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Water Withdrawals for Irrigation, Municipal, Mining, Thermoelectric-Power, and Drainage Uses in Arizona Outside of Active Management Areas, 1991-2000

Scientific Investigations Report 2004–5293

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photograph of irrigated alfafa. (Photograph taken by U.S. Geological Survey.)
Inset 1: Coal mining. (Photograph courtesy of Peabody Coal.)
Inset 2: Ground-water storage system. (Photograph courtesy of Arizona Water Company.)
Inset 3: Cholla thermoelectric powerplant near Joseph City, Arizona. (Photograph courtesy of Arizona Power Service.)
Inset 4: Ground-water withdrawal for drainage. (Photograph taken by U.S. Geological Survey.)

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By Saeid Tadayon

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Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Geological Survey, Reston, Virginia: 2005

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Suggested citation:
Tadayon, Saeid, 2005, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of Active Management Areas, 1991–2000: U.S. Geological Survey Scientific Investigations Report 2004-5293, 28 p.

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Conversion Factors and Datum

CONVERSION FACTORS

Multiply	By	To obtain
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter
acre-foot (acre-ft)	0.001233	cubic hectometer
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
gallon per minute (gal/min)	0.06309	liter per second
mile (mi)	1.609	kilometer

DATUM

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

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Water Withdrawals for Irrigation, Municipal, Mining, Thermoelectric-Power, and Drainage Uses in Arizona Outside of Active Management Areas, 1991–2000

By Saeid Tadayon

Abstract

Economic development in Arizona is largely influenced by access to adequate water supplies owing to the State's predominantly semiarid to arid climate. Water demand is met by pumping ground water from aquifers or by conveying surface water through a system of reservoirs and canals. Water-withdrawal data provide important information on how water demand affects the State's water resources. Information on water withdrawals also can help planners and managers assess the effectiveness of water-management policies, regulations, and conservation activities.

This report includes water-withdrawal data for irrigation, municipal, mining, thermoelectric-power, and drainage uses for 1991–2000, and describes the methods used to collect, compile, and estimate the data. Data are reported for the Arizona Department of Water Resources ground-water basins outside of Active Management Areas.

Because of the climate, ground water and surface water are used to irrigate nearly all agricultural fields in Arizona. Irrigation accounted for the largest use of water in the study area during 1991–2000. The amount of water withdrawn for irrigation varies greatly from year to year for some of the basins, primarily because of differences in the consumptive water requirement for different crops and because of changes in irrigated acreage.

The population of Arizona increased about 35 percent from 1991 to 2000—from about 3.79 million in 1991 to about 5.13 million in 2000. Correspondingly, water withdrawal for municipal use increased steadily in most of the basins during 1991–2000.

Ground-water withdrawals for mining did not show any consistent trends during 1991–2000. Increases and decreases in withdrawals for mining were most likely due to variations in mineral production. Mineral prices and competition from mining in other States and foreign countries probably result in annual increases or decreases in mineral production in Arizona.

Between 1991 and 2000, ground-water withdrawals for thermoelectric-power generation generally increased owing to an increase in production of electricity. Ground-water withdrawals for drainage of agricultural lands in the Lower Gila and Yuma Basins varied irregularly from year to year. Annual total water withdrawals are not presented in this report because for some years irrigation values for some of the basins are reported as "less than 1,000 acre-feet," and municipal and mining values for some of the basins are reported as "less than 300 acre-feet."

Introduction

Because of the predominantly semiarid to arid climate in Arizona, economic development in the State is largely influenced by access to adequate water supplies. Water demand is met by pumping ground water from aquifers or by conveying surface water through a system of reservoirs and canals. Water-withdrawal data in Arizona are collected by Federal, State, and local government agencies as well as by private organizations. Anthropogenic water use is a significant component of the hydrologic cycle in Arizona, and accurate spatial and temporal water-use data are useful for management of this valuable resource. Water-withdrawal data provide important information on how water demand affects the State's water resources. Information on water withdrawals also can help planners and managers assess the effectiveness of water-management policies, regulations, and conservation activities.

Water withdrawal in Arizona is dominated primarily by agriculture and secondarily by rapidly growing urban populations. Because of the low rainfall in Arizona, agriculture in Arizona depends heavily on the State's water resources. From 1991 to 2000, the population of Arizona increased about 35 percent, from about 3.79 million to about 5.13 million (U.S. Census Bureau, 2004; table 1 and fig. 1).

The U.S. Geological Survey (USGS), in cooperation with the Arizona Department of Water Resources (ADWR), collected and compiled annual ground-water and surface-water withdrawal data and estimated withdrawals for 1991–2000. Ground-water withdrawal data for irrigation, municipal, mining, thermoelectric-power, and drainage uses were compiled for ADWR ground-water basins outside of Active Management Areas (AMAs; fig. 2). Ground-water withdrawal data for the Douglas, Harquahala, and Joseph City Irrigation Non-Expansion Areas (INAs) were compiled by the ADWR (fig. 2). In this report, ground-water withdrawals for the Douglas Basin include withdrawals for the Douglas INA and withdrawals for the Little Colorado River Plateau Basin include withdrawals for the Joseph City INA. Data for metered surface-water diversions for irrigation also were compiled. Nonmetered surface-water withdrawals for irrigation were estimated but are not presented in this report.

Ground-water withdrawal.

Surface water from river.

Purpose and Scope

The purpose of this report is to present estimated annual ground-water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses for 1991–2000. The report also includes surface-water diversions by irrigation districts where the diversions were metered or were quantified by using nearby streamflow-gaging stations operated by the USGS or other agencies. It describes the methods used to collect, compile, and estimate withdrawal data for each of these water-use categories. The study area includes the ADWR ground-water basins outside of AMAs.

Table 1. Population in Arizona, 1991–2000.

[Data from U.S. Census Bureau, 2004]

Year	Population
1991	3,788,576
1992	3,915,740
1993	4,065,440
1994	4,245,089
1995	4,432,499
1996	4,586,940
1997	4,736,990
1998	4,883,342
1999	5,023,823
2000	5,130,632

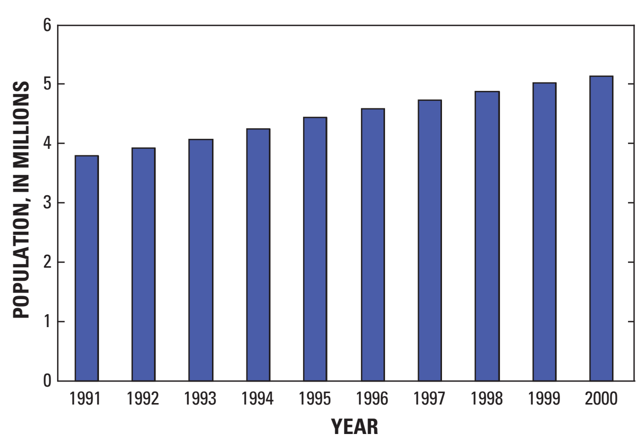
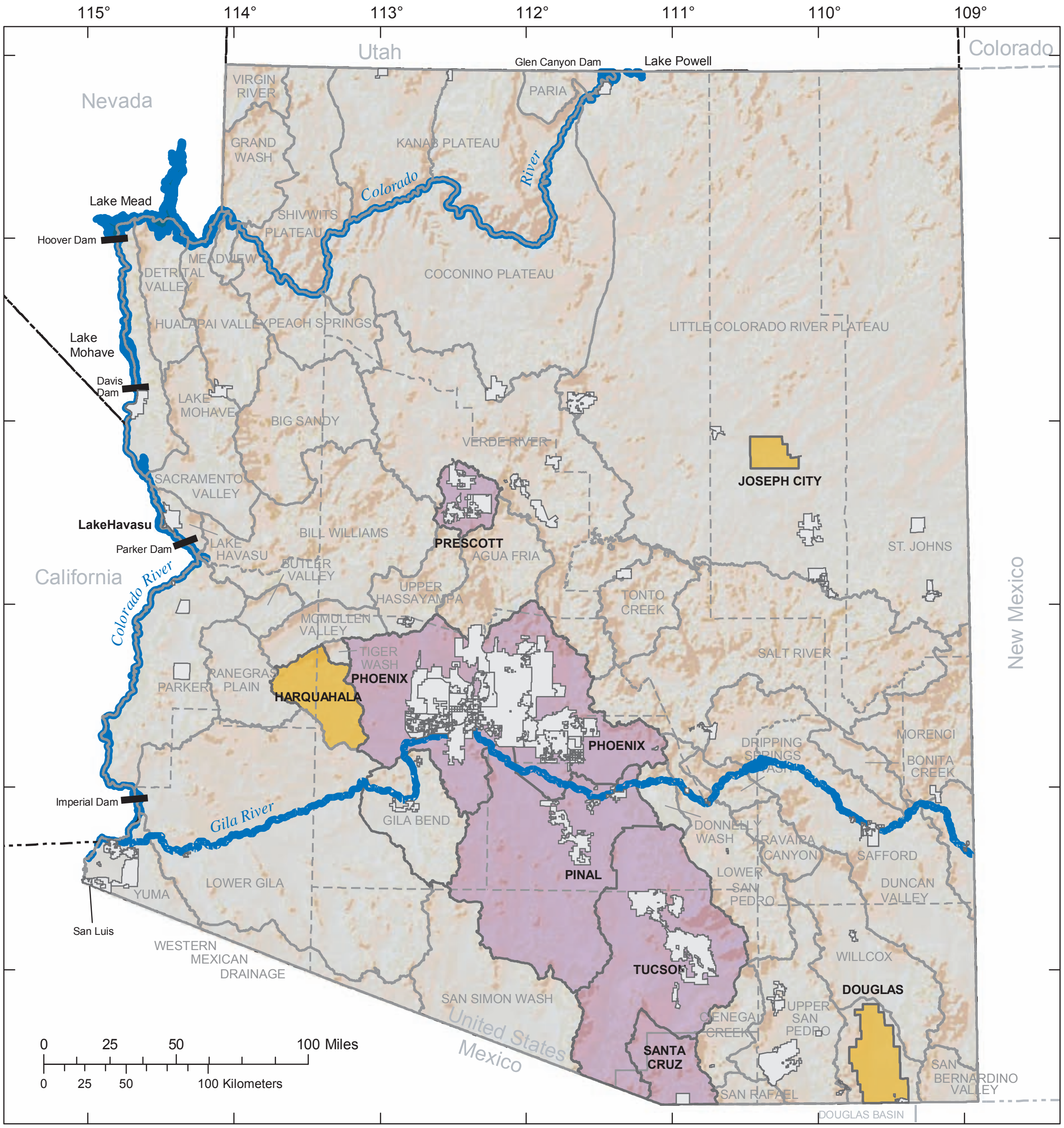


Figure 1. Population in Arizona, 1991–2000.



EXPLANATION

ARIZONA DEPARTMENT OF WATER RESOURCES

Active Management Area (AMA)

Irrigation Non-expansion Area (INA)

ARIZONA DEPARTMENT OF WATER RESOURCES GROUND-WATER BASIN

Figure 2. Arizona Department of Water Resources ground-water basins, Active Management Areas, and Irrigation Non-expansion Areas.

Irrigation withdrawal data represent the amount of ground water and surface water withdrawn for growing crops. Municipal withdrawal data include ground-water withdrawn by public and private water suppliers, and by self-supplied domestic users. Ground-water withdrawal data for mining represent withdrawals for metal mines and industrial-mineral mines. Ground-water withdrawal data for thermoelectric-power use represent withdrawals used for generating electricity. For 1991-2000, the USGS did not compile surface-water withdrawals for municipal, mining, and thermoelectric-power uses according to ADWR ground-water basins. Drainage withdrawal data represent withdrawals used to dewater the root zone in agricultural areas and withdrawals from Minute No. 242 (242 well field) used to address the problem of salinity of the Colorado River. In this report, water withdrawal refers to water removed from the ground or diverted from a surface-water source for various uses. The amount of water withdrawn for all categories shown in this report may not equal the actual amount of water used owing to water transfers or to the recirculation or reuse of water.

Previous Investigations

The USGS, in cooperation with the ADWR, collects and compiles ground-water withdrawal data for most areas in Arizona, and the USGS also compiles ground-water and surface-water withdrawal data in Arizona by county as part of a National water-use program. Data for years prior to and including 1990 were published in a series of reports and have been used in various hydrologic studies throughout the State.

Ground-water withdrawal data represent the amount of water pumped out of the ground for various uses and have been published in annual reports since 1955. Annual reports from 1955 to 1969 were published by the Arizona State Land Department. The Arizona Water Commission (precursor of the ADWR) published annual reports from 1970 to 1974, and the USGS published the reports from 1975 to 1990. In the 1975 report, annual ground-water withdrawals for some areas were estimated for years as far back as 1915. Estimates of the distribution of annual ground-water withdrawals in Arizona by use category were published only from 1975 to 1990. Ground-water withdrawals were estimated for irrigation, municipal, industrial, and livestock use, and for drainage of agricultural lands.

The withdrawal data and periodic water-level measurements are used in studies of Arizona's ground-water resources. Since 1939, the USGS and State of Arizona agencies have conducted joint studies to define the quantity, chemistry, and areal distribution of the resources and to monitor the effects of large-scale ground-water withdrawals. The USGS, in cooperation with the ADWR, published a series of reports from 1981 to 1994 entitled "Annual summary of ground-water conditions in Arizona" that included ground-water withdrawals by basin. Ground-water withdrawals in Arizona from 1915 to 1990 are shown in figure 3.

