Appendix B

Western Regional Water Characteristics

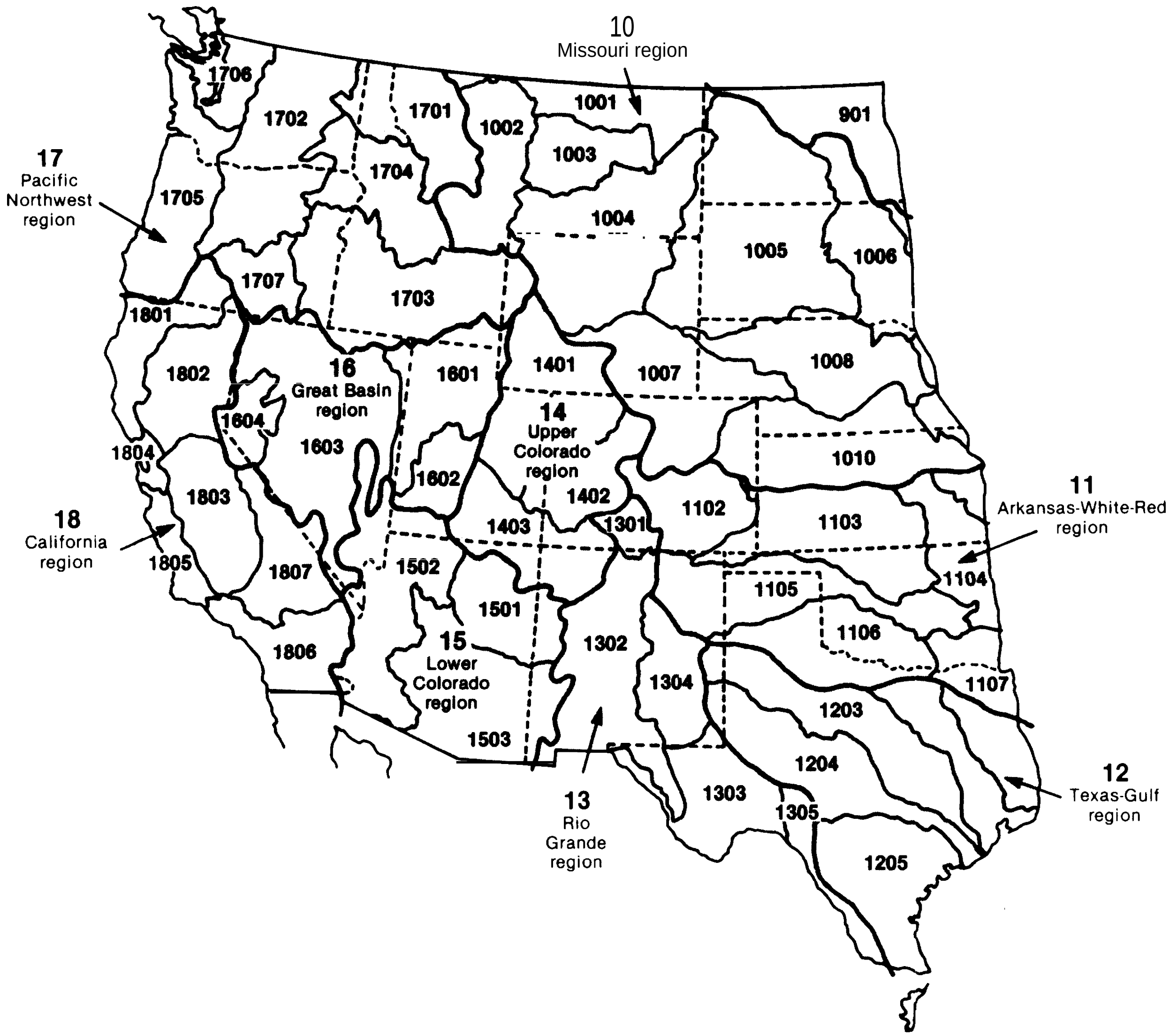
NOTE: This appendix presents in more detail the data on which **chapters** III and X have been based. The data are presented primarily in graphical and tabular form, designed generally to supplement the discussion of the water supply/use relationships of the Western United States with specific data or discussions related to each of the surface- and ground-water resource regions of the area. The main source for the surface water section of this appendix is the Second National Water Assessment (5). One of the primary difficulties in assessing a water-related problem in the Western United States today lies in the often incompatible data bases used to describe water supply/demand relationships in the region. Where such discrepancies are noted in this appendix, the reader is referred to the original publications from which the data were obtained.

The Water Resources Regions of the Western United States With Water Supply/Use Patterns for Selected Subregions

The fundamental hydrologic unit is the river basin. The United States was subdivided into 21 major water geographic units based on river basins in 1970 by the U.S. Water Resources Council. Hydrologic data are collected and organized according to these units, which are: 1) regions, 2) subregions, 3) accounting units, and 4) cataloging units. These hydrologic areas contain either the drainage area of a major river, such as the Missouri region, or the combined drainage areas of a series of rivers, such as the Texas-Gulf region. The second level of classification, the subregion, contains either an area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin, or a group of streams forming a coastal drainage area. All subregional boundaries are hydrologic except where discontinued at international boundaries. For the purposes of this discussion, only the region and subregion categories will be used. The subregion classification is that used in the Second National Water Assessment (5). This differs somewhat from the accounting units of the USGS which are also hydrologically defined.

The 17 Western States have been divided into nine water resources regions, containing 52 subregions (fig. B-l). There are wide variations among these water resources regions in the spatial and temporal availability of water and in the uses of that water (figs. B-2, B-3, B-4, B-5).

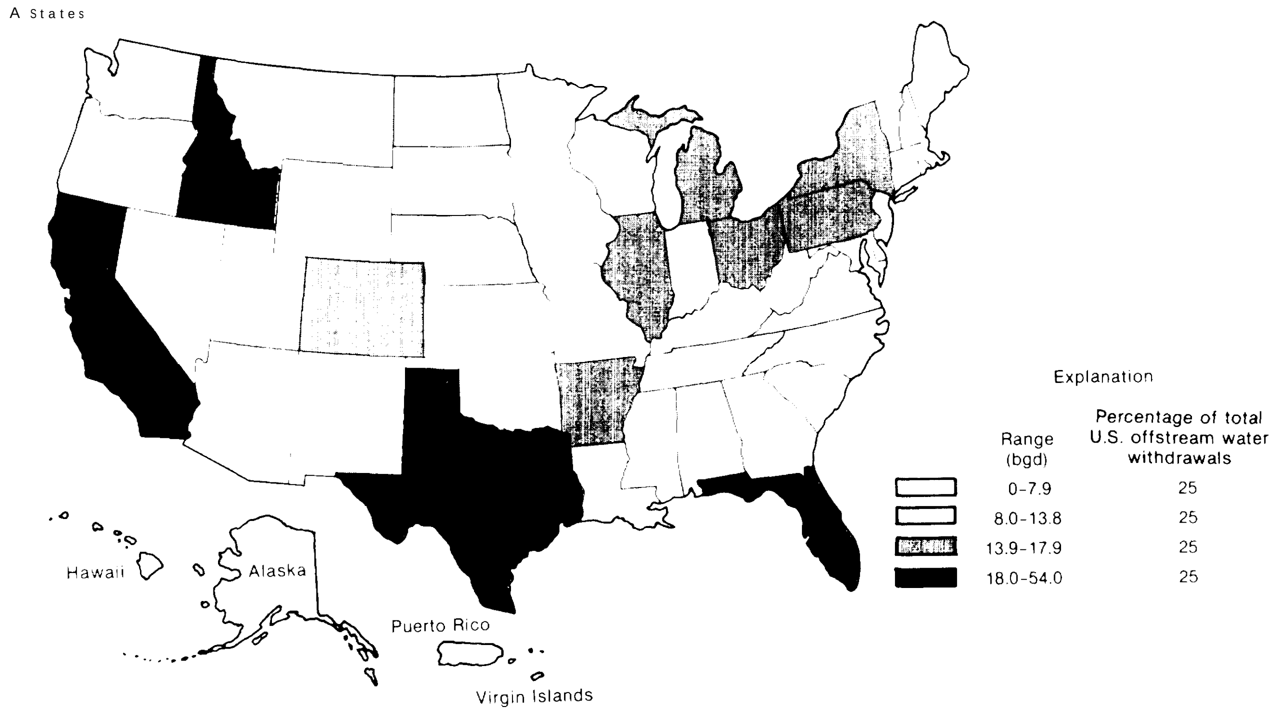
Figure B-1 .—Water Resources Regions and Subregions of the Arid and Semiarid Portions ‘of the United States

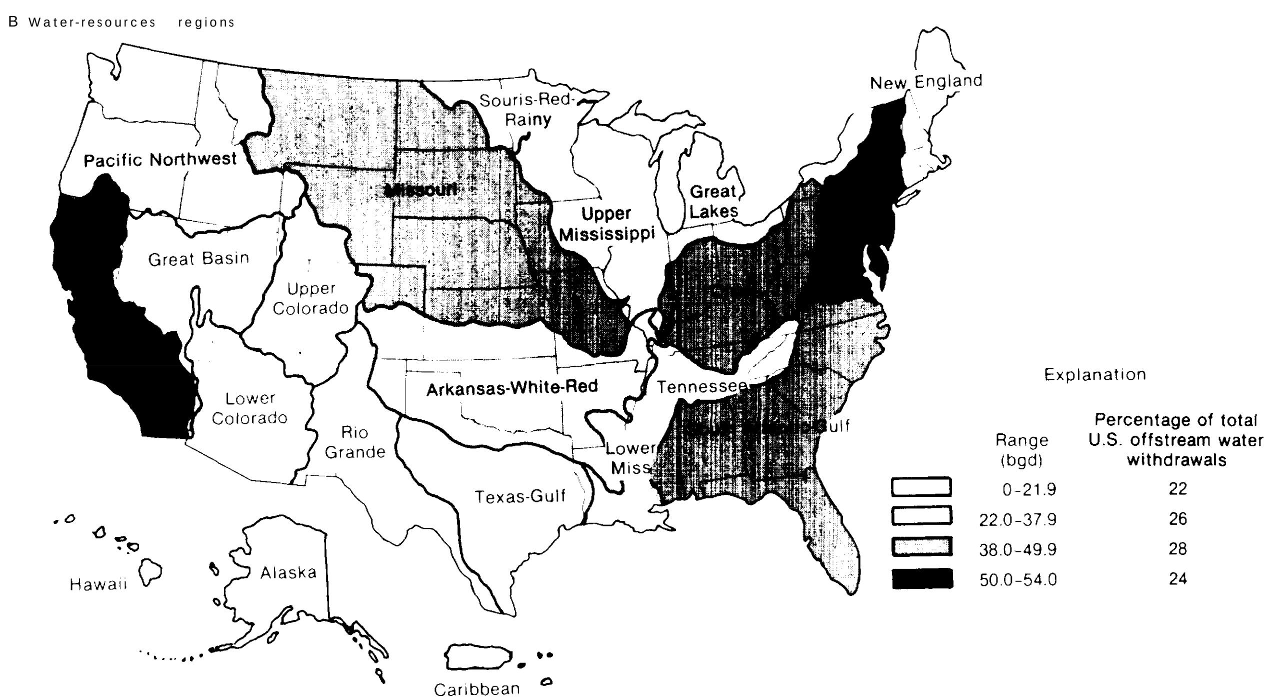


These are the subdivisions used by WRC in the Second National Water Assessment. The subregions do not correspond to those used by USGS.

SOURCE U.S Water Resources Council, The *Nation* Water Resources *1975-2000* (Washington, D.C U S Government Printing Office, 1978).

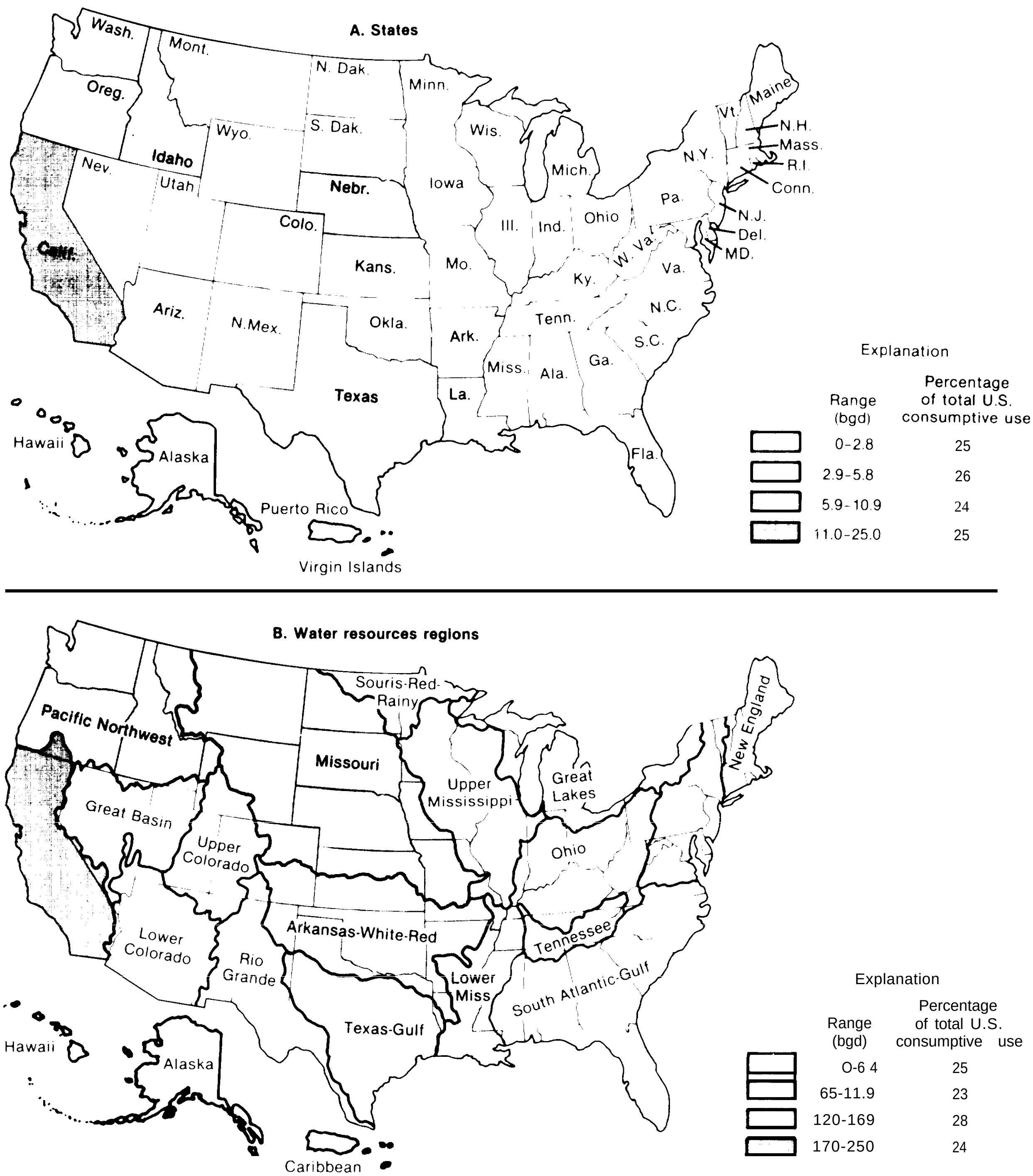
Figure B-2.—Total Off stream Water Withdrawals by States and Water Resources Regions, 1980





SOURCE W Solley, **E Chase, and W Mann** IV, Estimated Use of Wafer in the United States in 1980, U S. Geological Survey Circular 1001, 1983.

