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Availability and Use of Water in Nebraska, 1970

F. Butler Shaffer
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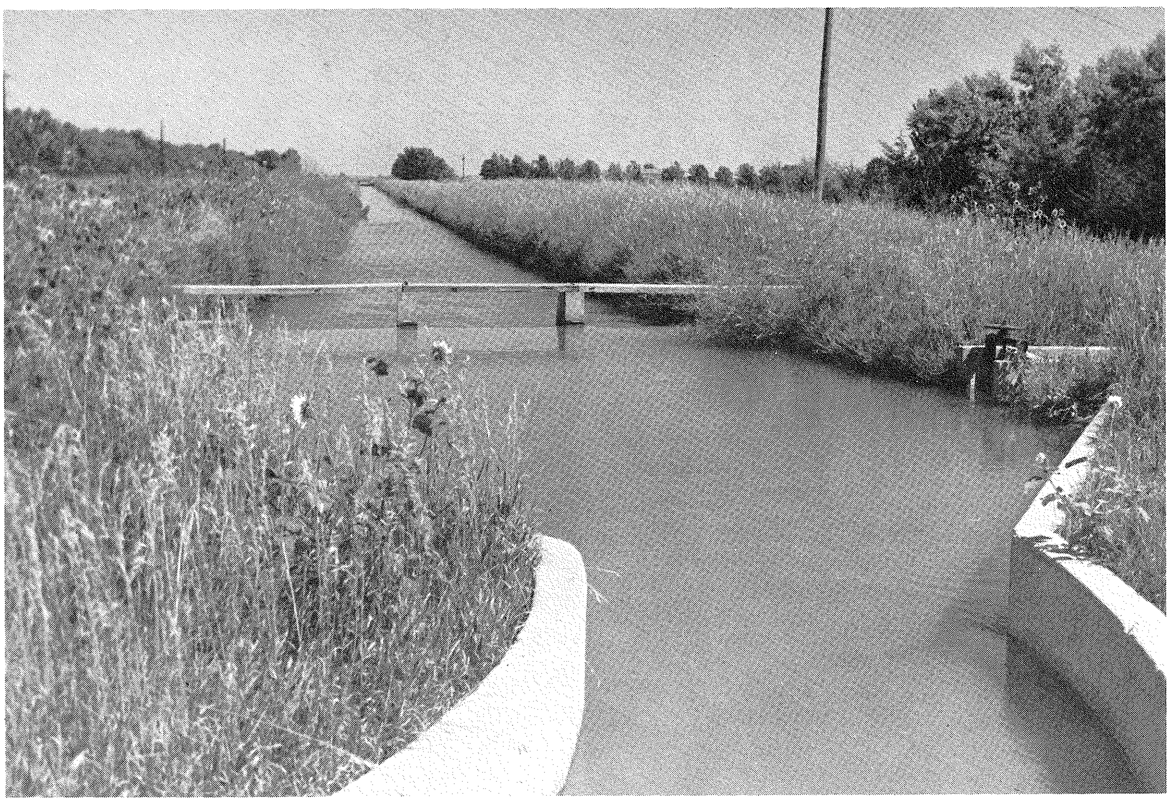

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CONTENTS

ILLUSTRATIONS

TABLES

AVAILABILITY AND USE OF WATER IN NEBRASKA, 1970

By F. Butler Shaffer

INTRODUCTION

Nebraska has a large total supply of water of good quality. Unfortunately, the supply is not uniformly distributed nor has the extent of its development been proportional to its distribution. The water available for use occurs as soil moisture (water available to plants), as surface water (water running over or impounded on the land surface), and as groundwater (water saturating porous rocks below the land surface). The ultimate source of Nebraska's water supply is precipitation on the state itself and on those parts of adjoining states--particularly Colorado and Wyoming--that drain into Nebraska.

This report describes the environmental conditions under which water occurs in the state, evaluates the annual increments to the stored supply, and quantitatively summarizes the current uses made of this important resource. This evaluation is for water year 1970 which began October 1, 1969 and ended September 30, 1970.

OCCURRENCE OF WATER

Soil Moisture

The moisture-holding capacity of a soil is governed largely by its texture and humic content. For example, a soil that consists mostly of sand and is low in humus holds little water compared with a soil that consists largely of silt and clay and is high in humus. The moisture-holding capacity of soils, especially those that are fine textured, changes with degree of compaction.

Soil moisture is classified by agriculturists as excess, available, and nonavailable. Excess moisture cannot be held in the soil by capillary forces and, therefore, moves downward under the influence of gravity; it can be highly injurious to some types of plants. Available moisture is retained by capillary forces and can be extracted by vegetation. Nonavailable moisture is adsorbed to the soil particles and cannot be extracted by vegetation.

A tremendous quantity of water can be stored in the soil, especially during periods when precipitation is abundant, direct evaporation is low, and vegetation is dormant or nearly so. According to the State and Federal Division of Agricultural Statistics, soil moisture in the top 4 feet of soil during the spring of 1970 was above normal. The moisture content was 4.61 inches, which is equivalent to 19.0 million acre-feet, as compared to 3.71 inches or 15.3 million acre-feet, for the 10-year average. By the fall of 1970 the moisture content was below normal, amounting to 3.89 inches, or 16.0 million acre-feet, as compared to 4.22 inches, or 17.4 million acre-feet, for the 10-year average. Thus during 1970, the soil moisture from spring to fall was depleted by 3.0 million acre-feet as compared to a gain of 2.1 million acre-feet for the 10-year average.

Surface Water

Nebraska streams differ widely in flow. Some are perennial, flowing even during long periods of little or no precipitation; others are intermittent, flowing only in response to overland runoff resulting from rain or rapid snowmelt. The natural discharge characteristics of all the principal streams have been altered considerably by direct diversions, by storage in and releases from reservoirs, by pumping from wells that tap valley alluvium, and by return flows from irrigation or from municipalities.

Streams that originate in the Sand Hills region, which constitutes about one-fifth of Nebraska, are noted for their constancy of flow. Because the sand is so porous, nearly all the precipitation infiltrates the ground and almost none runs off directly to the streams. Although a large part of the water is returned to the atmosphere through evapotranspiration, some infiltrates to the zone of saturation. It then percolates laterally toward some area of natural discharge, probably in the interdune valleys where native grasses thrive. Lakes, also fed by groundwater, are abundant in parts of the Sand Hills region. The rather small fraction discharging into streams is sufficient, even so, to sustain a rather large base flow. Such streams rarely overflow unless rapid breaking of the ice cover causes ice jams.

Streams that originate outside the Sand Hills region derive part or all of their flow from overland runoff. Some of these are perennial streams because, in addition to the overland runoff, they have a base flow that is maintained by groundwater discharge. Others are intermittent, flowing only in response to precipitation or snowmelt in excess of the moisture-retaining capacity of the soils within the area they drain. Both types of streams, especially the latter, are characterized by rather wide ranges in rate of discharge. Streams draining areas in which the soils have a low infiltration capacity generally are subject to flooding. Soil and moisture conservation practices such as contour farming, planting minor waterways to perennial grasses, and construction of flood-control detention dams help to reduce flood crests and extend the period of flow.

At the present time (1970), records of streamflow are being obtained continuously at 154 gaging stations and intermittently at an additional 181 sites. The average discharge of the principal rivers for the period of record is shown by figure 1.

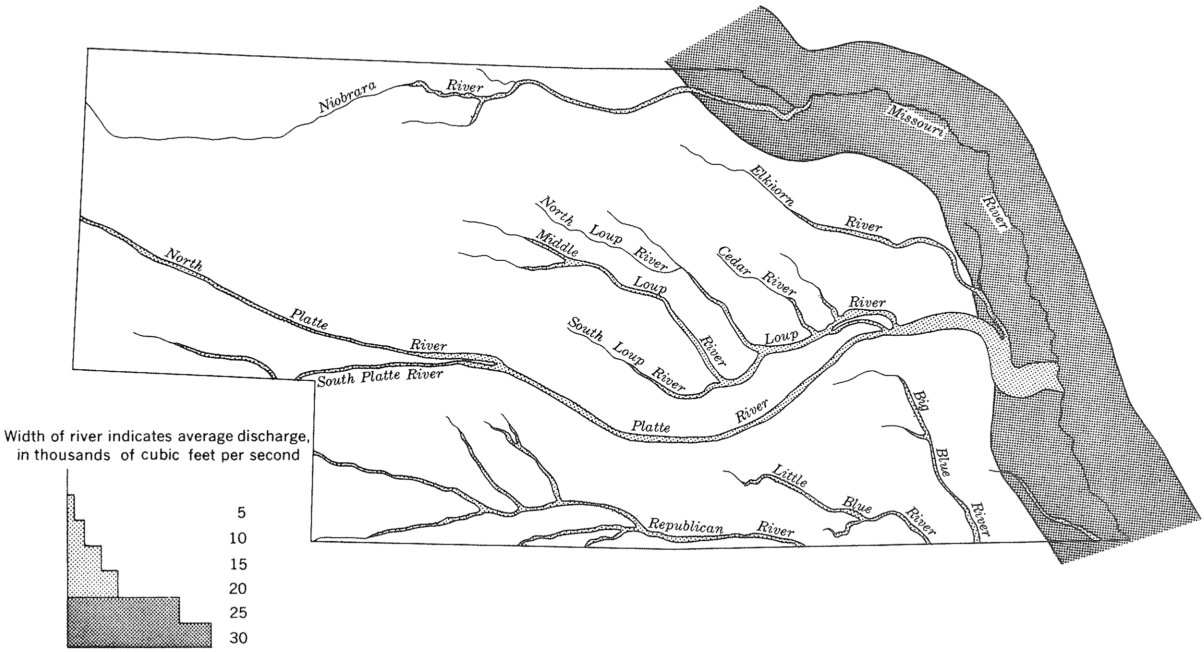

Figure 1.--Average discharge of the principal rivers.

The major reservoirs within the state (fig. 2 and table 1) have a combined initial storage capacity, including that for flood control, of about 4.37 million acre-feet. Not included in this total is the storage capacity of the Lewis and Clark Lake on the Missouri River. These bodies of water are used for recreation, irrigation, flood control, and generation of hydroelectric power. In addition, hundreds of small natural lakes occur in the Sand Hills region and thousands of stock ponds and small watershed reservoirs have been constructed in other parts of the state. Table 2 shows the small watershed project reservoirs constructed under the Watershed Protection and Flood Protection Act PL566.

Table 1.--Major reservoirs in Nebraska

[Use: F, flood control; I, irrigation; N, navigation; P, power generation; R, recreation]

Number on fig. 2	Stream and reservoir name	Maximum surface area (acres)	Storage, in acre-feet			Use	Year completed
			Dead	Total	Usable		
	White River						
1	Whitney1/	1,000	0	10,000	10,000	I,R	1925
	Niobrara River						
2	Box Butte	1,600	640	31,000	30,460	I,R	1946
	Snake River						
3	Merritt	2,906	1,600	74,500	72,900	I,R	1964
	Missouri River						
4	Lewis and Clark Lake2/	17,000	18,000	541,300	523,000	F,N,P,R	1956
	North Platte River						
5	Lake Alice1,3/	1,684	0	11,400	11,400	I,R	1912
6	Lake Minatare1/	2,160	1,424	60,766	57,342	I,R	1915
7	Lake McConaughy4/	32,200	90	1,948,000	1,948,000	I,P,R	1941
	Lodgepole Creek						
8	Oliver	200	0	7,500	7,500	I,R	1912
	North and South Platte Rivers						
9	Sutherland1/	4,350	2,960	181,460	72,480	I,P,R	1936
10	Lake Maloney1/	1,670	500	21,600	11,950	I,P,R	1936
	Platte River						
11	Jeffrey Canyon1/	620	5,700	11,500	5,800	I,P,R	1940
12	Tri-County Lakes5/	1,500	......	20,000	....	I,P,R	1940
13	Johnson Canyon1/	2,420	17,800	55,700	37,900	I,P,R	1940

	Middle Loup River						
14	Sherman1/	2,845	3,800	68,200	64,400	I,R	1962
	Loup River						
15	Lake Babcock1/	1,080	600	5,270	4,670	P,R	1936
	Salt Creek tributaries						
16	(6/)	4,300	......	....	....	F,R	1962-67
	Frenchman River						
17	Enders	2,560	8,470	44,480	36,010	F,I,R	1949
	Red Willow Creek						
18	Hugh Butler Lake7/	2,682	6,310	86,630	31,470	F,I,R	1962
	Medicine Creek8/						
19	Harry Strunk Lake	4,820	5,370	90,900	33,860	F,I,R	1949
	Republican River						
20	Swanson Lake9/	10,040	4,100	254,000	249,900	F,I,R	1953
21	Harlan County	22,800	0	850,000	850,000	F,I,R	1952

1/Offstream reservoir; filled by diversion from indicated stream.
2/Gavins Point Dam.
3/Upper and lower reservoirs.
4/Kingsley Dam.
5/Series of lakes along Tri-County Supply Canal.
6/10 reservoirs: Olive Creek, Bluestem, Wagon Train, Stagecoach, Yankee Hill, Conestoga, Twin Lakes, Pawnee, Holmes Lake, and Branched Oak.

7/Red Willow Dam.
8/Medicine Creek Dam.
9/Trenton Dam.

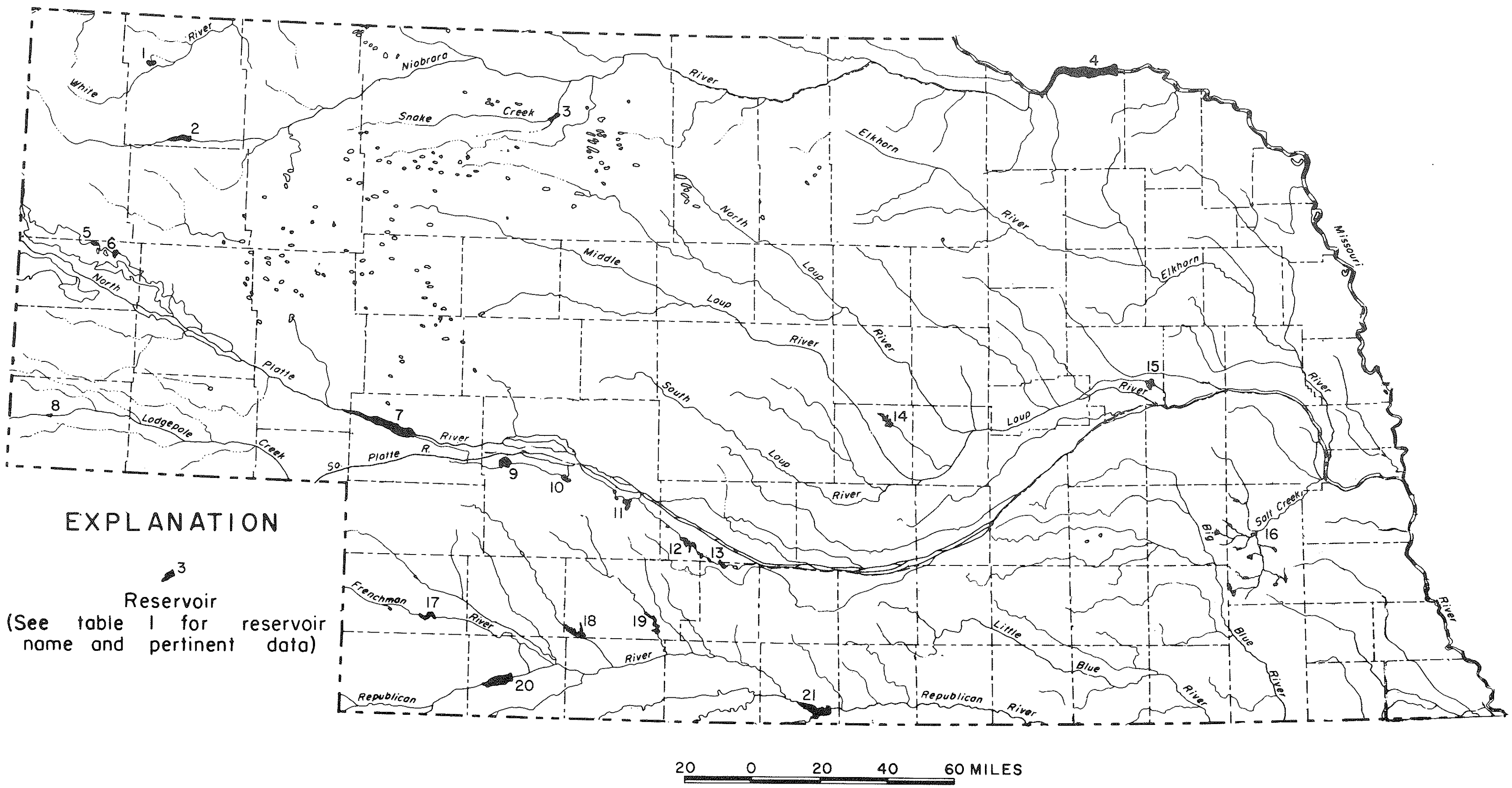

Figure 2.--Locations of major reservoirs.

Table 2.--Small watershed project reservoirs constructed under the Watershed Protection and Flood Protection Act PL566

River basin	Number of watersheds with reservoir storage	Surface area of permanent water pool	Flood control storage, in acre-feet
White River-Hat Creek......	3	2,200	15,000
Small Missouri River tributaries..............	12	6,500	66,000
North Platte River.........	11	3,600	45,000
South Platte River.........	4	1,300	22,000
Middle Platte River........	3	2,400	31,000
Loup River.................	8	4,500	59,000
Elkhorn River..............	15	10,200	122,000
Lower Platte River.........	11	5,400	70,000
Republican River...........	6	2,300	49,000
Little Blue River..........	2	800	8,000
Big Blue River.............	5	2,900	44,000
Nemaha River...............	14	7,800	116,000
State total...........	94	49,900	647,000

Groundwater

Well yields of more than 300 gpm (gallons per minute) can be obtained in more than half of Nebraska, and yields ranging from 1,500 to 2,500 gpm are or can be obtained in many places. Throughout much of the remainder of the state, yields greater than 20 gpm can be obtained. Figure 3 shows areas where wells commonly can be obtained that will yield large, medium, and small quantities of water.