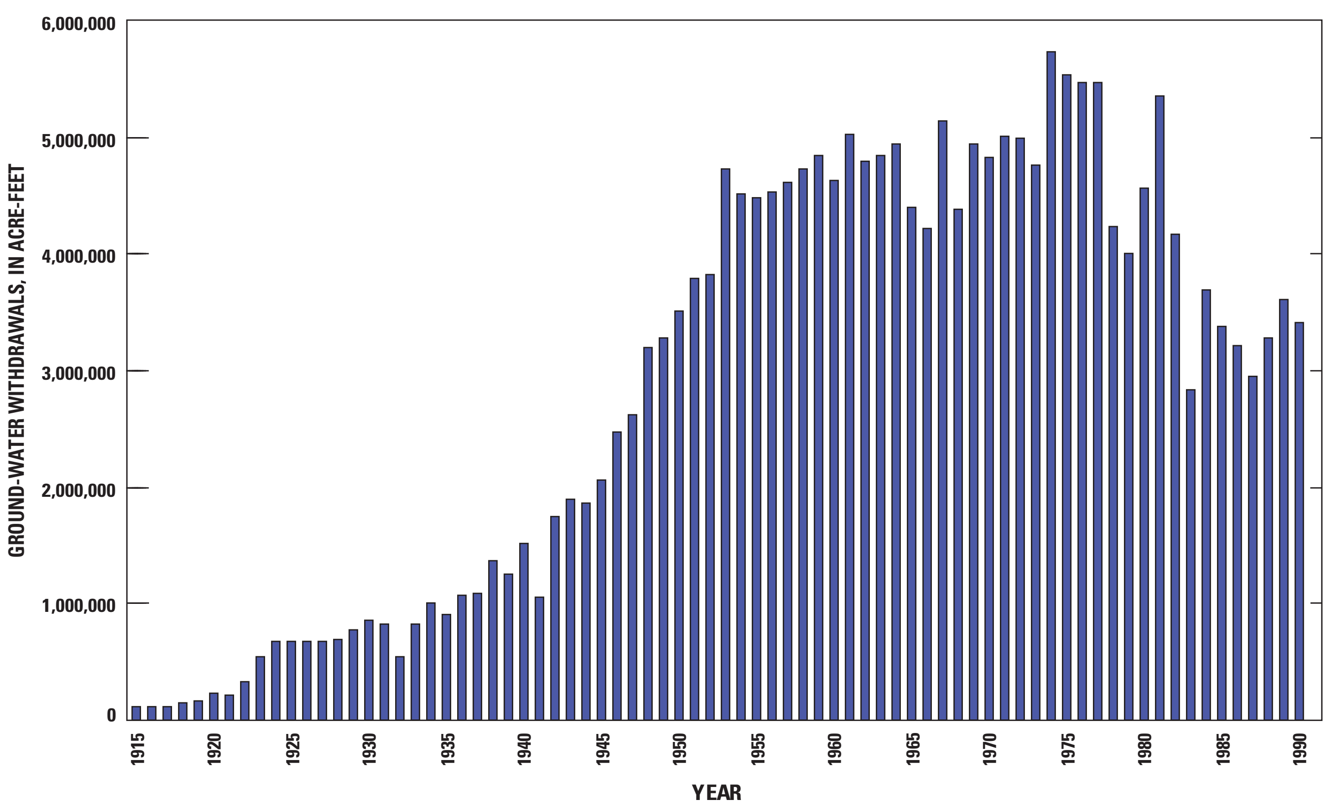


Figure 3. Estimated annual ground-water withdrawals in Arizona, 1915–90 (Anning and Duet, 1994).

In addition to the cooperative program with the ADWR, the USGS has collected and compiled ground-water and surface-water withdrawal data, and estimated withdrawals from related data, for Arizona since 1950 and publishes the data periodically as part of a National water-use program (MacKichan, 1951, 1957; MacKichan and Kammerer, 1961; Murray, 1968; Murray and Reeves, 1972, 1977; Solly and others, 1983, 1988, 1993, 1998; and Hutson and others, 2004). The primary categories used in these reports are irrigation, public supply, mining, thermoelectric power, domestic, commercial, and industrial; however, withdrawal data for two or more categories were combined in some years and were listed under separate categories in other years. Summaries of estimated withdrawals from 1950 through 2000 are presented in the USGS Circular report series entitled "Estimated use of water in the United States" (for example, Hutson and others, 2004).

Water Withdrawals

For the purpose of this report, withdrawals in each of the ADWR ground-water basins outside of AMAs are categorized by irrigation, municipal, mining, thermoelectric-power, and drainage use. Annual total withdrawals for each category are not given in this report because for some basins ground-water withdrawals for irrigation are reported as "less than 1,000 acre-feet" for some years and (or) ground-water withdrawals for municipal or mining use are reported as "less than 300 acre-feet" for some years. Ground-water withdrawal data for thermoelectric power and drainage were all greater than the reported value of 300 acre-feet during 1991-2000; however, to maintain consistency the annual total withdrawals for these categories also are not presented. Estimated annual water withdrawals for each basin are published as rounded values using the following criteria:

Values less than 1,000 acre-feet for irrigation are reported as "<1,000 acre-feet."

For municipal, mining, thermoelectric power, and drainage, values are reported as follows:

Values less than 300 acre-feet are reported as "<300 acre-feet."

Values from 300-999 acre-feet are reported to the nearest 50 acre-feet.

Values from 1,000 to 9,999 acre-feet are reported to the nearest 100 acre-feet.

Values from 10,000 to 99,999 acre-feet are reported to the nearest 500 acre-feet.

Values from 100,000 to 999,999 acre-feet are reported to the nearest 1,000 acre-feet.

Values of 1,000,000 acre-feet and greater are reported to the nearest 5,000 acre-feet.

Irrigation

Water used for irrigation is a significant component of the water budget in many ground-water basins in Arizona. The semi-arid to arid climate necessitates the use of ground water and (or) surface water for irrigation of nearly all agricultural fields in Arizona. Water withdrawals in the irrigation category are predominantly used for sustaining plant growth; however, the category also includes water used for chemical application, dust suppression, and leaching of salts from the root zone, and includes water lost in conveyance (Hutson and others, 2004). The category includes self-supplied withdrawals and deliveries from a combination of irrigation districts or government agencies. Data are presented for estimated ground-water withdrawals and for metered surface-water withdrawals.

Ground water is withdrawn for irrigation.

Surface water is withdrawn for irrigation.

Prior to 1991, the USGS estimated ground-water withdrawals for irrigation of crops in Arizona by using a power-divider method that used pump-efficiency and energy-consumption data. This method required field measurements of the discharge rate and the power-use rate for individual wells to provide an estimate of the average power required to pump 1 acre-foot of water from the well (Don Bills, U.S. Geological Survey, written commun., 2004). This method is no longer feasible for most of the basins because power data are not readily available. New methods have been used to compile or estimate water withdrawals and irrigated acreage for 1991–2000. Where available, metered ground-water and surface-water withdrawal data were used. Power data for 1991-94, however, were used to estimate ground-water withdrawals for irrigation in the Little Colorado River Plateau and Kanab Plateau Basins. Estimated ground-water withdrawals for these basins for 1995–2000 were extrapolated from the power data for 1991–94. For the remaining areas, estimated total withdrawals (ground water and surface water) were derived from calculations based on crop acreages, consumptive water requirement rates for crops, and irrigation efficiency for each county.

Alfalfa.

Barley. Photograph courtesy of U.S. Department of Agriculture.

Measuring ground-water pumping rate for estimation of withdrawals for irrigation.

Most of the crop-acreage data used to estimate withdrawals, by county, are from the Arizona Agricultural Statistics Service (AASS, annual reports entitled "Arizona Agricultural Statistics," published from 1992 to 2001). In some cases, county crop acreages were not published by the AASS in order to avoid disclosure of individual operations. Where the county crop-acreage data are not available, they are estimated from acreage data for prior years and (or) the 1992 and 1997 Census of Agriculture (U.S. Department of Agriculture, 1999).

Citrus.

Noncitrus orchard (pecan).


Corn.


Cotton.


Vegetables (peppers).


Wheat.

Consumptive water requirement rates for crops are determined by using a modified Blaney-Criddle method as described in Bureau of Reclamation (1992, appendix A). Inputs to the modified Blaney-Criddle method are latitude, average monthly temperature, total monthly precipitation, crop type, and crop planting and harvesting dates. Outputs from the modified Blaney-Criddle method are the consumptive water requirement by crop type for each month and the total for the growing season. Consumptive water requirement is the depth of irrigation water (feet), including precipitation, that is required consumptively for crop production (U.S. Department of Agriculture, 1967). Crop consumptive irrigation requirement is the planted acreage of the crop in the county multiplied by the consumptive water requirement and is reported in acre-feet.

County irrigation efficiency is the percentage of the crop consumptive water requirement divided by the total quantity of water withdrawn for irrigation in a particular county. Annual crop consumptive water requirements and irrigation withdrawals were estimated for all Arizona counties for 1980-90. The average county irrigation efficiency calculated for the 11-year period of 1980-90 (David Anning, U.S. Geological Survey, oral commun., 2004) was used for estimating withdrawals in this report. County irrigation efficiency takes into account conveyance losses and application losses. Conveyance losses are estimated as the difference between the volume of water applied to crops and the volume of water diverted from the source. Application losses include surface runoff, deep percolation, and losses due to irrigation system evaporation.

A variety of crops with different consumptive water requirements are grown in Arizona in a season. For 1991–2000, consumptive water requirements were estimated for the most common crops: alfalfa and other hay, barley, citrus and noncitrus orchards, corn, cotton, vegetables, and wheat. Estimated county irrigation withdrawals for a particular crop are based on the planted acreage of the crop, consumptive water requirement for the crop, and county irrigation efficiency. The following formula was used to estimate the withdrawal in a county for a particular crop:

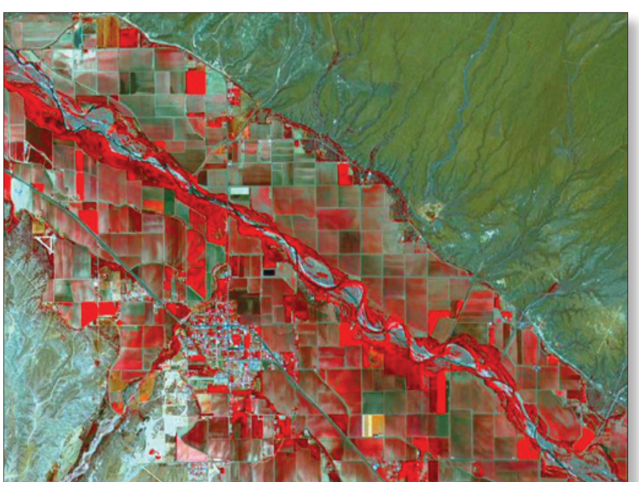
$$W = (A \times C) / E, \qquad (1)$$

where

- W is irrigation withdrawal, in acre-feet, for a particular crop;
- A is planted acreage of the crop in the county, in acres;
- C is consumptive water requirement for the crop based on the modified Blaney-Criddle method, in feet; and
- E is irrigation efficiency for the county, in decimal fraction.

Total irrigation withdrawals for the county were then determined by adding together withdrawals for each crop grown in the county. County withdrawal data were then disaggregated into the ground-water basins delineated by the ADWR. These basins, in most cases, cross county boundaries, and each county may include parts of several basins. The withdrawal data were disaggregated on the basis of the spatial distribution of irrigated acreage as determined from satellite images and aerial photographs and were estimated annually for each basin for 1991-2000.

In 2004, the USGS, in cooperation with the ADWR, the Natural Resources Conservation Service, and the Bureau of Reclamation, prepared a map of agricultural areas in Arizona (fig. 4). Agricultural field boundaries were delineated on the basis of satellite images and aerial photographs to disaggregate county crop acreage and compile the data by ADWR ground-water basins. For various reasons, different satellite images and aerial photographs were used by different agencies for digitizing field boundaries. Field boundaries were delineated using land satellite (Landsat) Thematic Mapper (TM) images, Satellite Pour l'Observation de la Terra (SPOT), Carterra Digital Ortho Quads (DOQ-5), or Digital Orthophoto Quadrangles (DOQs), or a combination of these sources to create a geographical information system (GIS) coverage. TM images, taken in 1993, were received from the Landsat 5 satellite and have a ground resolution of 30 meters. The SPOT satellite imagery (1997) has a ground resolution of 10 meters. Space Imaging's Carterra DOQ-5 product (1998) is a digital orthorectified satellite imagery that is formatted into USGS 7.5-minute quadrangles and has a ground resolution of 5 meters. A DOQ is a computer-generated image of an aerial photograph in which the image displacement caused by terrain relief and camera tilt has been removed; it has a ground resolution of 1 meter. DOQ images from 1992 to 1997 were used in this report.



Example of satellite image (Safford, Arizona, area) showing agricultural lands.

