed Treatment and Protection	4.7	14.2	24.0				
Wetlands and FWL Areas	1.3	1.3	1.8				
Forestry Management	-39.3	-142.0	-142.0				
Importations	0	0	0				
Exportations	0	0	0				
Precipitation Management	-70.0	-145.0	-295.0				
Total for North Platte River	22.9	27.7	15.6	10.8	51.2	88.4	78.5

1 Above 1970 Level of Depletions
2 Expected additional stream depletion 20 years later (2040) from ground-water pumping.

Table 29 – AVERAGE ANNUAL DEPLETIONS SOUTH PLATTE RIVER

Type of Use	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	105.0	118.0	133.0	4.2	17.7	29.0	43.0
Cropland Irrigation – Supplemental	60.8	111.5	176.4				
Irrigation Systems Rehabilitation	-11.1	-29.6	-55.5				
Municipal and Rural Domestic Use	97.0	255.8	404.2				
Industrial and Mineral	7.5	5.5	3.2				
Thermal-Electric Power	10.5	37.6	61.3				
Large Reservoir Evaporation	17.9	50.5	93.5				
Small Reservoir Evaporation	9.8	16.7	17.8				
Minor Ponds Evaporation	4.1	46.0	72.0				
Livestock	6.1	12.1	19.0	1.4	5.1	10.5	17.0
Watershed Treatment and Protection	6.2	18.5	30.8				
Wetlands and FWL Areas	2.3	2.3	2.3				
Forestry Management	-19.6	-71.1	-71.1				
Importations	-104.5[3]	-337.0	-337.0				
Conversion from Rural to Urban	-50.0	-80.0	-135.0				
Precipitation Management	-24.0	-73.0	-243.0				
Total for South Platte River	118.0	83.8	171.9	5.6	22.8	39.5	60.0

1 Above 1970 Level of Depletion.
2 Expected additional stream depletion 20 years later (2040) from ground-water pumping.
3 Imports from Colorado River watershed:

To Denver Area		To Cheyenne Area	
Homestake	33.6	Little Snake	10.0
Blue	37.9		
Moffat	23.0		

Table 30 – AVERAGE ANNUAL DEPLETIONS LOUP-ELKHORN-LOWER PLATTE RIVERS

	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
Type of Use	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	440.5	718.5	1026.3	295.7	204.0	593.0	1159.0
Cropland Irrigation – Supplemental[3]	107.0	189.0	206.5	32.0			
Irrigation Systems Rehabilitation	-6.5	-17.6	-32.8				
Municipal and Rural Domestic Use	6.1	14.7	27.8	31.1	0	8.0	18.9
Industrial and Mineral	0	0	0				
Thermal-Electric Power	2.8	11.2	16.4				
Large Reservoir Evaporation	39.7	72.3	162.5				
Small Reservoir Evaporation	13.0	36.2	54.6				
Minor Ponds Evaporation	1.3	10.3	26.7				
Livestock	17.4	34.6	54.5	15.1	14.7	30.2	48.4
Watershed Treatment and Protection	11.0	32.9	54.9				
Wetlands and FWL Areas	1.3	1.3	4.0				
Forestry Management	0	0	0				
Importations (From Niobrara subarea)	0	-150.0	-230.0				
Exportations (To Kansas Subbasin)	0	190.0	500.0				
Precipitation Management	0	0	0				
Total for Loup-Elkhorn-Lower Platte Rivers	633.6	1143.4	1871.4	373.9	218.7	631.2	1226.3

[1] Above 1970 Level of Depletion.
[2] Expected additional stream depletion 20 years later (2040) from ground-water pumping.
[3] Includes future streamflow depletion from pre-1970 ground-water developments.

Table 31 – AVERAGE ANNUAL DEPLETIONS NIOBRARA RIVER

	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
Type of Use	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	118.5	186.8	214.5	14.4	76.0	95.8	119.0
Cropland Irrigation – Supplemental[3]	7.5	11.0	13.8	2.5			
Irrigation Systems Rehabilitation	0	0	0				
Municipal and Rural Domestic Use	0.2	1.0	1.2	0.4	0.4	0.9	1.3
Industrial and Mineral	0	0	0				
Thermal-Electric Power	0	0	0				
Large Reservoir Evaporation	19.5	39.5	42.5				
Small Reservoir Evaporation	0	0	1.0				
Minor Ponds Evaporation	0.2	2.0	5.0				
Livestock	4.3	8.4	13.3	3.7	3.5	7.4	11.7
Watershed Treatment and Protection	2.7	8.1	13.5				
Wetlands and FWL Areas	0	0	0				
Forestry Management	0	0	0				
Importations	0	0	0				
Exportations (To Elkhorn)	0	150.0	230.0				
Precipitation Management	0	0	0				
Total for Niobrara River	152.9	406.8	534.8	21.0	79.9	104.1	132.0

[1] Above 1970 Level of Depletions.
[2] Expected additional depletion 20 years later.
[3] Supplemental irrigation plus depletion for pre-1970 ground-water irrigation development.

Table 32 – AVERAGE ANNUAL DEPLETIONS MIDDLE MISSOURI SUBBASIN

Type of Use	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	217.5	770.1	1527.4	9.4	21.7	75.5	128.2
Cropland Irrigation – Supplemental	0	0	0				
Irrigation Systems Rehabilitation	0	0	0				
Municipal and Rural Domestic Use	22.0	40.0	65.0	1.2	1.6	2.9	4.8
Industrial and Mineral	0	0	0				
Thermal-Electric Power	13.5	53.7	83.5				
Large Reservoir Evaporation	46.1	66.8	100.7				
Small Reservoir Evaporation	25.8	52.2	71.0				
Minor Ponds Evaporation	45.7	93.3	163.3				
Livestock	34.9	76.3	131.6	0.3	1.0	2.2	4.1
Watershed Treatment and Protection	46.7	141.7	237.5				
Wetlands and FWL Areas	27.1	40.6	40.6				
Forestry Management	0	0	0				
Importations	0	0	0				
Exportations	0	0	0				
Precipitation Management	0	0	0				
Total for Middle Missouri Subbasin	479.3[3]	1334.7[3]	2420.6[3]	10.9	24.3	80.6	137.1

[1] Above 1970 Level of Depletions.
[2] Expected additional stream depletion 20 years later (2040) from ground-water pumping.
[3] Includes depletions served by the Main Stem of Missouri River in incremental amounts of: 200.7 in 1980, 504.5 in 2000, and 552.2 in 2020; a total of 1257.5 above the 1970-level in 2020. Subbasin depletions above the 1970-level in 2020 are 1163.1.

Table 33 – AVERAGE ANNUAL DEPLETIONS KANSAS SUBBASIN

Type of Use	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
	1980	2000	2020	Lag[2]	1980	2000	2020
Cropland Irrigation – Full Service	97.7	403.1	826.0	341.6	841.1	1288.7	2257.2
Cropland Irrigation – Supplemental	0	0	0				
Irrigation Systems Rehabilitation	0	-4.7	-8.8				
Municipal and Rural Domestic Use	5.0	12.8	26.0	12.5	1.0	2.2	4.0
Industrial and Mineral	0.4	1.2	3.7	5.0	0.2	0.5	1.3
Thermal-Electric Power	9.2	26.0	41.9	2.3	1.2	3.4	4.9
Large Reservoir Evaporation	40.7	109.7	147.4				
Small Reservoir Evaporation	51.7	80.1	100.0				
Minor Ponds Evaporation	16.7	76.1	109.1				
Livestock	13.1	30.3	57.3	14.3	11.9	25.7	42.7
Watershed Treatment and Protection	23.1	55.6	87.7				
Wetlands and FWL Areas	11.1	21.7	21.7				
Importations	0	-190.0	-500.0[3]				
Ground-water and Stream Recharge[4]	0	[-24.5]	[-43.5]		0	-23.0	-75.0
Exportations	0	0	0				
Precipitation Management	0	0	0				
Total for Kansas Subbasin	268.7	621.9	912.0	375.7	855.4	1297.5	2235.1

[1] Cumulative depletions above 1970 level.
[2] Expected additional stream depletion 20 years later (2040) from ground-water pumping.
[3] Imports disposition: Irrigation 344.0, Evap. 37.5, Ground-water Recharge 75.0, Stream Accretion 43.5.
[4] Bracketed numbers are non-additive.

Table 34 – AVERAGE ANNUAL DEPLETIONS LOWER MISSOURI SUBBASIN

Type of Use	Average Annual Depletions in Thousand Acre-Feet[1]						
	Streamflow				Ground Water		
	1980	2000	2020	Lag	1980	2000	2020
Cropland Irrigation – Full Service	139.3	358.0	591.0		Ground-water withdrawals may temporarily deplete the water tables, but full restoration may be expected within 1 or 2 years owing to the significant rainfall. Because ground water cannot be permanently mined in these tributary streams, no depletion is assigned to ground water, and all expected depletions will directly diminish the local streamflow.		
Cropland Irrigation – Supplemental	0	0	0				
Irrigation Systems Rehabilitation	0	0	0				
Municipal and Rural Domestic Use	20.0	64.2	164.2				
Industrial and Mineral	8.0	13.0	22.0				
Thermal-Electric Power	14.8	66.3	109.3				
Large Reservoir Evaporation	102.4	185.5	185.5				
Small Reservoir Evaporation	70.8	121.6	152.5				
Minor Ponds Evaporation	40.7	129.7	195.2				
Livestock	34.0	73.0	129.0				
Watershed Treatment and Protection	16.8	18.9	20.1				
Wetlands and FWL Areas	14.3	17.2	18.8				
Forestry Management	0	0	0				
Importations	0	0	0				
Exportations	0	0	0				
Precipitation Management	0	0	0				
Total for Lower Missouri Subbasin	461.1	1047.4	1587.6				

[1] Above 1970 Level of Depletions.

minor except in the Platte-Niobrara and Kansas Subbasins. The last three columns of each table under the heading "Ground Water" represent depletions to the ground-water aquifer; that is, "mining" of the ground-water resource. Table 35 summarizes total depletions for all water uses by development periods and subbasins and at selected locations on the main stem of the Missouri River. Depletions shown are for the framework plan to meet the projected needs and do not consider possible budgetary constraints or any changes in economic projections.

Streamflow depletions for the Missouri Basin as a whole are also summarized by water-use categories in figure 37. Figure 38 illustrates the growth of depletions since 1865 and the expected future growth through 2020. Also shown is the remaining water supply at the mouth of the Missouri River, after allowances are made for depletion effects.

Table 35 – SUMMARY OF AVERAGE ANNUAL STREAMFLOW DEPLETIONS AT SELECTED LOCATIONS

Location	Incremental For Period Shown						1910 to 1970 Total	1910 to 2020 Total	1865 to 2020 Total
	1865[1] to 1910	1910 to 1949	1949 to 1970	1970 to 1980	1980 to 2000	2000 to 2020			
	(Thousand Acre-Feet)								
Missouri River at Fort Peck Dam	---	657.2[2]	465.4	280.0	424.0	46.0	1122.6	1872.6	
Upper Missouri Subbasin	---	673.2	585.1	368.2	441.0	181.3	1258.3	2248.8	
Yellowstone Subbasin	---	268.9	361.0	573.1	423.5	496.4	629.9	2122.9	
Missouri River at Williston, N.D.	---	942.1	946.1	941.3	864.5	677.7	1888.2	4371.7	
Missouri River at Garrison Dam	---	956.5	1573.5	1528.6	1766.9	2141.4	2530.0	7966.9	
Missouri River at Oahe Dam	---	990.7	2277.9	1988.7	2561.3	3239.6	3268.6	11058.2	
Missouri River at Big Bend Dam	---	998.2	2362.2	2003.7	2562.3	3242.6	3360.4	11169.0	
Missouri River at Fort Randall Dam	---	1023.9	2522.4	2070.7	2571.3	3254.6	3546.3	11442.9	
Missouri River at Gavins Point Dam	---	1030.3	2665.1	2223.6	2825.2	3382.6	3695.4	12126.8	
Western Dakota Subbasin	---	46.9	318.6	346.0	409.0	510.0	365.5	1630.5	
Eastern Dakota Subbasin	---	49.3	266.2	834.1	1351.6	2226.2	315.5	4727.4	
Missouri River at Sioux City, Ia.	2721.3	1038.9	2772.0	2267.5	2886.7	3571.0	3810.9	12536.1	15257.4
Missouri River at Omaha, Nebr..	---	1049.8	2843.3	2482.5	3236.7	4046.0	3893.1	13658.3	
Platte Subbasin (only)[3]	---	140.3	762.6	774.5	480.4	804.0	902.9	2961.8	
Missouri River at Nebraska City	---	1192.7	3666.9	3257.0	3717.1	4750.0	4859.6	16683.7	
Middle Missouri Subbasin	---	32.1	347.2	479.3	855.4	1085.9	379.3	2799.9	
Kansas Subbasin (only)	---	28.1	767.5	268.7	353.2	290.1	795.6	1707.6	
Missouri River at Kansas City, Mo.	---	1239.4	4649.3	3794.8	4571.0	5750.9	5888.7	20005.4	
Missouri River at Boonville, Mo.	---	1265.6	4753.7	4051.9	4902.3	6025.1	6019.3	20998.6	
Missouri River at Hermann, Mo.	5548.5	1280.9	4867.8	4257.9	5154.3	6262.1	6148.7	21823.0	27371.5
Lower Missouri Subbasin	---	41.5	218.5	461.1	586.3	540.2	260.0	1847.6	

[1] Available for this time period at Sioux City and Hermann only.
[2] Includes Fort Peck Reservoir evaporation of 441,000 acre-feet per year.
[3] Excludes Niobrara Basin depletions.

FIGURE 37
STREAMFLOW DEPLETIONS BY WATER USE, 1865-2020

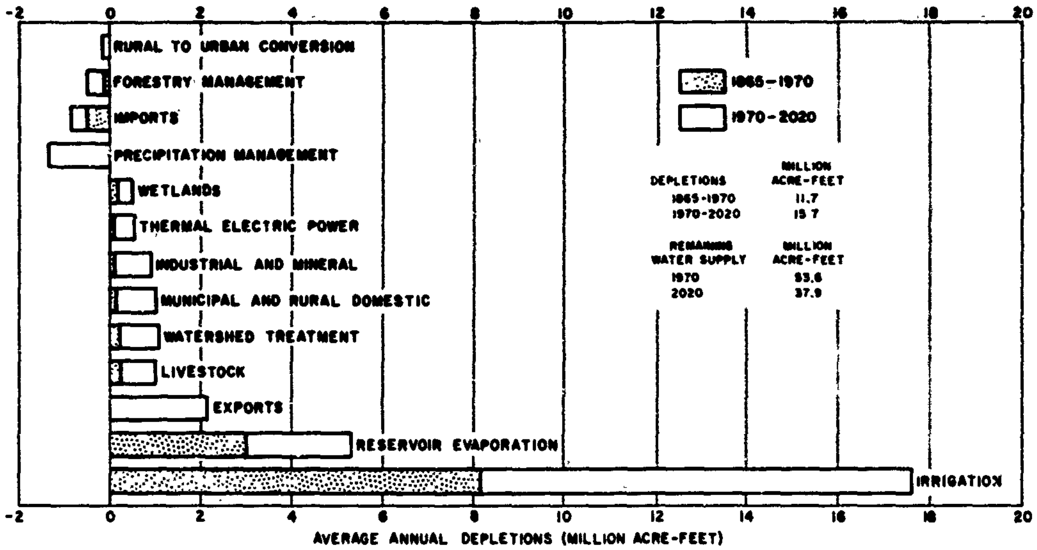
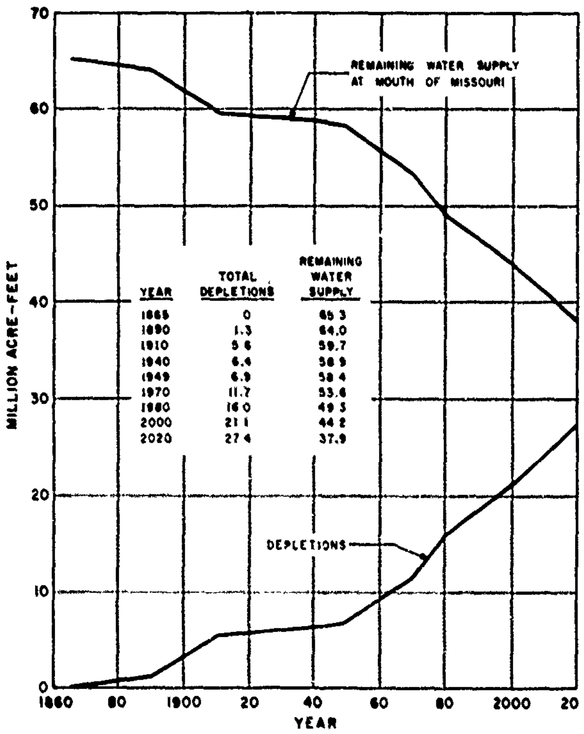


