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GEOTHERMAL DEVELOPMENT PLAN:

COCHISE/SANTA CRUZ COUNTIES

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ABSTRACT

The Cochise/Santa Cruz Counties Area Development Plan evaluated the regional market potential for utilizing geothermal energy. The study identified three potential geothermal resource areas with potential for resource temperatures less than 90°C (194°F). Geothermal resources are found to occur near the towns of Willcox, San Simon and Bowie. Population growth rates are expected to average three percent per year over the next 30 years in Willcox; Bowie and San Simon are expected to grow much slower. Regional employment is based on agriculture and copper mining, though future growth in trade, services and international trade is expected. A regional energy-use analysis is also included. Urban use, copper mining and agriculture are the principal water users in the region and substantial reductions in water use are anticipated in the future.

The development plan also contains a section identifying potential geothermal energy users in the region. Geothermal energy utilization projections suggest that by the year 2000, geothermal energy might economically provide the energy equivalent of 3,250,000 barrels of oil per year to the industrial sector. In addition, geothermal energy utilization might help stimulate an agricultural and livestock processing industry.

The utilization of geothermal energy for cooling systems is of vital interest, because Arizona consumes nearly 50 percent more electricity during the peak summer season due to electrical-driven air conditioning units. Geothermal-assisted heat pumps were shown to be

economical for nearly all areas of Arizona. Further, the necessary low-temperature geothermal resource is widely available, based on the known 3,000 thermal wells. Geothermal-driven absorption systems (with a resource above 105°C) is a second way to reduce electrical energy, and some areas of Arizona are believed to have such geothermal resources at economical depths.

Appendices to the report include state legislative update including agency contacts and a bibliography of related material.

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INTRODUCTION

Alternative sources of energy will have to be developed as the availability of traditional energy resources continues to diminish. Arizona is believed to have geothermal resources which potentially could supplement the existing energy supplies. Consequently, planning efforts have concentrated on estimating the potential of geothermal energy utilization in Arizona.

The State of Arizona was divided into local areas, in order to prepare "Geothermal Development Plans" (GDP) for each area. It was logical and convenient to follow country lines, such that four geothermal development plans were for one county each, namely, for Maricopa, Pima, Pinal and Yuma counties. The other three geothermal development plans consist of one or more counties on a regional basis. Although most of the work herein is based on 1979 data, certain items have been updated to 1981. This is especially true for the geothermal resource information, although it must be noted that there are few proven geothermal resources -- there are no commercial wells and only four developmental wells in the State of Arizona.

Geothermal development plans were prepared for seven distinct intrastate subdivisions. Geothermal resource prospects and the potential geothermal uses for each area are discussed in separate Geothermal Development Plans (GDPs). The major objective of the GDP is to provide information relevant to the prospective development and commercialization of geothermal energy for the specified areas. Attempts are made to match the available geothermal resources to potential residential, commercial, industrial and agricultural users.

GEOTHERMAL DEVELOPMENT PLANS

Arizona has been divided into seven distinct single or multicounty subdivisions for which Geothermal Development Plans (GDPs) for geothermal commercialization have been developed. A map of Arizona presented in Figure 1 shows these areas which are numbered in order of planning priority.

This GDP is concerned with Cochise and Santa Cruz counties. Both metric and English units are provided in the text. However, only metric units appear in the tables and figures. For convenience, some common conversion factors are listed in Table 1. In this report, one million Btu = MBtu.

TABLE 1: SOME COMMON CONVERSION FACTORS

Length and Volume Conversions:

To Convert:	Multiply By:	To Obtain:
meters	3.281	feet
kilometers	0.6214	miles
cubic kilometers	0.2399	cubic miles
liters	0.2642	gallons

Temperature Conversions: $^{o}F = (1.8 \times {}^{o}C) + 32$

GEOTHERMAL RESOURCES

General Information

Cochise and Santa Cruz Counties lie entirely within the basin and range physiographic province which is characterized by numerous mountain ranges rising abruptly from broad valleys. Three areas believed to store thermal water at depths of less than 1200 m (3,937 ft) have been identified within the county. Cochise and Santa Cruz Counties are shown in Figure 2 and labeled areas identify the suspected resource areas.

PRIORITIES

I) Maricopa
II) Pima
III) Graham/Greenlee
IV) Pinal
V) Yuma
VI) Cochise/Santa Cruz
VII) Northern Counties
(1,3,4,8,9,13)

COUNTY NAMES

1. Apache
2. Cochise
3. Coconino
4. Gila
5. Graham
6. Greenlee
7. Maricopa
8. Mohave
9. Navajo
10. Pima
11. Pinal
12. Santa Cruz
13. Yavapai
14. Yuma