When metered ground-water or surface-water withdrawal data were not available for a particular basin, total irrigation withdrawal typically was estimated from the annual county consumptive water requirement and basin-wide irrigated acreage as determined from satellite images and aerial photographs. For several basins, irrigated acreages were estimated from published reports of other agencies or from unpublished information supplied to the USGS. Total irrigation withdrawal for a particular basin was estimated using the following formula:

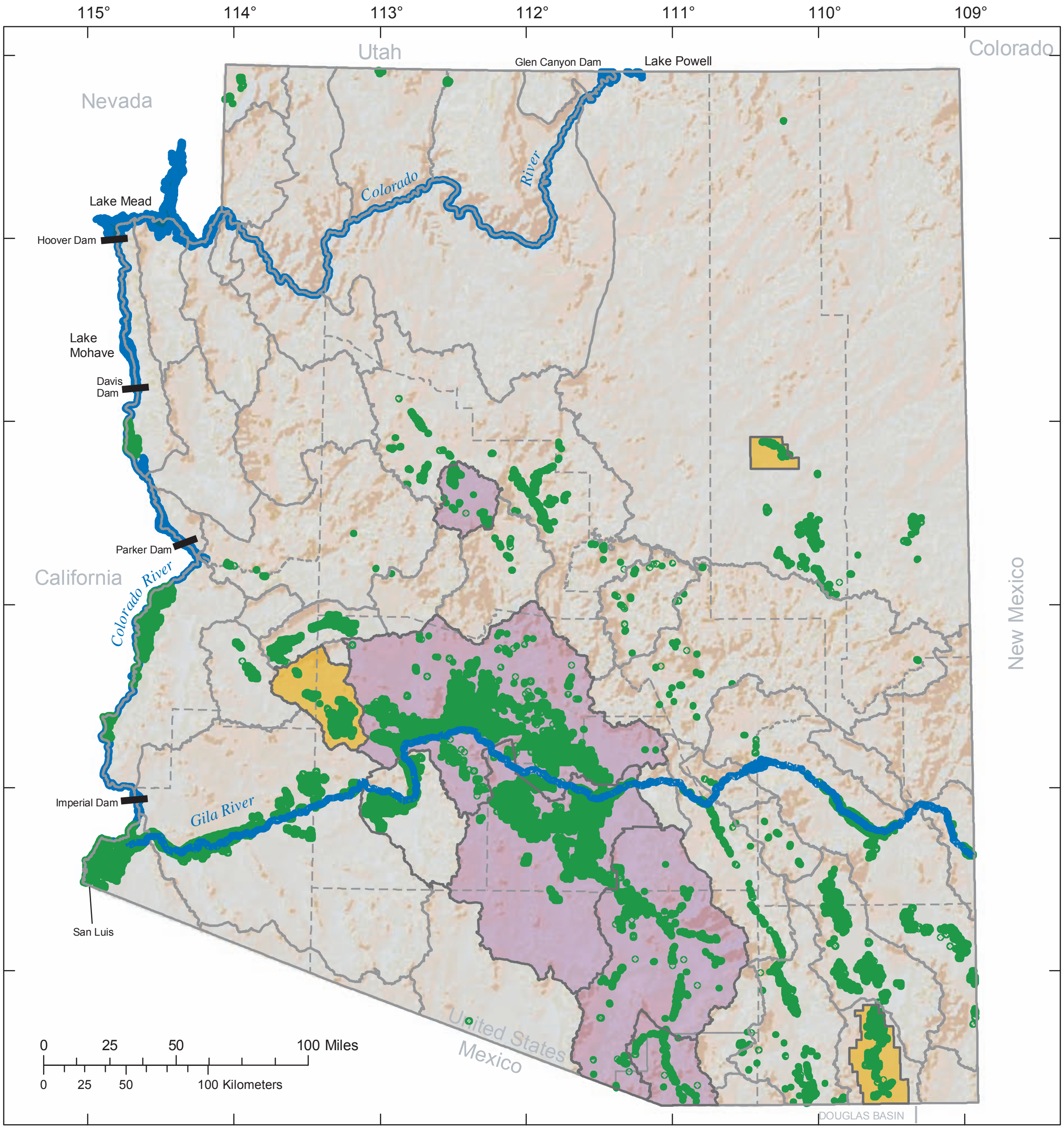
$$WB = (WT / AT) \times PB, \qquad (2)$$

where

- *WB* is total irrigation withdrawal for a particular basin for a given year, in acre-feet;
- *WT* is total irrigation withdrawal for the county in which all or part of the basin lies for a given year, in acre-feet;
- *AT* is total planted acreage of crops in the county for a given year, in acres; and
- *PB* is irrigated acreage in the basin as determined from satellite images and aerial photographs, published reports, and unpublished information supplied to the USGS, in acres.

When measured surface-water withdrawals were available for a basin, irrigation ground-water withdrawals were estimated by subtracting the metered amount of surface water from the total irrigation withdrawals. For the Yuma Basin, metered surface-water data are available; however, ground-water data are not available and the common practice of multicropping in the basin makes it difficult to accurately estimate irrigation withdrawals. Consequently, ground-water withdrawals for the Yuma Basin are estimated on the basis of withdrawal data reported for 1990. Both surface-water and ground-water withdrawals are delivered to agricultural fields in the Little Colorado River Plateau, Lower San Pedro, Salt River, Tonto Creek, Upper San Pedro, Verde River, and Virgin River Basins; however, the surface-water deliveries are not measured in these basins and are not presented in this report. This report includes only annual metered surface-water withdrawal data for irrigation.

Estimates of annual ground-water and surface-water withdrawals for irrigation for 1991-2000 are summarized in tables 2 and 3 and are represented graphically in figures 5 and 6. The amount of water withdrawn for irrigation in some basins can vary greatly from year to year. This variation is primarily due to differences in the consumptive water requirement for different crops and to differences in irrigated acreage.



EXPLANATION

ARIZONA DEPARTMENT OF WATER RESOURCES

Active Management Area (AMA)

Irrigation Non-expansion Area (INA)

AGRICULTURAL AREAS DELINEATED BY THE U.S. GEOLOGICAL SURVEY IN COOPERATION WITH THE ARIZONA DEPARTMENT OF WATER RESOURCES, THE NATURAL RESOURCES CONSERVATION SERVICE, AND THE BUREAU OF RECLAMATION

ARIZONA DEPARTMENT OF WATER RESOURCES GROUND-WATER BASIN

Figure 4. Agricultural areas delineated on the basis of satellite images and aerial photographs, Arizona, 1992–98.

Table 2. Estimated annual ground-water withdrawals for irrigation in ground-water basins outside of Active Management Areas, Arizona, 1991-2000.

[Values in acre-feet (rounded). Data not available for other basins. INA, Irrigation Non-expansion area; –, no data; <, less than]

Basin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agua Fria	1,200	1,300	1,400	1,300	1,400	1,500	1,400	1,100	1,100	1,500
Aravaipa Canyon	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000
Bill Williams	18,500	18,500	18,500	18,500	4,200	4,200	4,200	4,200	4,200	4,200
Butler Valley	–	–	–	2,200	4,500	2,300	8,900	9,900	11,000	9,500
Douglas	31,000	34,000	32,500	36,500	30,000	37,500	39,500	37,000	32,500	39,000
Duncan Valley	7,200	5,300	6,300	5,900	4,800	9,300	6,300	5,600	6,700	13,500
Gila Bend	237,000	213,000	233,000	248,000	256,000	238,000	255,000	203,000	228,000	294,000
Harquahala INA	2,000	3,000	6,800	16,000	19,500	29,000	21,000	18,000	23,000	27,500
Kanab Plateau	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Lake Mohave	36,500	33,000	35,500	40,500	38,000	44,000	41,500	28,500	31,000	33,000
Little Colorado River Plateau[1]	37,000	36,000	36,000	34,500	34,500	34,500	34,500	34,500	34,500	34,500
Lower Gila	164,000	164,000	161,000	169,000	169,000	158,000	162,000	142,000	157,000	171,000
Lower San Pedro	12,500	12,500	12,500	13,500	13,000	12,500	14,000	12,500	13,500	14,000
McMullen Valley	76,000	73,000	74,500	80,500	80,000	81,000	81,000	72,000	78,500	86,000
Parker	3,200	2,400	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000
Ranegras Plain	29,000	27,000	29,000	31,000	32,000	32,500	31,500	29,500	32,500	34,000
Safford	79,000	60,000	91,500	108,000	91,500	106,500	64,500	67,500	76,000	142,000
Salt River	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000
San Simon Wash	4,000	3,900	4,000	4,300	3,700	3,600	4,400	3,400	3,600	3,800
Tonto Creek	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000
Upper San Pedro	17,000	17,000	16,500	16,000	16,000	15,500	15,500	15,000	15,000	14,500
Verde River	7,200	8,000	8,800	8,200	8,500	9,700	9,000	7,100	6,700	9,300
Virgin River	7,700	7,200	7,700	8,100	8,400	8,600	8,000	7,500	8,500	8,800
Willcox	124,000	112,000	128,000	130,000	124,000	125,000	127,000	128,000	104,000	134,000
Yuma	120,000	121,000	119,000	122,000	124,000	112,000	115,000	101,000	113,000	121,000

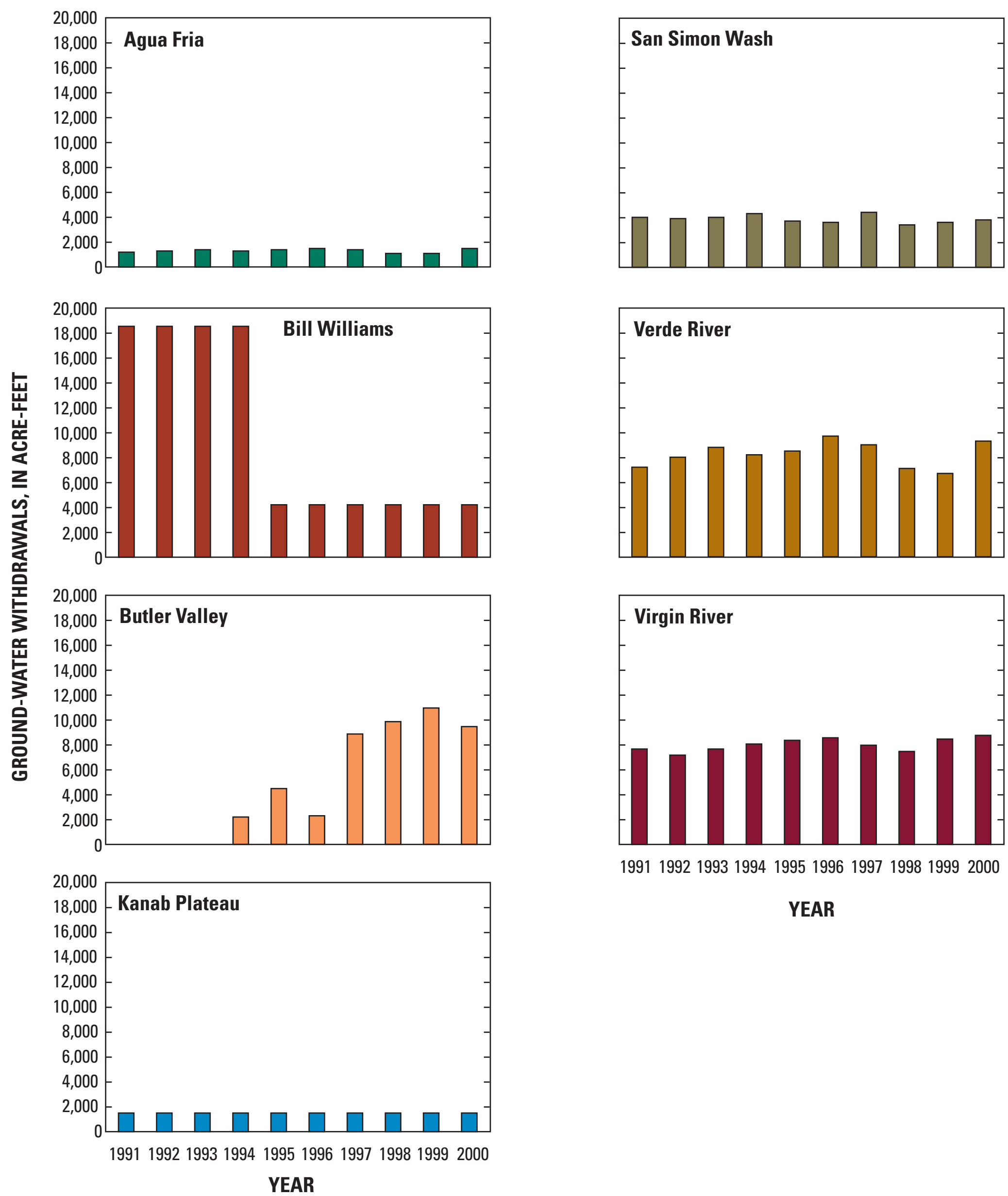
[1]Withdrawal values include withdrawals within the Joseph City Irrigation Non-expansion Area.

Table 3. Annual metered surface-water withdrawals for irrigation in ground-water basins outside of Active Management Areas, Arizona, 1991-2000.