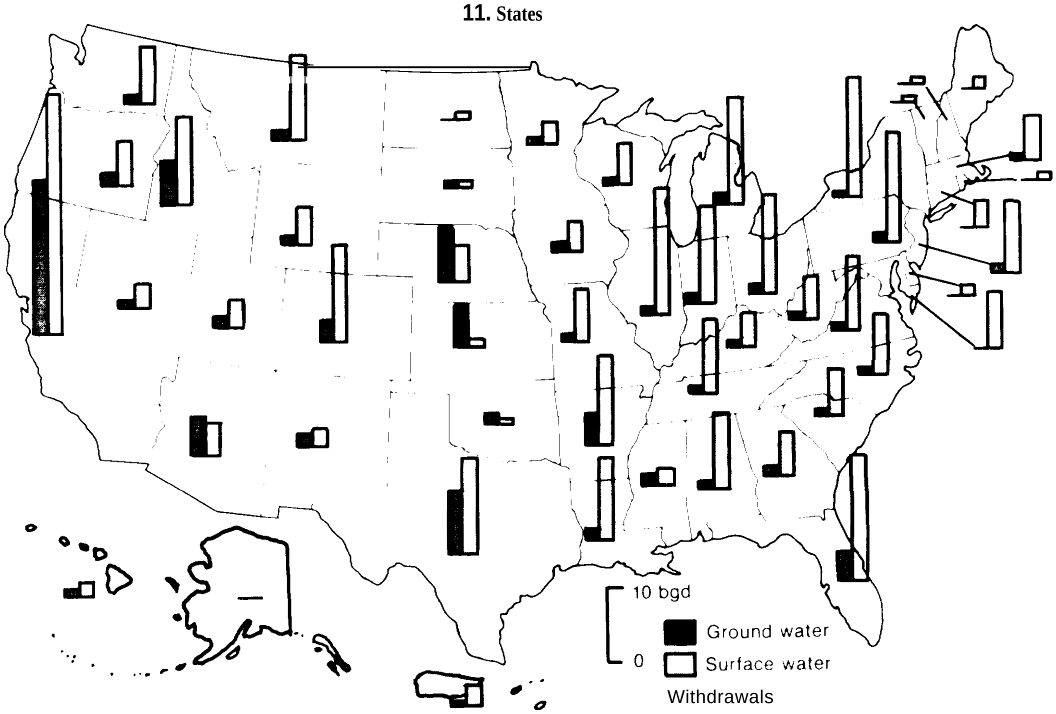
Figure B.3.—Freshwater Consumptive Use, by State and Water Resources Regions, 1980



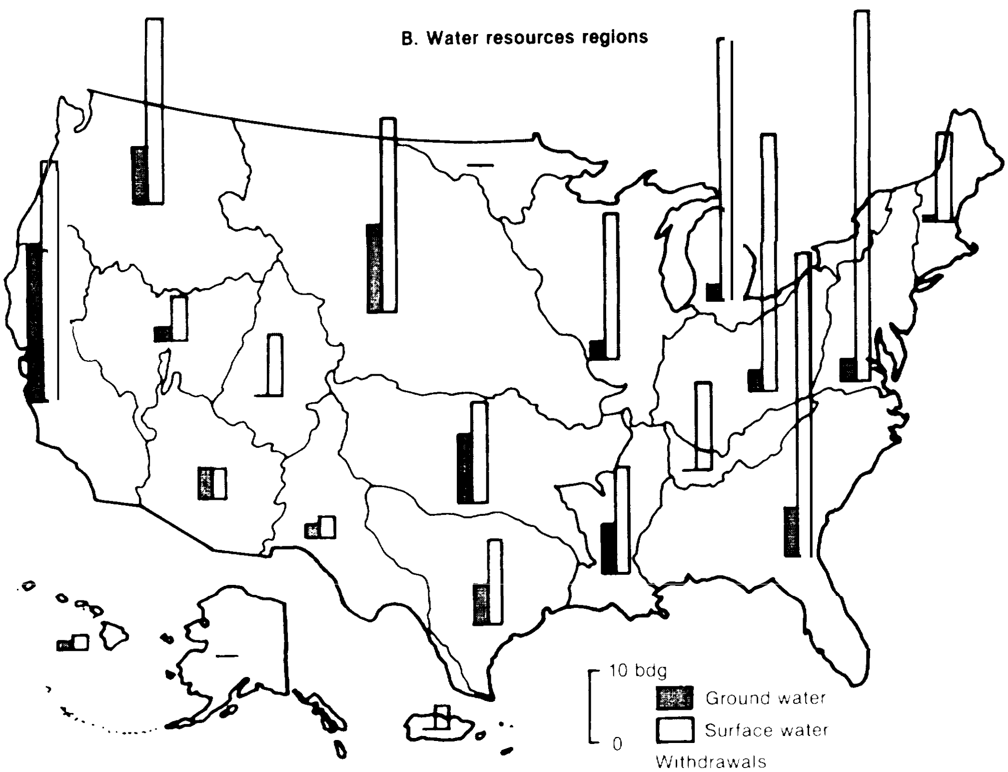
SOURCE W. Solley, E. Chase, and W. Mann IV, *Estimated Use of Water in the United States in 1980,* U.S. Geological Survey Circular 1001, 1983

Figure B-4.—Withdrawals for Off stream Use From Ground and Surface Water Sources, by States and Water Resources Regions, 1980

11. States

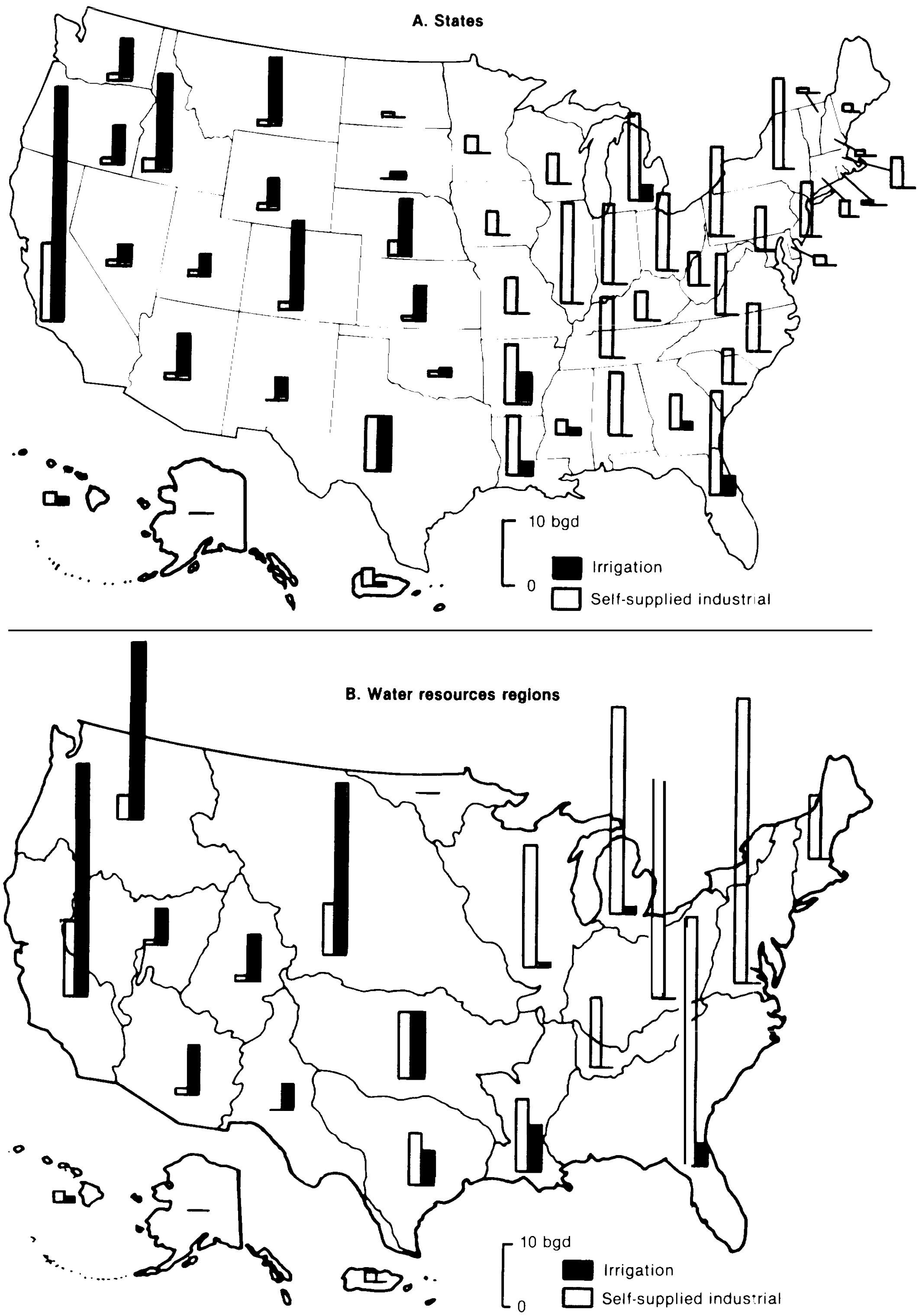


B. Water resources regions



SOURCE W Solley, E Chase, and W Mann IV, *Estimated Use of Water in the United* States In *1980* U S Geological Survey Circular 1001, 1983

Figure B-5.—Comparison of Withdrawals for Self-Supplied Industrial Use and Irrigation Use, by States and Water Resources Regions, 1980



SOURCE: W Solley, E. Chase, and W. Mann IV, *Estimated Use of Water in the United States in 1980,* US. Geological Survey Circular 1001, 1983.

Water-Region Maps

The Missouri River Basin: Water Resources Region 10

The Missouri River Basin—including portions of Montana, Wyoming, Colorado, North and South Dakota, Nebraska, and Kansas—contains one-sixth the land area of the 48 contiguous States, about 511,309 square miles (mi[2]). Estimates of annual runoff range from 49,4 million acre-feet (maf) (5) to 60,5 maf (4). There are six large constructed reservoirs on the Missouri mainstem and these, together with tributary reservoirs, have a normal storage capacity of slightly more than 83 maf. This storage capacity is approximately 1.7 times the mean annual flow. Total withdrawals of water for all uses is approximately 43 maf, one-half of normal storage. Withdrawals for irrigation are slightly more than 35 maf, or 81 percent of all withdrawals. Forty-one percent of all water withdrawn is consumed, the majority for irrigated agriculture.

The relationship between water availabi ity and water use varies greatly within this region. As can be seen in figure B-6, in general there is a surplus of water over demand in the northern States of Montana and North and South Dakota, while the southern States in the basin—Colorado, Nebraska, and Kansas—use all of the available surface water and make up the deficit between supply and use by extracting water from ground water aquifers during the period of deficit. The extent to which current levels of water use can be sustained will largely be determined by the availability of ground water reserves. Without some shift in water use patterns, it is apparent that existing surface water resources are totally committed in the southern portion of the basin.