FIGURE 38
AVERAGE ANNUAL WATER SUPPLY AND DEPLETIONS
TOTAL MISSOURI BASIN, 1865-2020



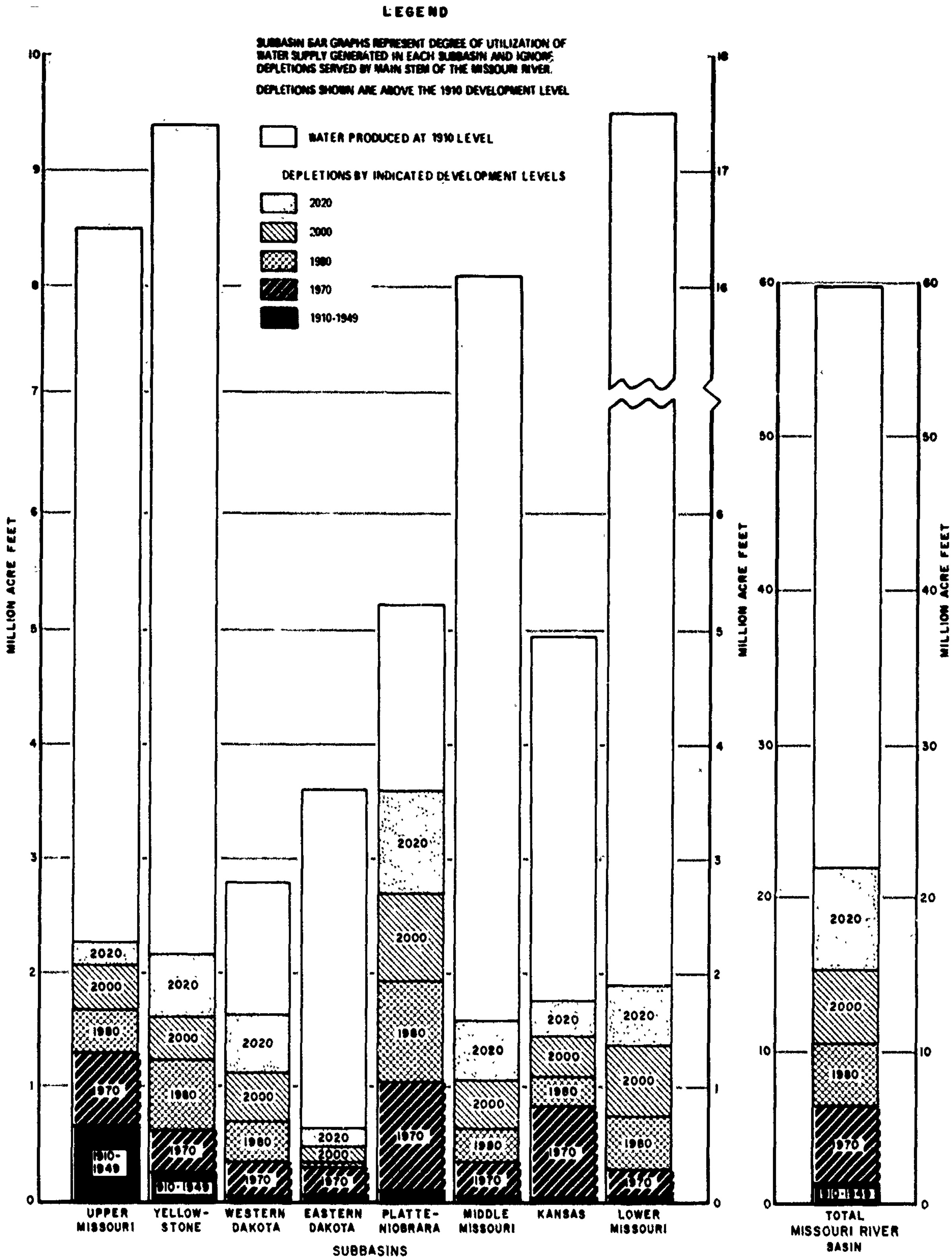
WATER AVAILABILITY AND USE BY DEVELOPMENT PERIODS AND SUBBASINS

The detailed streamflow depletion data in tables 22 through 35 illustrate the depleting effects of proposed water-resource developments, but do not indicate the degree to which each subbasin's water supply is utilized or the magnitude of the remaining water supply. Figure 39 has been prepared to illustrate these aspects of the framework plan.

The depletion totals listed in tables 22 through 35 represent net depletions by development periods, utilizing "made" water to offset exports and consumptive use. "Made" water in this context represents additions to each subbasin's normal water supply by imports, precipitation management, forestry management, and conversion of land use from rural to urban. Figure 39 indicates the degree of utilization of the water supply originating in each subbasin. This assumes that "made" water will be available, as projected, to offset depletions. Figure 39 indicates that by the year 2020 proposed projects deplete less than half the available water supply in the Upper Missouri, Yellowstone, Eastern Dakota, Middle Missouri, the Kansas, and Lower Missouri subbasins. In none of these subbasins is the "made" water a significant portion of the water supply or necessary in an overall sense to the planned developments. However, in the Platte-Niobrara Subbasin, the "made" water is very significant to the framework plan. In fact, analysis of the Platte River apart from the Niobrara River indicates that the estimated depletions in the 1910-2020 period exceed the 1910 water supply and the level of developments contemplated can be achieved only through utilization of water from, primarily, imports and precipitation management. In the Western Dakota Subbasin, the dependence on "made" water is not apparent, but the planned developments result in depletion of over half the water supply, an unusually high ratio of use for a multiple-stream subbasin.

FIGURE 39

AVERAGE ANNUAL STREAMFLOW DEPLETIONS AND AVAILABLE WATER SUPPLY BY SUBBASINS AND DEVELOPMENT PERIODS



For the Missouri Basin as a whole, depletions during the 1910-2020 period total almost 22 million acre-feet, about 37% of the 1910 water supply. This magnitude of water use markedly affects the services provided by the main stem reservoirs and reduces flow levels available along the Missouri and the Mississippi rivers.

MISSOURI RIVER MAIN STEM RESERVOIR REGULATION AT FUTURE DEVELOPMENT LEVELS

The Missouri River main stem reservoirs were described in chapter 6 of this report. This description included physical characteristics, storage allocations, general criteria for system regulation, and a summary of accomplishments of the reservoir system to date. Also included was a discussion of a 1970-level regulation study designed to evaluate the effects of operation of an initially filled reservoir system during a long period of hydrologic record with streamflows depleted by the 1970-level projects.

To evaluate the effects of the main stem reservoir system at future development levels, 1980-level, 2000-level and 2020-level regulation studies were made, similar to the 1970-level study, extending through the historical record period, 1898-1968. The results of these studies, when compared with the 1970-level studies, are indicative of the effects of added basin development upon the basic functions of the main stem system and upon Missouri River streamflows below the system.

In the development of these future level studies, it was necessary to estimate the effects of the passage of time and basin development upon the physical characteristics of the reservoir system and the functional requirements of the system. The transport of sediment into the reservoirs, and its accumulation therein, effectively reduces the storage space available within the system to serve project purposes. The estimated annual sediment inflow to each of the main stem projects is given in table 18. It was assumed that this sediment would deposit within each of the reservoirs and reduce storage capacity in the same proportion as the storage contained within any specific zone is related to the total storage of the reservoir. It was further assumed that storage requirements for specific purposes (flood control, etc.) would be reduced with continued basin development at a rate equal to the sediment depletion of each of these storage zones, resulting in pertinent elevations defining storage zones remaining at their current level. A tabulation of the storage allocations assumed for these studies is given in table 36. The purpose of each zone is described in chapter 6.

Table 36 – STORAGE ALLOCATIONS MISSOURI RIVER MAIN STEM RESERVOIR SYSTEM

Year	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point	System
			(Thousand Acre-Feet)				
Exclusive Flood Control							
1970	1,000	1,500	1,100	175	1,000	65	4,840
1980	900	1,500	1,100	165	900	60	4,625
2000	900	1,400	1,000	160	900	55	4,415
2020	900	1,400	1,000	150	800	45	4,295
Annual Flood Control and Multiple Use							
1970	2,700	4,300	3,200	...	1,300	100	11,600
1980	2,700	4,200	3,100	...	1,300	90	11,390
2000	2,600	4,100	3,000	...	1,200	85	10,985
2020	2,500	3,900	2,900	...	1,100	75	10,475
Carryover Multiple Use							
1970	11,100	13,600	13,800	260	2,200	200	41,160
1980	10,900	13,200	13,400	250	2,100	185	40,035
2000	10,700	12,700	13,000	235	1,900	165	38,700
2020	10,500	12,300	12,600	220	1,800	150	37,570
Inactive							
1970	4,300	5,000	5,500	1,465	1,200	175	17,640
1980	4,300	4,800	5,300	1,400	1,200	160	17,160
2000	4,200	4,700	5,200	1,325	1,100	145	16,670
2020	4,100	4,500	5,000	1,255	1,000	130	15,985
Total							
1970	19,100	24,400	23,600	1,900	5,700	540	75,240
1980	18,800	23,700	22,900	1,815	5,500	495	73,210
2000	18,400	22,900	22,200	1,720	5,100	450	70,770
2020	18,000	22,100	21,500	1,625	4,700	400	68,325

It was also assumed that continued operation of the reservoir system would result in continued degradation below three of the main stem projects. The Garrison tailwater was assumed to lower one foot from the present level by 1980 with an additional 7 feet occurring prior to 2000, then holding through 2020. At Fort Randall, the tailwater was assumed to lower 5 feet by 1980, an additional 5 feet by the year 2000, then stabilizing through 2020. Gavins Point tailwater elevation 1 foot below present levels was assumed by 1980 with an additional 10 feet of drop for the 2000 and 2020 studies. No change from present levels was assumed below Fort Peck, Oahe and Big Bend.

Conditions and objectives of the future level regulation studies were similar to those of the 1970-level study, with consideration given to the planned increase in water resource developments. Reach boundaries utilized, monthly reservoir evaporation rates, and historical streamflow for the 1898-1968 period were identical with the 1970 studies. Adjustments to the historical flows were made to recognize the basin development which has actually occurred since the date of the flows and also to recognize the further basin development which is expected to occur in the future to the time of the development level under consideration. Month-by-month adjustments for the level under study were obtained by abbreviated reservoir regulation studies, similar to those described in chapter 6. A portion of the flood control storage space that is planned to be provided in the new upstream tributary reservoirs was assumed to be available for replacement of annual flood control and multiple-use space in the main stem system, thereby effectively increasing the permissible system storage at the base of the annual flood control and multiple-use zone by a corresponding amount. The amount of this type of space assumed for 1980-level studies was 1,200,000 acre-feet, identical to that considered available for the 1970-level studies. The amount of this type of space available was assumed to be 2,200,000 acre-feet by the year 2000 and 2,600,000 acre-feet by 2020.

Powerplant characteristics with limits on peaking and generation were assumed to be unchanged from those used in the 1970 studies. Maximum and minimum release limitations were also identical to the 1970-level studies. As with the 1970-level studies, minimum releases from all projects above Gavins Point were assumed adequate to meet water quality control requirements in the affected downstream reaches. Releases from Gavins Point were increased when necessary to meet minimum water quality control requirements of 1,000 cfs at Sioux City, 3,000 cfs at Omaha and 2,000 cfs at Kansas City during the 1980-level studies, respective flows of 1,000, 3,500 and 3,000 cfs for the 2000-level studies and 1,000, 4,000 and 4,000 cfs for the 2020-level studies.

Flow requirements for navigation below the system were assumed to be similar to those selected for the 1970-level studies. Shortening of the navigation season, when necessary, was also done in a similar manner. A further criterion specified that navigation season lengths would not be reduced to less than a 4-month duration. If storage levels were expected to fall to such an extent that season lengths of at least 4 months could not be supported, navigation would be discontinued until such time sufficient storage had again been accumulated to provide 4-month or longer navigation seasons.

Regulation criteria for flood control, the release of water in excess of navigation requirements as a storage evacuation measure, and the selection of navigation and non-navigation system release rates were similar to those utilized for the 1970-level studies described in chapter 6. Rules specifying the internal regulation of the system were also quite similar to those given for the 1970-level studies. An addition was that, during years when it was not possible to maintain the navigation function below the system, the drawdown of Fort Randall would not be made. Under such conditions, releases from Big Bend, Fort Randall, and Gavins Point would be based on passing Oahe releases of 6,000 cfs plus incremental inflows between Oahe and the affected project.

Long-range reservoir regulation studies of this type are exceedingly complex, involving the development of numerous detailed criteria intended to regulate each reservoir within the system in a reasonable manner within the framework of the general criteria developed to sustain the functions for which the system was authorized. These criteria must be applied on a month-by-month (or shorter time interval) basis through the period of examined record. As a consequence, even with the maximum practical use of electronic computers, limitations on the time and effort which can be expended prohibit a completely exhaustive investigation into what might be considered the optimum manner of reservoir regulation for each of the development levels under consideration. With the assumptions which are required to project the effects of basin development on future flows, such an exhaustive investigation probably would serve no useful purpose. Therefore, it can be considered that the studies which have been made are exploratory in nature, but present both qualitative and reasonably valid quantitative estimates of the effects that future basin development will have upon the functions of the main stem system and Missouri River flows below the system.

Conclusions, resulting from analyses of these studies, are as follow:

a. The studies demonstrate that for all basin development levels the reservoir system, with assigned flood control storage capacities, was fully effective for flood control for all runoff conditions experienced during the 1898-1968 period of record, as adjusted to the appropriate levels of basin development. A reserve of exclusive flood control storage space was maintained at all times. In addition, releases from individual projects did not exceed their respective downstream channel capacities. Sioux City flows were at all times at or below the level permitted by the downstream flood potential. Under 1970-level conditions, there were 30 months during the 1898-1968 record period when, due to the downstream flood potential, system releases had to be reduced below the levels which would be indicated for storage evacuation purposes alone. At the 1980-level of development, system release reductions for this reason were required for only 6 months during the same record period, while at the 2000- and 2020-levels no such reductions were necessary.

b. Sufficient releases were maintained from the reservoirs during all of the examined levels of development to meet the requirements for irrigation from the river below the projects. The effects of irrigation projects upon inflows into the system and releases from the system were considered throughout the studies. Diversions from both Garrison and Oahe reservoirs for irrigation of lands in the eastern Dakotas, at appropriate levels, were considered in the post-1970 studies.

c. Navigation flows averaging 25,000 to 35,000 cfs at Sioux City were maintained from 23 March through 22 November to provide full 8-month service to navigation for 66 years of the 71-year study of the 1970-level development. With the anticipated 1980-level development the number of years during the 71-year record period with full length navigation seasons was reduced to 61. By the year 2000, full length navigation seasons would appear practical only during 43 years of the record period and this number is further reduced to only 15 years by 2020. The extreme drought period which occurred in the 1930's resulted in a slight decrease of navigation season lengths during 5 years of the 1970-level study. The 1980-level development required substantial decreases in the navigation season lengths for 9 years of the 1930 drought. In addition, at this level, the 1961 navigation season length was also reduced below the full service level as a result of drought conditions prevailing prior to and including that year. The 2000-level of development was accompanied by 14 successive years during the 1930 drought period during which extreme reductions to the navigation season length were made. It was necessary to completely eliminate navigation releases for one year of this period. The drought of the late 1950's and early 1960's required navigation releases for the 2000-level study to be reduced from full service levels for 10 successive years while short term deficiencies in water supply outside of these main drought periods resulted in shortening of the navigation season during 4 other years. By the year 2020, the effect of basin development on the navigation function of the system becomes extreme. In only 15 years of the 71-year period of record was it possible to provide full 8-month navigation seasons. It was necessary to eliminate navigation entirely for 11 successive years of the 1930 drought and for 2 successive years of the drought of the late 1950's. Shortened seasons were quite common through the entire record period. The distribution of navigation season lengths during the 1898-1968 period for each of the examined development levels is shown by the following tabulation:

Season Length, Months	*Years Experienced for Indicated Development Level*			
	1970	*1980*	*2000*	*2020*
8.00	66	61	43	15
7.75	1		3	3
7.50		1		2
7.25	1			1
7.00	1		3	4
6.75	2	1	2	5
6.50			2	4
6.25		1		4
6.00			5	7
5.75		3	1	2
5.50		2	2	1
5.25		2		
5.00			1	1
4.75				1
4.50				
4.25			1	2
4.00			7	6
0.00			1	13
Total	71	71	71	71

d. Water quality control requirements on the Missouri River were met throughout the study period for all development levels. During all years with full 8-month navigation seasons, and in all years while navigation releases were being made, releases for other purposes exceeded the water quality control requirements. Additionally, during those years when navigation was eliminated and system releases were based on water required for power peaking operations, they were generally sufficient to meet the water quality control requirements. During other non-navigation periods, preceded by a shortened navigation season, these requirements (and water intake requirements) established system releases.

e. The nameplate power rating and the December peaking capability at the end of the fourth year of the drought of the 1930's were as shown in the following table. The main stem hydroelectric capability shown for 2020 represents about one-third of the total existing and projected hydro capacity in the basin at that time, and about 1-1/2 percent of the combined thermal and hydro capacity by that date in the power region.