[Values in acre-feet (rounded). Data not available for other basins. INA, Irrigation-Non-expansion Area]

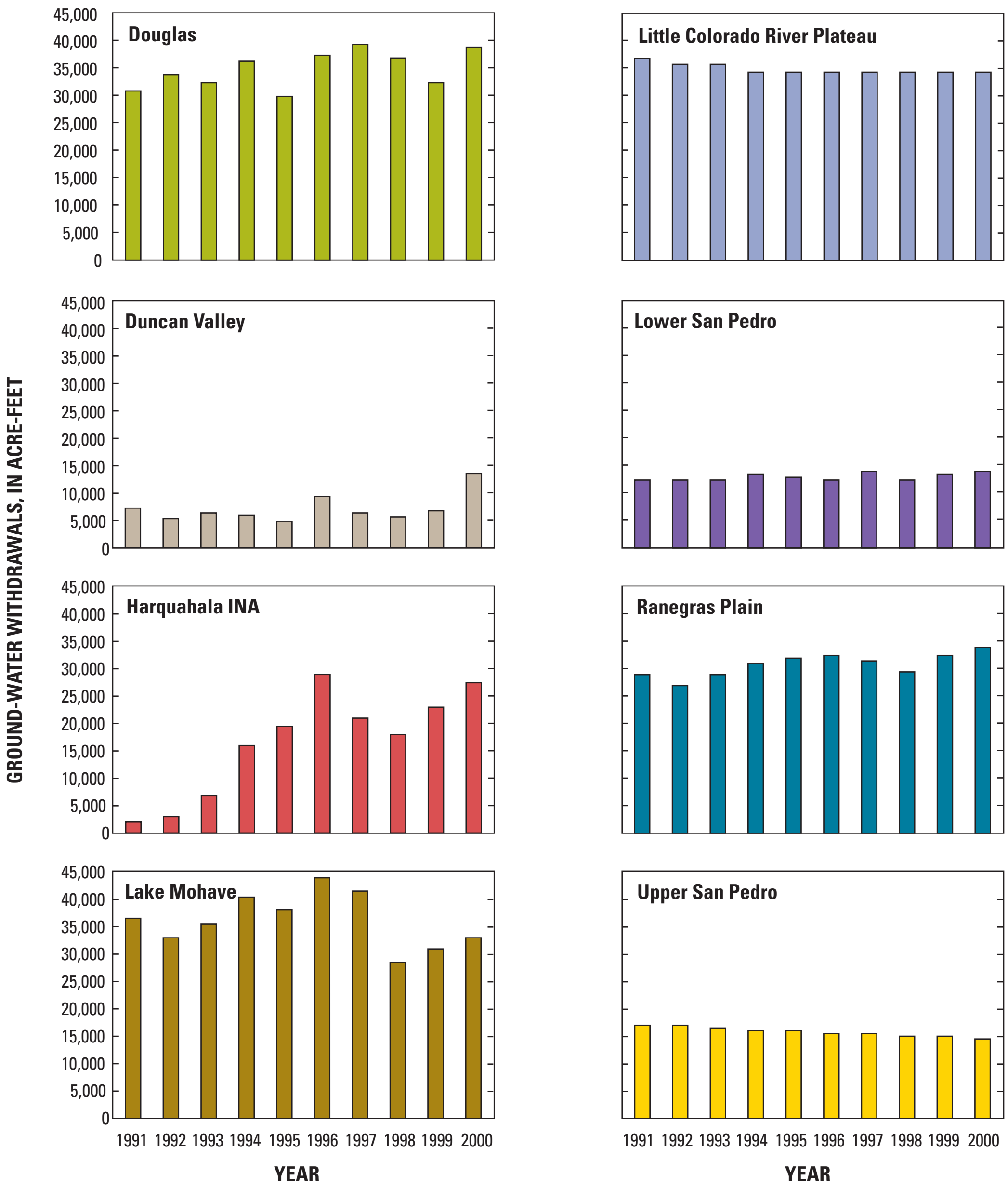
Basin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Gila Bend	70,000	88,000	66,500	76,000	57,000	78,000	69,500	74,500	72,500	48,000
Harquahala INA	35,000	21,000	27,500	52,500	103,000	113,500	116,000	78,000	55,500	62,500
Lake Mohave	59,000	44,500	59,000	58,000	62,500	66,500	67,500	61,000	79,500	66,000
Lower Gila	435,000	369,000	285,000	357,000	377,000	400,000	410,000	393,000	365,000	388,000
Parker	664,000	611,000	630,000	708,000	696,000	748,000	666,000	625,000	631,000	663,000
Safford[1]	136,000	133,000	130,000	120,000	120,000	103,000	135,000	138,000	116,000	53,500
Yuma	725,000	691,000	683,000	718,000	738,000	772,000	727,000	744,000	794,000	820,000

[1]Withdrawals include diversions to the Duncan Valley Basin.



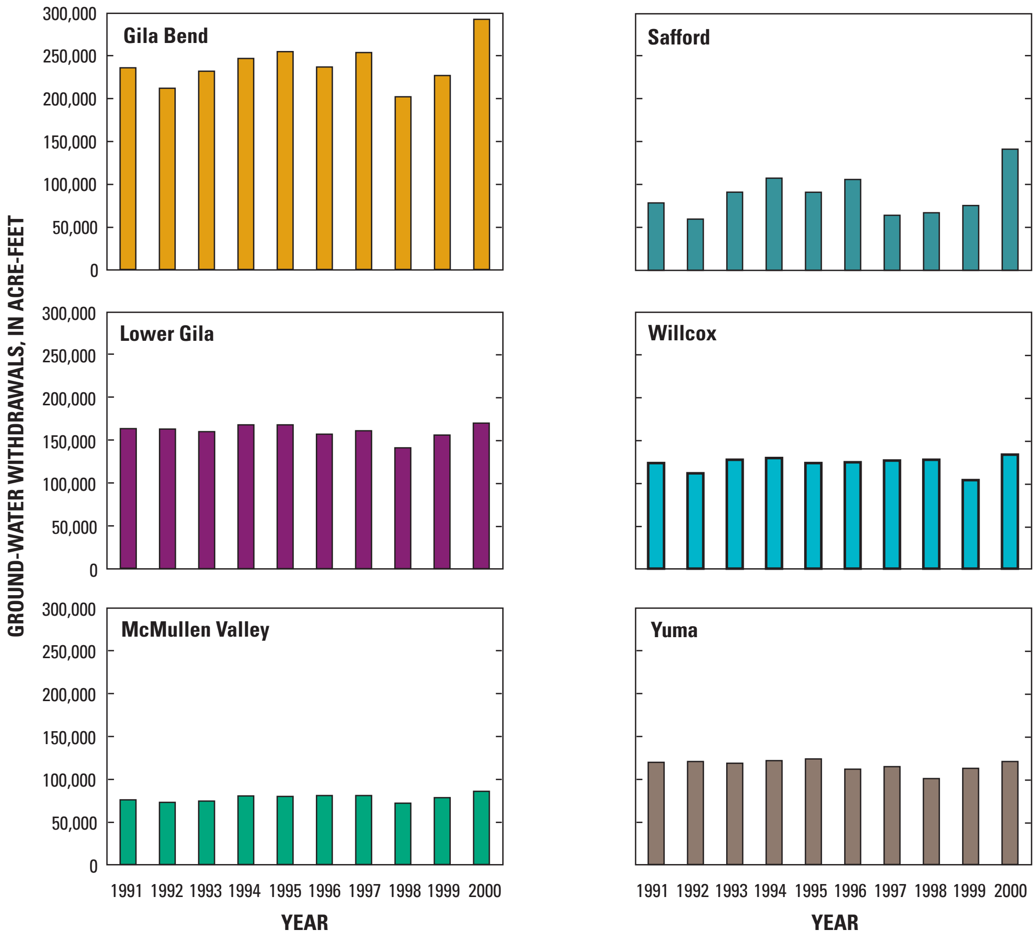
A. **1,000–9,500 acre-feet**

Figure 5. Estimated annual ground-water withdrawals for irrigation in ground-water basins outside of Active Management Areas, Arizona, 1991–2000.



B. **13,500–39,000 acre-feet**

Figure 5. Continued.



C. **86,000–294,000 acre-feet**

Figure 5. Continued.

The largest ground-water withdrawals in the study area from 1991 to 2000 were in the Gila Bend Basin. Withdrawals in the basin were smallest (203,000 acre-feet) in 1998 and largest (294,000 acre-feet) in 2000 (table 2 and fig. 5*C*). Most of the surface-water withdrawals during 1991-2000 were in the Lower Gila, Parker, and Yuma Basins (table 3). Surface-water withdrawals in the Parker Basin fluctuated from a minimum of 611,000 acre-feet in 1992 to a maximum of 748,000 acre-feet in 1996 (table 3 and fig. 6).

Ground-water withdrawals in the Duncan Valley and Safford Basins in 2000 were 13,500 and 142,000 acre-feet, respectively (table 2). In addition 53,500 acre-feet of surface water was diverted from the Gila River to agricultural lands in the Safford Basin in 2000. Part of the surface water diverted to the Safford Basin was then delivered to agricultural lands in the Duncan Valley Basin; consequently, only the amount diverted to the Safford Basin is shown in table 3. The increase in ground-water withdrawals in the Duncan Valley and Safford Basins in some years was offset by a decrease in the amount of surface water diverted.

Ground-water withdrawals in the Willcox Basin were smaller in 1992 (112,000 acre-feet) and 1999 (104,000 acre-feet) than in other years, primarily because of differences in consumptive water requirement rates for different crops (table 2 and fig. 5*C*). Ground-water withdrawals in the Butler Valley Basin generally have increased from 1994 to 2000. Between 1991 and 1993, no crops were planted in the basin (Bill Remick, Arizona Department of Water Resources, written commun., 2004). In the Bill Williams Basin, ground-water withdrawals remained at 18,500 acre-feet from 1991 to 1994 and decreased to about 4,200 acre-feet from 1995 to 2000 (table 2 and fig. 5*A*). The decrease primarily was due to the retirement of some agricultural lands in the basin after 1995 (Andrew Hautzinger, U.S. Fish and Wildlife Service, oral commun., 2004). The amount of ground water withdrawn for irrigation varied from year to year in the Gila Bend, Lower Gila, Safford, and Yuma Basins, primarily because of differences in consumptive water requirement rates for different crops and fluctuations in measured surface-water withdrawals.

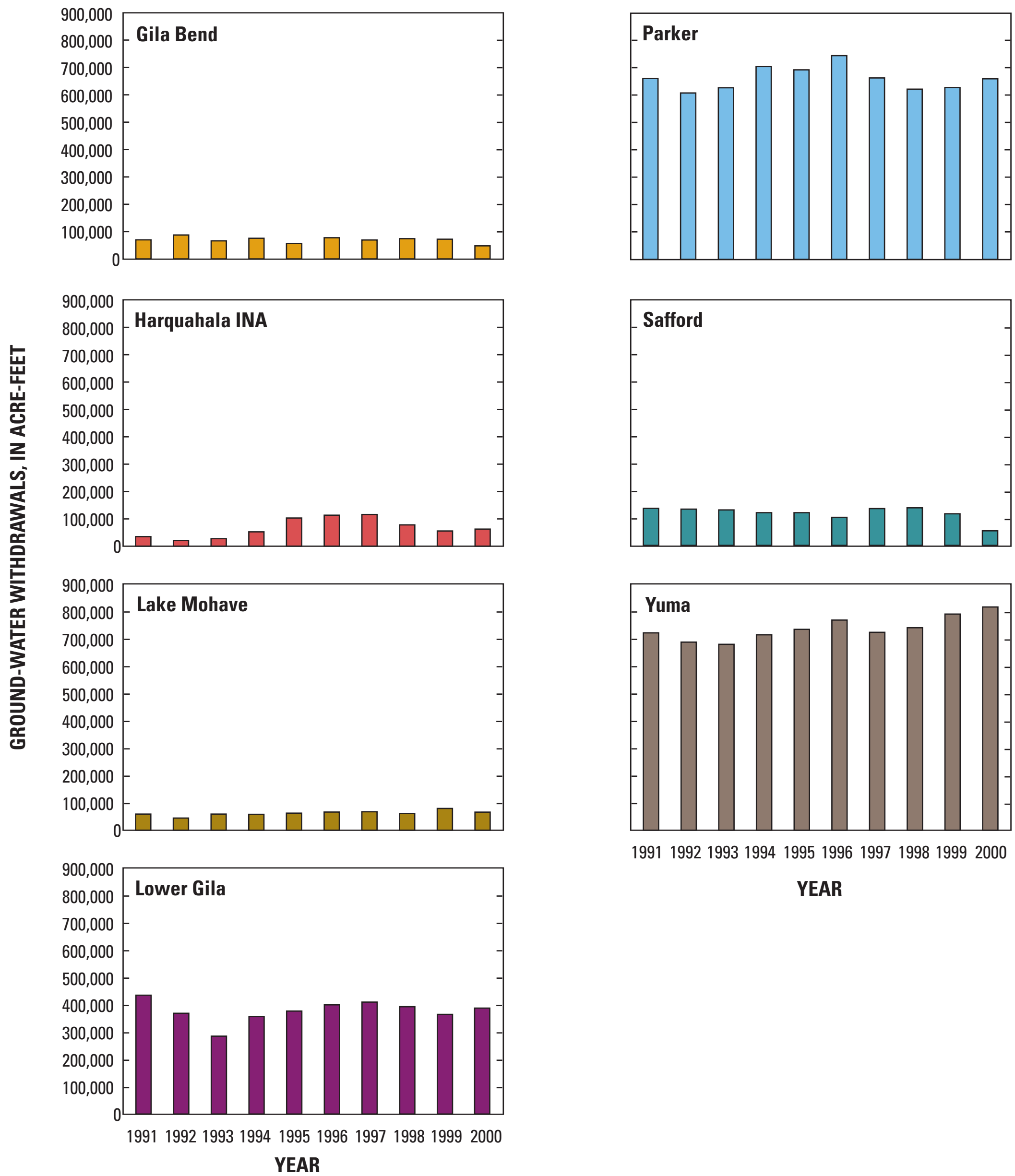


Figure 6. Annual metered surface-water withdrawals for irrigation in ground-water basins outside of Active Management Areas, Arizona, 1991–2000.

The largest surface-water withdrawals for irrigation were in the Lower Gila, Parker, and Yuma Basins where surface water is readily available from the Colorado River (table 3). In these basins, surface water constituted most of the total irrigation withdrawals (tables 2 and 3); surface-water withdrawals supply almost all water for irrigation in the Parker Basin. Because of the climate and the availability of water, some farmers are multicropping in the Lake Mohave, Parker, and Yuma Basins. Multicropping also is practiced in other parts of the study area, such as the Lower Gila and Gila Bend Basins. Within the study area, annual metered surface-water withdrawals for irrigation are greater than estimated annual ground-water withdrawals. This is due to the availability of surface water in agricultural areas along the Colorado River.