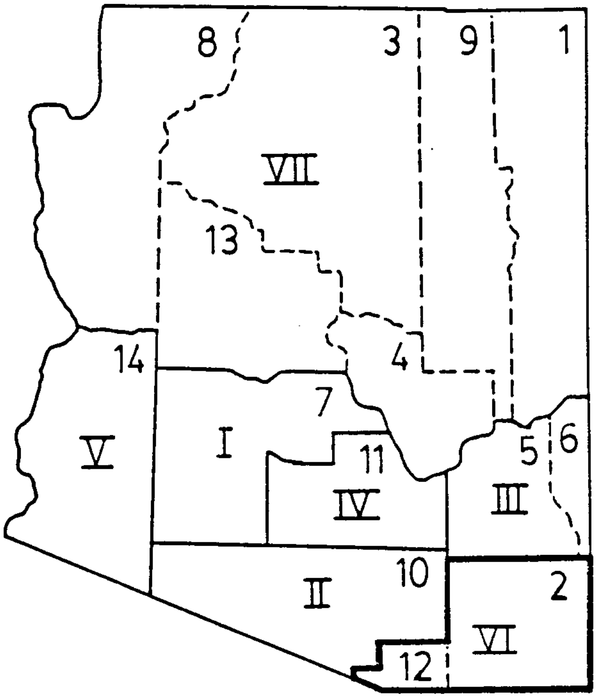


Figure 1: Geothermal Development Plans for Arizona

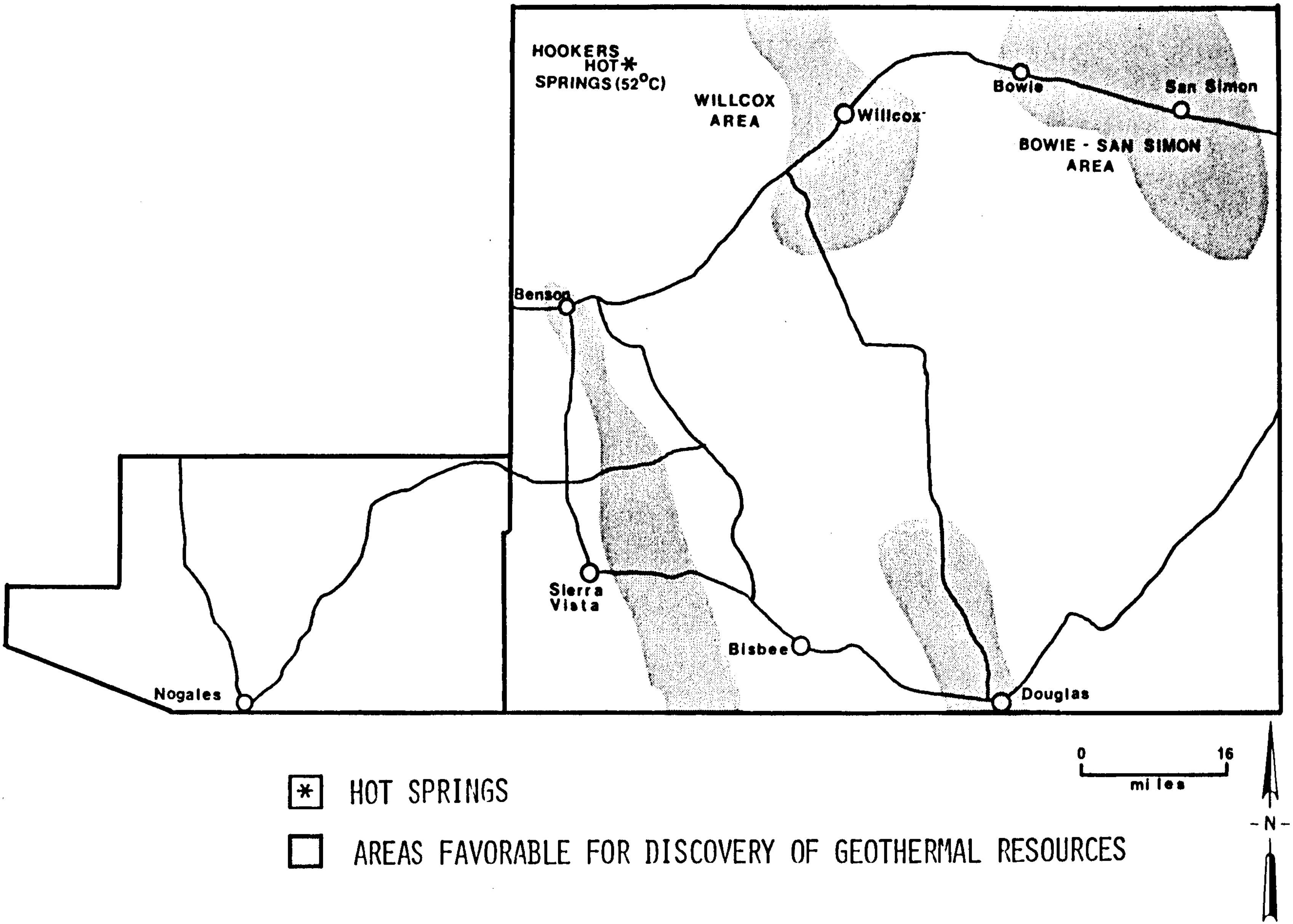


Figure 2: Locations of Potential Geothermal Resource Areas in Cochise and Santa Cruz Counties

To date, most of the areas highlighted in Figure 2 remain relatively unexplored for geothermal resources. The three areas presented on the map were identified as probable areas based on water well data. Each area has been explored in a preliminary manner by the Arizona Bureau of Geology and Mineral Technology - Geothermal Group. General results for the investigated areas are presented within this chapter.

Based on studies conducted in the basin and range province, certain general characteristics have been identified that help recognize low temperature geothermal occurrences. First, USGS defines a possible geothermal resource area as having water temperatures $10^{\circ}C$ ($18^{\circ}F$) greater than the mean annual air temperature and temperature gradients (i.e. temperature changes with depth) greater than $25^{\circ}C/km$ ($1.4^{\circ}F/100$ ft). Each of the areas identified on the map (Figure 2) meet these criteria. Second, in Nevada, Utah and Arizona major range bounding faults act as conduits for warm to hot water to rise from depth toward the surface. The heat source can be either shallow magmatic intrusion or deep circulation in a normal temperature gradient regime. Such heat sources do not usually produce the high temperatures that result from a magmatic heat source. However, valleys in southern Arizona are basin-range grabens bound by deep faults. Thus, low temperature ($<90^{\circ}C$, $194^{\circ}F$) geothermal resources might reasonably be expected to occur in most deep basins.

A state geothermal map compiled by the Arizona Bureau of Geology and Mineral Technology - Geothermal Group and published by the National Oceanographic and Atmospheric Administration provides a complete and updated listing of data concerning thermal well and spring locations as well as temperature and depth estimates, flow rates and total dissolved solids.

This map can be obtained free of charge in July, 1982 by writing to the Arizona Bureau of Geology, 845 N. Park Avenue, Tucson, Arizona 85719.

Summary of Cochise and Santa Cruz Counties

Over a five year period, geologists from the Arizona Bureau of Geology and Mineral Technology have performed preliminary geothermal resource exploration in and assessment of a number of locations around Arizona. Though the work performed was preliminary, a synopsis of resource study areas and results is included in this section. Three specific areas within Cochise and Santa Cruz Counties are summarized in order to give the reader some indication of resource locations, work performed and potential resource quality. The reader is referred to the reference section of this report for locating detalied studies to prepare this report.

San Simon Area

The San Simon area lies astride Interstate 10 in the southern Safford - San Simon Basin. Prior to extensive ground water withdrawal and attendant water table lowering, the area had numerous thermal artesian wells (>30°C) used for irrigating crops. Because the upper static water table was relatively deep and the means for pumping from this aquifer was not feasible during the early 1900s, deep wells were drilled to tap an artesian aquifer, which was discovered by Southern Pacific Railroad.

Geothermal potential at depths greater than 1 km (3,281 ft) in the San Simon area may be good. In 1938, a deep oil and gas test, the Funk Benevolent 1 Fee, was completed to 2,032 m (6,667 ft). In a 1940 memorandum, E. D. Wilson of the Arizona Bureau of Mines gave an account of a visit to this well site where he was told that 134°C (273°F) water was encountered in the lower 100 m (328 ft) of the hole. If this temperature accurately describes bottom-hole conditions, the estimated temperature gradient is 57°C/km (3.1°F/100 ft). This temperature gradient is above the 46°C/km (2.5°F/100 ft) average gradient estimated using shallow (<300 m, 984 ft) well data. The San Simon area, therefore, may have good potential for 1 to 2.5 km (3,280 to 8,200 ft) geothermal resources between 100°C (212°F) and 140°C (284°F).