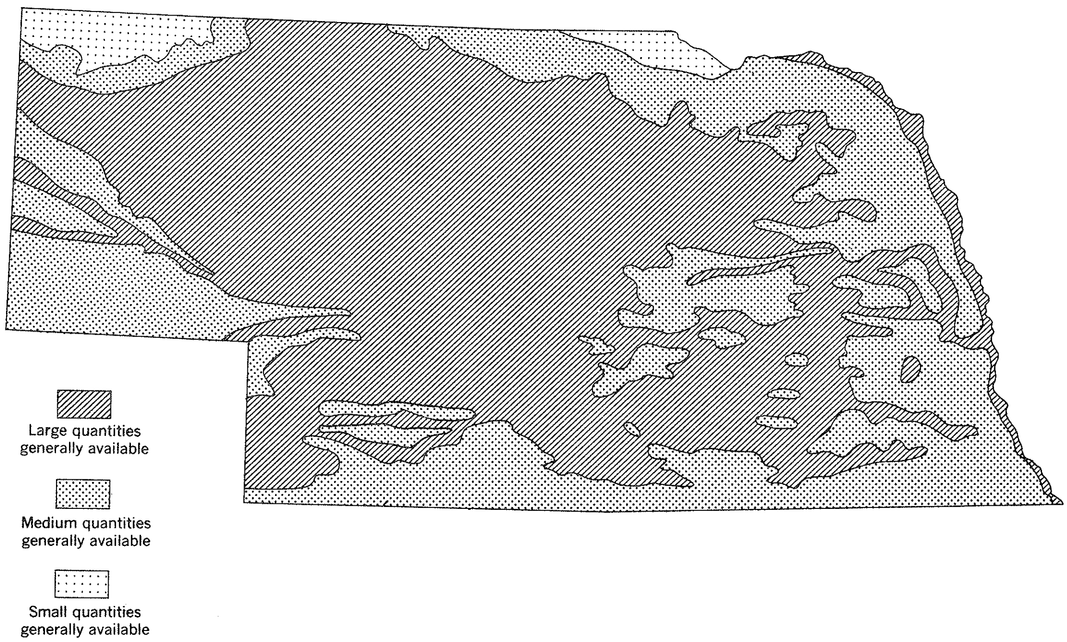

Figure 3.--Availability of groundwater.

Groundwater percolates laterally very slowly toward areas of either natural or artificial discharge at the land surface. The natural rate of movement probably is no greater than 1 or 2 feet per day. In the immediate vicinity of wells that are being pumped, however, the hydraulic gradient is steepened and movement is more rapid.

All municipal water systems except those of Omaha, Long Pine, and Crawford are supplied from wells. Omaha obtains 60 percent of its water supply from the Missouri River and 40 percent from a well field in the Platte River valley south of Omaha. Wells also supply much of the water for industries and commercial establishments. Water applied to three-fourths of the 4.1 million acres of irrigated land in the state is pumped from wells, as is all water used in rural homes and much of the water supplied to livestock.

It is estimated that the aquifers underlying the state contain about 1.7 billion acre-feet of water, an amount sufficient to fill a reservoir the size of the state to a depth of 34 feet. The quantity of groundwater now stored beneath Nebraska probably is as large or even larger than before development of the resource began. The additions to storage have resulted from use of surface water for irrigation and seepage from canals allowing infiltration of applied water in excess of crop needs. Because groundwater moves slowly, the problems resulting from depletion in one area will not be solved through lateral percolation from upgradient areas having excess water. Where annual withdrawals of groundwater continue to be large, the supply remaining in storage will diminish progressively unless replenished artificially.

WATER QUALITY

As atmospheric vapor condenses to droplets and falls to the earth, it dissolves gases and either dissolves or washes mineral material from the air. Thus, on reaching the earth's surface, water is already slightly mineralized. As it comes into contact with a variety of soluble substances in its travel over the surface or through pores in the soil and underlying rocks, it becomes increasingly mineralized.

The total dissolved-solids concentrations in groundwater in the northwestern half of Nebraska commonly is less than 300 mg/l (milligrams per liter). In the southeastern half it commonly is between 300 and 500 mg/l. As shown in figure 4, areas of higher dissolved-solids concentrations are present where irrigation has been practiced for many years and in places where well yields are very small. Most of the groundwater is of the calcium bicarbonate type, although some contains sulfate as the major constituent. Except in the Sand Hills region, most of the groundwater is very hard.

The quality of the water in most of the natural lakes in the Sand Hills region is like that of the groundwater that maintains them. However, the water in a few lakes is high in sodium and potassium carbonates and more mineralized than is the groundwater in the general vicinity. On-river reservoirs retain flood flows and the stored water is thus less mineralized than that of the normal base flows.

Water in streams differs in chemical quality from one stream to another, from one reach to another in the same stream, and from one rate of discharge to another at the same point on a stream.

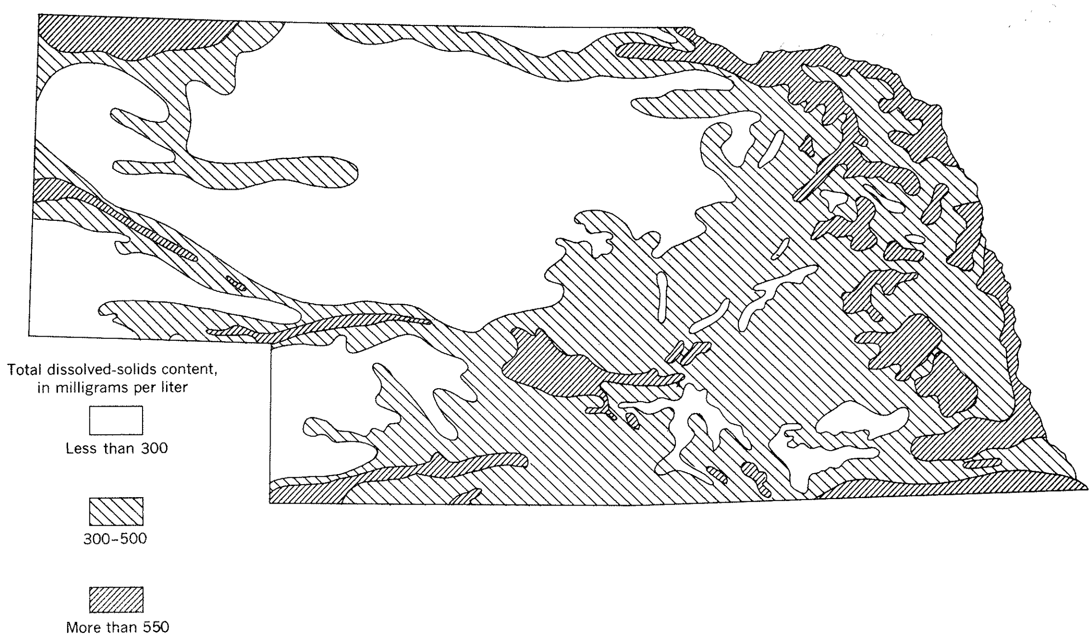

Figure 4.--Dissolved-solids concentrations in groundwater.

Low flows in streams are more highly mineralized than high flows because the former are maintained by groundwater ordinarily having a greater dissolved-solids content than does the overland runoff. Return flow from irrigated areas and effluent from municipalities and industrial plants add to the mineralization of stream water.

The Niobrara, Loup, Elkhorn, and Big and Little Blue Rivers generally have a dissolved-solids content of less than 350 mg/l. The North Platte, Platte, and Republican Rivers generally have dissolved-solids concentrations between 350 and 700 mg/l. Higher concentrations, but generally less than 1,800 mg/l, characterize the South Platte and Nemaha Rivers. The low flows of Salt Creek and a few other small streams maintained partly by discharge of highly mineralized groundwater may at times contain several thousand parts per million of dissolved solids. Most stream water in Nebraska is of the calcium bicarbonate type.

The concentrations of suspended sediment in streams also differ considerably from one stream to another, from one reach to another in the same stream, and from one time to another at the same place on the stream. The important factors determining the concentrations of suspended sediment are the quantity and rate of runoff and the susceptibility of the terrain to erosion.

Suspended-sediment concentrations in Nebraska streams range from about 300 mg/l to more than 6,000 mg/l. A long reach of the Niobrara, the upper Loups, the North and South Plattes, and much of the Platte generally contain less than 2,000 mg/l of suspended sediment, whereas the White, the Republican, and streams along the eastern border of the state generally contain more than 6,000 mg/l.

THE ANNUAL WATER SUPPLY

An annual water supply, available for management and use, is closely related to the already described stored supply of water. In this report the annual supply for the state, or for any of its subregions, is considered to be the sum of the following: precipitation, inflow via streams and canals, net decreases in surface-reservoir storage, and withdrawals from the Missouri River for use within Nebraska. All of these are measured quantities, and those given in this report are for the 1970 water year (October 1, 1969 to September 30, 1970). For the state as a whole, the components of the 1970 annual supply consisted of the amounts shown below:

Annual water supply, water year 1970

	Millions of acre-feet
Precipitation...........	83.818
Inflow..................	2.109
Net decreases in reservoir storage.....	.195
Withdrawals from Missouri River........	.047
Total..............	86.169

The total is about 4.0 million acre-feet more than in water-year 1964, the only other similar evaluation of Nebraska's water supply (Shaffer, 1966).

Division of the state into 13 subregions permits a more precise quantitative evaluation of the water supply and water use of the state. Each subregion is characterized by the stream or streams draining it and is identified by a number for easy reference. The boundaries of the subregions and the sites where inflow, outflow, and major reservoir releases are gaged are shown in Figure 5. Table 3 lists pertinent information about each subregion.

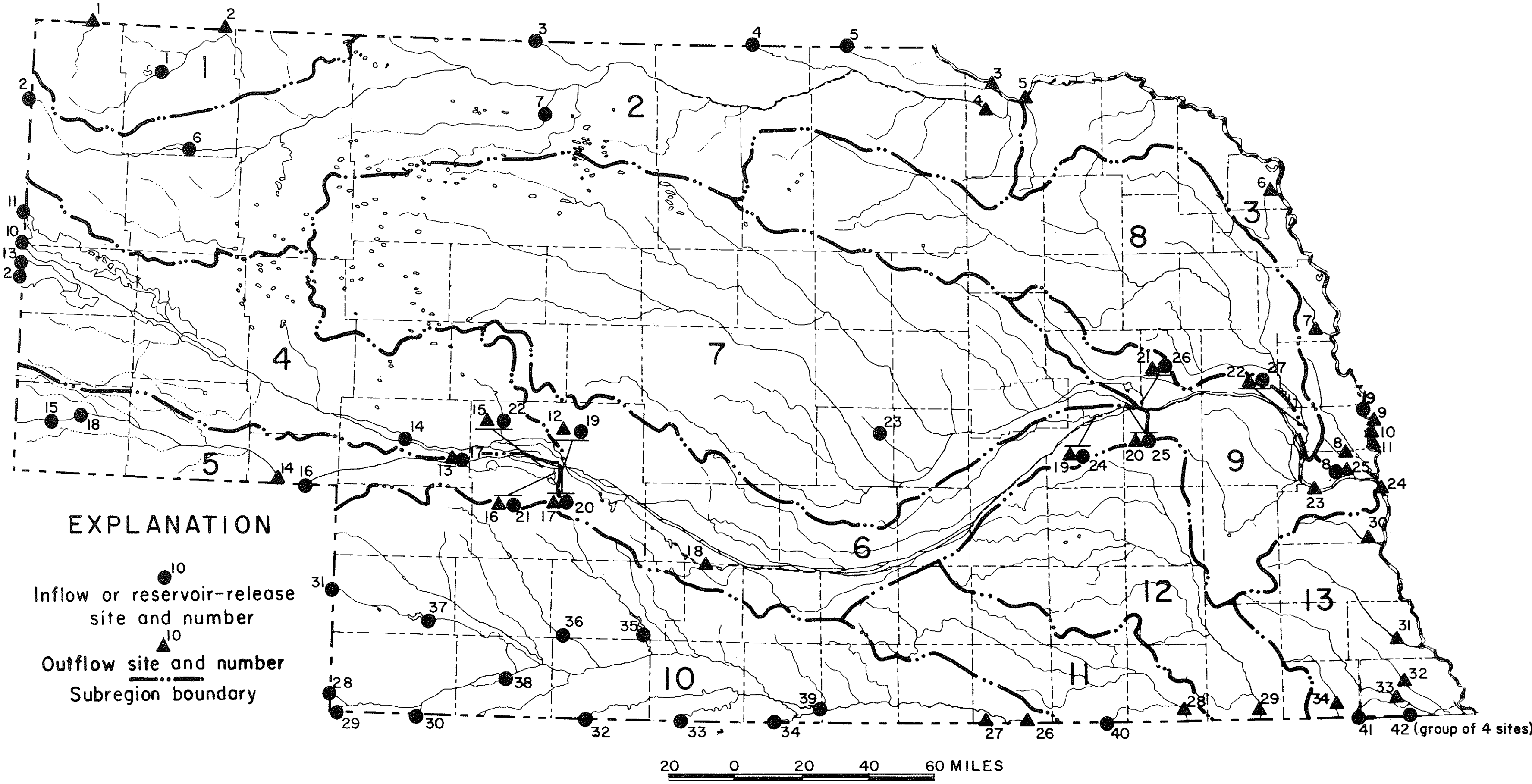

Figure 5.--Sites of gaged inflow to, reservoir releases in, and outflow from 13 subregions of Nebraska.

Table 3.--Water-supply regions of Nebraska

Subregion number	Area, in square miles	Percent of state area	Stream or streams draining subregion
1	2,124	2.8	White River and Hat Creek
2	11,847	15.3	Niobrara River and Ponca Creek
3	2,950	3.8	Tributaries of Missouri River between mouth of Niobrara River and mouth of Platte River
4	7,136	9.2	North Platte River
5	3,143	4.1	South Platte River and Lodgepole Creek
6	5,182	6.7	Platte River between junction of North and South Platte Rivers and mouth of Loup River
7	15,213	19.7	Loup River
8	6,989	9.1	Elkhorn River
9	3,043	3.9	Platte River between mouth of Loup River and mouth of Platte River including Salt Creek
10	9,630	12.5	Republican River
11	2,649	3.4	Little Blue River
12	4,564	5.9	Big Blue River
13	2,757	3.6	Nemaha and Little Nemaha Rivers and Weeping Water Creek

The distribution of precipitation on Nebraska during water year 1970 is shown in figure 6 by lines of equal precipitation. The average for the state was 20.27 inches, which is equivalent to 83.8 million acre-feet, or 97.3 percent of the annual water supply. Precipitation in water year 1970 was 0.71 inch more than in water year 1964, 1.16 inches less than the National Weather Service normal annual precipitation for Nebraska and 2.27 inches less than the average annual precipitation during the 1900-70 period. The average precipitation on each subregion in water year 1970, computed by the Thiessen method of weighting, was as follows:

Subregion		Weighted average
Number	Name	precipitation (feet)
1	White-Hat................	1.267
2	Niobrara................	1.475
3	Missouri tributaries....	1.930
4	North Platte............	1.248
5	South Platte............	1.504
6	Middle Platte...........	1.778
7	Loup.....................	1.637
8	Elkhorn..................	1.956
9	Lower Platte............	2.124
10	Republican..............	1.565
11	Little Blue.............	2.080
12	Big Blue................	2.112
13	Nemaha..................	2.540

October, the first month of the 1970 water year, was exceptionally wet throughout the state (fig. 7). The resulting abundant soil moisture contributed to record yields of winter wheat averaging 38 bushels per acre. Although precipitation during the late fall, winter, and early spring was near normal, the summer of 1970 was very dry; in fact August was the driest in 40 years in both the panhandle and southwestern parts of the state. As a consequence, dryland crops deteriorated from the short supply of moisture which in August was accompanied by higher than normal temperatures in most subregions of the state. (See fig. 7.) Yields of sorghum, for example, were the least since 1964, and yields of corn, despite the large acreage under irrigation, were 3 bushels less per acre than the average for the preceding 5 years. Major irrigation projects had adequate reservoir storage to supply water needs; however, some irrigators who customarily divert or pump directly from streams had to defer to those having prior rights because flows were so low. Above-normal precipitation the last month of the water year in all but the southwest, north-central, and panhandle parts of the state helped to restore soil moisture but was too late to help dryland crops.

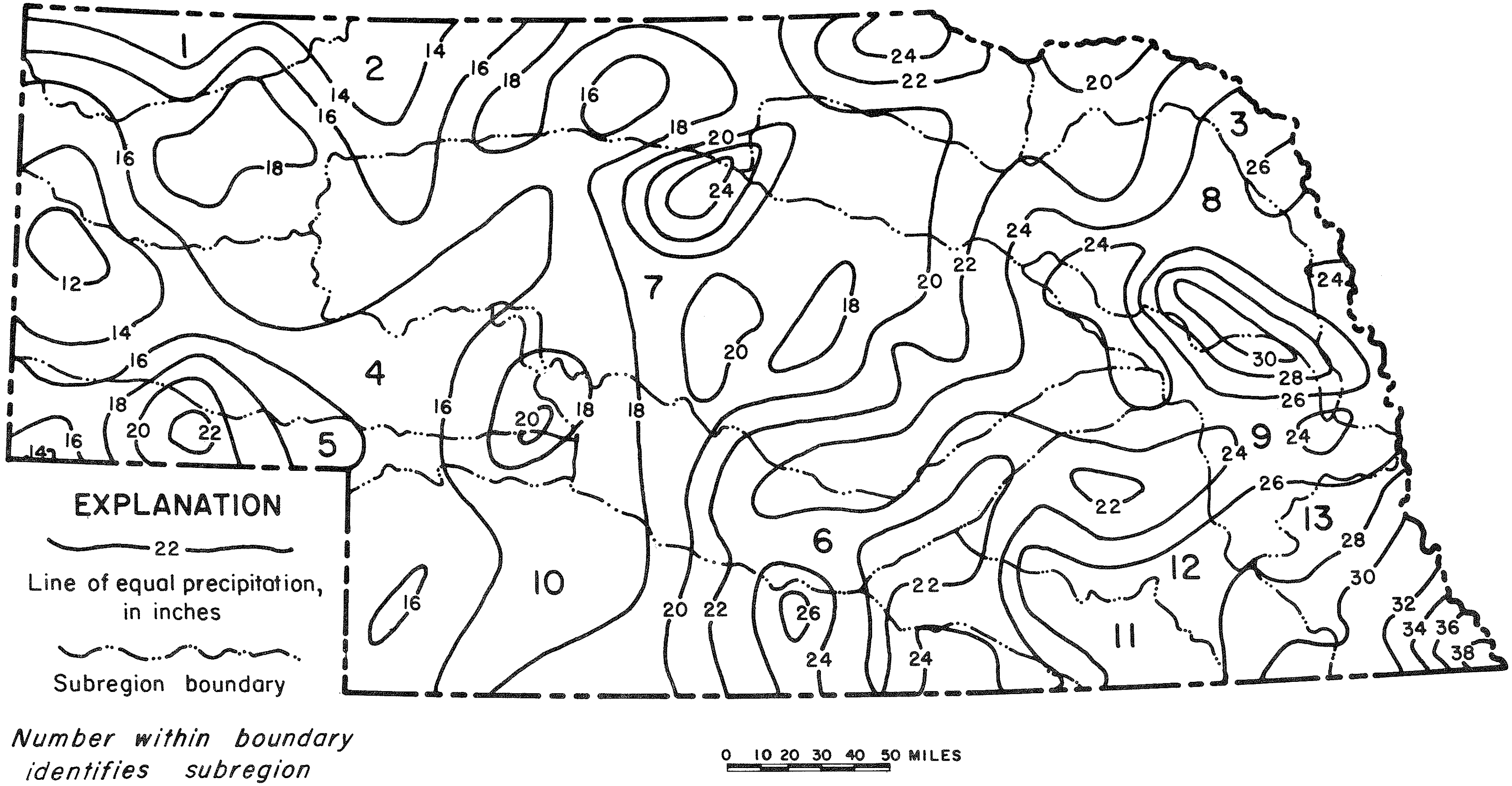

Figure 6.--Distribution of precipitation, water year 1970.