Water Resources Region 10: Missouri River

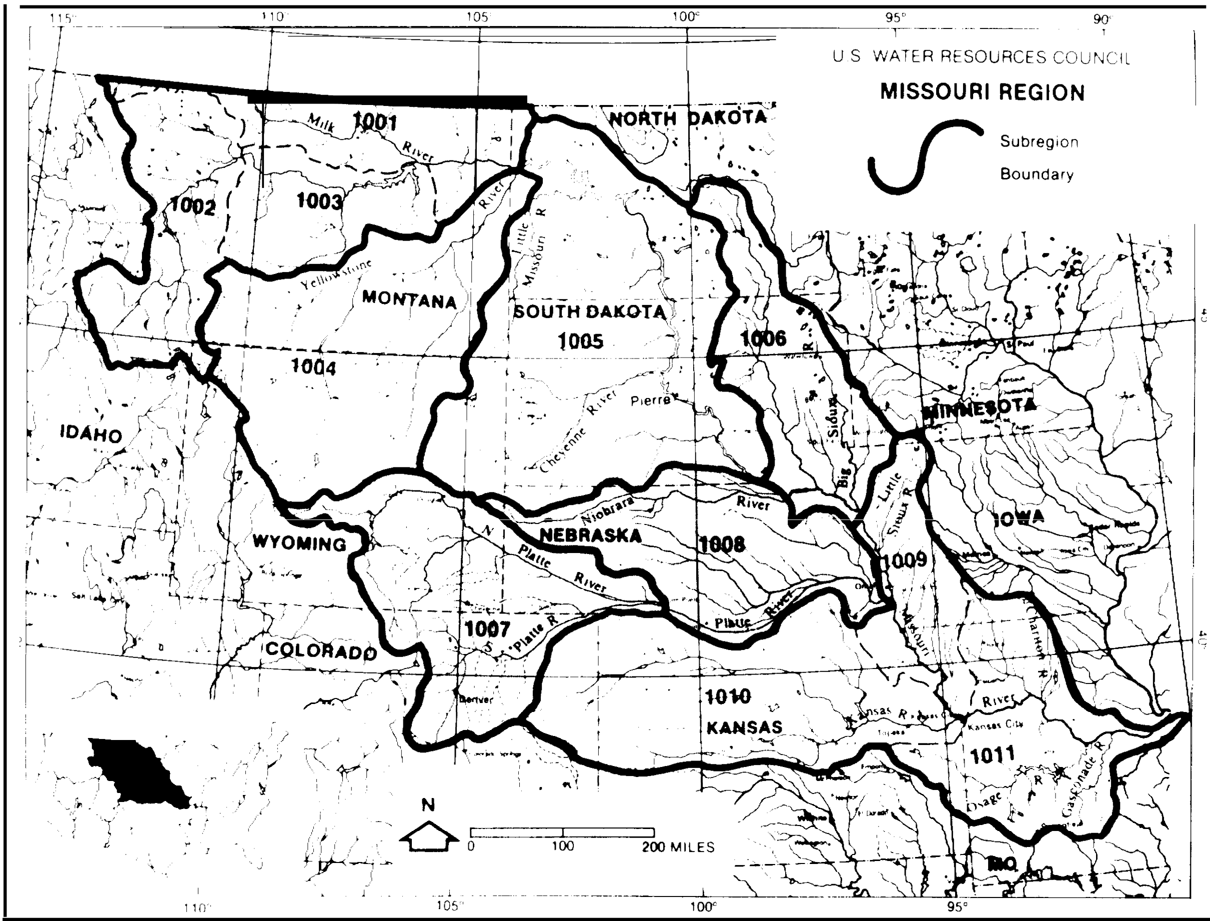
The relationship between water supply and use by month for selected subregions of the Missouri River Basin. While there is an excess of supply over demand during all months in the northern sections of this basin, most subregions in the southern parts experience a water supply shortage during the summer months when use is at the annual maximum.

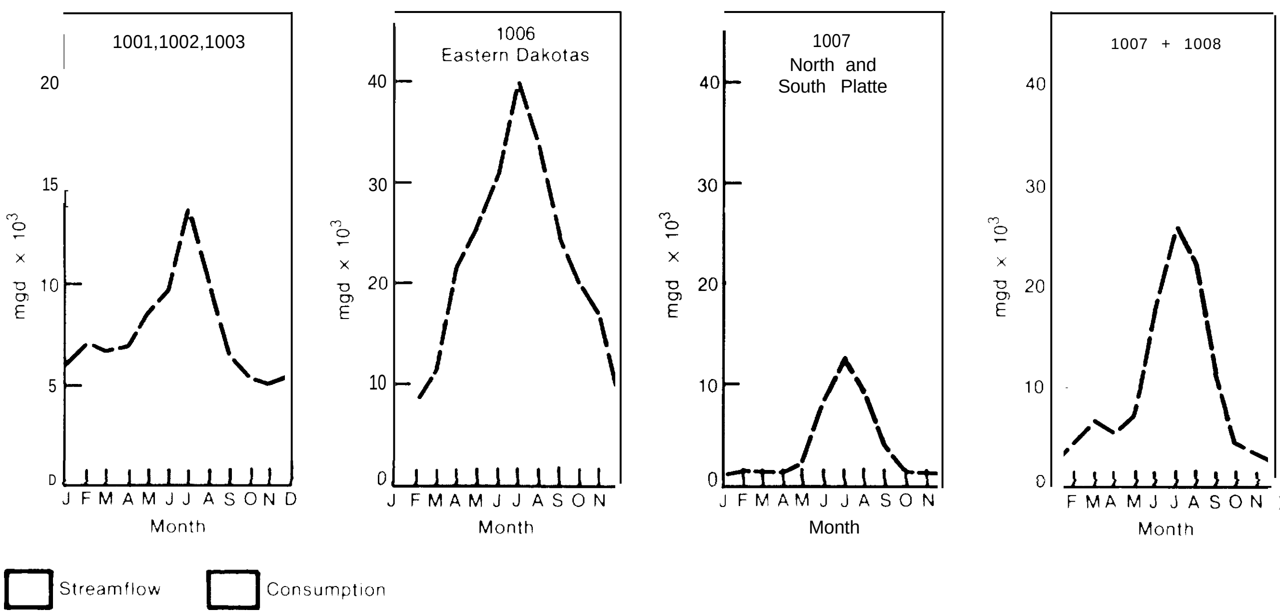
Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals Total (mgd)	Ground water withdrawals Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption (mgd)	Off stream use to total streamflow (mgd)
1001	5,910	134	22	1	82	923	318	230/o
1002	4,770	1,373	59	0	230	4,376	1,315	22
1003	5,530	5,081	11	1	545	335	150	21
1004 . . . .,	7,760	1,017	165	7	203	7,306	2,086	21
1005	14,200	14,415	179	10	2,186	1,145	512	24
1006	16,500	191	177	13	134	244	180	22
1007	1,020	2,474	1,849	435	366	8,825	3,314	85
1008	3,920	153	2,996	450	134	5,477	3,346	69
1009	24,800	36	288	30	12	2,084	186	32
1010	3,910	931	4,432	1,600	842	5,808	3,866	63
1o11	44,100	1,536	229	10	190	1,493	196	27
Total region . .	44,100	27,161	10,407	2,557	4,924	38,016	15,469	

Key mgd = million gallons per day (multiply by 1,120 to obtain acre-f t/year) bg = billion gallons (multiply by 3,070 to obtain million acre-ft)

SOURCE Second National Water Assessment, 1978

Figure B-6.—The Missouri Water Resources Region





The Arkansas, White, and Red River Basins: Water Resources Region 11

The Arkansas-White-Red region covers about 244,000 mi^2, 7 percent of the Nation. It lies in the south-central portion of the United States between the Continental Divide and the Mississippi River. Three major rivers—the Arkansas, White, and Red—drain the region, which includes all of Oklahoma and parts of Colorado, New Mexico, Kansas, Missouri, Arkansas, Texas, and Louisiana. It has been included in the present assessment because much of the basin lies in the southern Great Plains region of the Western United States.

The total surface flow from the region in an average year is estimated at 70.1 maf (5) and 81.8 maf (4). Normal storage in reservoirs in the region is 30.3 maf, or approximately 45 percent of the mean annual streamflow of the region. Total withdrawals for all uses in 1975 were 14.4 maf, of which 11.2 maf, or 78 percent, were withdrawn for irrigation. Sixty-three percent of all water withdrawn is consumed, the majority (88 percent) by irrigated agriculture.

Water supply and use relationships, which are illustrated graphically for various selected subregions within the basin in figure B-7, vary widely, both spatially and temporally, throughout this basin. Headwaters subregions, as represented by 1102, the upper Arkansas River, have a high apparent excess of supply. The intermediate reaches of the Arkansas and Red Rivers, in portions of Kansas, Oklahoma, and Texas, experience periods of 2 months (July-August) when demands made on the surface water resources exceed the supply, while in the lower reaches of these same rivers, in eastern Oklahoma and Texas, supply generally exceeds use. The deficit in supply in the middle reaches of the Arkansas and Red Rivers has been met by overdrafting the Ogallala aquifer, which is now showing signs of depletion in portions of this area. Here, water-use patterns and trends will have to be modified if a balance between available water supplies and water uses is to be achieved.

Water Resources Region 11: Arkansas-White. Red Rivers

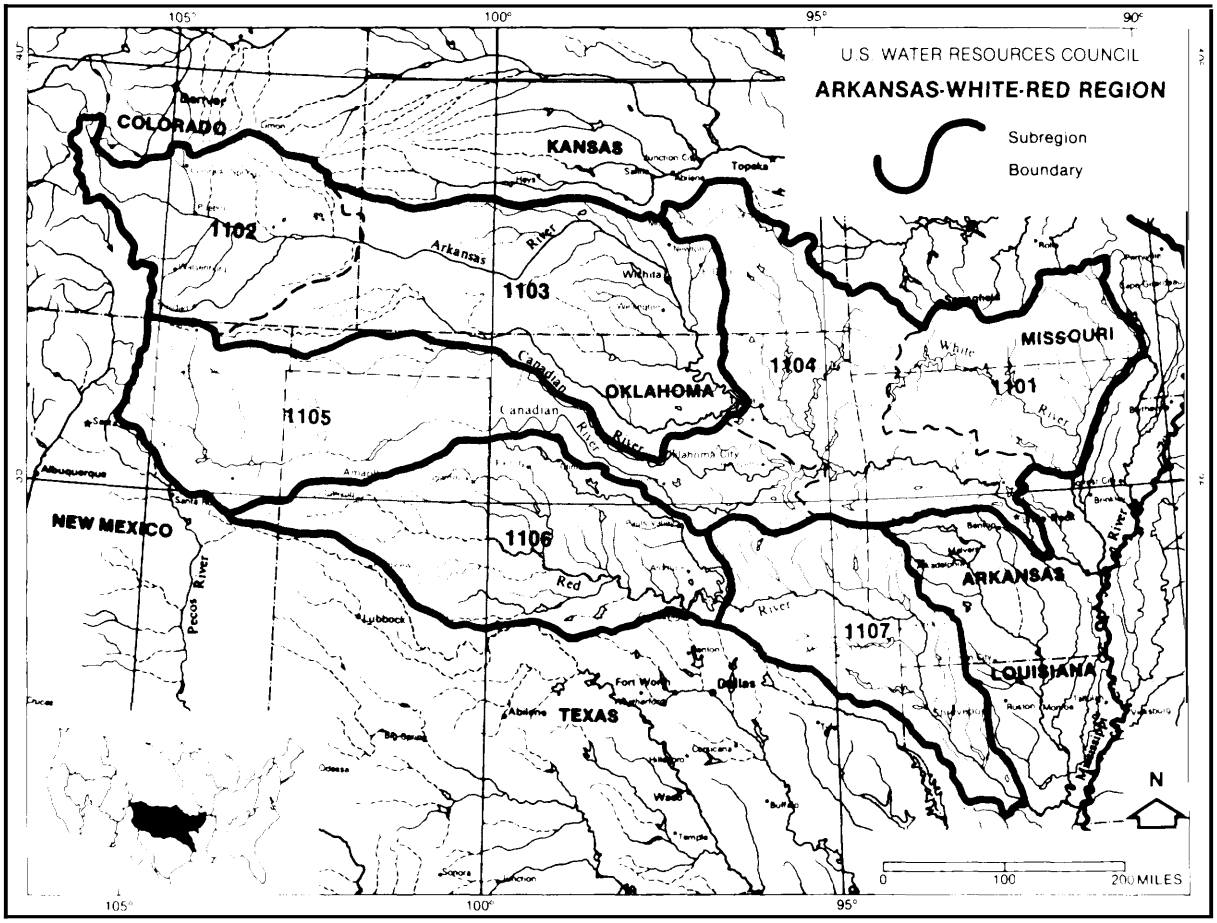
Water supply and use for the Arkansas-White-Red water resources region. Natural supply exceeds the demand during the winter months in the region as a whole. However, during the summer months when agricultural use is at its peak, water use either exceeds supply or approaches it very closely in most subregions.

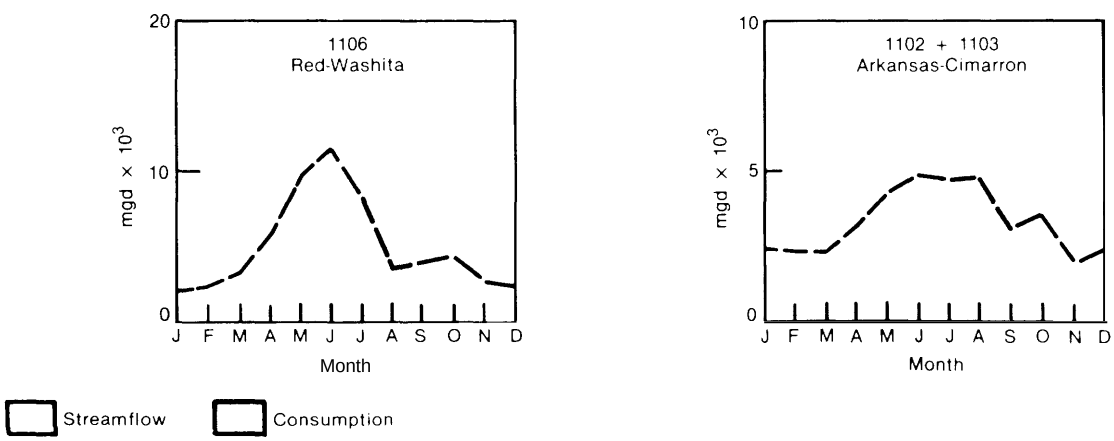
Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals: Total (mgd)	Ground water withdrawals: Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption (mgd)	Offstream use to total streamflow (mgd)
1001	15,900	3,477	301	2	0	196	96	1 %
1002	155	416	217	21	126	1,800	743	85
1003	4,280	198	3,619	2,098	547	3,456	2,031	56
1004	27,000	2,107	150	6	203	1,024	299	19
1005	3,540	1,466	2,805	2,069	659	3,168	2,440	62
1006	2,320	1,473	1,647	1,259	1,007	2,746	2,276	68
1007	1,970	736	107	2	73	478	179	12
Total region . .	62,600	9,853	8,646	5,457	2,615	12,868	‘8,064	

Key: mgd = million gallons per day (multiply by 1,120 to obtain acre-ft/year) bg = billion gallons (multiply by 3,070 to obtain million acre-f t).

SOURCE: Second National Water Assessment, 1978.