Municipal

Municipal-withdrawal data in this report represent water withdrawn by public and private water suppliers and self-supplied domestic users. Public and private water suppliers deliver water to residential, commercial, industrial, and municipal users. Self-supplied domestic withdrawals primarily are for residential use. Annual estimated ground-water withdrawals for municipal use are listed by ADWR basin for areas outside of AMAs (table 4).

In the study area, complete data sets from the private and public-water suppliers were not available for the Agua Fria, Cienega Creek, Ranegras Plain, and San Simon Wash Basins. Therefore, municipal ground-water withdrawals for these basins from 1991 to 2000 were estimated using population in the basins and per-capita water use for the county in which the basins are located. Populations were estimated from the 1990 population listed in the Arizona Water Resources Assessment report, which was taken from the 1990 Census and the 2000 Topologically Integrated Geographic Encoding and Referencing (TIGER) Census data set (Arizona Department of Water Resources, 1994; U.S. Census Bureau, 2000). Per-capita water use was estimated from averages of data for 1990, 1995, and 2000 that were reported for the State in the reports entitled “Estimated use of water in the United States” (water.usgs.gov/watuse/). Per-capita water use was calculated by dividing the withdrawals by public and private water suppliers for each county by the estimated population served in the county for 1990, 1995, and 2000.

Municipal ground-water withdrawals for 17 basins are listed as less than 300 acre-feet per year (table 4); however, withdrawals in the Butler Valley, Dripping Springs Wash, Grand Wash, and Tiger Wash Basins are considered to be negligible owing to the sparse populations in these basins (Arizona Department of Water Resources, 1994; U.S. Census Bureau, 2000; Bill Remick, Arizona Department of Water Resources, oral commun., 2004). Some of the basins, such as Bill Williams, Cienega Creek, Douglas, Lower Gila, Lower San Pedro, McMullen Valley, and San Simon Wash, did not show large increases in withdrawals from 1991 to 2000. The withdrawal was greatest in the Little Colorado River Plateau Basin, where it increased from 20,500 acre-feet in 1991 to 27,000 acre-feet in 2000 (table 4 and fig. 7*C*). A combination of ground water and surface water is withdrawn for municipal use in some parts of the State. In these areas, fluctuations in surface-water withdrawals for municipal use in a particular year will affect the amount of ground water withdrawn. Municipal ground-water withdrawals in most of the basins increased steadily from 1991 to 2000 (table 4) as a result of population growth. In addition to population growth, the amount of water withdrawn also can be affected by climate, water-saving technologies, pricing, and use of alternative sources, such as water harvesting.

Public Water Suppliers

Withdrawals from public water suppliers refer to ground water withdrawn by a publicly owned, community water system for use by cities, rural water districts, mobile-home parks, Indian reservations, or military bases. Data for municipal withdrawals by public water suppliers were obtained primarily by telephone or written surveys. Several suppliers, however, did not provide the USGS with withdrawal data for some years. Missing data from these suppliers were estimated by extrapolating data from other years. Several public water suppliers reported water deliveries rather than ground-water withdrawals. In these instances, ground-water withdrawals were estimated by adding 10 percent to the water deliveries reported to the USGS to account for water losses in the distribution systems. The 10 percent water losses in the distribution system were based on the average of water losses for 1995 that were reported for Arizona in the report entitled “Estimated use of water in the United States” (water.usgs.gov/watuse/).

Table 4. Estimated annual ground-water withdrawals for municipal use in ground-water basins outside of Active Management Areas, Arizona, 1991-2000.

[Values in acre-feet (rounded). INA, Irrigation Non-expansion Area; <, less than]

Basin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agua Fria	950	1,000	1,100	1,200	1,300	1,300	1,400	1,500	1,600	1,700
Aravaipa Canyon	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Big Sandy	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Bill Williams	500	500	500	500	500	500	500	500	550	550
Bonita Creek	2,800	2,800	2,200	2,400	3,200	3,300	3,300	3,300	3,300	3,300
Butler Valley	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Cienega Creek	450	500	500	500	500	500	550	550	550	550
Coconino Plateau	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Detrital Valley	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Donnelly Wash	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Douglas	5,500	5,400	4,800	6,000	5,200	7,000	6,000	6,000	6,000	5,800
Dripping Springs Wash	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Duncan Valley	650	650	650	600	650	700	700	750	800	1,000
Gila Bend	800	800	850	800	800	800	800	750	850	900
Grand Wash	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Harquahala INA	900	900	950	900	900	900	900	950	950	950
Hualapai Valley	4,400	5,400	5,400	6,000	6,300	7,000	6,900	6,800	7,500	8,200
Kanab Plateau	750	800	800	850	850	900	950	1,000	1,000	1,100
Lake Havasu	12,500	13,000	13,500	14,500	14,500	15,000	15,500	14,500	14,000	15,500
Lake Mohave	16,000	18,500	18,500	19,000	19,500	20,500	20,000	19,500	21,000	22,000
Little Colorado River Plateau[1]	20,500	20,500	20,000	21,000	21,000	24,000	24,000	22,000	24,500	27,000
Lower Gila	1,900	1,800	1,800	1,800	1,800	1,900	1,900	1,900	1,900	2,000
Lower San Pedro	2,500	2,400	2,500	2,500	2,500	2,600	2,600	2,400	2,400	2,500
McMullen Valley	450	450	450	500	500	500	500	500	500	500
Meadview	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Morenci	2,700	2,500	2,800	3,000	2,900	2,900	2,900	2,800	2,900	3,000
Paria	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Parker	2,700	2,700	2,800	3,100	3,100	3,200	3,200	3,200	3,200	3,300
Peach Springs	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Ranegras Plain	<300	<300	<300	<300	<300	<300	<300	<300	300	350
Sacramento Valley	1,300	1,500	1,500	1,600	1,700	1,700	1,600	1,800	1,900	1,800
Safford	2,500	2,400	3,500	4,200	2,700	2,700	2,800	2,800	2,800	3,000
Salt River	3,100	3,000	3,300	3,200	3,200	3,500	3,500	3,400	3,200	3,400
San Bernadino Valley	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
San Rafael	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
San Simon Wash	900	900	900	900	900	950	950	950	950	950
Shivwits Plateau	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Tiger Wash	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Tonto Creek	1,400	1,400	1,600	1,600	1,800	1,800	1,900	1,800	1,900	2,100
Upper Hassayampa	2,100	2,100	2,200	2,400	2,400	2,600	2,600	2,500	2,700	2,700
Upper San Pedro	14,500	15,000	15,500	16,500	16,500	16,500	17,500	17,500	17,500	18,000
Verde River	9,300	9,000	10,000	10,500	11,000	12,000	12,000	11,500	12,000	13,000
Virgin River	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Western Mexican Drainage	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Willcox	2,500	2,600	2,500	2,600	2,600	2,700	2,800	2,800	2,600	2,700
Yuma	7,200	7,800	8,300	8,600	8,700	10,500	10,500	10,000	11,000	11,500

[1]Withdrawal values include withdrawals within the Joseph City Irrigation Non-expansion Area.

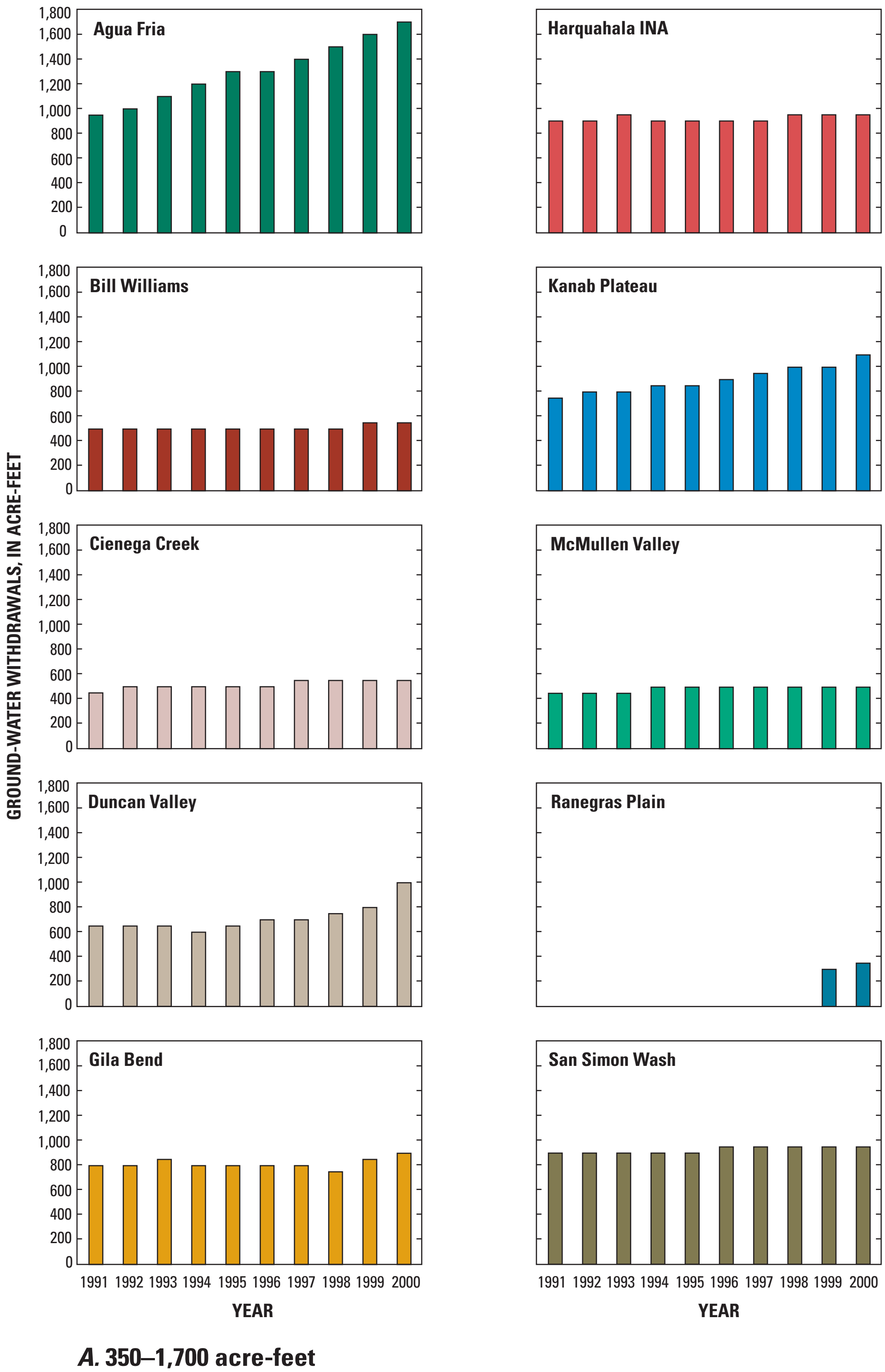
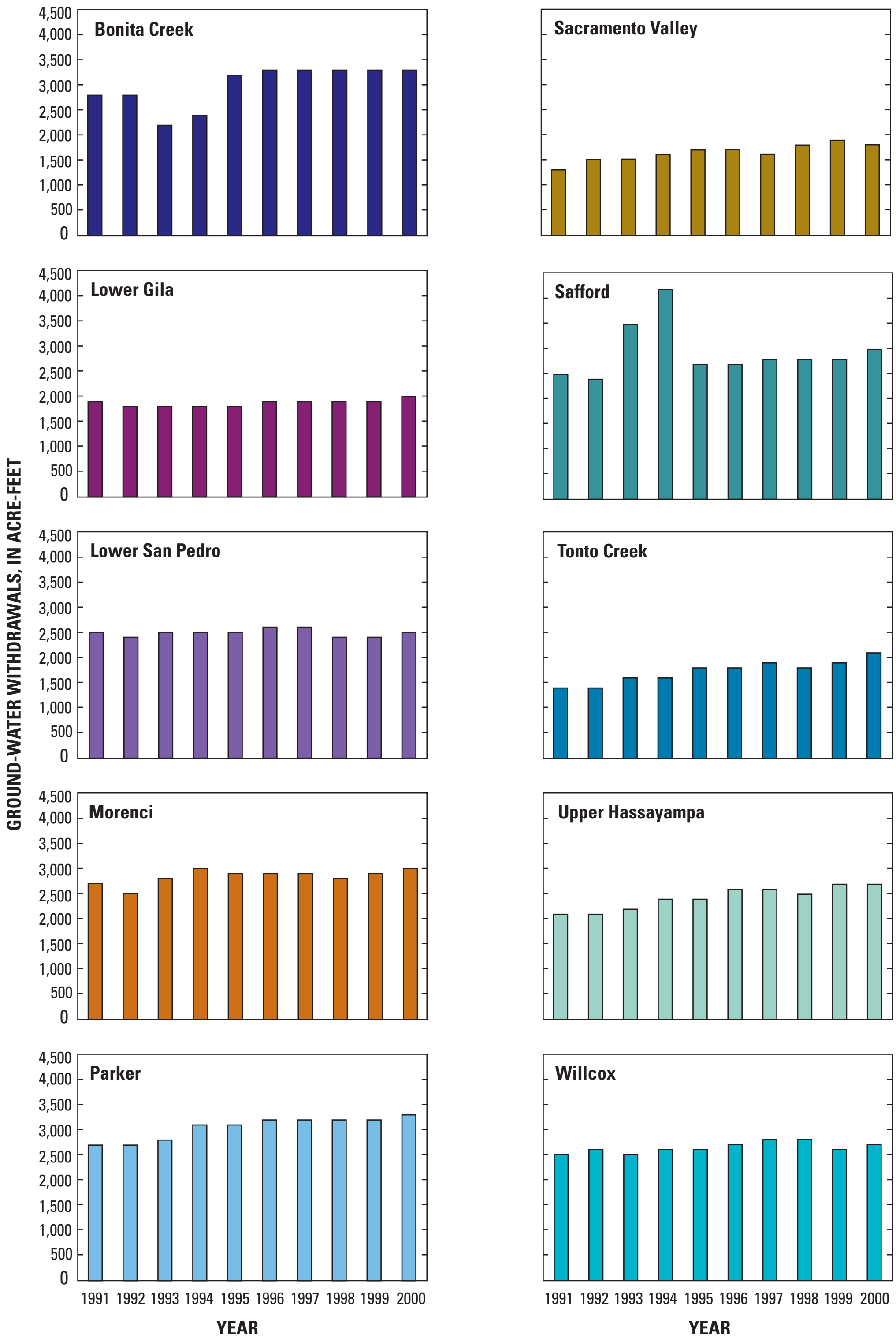
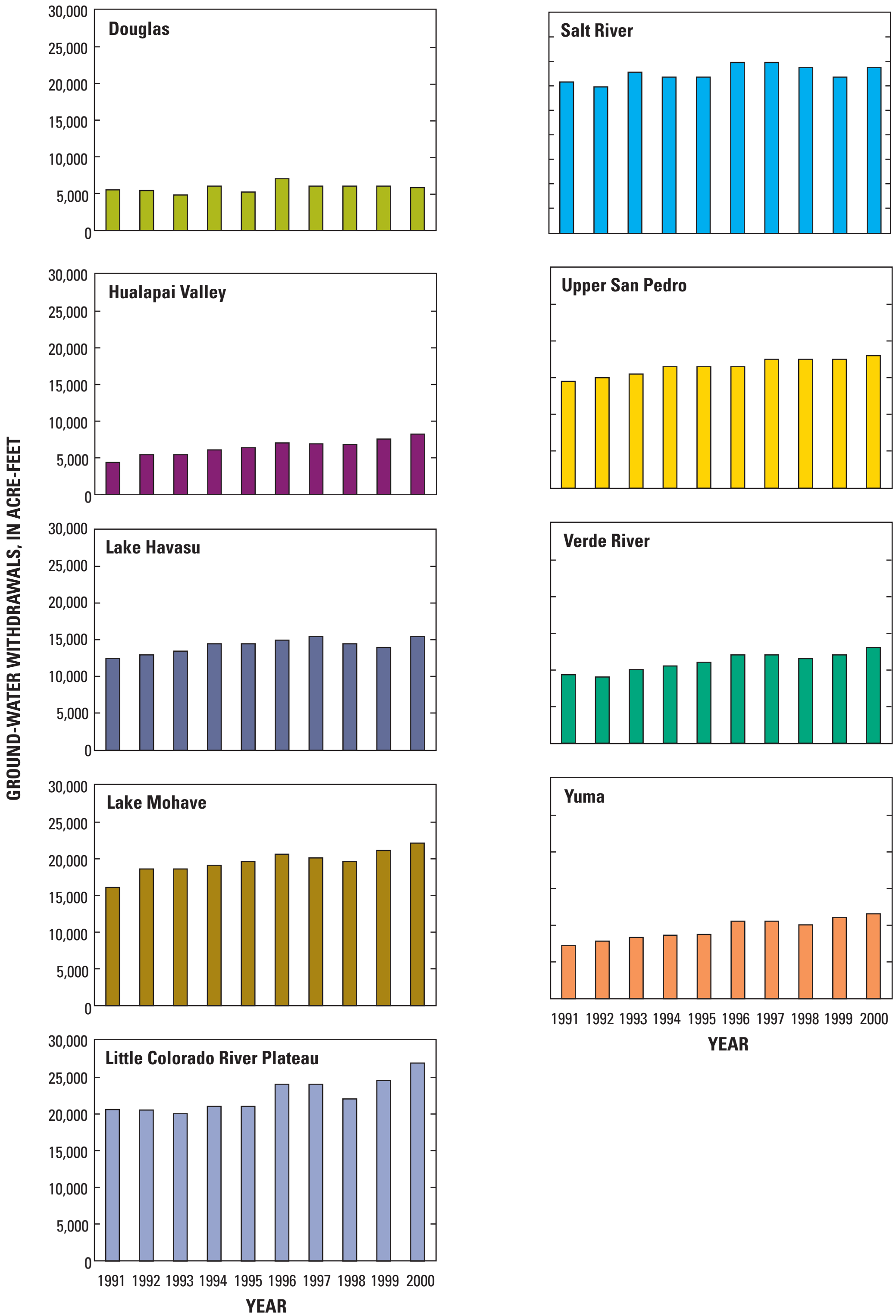