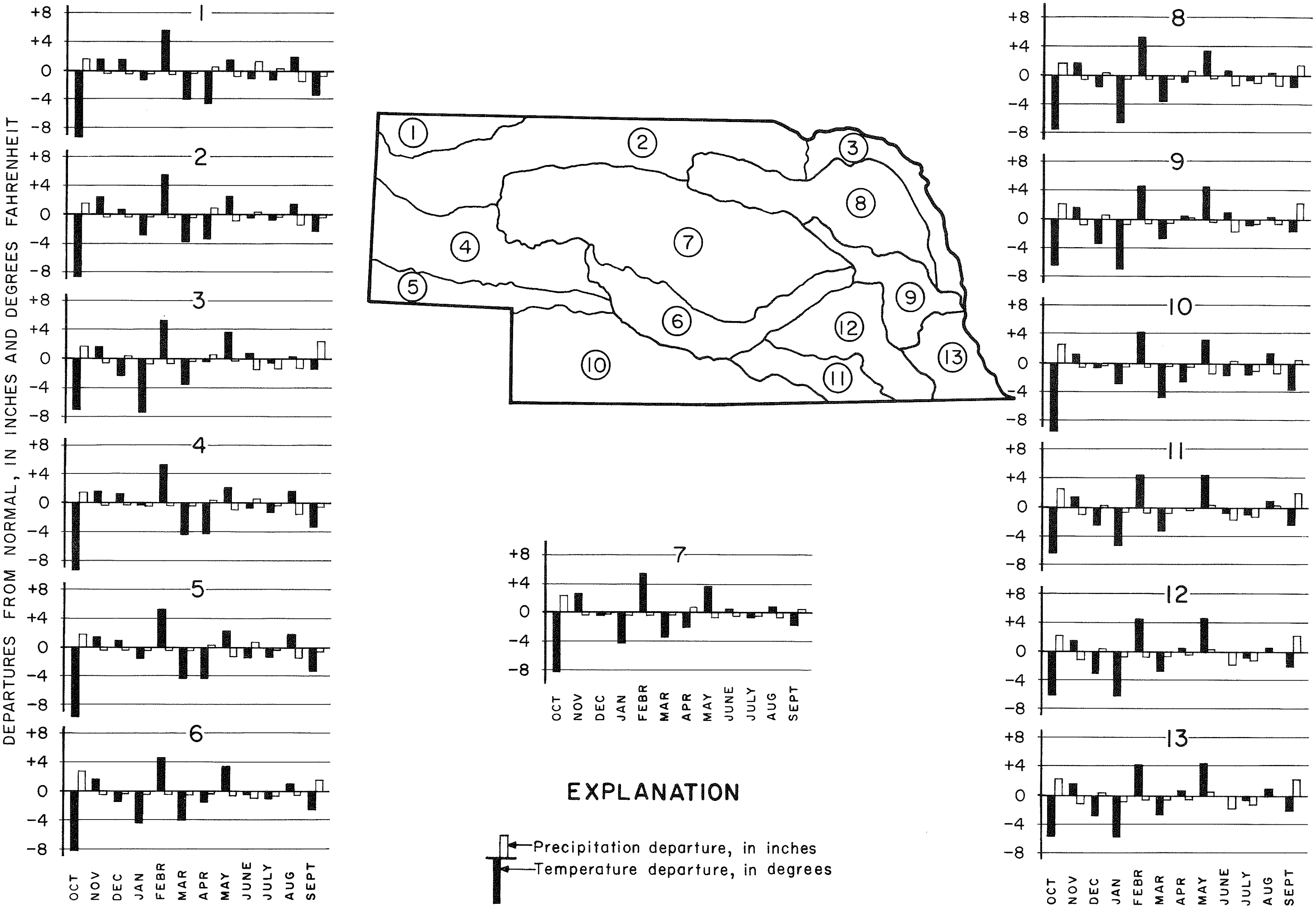

Figure 7.--Monthly departures from average precipitation and temperature, water year 1970.

Inflow to the state amounted to 2.1 million acre-feet, considerably more than normal. Snowmelt in the mountainous parts of the North and South Platte basins was enough to fill reservoirs to overflowing before the irrigation season began. Inflow during the 1970 water year was 75 percent greater than the 1964 water year. These inflow figures do not include the Missouri River, even though its water is available as a source of supply to eastern Nebraska. Flow in the Missouri River is regular because of Lewis and Clark Lake and other upstream reservoirs. Five miles downstream from Gavins Point Dam, which forms Lewis and Clark Lake, the mean discharge for January 1970 (the month of least flow) was 15,920 cubic feet per second. The mean annual discharge at that site since 1930 has been 24,600 cubic feet per second. The 1970 water year mean discharge was 32,130 cubic feet per second.

About 60 percent of the municipal supply of Omaha, or 47,300 acre-feet in water year 1970, was obtained from the Missouri River and so is considered as an addition to the state's annual water supply. The 0.5 million acre-feet of Missouri River water used for cooling at the Jones Street and North Omaha stations of the Omaha Public Power District could be included also, but because the water used--except for the small fraction evaporated in the cooling process--is returned directly to the river, it is not considered to be a part of the annual supply. Beginning about 1973, when the nuclear power plants now under construction at Fort Calhoun in Washington County and at Brownville in Nemaha County begin operation, use of the river water for cooling will increase considerably.

All but one of the irrigation reservoirs in the state contained less water at the end of the 1970 water year than at the beginning. A net total of 195,000 acre-feet was withdrawn from reservoir storage. This was about 71 percent of the net decrease of water in storage during the 1964 water year.

DISPOSITION OF THE ANNUAL SUPPLY

Outflow

Surface outflow is the water flowing out of the state, or any of the subregions, over the surface of the land. This outflow, for accounting purposes, also includes the net increases in the storage of the surface reservoirs in the state or any subregion.

Surface outflow is derived from the components of the annual supply, groundwater seepage, from irrigation water, and waste water discharged from municipalities that are supplied by wells.

The fraction from each source differs considerably from subregion to subregion and from year to year and cannot be measured precisely. In some years outflow from subregion 2, 7, and 9 consists mostly of groundwater seepage, which is a loss from the stored water supply. Most of the outflow from the other subregions is derived from the annual supply.

During water year 1970, outflow from the state was nearly 6.0 million acre-feet, or 73 percent of the 10-year average of 8.2 million acre-feet. It was about 2.8 times the amount of inflow to the state and amounted to 6.9 percent of the state's water supply for the year. Outflow via the Platte River was 3.3 million acre-feet, or 56 percent of the total from the State, and that via the Niobrara River amounted to 1.0 million acre-feet, or 17 percent of the total. The total outflow in water year 1970 was nearly 1.0 million acre-feet less than that in water year 1964 even though the water supply for 1970 was slightly more.

About 85 percent of the outflow from the state was gaged; the remainder was estimated. The discharge records for Hat Creek near Edgemont, South Dakota, and for White River at Slim Butte, South Dakota, were used in estimating outflow via those streams. The ratio of runoff to precipitation, which averages 0.08 in eastern Nebraska, was used for estimating outflow from all other ungaged areas.

Although to make as much use of the total water supply as possible is a desirable goal, it should be realized that outflow is necessary for fish and wildlife survival, for dilution and disposal of natural wastes and for compliance with interstate compacts. Furthermore, impoundment of all runoff from floods would be highly uneconomic even if sites for storage of such large quantities of water were available.

Consumptive Use

The difference between the annual water supply and outflow is here termed consumptive use. It consists mostly of water that is returned to the atmosphere by evaporation from soil and exposed water surfaces and by transpiration. Minor amounts are used by animals and industrial processes. Net increases in water stored in the soil, in groundwater reservoir, in natural lakes, and in ungaged surface reservoirs are also incorporated into the consumptive use figure.

In Nebraska, mean annual evaporation from lake surfaces ranges from about 38 inches in the northeast part to 54 inches in the southwest part of the state (fig. 8). As shown by the graph in figure 9, 76 percent of the total evaporation from lake surfaces occurs during the growing season (May through

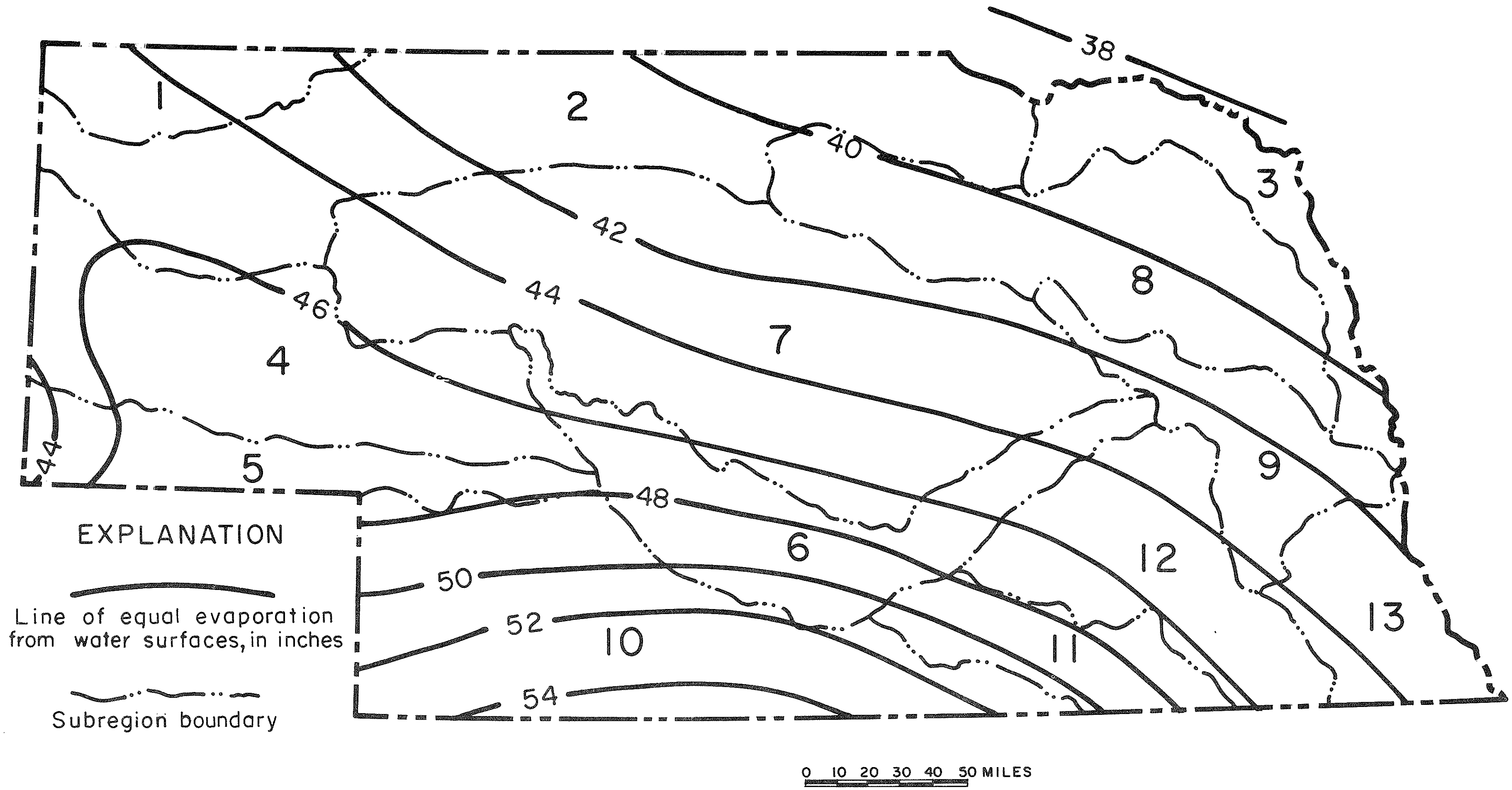

Figure 8.--Mean annual evaporation from lake surfaces.

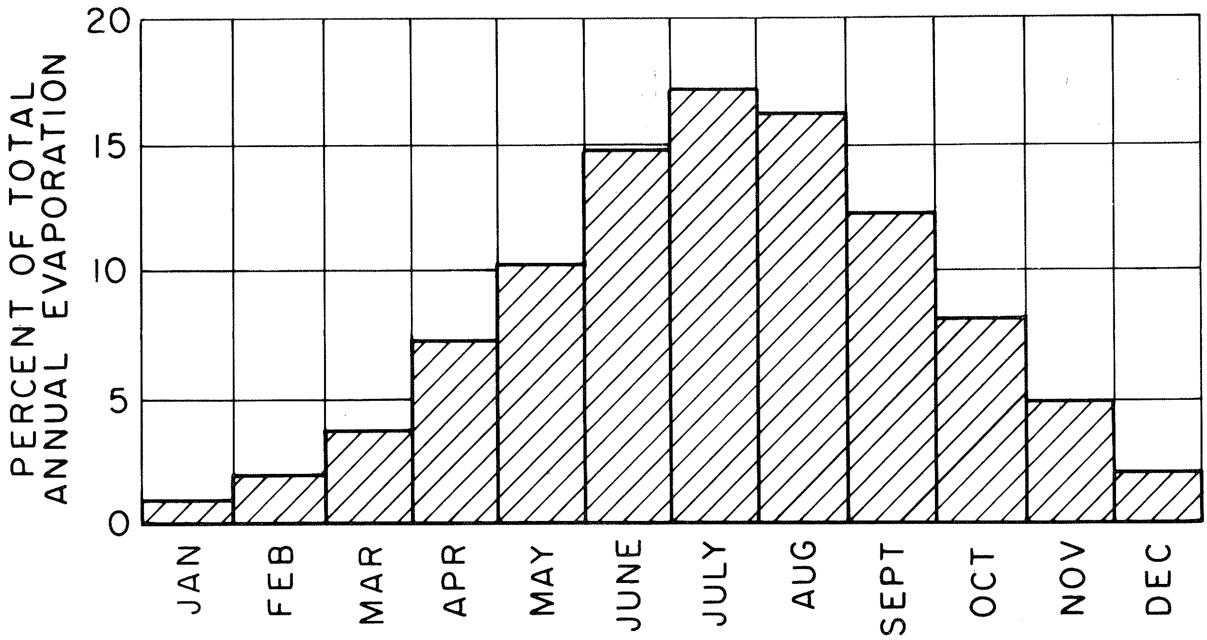

Figure 9.--Monthly evaporation in percent of annual evaporation

October) and 48 percent of the total occurs during the 3-month period June through August. Even though the annual potential evaporation from all surfaces is somewhat less than the mean annual evaporation from lake surfaces, it almost always exceeds annual precipitation in all parts of Nebraska.

Water pumped from wells is withdrawn wholly from storage and it does not constitute a consumptively used fraction of the annual water supply. Only where pumpage induces seepage from streams or salvages water that would be lost through evapotranspiration is part of the amount withdrawn chargeable to consumptive use of the annual supply.

In water year 1970 consumptive use for the state as a whole amounted to 80.2 million acre-feet, or 93.1 percent of the annual water supply; whereas in water year 1964, it was 75.2 million acre-feet and about 91.6 percent of that year's annual water supply.

WATER SUPPLY, OUTFLOW, AND CONSUMPTIVE USE IN WATER YEAR 1970

On succeeding pages the following information relating to water year 1970 is given for each of the 13 subregions of Nebraska: amount of precipitation, names of gaged streams and canals that convey water in and the amount of inflow through each, estimates of ungaged inflow, net decreases or increases in amount of water stored in surface reservoirs, names of gaged streams and canals that convey water out and amount of outflow through each, estimates of ungaged outflow, and amount of consumptive use. All these values are given in acre-feet. Outflow and consumptive use are expressed also as percent of the annual water supply and as water equivalent (uniform depth of water, in feet, over the entire subregion). Table 4 on pages 36-37 summarizes the detailed information in a form that facilitates ready comparison of values for the subregions. Figure 10 on page 35 is a graphic representation of the total water supply in each subregion and the amount leaving each subregion as outflow. Inflow, which is the lower part of bar labelled total water supply, includes minor decreases in surface-reservoir storage.

Subregion 1

White River and Hat Creek drainage areas

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (1,359,360 acres x 1.267 ft)............................		1,722.3
Inflow.................................		.0
Decrease in surface storage, Whitney Reservoir............................	● 1	.9
Total annual water supply......		1,723.2
Outflow		
Hat Creek at State line (estimated)....	▲ 1	7.0
White River at State line (adjusted)...	▲ 2	19.6
Total outflow..................		26.6
Consumptive use (annual water supply minus outflow........................		1,696.6

	Percent of water supply	Water equivalent (feet)
Outflow.............	1.5	0.019
Consumptive use.....	98.5	1.248

Subregion 2

Niobrara River and Ponca Creek drainage areas

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (7,582,080 acres x 1.475 ft)............................		11,183.6
Inflow:		
Niobrara River at State line.........	● 2	2.9
Minnechaduza Creek near Kilgore......	● 3	7.6
Keya Paha River near State line (adjusted).....................	● 4	29.8
Ponca Creek at Anoka (adjusted)......	● 5	8.0
Decrease in surface storage:		
Box Butte Reservoir..................	● 6	1.7
Merritt Reservoir....................	● 7	17.0
Total annual water supply......		11,250.6
Outflow		
Ponca Creek at Verdel..................	▲ 3	24.3
Niobrara River near Verdel.............	▲ 4	1,031.0
Ungaged (estimated)....................		64.1
Total outflow..................		1,119.4
Consumptive use (annual water supply minus outflow).....................		10,131.2

	Percent of water supply	Water equivalent (feet)
Outflow.............	9.95	0.148
Consumptive use.....	90.05	1.336

Subregion 3

Missouri River tributary drainage areas

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (1,888,000 acres x 1.930 ft)............................		3,643.8
Inflow:		
Omaha water system intake from well field in Platte River valley........	● 8	31.3
Omaha water system intake from Missouri River......................	● 9	47.3
Total annual water supply.......		3,722.4
Outflow		
Bazile Creek near Niobrara..............	▲ 5	41.6
Omaha Creek at Homer....................	▲ 6	16.8
Tekamah Creek at Tekamah................	▲ 7	1.1
Sewage effluent from Omaha:		
Papillion treatment plant.............	▲ 8	25.8
Missouri River treatment plant........	▲ 9	33.7
District No. 31 treatment plant.......	▲ 10	7.8
Western Electric treatment plant......	▲ 11	5.6
Ungaged (estimated).....................		240.0
Total outflow...................		372.4
Consumptive use (annual water supply minus outflow)......................		3,350.4

	Percent of water supply	Water equivalent (feet)
Outflow............	10.0	0.197
Consumptive use....	90.0	1.775

Subregion 4

North Platte River drainage area

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (4,567,040 acres x 1.248 ft)		5,699.7
Inflow:		
North Platte River at State line	● 10	519.2
Interstate Canal at State line (estimated)	● 11	304.0
Fort Laramie Canal at State line	● 12	131.1
Mitchell and Gering Canals at State line	● 13	67.0
Decrease in surface storage (Lake McConaughy)	● 14	5.6
Total annual water supply		6,726.6
Outflow		
North Platte River at North Platte	▲ 12	425.6
Sutherland Supply Canal	▲ 13	669.8
Total outflow		1,095.4
Consumptive use (annual water supply minus outflow)		5,631.2

	Percent of water supply	Water equivalent (feet)
Outflow	16.3	0.240
Consumptive use	83.7	1.233

Subregion 5

South Platte River and Lodgepole Creek drainage areas

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (2,011,520 acres x 1.504 ft)...............................		3,025.3
Inflow:		
Lodgepole Creek at Bushnell...........	● 15	5.9
South Platte River at Julesburg.......	● 16	814.1
Sutherland Supply Canal...............	● 17	669.8
Decrease in surface storage, Oliver Reservoir.............................	● 18	0
Total annual water supply.......		4,515.1
Outflow		
Lodgepole Creek at Ralston..............	▲ 14	6.2
Fremont Slough at North Platte..........	▲ 15	19.0
Sutherland Supply Canal.................	▲ 16	1/ 952.7
South Platte River at North Platte......	▲ 17	357.2
Total outflow..................		1,335.1
Consumptive use (annual water supply minus outflow).........................		3,180.0

	Percent of water supply	Water equivalent (feet)
Outflow.............	29.6	0.664
Consumptive use.....	70.4	1.581

1/ Includes some water diverted from South Platte River.