Figure B-7.—The Arkansas-White-Red Water Resources Region





SOURCE Second National Water Assessment

The Texas-Gulf Basins: Water Resources Region 12

The Texas-Gulf region extends from the Gulf of Mexico northwest for some 650 miles into the southern Great Plains, Almost all of the region (94 percent) lies within the State of Texas, although small portions of Louisiana (1 percent] and New Mexico (5 percent) are included, The total surface area of the region is about 177,700 mi^2, approximately 5 percent of the total surface area of the Nation. The region consists of the drainage areas of the Sabine, Neches, Trinity, San Jacinto Brazes, Colorado, Lavaca, Guadalupe, San Antonio, and Nueces Rivers. These rivers drain in a general southeasterly course to the Gulf of Mexico. The total streamflow from the region during an average year is estimated to be 31.7 maf (5) and 35.8 maf (4). Streamflow has been as low as 12.7 maf during dry years. Normal storage in the basin is 23.5 maf, or 74 percent of the mean annual streamflow. Total withdrawals in the region are 19 maf annually, of which 8.1, or 43 percent, are from ground water. Sixty-eight percent of the total withdrawals were for irrigation, of the total withdrawals, 12.6 maf were consumed, of which irrigation consumed 10.5, or 83 percent,

Streamflow volumes decrease from east to west across the region, while considerable irrigated agriculture is practiced in both the northern and western portions of the basin. This creates an imbalance between supply and use curves, which is illustrated graphically in figure B-8 for the two central subregions, the Brazes *(1203)* and Colorado *(1204).* It can be seen that in both these subregions, use exceeds surface supply during all or much of the months of June, July, August, and September. This excess demand has been met in the past by overdrafting portions of the Ogallala and Edwards-Trinity aquifers, which underlie the extreme western boundary of the region. At least in the case of the Ogallala aquifer, local depletions are occurring and can be expected to grow as declining water tables and rising energy costs further restrict the use of this water source.

Water Resources Region 12: Texas-Gulf Region

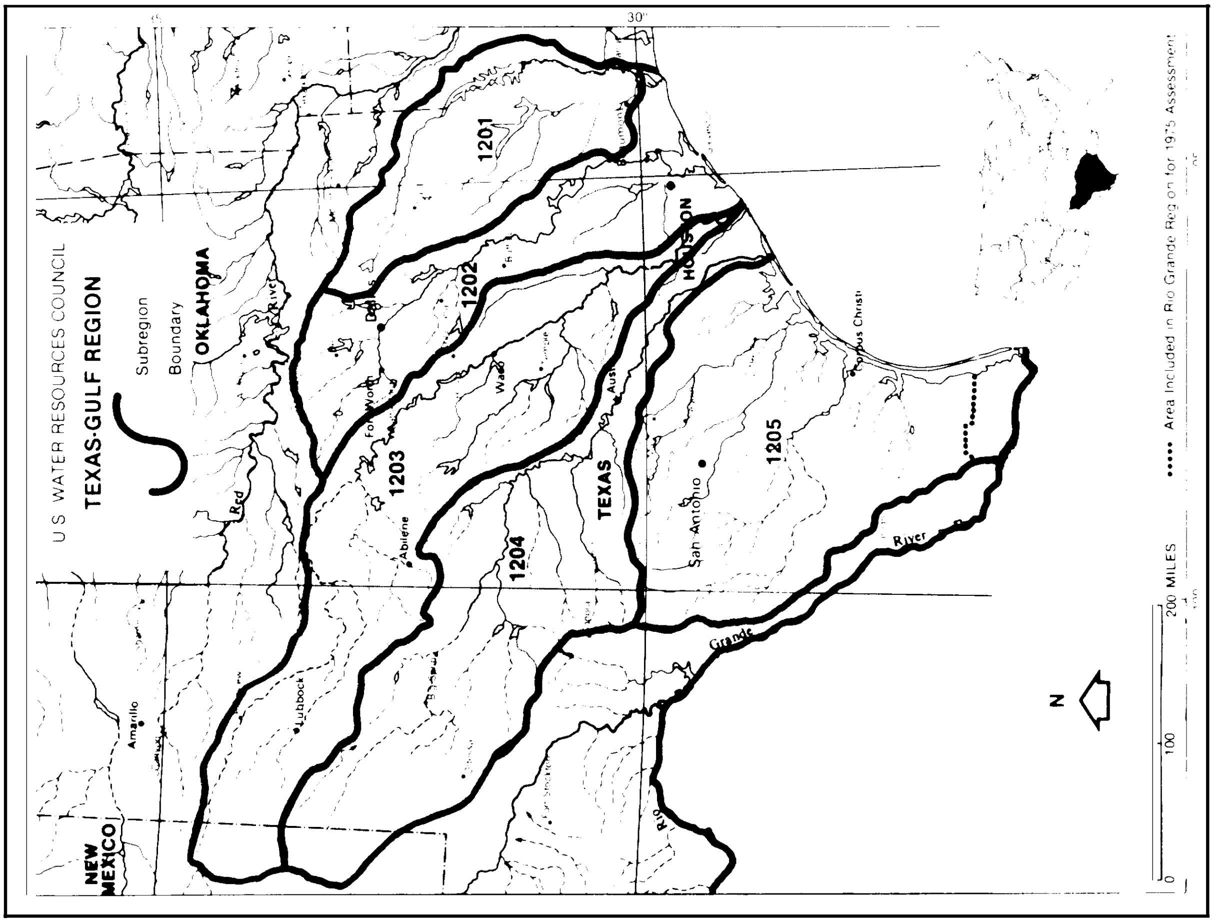
In the central portion of the Texas-Gulf region, the use of water exceeds the supply during all summer months. An east-west gradient of water availability exists such that the supply-use relationship becomes progressively poorer from the Sabine-Neches subregion in the east to the Nueces subregion in the southwestern portion of the State of Texas,

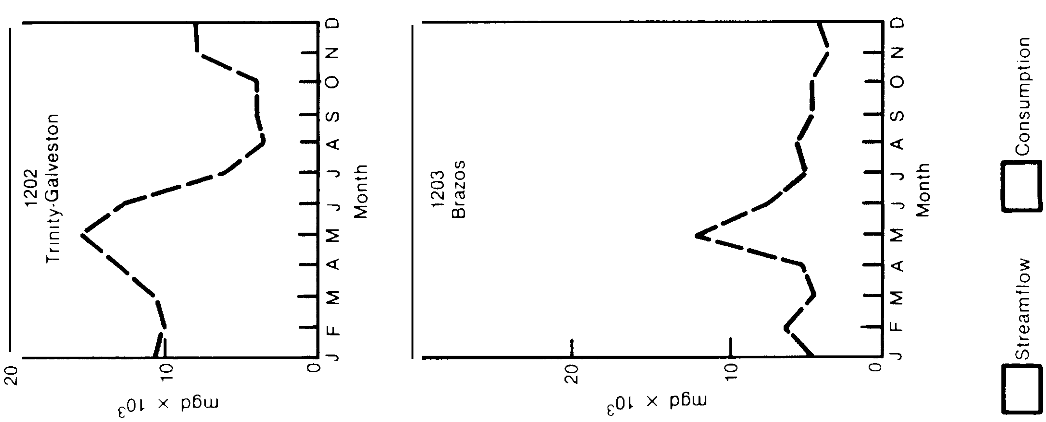
Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals: Total (mgd)	Ground water withdrawals: Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption (mgd)	Offstream use to total streamflow (mgd)
1201	10,300	3,065	163	– 39	49	2,926	502	5 %
1202	*7,500*	1,913	617	297	335	9,641	1,601	18
1203	1,810	1,262	1,215	1,157	473	4,758	3,061	84
1204	4,720	1,032	4,395	3,767	694	6,255	4,850	82
1205	3,940	387	832	318	154	2,508	1,245	26
Total region	28,270	7,660	7,222	5,578	1,705	26,088	11,259	

Key mgd = million gallons per day (multiply by 1,120 to obtain acre. ft/year). bg = billion gallons (multiply by 3,070 to obtain million **acre-ft)**

SOURCE Second National **Water Assessment, 1978**

Figure B-8.—The Texas-Gulf Water Resources Region





The Rio Grande Basin: Water Resources Region 13

The Rio Grande originates on the eastern slopes of the Continental Divide in Colorado and flows south through New Mexico to enter Texas at El Paso. Along the Texas reach of the river, it forms the international boundary between the United States and Mexico. The total drainage area is 230,000 mi^2, of which 93,000 mi^2 are in Mexico and 137,000 mi^2 are in the United States. Forty-eight thousand square miles drain into closed basins. The principal tributaries of the Rio Grande and the Pecos River, draining portions of New Mexico and Texas, are the Rio Conchos in Mexico, the Rio Puerco in New Mexico, and the Rio Chama in New Mexico.

The streamflow in the Rio Grande basin is largely derived from melting snow in the mountains in the northern portion of the region. Because of historical patterns of water diversion for irrigated agriculture, which predate European settlement of the region and the initiation of systematic streamflow measurements, and because of contributions from the Mexican portion of the basin to total streamflow at the mouth of the river, water supply estimates based on total streamflow measurements are, in all probability, misleading. The mean annual flow of the Rio Grande originating within the United States portion of the basin is estimated to be 1.4 maf (5) or **5.6** maf (4). This fourfold difference in estimates of annual flow volumes make management decisions regarding the Rio Grande basin particularly difficult. The aggregate surface storage in the basin is estimated to be 7.8 maf.

Total withdrawals are estimated to be 7.1 maf, of which 6.4 maf, or 90 percent, are for irrigated agriculture. Total consumption is estimated to be 4.8 maf, of which 92 percent is used by irrigation. Ground water withdrawals are 2.6 maf/year, which is 37 percent of the total withdrawal.

While there is apparently a serious question concerning the accuracy of the supply data for the Rio Grande basin, some idea of the nature of the extent to which the water resources are being used can be obtained from an examination of figure B-9. This graphic comparison of supply and use relationships is for the upper Rio Grande and Pecos Rivers, where the ambiguities of the lower reaches are minimized to some extent. It can be seen that in both subregions (1303 and 1304) use slightly exceeds supply during most months of the year. The statement of the Second National Water Assessment that "there are no surplus flows to meet new demands or to expand existing uses" appears to be correct. Because it is also estimated that ground water withdrawals represent an overdrafting of the basin aquifers by as much as 700,000 acre-ft/yr, it would seem that a gradual reduction from current use levels is inevitable.

Water Resources Region 13: Rio Grande River

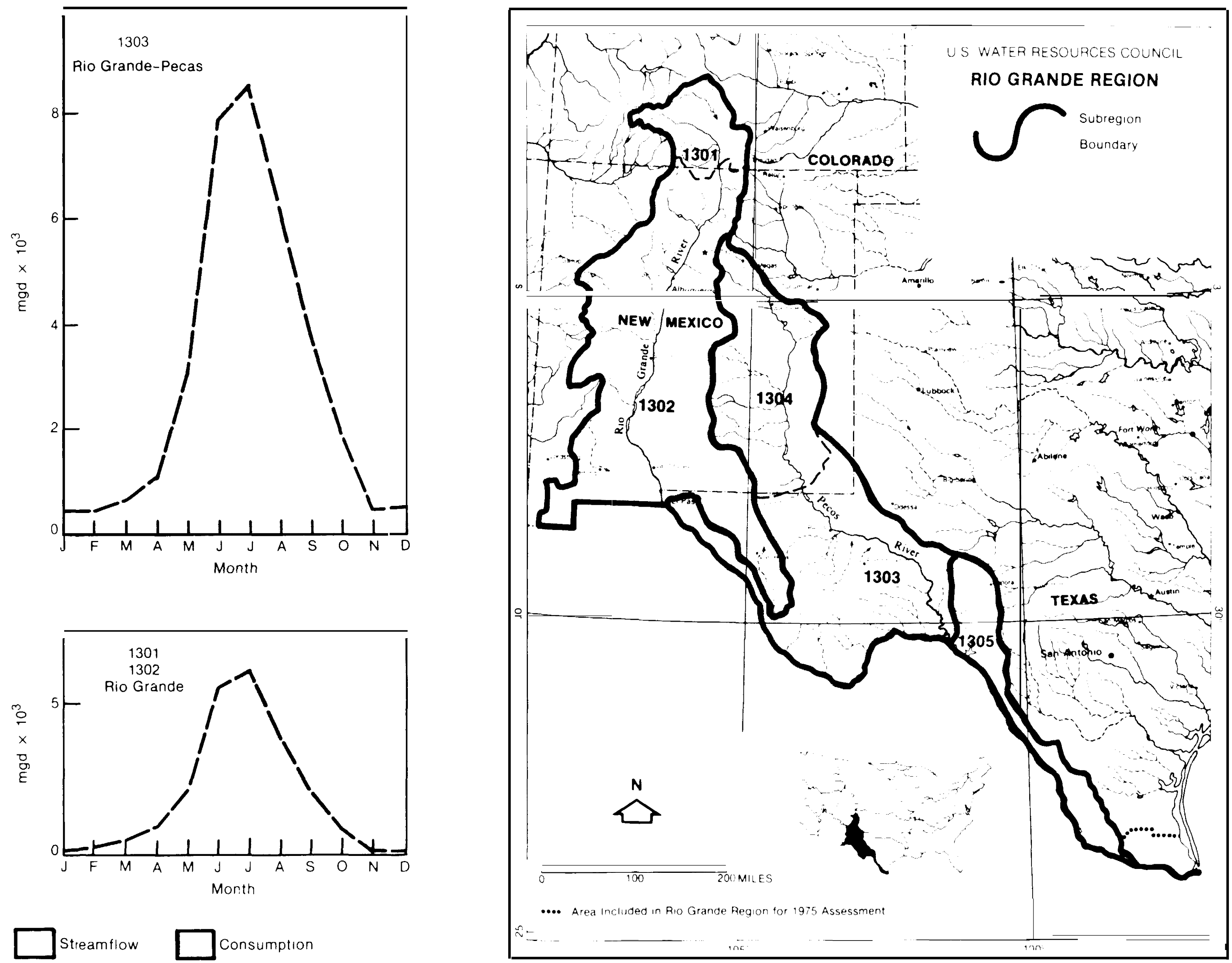
In this entire region, water use exceeds or equals supply during virtually all months of the year. Water supply in the lower Rio Grande is difficult to assess, owing to the ungaged contribution from Mexico. The available data suggest that there is little or no excess water in the lower reaches of the Rio Grande River.

Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals Total (mgd)	Ground water withdrawals Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption imgd)	Off stream use to total streamflow (mgd)
1301	267	114	590	0	18	932	581	690/o
1302	343	1,071	611	265	129	2,118	1,247	96
1303	582	108	679	290	73	873	630	102
1304	122	58	400	89	74	897	562	94
1305	1,230	1,183	55	13	436	1,501	1,220	88
Total region . .	1,230	2,534	2,335	657	730	6,321	4,240	

Key mgd = million gallons per day (multiply by 1,120 to obtain acre-ft/year) bg = billion gallons (multiply by 3,070 to obtain million acre-ft)

SOURCE Second National Water Assessment, 1978

Figure B-9.—The Rio Grande Water Resources Region



The Colorado River Basin: Water Resources Regions 14 and 15

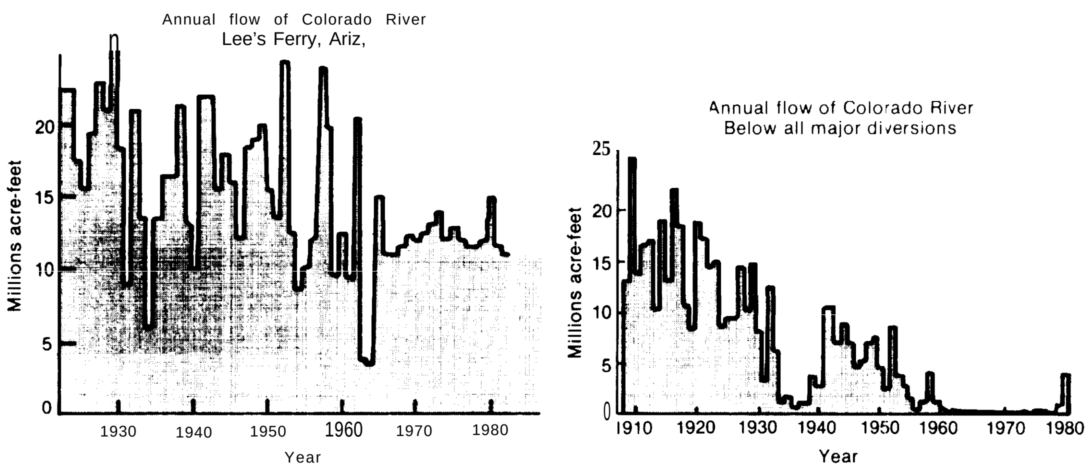
It has become customary in most discussions of regional water resources to divide the Colorado River Basin into an upper region (14) and a lower region (15) at Lee's Ferry, Ariz. This division is designed to reflect provisions of the Colorado River Compact but has limited hydrologic utility.

The Colorado River Basin has a total surface area of approximately 257,000 mi^2, of which slightly more than 100,000 mi^2 are in the upper basin. This basin lies immediately west of the Continental Divide and includes parts of Wyoming, Utah, Colorado, Arizona, New Mexico, and Nevada.

Estimates of mean annual streamflow for the entire Colorado River Basin vary from a low of 12.4 maf (5) to a high of 18.1 maf (4), Historically, the flow of the river has varied widely, and the value given for a mean annual discharge depends very much on the period of time represented by the data on which it is based, While this is equally true of virtually all rivers in the Western United States, which have a high variability from year to year, it is perhaps most interesting in terms of the Colorado River. Because the mean flow of the river has declined since the original division of the annual streamflow among the upper and lower basin States, it has become a well-known example of the need to understand fully, prior to any allocations, the regime of any hydrologic regime subject to political agreement (fig, B-10).

Figure B-10.—The Colorado River Basin Water Resources Region

The annual flow of the Colorado River at Lee's Ferry, Ariz., immediately downstream from Lake Powell (above) and at its outflow into the Gulf of California (below). The trend toward lower annual flow volumes in recent decades is largely confined to the lower Colorado, where a majority of the water diversions are located.



SOURCE: J Bredehoeft, "Physical Limitations on Water Resources in the Arid West, " paper presented at *Impacts of Limited Water for Agriculture in the Arid West,* Asilomar, Calif., 1982.

Water Resources Region 14: Upper Colorado River

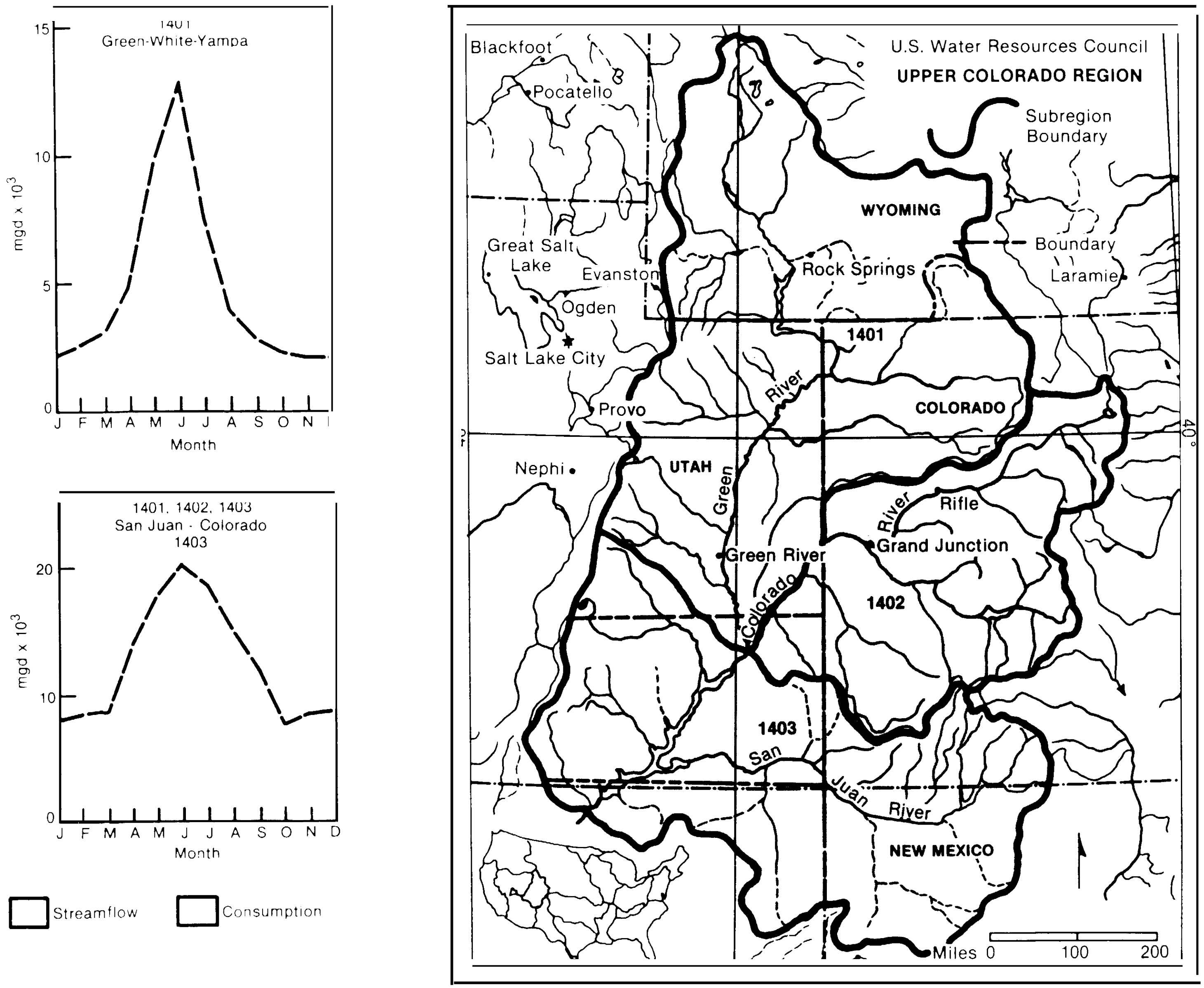
Water supply and use for the Upper Colorado Water Resources Region. For this entire region, current water supply exceeds demand during every month of the year.

Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals: Total (mgd)	Ground water withdrawals: Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption (mgd)	Off stream use to total streamflow (mgd)
1401	3,680	1,677	64	0	115	3,186	1,019	22 "/0
1402	4,740	948	24	0	27	2,532	987	17
1403	10,000	702	38	0	569	1,151	434	20
Total region . .	10,000	3,328	126	0	711	6,869	2,440	

Key: mgd = million gallons per day (multiply by 1,120 to obtain acre-ft/year) bg = billion gallons (multiply by 3,070 to obtain million acre-ft)

SOURCE Second National Water Assessment, 1978

Figure B-11.—The Upper Colorado Water Resources Region



Both water supply and use characteristics of the region vary widely between the upper and lower basins and is largely the result of a much lower population in the upper basin (344,000 v. 2,400,000 in the lower basin (1975 data)).

Normal reservoir storage in the basin is 71.5 maf, of which 61.3 maf (86 percent) are located in the lower basin, This represents 5.8 times the mean annual flow of the Colorado River, as estimated by the Second National Assessment, Ground water withdrawals from subsurface storage are estimated at 5.7 maf/year, More than 95 percent of these withdrawals occur in the lower basin and are estimated to consist of at least 50 percent of overdrafted water that is not being recharged.

Total withdrawals for the basin as a whole are 14.1 maf annually, of which slightly more than half are made in the lower basin. Consumption is somewhat less equally divided. In the upper basin, 2.7 maf are consumed annually, while in the lower basin, 5.2 maf, or almost twice as much, are consumed. Withdrawals for irrigation are 94 percent and 89 percent for the upper and lower basins, respectively, while consumption by irrigation is higher in the lower basin, 45 percent to 32 percent of total withdrawals.

Supply and use relationships for individual subregions within the upper and lower basins are shown graphically in figures B-11 and B-12. The Second National Assessment states that "The Colorado River system is one of the most controlled, overburdened, and most oversubscribed river systems in the Nation. "

For individual subregions within the basin, there is an excess of water supply over water use in all subregions of the upper basin, while demand exceeds supply, often significantly, in the subregions of the lower basin. The water deficit is being made up by ground water overdrafting, which must continue if water-use patterns are not to change dramatically in the lower basin Whether this overdrafting can be continued into the indefinite future is a matter of some speculation, given the spatially variable nature of the ground water resource and the fact that the water table is now declining at a rate of 4 to **10** ft/yr in certain critical areas of the region. With the completion of the Central Arizona Project, the Second National Assessment reports that "essentially all renewable surface and ground water supplies will , , , be utilized" and water supplies will become inadequate to meet the needs of the basin sometime before the year 2000.

Water Resources Region 15: Lower Colorado River

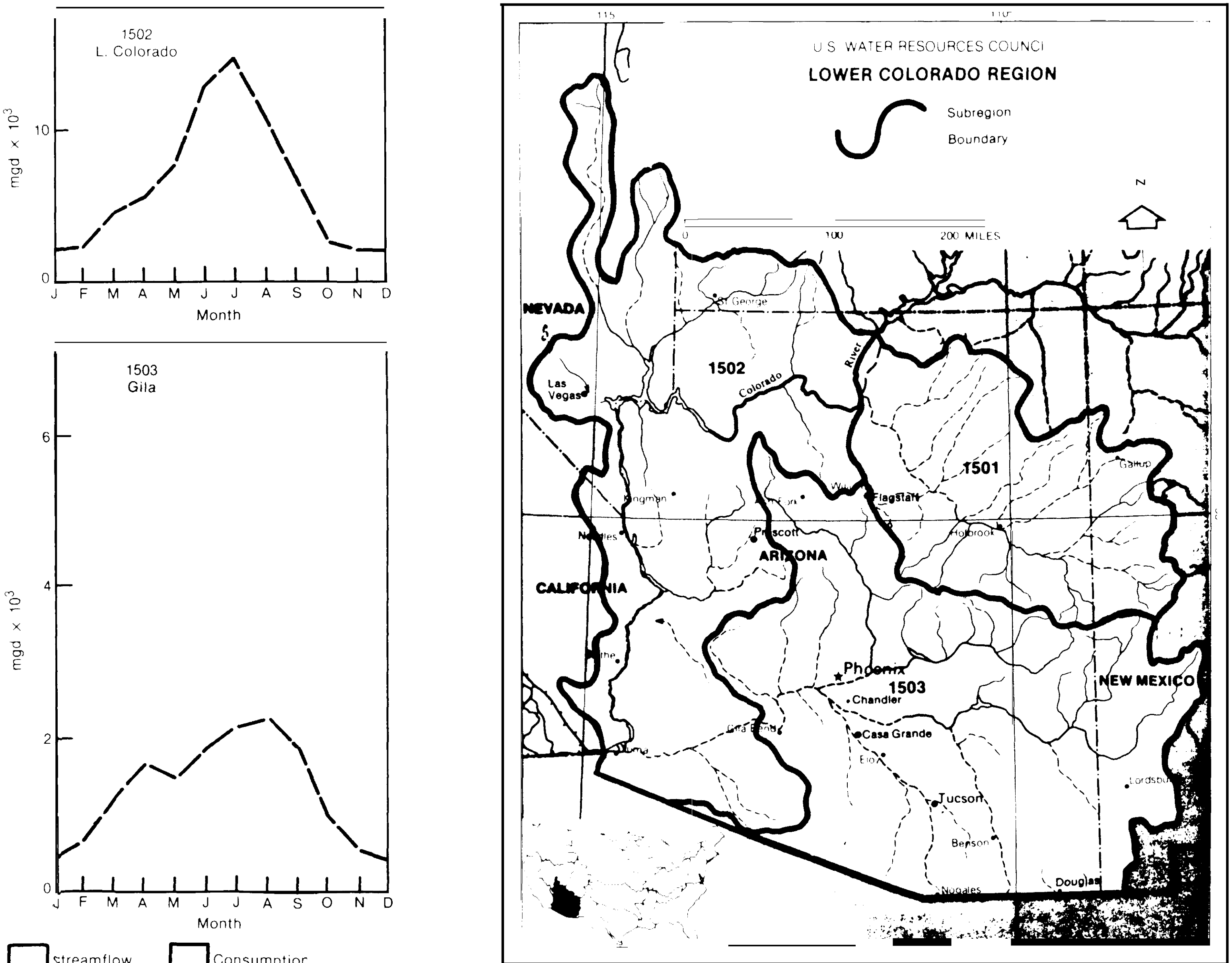
The relationship between supply and use In the Lower Colorado River basin. In two of the three subregions, the use of water exceeds the supply in all but one month of the year. In the Gila River subregion, which includes the clties of Phoenix and Tucson, Ariz., the imbalance between supply and use IS particularly extreme,

Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals Total (mgd)	Ground water withdrawals Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption (mgd)	Off stream use to total streamflow (mgd)
1501	272	50	70	5	31	220	73	21 "/0
1502	1,550	18,863	960	290	1,020	2,424	1,059	114
1503	20	1,049	3,978	2,120	151	6,273	3,463	254
Total region . .	1,550	19,962	5,008	2,415	1,202	8,917	4,595	

Key mgd - million gallons per day (multiply by 1,120 to **obtain** acre. ft/year) bg = billion gallons (multiply by 3,070 to obtain million acre-ft)

SOURCE Second National Water Assessment, 1978

Figure B-12.—The Lower Colorado River Water Resources Region



The Great Basin: Water Resources Region 16

The Great Basin is a closed interior basin, lying between the Rocky Mountains and the Sierra Nevada Mountains of California, from which there is no drainage. All precipitation falling in the basin and all runoff entering it from the surrounding mountains must ultimately leave by evapotranspiration or, possibly, ground water runout. The Great Basin encompasses the western half of the State of Utah and virtually all of Nevada and it has a surface area of 137,000 mi^2. Mean annual runoff has been variously estimated at between 2.9 maf (5) and 8.4 maf (4]. Average annual precipitation in this basin is probably less than 10 inches/yr, while potential evapotranspiration values are estimated to be several times this value. This suggests that relatively little water is available for soil or ground water recharge. The high range in the estimates of runoff into this basin results, at least in part, from a lack of actual measurements of the water produced from these many mountain sources and from a certain amount of ambiguity concerning the ratio of rain and snowfall to runoff.