Most thermal waters encountered in artesian wells are of a sodium bicarbonate composition. In the northern portion of the San Simon area, sodium chloride - sulfate bearing water with total dissolved solids up to 5,400 mg/l is encountered. Fluoride and boron contents are also exceptionally high, with flouride concentrations over 25 mg/l.

Bowie Area

At least 20 irrigation wells in the area surrounding Bowie produce 30°C (86°F) to 37°C (98.6°F) water from depths of 183 m (600 ft) to 610 m (2,000 ft). Chemical quality of the thermal water is generally good. Total dissolved solids range mostly between 250 mg/l and 500 mg/l. Fluoride concentrations are generally less than 3.0 mg/l, although a few wells produce water with fluoride over 7.0 mg/l.

Several wells in this area, producing sodium bicarbonate water with low magnesium, high sodium-potassium-calcium geothermometers, and an apparent structural intersection support the hypothesis that a deep (>2 km, 6,562 ft) moderate temperature geothermal reservoir (<124°C, 255°F) occurs south of Bowie. The most anomalous well has a discharge temperature of 35°C (95°F) from a depth of 145 m (476 ft) and an estimated average temperature gradient of 124°C/km (6.8°F/100 ft). All other wells in the area have estimated temperature gradients between 30°C/km (1.6°F/100 ft) and 80°C/km (4.4°F/100 ft) and a mean temperature gradient of 49°C/km (3.7°F/100 ft).

Willcox Area

Twelve water wells in the Willcox basin produce 31°C (88°F) to 54°C (129°F) thermal water from depth of 214 m (702 ft) to 832 m (2,730 ft). The warmest well produces 54°C (129°F) water from a depth of 445 m (1,460 ft). Three areas north and northwest of the town of Willcox have been identified as probable geothermal resource areas. Based on chemical geothermometers of selected wells in the Willcox basin, temperatures of 70°C (158°F) are probable at depths of less than 1 km (3,281 ft) within the three areas. Additionally, one deep well drilled to 2,028 m (6,654 ft), but outside of the three areas, encountered a bottom hole temperature of 87°C (189°F). The estimated temperature gradient was 35°C/km (1.9F/100 ft). The average estimated temperature gradient for wells within the three areas is 74°C/km (4.0°F/100 ft.)

Chemically, two types of thermal water are encountered in the Willcox basin; sodium-choride-bicarbonate water and sodium-bicarbonate-sulfate water. Total dissolved solids range from 267 mg/1 to 1370 mg/1. In general, water quality improves significantly in the deeper wells which is especially apparent from wells drilled deeper than 460 m (1,500 ft). It is spectulated that this unusual trend is due to salts from the Willcox Playa.

ECONOMY

Population

The 1980 combined population of Cochise and Santa Cruz counties was 107,176. The total land area of 7,502 square miles gives the two counties a population density of 14.3 persons per square mile. Ethnic breakdown of the population is 52 percent white, 40 percent Hispanic, 2 percent black, and 0.2 percent Indian.

Growth

Historically, the population of Cochise County has grown at an annual rate of 3.0 percent; projections show steady, continued growth (see Figure 3). Growth is expected to be centered principally to the south and west of the city of Willcox, the fastest growing city in the county.

Santa Cruz County has traditionally experienced slow growth; however, from 1968 to 1978 the population increased by 38.4 percent. Figure 4 shows that the population of Santa Cruz County is expected to continue to rise more rapidly than it has in the past.

Major towns in the two counties and their projected populations to the year 2000 are listed in Table 2.

TABLE 2: MAJOR TOWNS IN COCHISE AND SANTA CRUZ COUNTIES AND THEIR CURRENT AND PROJECTED POPULATIONS

Cochise	1979	2000
Sierra Vista	25,969	37,487
Douglas	13,342	19,160
Bisbee	10,119	14,155
Benson	4,333	6,153
Willcox	3,487	5,343
Santa Cruz	**1979**	**2000**
Santa Cruz	19,635	32,950
Nogales	14,646	26,502
Patagonia	1,009	1,850