Subregion 6

Middle Platte River drainage area

	Site symbol and no. on fig. 5.	Thousands of acre-feet
Water supply		
Precipitation (3,316,480 acres x 1.778 ft)............................		5,896.7
Inflow:		
North Platte River at North Platte...	● 19	425.6
South Platte River at North Platte...	● 20	357.2
Sutherland Supply Canal near North Platte......................	● 21	952.7
Fremont Slough at North Platte.......	● 22	19.0
Total annual water supply.....		7,651.2
Outflow		
Storage increase, Johnson Reservoir....	▲ 18	5.5
Platte River at Duncan..................	▲ 19	1,277.0
Ungaged (estimated).....................		22.4
Total outflow.................		1,304.9
Consumptive use (annual water supply minus outflow)......................		6,346.3

	Percent of water supply	Water equivalent (feet)
Outflow.............	17.1	0.393
Consumptive use.....	82.9	1.914

Subregion 7

Loup River drainage area

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (9,736,320 acres x 1.637 ft)............................		15,938.4
Inflow.................................		.0
Decrease in surface storage (Sherman Reservoir)...........................	● 23	6.7
Total annual water supply...		15,945.1
Outflow		
Loup River at Columbus.................	▲ 20	372.3
Loup River Power Canal (90 percent of amount diverted into canal at Genoa).	▲ 21	964.0
Total outflow...............		1,336.3
Consumptive use (annual water supply minus outflow)......................		14,608.8

	Percent of water supply	Water equivalent (feet)
Outflow............	8.4	0.137
Consumptive use....	91.6	1.500

Subregion 8

Elkhorn River drainage area

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (4,472,960 acres x 1.956 ft)............................		8,749.1
Inflow................................		.0
Total annual water supply.....		8,749.1
Outflow		
Elkhorn River at Waterloo................	▲ 22	551.4
Ungaged (estimated)......................		3.8
Total outflow..................		555.2
Consumptive use (annual water supply minus outflow.........................		8,193.9

	Percent of water supply	Water equivalent (feet)
Outflow............	6.35	0.124
Consumptive use....	93.65	1.832

Subregion 9

Lower Platte River drainage area

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (1,947,520 acres x 2.124 ft)		4,136.5
Inflow:		
Platte River at Duncan	● 24	1,277.0
Ungaged inflow from subregion 6 (estimated)		22.4
Loup River at Columbus	● 25	372.3
Loup River Power Canal (90 percent of amount diverted into canal at Genoa)	● 26	964.0
Elkhorn River at Waterloo	● 27	551.4
Ungaged outflow from subregion 8 (estimated)		3.8
Total annual water supply		7,327.4
Outflow		
Platte River at South Bend	▲ 23	3,269.0
Ungaged (estimated)		27.2
Effluent from Allied Chemical Plant	▲ 24	24.7
Pumpage into Omaha water system	▲ 25	31.3
Total outflow		3,352.2
Consumptive use (annual water supply minus outflow)		3,975.2

	Percent of water supply	Water equivalent (feet)
Outflow	45.7	1.721
Consumptive use	54.3	2,041

Subregion 10

Republican River drainage area

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (6,163,200 acres x 1.565 ft)		9,645.4
Inflow:		
North Fork Republican River at State line	● 28	32.4
Arikaree River at Haigler	● 29	7.1
South Fork Republican River near Benkelman	● 30	25.4
Frenchman Creek at State line	● 31	10.9
Beaver Creek at State line	● 32	1.9
Sappa Creek near Beaver City	● 33	8.0
Prairie Dog Creek at State line	● 34	6.0
Decreases in surface storage:		
Harry Strunk Reservoir	● 35	12.5
Hugh Butler Reservoir	● 36	4.6
Enders Reservoir	● 37	1.0
Swanson Reservoir	● 38	26.7
Harlan County	● 39	118.3
Total annual water supply		9,900.2
Outflow		
Republican River near Hardy	▲ 46	236.2
Courtland Canal at State line	▲ 47	99.4
Total outflow		335.6
Consumptive use (annual water supply minus outflow)		9,564.6

	Percent of water supply	Water equivalent (feet)
Outflow	3.39	0.054
Consumptive use	96.61	1.552

Subregion 11

Little Blue River drainage area

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (1,695,360 acres x 2.08 ft)................................		3,526.3
Inflow, Rose Creek (estimated)..........	● 40	10.2
Total annual water supply...		3,536.5
Outflow		
Little Blue River near Fairbury.........	▲ 28	137.6
Ungaged (estimated)......................		43.4
Total outflow...............		181.0
Consumptive use (annual water supply minus outflow)......................		3,355.5

	Percent of water supply	Water equivalent (feet)
Outflow............	5.12	0.107
Consumptive use....	94.88	1.979

Subregion 12

Big Blue River drainage area

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (2,920,960 acres x 2.112 ft)		6,169.1
Inflow		.0
Total annual water supply		6,169.1
Outflow		
Big Blue River at Barneston	▲ 29	191.0
Ungaged (estimated)		15.3
Total outflow		206.3
Consumptive use (annual water supply minus outflow)		5,962.8

	Percent of water supply	Water equivalent (feet)
Outflow	3.34	0.071
Consumptive use	96.66	2.041

Subregion 13

Nemaha River, Little Nemaha River, and Weeping Water Creek drainage areas

	Site symbol and no. on fig. 5	Thousands of acre-feet
Water supply		
Precipitation (1,764,480 acres x 2.540 ft)		4,481.8
Inflow:		
South Fork Nemaha River at State line (estimated)	● 41	42.6
Rock, Pony, Walnut, and Roys Creeks at State line	● 42	27.6
Total annual water supply		4,552.0
Outflow		
Weeping Water Creek at Union	▲ 30	24.1
Little Nemaha River at Auburn	▲ 31	55.5
Muddy Creek near Verdon	▲ 32	17.2
Big Nemaha River at Falls City	▲ 33	163.3
Turkey Creek at State line (estimated)	▲ 34	12.2
Ungaged (estimated)		112.6
Total outflow		384.9
Consumptive use (annual water supply minus outflow)		4,167.1

	Percent of water supply	Water equivalent (feet)
Outflow	8.46	0.218
Consumptive use	91.54	2.362

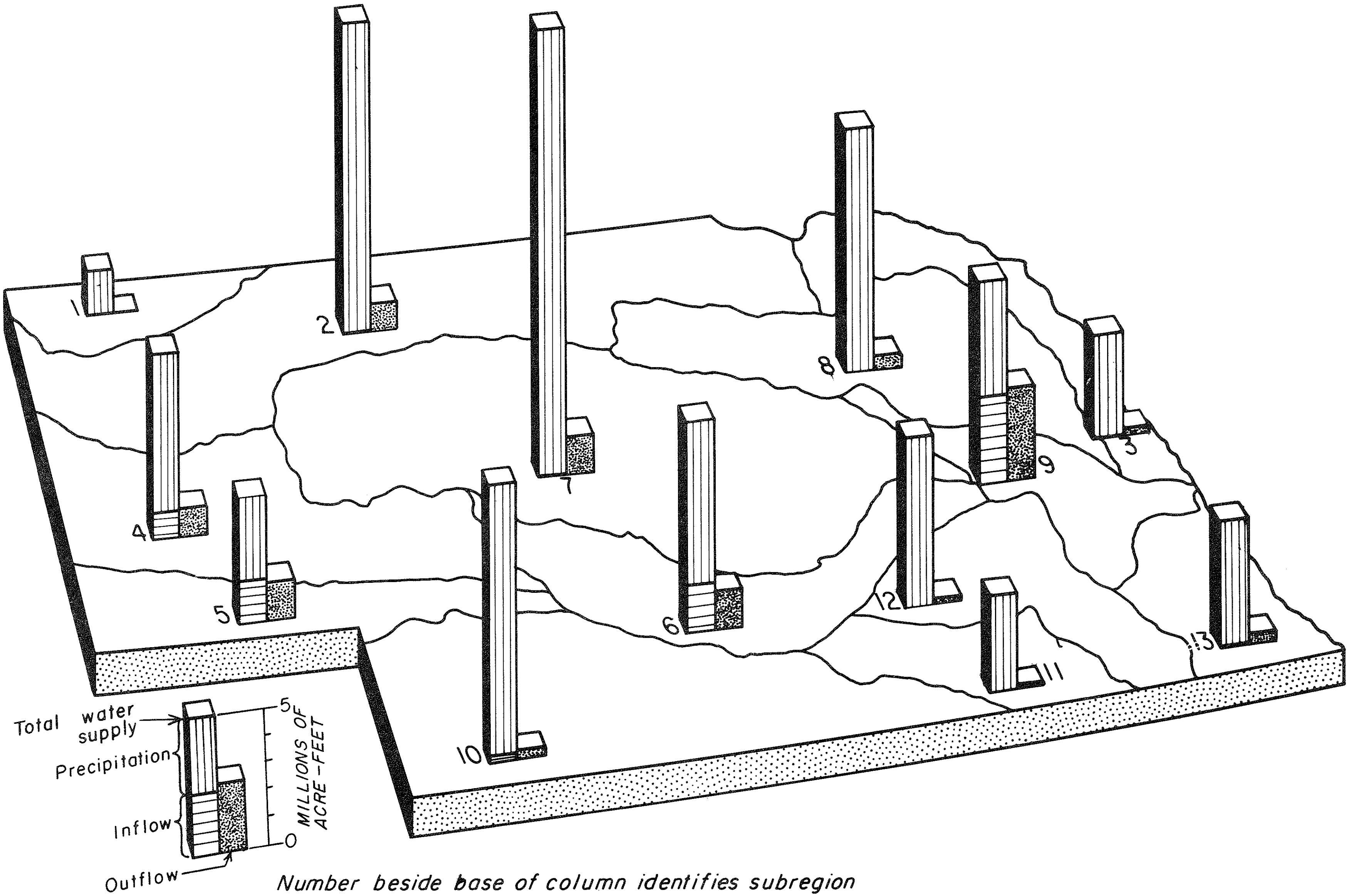

Figure 10.--Amounts of precipitation on, inflow to, and outflow from 13 subregions of Nebraska, water year 1970.

Table 4.--Summary of annual water supply, outflow,

Subregion No.	Subregion Name	Area (thousands of acres)	Source of: Precipitation (thousands of acre-feet)	Source of: Inflow: To subregion (thousands of acre-feet)	Source of: Inflow: To State (thousands of acre-feet)
		(1)	(2)	(3)	
1	White-Hat.............	1,359.4	1,722.3	0.0	0.0
2	Niobrara..............	7,582.1	11,183.6	48.3	48.3
3	Missouri tributaries..	1,888.0	3,643.8	78.6	47.3
4	North Platte..........	4,567.0	5,699.7	1,021.3	1,021.3
5	South Platte..........	2,011.5	3,025.3	1,489.8	820.0
6	Middle Platte.........	3,316.5	5,896.7	1,754.5	.0
7	Loup..................	9,736.3	15,938.4	.0	.0
8	Elkhorn...............	4,473.0	8,749.1	.0	.0
9	Lower Platte..........	1,947.5	4,136.5	3,190.9	.0
10	Republican............	6,163.2	9,645.4	91.7	91.7
11	Little Blue...........	1,695.4	3,526.3	10.2	10.2
12	Big Blue..............	2,921.0	6,169.1	.0	.0
13	Nemaha................	1,764.5	4,481.8	70.2	70.2

1/ Sum of columns 2, 3, and 4.

2/ Difference between columns 5 and 6.

3/ Column 7 divided by column 1.

and consumptive use, water year 1970

water-supply		Outflow			Consumptive use	
		From subregion				
Decreases in reservoir storage (thousands of acre-feet)	Total[1] (thousands of acre-feet)	(Thousands of acre-feet)	Percent of annual water supply	From State (thousands of acre-feet)	Volume[2] (thousands of acre-feet)	Water equivalent[3] (feet)
(4)	(5)	(6)			(7)	(8)
0.9	1,723.2	26.6	1.54	26.6	1,696.6	1.25
18.7	11,250.6	1,119.4	9.95	1,119.4	10,131.2	1.34
.0	3,722.4	372.4	10.00	372.4	3,350.0	1.77
5.6	6,726.6	1,095.4	16.30	.0	5,631.2	1.23
.0	4,515.1	1,335.1	29.60	.0	3,180.0	1.58
.0	7,651.2	1,304.9	17.10	.0	6,346.3	1.91
6.7	15,945.1	1,366.3	8.40	.0	14,608.8	1.50
.0	8,749.1	552.2	6.35	.0	8,193.9	1.83
.0	7,327.4	3,352.2	45.80	3,320.9	3,975.2	2.04
163.1	9,900.2	335.6	3.39	335.6	9,564.6	1.55
.0	3,536.5	181.0	5.13	181.0	3,355.5	1.98
.0	6,169.1	206.3	3.34	206.3	5,962.8	2.04
.0	4,552.0	384.9	8.46	384.9	4,167.1	2.36

CURRENT USE OF WATER

General

Water commonly is referred to as a transient resource. However, the term "transient" far more aptly describes the annual water supply than it does the stored supply.[1] Both supplies are available for use; but, generally speaking, most of the annual supply is available for current use only, whereas the stored supply is available for use now or at some future time. Although Nebraskans make much use of both types of supply, there exist many opportunities for greater and more efficient use. For examples: land-management practices such as contour farming could be more generally applied; additional reservoirs could be constructed; natural increments to groundwater storage could be supplemented with recharge water diverted from streams or surface impoundments; excessive use and waste of water could be reduced; improved techniques of irrigating could be more generally practiced; and water-treatment facilities could be improved so as to minimize the amount of water required for waste conveyance.

Since the first settlers arrived in Nebraska, use of the water resources has been on the increase. In pioneer days, as now, most of the annual supply returned to the atmosphere and only a small fraction left the state as streamflow. However, as the amount of land planted to crops increased, more of the annual supply was consumed beneficially. At the present time about 28 percent of the land area is used for production of field and garden crops, and about 4.5 percent is in wild hay that is harvested. Much of the remainder of the state is used for grazing of livestock.

Irrigation

Irrigation development, in part influenced by climatic conditions, has not advanced at a uniform rate. Droughts of the 1890's, the 1930's, and the middle 1950's were especially effective spurs to expansion of irrigated acreages. Information on the number of acres irrigated in Nebraska in various years is available from the U. S. Bureau of Census, the Nebraska Department of Water Resources,

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[1] Reed (1966, pl. 4) estimates the stored water supply is 1.68 billion acre-feet, or about 195 times the annual water supply in 1970.

and the State-Federal Division of Agricultural Statistics. Although not wholly consistent, particularly for the earlier years, the data demonstrate the marked upward trend in irrigated acreage beginning with the end of World War II (fig. 11).

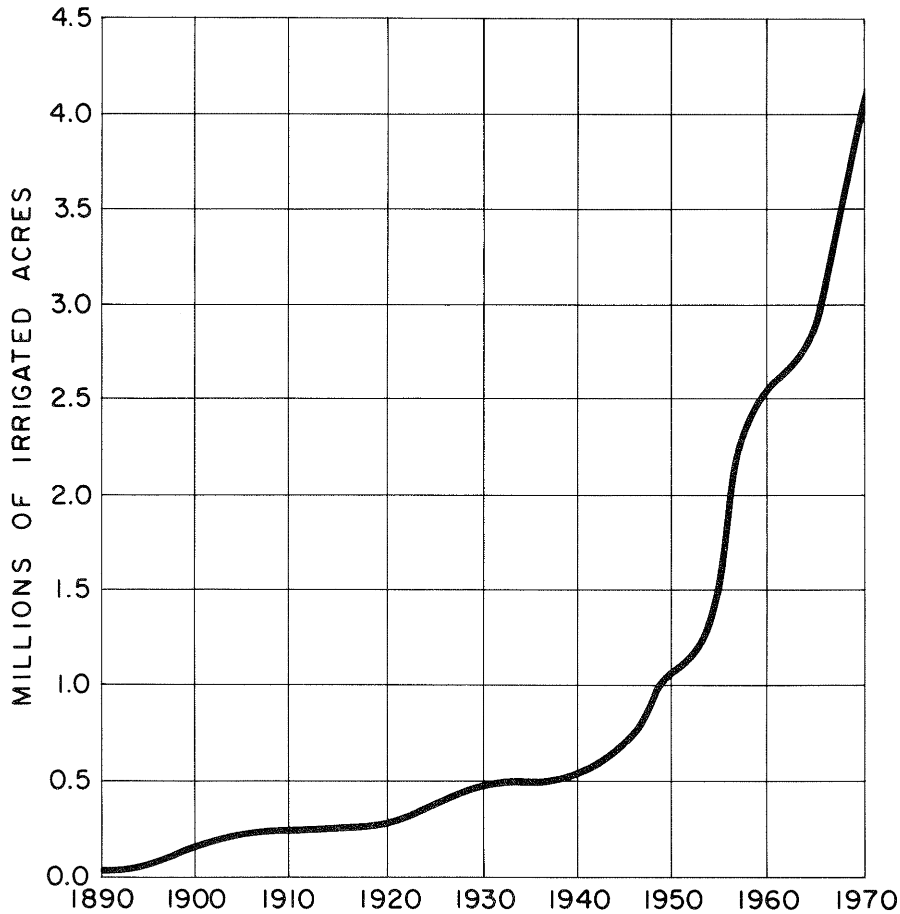

Figure 11.--Irrigated acreage, 1890-1970.