Normal surface storage in the basin is **3,8** maf. Surface area storage 130,000 acres, from which 355,000 acre-ft are estimated to be lost annually to evapotranspiration. This amount represen s a specific alue of 2.7 ft of water annually-and is approximately 12 percent of the low estimate of total annual runoff into the basin.

Available ground water resources are estimated to be approximately 525 maf, of which 1.6 maf are withdrawn annually for an estimated overdraft of 662,000 acre-ft over recharge.

Total annual withdrawals within the Great Basin are 9 maf, of which 4.2 maf are consumed. Irrigated agriculture accounts for 7.8 maf of the withdrawals (87 percent) and 3,6 maf of the consumptive losses (86 percent). The existing estimated ground water overdraft represents approximately 7 percent of total withdrawals.

It can be seen from an inspection of figure B-13 that subregions on both the east (1601) and west (1604) sides of the Great Basin have very similar water supply/use characteristics. In both cases, supply exceeds demand during winter, whereas during July to September or October, supply and demand curves are almost identical. In subregion 1602, the Sevier River basin in southeastern Utah, demand exceeds supply during almost every month of the year.

Water Resources Region 16: Great Basin

The relationship between water supply and use for the Great Basin region of Utah and Nevada This arid area depends on the mountains to the east and west for its water supply. With the exception of the Sewer Lake subregion (1602) in southwestern Utah, where use exceeds the supply during most months of the year, there is an annual excess of water over demand Water supply and use are equal during the summer months over the entire region.

Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals Total (mgd)	Ground water withdrawals Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption (mgd)	Off stream use to total streamflow (mgd)
1601 : . . . :	1,640	680	581	43	98	3,557	‘1 ,255	44 %
1602	114	178	321	240	59	1,153	599	127
1603	132	144	433	286	93	1,770	,077	117
1604 ., ...	676	236	89	22	77	1,511	848	56
Total region . .	2,562	1,239	1,424	591	327	7,991	3,779	

Key mgd million gallons per day (multiply by 1,120 to obtain acre. ft/year) bg = billion **gallons (multlply by 3,070 to obtain million acre-ft)**

SOURCE Second National Water Assessment, 1978

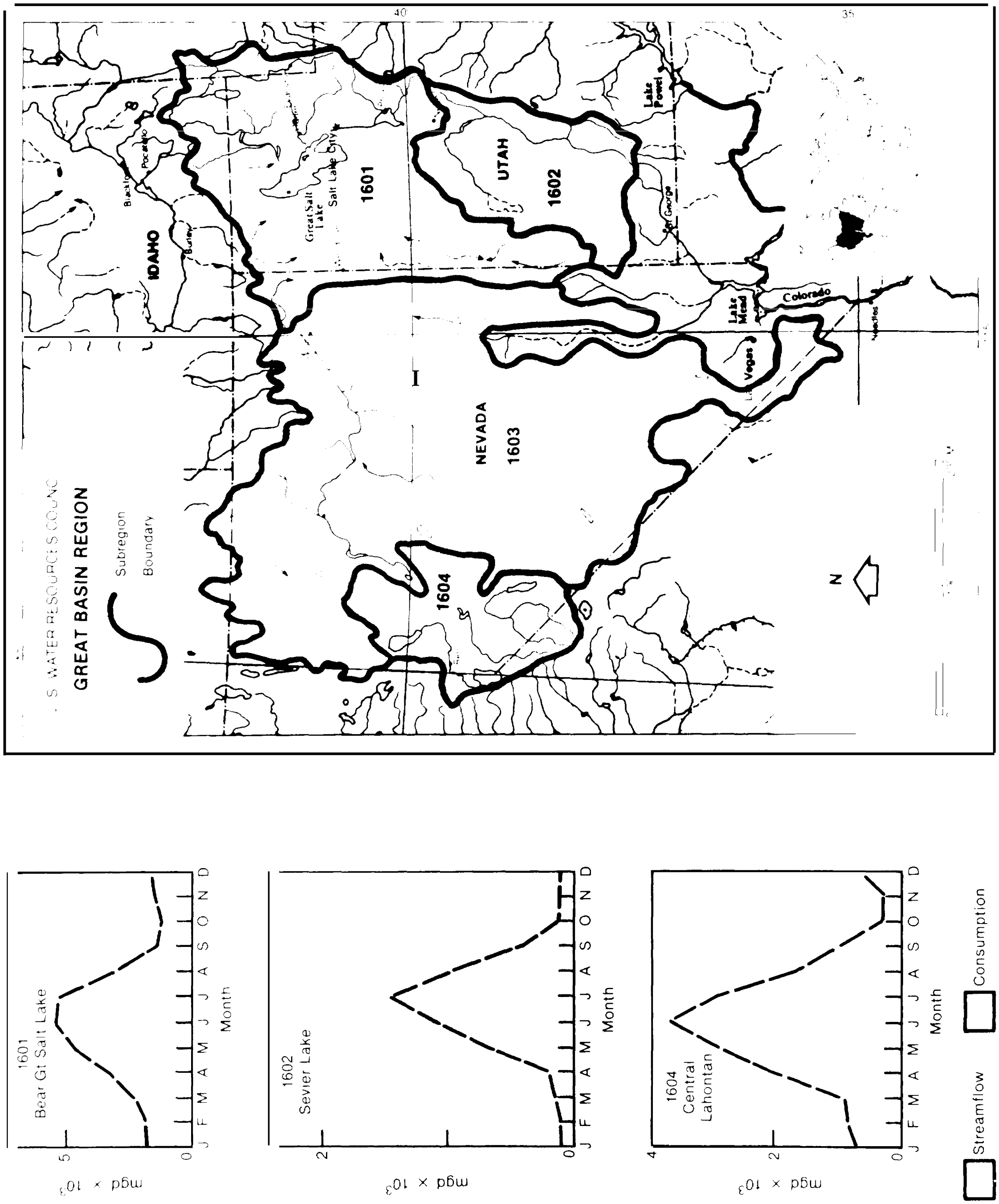


Figure B-13.—The Great Basin Water Resources Region

The Pacific Northwest Basins: Water Resources Region 17

The Columbia River Basin, which drains sections of Montana, Idaho, Washington, Oregon, Nevada, and the Canadian Province of British Columbia, has a surface area of approximately 275,000 mi^2 (160 million acres) and discharges an estimated 235 to 286 maf into the Pacific Ocean each year, This represents approximately 50 percent of all the surface water available annually in the 17 Western States and is roughly 20 percent of all the surface discharge from the entire continental United States. Of the approximately 140 maf discharged by the Columbia River each year, nearly 50 percent enters the United States from the province of British Columbia. The remainder is largely produced by melting snowpacks in the mountains of western Montana, the Idaho "panhandle," and the east slopes of the Cascade Mountains in Washington State.

Discussions of water supply and demand in the Pacific Northwest region are complicated by the extreme variability that characterizes this region and competing uses for water, Average annual runoff depth ranges from less than 1 inch in portions of the interior of Washington State to more than 100 inches at the higher elevations of the Cascade Range along the western coast,

The region is divided into two hydrologic provinces by the Cascade Range. On the west slope of this range, water is plentiful and fairly uniformly distributed. East of the range, water is plentiful, but concentrated in channels of the Columbia River and its major tributaries, the Snake and Clark Fork Rivers, thus draining the west slopes of the Rocky Mountains in Idaho and Montana.

While the question of instream flow maintenance is not unique to this river basin, it is particularly well defined here because of the economic value of the various competing instream and offstream uses. If all competing uses are considered, the water resources of the Pacific Northwest east of the Cascade Range in the Columbia River basin, are fully used.

The normal reservoir storage in the region is 54.8 maf, which is slightly less than 20 percent of the mean annual discharge. Over 1.7 billion acre-ft are required annually for the generation of hydroelectric power in the basin. This means that all water passing through the reservoir system must be used approximately seven times for existing hydroelectric generation. While this water is theoretically available at all times for other uses, in practice, conflicts arise. Ground water withdrawals (8.2 maf/yr) are the third highest of all the water resources regions in the Western United States. Ground water overdrafting exists locally and could create local shortages in the future.

Total withdrawals (42 maf annually) and offstream consumption (13 maf annually, of which irrigation consumes almost 12.5 maf) are among the highest in the Western United States.

Figure B-14 illustrates the supply-use aspects of the basin for two selected subregions. In the Upper Snake River, use of water is within 15 percent of supply during July and August. Maximum offstream uses for the main Columbia River (subregion 1702) never exceed 30 percent of monthly streamflow. Only if instream flow requirements for the salmon fishing industry, navigation, and hydroelectric generation are factored into the supply-use question can an accurate picture of water use in the Columbia River basin be obtained. If it is assumed that the demand for electricity remains essentially constant throughout the year, the Columbia River is heavily overcommitted.

Water Resources Region 17: Pacific Northwest

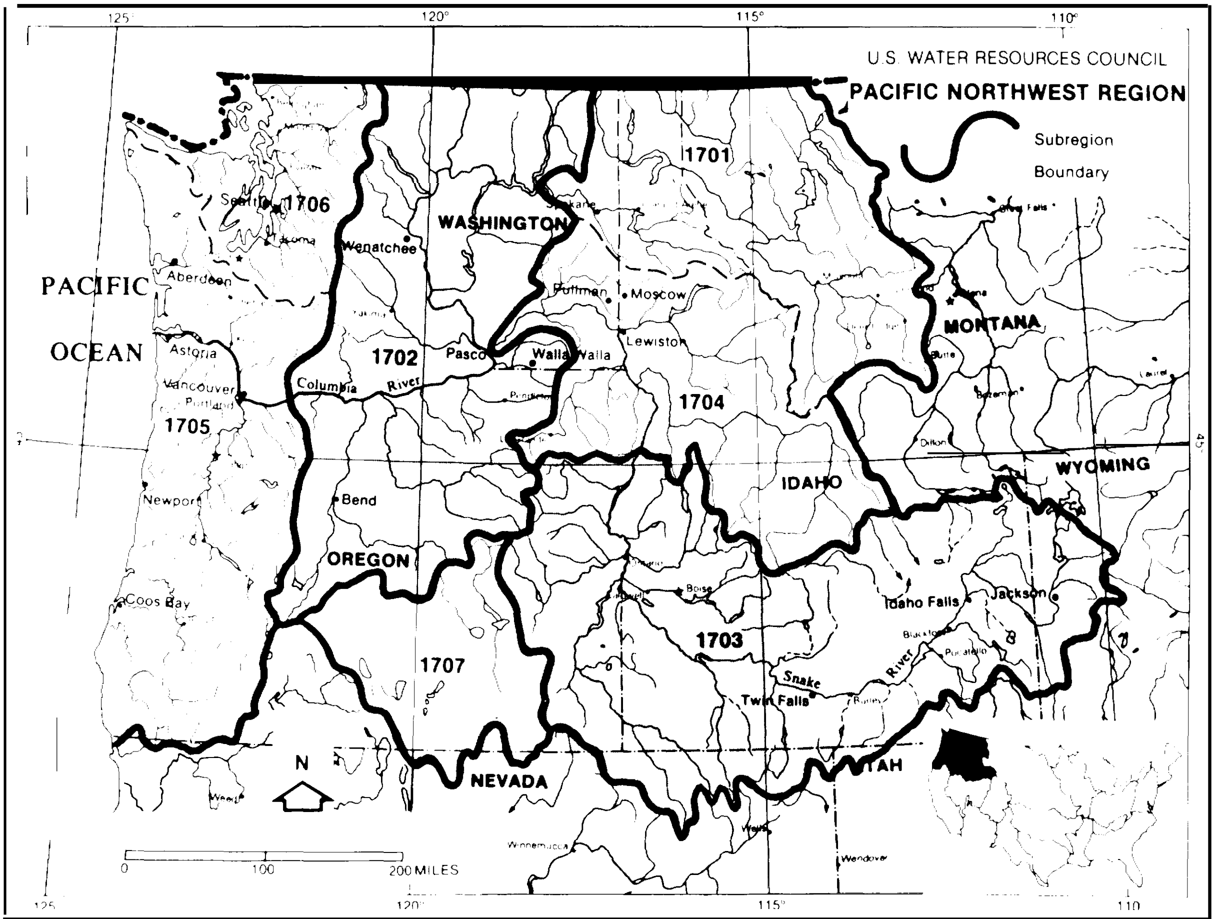
Relationship between supply and use in the Pacific Northwest region. While this region is often considered to be a water surplus area, it is apparent that along the Upper Snake River, water use is approaching supply during the summer months of each year. Along the Columbia River, the various uses to which the water is put (e.g., hydroelectric generation, fishery support, irrigation) mean that little excess water is actually available once all these demands are satisfied,