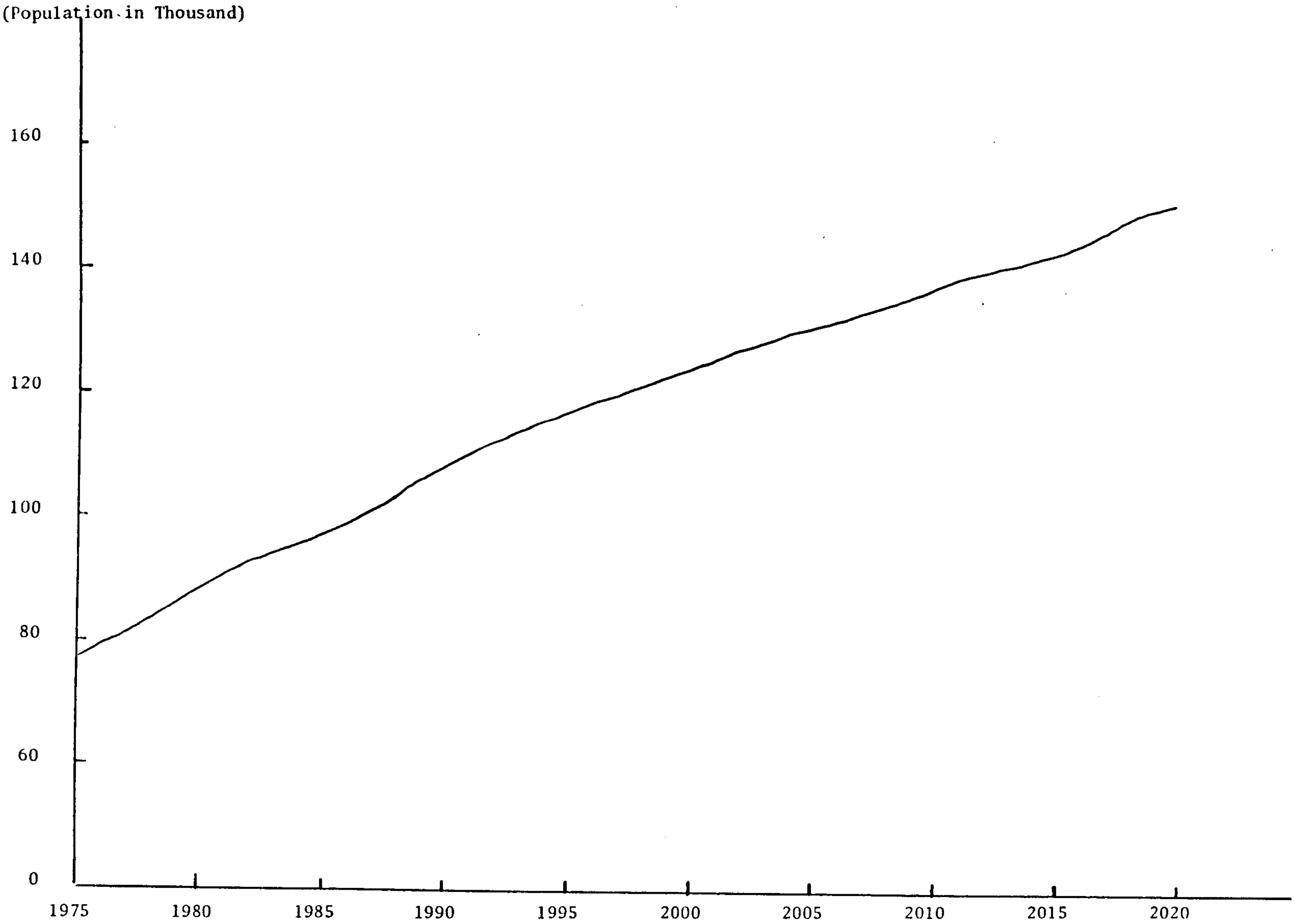


Figure 3: Population Projections for Cochise County.
Source: Technical Advisory Committee (DES)

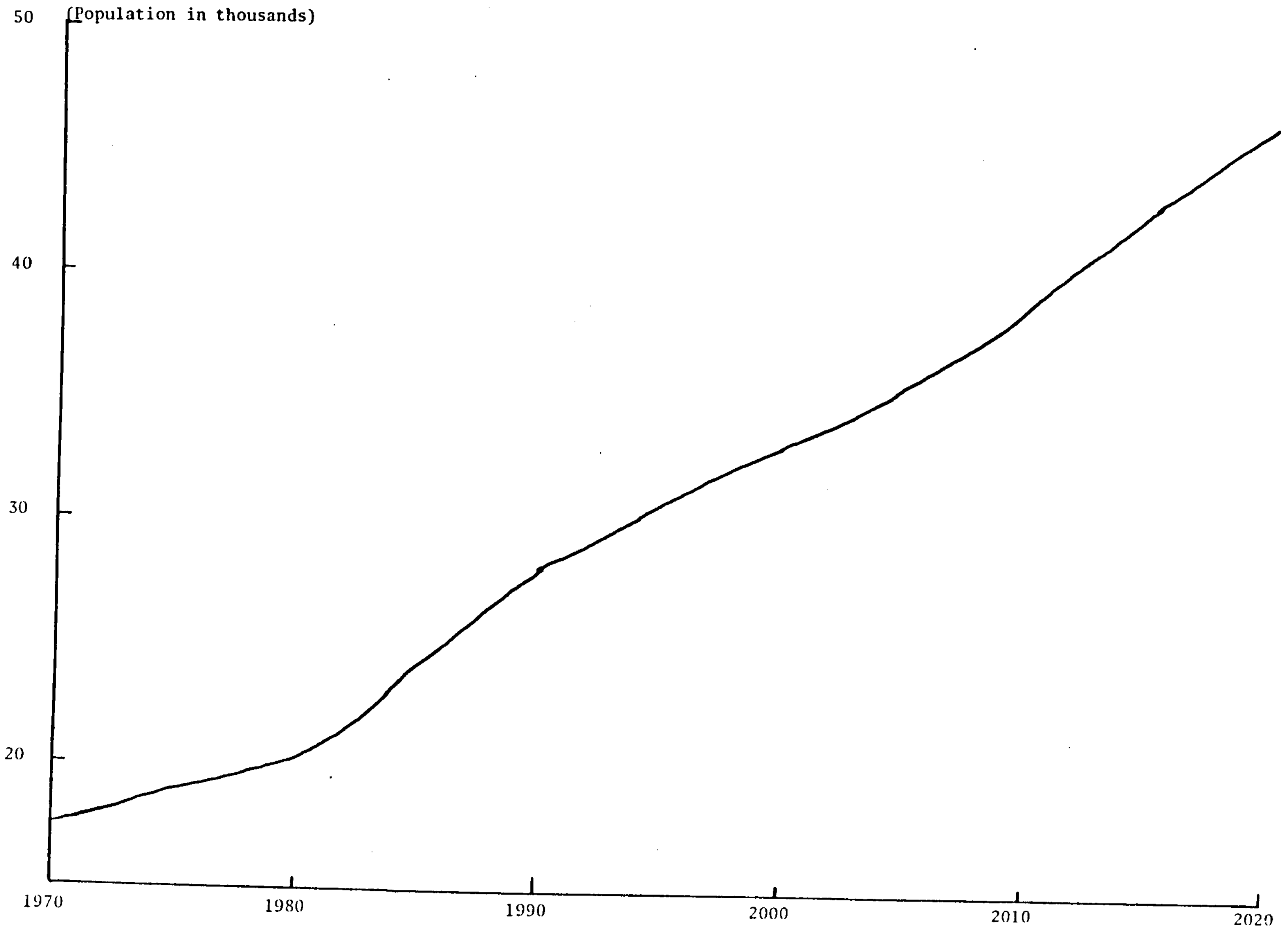


Figure 4: Population Projections for Santa Cruz County.
Source: Technical Advisory Committee (DES)

Industry and Employment

The agricultural sector is of major importance to the Cochise County economy. The county, accounting for 43 percent of Arizona's grain sorghum and 90 percent of its corn production, is the primary producer of feed grain in the state. In addition the Willcox area produces 31 percent of the state's hogs and 17 percent of its range cattle. In 1977, crop and livestock receipts amounted to $61.5 million and $35.4 million, respectively.

Presently, agriculture accounts for only four percent of total employment in Cochise County; no significant changes regarding agricultural employment are expected over the next 20 years. However, as the population increases, employment in the trade and service sectors is expected to increase from the current level of 20 percent of total employment to 26 percent by the year 2000.

Santa Cruz County's economy is based on tourism and international trade with the wholesale and retail trade sectors accounting for nearly 50 percent of the total employment in the county. Although it is not the county's fastest growing city, Nogales is the most important in terms of trade. Lying on the U.S./Mexican border, Nogales is expected to grow rapidly as trade between the two countries increases.