Only surface-water supplies were used in irrigation for many years, beginning soon after the Civil War. All such irrigation was restricted to valley areas until the early 1940's, when completion of the Tri-County Irrigation Project (subregion 6) made possible the diversion of river water to an extensive upland area in Gosper, Phelps, and Kearney Counties. Under the program for development of the Missouri River basin, several other gravity-type irrigation projects, some serving upland areas, were constructed. By the middle 1960's the total acreage irrigated from surface-water diversions had increased to 1.1 million acres. No additional projects have been constructed since that time. In water year 1970, the total diversions amounted to 2.3 million acre-feet, or 2.1 acre-feet per irrigated acre. Not all the water diverted for irrigation actually was applied to crops as an estimated 30 to 40 percent was lost by seepage and evaporation between the point of diversion and the point of delivery. Data on use of surface water for irrigation in each of the subregions are given in table 5.

Table 5.--Use of surface water for irrigation, 1970[1/]

Subregion		Area irrigated (acres)	Amount of water diverted		
No.	Name		Acre-feet	Acre-feet per acre	Millions of gallons per day
1	White-Hat............	26,600	25,250	0.95	22.5
2	Niobrara.............	59,700	105,000	1.76	93:8
3	Missouri tributaries.	6,000	6,000	1.00	5.4
4	North Platte.........	364,600	1,220,000	3.35	1,090.0
5	South Platte.........	28,300	43,500	1.54	38.8
6	Middle Platte........	296,400	411,400	1.39	367.4
7	Loup.................	121,200	230,000	1.90	205.4
8	Elkhorn..............	20,400	20,400	1.00	18.2
9	Lower Platte.........	9,600	9,600	1.00	8.6
10	Republican...........	107,700	192,790	1.79	172.1
11	Little Blue..........	13,300	13,300	1.00	11.9
12	Big Blue.............	40,300	40,300	1.00	36.0
13	Nemaha...............	7,770	7,770	1.00	6.9

1/ Data from Nebraska Department of Water Resources

Acreages irrigated in each subregion with surface water and with groundwater are shown graphically in figure 12. The proportionate amounts of groundwater and surface water used for irrigation in water year 1970 differ considerably from one subregion to another (fig. 13). For example, in subregion 4 almost 12 times more surface water than groundwater was used whereas in subregion 12, 17 times more groundwater than surface water was used. For the state as a whole in water year 1970 use of groundwater for irrigation exceeded use of surface water by nearly one-third.

About 56 percent of the acreage under surface-water irrigation is served by either a Federal irrigation project or a public power and irrigation project. The extent of project lands by subregion is shown below.

Extent of irrigation project lands

Subregion		Federal irrigation projects (acres)	Public power and irrigation projects (acres)
No.	Name		
2	Niobrara.........	37,600	....
4	North Platte.....	164,000	....
6	Middle Platte....	....	230,000
7	Loup.............	46,000	54,600
10	Republican.......	87,000	....

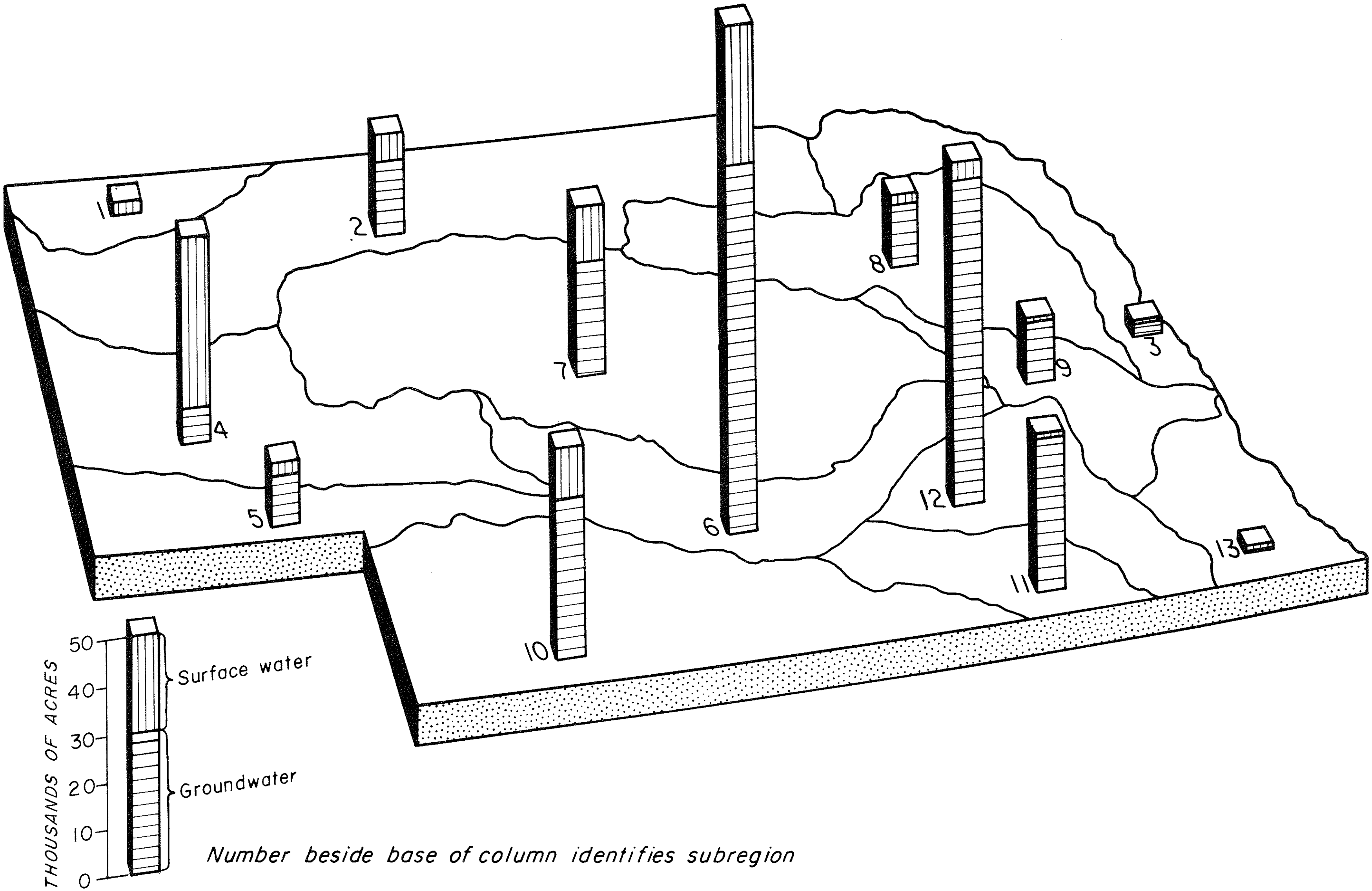

Figure 12.--Irrigated acreage in 13 subregions of Nebraska, 1970.

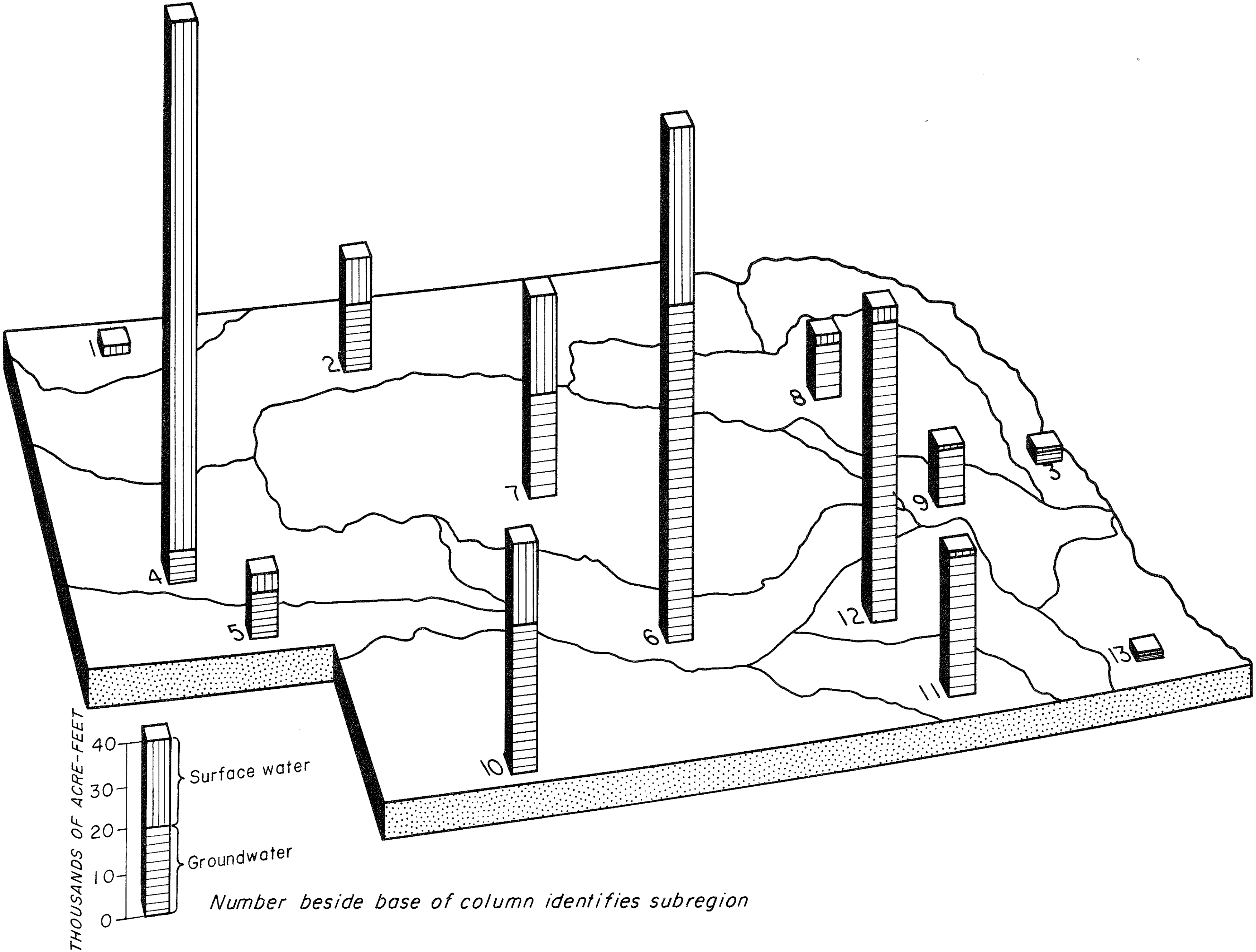

Figure 13.--Amount of water used for irrigation in 13 subregions of Nebraska, 1970.

Use of groundwater for irrigation, which began in the 1920's was similarly restricted to valley lands until the late 1930's when drilling techniques and development of deep-well turbine pumps made feasible the withdrawal of groundwater for irrigation supplies from the greater depths to water in upland areas. With the end of World War II, equipment for drilling again became available, and many wells were drilled in the next few years, especially in the upland part of subregion 12. A second surge in drilling activity occurred during and after the drought of the middle 1950's. By the end of 1970 the number of registered irrigation wells had grown to 35,685 and the total area irrigated from wells to nearly 3 million acres, or an average of 84 acres per well. During the growing season of that year pumpage from irrigation wells was about 3.0 million acre-feet, or 1.0 acre-foot per irrigated acre. Less groundwater than surface water was required per acre irrigated because losses due to seepage and evaporation are minimized when groundwater is used. It is estimated that 10 percent of the groundwater applied to the soil runs off to streams or infiltrates below the reach of roots and is returned to the zone of saturation. Each of the 13 subregions contains some land irrigated with groundwater. Table 6 shows the area irrigated and amount of water pumped for each subregion.

Table 6.--Use of groundwater for irrigation, 1970 1/

Subregion		Area irrigated (acres)	Amount of water pumped (millions of gallons per day)
No.	Name		
1	White-Hat..................	1,050	0.9
2	Niobrara..................	154,310	137.7
3	Missouri tributaries......	26,490	23.6
4	North Platte..............	70,660	63.1
5	South Platte..............	103,440	92.4
6	Middle Platte.............	774,190	691.4
7	Loup......................	237,935	212.5
8	Elkhorn...................	129,585	115.7
9	Lower Platte..............	130,040	116.1
10	Republican................	337,815	301.7
11	Little Blue...............	320,710	286.4
12	Big Blue..................	684,890	611.6
13	Nemaha....................	6,660	5.9

1/ Data from Conservation and Survey Division, University of Nebraska

The greatest density of irrigation wells--average 4 to 5 wells per square mile--is in Hall and Merrick Counties in the eastern part of subregion 6. Two other counties in subregion 6 and four counties in the western part of subregion 12 have average densities of 2 to 3 wells per square mile. The total number and approximate density of registered irrigation wells in each county are shown in figure 14.

As shown by the size of the circles in figure 15, the amounts of surface water and groundwater used for irrigation in 1970 dwarf the amounts used for rural, industrial, and municipal purposes. The present prospect is for relatively small increase in average annual use of surface water for irrigation in coming years. On the other hand, average annual pumpage of groundwater for irrigation is expected to continue its higher rate of increase. (See figure 16.) Rural use of water may increase, but only slightly, in comparison to that of industrial and municipal use.

In parts of Nebraska the water table, or upper surface of the shallowest groundwater supply, is so near the land surface that plants can absorb water from the capillary fringe (a zone of moist sediment immediately above the water table). The thickness of the capillary fringe is governed by the texture of the sediments just above the water table--it is only a few inches thick in coarse-textured sediments and may exceed 8 feet in fine-textured sediments. When plant roots absorb water from the capillary fringe, the imbibed water is replaced by capillary rise from the underlying saturated zone. As long as the capillary fringe is within the reach of plant roots, a continuous supply of moisture is available for plant growth. Vegetation thus supplied is said to be subirrigated. John Elder of the Conservation and Survey Division has prepared a map (fig. 17) showing the principal areas where subirrigation occurs in Nebraska and has estimated their extent at 2.5 million acres. About 0.9 million acres has been replaced by crops; most of the remaining native vegetation consists of wild hay, much of which is harvested for cattle feed. Surface applications of water are made to about 20 percent of the subirrigated area, thereby increasing the amount of water available for plant use.

The amount of water consumed annually by subirrigated vegetation depends on the plant species, on the depth to the water table, and on climatic conditions. It thus varies considerably from place to place and from year to year. It is estimated that 2 feet of water per year is a reasonable average value for use of water by subirrigated vegetation in Nebraska. If this value is applied to the estimated 2.5 million acres of shallow water table, a water use of 5.0 million acre-feet per year is indicated. Most areas of shallow water table are areas where a large fraction of precipitation infiltrates to the zone of saturation. Thus, part of the water consumed is derived from the annual water supply and part from the stored supply.

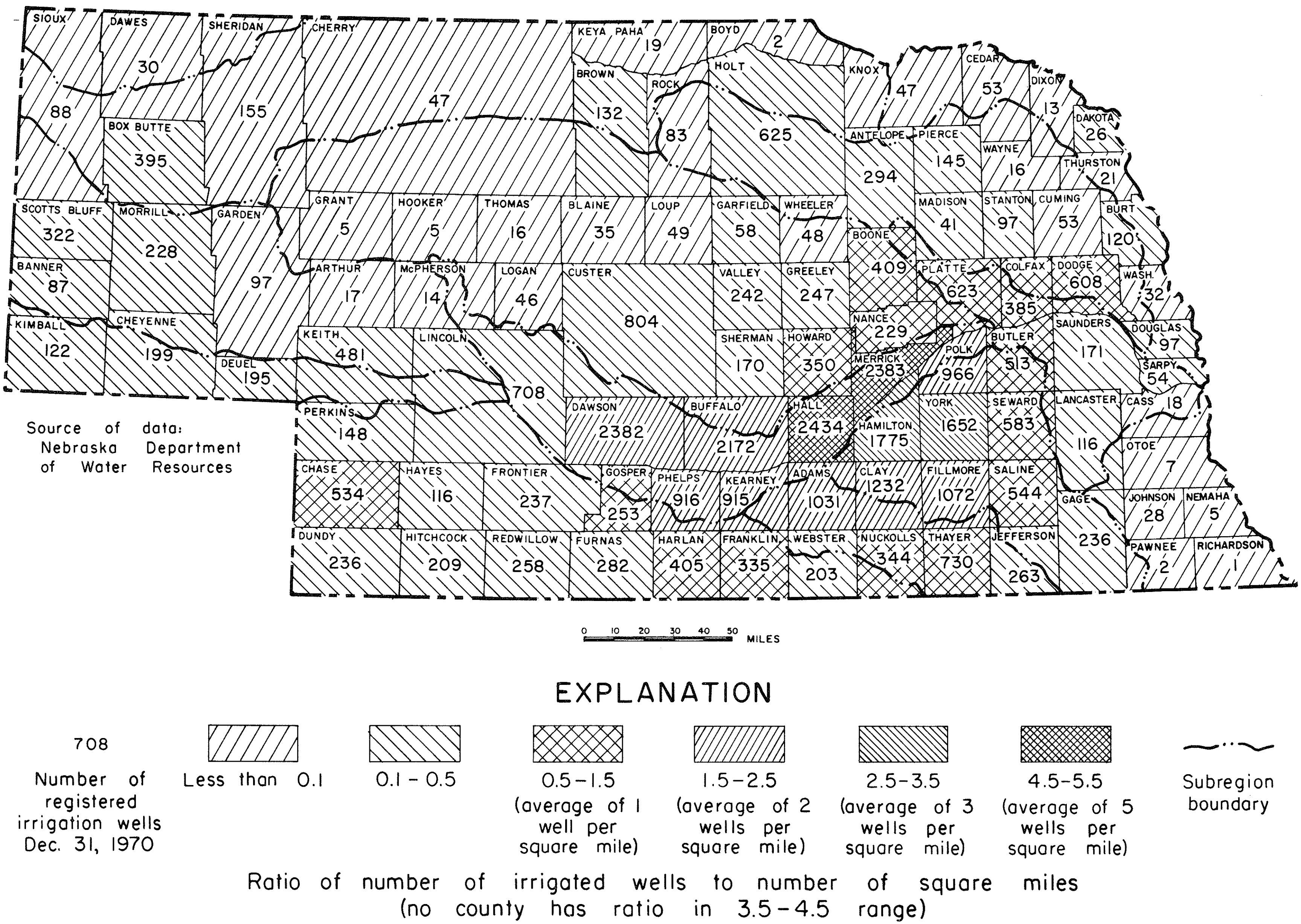

Figure 14.--Number and density of irrigation wells in each county, 1970.