	Nameplate Rating 1,000 KW	*December 1933 Capability 1,000 KW*			
		1970	*1980*	*2000*	*2020*
Fort Peck	165	185	179	171	176
Garrison	400	399	379	405	363
Oahe	595	526	488	504	421
Big Bend	468	538	538	538	528
Fort Randall	320	277	302	335	360
Gavins Point	100	66	67	77	77
	2048	1991	1953	2030	1925

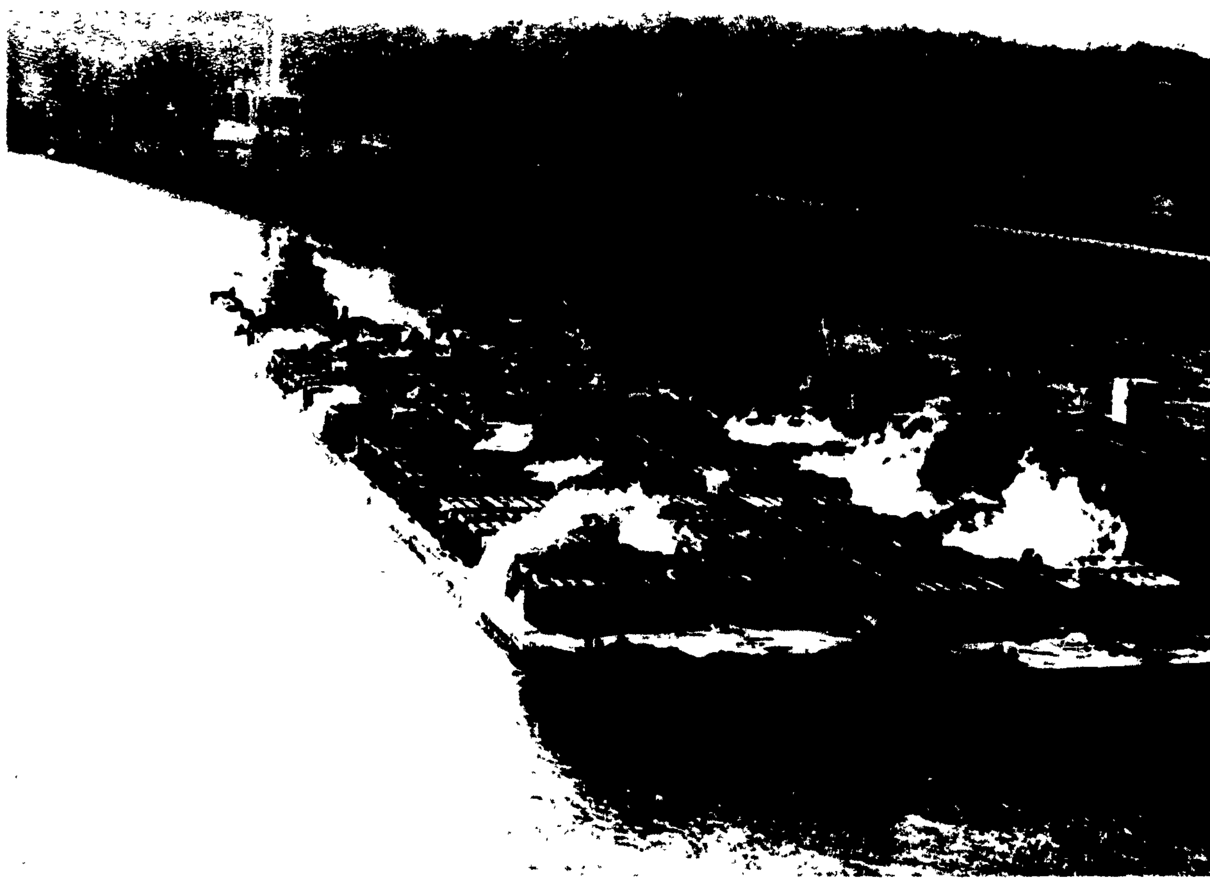
The preceding table indicates that future development is estimated to have only a minor effect upon the peaking capability of the system as a whole. Although the amount of system storage in December 1933 varied from 41.9 million acre-feet with the 1970-development level to 37.3, 35.6, and 31.5 million acre-feet, respectively for 1980-, 2000-, and 2020-development levels, the reduced storage content in later development levels is partially compensated for by the deposition of sediment within the reservoirs, which causes higher pool levels for a given storage. In addition, the assumptions regarding tailwater lowering have the effect of maintaining comparable peaking capability even with lowered pool levels. The apparent anomaly, indicating an increase in the peaking capability from the 1980- to the 2000-development level, results from the relatively minor difference in system storage at the two levels combined with the assumptions that sediment would accumulate at a normal rate through the 20-year period and that substantial lowering of tailwater elevations of particular projects (as described in a preceding paragraph) would occur during the period. This anomaly could have been removed by modifying the 2000-development level reservoir regulation criteria to provide somewhat better service to navigation and power in the months and years preceding December 1933, with a compensating reduction in service following this date, but it was reasoned that the results obtained were adequate for a framework study.

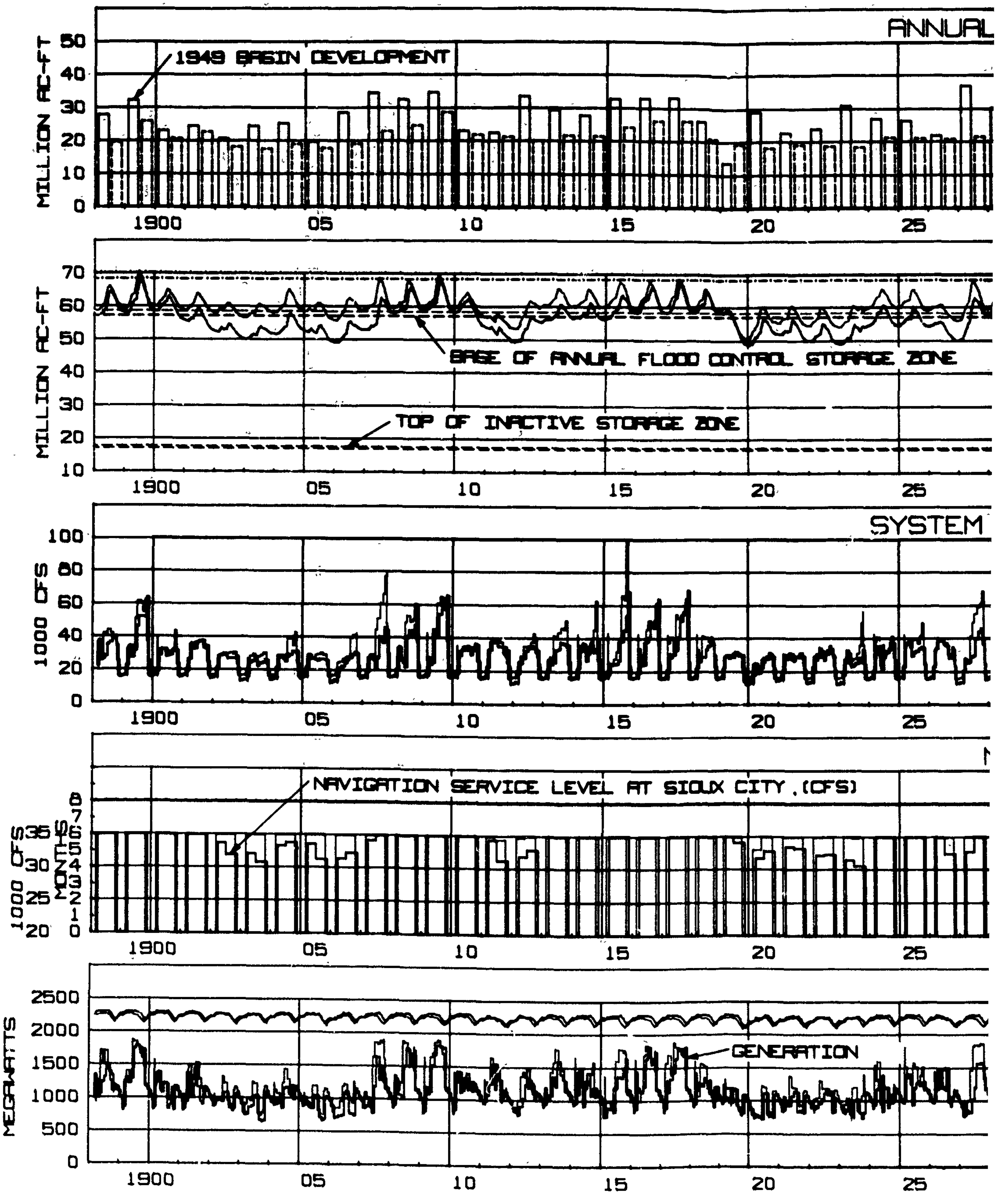
f. The average monthly distribution of system energy for the entire record period was as shown in the following table. The main stem energy generation shown for 2020 represents about one-fourth of the total projected hydroelectric generation in the basin and about 1 percent of the total energy requirements by that date in the power region.

	Average Generation, Million KWH			
	1970	*1980*	*2000*	*2020*
March 16-31	358	330	297	232
April	724	677	610	536
May	773	733	642	555
June	742	673	600	522
July	922	805	730	631
August	958	891	789	630
September	800	739	671	550
October	802	736	635	489
November 1-15	367	332	292	220
November 16-30	390	352	309	209
December	778	722	615	431
January	720	662	561	370
February	596	552	466	308
March 1-15	300	283	248	181
Annual	9230	8487	7465	5864

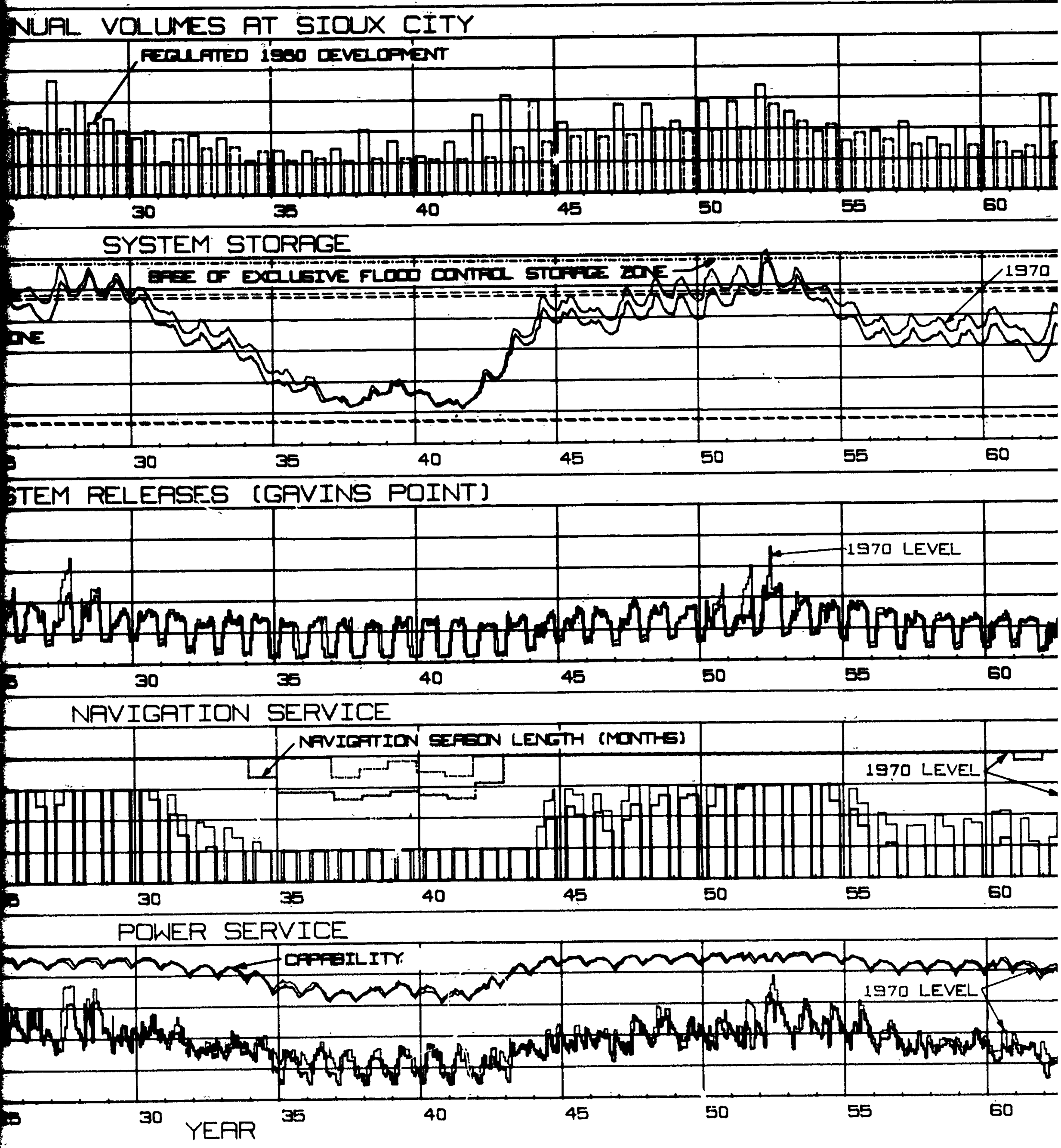
Salient features of the 1970-level study were presented in chapter 6 of this appendix. Plates 33 through 40 of this chapter present similar features of the 1980-, 2000- and 2020-level studies. Annual volumes at Sioux City through the 1898-1968 record period for each of the development levels are compared with similar volumes at the approximate 1949 level of water resource development, uncontrolled by main stem reservoirs, illustrating the effects of the development including main stem regulation upon runoff at this location. System storage at the appropriate development levels is also shown on these plates, and is compared with the 1970-level system storage. This comparison indicates the estimated effects of sedimentation upon the zones containing specific types of storage in the system, as well as the effects of anticipated water-resource development. Also shown on these plates are the services provided the functions of power and navigation and the comparison of the increased development level upon these services with the services provided at the 1970-level. Plate 40 presents flow-duration curves indicating the effects of the main stem system and the development of water resources at selected locations below the main stem system. Detailed results of these studies, month by month, through the 1898-1968 record period, as well as summarizations of specific elements related to the system or projects comprising the system are on file in the Reservoir Control Center, Missouri River Division, Corps of Engineers.

The "historic" conditions hydrographs and curves shown on plates 36 and 40 represent actual flows prior to construction of the main stem reservoirs. Subsequent to closure of these reservoirs, the "historic" curves on the referenced plates show monthly flows as they would have occurred without regulation by the main stem system.

