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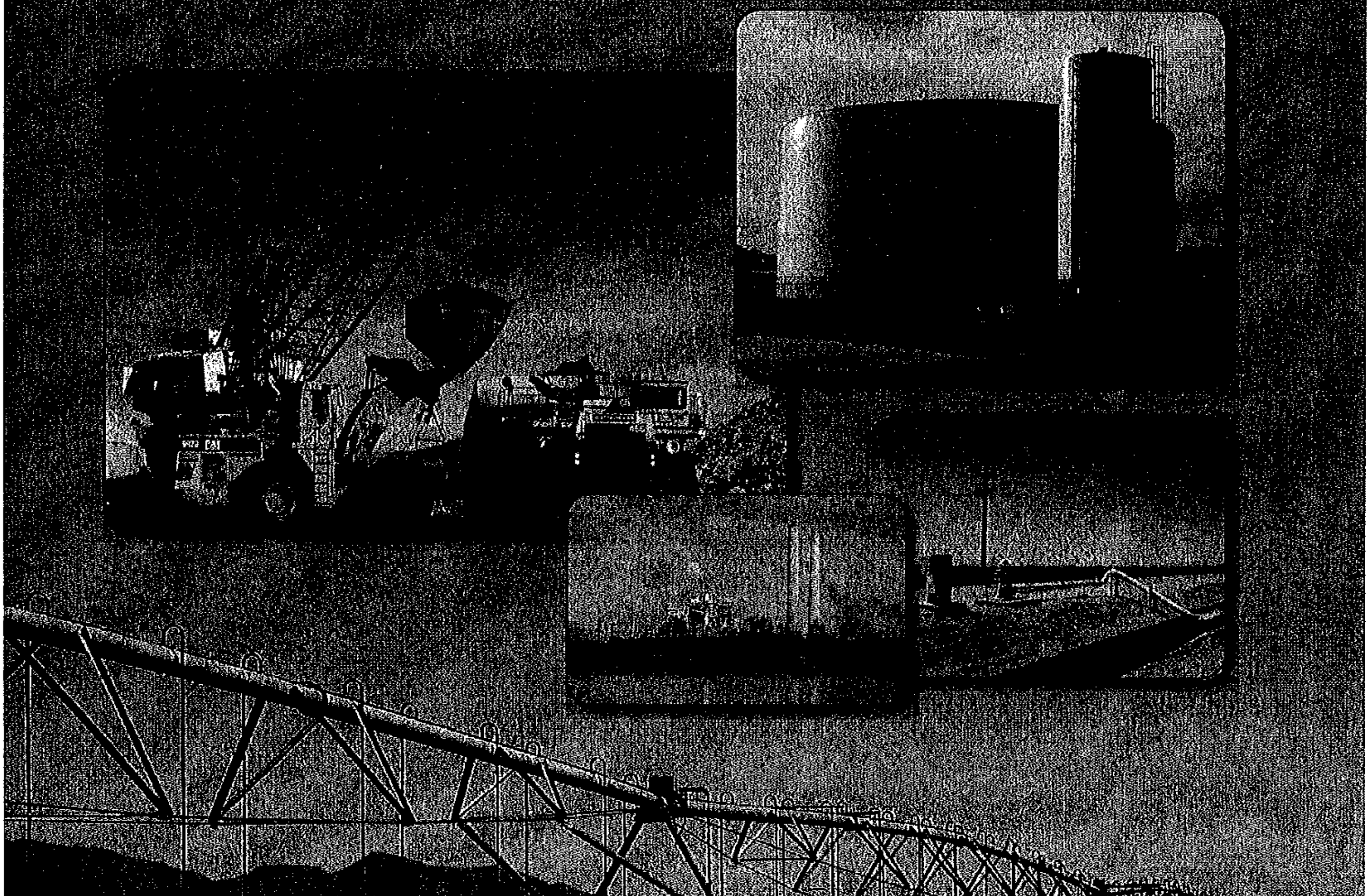
Water Withdrawals for Irrigation, Municipal, Mining, Thermoelectric-Power, and Drainage Uses in Arizona Outside of Active Management Areas, 1991-2000