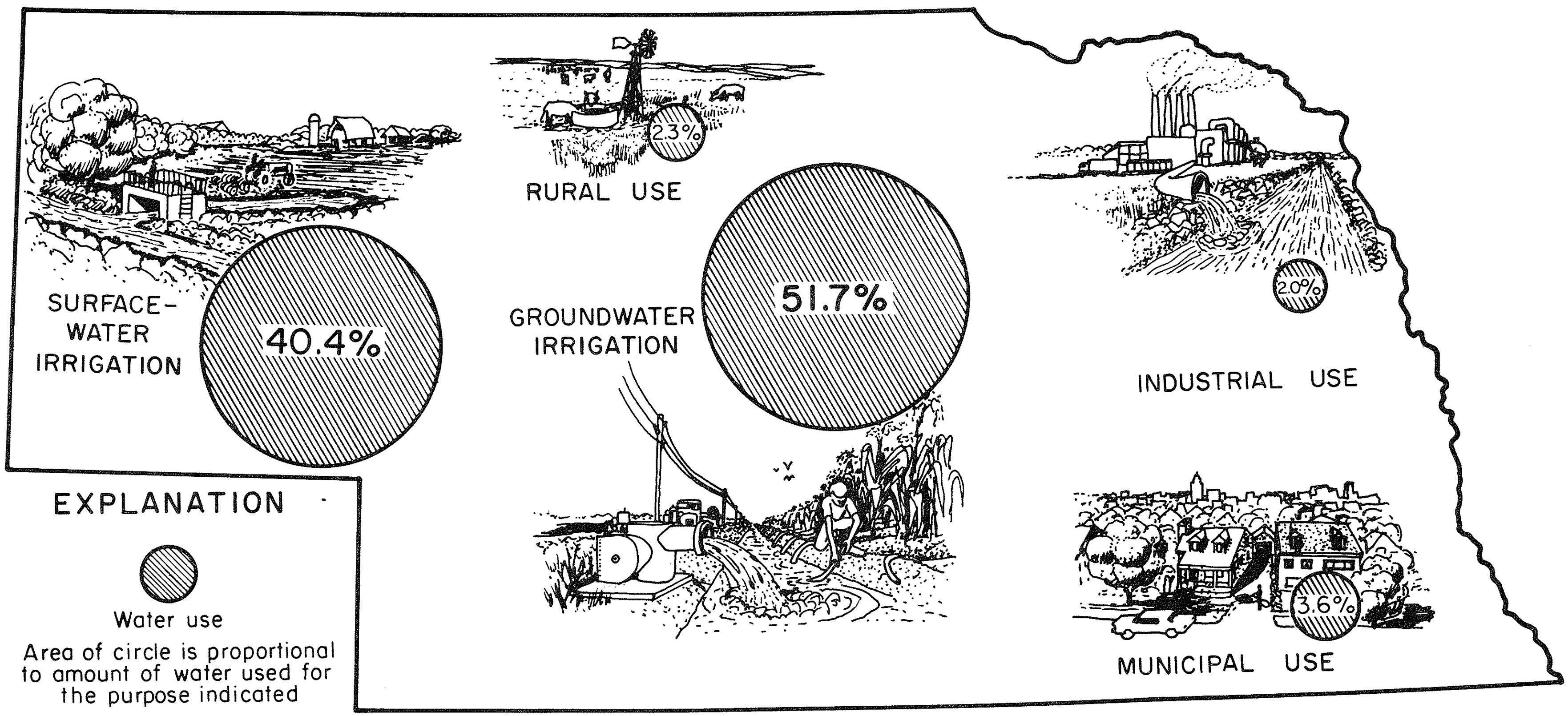

Figure 15.--Relative amounts of surface water and groundwater used for irrigation and amounts of rural, industrial, and municipal use, 1970.

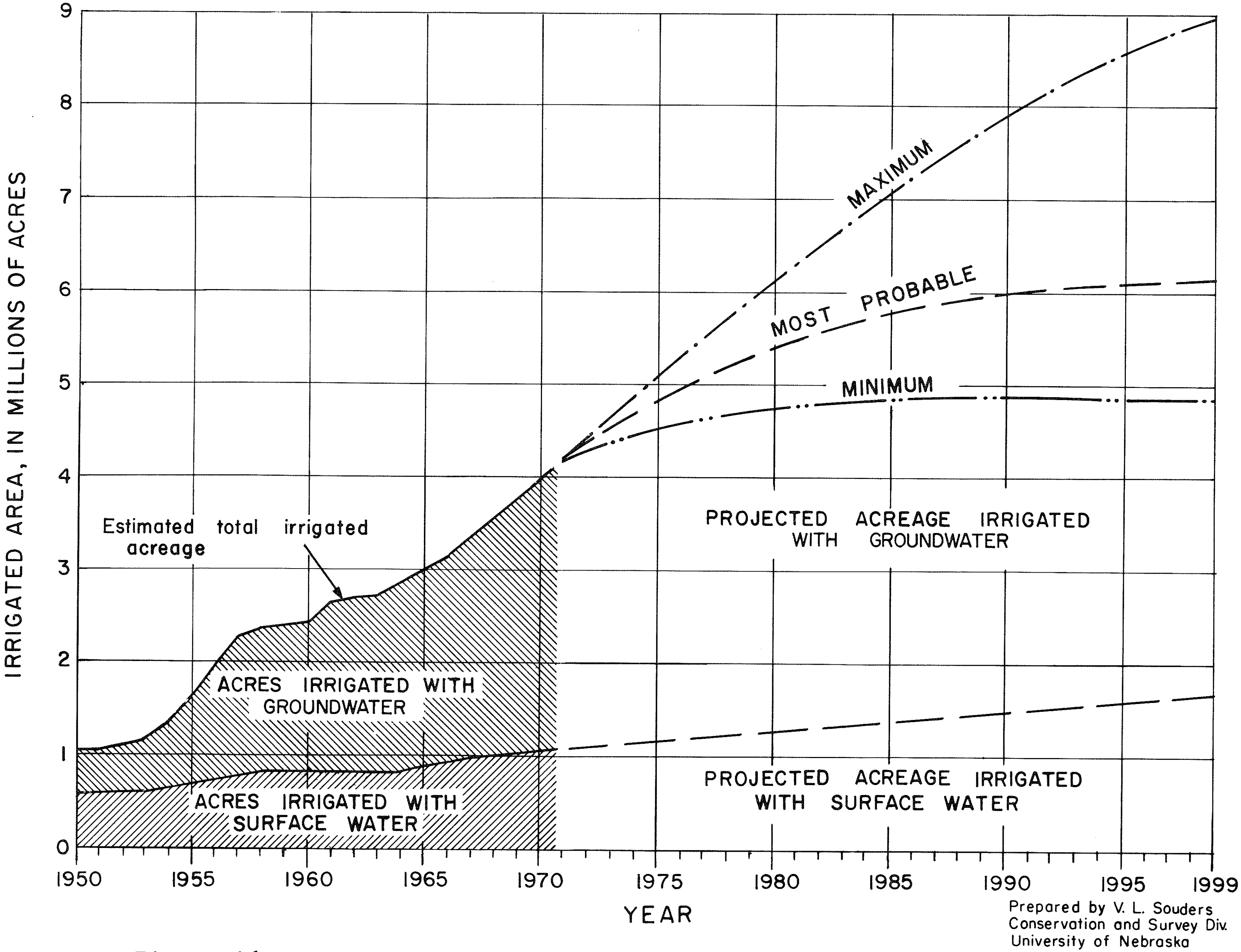

Figure 16.--Past, present, and projected irrigated area in Nebraska.

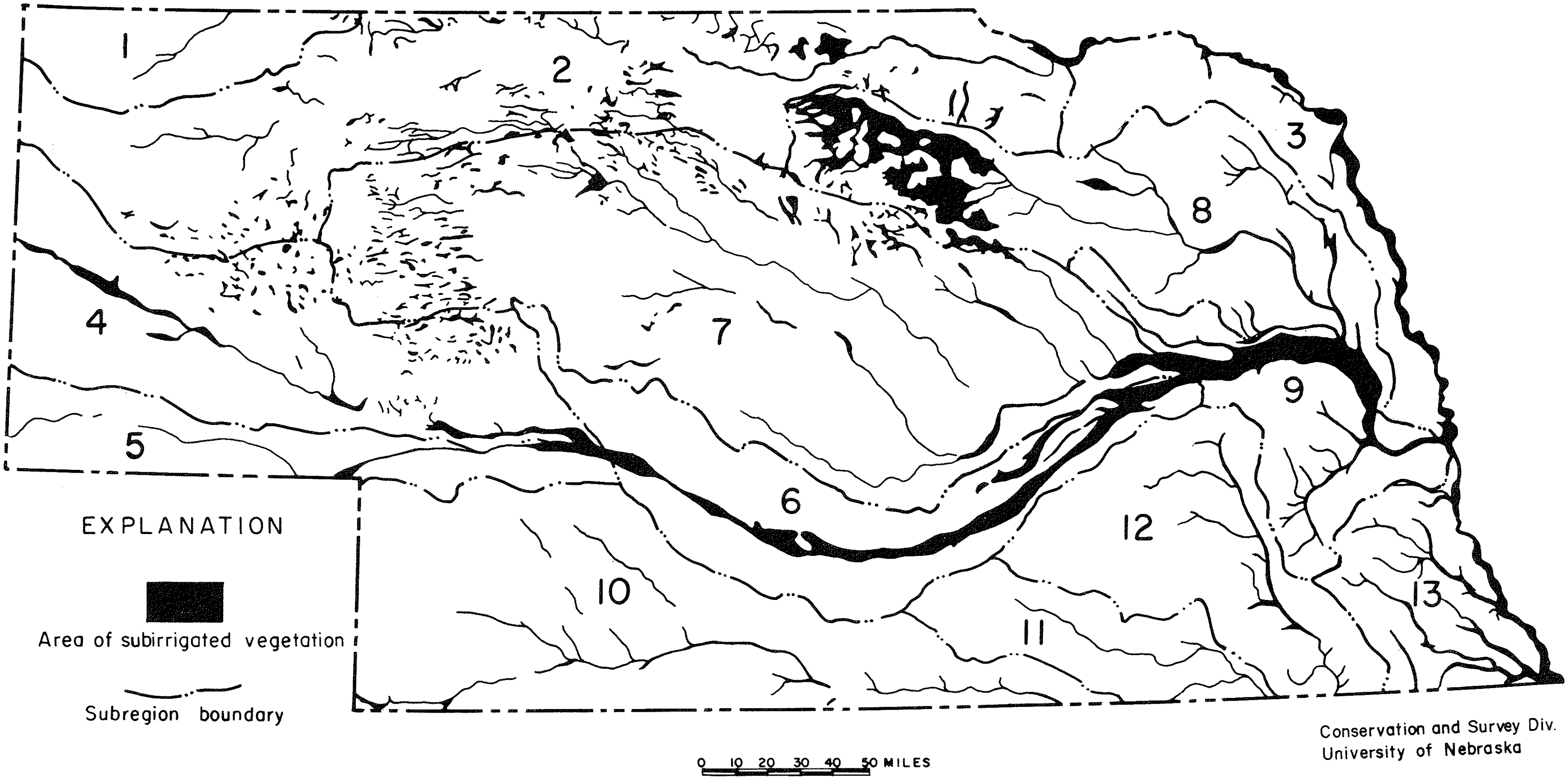

Figure 17.--Principal areas of subirrigated vegetation.

Evaporation From Exposed Water Surfaces

Although impounding water behind dams holds water back for a variety of uses, the stored water is subject to evaporation. The rate of water loss from a given reservoir depends on climatic conditions, which can change rapidly, and on surface area, which changes relatively slowly. The combined surface area of the large multiple-purpose reservoirs in the state ranges from about 76,000 acres (conservation pool stage) to 120,000 acres (maximum stage). In addition, there are about 46,200 small watershed reservoirs, farm ponds, and lakes. The combined surface areas of these, together with the surface area of streams having a width greater than one-eighth mile, is estimated at 459,000 acres.

Areas inundated through creation of surface reservoirs previously lost water through evapotranspiration. Therefore, a reasonable value for this evapotranspiration loss must be subtracted from the value for actual evaporation loss if the consumptive-use effects of surface impoundments are to be evaluated. These adjustments are made in table 7, which gives the estimated amount of additional consumptive use due to evaporation from reservoir surfaces for each subregion. Figure 18 is a graphical representation of the subregion amounts of evaporation from surface-water bodies in excess of the evapotranspiration that would have occurred if those exposed water surfaces did not exist. For the entire state, the amount is 1.13 million acre-feet, or an average 1.01 billion gallons per day.

Human Use

According to the 1970 census, the population of Nebraska is 1,483,791, a 5.1 percent increase from the population count recorded in the 1960 census. About 75 percent of the 1970 population is classed as urban, whereas 69 percent was so classed in 1960. Currently the urban population exceeds the rural in all subregions except 2 and 7 (fig. 19). Furthermore, the combined urban populations of subregions 3 and 9, which contain the two largest metropolitan areas, is almost as large as the combined urban population of all other subregions combined.

Water for human use includes all the water distributed through municipal-supply systems and all the water pumped from farm wells and used primarily for domestic purposes. If municipally supplied, water for human use includes much more than that used for drinking, cooking, sanitation, and other purposes in private residences and apartment houses. Among the other uses are the following: lawn and garden watering; car washing;

Table 7.--Evaporation from surface reservoirs

Subregion No.	Subregion Name	Values for Average annual evaporation from water surfaces[1/] Inches	Feet	Con sump-tive use 1970[2/] (feet)	Net evapora-tion[3/] (feet)
			(1)	(2)	(3)
1	White-Hat....................	44	3.67	1.25	2.42
2	Niobrara.....................	42	3.50	1.34	2.16
3	Missouri tributaries........	39	3.25	1.77	1.48
4	North Platte................	46	3.84	1.23	2.61
5	South Platte................	47	3.92	1.58	2.34
6	Middle Platte...............	48	4.00	1.91	2.09
7	Loup.........................	44	3.67	1.50	2.17
8	Elkhorn.....................	40	3.33	1.83	1.50
9	Lower Platte................	42	3.50	2.04	1.46
10	Republican..................	52	4.33	1.55	2.78
11	Little Blue.................	49	4.08	1.98	2.10
12	Big Blue....................	45	3.75	2.04	1.71
13	Nemaha......................	43	3.58	2.36	1.22

1/ Values from fig. 8.
2/ From area equivalent to combined reservoir surfaces, values from
3/ Column 1 minus column 2.
4/ Conservation pool.
5/ Column 3 times column 4.
6/ Column 3 times column 7.
7/ Column 5 plus column 8.
8/ Column 6 plus column 9.
(Surface area of small reservoirs, farm ponds and lakes furnished by

and other exposed water surfaces, 1970

Multiple-purpose reservoirs			Small reservoirs, farm ponds, lakes, and streams			Total net evaporation loss	
Surface area[4/] (thousands of acres)	Net evaporation loss		Surface area (thousands of acres)	Net evaporation loss			
	Thousands of acre-feet[5/]	Millions of gallons per day		Thousands of acre-feet[6/]	Millions of gallons per day	Thousands of acre-feet[7/]	Millions of gallons per day[8/]
(4)	(5)	(6)	(7)	(8)	(9)		
1.0	2.4	2.1	4.9	11.8	10.5	14.2	12.6
4.5	9.7	8.6	62.7	135.5	120.7	145.7	129.3
.0	.0	.0	25.3	37.4	33.3	37.4	33.3
35.5	92.6	82.5	54.1	141.0	125.6	233.6	208.1
5.1	11.9	10.6	11.9	27.8	24.8	39.7	35.4
3.0	6.3	5.6	75.4	157.5	140.5	163.8	146.1
2.8	6.1	5.4	100.9	219.0	195.3	225.1	200.7
.0	.0	.0	33.7	50.6	45.1	50.6	45.1
.9	1.3	1.2	29.6	43.2	38.5	44.5	39.7
23.3	64.8	57.8	15.2	42.2	37.6	107.0	95.4
.0	.0	.0	7.0	14.7	13.1	14.7	13.1
.0	.0	.0	14.5	24.7	22.0	24.7	22.0
.0	.0	.0	23.8	29.1	25.9	29.1	25.9

water supply-outflow analyses for subregions, p. 22 to 34.

the Soil Conservation Service.)

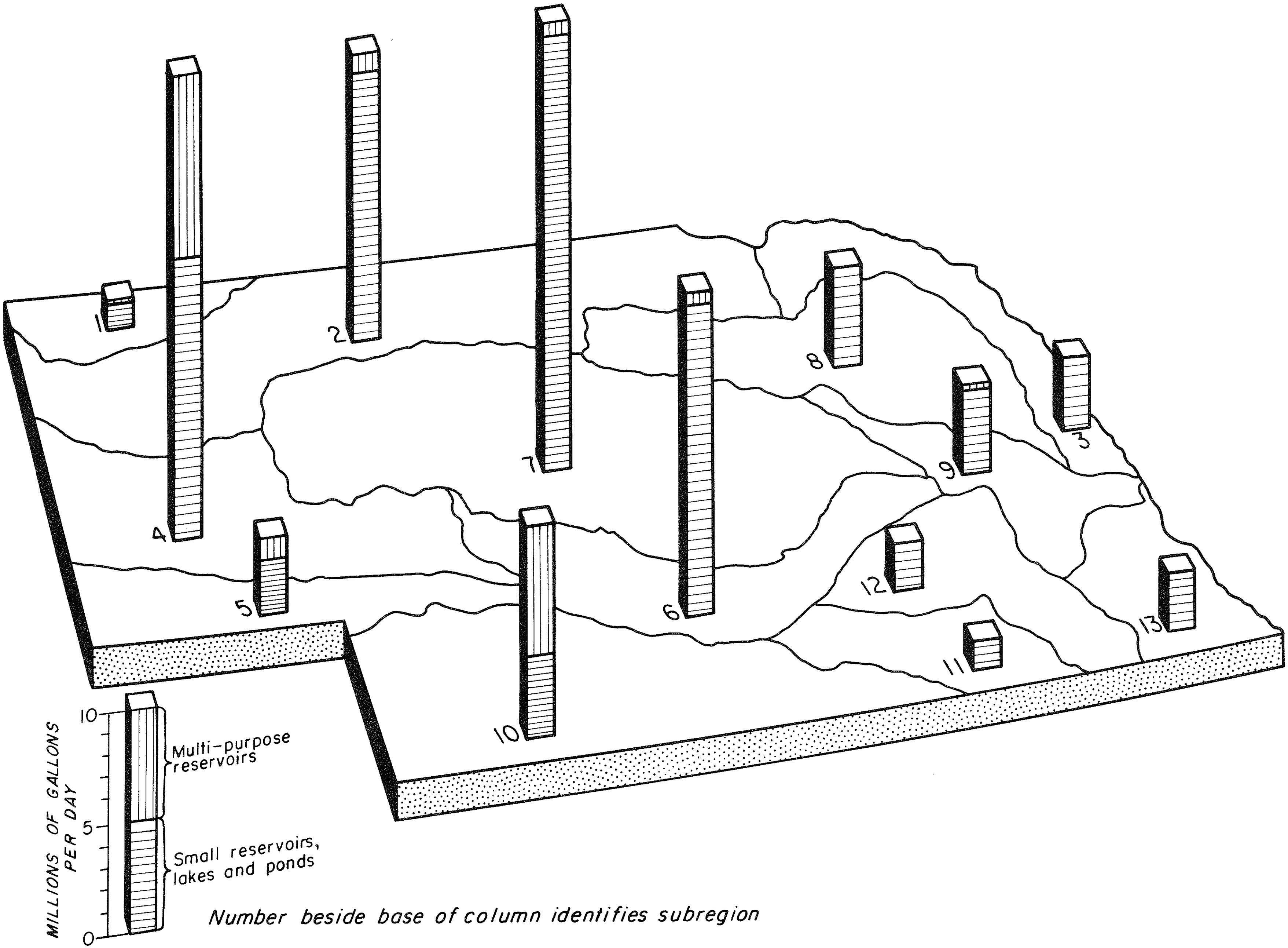

Figure 18.--Additional amounts of consumptive use due to evaporation from reservoirs.