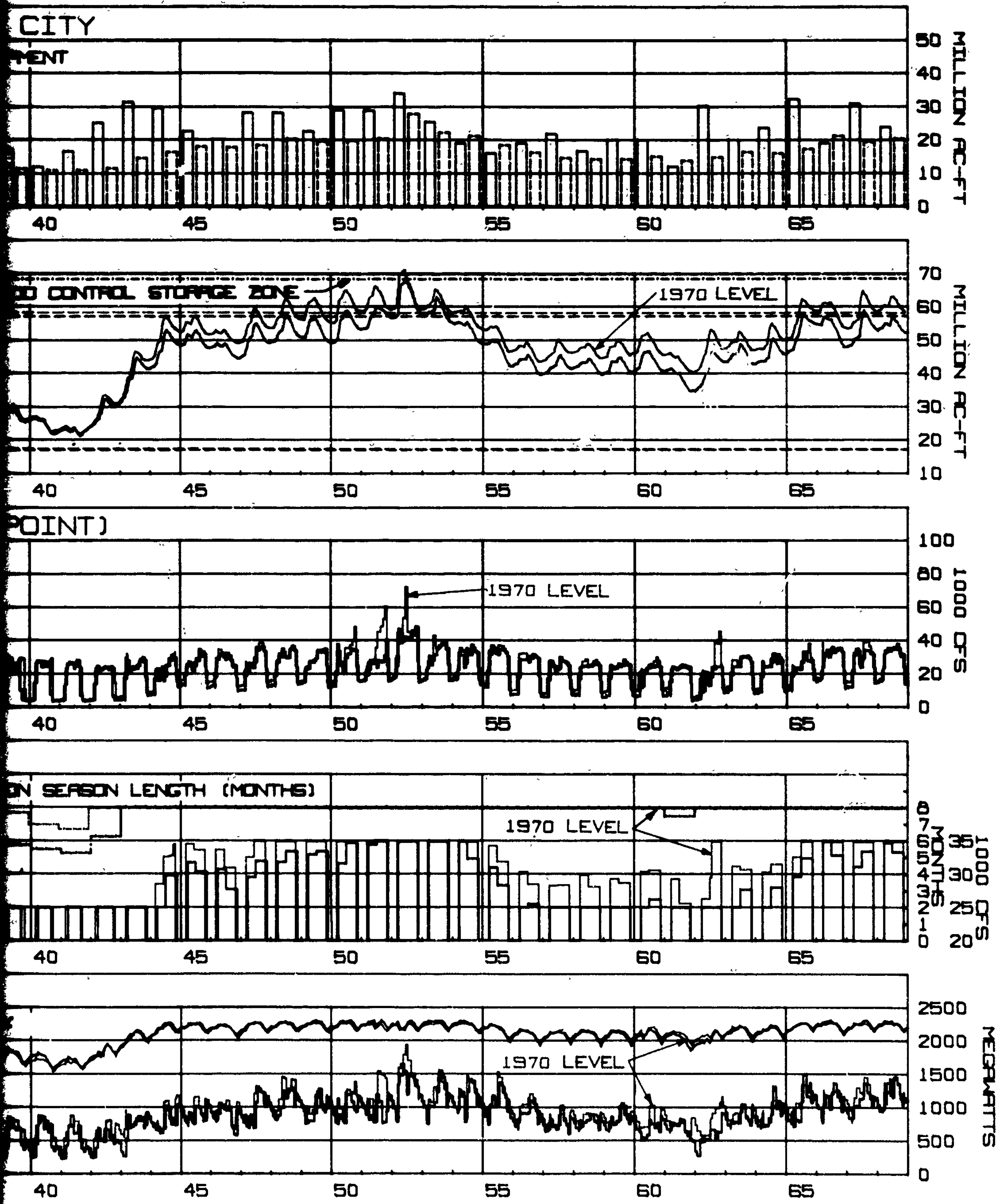




MISSOURI RIVER MAIN STEM RESERV

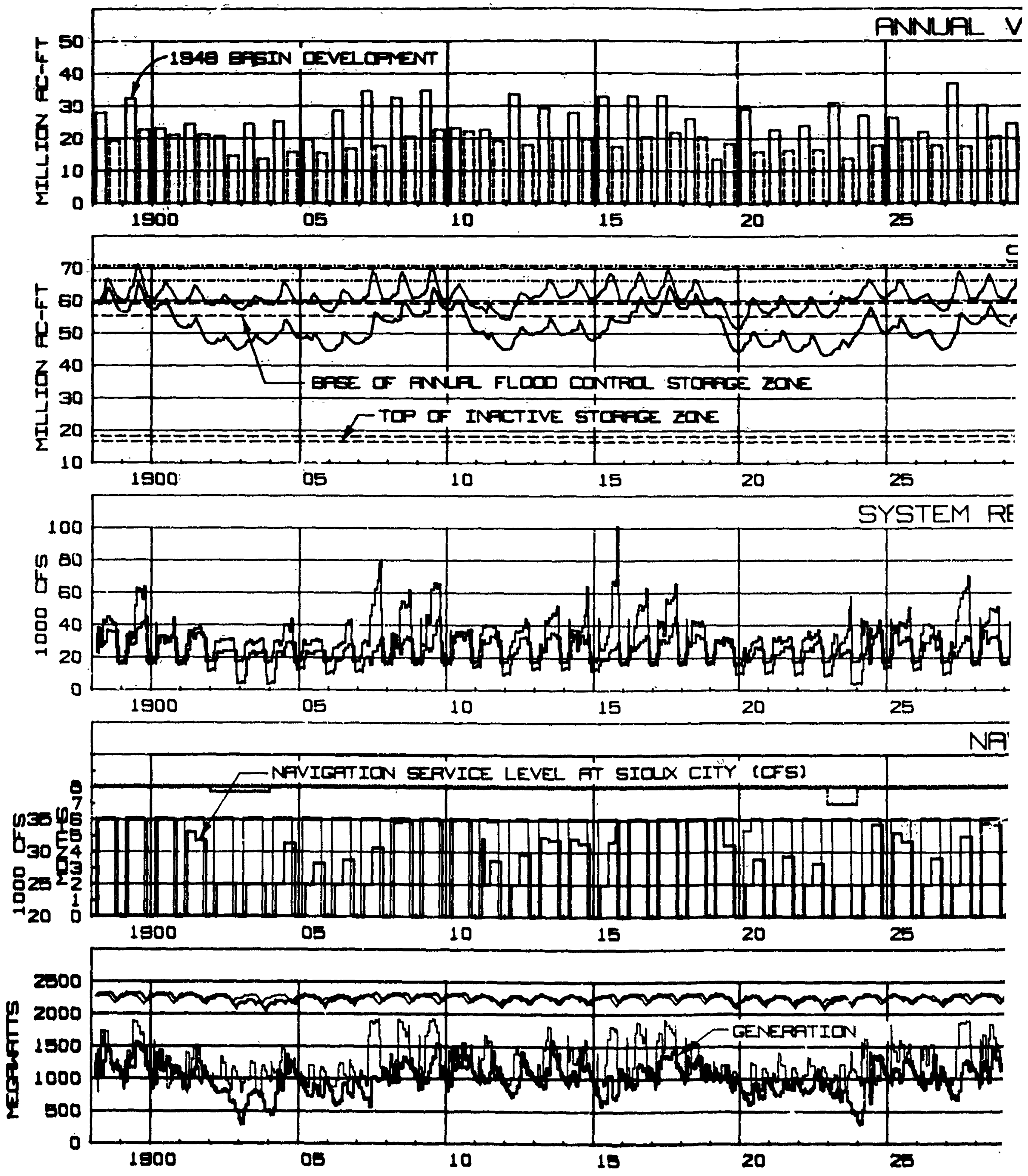


ERVOIR OPERATIONS FOR 1980 LEVEL OF DEVELOPME

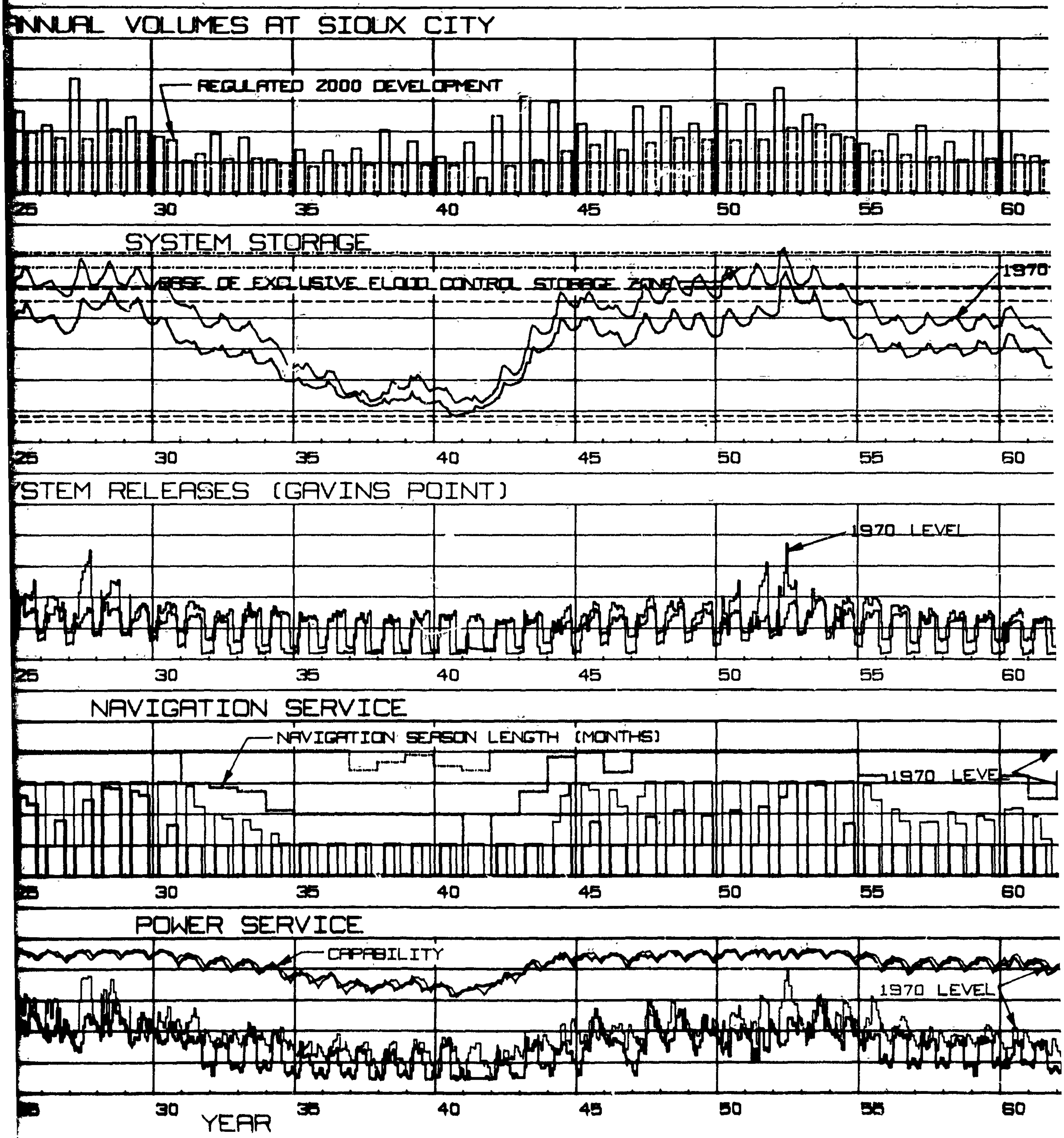


S FOR 1980 LEVEL OF DEVELOPMENT

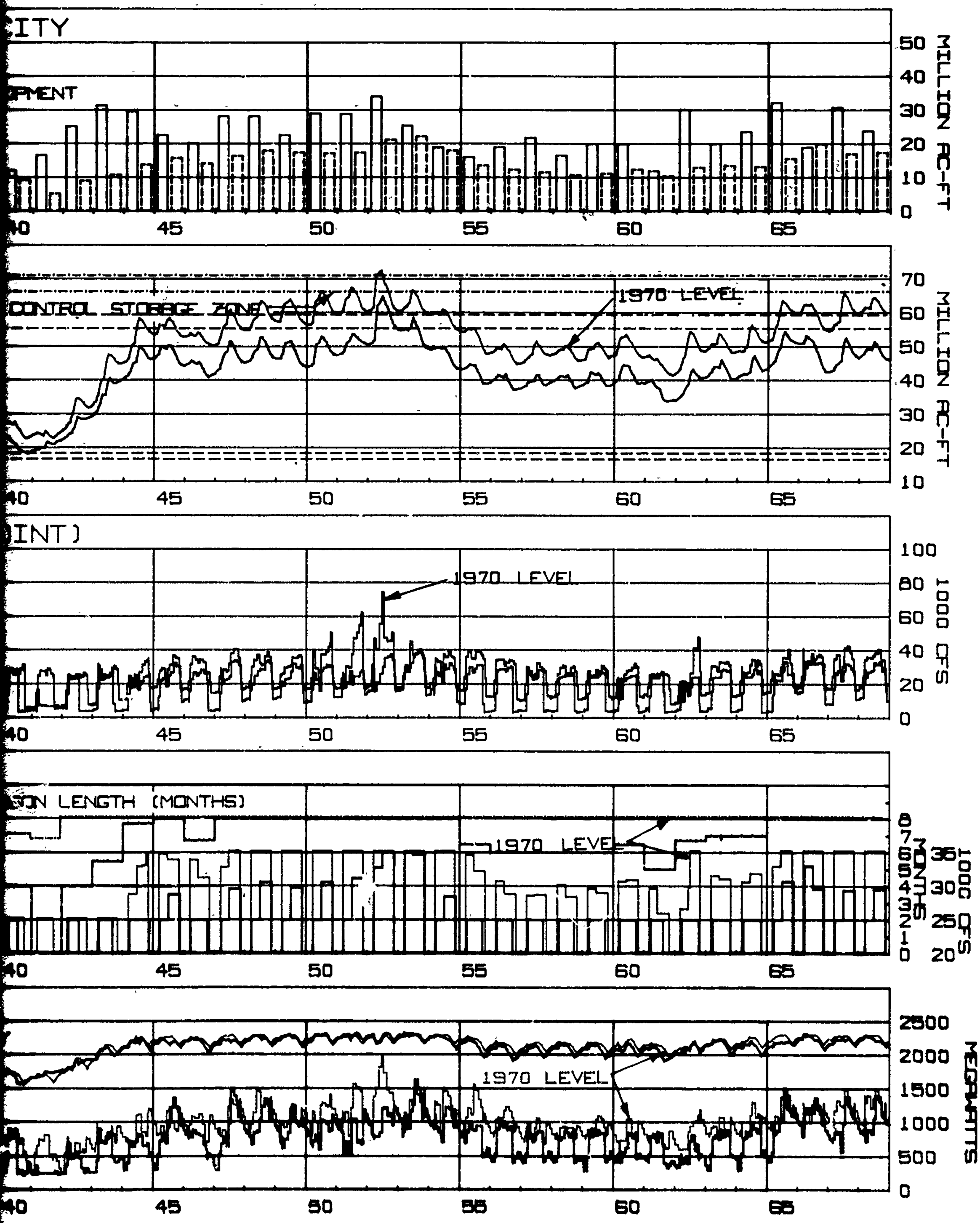
PLATE 33



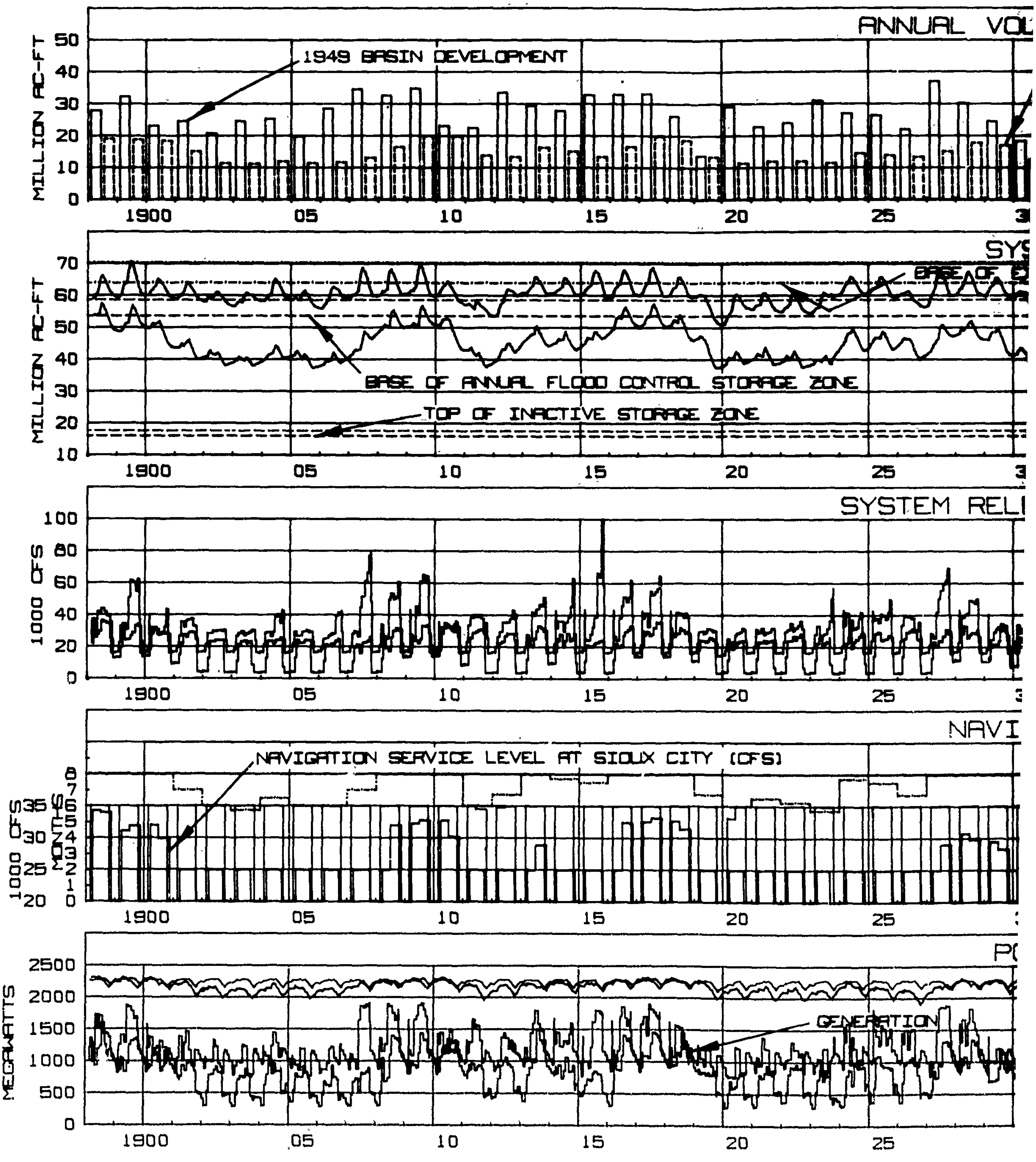
MISSOURI RIVER MAIN STEM RESERVO



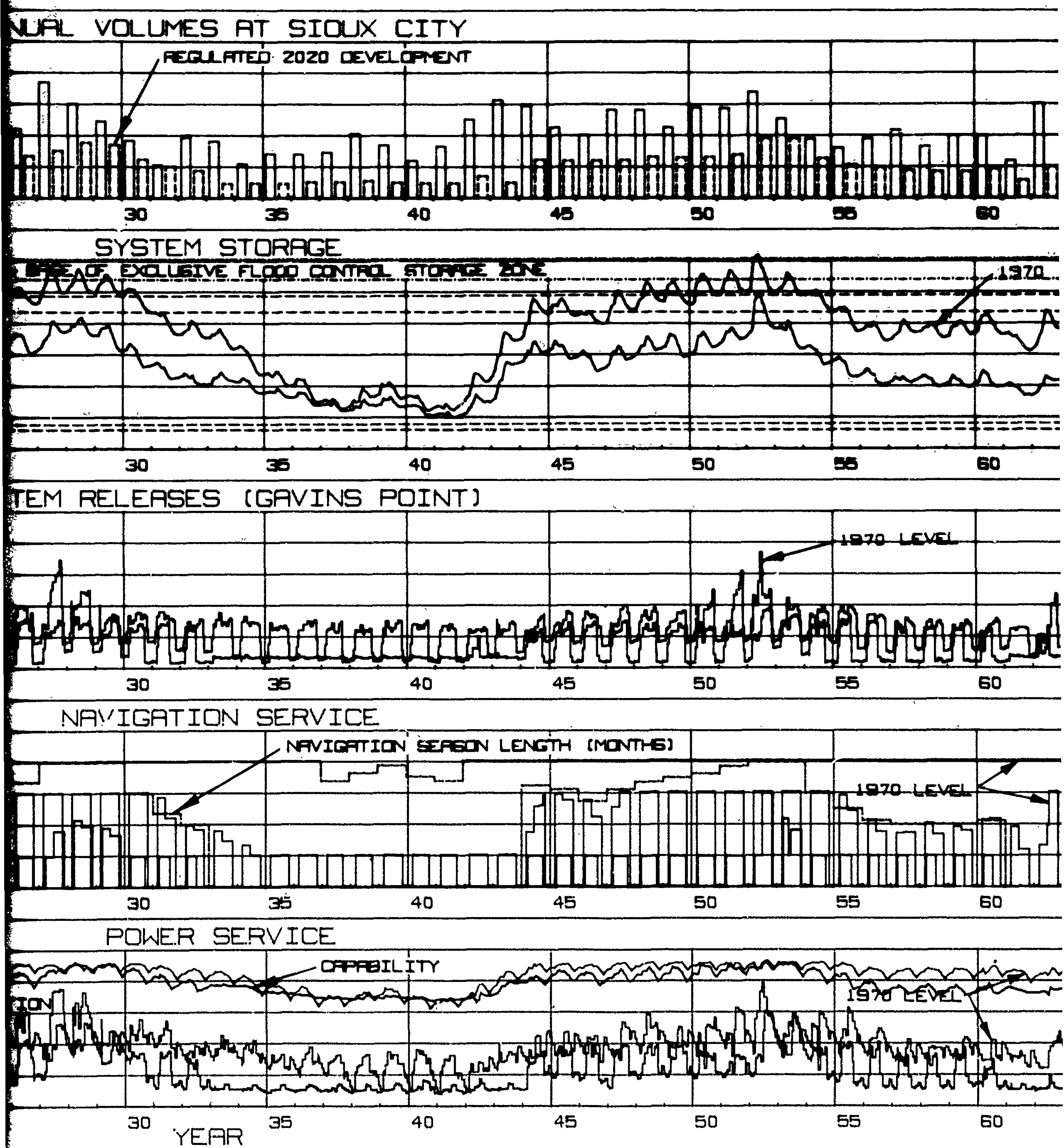