Figure 5 gives current and projected employment levels for the various sectors in Cochise and Santa Cruz counties. As shown by the figure, the service sector and federal government (civilian) and local government employment contribute significantly to the economy of the counties. Currently, manufacturing employs considerably fewer people than do the service and government sectors, but employment in manufacturing is projected to more

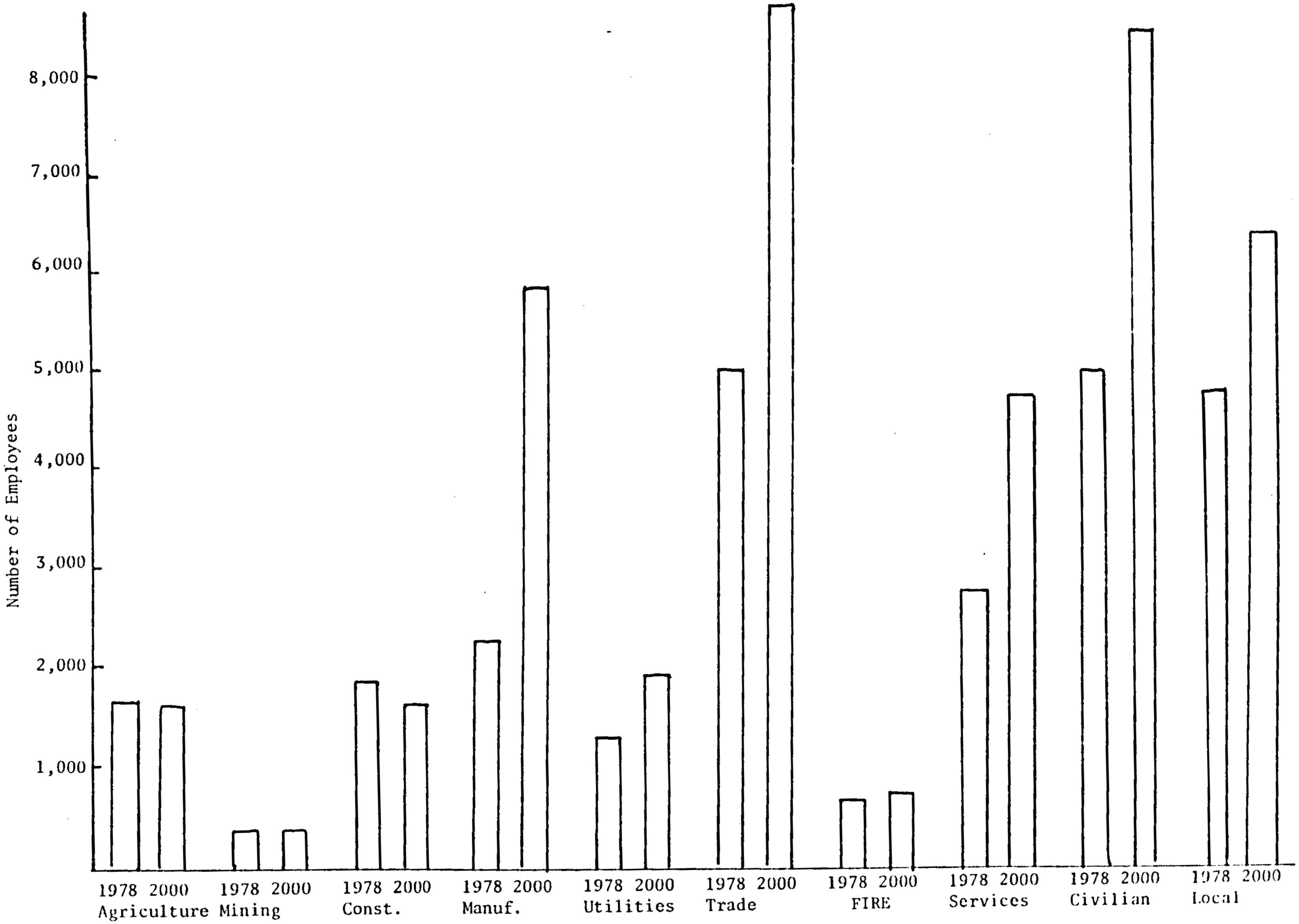


Figure 5: Employment Sector Projections for Cochise/Santa Cruz Counties.
Source: Department of Economic Security

than double by the year 2000. Construction employs even fewer people than manufacturing and employment in construction is expected to decline at an annual rate of 0.9 percent.

Income

Positive growth trends in both counties are also indicated by other economic indicators. Projections of growth of personal per capita income for both counties are presented in Figure 6; annual growth rates for Cochise and Santa Cruz counties are 2.9 percent and 3.0 percent, respectively. These income growth figures are lower than those found in the more populous counties of Maricopa and Pima.

Other Economic Indicators

Other indicators of the health of the economy include retail sales and bank deposits. Between 1968 and 1978, the value of retail sales increased 209 percent in Cochise County and 153 percent in Santa Cruz County; bank deposits increased 189 percent in Cochise County and 354 percent in Santa Cruz County over the ten-year period.

LAND OWNERSHIP

Figures 7 and 8 show general land ownership maps for Cochise and Santa Cruz counties, respectively. Table 3 gives acreage breakdowns for each ownership class. Acquisition of surface and mineral rights varies according to which sector owns the land.

ENERGY USE

Sulphur Springs Valley Cooperative, Inc. provides electricity to Cochise County. Monthly electricity sales during 1979 for four of the area's largest users are shown in Figure 9. Residential consumers show a high demand for electricity during the winter months when it is used