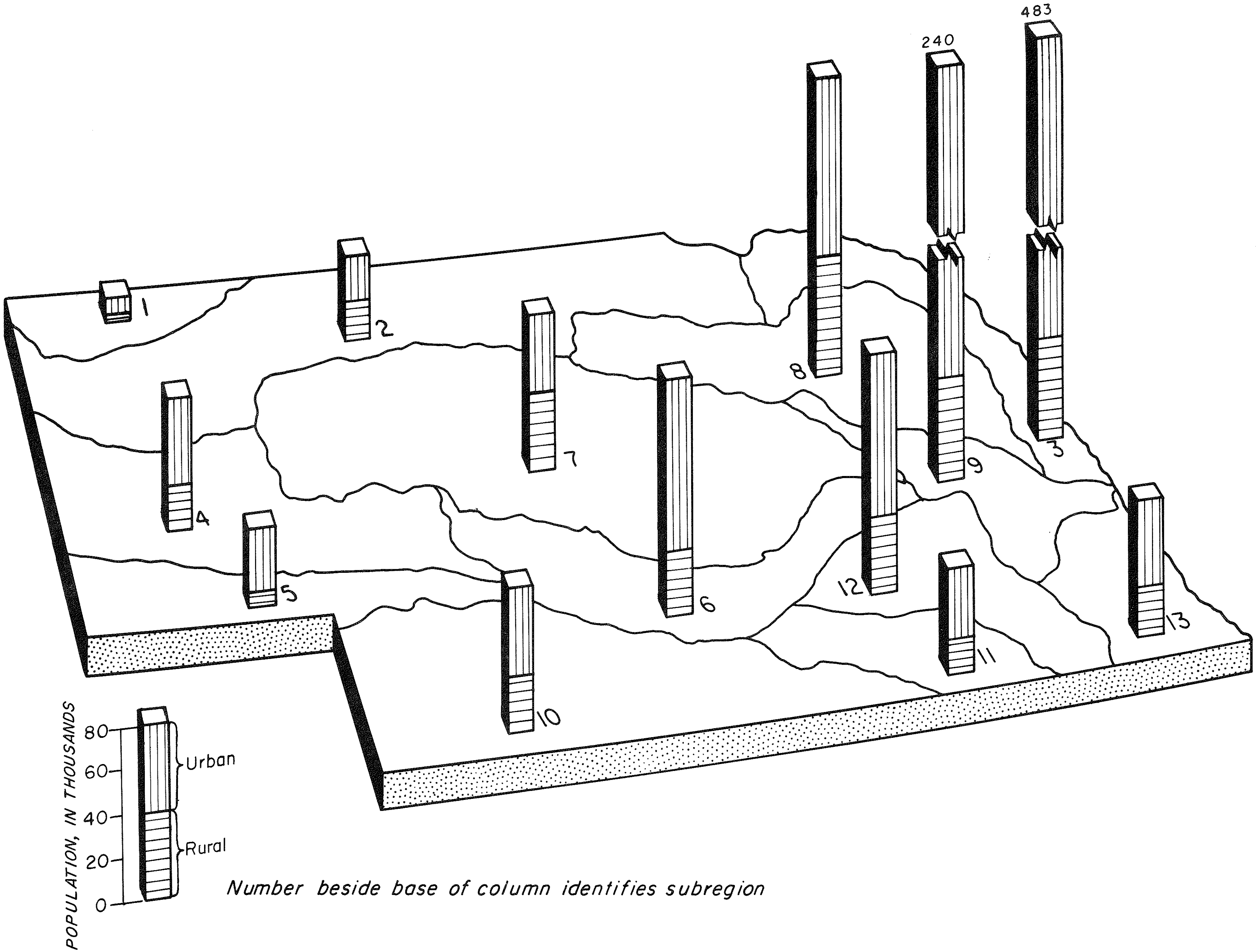

Figure 19.--Urban and rural populations in 13 subregions of Nebraska, 1970.

drinking and sanitation in stores, restaurants, other commercial establishments, and public buildings; fire fighting; street washing; filling and flushing swimmingpools; commercial laundering; industrial processing and manufacturing; and cooling at fuel-electric plants. As water distribution from most municipal plants is metered, the reported values for urban human use are relatively precise. On the other hand, water for rural domestic use must be estimated on the basis of rural population.

The urban population--1,119,300 persons in 1970--is served by 463 municipal supply systems. Total urban use in 1970 was 188 million gallons per day, which is equivalent to 210 thousand acre-feet for the year, and per capita use averages 168 gallons per day. About 82 percent of the total supply was pumped from wells, but because some of the principal municipal supply wells are located near a stream, part of the water pumped was induced seepage from stream flow. Hence, some of the municipal pumpage is derived from the annual supply rather than all from the stored supply. Lincoln, population 149,518, is the largest city obtaining all of its water supplies from wells. Most comes from a well field in the Platte River valley near Ashland, but a few wells located within Lincoln city limits are pumped to meet peak demands. Omaha, population 359,000, formerly derived all its supply from the Missouri River but now obtains about 40 percent of its supply from wells along the Platte River 4.5 to 6 miles upstream from the river's mouth. The community of Long Pine, population 363, obtains its water supply from springs along Long Pine Creek. Crawford, population 1,300, is the only community obtaining its entire supply from a surface-water source. Urban use in the 13 subregions during water year 1970 is shown in table 8.

Table 8.--Urban water use, 1970

Subregion		Quantity	
No.	Name	Thousands of acre-feet	Millions of gallons per day
1	White-Hat	1.2	1.1
2	Niobrara	4.3	3.8
3	Missouri tributaries	77.8	69.5
4	North Platte	9.3	8.3
5	South Platte	6.0	5.4
6	Middle Platte	22.6	20.2
7	Loup	5.2	4.6
8	Elkhorn	16.0	14.3
9	Lower Platte	34.2	30.5
10	Republican	8.0	7.1
11	Little Blue	6.8	6.1
12	Big Blue	12.4	11.1
13	Nemaha	6.6	5.9

Rural use of water, exclusive of irrigation supplies, is for domestic purposes and watering of livestock. All domestic supplies and most livestock supplies are obtained from wells and thus are withdrawn from storage. Livestock supplies exceed rural domestic use by factors ranging from 2.4 to 9.5 in the various subregions, as shown in table 9 and by figure 20.

Table 9.--Rural domestic and livestock use, 1970

Subregion		Quantity for domestic purposes		Quantity for watering livestock	
No.	Name	Thousands of acre-feet	Millions of gallons per day	Thousands of acre-feet	Millions of gallons per day
1	White-Hat	0.2	0.2	1.3	1.2
2	Niobrara	1.2	1.1	11.8	10.5
3	Missouri tributaries	3.1	2.8	9.4	8.4
4	North Platte	1.3	1.2	6.3	5.6
5	South Platte	.4	.4	1.9	1.7
6	Middle Platte	2.0	1.8	10.9	9.7
7	Loup	2.5	2.2	19.9	17.8
8	Elkhorn	3.7	3.3	10.4	9.3
9	Lower Platte	3.1	2.8	7.6	6.8
10	Republican	1.7	1.5	10.5	9.4
11	Little Blue	1.0	.9	4.7	4.2
12	Big Blue	2.5	2.2	9.9	8.8
13	Nemaha	1.5	1.3	6.3	5.6

Industrial Use

Several important industrial and commercial water users have their own source of supply and the volume of water used by them is not included in any water-use values already given. Such usage, exclusive of water used for cooling at the major fuel-electric power plants or for generation of electricity at hydroelectric plants, was as follows: 7.4 mgd (million gallons per day) for injection in secondary recovery of oil (subregions 4, 5, and 10); 16.0 mgd for processing sugar beets by Great Western Sugar Co. (subregion 4); 21.0 mgd in manufacture of chemicals by Allied Chemical Co. (subregion 9); and 1.7 mgd for various purposes at State institutions (mostly in subregion 9). Other usage, including water needed for commercial food processing and small self-supplies industries, is estimated at 55.2 mgd. Thus, total water used by self-supplied industries in water year 1970 amounted to about 101.3 mgd, or 90.6 thousand acre-feet per year. All this water is obtained from wells. However, not all the pumpage is derived from the stored supply because many of the wells are

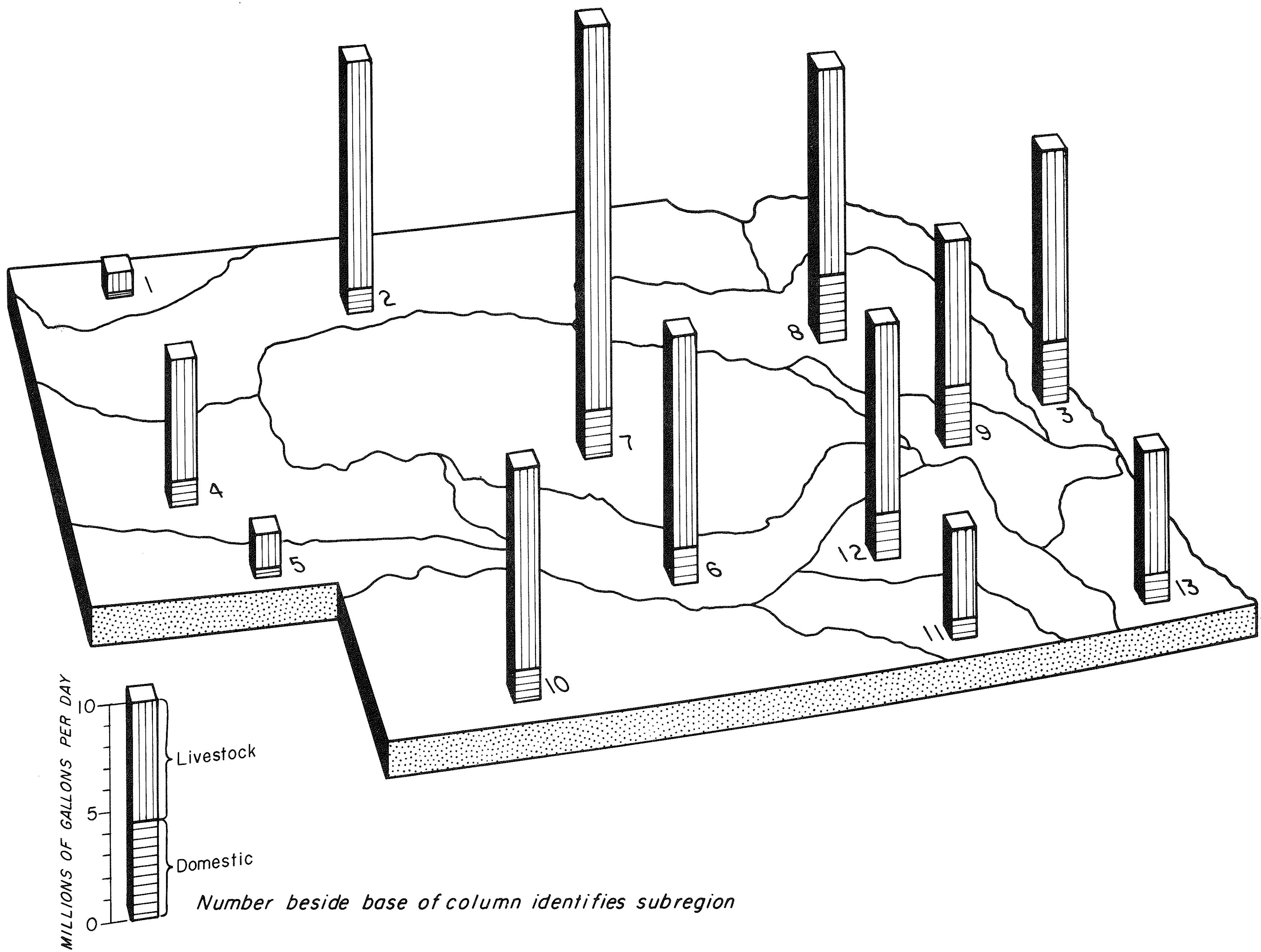

Figure 20.--Rural water use for domestic purposes and watering of livestock in 13 subregions of Nebraska, 1970.

located in valleys where water yielded by wells ordinarily is derived, at least in part, from the annual supply.

The quantity of water used for cooling at fuel-electric power plants in 1970 amounted to 878.5 mgd, or 984 thousand acre-feet per year. Fuel-electric plants in Omaha (subregion 3) obtain 526.9 mgd direct from the Missouri River and 9.2 mgd from wells and all the return water is discharged to the Missouri River. The 74.0 mgd used at the Canady Stream Plant of the Central Nebraska Public Power and Irrigation District (subregion 6) is derived from and returned to the District's supply canal. All the 143.5 mgd of cooling water used at the Hallam Plant of the Consumers Public Power District is pumped from wells and the return is held in ponds before it is discharged to Olive Branch, a tributary of Salt Creek in subregion 9. The remaining 124.9 mgd is the combined usage of the smaller self-supplied fuel-electric plants and is derived entirely from groundwater sources. Thus, part of the water used for cooling at fuel-electric power plants is derived from the stored supply and most of the water thus obtained becomes an addition to streamflow. Because only a small fraction of the cooling water is vaporized, this usage is not regarded as consumptive. The amount of water used for cooling at fuel-electric power plants is given in table 10 for each subregion.

Table 10.—Use of water for cooling at fuel-electric power plants, 1970

Subregion		Surface water		Ground water	
No.	Name	Thousands of acre-feet	Millions of gallons per day	Thousands of acre-feet	Millions of gallons per day
1	White-Hat	0.0	0.0	0.0	0.0
2	Niobrara	.0	.0	.0	.0
3	Missouri tributaries	590.0	526.9	10.3	9.2
4	North Platte	.0	.0	27.8	24.8
5	South Platte	.0	.0	4.4	3.9
6	Middle Platte	82.9	74.0	38.9	31.2
7	Loup	.0	.0	.0	.0
8	Elkhorn	.0	.0	.0	.0
9	Lower Platte	.0	.0	198.4	177.2
10	Republican	.0	.0	.0	.0
11	Little Blue	7.2	6.4	.0	.0
12	Big Blue	.0	.0	23.3	20.8
13	Nemaha	.0	.0	4.6	4.1

Water used to generate electricity at 20 hydroelectric plants in Nebraska exceeds the combined usage of water for all other purposes. It would be a wholly nonconsumptive use if not for the relatively small loss of water by evaporation from storage reservoirs (already evaluated). Considerable reuse of water is involved as more than one hydroelectric plant may be situated on the same stream and the water used at an upstream plant may be used again at downstream plants. Furthermore, return flows from other uses are included in the amounts reported here as used by hydroelectric plants, and the water so used is available for any of a variety of uses downstream from the plants. Total usage, including reuse, amounted to nearly 8.7 million acre-feet, or about 7,800 mgd, which is more than the total outflow from the state in water year 1970. Excluding reuse, only 3.1 million acre-feet was used, which means that a little more than half of the outflow in water year 1970 was used at least once for generation of hydroelectric power. The hydroelectric plants are located in 6 of the 13 subregions, as shown in table 11.

Summary

The amounts of water used for various purposes in the 13 subregions are recapitulated in table 12 and graphically portrayed in figures 21 and 22. Figure 21 shows amounts of surface-water and groundwater use as given in columns 12 and 13 of the table--that is, exclusive of evaporation from reservoirs and amounts passing through hydroelectric plants. The diagrams in figure 22 show total water-use amounts regardless of source and illustrates the relative amount utilized by hydroelectric plants. In both figures the size of the individual pie diagram is proportional to the total quantity of water used as indicated by the numerical value beneath each diagram.

Subregion 4 (North Platte) is outstanding for its large use of surface water, mostly for irrigation. Other subregions in which use of surface water for irrigation is considerable are 6 (Middle Platte), 7 (Loup), and 10 (Republican). The rather large use of surface water in subregion 3 (Missouri tributaries) is for cooling at fuel-electric power plants, a use that is largely nonconsumptive. Subregions 2 (Niobrara), 7 (Loup), 8 (Elkhorn), and 9 (lower Platte) have considerable potential for additional development of their surface-water supply. Of these, subregion 9 stands out for its extremely large potential, as outflow from it far exceeds that of any other subregion.

Subregions 6 (Middle Platte) and 12 (Big Blue) lead all the others in groundwater use. In subregion 6, withdrawals from the stored supply are largely replaced from the annual supply and, because of this interchange, the groundwater resource is little depleted. In subregion 12, however, withdrawals are replaced in only small measure from the annual supply, and the prospect is for progressive diminution of the resource.