SERVOIR OPERATIONS FOR 2000 LEVEL OF DEVELOPM



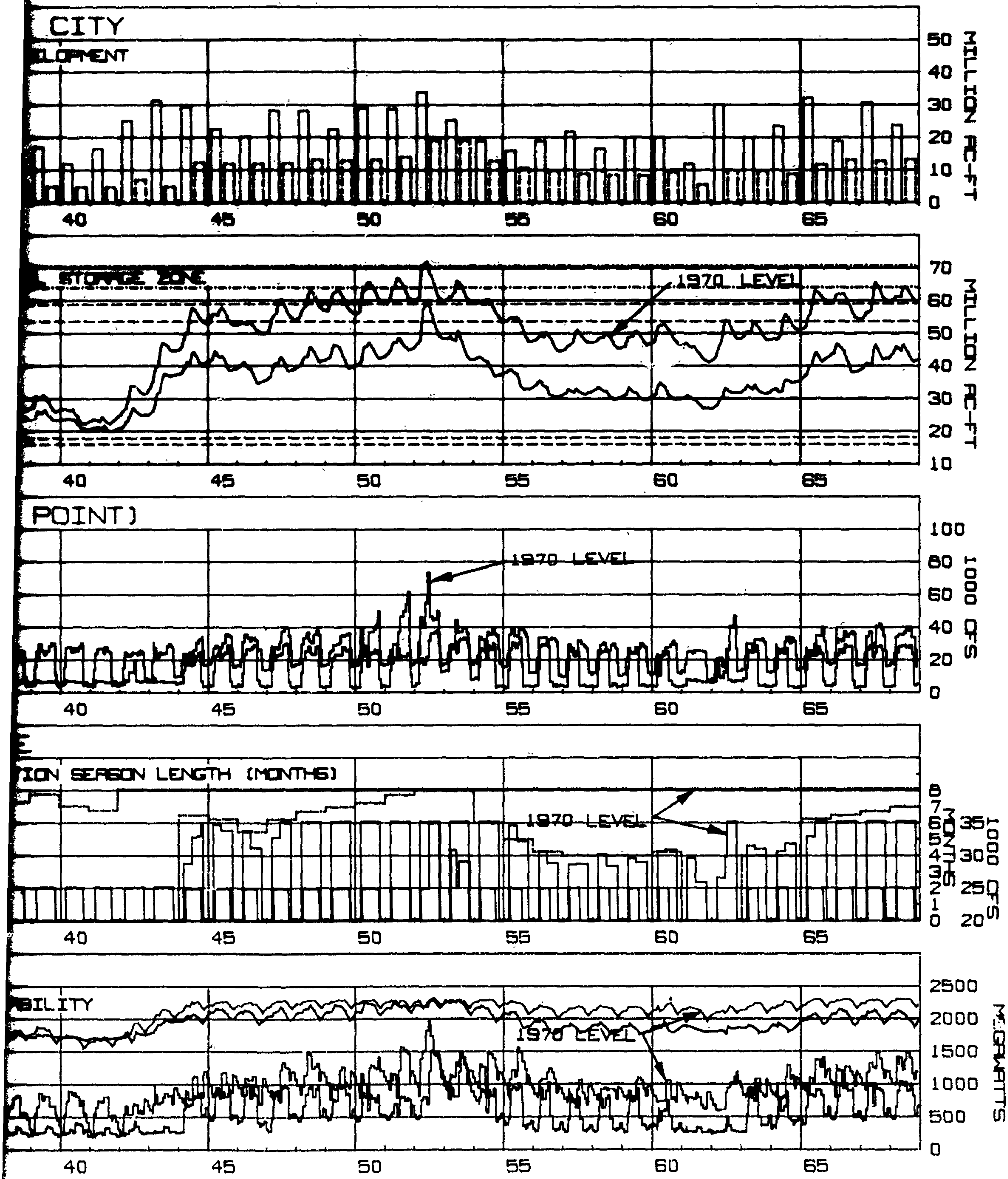
FOR 2000 LEVEL OF DEVELOPMENT



MISSOURI RIVER MAIN STEM RESERVOIF

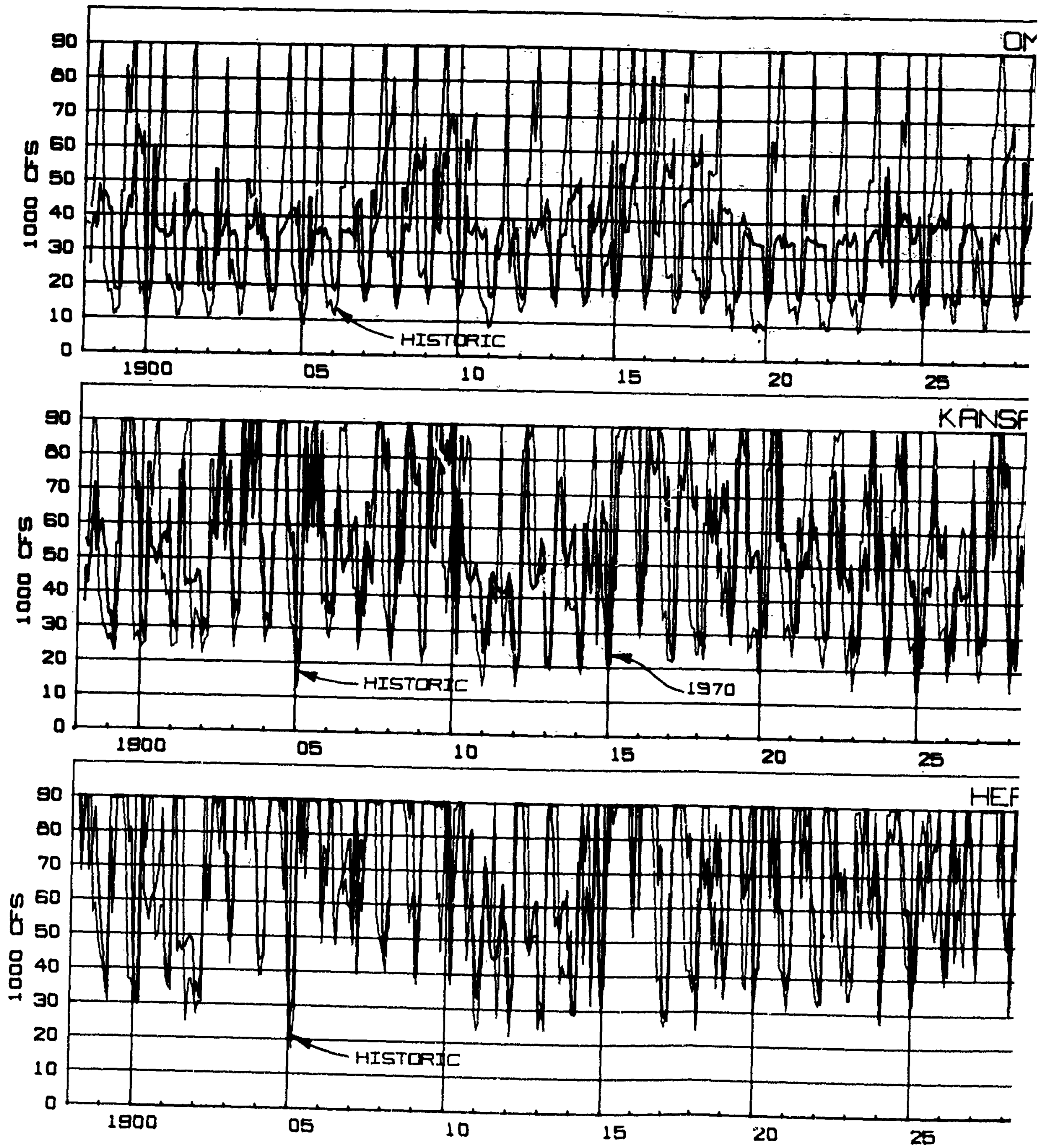


ERVOIR OPERATIONS FOR 2020 LEVEL OF DEVELOPME

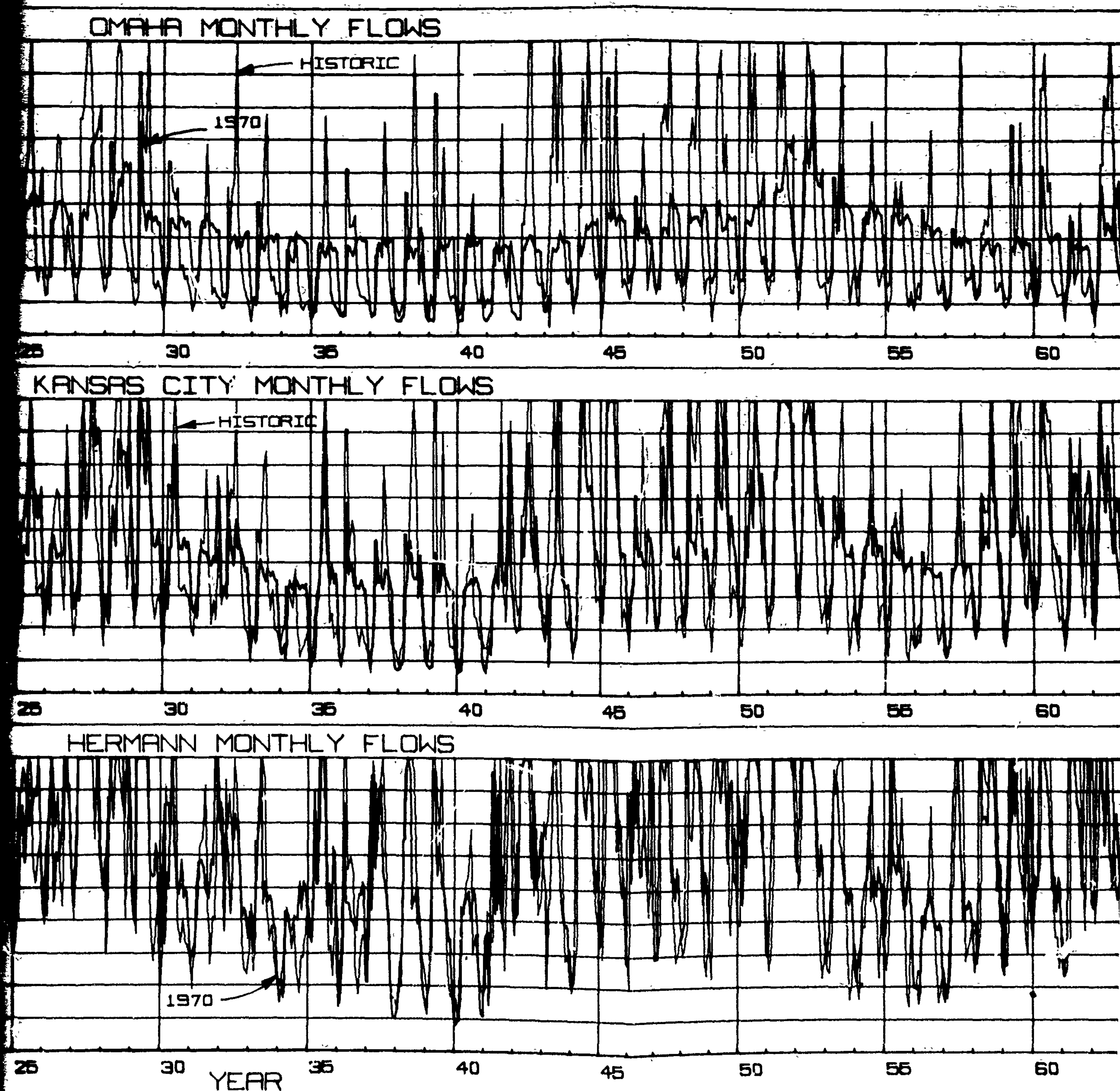


NS FOR 2020 LEVEL OF DEVELOPMENT

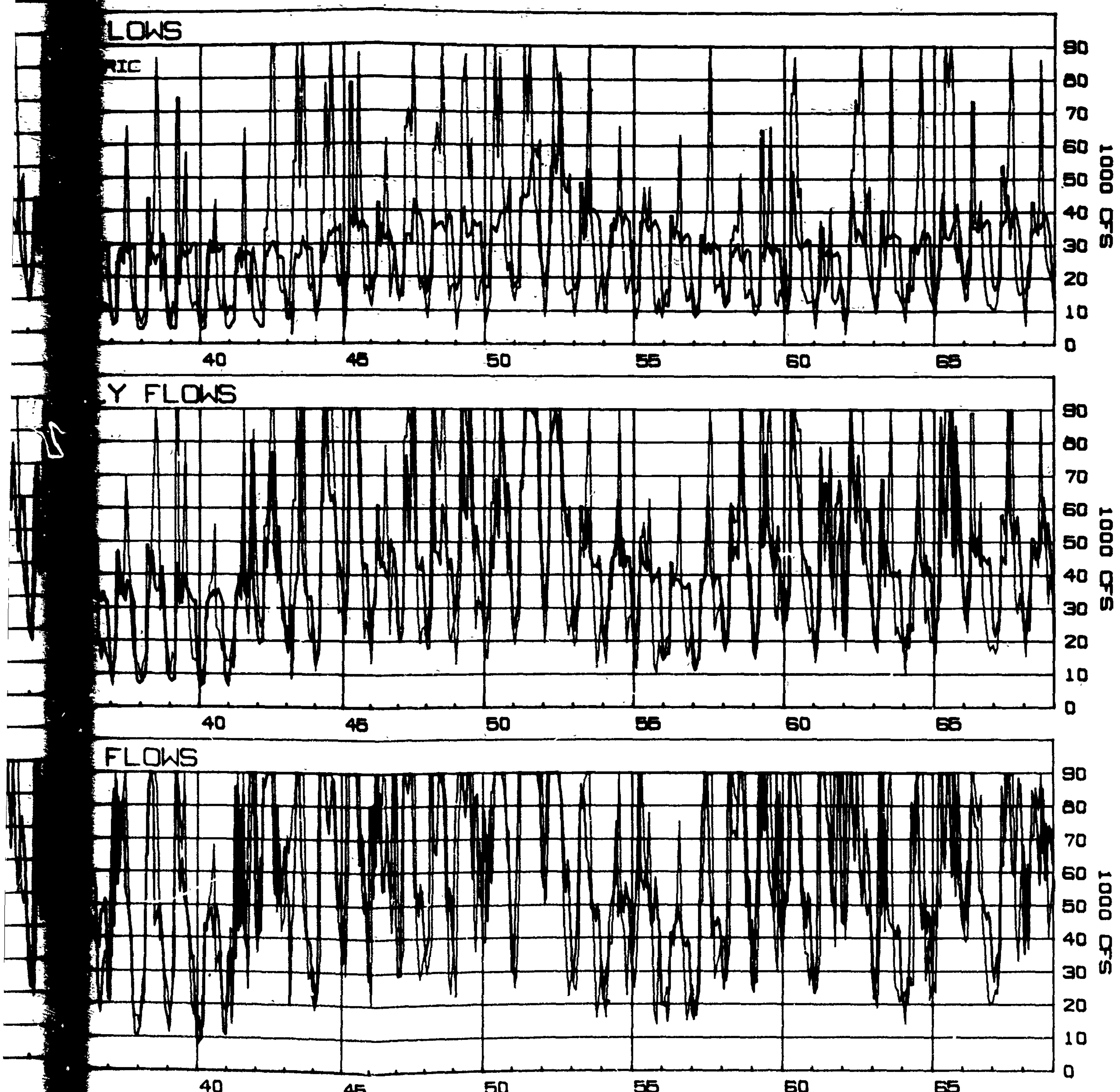
PLATE 35



AVERAGE MONTHLY STREAMFLOWS FOR 1970