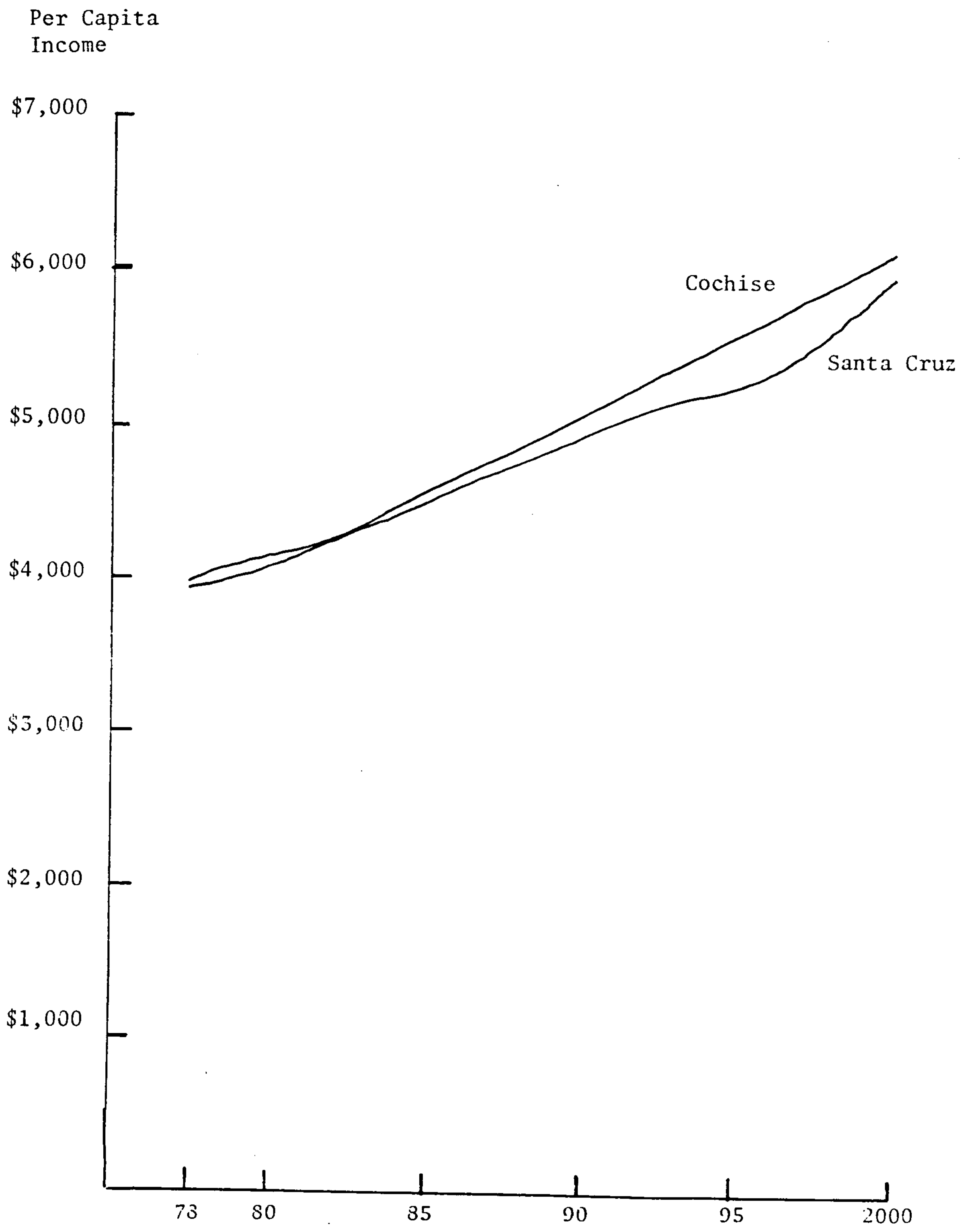


Figure 6: Projections of Personal Per Capita Income for Cochise and Santa Cruz Counties (1972 Dollars).
Source: Department of Economic Security

Figure 7: General Land Ownership Map for Cochise County
Source: Arizona Water Commission (1977)

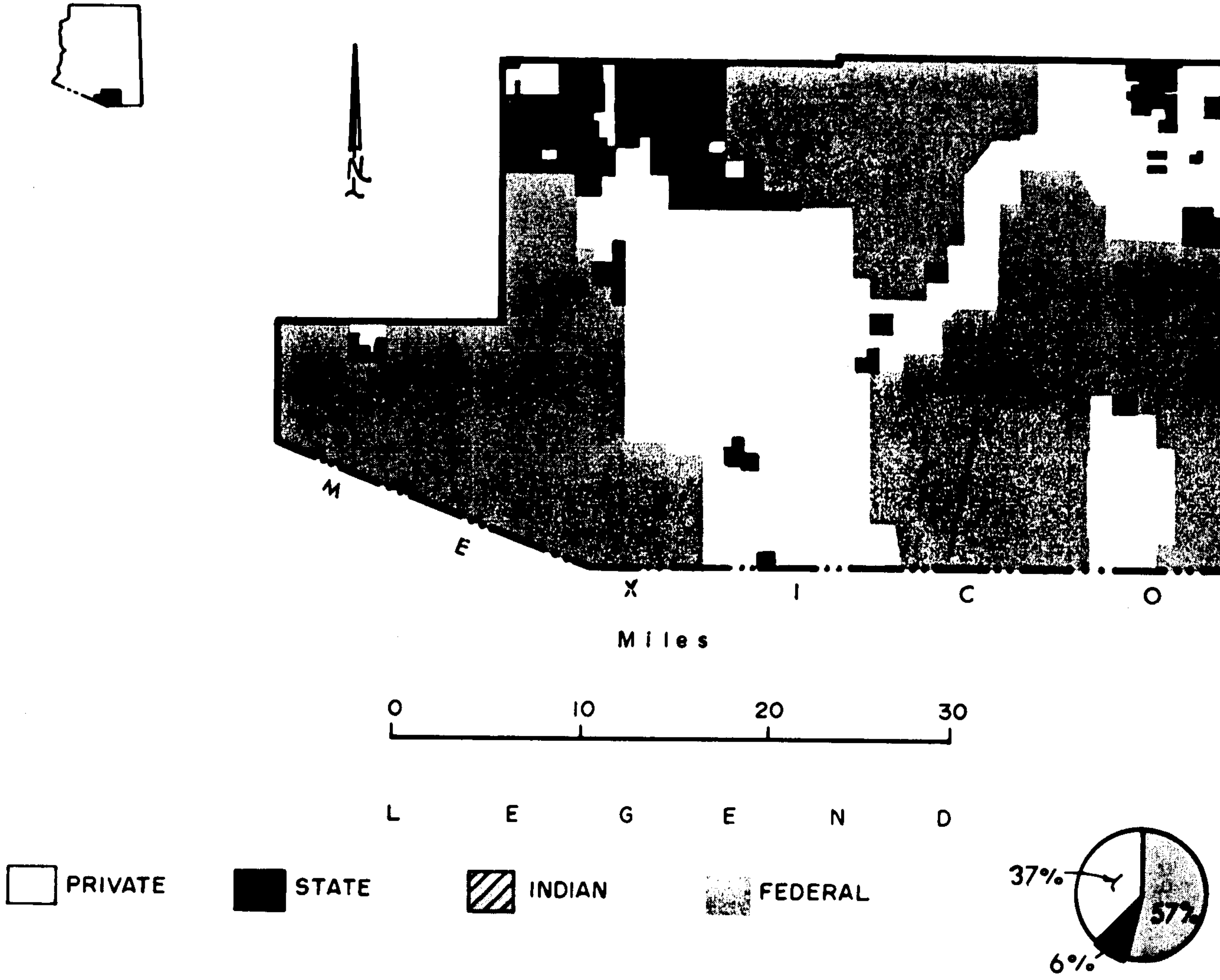


Figure 8: General Land Ownership Map for Santa Cruz County
Source: Arizona Water Commission (1977)