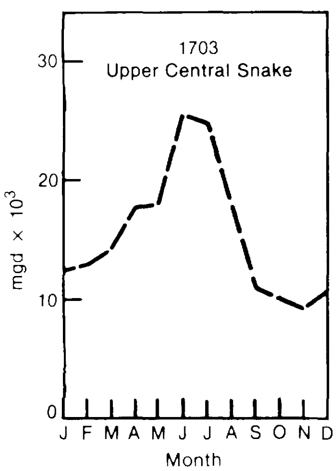
Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals Total (mgd)	Ground water withdrawals Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption (mgd)	Off stream use to total streamflow (mgd)
1701 . . .	31,400	3,579	242	10	406	1,924	626	2%0
1702	115,000	6,107	742	332	664	7,774	4,023	8
1703	10,600	4,082	5,591	225	830	20,640	5,128	33
1704 ... , ...	29.700	1,061	102	30	89	1,422	439	16
1705	212,000	1,796	440	16	0	2,404	756	5
1706	42,200	1,139	178	0	0	1,098	194	1
1707	1,070	76	53	14	25	2,364	747	41
Total region . .	255,270	17,839	7,348	627	2,014	37,626	11,913	

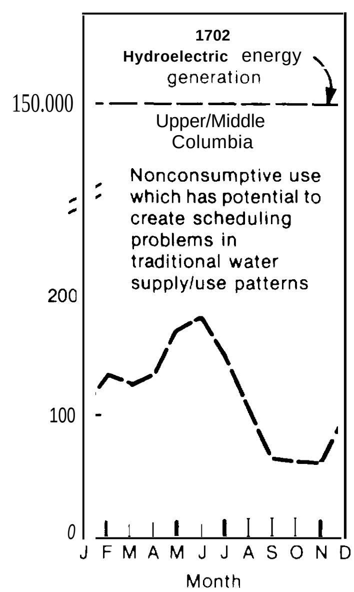
Key mgd = million gallons per day (multiply by 1,120 to obtain acre. ft/year) bg = billion gallons (multiply by 3,070 to obtain million acre-ft)

SOURCE Second National Water Assessment, 1978

Figure B-14.—The Pacific Northwest Water Resources Region







Streamflow Consumption

25-160 0 - 25 : QL 3

The California Basins: Water Resources Region 18

The California region includes the State of California and Klamath County, Ore. It has a total surface area of approximately 160,000 mi^2 and a mean annual surface runoff variously estimated at between 53 maf/yr (5) and 69 maf/yr (4). According to WRC, approximately 85 percent (45 maf/yr) is discharged from two subregions in the northern portion of the State, the Klamath and Sacramento Rivers. At the same time, more than half of the approximately 21 million inhabitants of the State live in subregion 1806, which includes the metropolitan areas of Los Angeles and San Diego. This subregion has an annual discharge of 6.5 maf annually, slightly more than 10 percent of the total runoff of the State (5). The fact that significant amounts of irrigated agriculture also exist in the southern half of California, principally in the San Joaquin Valley, only serves to compound the severe water supply-use imbalance in the State.

Normal reservoir storage for California as a whole is approximately 39 maf, which is equivalent to less than 75 percent of the smaller of the two estimates of total streamflow. The California water resources region ranks first among those in the Western United States in terms of total water withdrawals (44.4 maf), total ground water withdrawals (21.5 maf), total water consumed (29.8 maf), and total water consumed by irrigation (27.2 maf).

A comparison of supply-use curves for northern and southern subregions within the State illustrates the imbalance (fig, B-15). In the Sacramento River basin (1802), in spite of extensive irrigated agriculture, water supplies exceed uses during all months of the year. In two southern basins, the San Joaquin River and the Los Angeles-San Diego basins, water demand slightly exceeds surface supplies during almost every month of the year. There appears to be no water available for future development in the southern portion of the State without some change in water supply or use patterns.

Water Resources Region 18: California

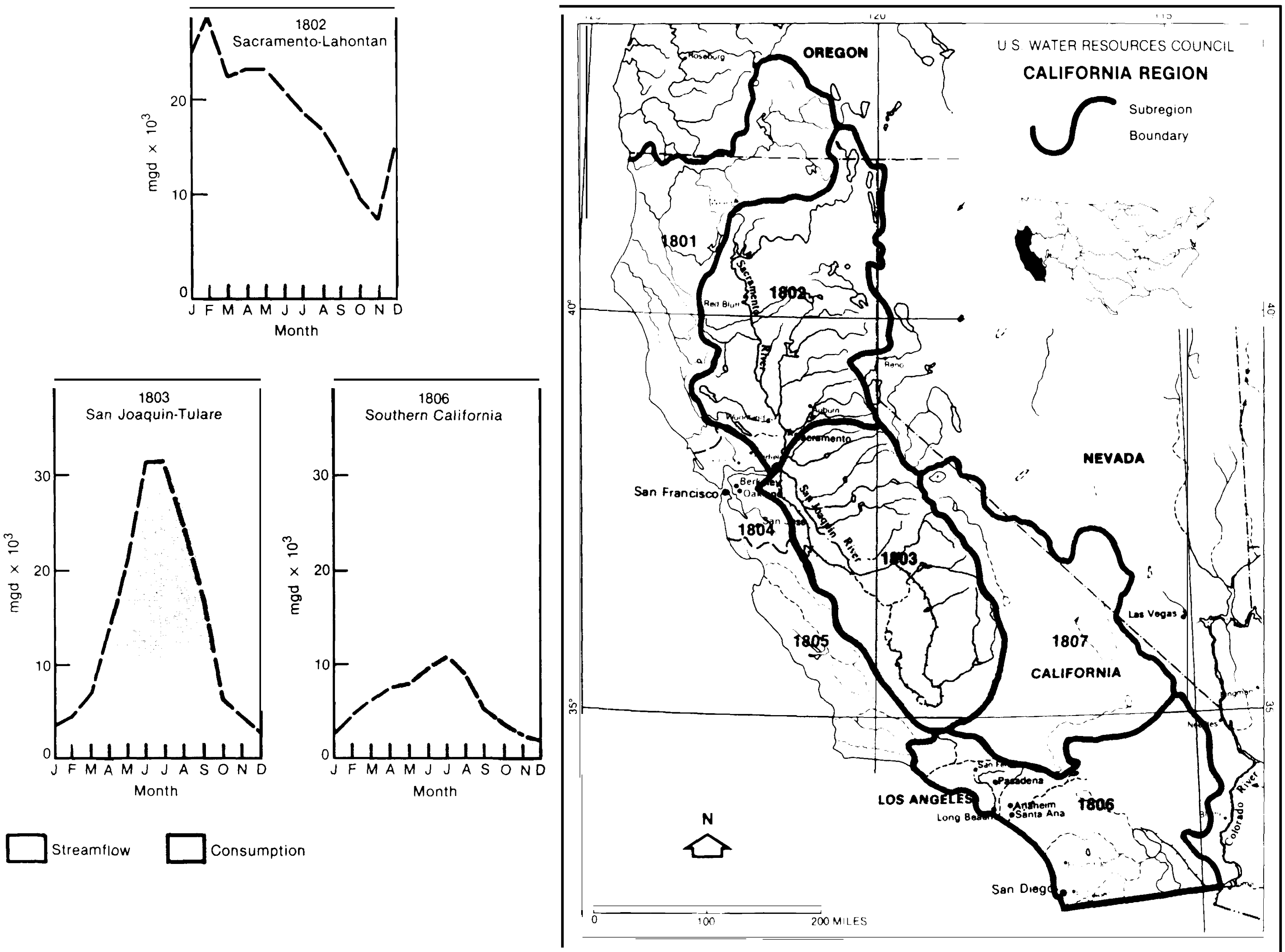
The relationship between water supply and use for selected subregions in the California region. This is a graphic illustration of the water imbalance between the northern and southern portions in California. In a northern subregion (the Sacramento), supply exceeds use during all months of the year, while in the central San Joaquin-Tulare and southern California subregions, virtually all available water is used during every month of the year.

Subregion	Mean streamflow (mgd)	Normal surface storage (bg)	Ground water withdrawals Total (mgd)	Ground water withdrawals Overdraft (mgd)	Evaporation from reservoirs, stockponds (mgd)	Withdrawals (mgd) (fresh and saline)	Total consumption (mgd)	Off stream use to total streamflow (mgd)
1801	26,000	1,298	181	0	0	2,256	737	3 %
1802	13,900	5,446	4,052	233	138	7,756	5,398	28
1803	2,830	3,717	10,659	1,250	315	17,828	12,649	89
1804	2,570	790	616	0	13	7,744	809	24
1805	1,490	412	1,181	83	20	3,999	833	37
1806	446	850	2,020	491	137	14,168	5,887	101
1807	139	183	451	140	46	454	328	100
Total region	47,375	12,697	19,160	2,197	669	54,205	26,641	

Key" mgd = million gallons per day (multiply by 1,120 to obtain acre-ft/year) bg = billion gallons (multiply by 3,070 to obtain million acre-ft)

SOURCE Second National Water Assessment, 1978

Figure B-15.—The California Water Resources Region



Ground-Water Resources Regions

The availability, ease of extraction, and total quantity of ground water present at a site is determined largely by the local geology, climate, and surface hydrologic regime. While climate and the surface hydrologic regime commonly vary together at a site, the geology, which determines the extent to which rocks will hold and transmit ground water, often varies independently of the surface environment. For this reason, ground-water resources regions do not necessarily correspond to surface-water resources regions. In assigning an area to a given ground-water resources region, arbitrary decisions must often be made concerning the relative importance of climate and geology. For the purposes of this assessment, the delineation of these regions used is that originally developed by Thomas and subsequently adopted by others (1), The general location these regions in shown in figure B-16. They are:

1. Western Mountain Ranges,
2. Alluvial Basins,
3. Columbia Lava Plateau,
4. Colorado Plateaus and Wyoming Basin,
5. High Plains,
6. Unglaciated Central Region, and
7. Glaciated Central Region.

Western Mountain Ranges

The Western mountain ranges, consisting primarily of the Rocky Mountains and the Cascade and Sierra Mountain ranges near the Pacific Coast, serve as the principal source of water in the Western United States because the bulk of the regional precipitation falls here and resulting runoff supplies streams and aquifers. Rocks in the region are generally hard and dense, They shed water rather than absorbing it and ground water is limited although some ground water may be extracted from alluvial materials, sands, and gravels, filling the floors of small intermontane valleys.

Most local water supplies are obtained from springs, wells in valleys, and surface reservoirs, Not enough wells have been drilled in the higher mountains to establish any trends in ground water availability, although the character of the rocks there indicate that such water may be obtained from fractured areas. Because of the limited human use of the Western mountains ranges, no widespread water-quality problems have been mentioned in the literature,

Alluvial Basins

Alluvial basins are found in a southwestern tier of States reaching from California to central New Mexico. They reach as far north as northern Nevada and include portions of western Utah and southern Arizona. The basins in this region consist of erosional materials removed from the adjacent mountains and deposited as alluvium in the basin floors, This alluvial material is composed of interbedded sands, gravels, and clays and is recharged principally by streams flowing across it that originate in the surrounding highlands, The alluvial fill functions as an ideal aquifer and creates an opportunity for development of high-yielding wells,

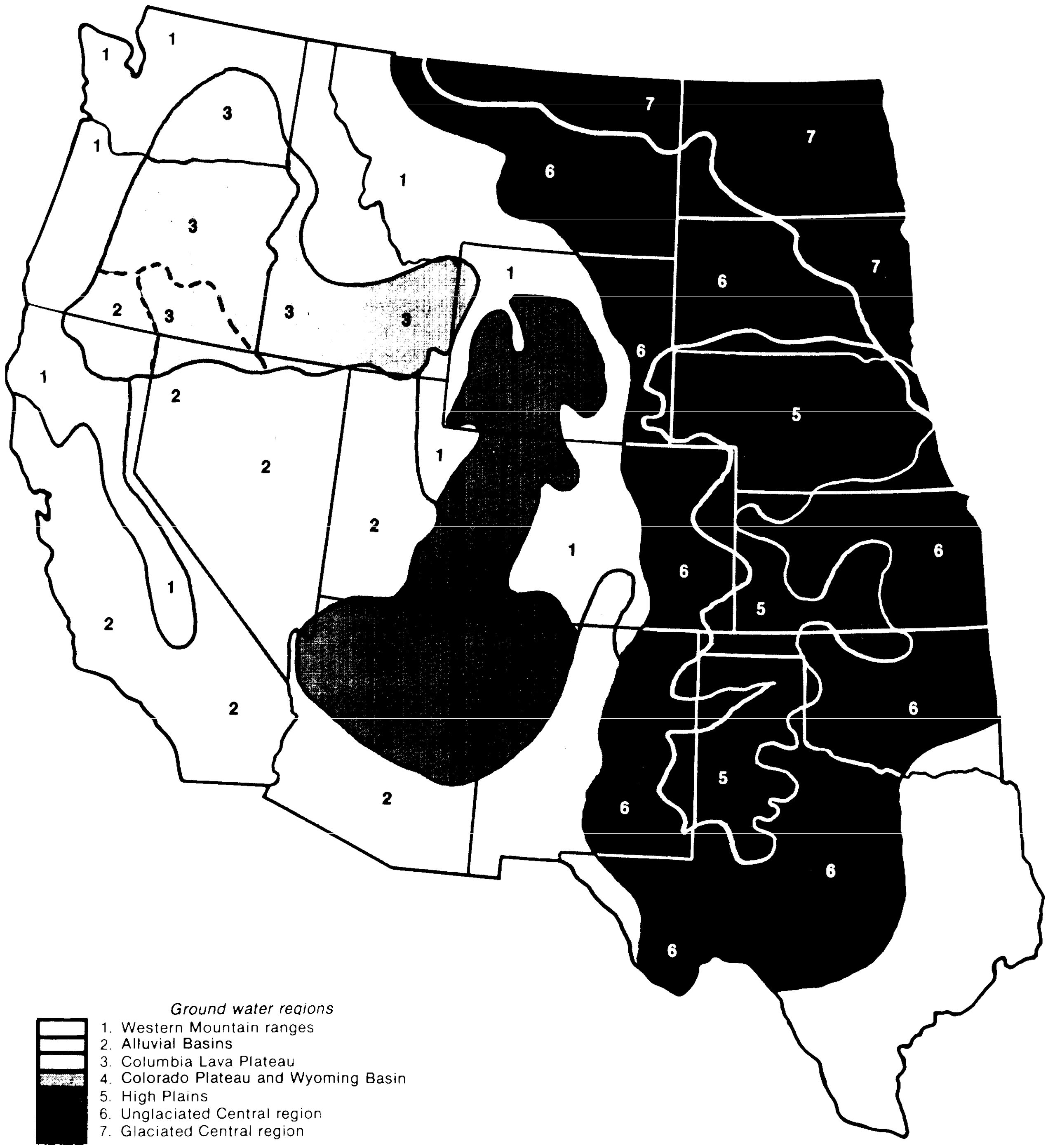
Ground water development for irrigated agriculture has been extensive in this region because of the prevailing arid climate. The rate of recharge of these aquifers is generally much less than the rate at which water is extracted from this source, and ground water levels are declining as the amount of water in storage is depleted. The local significance of this problem varies, depending on the amount of ground water use and the source and volume of the recharge water. Locally, artificial recharge has helped alleviate the problem of ground water depletion.