Figure 7. Estimated annual ground-water withdrawals for municipal use in ground-water basins outside of Active Management Areas, Arizona, 1991–2000.



***B.* 1,800–3,300 acre-feet**

Figure 7. Continued.



C. **3,400–27,000 acre-feet**

Figure 7. Continued.

Private Water Suppliers

Private water suppliers reported water deliveries rather than ground-water withdrawals to the Arizona Corporation Commission (ACC), which was the primary provider of delivery data for private water suppliers for 1991–2000. Some private water suppliers are not required to report their deliveries to the ACC; withdrawals by these suppliers are not included in this report. Ground-water withdrawals were estimated by adding 10 percent to the water deliveries to account for losses in the distribution systems. The losses in the distribution systems were based on the average of data for 1995 that were reported for Arizona in the report entitled “Estimated use of water in the United States” (water.usgs.gov/watuse/). In some years, the data provided were incomplete because some suppliers did not report their deliveries to the ACC. Another problem was that data were sometimes reported to the ACC in incorrect units. In many cases, the suppliers reported their deliveries in gallons or other units instead of thousands of gallons, which was the requested format.

Steps were taken to rectify the data from the ACC. Missing data were estimated by extrapolating available data from other years. To detect errors caused by the use of incorrect reporting units, the ratio of reported deliveries to the total number of customers served by the suppliers was compared to the reported deliveries and number of customers served for previous or subsequent years. In some instances, the reported deliveries were off by one or more orders of magnitude. In instances where the data were suspected to be erroneous, the delivery data were modified to agree with estimates obtained through this comparison procedure.

Self-Supplied Domestic Users

The self-supplied domestic water users are all individuals who do not receive water from public or private water suppliers. Domestic wells are the principal source of water for most homes in rural areas of Arizona. Self-supplied domestic water use includes water for household purposes such as drinking, food preparation, washing clothes and dishes, bathing, flushing toilets, washing vehicles, and watering lawns and gardens. Ground-water withdrawals for self-supplied domestic uses for 1990, 1995, and 2000 were estimated to be about 1 percent of the total ground-water withdrawals reported in the USGS Circular report series entitled “Estimated use of water in the United States” (water.usgs.gov/watuse/). In some of the ADWR ground-water basins, however, water withdrawals by self-supplied domestic users could represent a substantial percentage of the municipal withdrawals.

Self-supplied domestic well.

Self-supplied domestic withdrawals are rarely measured or reported. Consequently, these withdrawals were estimated from the self-supplied domestic population and the per-capita water use. The self-supplied domestic population was estimated on the basis of the 1990 Census of Population and Housing (U.S. Department of Commerce, 1992).

To determine the self-supplied domestic population in each ADWR ground-water basin, the individual county population had to be disaggregated into separate ADWR ground-water basins. This was done using tables and maps from the U.S. Census (U.S. Department of Commerce, 1992). After disaggregating the county population into the ADWR ground-water basins, the population for each basin in a county was added together and the total was compared with the county population to verify the result. The population in each ground-water basin was then multiplied by the percentage of housing units in the basin that did not obtain water from public and (or) private water suppliers for 1990. The resulting number is the self-supplied domestic population in the basin. No information is available from the U.S. Census for the self-supplied domestic population in Arizona since 1990.

Self-supplied domestic withdrawals for each basin were estimated by multiplying the self-supplied domestic population in each county by the estimated per-capita water use from (1994) for the San Pedro River watershed (boundaries undefined). Ten Eyck estimated that a typical household of three people used 1.0 acre-foot of water per year for residential purposes. Because no information is available for the self-supplied domestic population after 1990 from the U.S. Census, the self-supplied domestic population totals and withdrawals were assumed to be constant for 1991–2000. The ADWR estimated and reported self-supplied domestic withdrawals in the Upper San Pedro Basin for 1990 and 2000 (Linda Stitzer, Arizona Department of Water Resources, written commun., 2004). Self-supplied domestic withdrawals for the Upper San Pedro Basin for 1991 through 1999 were estimated by extrapolating the ADWR data from 1990 and 2000.

Mining

Water withdrawn for mining in Arizona is used for the extraction of naturally occurring materials and for dewatering, milling, dust control, washing of equipment, and other activities and preparations that are part of mining activities.

Peabody Coal mines high-quality low-sulfur coal in the Little Colorado River Plateau Basin. Photograph courtesy of Peabody Coal.

Mines in Arizona are categorized as either metal mines or industrial-mineral mines (Phillips and others, 1994, 2000) in this report. Metal mines include copper, gold, silver, and molybdenum. Industrial minerals include sand and gravel, cement, coal, clay, diatomite, gypsum, and silica (Phillips and others, 2000).

Copper and coal mining rank first and second in economic importance in Arizona, respectively (Phillips and others, 2000). Arizona has continued to be the leading producer of copper in the Nation and accounted for about 62 percent of the U.S. copper production in 1991 and about 65 percent in 2000 (Phillips and others, 1992, 2002). Metals such as gold, molybdenum, and silver commonly are recovered from ore that is primarily mined for copper. Mines in the Black Mesa and Kayenta areas produce high quality low sulfur coal in the Little Colorado River Plateau Basin (Phillips and others, 2000).

Ground-water withdrawal data for mining were collected or estimated for mines in ADWR ground-water basins outside of AMAs (table 5). Ground-water withdrawal data were obtained directly from each mining company. The companies provided the ground-water withdrawal data over the telephone, by fax, or by e-mail. Some of the mining companies contacted do not use water for their operations and are considered to be dry mining. Ground-water withdrawal data for one of the copper mining operations were not available after 1994. For that mining company, correlations between ground-water withdrawals and copper production for 1991–94 were used to estimate the withdrawals for 1995–2000. Copper production information was obtained from the Arizona Department of Mines and Minerals (Niles Niemuth, Arizona Department of Mines and Mineral Resources, written commun., 2001). Withdrawals can change from year to year as mining companies change their methods of extracting ores and as market prices fluctuate.

Most sand and gravel and cement operations do not meter their ground-water withdrawals and lack gages on their wells. Ground-water withdrawal data were estimated for most of the sand and gravel operations and some of the mining operations that did not respond to inquiries about water withdrawals. The withdrawals were estimated on the basis of daily operating hours of the facilities and rated discharge capacity of the wells. Annual ground-water withdrawals were estimated by using the following formula:

Table 5. Estimated annual ground-water withdrawals for mining use in ground-water basins outside of Active Management Areas, Arizona, 1991-2000.

[Values in acre-feet (rounded). Data not available for other basins. <, less than]

Basin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Big Sandy	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Bill Williams	16,000	13,500	17,000	19,000	19,000	20,000	22,000	19,000	20,500	22,000
Hualapai Valley	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Lake Havasu	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Lake Mohave	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Little Colorado River Plateau[1]	4,200	4,000	3,900	4,200	4,500	4,200	4,300	4,200	4,600	4,900
Lower San Pedro	30,000	31,500	29,500	32,000	31,000	32,500	30,500	28,500	23,000	16,000
Morenci	14,500	12,500	14,000	14,500	13,000	16,000	18,000	18,500	18,500	18,000
Peach Springs	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Sacramento Valley	<300	<300	<300	<300	<300	<300	<300	<300	300	350
Safford	700	750	600	600	600	700	450	500	400	450
Salt River	10,000	10,500	10,000	10,500	10,500	11,000	6,500	5,000	6,000	8,000
Upper San Pedro	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Verde River	1,200	1,200	1,200	1,300	1,300	1,300	1,100	1,200	1,200	1,200
Willcox	300	300	300	300	300	300	<300	<300	450	<300
Yuma	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300

[1]Withdrawal values include withdrawals within the Joseph City Irrigation Non-expansion Area.

$$V = Q \times D \times H \times M \,/\, 325{,}851, \qquad (3)$$

where

- V is volume of water pumped, in acre-feet;
- Q is pumping rate, in gallons per minute;
- D is 365 days per year;
- H is hours of operation per day;
- M is 60 minutes per hour; and
- 325,851 is factor to convert gallons to acre-feet.

Ground-water withdrawals for mining were largest in the Lower San Pedro Basin (table 5 and fig. 8). Ground-water withdrawals for mining decreased substantially from 32,500 acre-feet in 1996 to 16,000 acre-feet in 2000 (table 5). In the Salt River Basin, ground-water withdrawals for mining decreased substantially from 11,000 acre-feet in 1996 to 5,000 acre-feet in 1998 (table 5). Annual increases or decreases in ground-water withdrawals for mining are mostly due to fluctuations in mineral production, which is driven by market prices. Variations in the amount of highway construction also can contribute to changes in water withdrawal for mining.