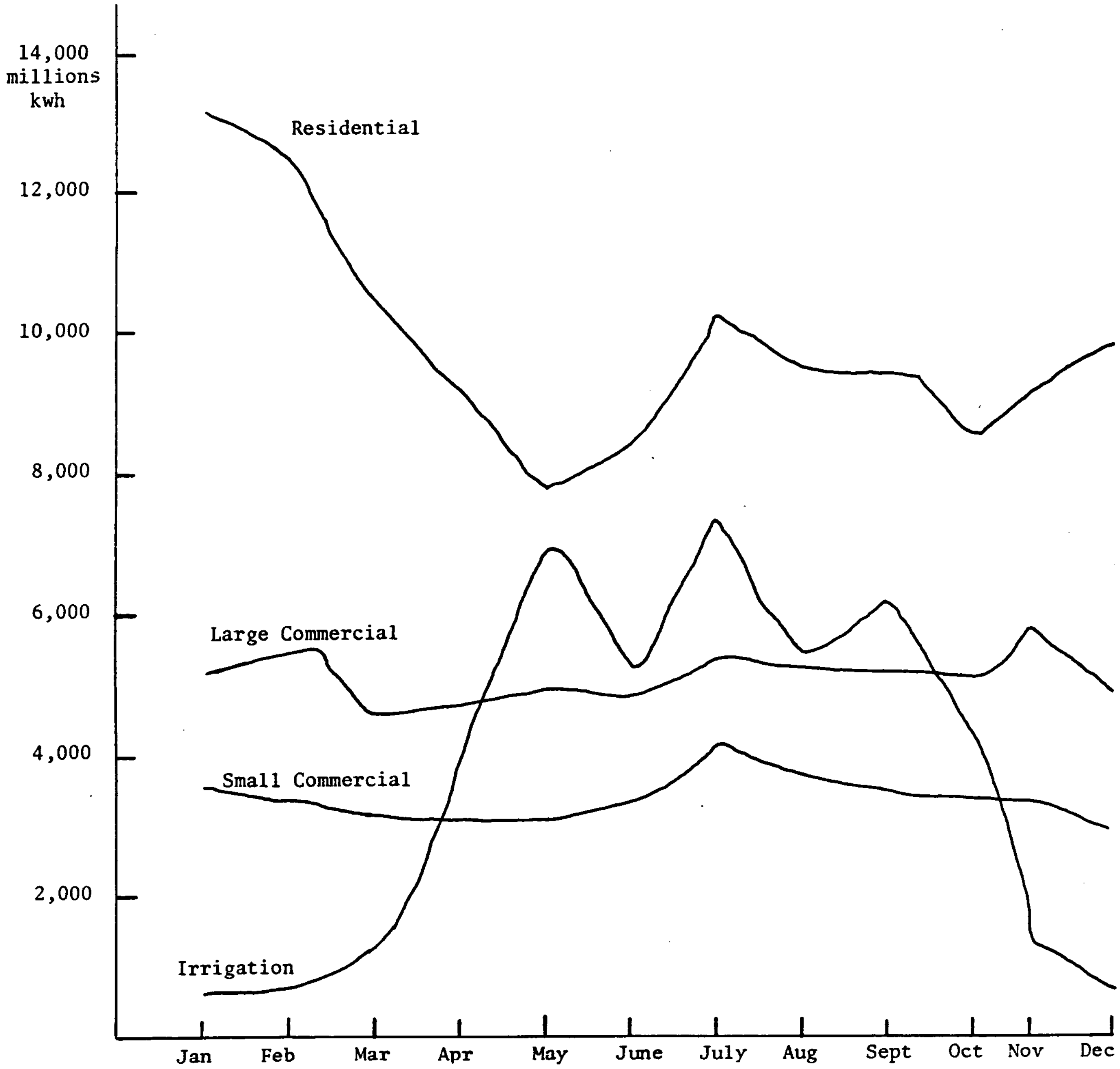


Figure 9: Electricity Sales for Sulphur Springs Valley Cooperative, Inc. in Cochise County.

TABLE 3: BREAKDOWN OF LAND OWNERSHIP IN COCHISE AND SANTA CRUZ COUNTIES

	Cochise %	Total Acres	Santa Cruz %	Total Acres
Federal	23	92,092	57	454,290
State	36	1,441,440	6	47,820
Indian	0	----	0	---
Private	41	1,641,640	37	294,890
Total	100	4,004,000	100	797,000

for space heating. A high demand for electricity occurs again in the summer months when it is used for irrigation and space cooling.

Citizens Utilities provides electricity to Santa Cruz County. Monthly electricity sales during 1979 for four of the area's largest users are shown in Figure 10. Again, residential consumers show high demand for electricity in the winter months and in the summer months when it is needed for space heating and space cooling, respectively. This pattern of electricity use by the residential sector is not typical for cities such as Phoenix or Tucson. For these cities, the use of electricity is highest in the summer months when it is used for space cooling. Demand for electricity is lowest in the winter months since natural gas is used to heat the homes.

The Town of Benson, the Willcox City Government and Arizona Public Service Company are among the several utility companies that supply natural gas to Cochise County. Natural gas is used during the winter months for space heating and is used year-round to heat water. Figure 11 presents the estimated monthly natural gas sales for 1979 for both the Town of Benson and the Willcox City Government. For the residential sector, both utility companies show a peak in gas sales during the winter months with usage dropping off rapidly in the spring.