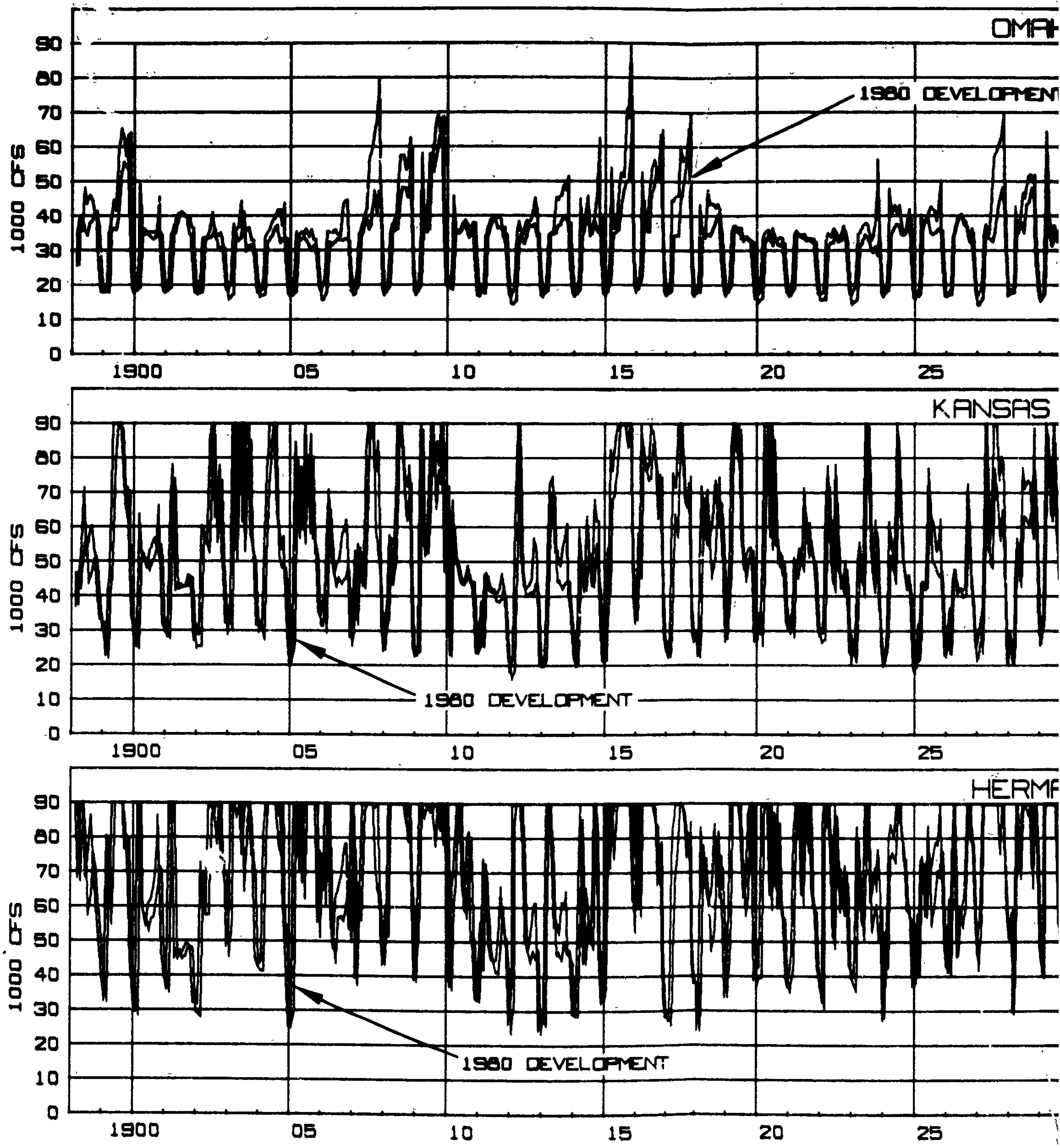


1970 LEVEL OF DEVELOPMENT AND FOR HISTORIC CON

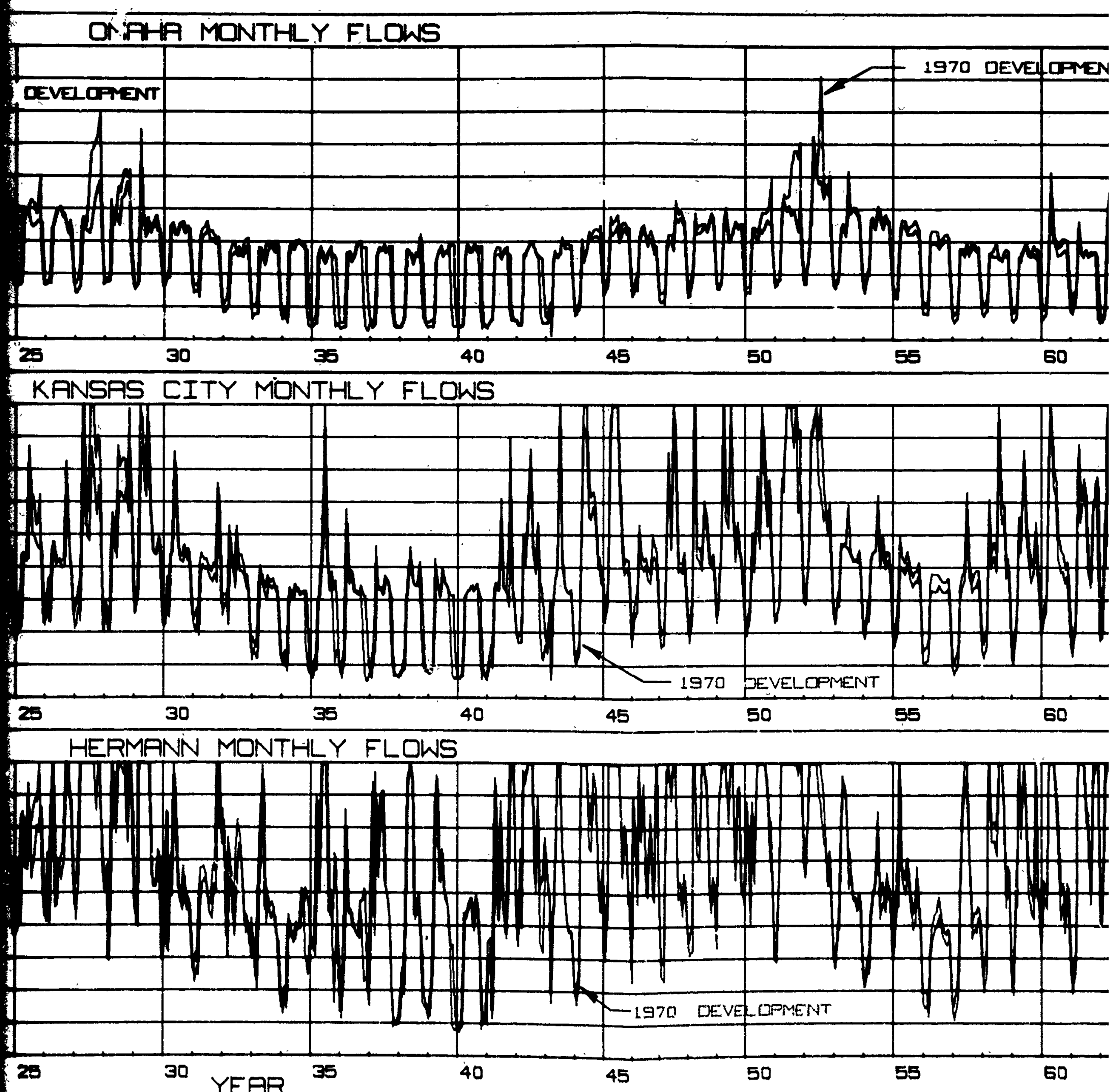


IND DEVELOPMENT AND FOR HISTORIC CONDITIONS

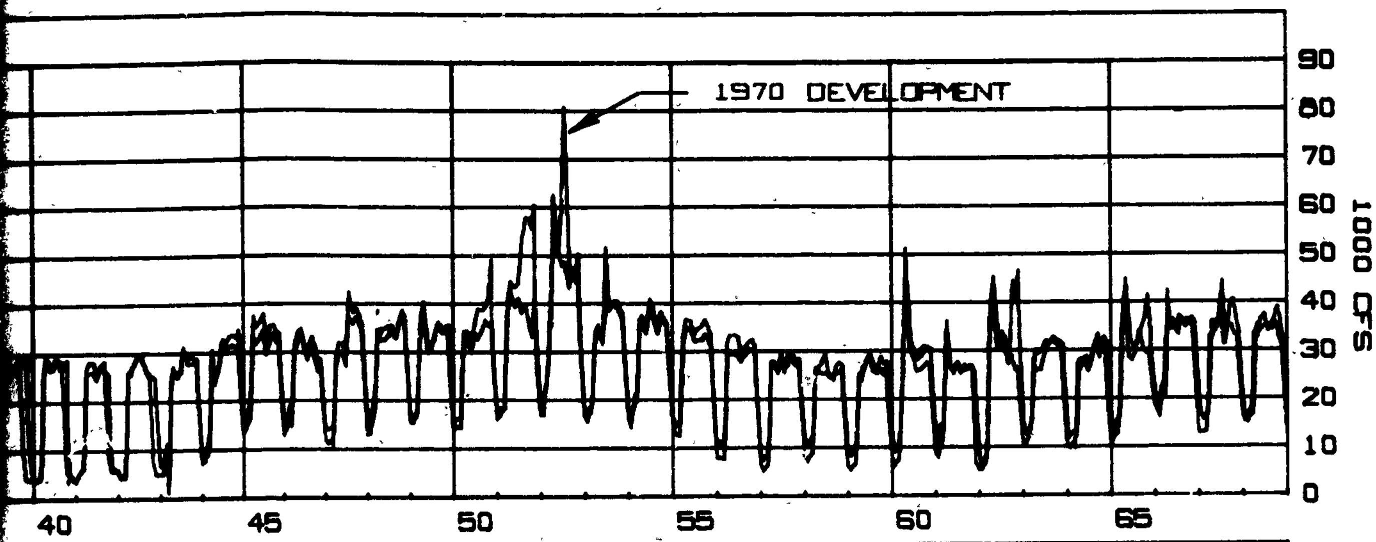
PLATE 36

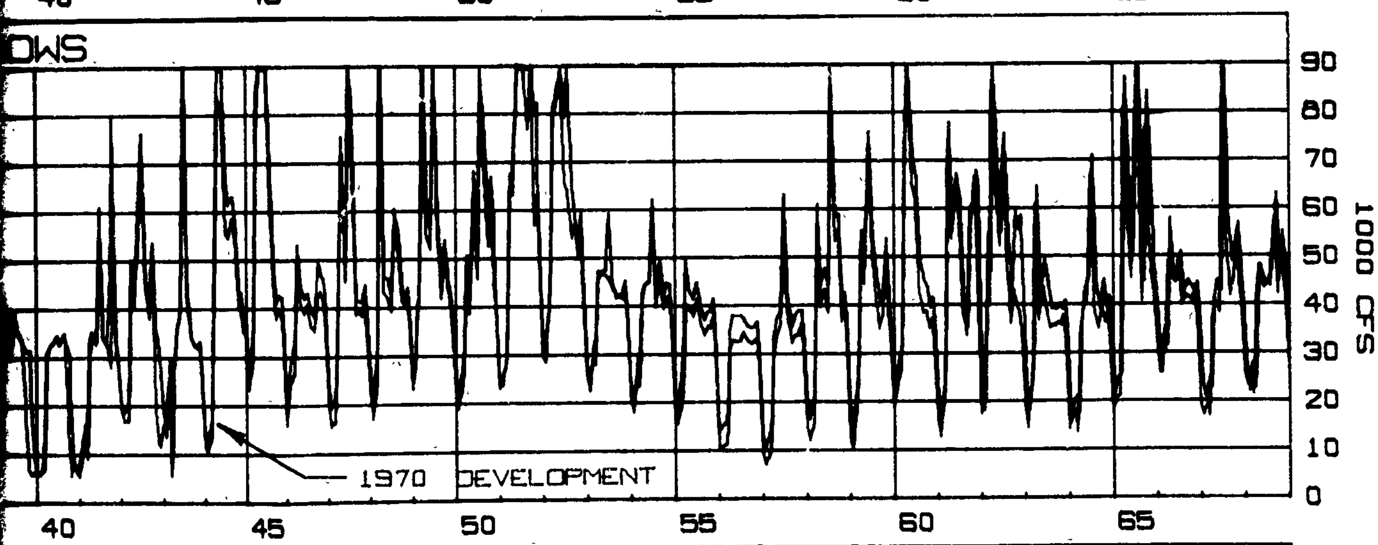


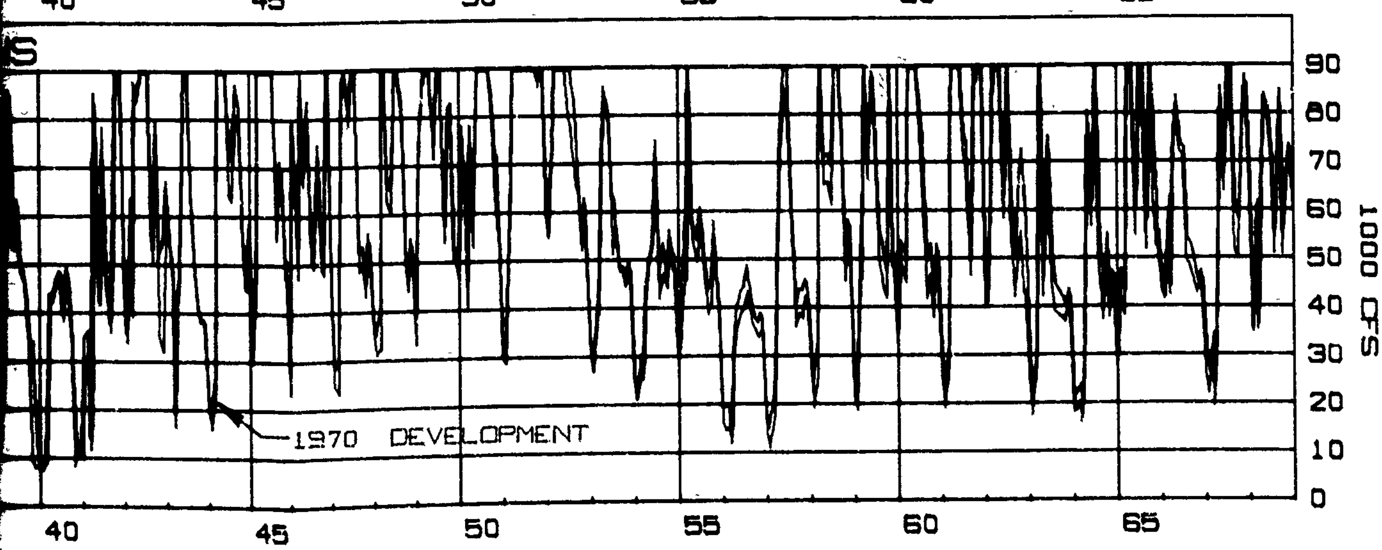
AVERAGE MONTHLY STREAMFLOWS F



LOWS FOR 1970 AND 1980 LEVELS OF DEVELOPMENT

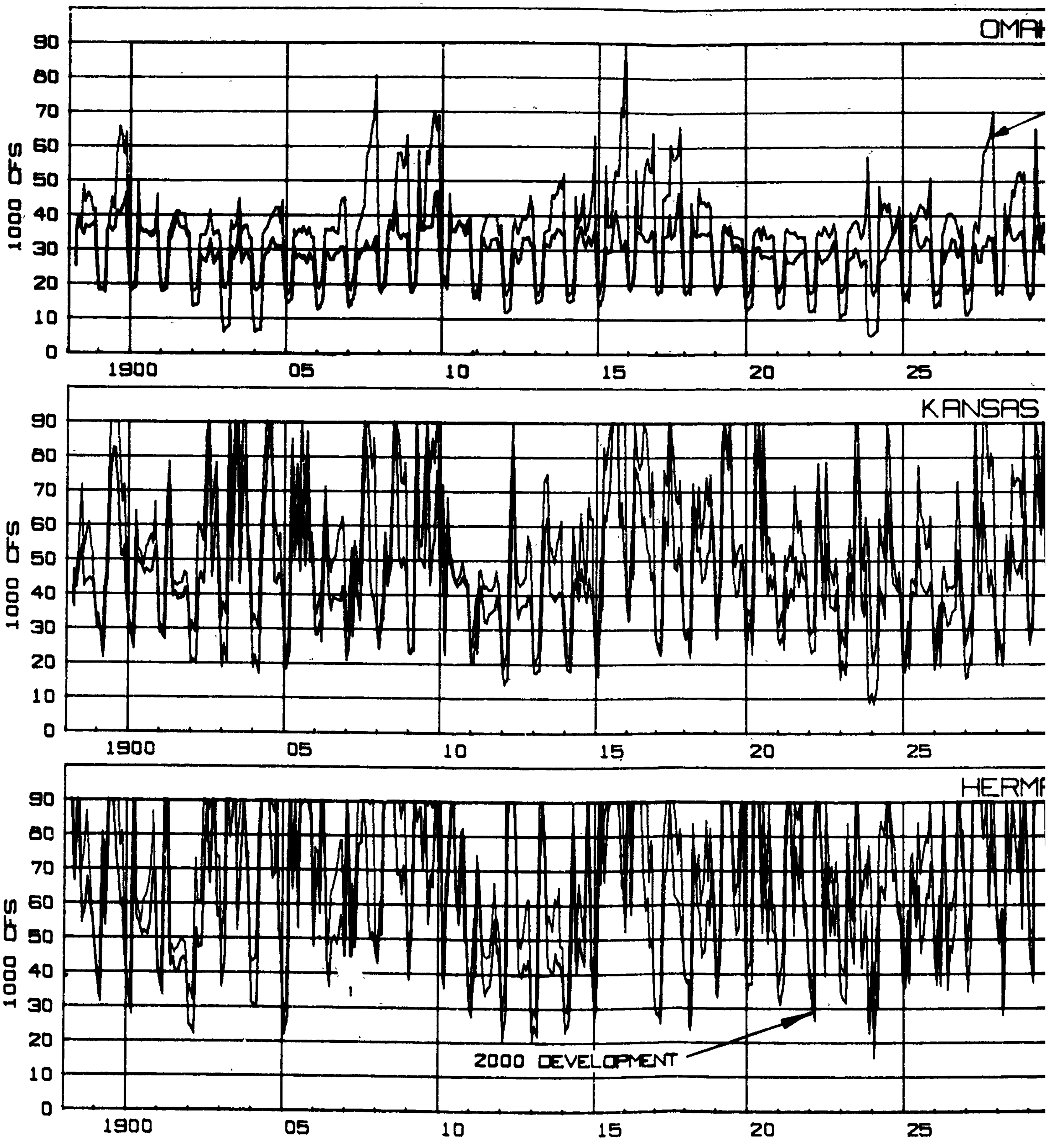