Scientific Investigations Report 2004–5293

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

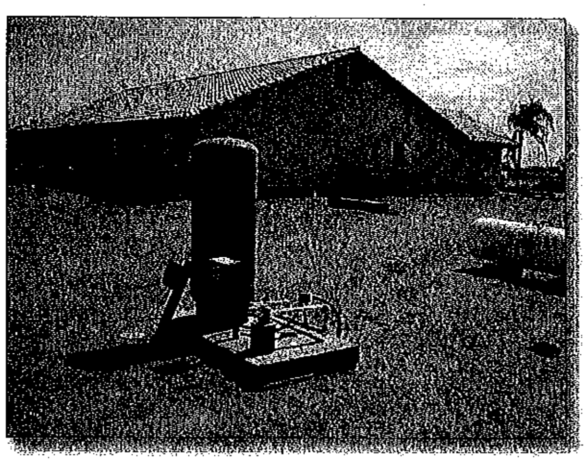
Private Water Suppliers

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.

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

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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.

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

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.

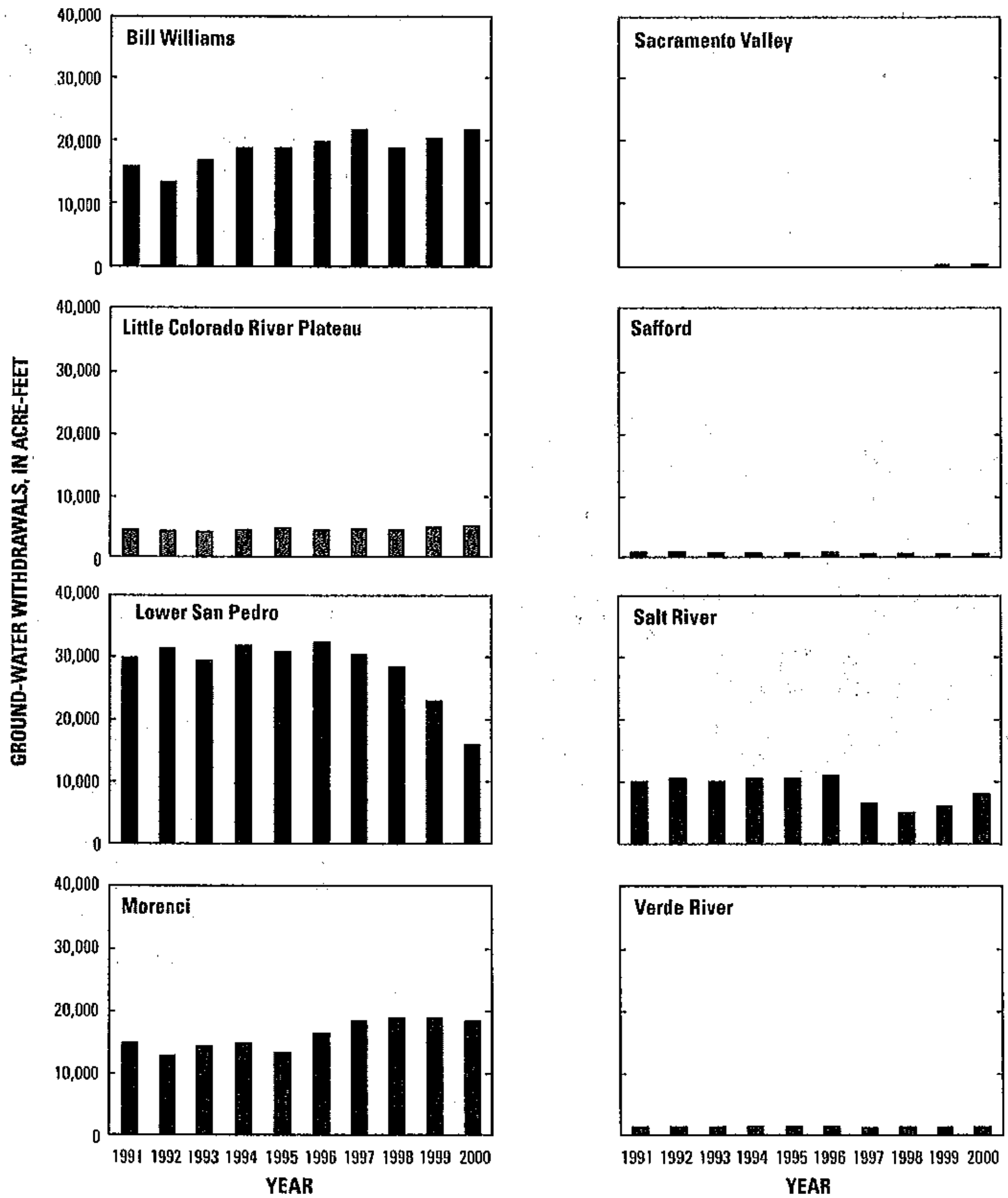