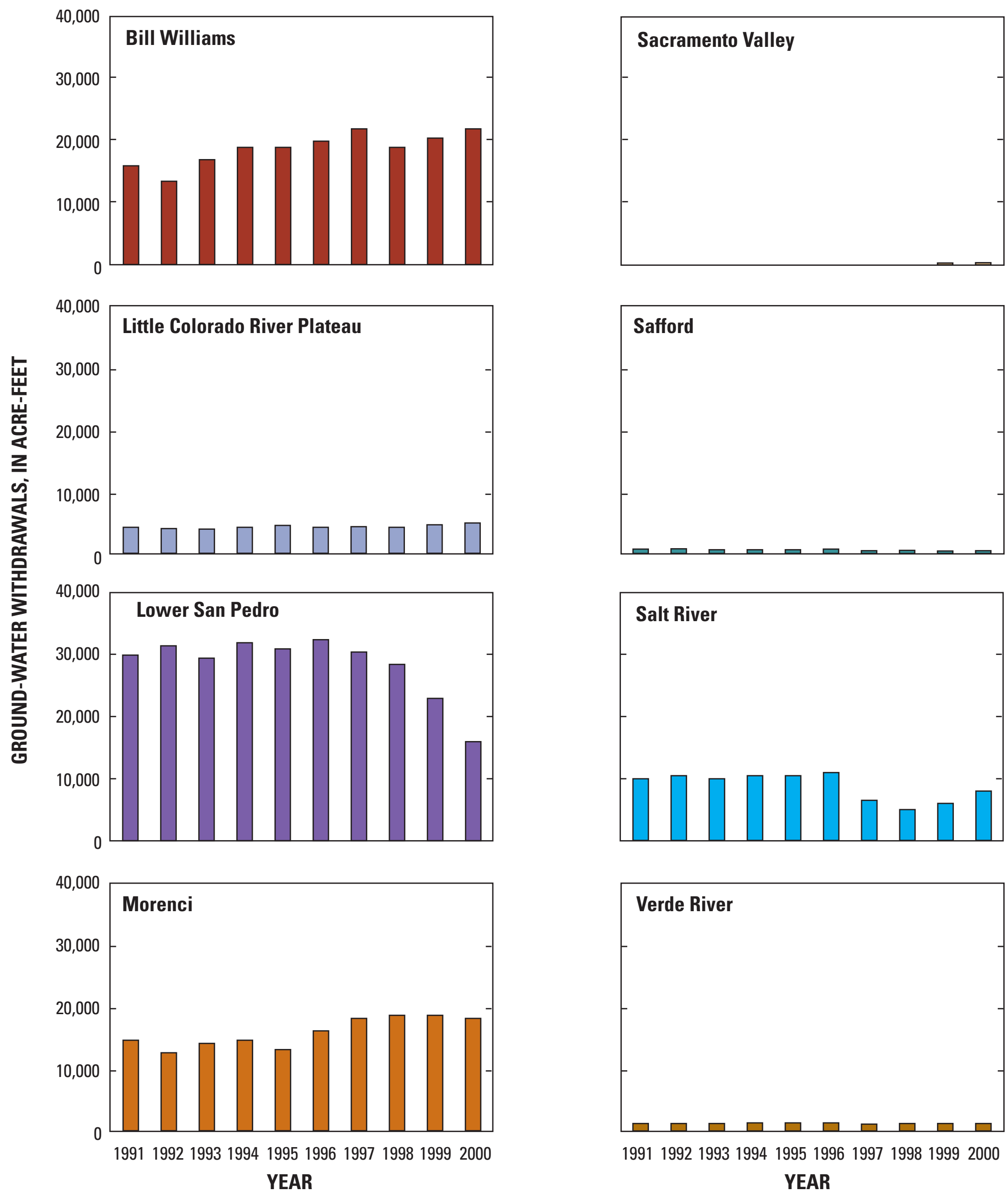


Figure 8. Estimated annual ground-water withdrawals for mining in ground-water basins outside of Active Management Areas, Arizona, 1991–2000.

Thermoelectric Power

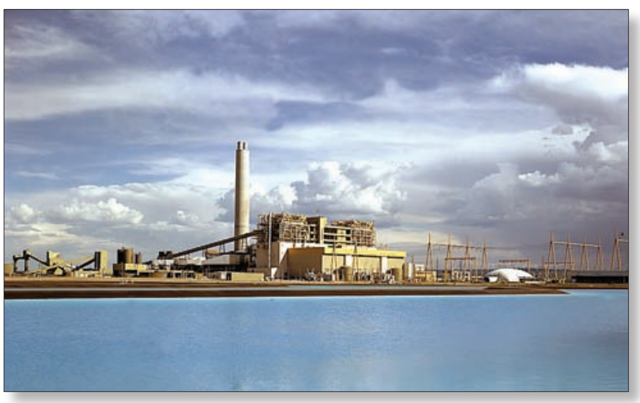
Thermoelectric powerplants require water and fuel to generate electricity. Water is used in power generation to (1) process feed water for steam, (2) cool steam and thereby facilitate condensation and steam reuse, and (3) remove sulfur dioxide. Some water, however, may be used for cleaning and pollution control. The amount of water withdrawn by thermoelectric powerplants primarily is a function of powerplant size and the type of cooling system.

Ground-water withdrawal data for thermoelectric-power generation were collected from four plants outside of AMAs. Powerplants that reported withdrawals of ground water were the Apache plant in the Willcox Basin, and the Cholla, Coronado, and Springerville plants in the Little Colorado River Plateau Basin. All these plants use coal as a fuel for generating electricity. Water-withdrawal data were obtained directly from each plant. The plants use water primarily for creating high-pressure steam, which is directed against the blades of a turbine, thus creating mechanical energy (Steff Koeneman, Arizona Electric Power Cooperative, written commun., 2004). The amount of power generated each year, in gigawatts, also was obtained from each plant.

Ground-water withdrawals and energy generated in the Little Colorado River Plateau Basin increased from 1991 to 1994, decreased in 1995, and increased steadily from 1996 to 2000 (table 6 and fig. 9). Ground-water withdrawals increased by 5,500 acre-feet, or 20 percent, and energy generated increased 5,000 gigawatts, or 42 percent, between 1991 and 2000 (table 6 and fig. 9). In general, there is a positive correlation between ground-water withdrawals and power generated in the Little Colorado River Plateau Basin.

Ground-water withdrawals for thermoelectric-power generation in the Willcox Basin decreased from 1991 to 1993, increased in 1994, decreased from 1994 to 1996, and increased steadily from 1997 to 2000 (table 6 and fig 10). There is a positive correlation between ground-water withdrawals and power generated in the Willcox Basin from 1996 to 2000; however, there is no correlation from 1991 to 1995.

The demand for electricity and, consequently, the amount of water withdrawn by powerplants are influenced by various economic conditions: income, population, weather, and the price of electricity. The data generally indicate an increasing trend in power production and ground-water withdrawals.



Coronado Thermoelectric Powerplant near St. Johns, Arizona. Photograph courtesy of Salt River Project.

Table 6. Annual ground-water withdrawals for thermoelectric power in ground-water basins outside of Active Management Areas, Arizona, 1991-2000.

[Values in acre-feet (rounded). Data not available for other basins]

Year	Basin	
	Little Colorado River Plateau[1]	Willcox
1991	27,500	6,600
1992	29,000	6,500
1993	29,500	5,000
1994	34,500	5,900
1995	27,000	5,700
1996	29,500	4,100
1997	32,000	4,600
1998	32,000	5,600
1999	34,000	5,700
2000	33,000	6,000

[1]Withdrawal values include withdrawals within the Joseph City Irrigation Non-expansion Area.

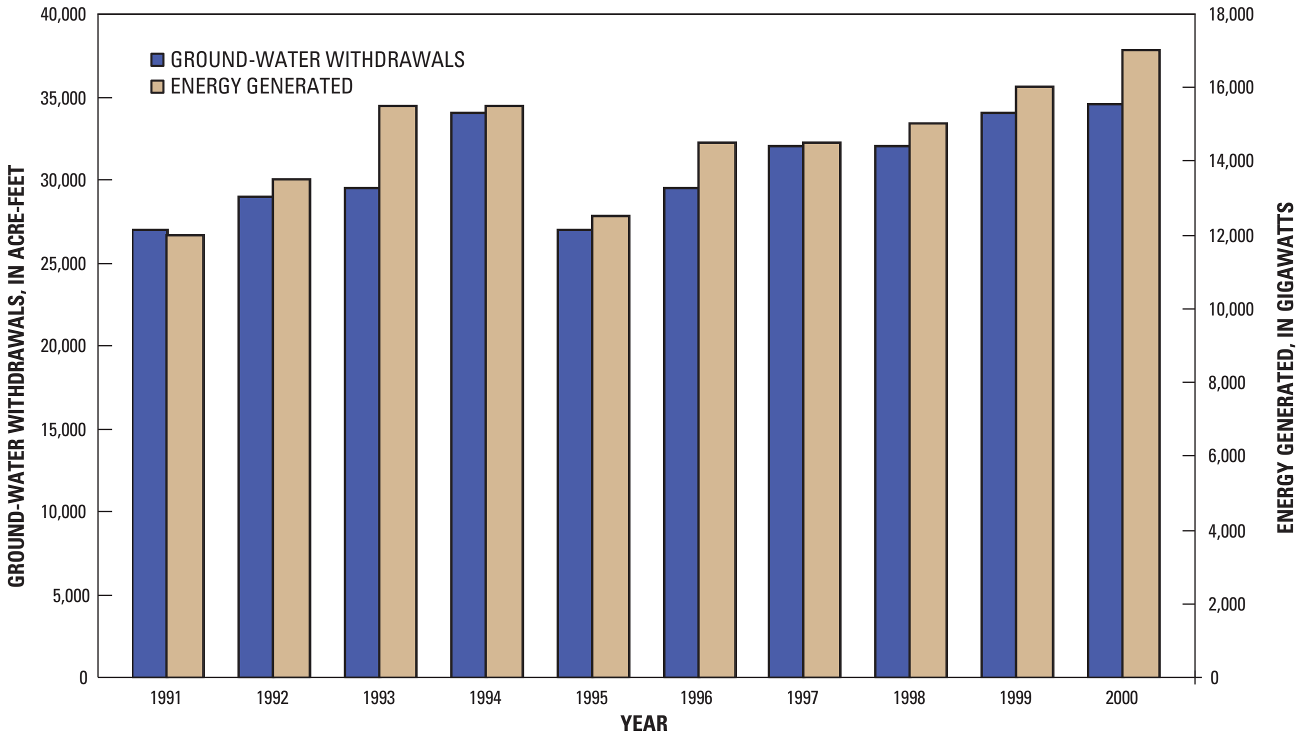


Figure 9. Ground-water withdrawals and energy generated by thermoelectric powerplants in the Little Colorado River Plateau Basin, Arizona, 1991–2000.

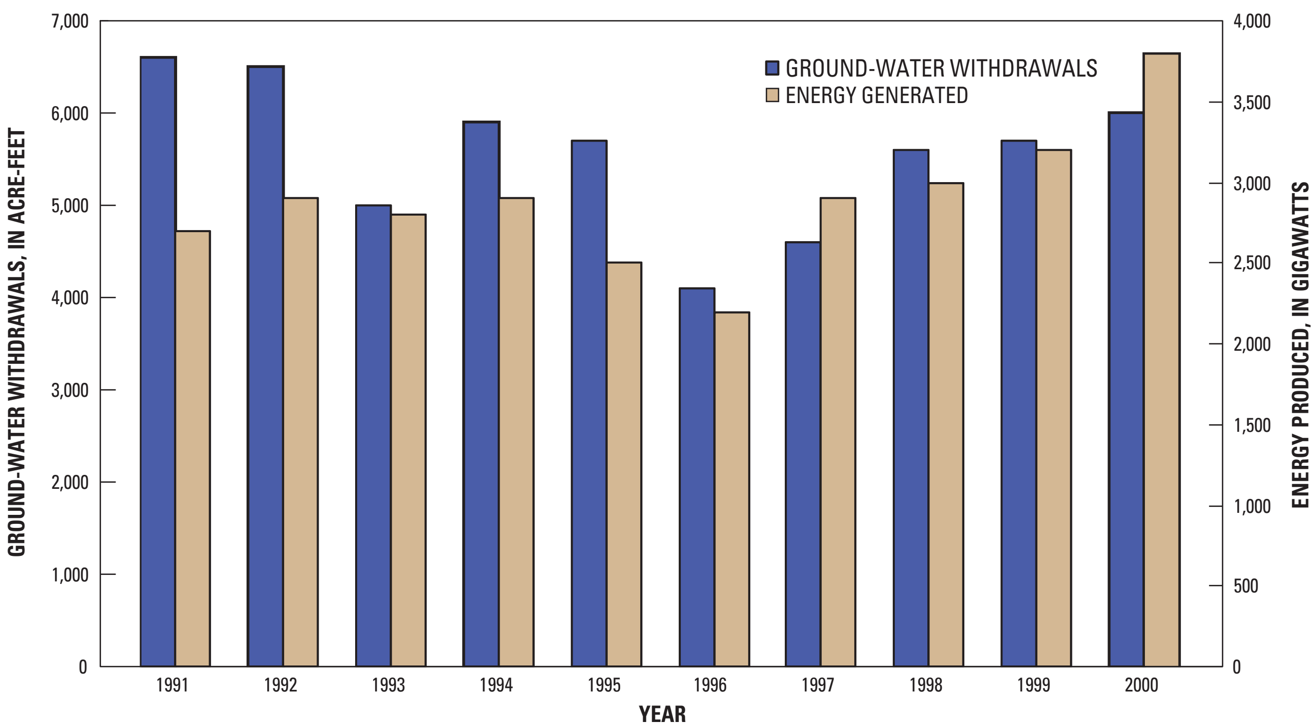


Figure 10. Ground-water withdrawals and energy generated by the thermoelectric powerplant in the Willcox Basin, Arizona, 1991–2000.