Table 11.--Use of water for generation of hydroelectric power, 1970

Subregion		Source of water	Plant or site name	Amount of water used	
No.	Name			Thousands of acre-feet	Millions of gallons per day
2	Niobrara..........	Minnechaduza Creek......	Valentine.....	21	19
		Niobrara River..........	....do........	517	462
		.....do................	Spencer.......	914	816
5	South Platte......	North Platte and South Platte Rivers.........	Sutherland....	953	851
6	Middle Platte.....	Platte River............	Jeffrey.......	1,318	1,177
		.....do................	Gothenburg....	61	54
		.....do................	Johnson No. 1.	966	863
		.....do................	Johnson No. 2.	966	863
		.....do................	Kearney.......	77	69
7	Loup.............	Cedar River.............	Erickson......	80	71
		.....do................	Spalding......	99	88
		Middle Loup River.......	Boelus........	445	397
		Loup River..............	Monroe........	964	861
		.....do................	Columbus......	964	861
8	Elkhorn..........	North Fork Elkhorn River.................	Norfolk.......	33	29
12	Big Blue.........	Big Blue River..........	Wilber........	46	41
		.....do................	DeWitt........	46	41
		.....do................	Holmesville...	60	54
		.....do................	Blue Springs..	60	54
		.....do................	Barneston.....	96	86

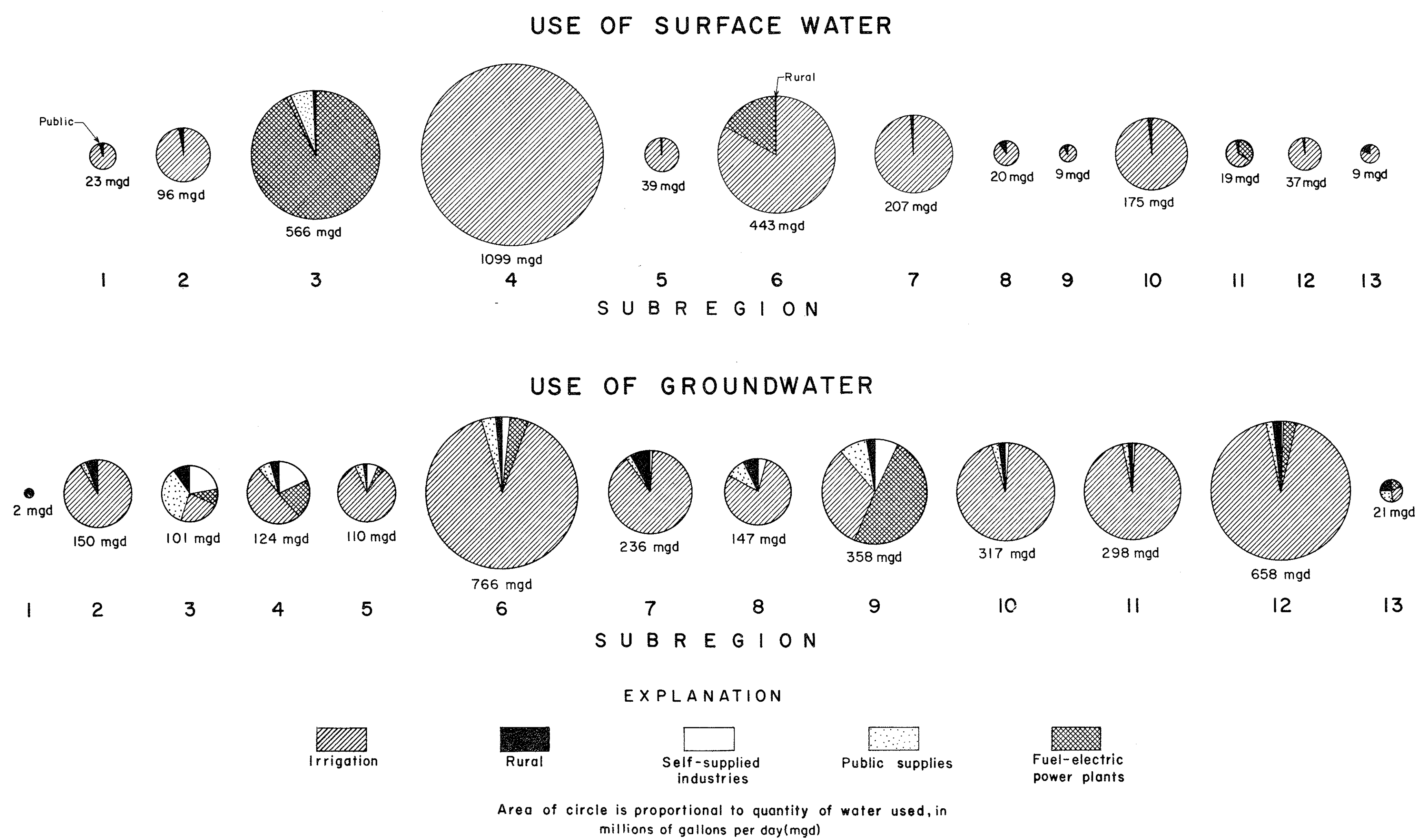

Figure 21.--Relative amounts of surface water and groundwater used for different purposes (exclusive of amount evaporated from open water surfaces and amount used for generation of hydroelectric power) in 13 subregions of Nebraska, 1970.

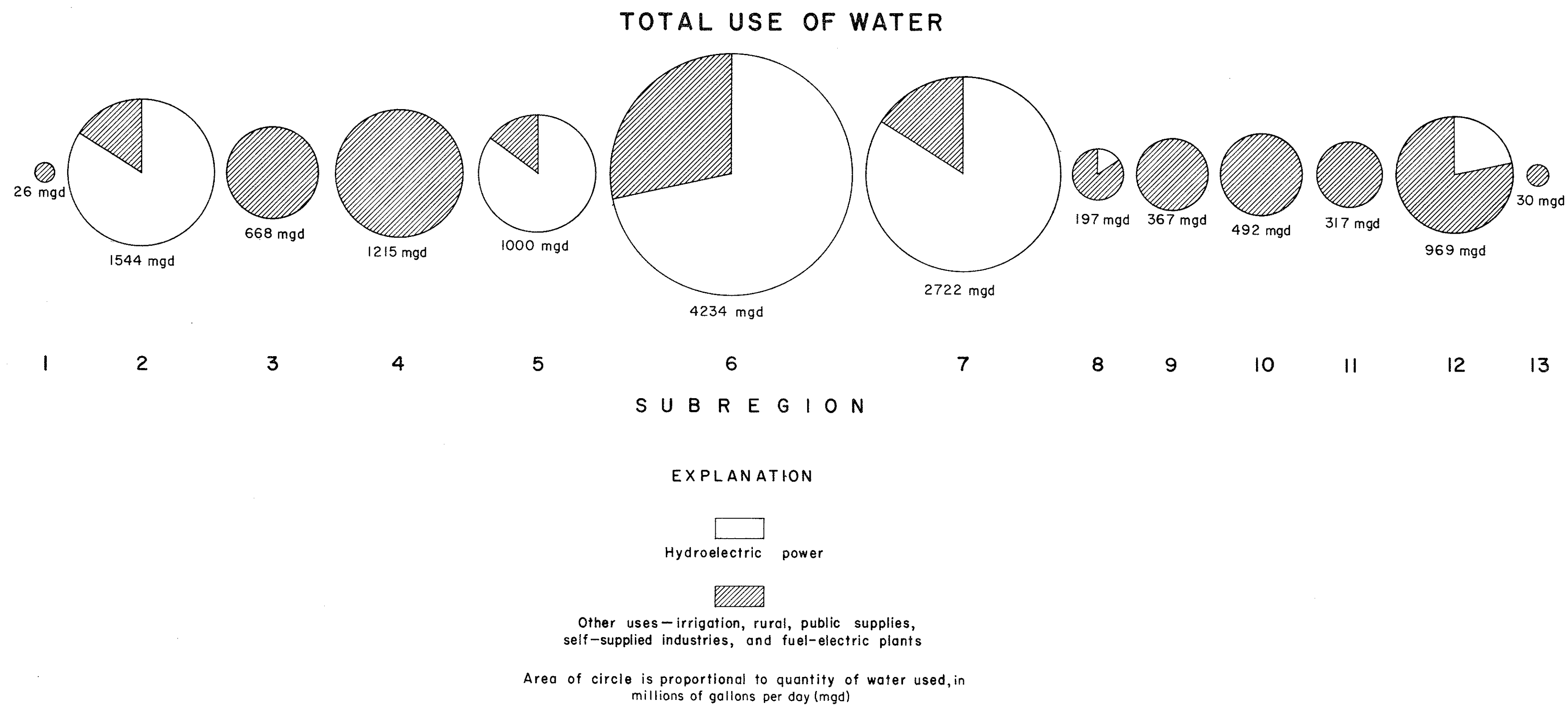

Figure 22.--Relative amounts of water used for generation of hydroelectric power and for all other uses combined in 13 subregions of Nebraska, 1970.

Table 12.--Summary

[Units of measurement: Millions of gallons per day in

Subregion		Irrigation[1]		Net evaporation from reservoirs and lakes	Municipalities[2]		Rural domestic and livestock	
No.	Name	Surface water	Ground-water		Surface water	Ground-water	Surface water	Ground-water
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	White-Hat...........	22.5	0.9	12.6	0.2	0.9	0.7	0.7
2	Niobrara............	93.8	137.7	129.3	.0	3.8	2.6	9.0
3	Missouri tributaries.......	5.4	23.6	33.3	33.8	35.7	1.8	9.4
4	North Platte........	1,090.0	63.1	208.1	.0	8.3	1.1	5.7
5	South Platte........	38.8	92.4	35.4	.0	5.4	.3	1.8
6	Middle Platte.......	367.4	691.4	146.1	.0	20.2	1.4	10.1
7	Loup................	205.4	212.5	200.7	.0	4.6	1.8	18.2
8	Elkhorn.............	18.2	115.7	45.1	.0	14.3	1.9	10.7
9	Lower Platte........	8.6	116.1	39.7	.0	30.5	.7	8.9
10	Republican..........	172.1	301.7	95.4	.0	7.1	3.3	7.6
11	Little Blue.........	11.9	286.4	13.1	.0	6.1	.6	4.5
12	Big Blue............	36.0	611.6	22.0	.0	11.1	.9	10.1
13	Nemaha..............	6.9	5.9	25.9	.0	5.9	1.7	5.2
	Entire state....	2,077.0	2,659.0	1,006.7	34.0	153.9	18.8	101.9

1/ Conveyance losses included.
2/ Includes some commercial and industrial uses.

of water use, 1970

columns 1 through 13; gallons per day in columns 15 through 17

Self-supplied industries (ground-water only)	Fuel-electric power plants		Hydro-electric power plants	Total use (exclusive of columns 3 and 11)		Population (thousands)	Per capita use (exclusive of columns 3 and 11)		
	Surface water	Ground-water		Surface water	Ground-water		Surface water	Ground-water	Total
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
0.0	0.0	0.0	0	23.4	2.5	10.0	2,340	250	2,590
.0	.0	.0	1,297	96.4	150.5	40.3	2,392	3,734	6,126
22.7	526.9	9.2	0	567.9	100.6	483.1	1,176	208	1,384
22.4	.0	24.8	0	1,091.1	124.3	61.1	17,880	2,030	19,910
6.3	.0	3.9	851	39.1	109.8	37.1	1,054	2,960	4,014
12.7	74.0	31.2	3,026	442.8	765.6	109.7	4,036	6,970	11,006
.3	.0	.0	2,279	207.2	235.6	73.0	2,838	3,230	6,068
5.9	.0	.0	30	20.1	146.6	137.8	146	1,065	1,211
25.4	.0	177.2	0	9.3	358.1	240.4	39	1,487	1,526
.2	.0	.0	0	175.4	316.6	67.3	2,606	4,700	7,306
1.5	6.4	.0	0	18.9	298.5	49.5	382	6,040	6,422
3.9	.0	20.8	275	36.9	657.5	111.2	332	5,920	6,252
.0	.0	4.1	0	8.6	21.1	63.2	136	334	470
101.3	607.3	271.2	7,758	2,737.1	3,287.3	1,483.7	1,845	2,215	4,060

The northwestern half of subregion 7 and relatively small parts of the adjoining subregions 2 (Niobrara) and 7 (Elkhorn) constitute the Sand Hills region of Nebraska and is purported to have a tremendous potential for development of its groundwater resource. In this region, much water is consumed annually by evapotranspiration from subirrigated native vegetation. Pumping from wells would not only salvage some of this loss but would also create additional storage space for a larger fraction of the annual supply.

The diagrams that include reservoir evaporation and amounts used for generation of hydroelectric power (fig. 22) show that in subregions 2 (Niobrara), 5 (South Platte), 6 (Middle Platte), and 7 (Loup) the amounts used for power generation far exceed all other uses of surface water and groundwater combined.

Per capita use, computed from the values in columns 1, 2, and 4 through 10 in table 12 and plotted in figure 23, averages nearly 20,000 gallons per day in subregion 4 (North Platte); 11,000 gallons per day in subregion 6 (Middle Platte); and more than 6,000 gallons per day in subregions 2 (Niobrara), 7 (Loup), 10 (Republican), 11 (Little Blue) and 12 (Big Blue). For the state as a whole, per capita use averages about 4,000 gallons per day. However, urban per capita use for domestic, municipal, and such commercial and industrial needs as are supplied from public supply systems is only 168 gallons per day. Rural per capita use for domestic purposes is an even smaller value.

CONCLUSION

Water available for use in Nebraska during water year 1970 consisted of precipitation and inflow during that year, and holdover storage of precipitation and inflow during past years. Lakes and surface reservoirs, soil moisture, and groundwater in the state at the beginning of the water year constitute the holdover storage. Some of the precipitation evaporated before any beneficial use could be made of it, some infiltrated the soil, and some flowed overland to streams. Of the part infiltrating the soil, most was either evaporated or used by vegetation; a small fraction remained as soil moisture at the end of the year or was added to groundwater storage during the year. Stream inflow to the state was augmented by the overland runoff from precipitation and by natural seepage from groundwater storage. Of the water that became streamflow, part was used consumptively, part was used nonconsumptively, and part was unused. Except for water impounded in surface reservoirs, for water evaporated from stream surfaces and for seepage into streambeds, streamflow not used consumptively was lost to the state as outflow. Groundwater storage was depleted during the year by evapotranspiration in areas of subirrigated

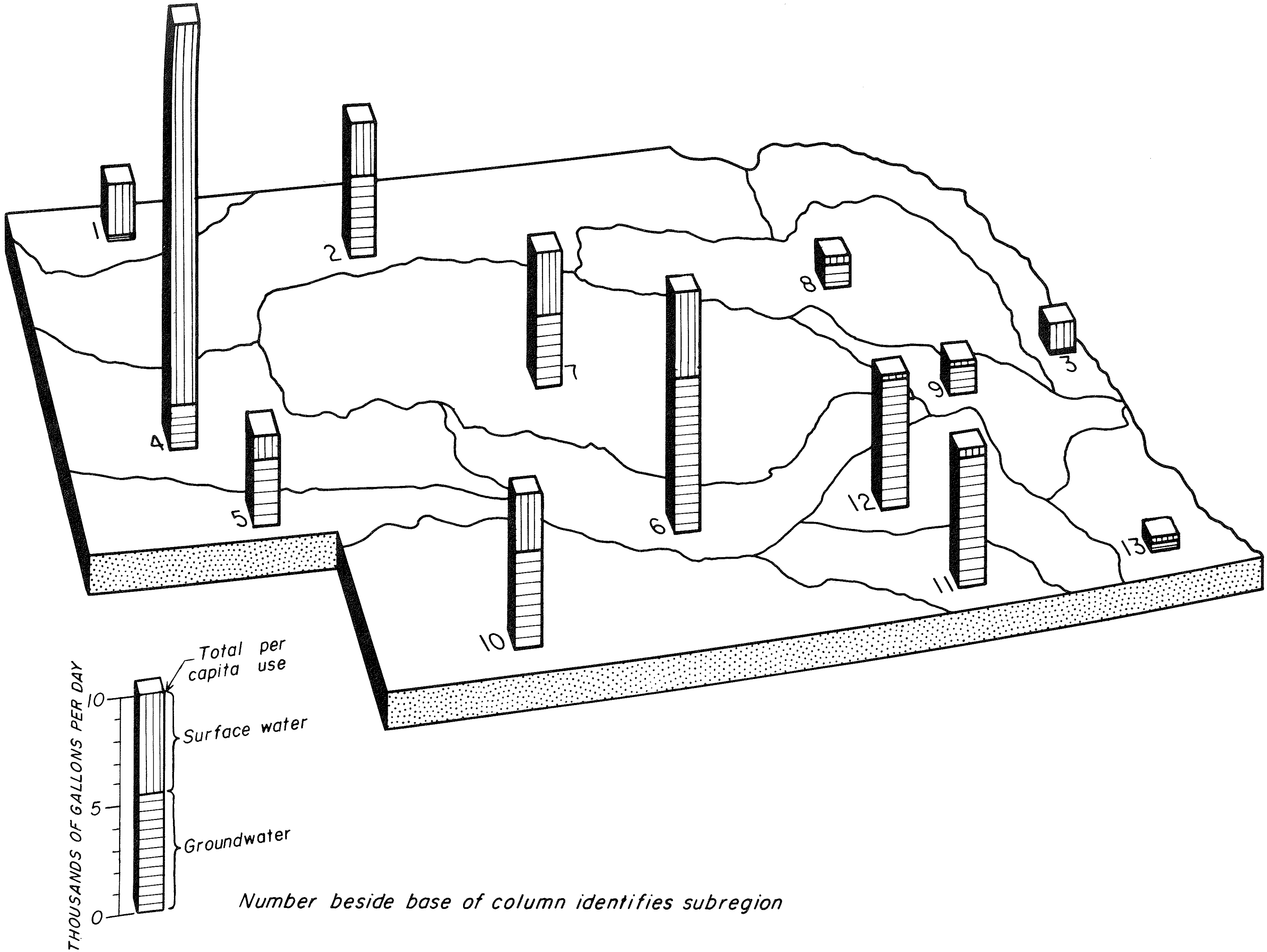

Figure 23.--Per capita use of surface water and groundwater in 13 subregions of Nebraska, 1970.

vegetation, by outflow into stream channels and by pumping from wells. However, the quantity of groundwater still in storage at the year's end was many times greater than the combined quantities lost. Of the consumptive usage resulting from man's activities, considerably more than half was derived from holdover storage and the remainder from the annual supply.

In water year 1970 about 5.3 million acre-feet--2.3 million acre-feet of surface water and 3.0 million acre-feet of groundwater--was used for irrigation. This amount was 1.3 million acre-feet more than in 1964, the year for which a similar inventory of water was made. This increase was due largely to greater use of groundwater. Reservoir losses were an estimated 1.1 million acre-feet, which is five times the estimated value for 1964. Although a small part of this large difference is due to an increase in extent of open water, the greater part is due to the availability of more accurate information on which to base the estimate for 1970. Use of water supplied by municipalities averaged 187.9 mgd, an increase of 12 mgd over 1964, and water for rural domestic and livestock use was an estimated 121 mgd, an increase of 21 mgd over 1964. A large part of the increase in urban use was due to the greater amount of water used for air conditioning and for sprinkling lawns during the drier and warmer summer of 1970 compared to 1964. Self-supplied industries used 101 mgd, a 150 percent increase over 1964. Greater pumpage at the Allied Chemical Plant plus pumpage by several new industries account for most of this large increase. Reported use of water for cooling at fuel-electric plants was 879 mgd, an increase of 187 mgd over that reported in 1964. Usage of water for generation of electric power at hydroelectric plants was 7,758 mgd, or slightly less than in 1964.

Water use totaled about 14.8 billion gallons per day (16.5 million acre-feet) in water year 1970 for the state of Nebraska.

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