Figure 8. Estimated annual ground-water withdrawals for mining in ground-water basins outside of Active Management Areas, Arizona, 1991–2000.

Thermoelectric Power

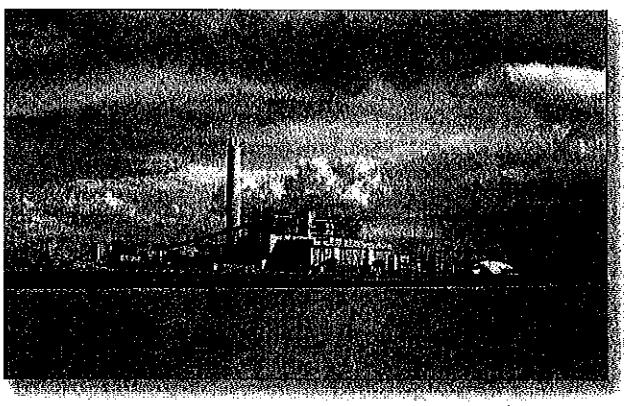
Thermoelectric powerplants require water and fuel to generate electricity. Water is used in power generation to (1) process feed water for steam, (2) cool steam and thereby facilitate condensation and steam reuse, and (3) remove sulfur dioxide. Some water, however, may be used for cleaning and pollution 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.

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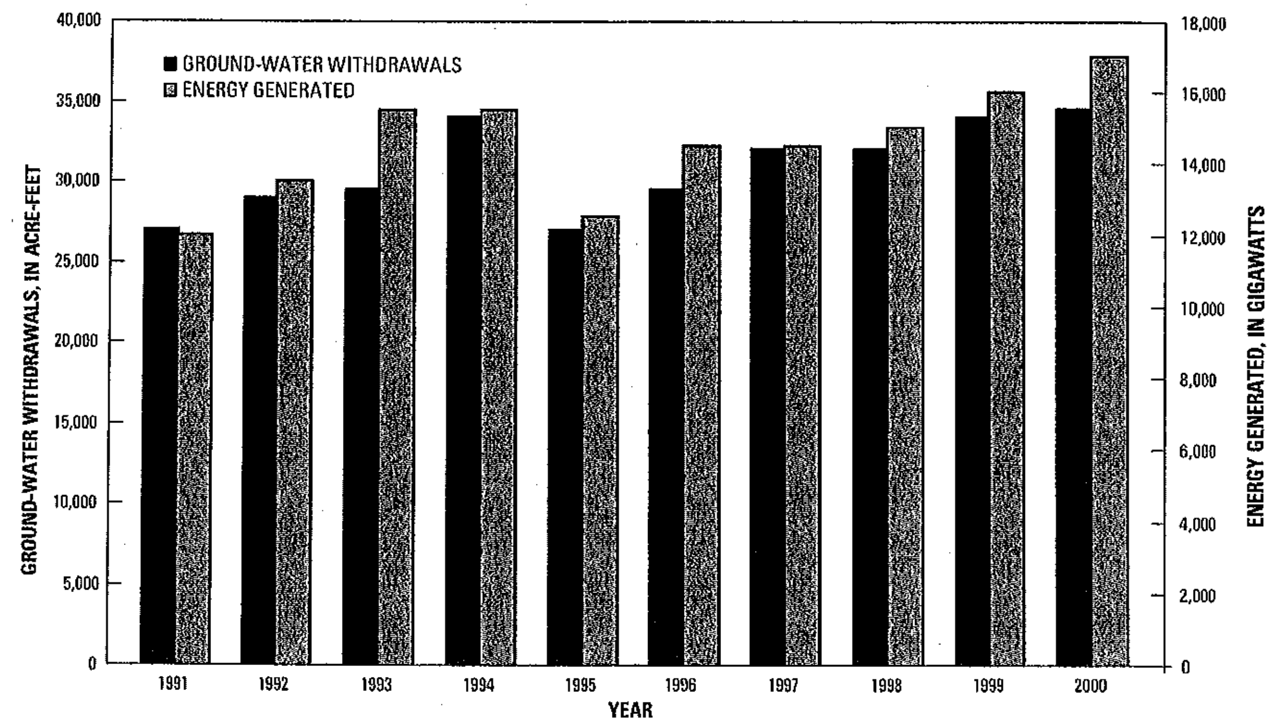