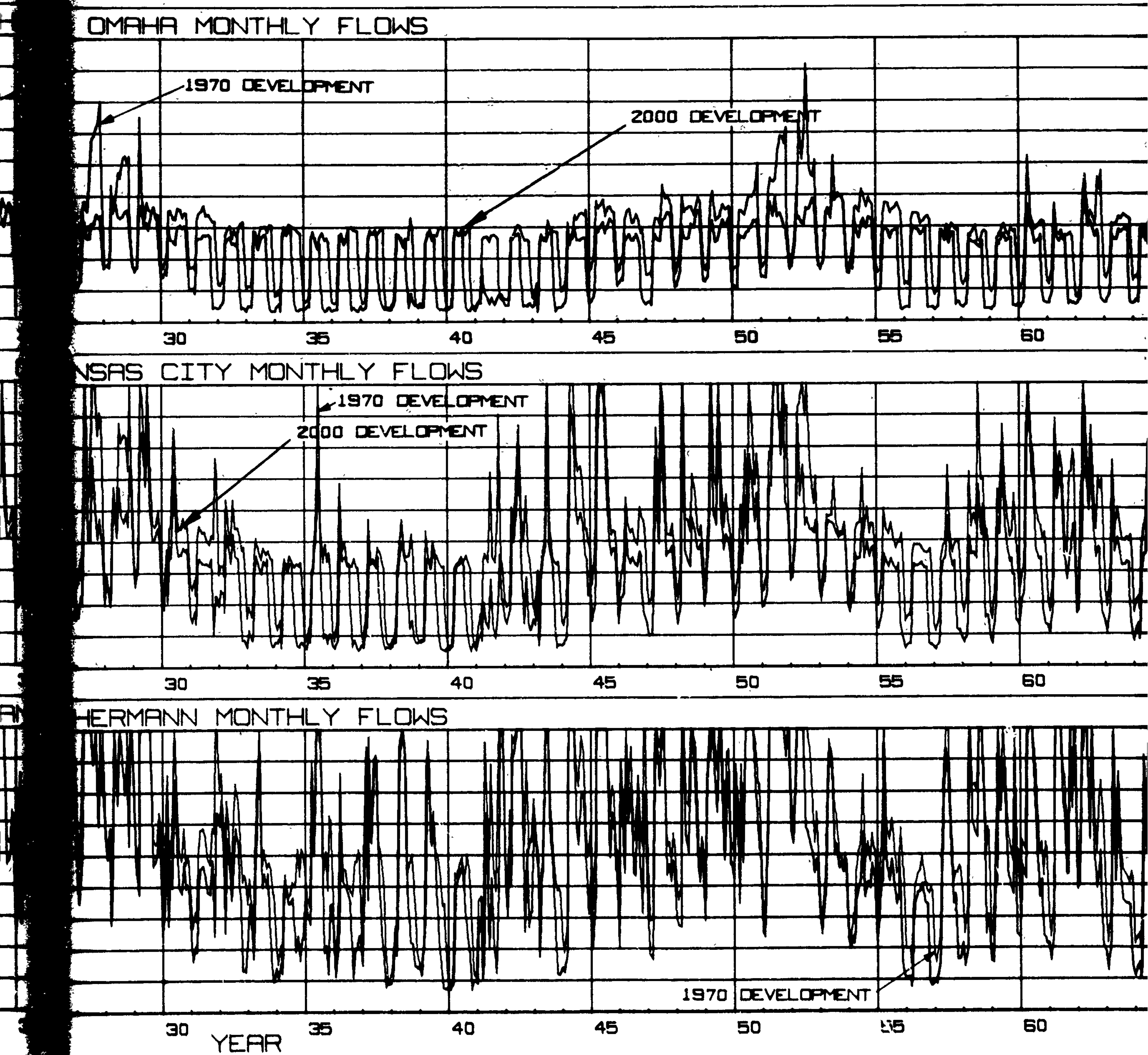


1980 LEVELS OF DEVELOPMENT

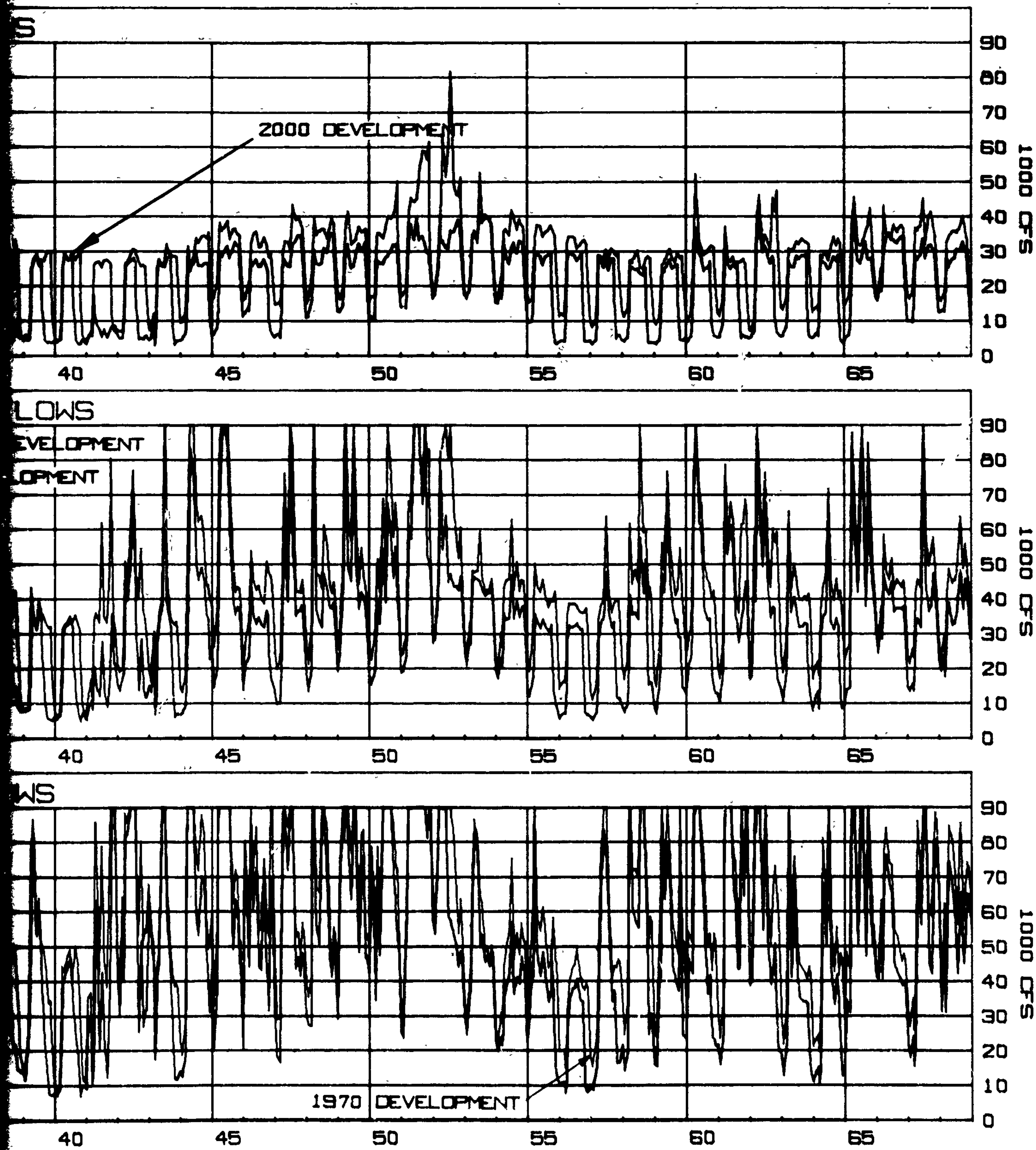
PLATE 37



AVERAGE MONTHLY STREAMFLOWS F

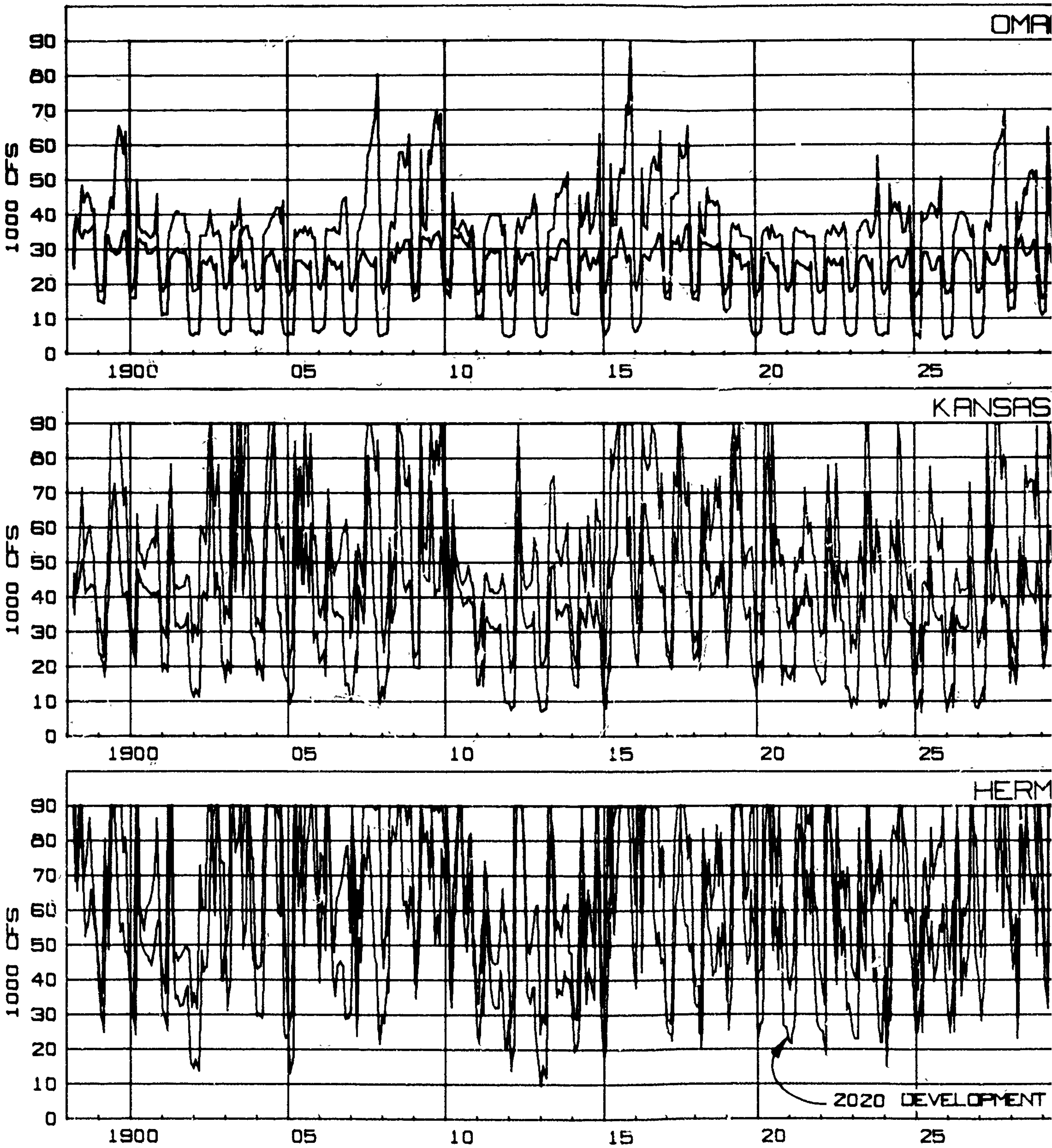


NS FOR 1970 AND 2000 LEVELS OF DEVELOPMENT

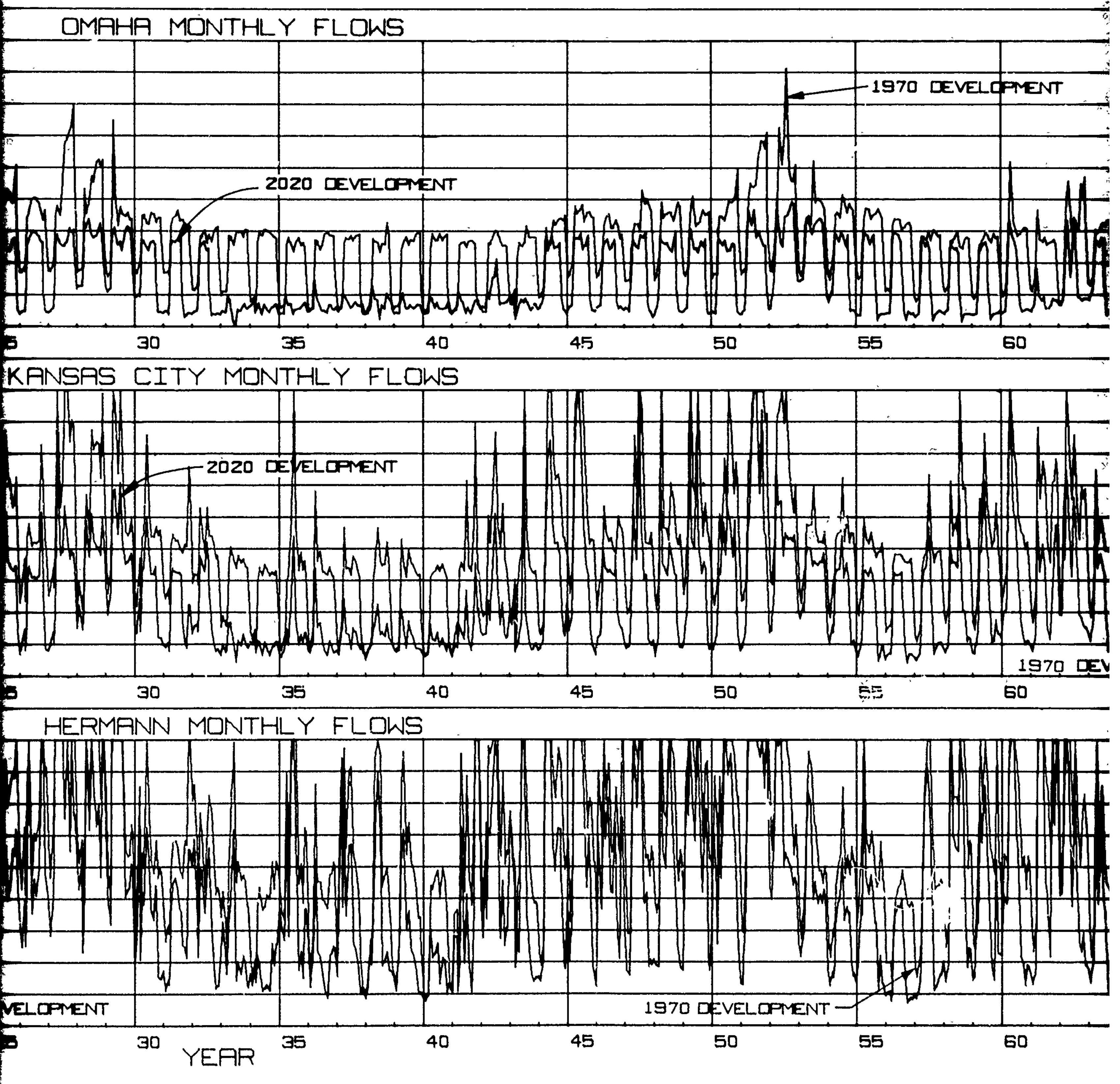


D 2000 LEVELS OF DEVELOPMENT

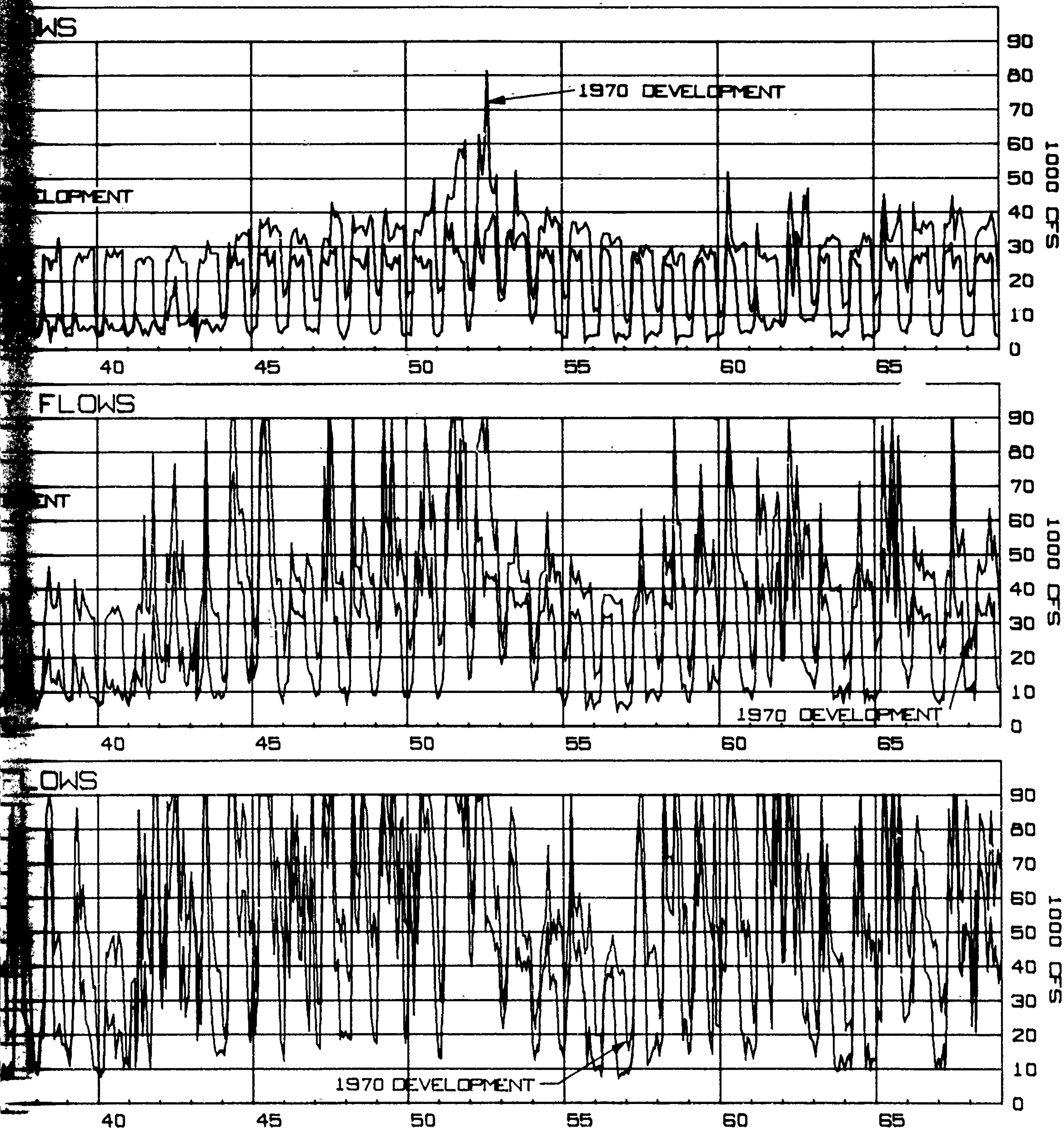
PLATE 38



AVERAGE MONTHLY STREAMFLOWS F