Ground water is a very important source of water in this region, where surface runoff is generally nonexistent over a large percentage of the area, For example, in Arizona, 61 percent of the total water use is derived from ground water. Given the extent to which this resource is being consumed and contaminated in the areas of highest use, there is legitimate cause for concern regarding the future potable water availability in some portions of the aquifers underlying the major population centers of this region (see ch. IV for a discussion of general water-quality problems affecting or likely to affect the West).

Locally, in such areas as Phoenix and Tucson, Ariz., the alluvial aquifers are intensively used. It is estimated that in Maricopa County, which includes the City of Phoenix, ground water use was 30 times the rate of natural recharge. For Pinal County, ground water depletion was estimated to be 12 times the rate of recharge. In the Tucson valley, the rate of overdraft is three to one.

For California, the largest user of ground water in this region, ground water supplies about 48 percent (21.5 maf) of the total annual freshwater withdrawals in the region, representing an estimated

Figure B-16.—The Major Ground Water Regions of the Western United States



SOURCE D Todd, *Ground Water Hydrology,* 2d ed (New York John Wiley & Sons. Inc , 1980) overdraft of 2,197 million gallons per day (2.5 maf/yr), or 11.5 percent of estimated average annual recharge.

A number of ground-water quality problems have been identified in this ground-water resource region by Federal and State agencies, including the intrusion of seawater into aquifers as the result of overdrafting of ground water, water-quality degradation from percolation of irrigation waters, and localized pollution of ground water from industrial and municipal sources.

The availability of large quantities of ground water has been a significant factor in the economic growth of the Southwestern United States. The continued availability of this resource for existing uses, given the extent to which it is being "mined" and the potential for serious pollution from both agricultural, municipal, and industrial sources, is questionable.

Columbia Lava Plateau

This ground-water resource region is located principally in eastern Washington and southern Idaho, Geologically, it was formed largely by surface volcanic rocks, mainly lava flows, interbedded with or overlain by alluvium and lake sediments. Water originates chiefly from the mountains to the east and west of the Plateau, the Cascade and Rocky Mountain ranges. The lava flows tend to be highly permeable, as a result of cracks which formed at the time the lava cooled, and thus form highly productive aquifers. Large volumes of excess ground water discharge as major springs are the source of surface rivers that drain into the Snake and Columbia Rivers. Ground water is most readily available in the valley bottoms because of the great thickness of the lava flows. In the higher plateau areas, however, deep wells may be required to extract ground water for irrigation.

No widespread water-quality problems have been reported for this region. The Water Resources Council estimates that approximately 8.2 maf of water are withdrawn annually from the ground water storage in this region, representing an estimated 8.5 percent overdraft, or 70,000 acre-ft in excess of natural annual recharge. This overdraft may be localized, however; USGS states that "[o]n the Snake River Plain in Idaho, . . . excess irrigation water has filtered into the ground and joined the original ground water body, increasing the rate of recharge of ground water into the Snake River by nearly 50 percent. In this area as a whole, . . . water has not been mined, it has been put in the bank" (l).

Colorado Plateaus and Wyoming Basin

The Colorado Pleateus and Wyoming Basin region is located in southwestern Wyoming and in the Four Corners region of portions of Utah, Arizona, Colorado, and New Mexico. The aquifers in this region consist of consolidated rocks that are generally horizontal but have been folded, tilted, or fractured in places. This region is arid to semiarid, generally at an altitude high above sea level, and deeply dissected by the rivers and streams flowing through it. Prospects for large-scale ground water development are poor. Small water supplies for domestic and livestock purposes are generally available, however, Most aquifiers are sandstone beds, although limestone and alluvium also yield water in a few places. No estimates exist of ground water consumption specifically for this resource region, It is assumed to be low, since there is limited water to be withdrawn from ground water storage, Ground water quality problems identified by the Second National Assessment for this region include high levels of dissolved solids and contamination by toxic industrial wastes in portions of Colorado and New Mexico.

The High Plains (Ogallala Aquifer]

Probably the best known aquifer in the Western United States is the High Plains, or Ogallala, aquifer. This ground-water resource region includes most of Nebraska and Kansas and portions of eastern Colorado, New Mexico, and the Texas and Oklahoma panhandle. The problems of the Texas, Kansas, and Oklahoma sections of the aquifer have come to typify, for the press and public, some of the problems represented by ground water overdrafts.

In portions of Colorado, Nebraska, Texas, Oklahoma and Kansas, alluvium forms a vast plain extending eastward from the Rocky Mountains, The bulk of it is classified as a single stratigraphic unit, the Ogallala Formation, which covers older rocks to thicknesses exceeding 450 ft. The sand and gravel of the formation constitute an aquifer that may yield as much as 1,000 gallons per minute, locally, The region is generally semiarid so that ground water recharge from precipitation is extremely small. The productiveness of wells has encouraged pumping of ground water, however, especially for irrigation in Texas. This water has been derived primarily from storage. As a result, water tables have declined substantially since extensive pumping began in the 1950's.

The Ogallala aquifer has been used to support irrigated agriculture in the high plains of Texas since the development of suitable high-speed engines and turbine centrifugal pumps in the mid-1930's, Significant use of the ground water resources of the southern portion of the aquifer did not begin until the 1950's, however, spurred by the development of center-pivot sprinkler systems and the availability of low-cost natural gas. Even though the problem of overdrafting the Ogallala aquifer was recognized almost from the outset of extensive agricultural use, pumping from the aquifer increased from 1.9 maf in 1950 to 11.1 maf in 1975 in the Texas portion of the aquifer alone.

Some elements of the ground water problem in the High Plains region are generally instructive for other portions of the Western United States where the future of ground water resources is in doubt, Ground water mining has widely differing effects, even with in an area that is relatively homogeneous with respect to geology, climate, and agricultural use. Throughout the High Plains region, the ground water source is referred to as a single aquifer. However, the properties and characteristics of that aquifer vary greatly from Nebraska to the Texas panhandle, and ground water is unevenly distributed within and among the individual States. Depending on the configuration of the aquifer and its physical composition, individual areas will be affected very differently by ground water mining.

The dewatering of the Ogallala aquifer has had the most serious consequences in the Texas, Oklahoma, Kansas, and Colorado portions, where the aquifer is thinner, the saturated thickness is less, and the permeability is generally lower, Even there, however, the natural variability of the aquifer has produced water level declines ranging from 20 to more than 120 ft, so that there is no single impact on irrigated agriculture. In the northern portion of the aquifer, primarily Nebraska, the saturated thickness is up to 10 times that of the southern portion, and nearly 60 percent of all the water contained in the aquifer is found there (3). Even in this relatively water-rich portion of the aquifer, " . . . the ground water pinch is prompting officials to consider allocating available ground water by metering it in control areas of the Natural Resources District" (2). In spite of the overall volume of water in the northern portion of the aquifer, there have been water-level declines in some areas necessitating deeper wells and higher pumping lifts with increased pumping costs. The continued use of the large volumes of water required by irrigated agriculture in the northern portion of the Ogallala aquifer will become increasingly affected by institutional and economic factors, such as the legal status of ground water and energy costs.

Unglaciated Central Region

This is a large and complex ground-water resource region, extending from southern New Mexico to the southeastern portion of Montana, from east of the Rocky Mountains to east of the High Plains region in central Texas, Oklahoma, and the southeastern corner of Kansas. It is an area of plains and plateaus underlain by consolidated rocks. Alluvial deposits of substantial width and thickness form good aquifers along the Arkansas, Platte, and Missouri Rivers but are not generally important elsewhere. Aquifers in most of the region are composed of limestone or sandstone with low to moderate yields. Some of the most unproductive aquifers in the Western United States are found in this region because of low water yields, high salinity, or a combination of both. On the other hand, wells drilled into cavernous limestone may yield large amounts of high-quality water. This extreme local variability makes generalizations concerning ground water availability or quality in this region unreliable. Local testing is required to establish the values for both. Except locally, ground water does not represent a major source of water in the region.

No problems with ground water availability for this region were discussed in the Second National Water Assessment. Water-quality problems, generally involving high levels of salinity, are identified for portions of central Texas and Oklahoma.

Glaciated Central Region

This region is quite similar to the Unglaciated Central region except for the mantle of unconsolidated deposits of the ice and meltwaters of the continental glaciers that covered it at one time. It includes the northern portion of Montana, much of North Dakota and eastern South Dakota, and a small portion of northeastern Kansas. The glacial materials consist mostly of fine-grained rock debris intermixed with beds of sands and gravels. In portions of the area, the glacier material is nearly 1,000 ft thick and forms an important aquifer. In this region, 1arge-diameter wells yield sufficient water to meet domestic needs.

Hazardous Waste Sites by State

Arizona:
Scottsdale . . . . Indian Bend Wash Area
Kingman . . . . . Kingman Airport Industrial Area
Goodyear . . . . Litchfield Airport Area
Globe . . . . Mt. View Mobile Home* **
Tucson . . . . Tucson International Airport*
Phoenix ., ... 19th Avenue Landfill*

California:
Rancho Cordova . . . Aerojet*
Hoopa . . . . Celtor Chemical
Ukiah . . . . Coast Wood Preserving
Redding . . . . Iron Mountain Mine*
Sacramento . . . . Jibboom Junkyard
Richmond . . . . Liquid Gold
Fullerton . . . . McColl
Cloverdale . . . . MGM Brakes
Fresno . . . . Purity Oil Sales, Inc.
Fresno . . . . Selma Pressure Treating
Glen Avon Heights . . Stringfello* *

Colorado:
Leadville . . . . California Gulch
Idaho Springs . . . . . . Central City, Clear Creek*
Denver . . . . Denver Radium Site*
Boulder ., ... Marshall Landfill* * *
Commerce City . . . . . Sand Creek
Commerce City . . . . . . Woodbury Chemical*

Idaho:
Rathdrum . . . . Arrcom (Drexler Enterprises)
Smelterville . . . . Bunker Hill
Caldwell . . . . Flynn Lumber Co.

Kansas:
Arkansas City . . . . Arkansas City Dump* * *
Holiday . . . . Doepke Disposal, Holiday
Wichita . . . . John's Sludge Pond
Cherokee County . . . Tar Creek, Cherokee Co.

Montana:
Anaconda . . . . Anaconda—Anaconda
Libby . . . . Libby Ground Water
Milltown ., ... Milltown
Silver Box/
Dear Lodge . . . . . . Silver Bow Creek

North Dakota:
Southeastern . . . . Arsenic Trioxide Site* **

Nebraska:
Beatrice . . Phillips Chemical

New Mexico:
Clovis . . . . ATSF/Clovis*
Milan . . . . Homestake*
Albuquerque . . . . South Valley* **
Churchrock . . . . United Nuclear Corp. *

Oklahoma:
Criner. . . . . Criner/Hardage*
Ottawa County . . . . . Tar Creed*

Oregon:
Portland . . . . Gould, Inc.
Albany . . . . Teledyne Wah Chang

South Dakota:
Whitewood ., ... Whitewood Creek* * *

Texas:
Grand Prairie . . . . . . Bio-Ecology*
Houston . . . . Crystal Chemical*
Crosby . . . . French, Ltd. *
Houston . . . . Harris (Farley St.)*
Highlands . . ., ... Highlands Acid Pit*
La Marque. , ... Motco " * *
Crosby . . . . Sikes Disposal Pits*
Orange County . . . . . Triangle Chemical

Utah:
Salt Lake City . . . . . . Rose Park Sludge Pit* * *

Washington:
Spokane . . . . Colbert landfill
Tacoma ... . Commencement Bay, Near Shore Tide Flat*
Tacoma ... . Commencement Bay, S. Tacoma Channel*

Wyoming:
Laramie ... . Baxter/Union Pacific

● ↑ IPL/EEI ● ● = **States' Designated** Top Priority Site
"IPL" means the Interim Priorities List of 115 sites announced m October 1981. "EEL" refers to the Expanded Eligibility List, an addttional 45 sites designated in July 1982 as eligible for remedial actions

SOURCE **U S Environmental Protection Agency,** *Hazardous Waste Sites by State,* Proposed Superfund Priorities List, December 1982

Appendix B References

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2. Lehr, Jay H., "Data Base on Ground Water Quality and Availability: Effects on Productivity of U.S. Croplands and Rangelands, " *Impacts of Technology on U.S. Cropland and Rangeland Productivity, vol.* 11, Part C, Background Papers, December *1982.*
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5. U.S. Water Resources Council, *The Nation Water Resources* 1975-2000, Second National Water Assessment (Washington, D. C.: U.S. Government Printing Office, 1978).