Figure 9. Ground-water withdrawals and energy generated by thermoelectric powerplants in the Little Colorado River Plateau Basin, Arizona, 1991–2000.

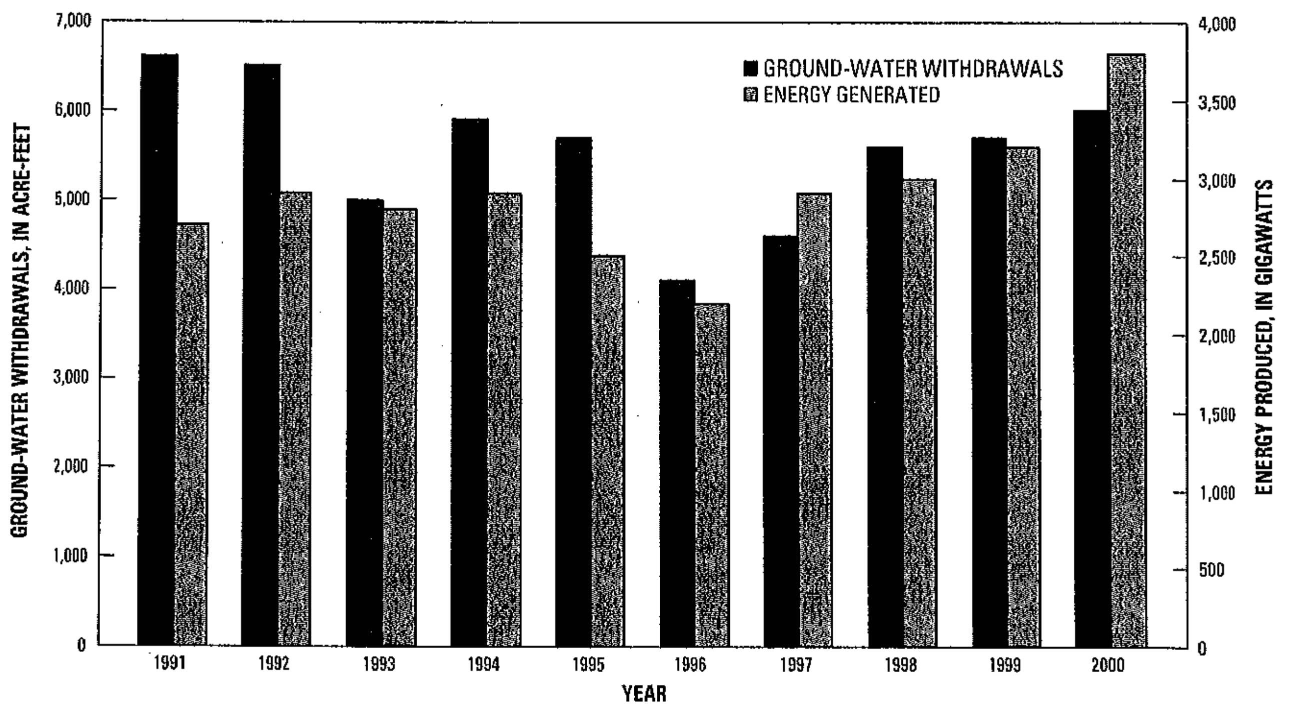

Figure 10. Ground-water withdrawals and energy generated by the thermoelectric powerplant in the Willcox Basin, Arizona, 1991–2000.