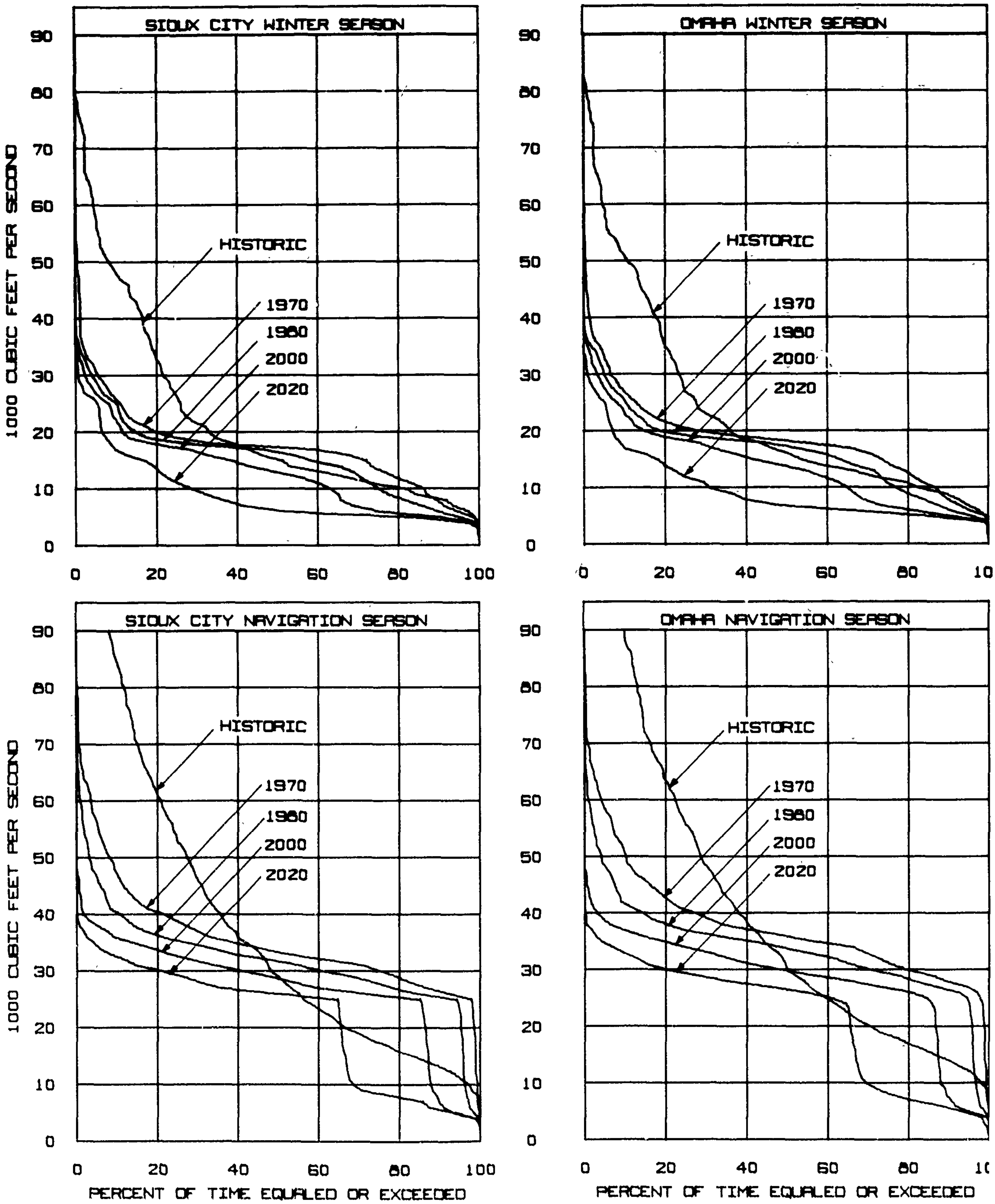


OWS FOR 1970 AND 2020 LEVELS OF DEVELOPMENT

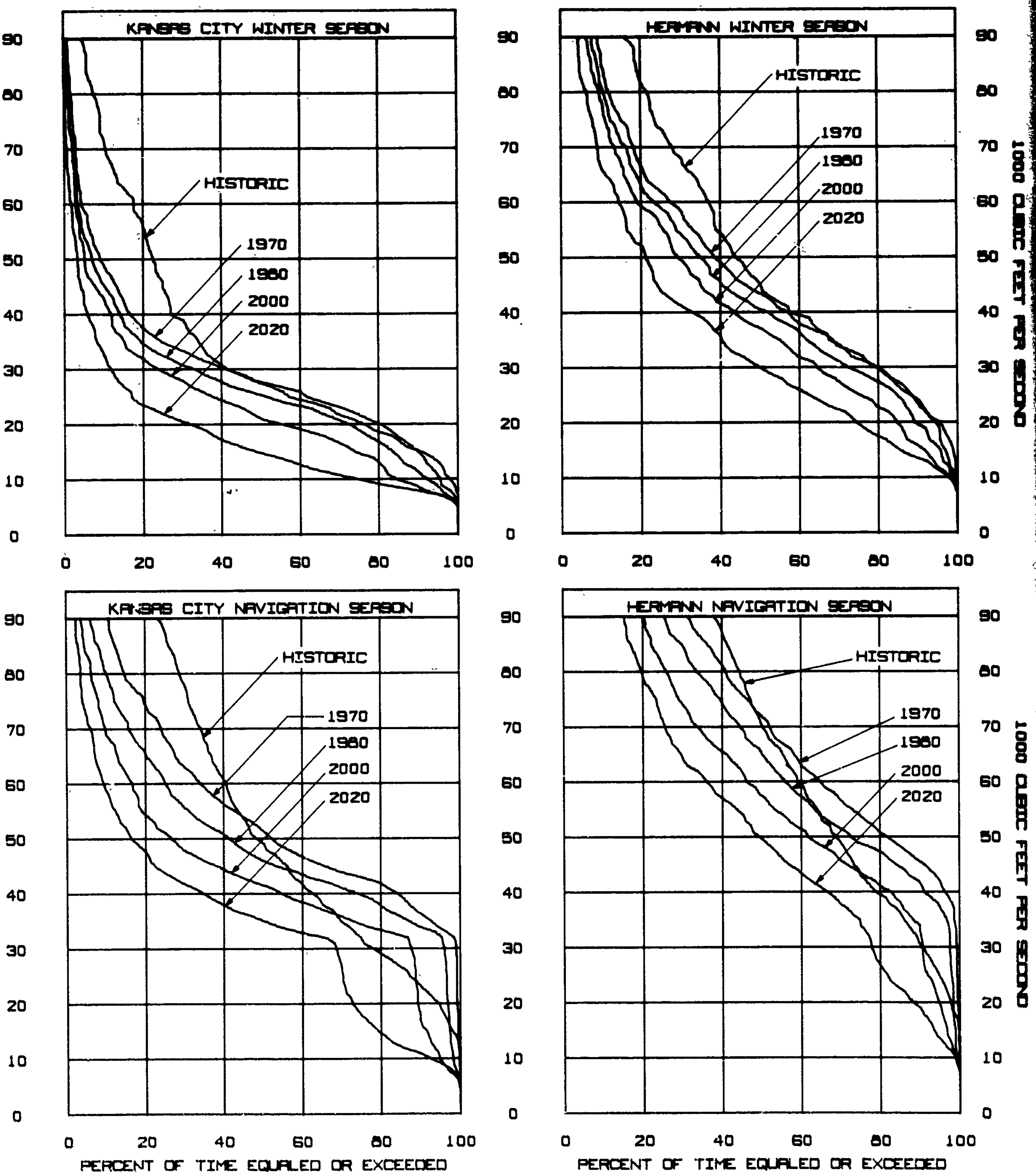


ND 2020 LEVELS OF DEVELOPMENT

PLATE 39


SIOUX CITY WINTER SEASON
OMAHA WINTER SEASON
SIOUX CITY NAVIGATION SEASON
OMAHA NAVIGATION SEASON
HISTORIC
1970
1980
2000
2020
1000 CUBIC FEET PER SECOND
PERCENT OF TIME EQUALED OR EXCEEDED
0
10
20
30
40
50
60
70
80
90
100

STREAMFL(



LOW DURATION CURVES