Drainage

Ground-water withdrawals for irrigation drainage reported here are those used to dewater the root zone in certain agricultural areas (table 7), and those from Minute No. 242 (242 well field; table 8). Withdrawals from the 242 well field are used to provide water deliveries to Mexico as obligated by treaty (Russell Grimes, Bureau of Reclamation, oral commun., 2004). Agricultural lands are drained primarily to remove excess water from the soil and to minimize crop stress caused by salt buildup in the soil profile (Luthin, 1978). Drainage also helps to promote better root growth, improve the quality of crops, and increase crop yield (Busman and Sands, 2002). Percolated irrigation water in some areas in Arizona has raised the ground-water level and subsequently led to waterlogging or salinity problems. Ground water is withdrawn for drainage in the Yuma and the Lower Gila Basins.

Drainage data for agricultural lands in the Lower Gila and Yuma Basins are published in the USGS annual water resources data report for Arizona (McCormack and others, 2002). The amount of water withdrawn in the Lower Gila Basin ranged from a minimum of 9,000 acre-feet in 1993 to a maximum of 145,000 acre-feet in 1991 (table 7 and fig. 11). The amount of water withdrawn in 1993 was small because drainage wells were shut down for a time during and following flooding along the Gila River. In the Yuma Basin, withdrawals were smallest (51,000 acre-feet) in 1992 and largest (113,000 acre-feet) in 1999 (table 7 and fig. 11).

The purpose of the 242 well field is to deliver water to Mexico to comply with treaty obligations for assured supplies of Colorado River water (Bureau of Reclamation, 2004). Ground water is pumped at San Luis in the Yuma Basin near the International Border with Mexico and is conveyed to Mexico by means of a canal (lateral 242). Wells in the 242 well field are about 600 feet deep and designed to pump an average of 7.5 cubic feet per second (Bureau of Reclamation, 2004). There are 21 wells in the 242 well field.

Ground water is withdrawn to dewater the root zone in some agricultural areas.

Data for the 242 well field were obtained from the Bureau of Reclamation (Jerry Davis, Bureau of Reclamation, written commun., 2003) and the International Boundary and Water Commission. Annual ground-water withdrawals for the 242 well field in the Yuma Basin are presented in table 8 and shown in figure 12. Ground-water withdrawals from the 242 well field were largest in 1991 (31,000 acre-feet) and smallest in 1997 (450 acre-feet). Changes in annual withdrawals from the 242 well field were due to increases or decreases in water delivery from U.S. water districts to Mexico. In some years the water districts did not deliver all their available Colorado River allocations in the Yuma area for irrigation because they were not needed, and the excess water was delivered to Mexico (Jerry Davis, Bureau of Reclamation, oral commun., 2004). In these years, the pumpage from the 242 well field was reduced and less water from the well field was delivered to Mexico.

Table 7. Annual ground-water withdrawals for drainage of agricultural lands in ground-water basins outside of Active Management Areas, Arizona, 1991–2000.

[Values in acre-feet (rounded)]

Year	Basin	
	Lower Gila	Yuma
1991	145,000	73,000
1992	116,000	51,000
1993	9,000	69,500
1994	50,000	53,000
1995	122,000	86,000
1996	120,000	83,000
1997	91,500	99,000
1998	98,500	107,000
1999	95,500	113,000
2000	110,000	107,000

Table 8. Annual ground-water withdrawals for the 242 well field near Yuma, Arizona, 1991-2000.

[Values in acre-feet (rounded)]

Year	Yuma Basin
1991	31,000
1992	23,500
1993	6,900
1994	19,000
1995	12,500
1996	6,200
1997	450
1998	5,200
1999	4,000
2000	4,300

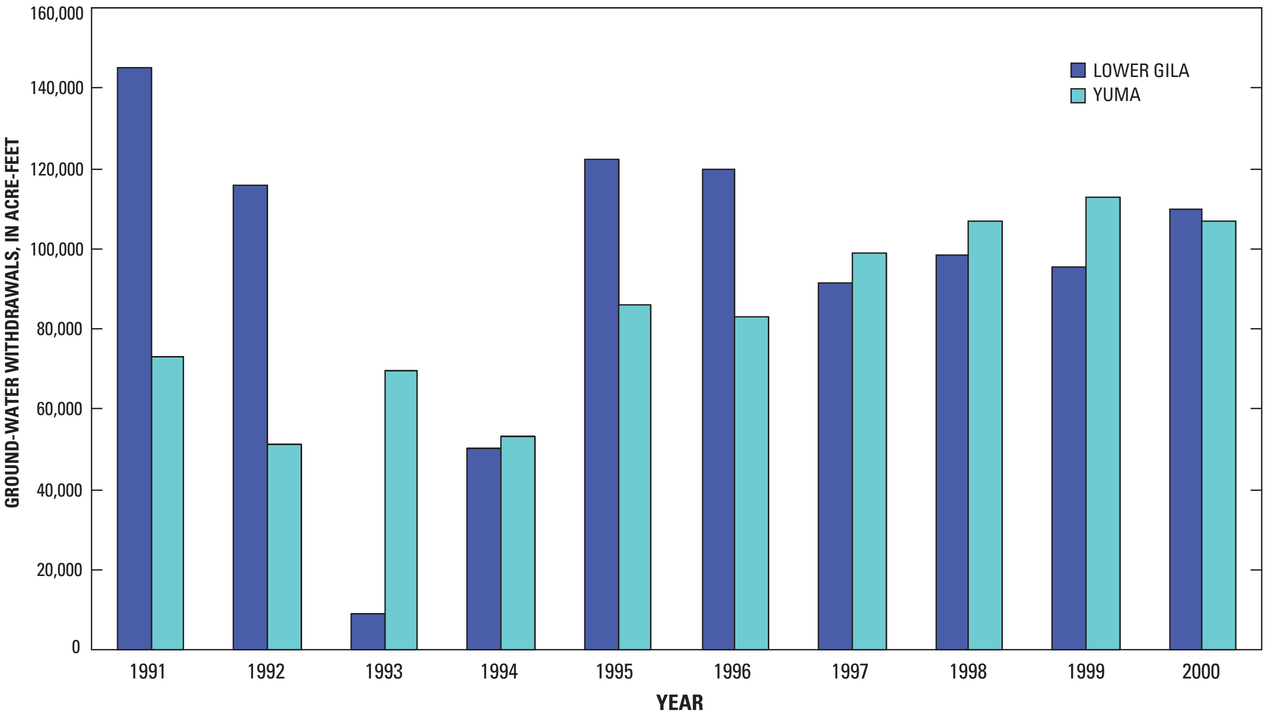


Figure 11. Annual ground-water withdrawals for drainage of agricultural lands in the Lower Gila and Yuma Basins, 1991–2000.

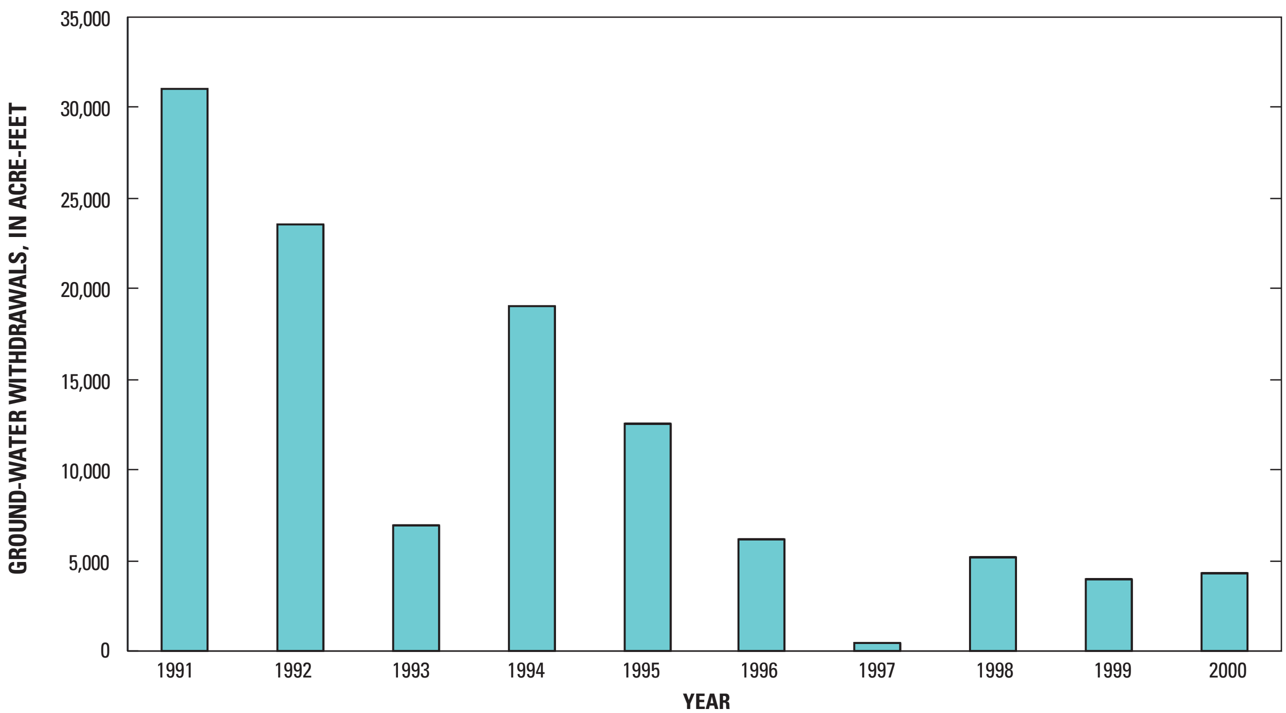


Figure 12. Annual ground-water withdrawals for the 242 well field in the Yuma Basin, Arizona, 1991–2000.

Summary

Access to adequate water supplies is a primary factor in economic development in Arizona. Because of the mostly semiarid to arid climate in the State, water demand is met by pumping ground water from aquifers or by conveying surface water through a system of reservoirs and canals. Water-withdrawal data provide important information on how water demand affects the State's water resources. Information on water withdrawals also can help planners and managers assess the effectiveness of water-management policies, regulations, and conservation activities.

Ground-water withdrawal data were collected, compiled, and estimated for irrigation, municipal, mining, thermoelectric-power, and drainage use in Arizona Department of Water Resources ground-water basins outside Active Management Areas for 1991-2000. Data for metered surface-water diversions also were compiled. Both surface-water and ground-water withdrawals are delivered to agricultural fields in the Little Colorado River Plateau, Lower San Pedro, Salt River, Tonto Creek, Upper San Pedro, Verde River, and Virgin River Basins; however, the surface-water deliveries are not measured and are not presented in this report. This report includes only annual metered surface-water withdrawals for irrigation.

Water withdrawal in Arizona is dominated primarily by agriculture use and secondarily by municipal use for rapidly growing urban populations. Because of low rainfall, agriculture in Arizona depends heavily on the State's water resources. Several methods were used to compile or estimate water withdrawals and irrigated acreage for 1991–2000. A variety of crops are grown in Arizona, and different crops use different amounts of water over the course of the growing season. For 1991–2000, consumptive water requirements were estimated for the most common crops: alfalfa and other hay, barley, citrus and noncitrus orchards, corn, cotton, vegetables, and wheat. Total withdrawals were calculated as the county irrigation efficiency and consumptive water requirement within the study area.

The largest ground-water withdrawals for irrigation were in the Gila Bend Basin and ranged from 203,000 acre-feet in 1998 to 294,000 acre-feet in 2000. The largest surface-water withdrawals for irrigation were in the Lower Gila, Parker, and Yuma Basins where surface water is available from the Colorado River. In some of the basins, the amount of water used for irrigation varied greatly from year to year. This was due to differences in consumptive water requirement rates for different crops and differences in irrigated acreage.

Withdrawals categorized as municipal in this report include water supplied by public and private-water suppliers, and self-supplied domestic users. Municipal ground-water withdrawals for most of the basins steadily increased from 1991 to 2000, following the trend of increasing population. The largest withdrawals were in the Little Colorado River Plateau Basin where they increased from 20,500 acre-feet in 1991 to 27,000 acre-feet in 2000. Population growth is the primary cause for the increase in municipal ground-water withdrawals during 1991–2000.

In most years, the largest ground-water withdrawals for mining were in the Lower San Pedro Basin. Ground-water withdrawals for mining decreased substantially from 32,500 acre-feet in 1996 to 16,000 acre-feet in 2000. In the Salt River Basin, ground-water withdrawals for mining decreased substantially from 11,000 acre-feet in 1996 to 5,000 acre-feet in 1998. Annual increases or decreases in ground-water withdrawals for mining primarily are due to fluctuations in mineral production, which is driven by market prices.

Ground-water withdrawals by thermoelectric powerplants increased by 5,500 acre-feet, or 20 percent, between 1991 and 2000. There is a positive correlation between ground-water withdrawals for thermoelectric power generation and power generated in the Willcox Basin from 1996 to 2000; however, there was no correlation from 1991 to 1995. The demand for electricity is influenced by various factors, including personal income, population, weather, and the price of electricity.

Data on ground-water withdrawals for irrigation drainage represent withdrawals for dewatering the root zone in agricultural areas and withdrawals from the 242 well field, which provides water deliveries to Mexico as obligated by treaty. Ground-water withdrawals for drainage of agricultural lands and from the 242 well field varied from year to year.

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Manuscript approved for publication, December 9, 2004

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SIR 2004–5293

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