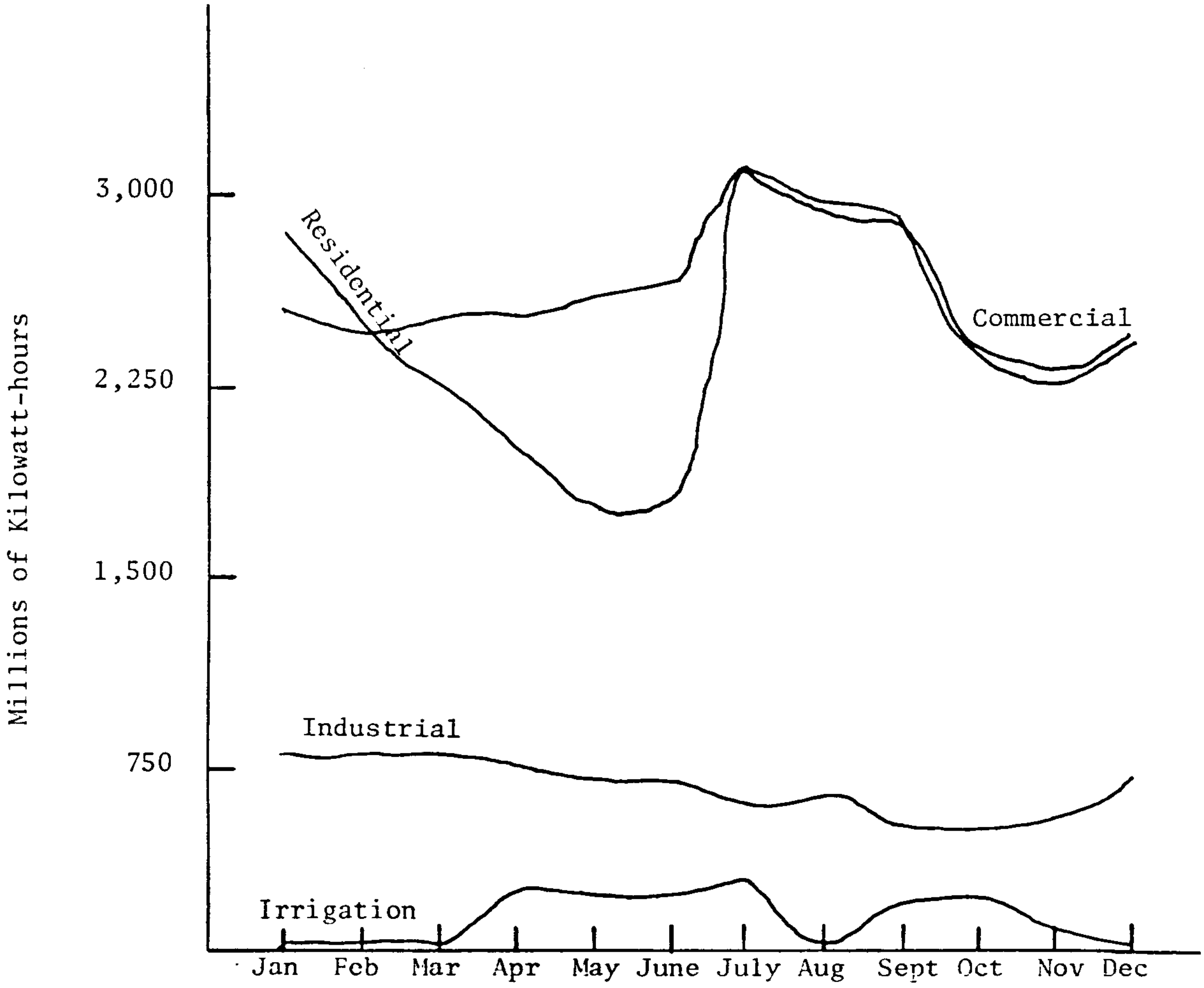


Figure 10: Electricity Sales for Citizens Utilities Company in Santa Cruz County.

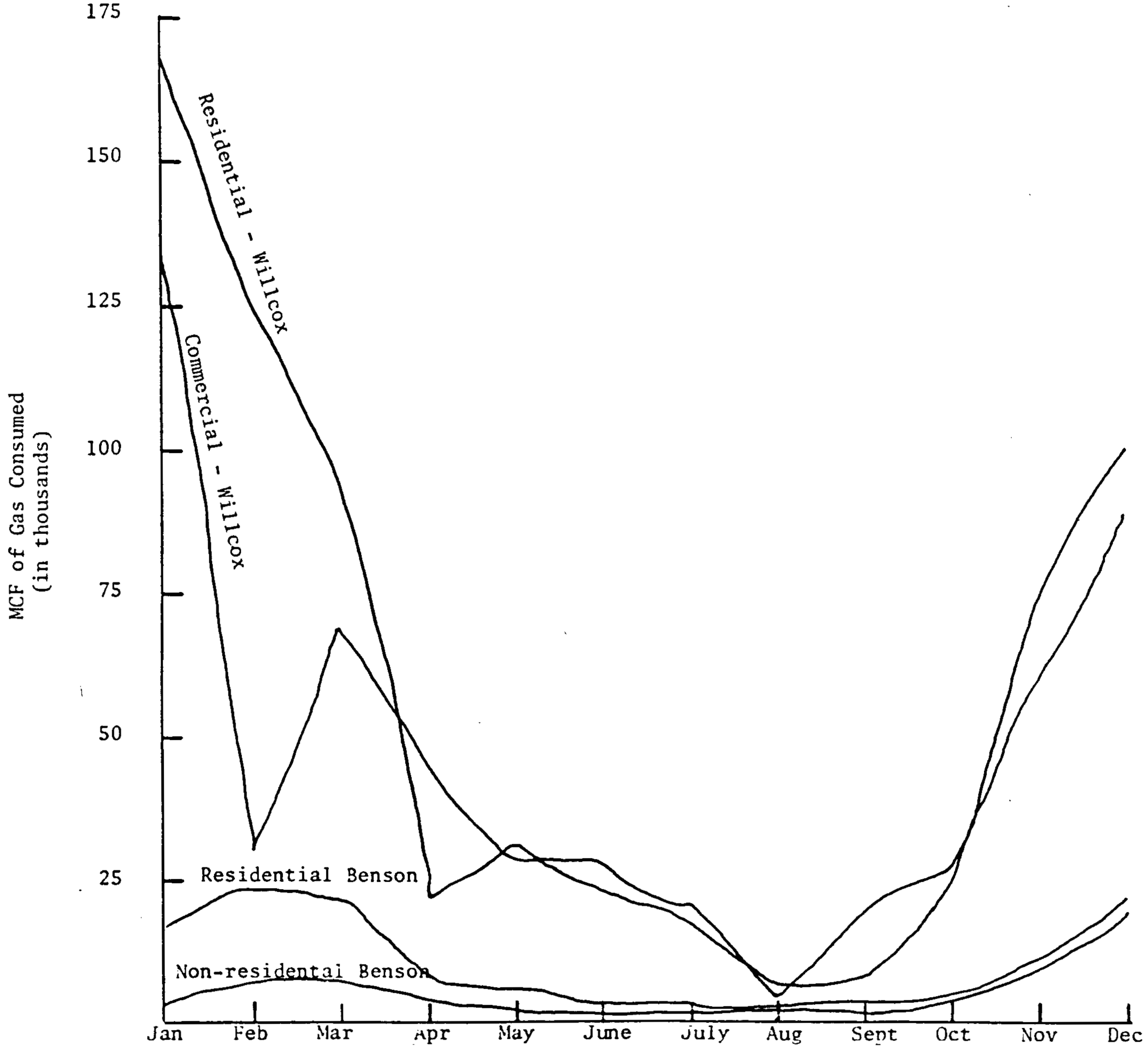


Figure 11: Estimated Monthly Natural Gas Sales in Cochise County by the Town of Benson and Willcox City Government, 1979.

WATER

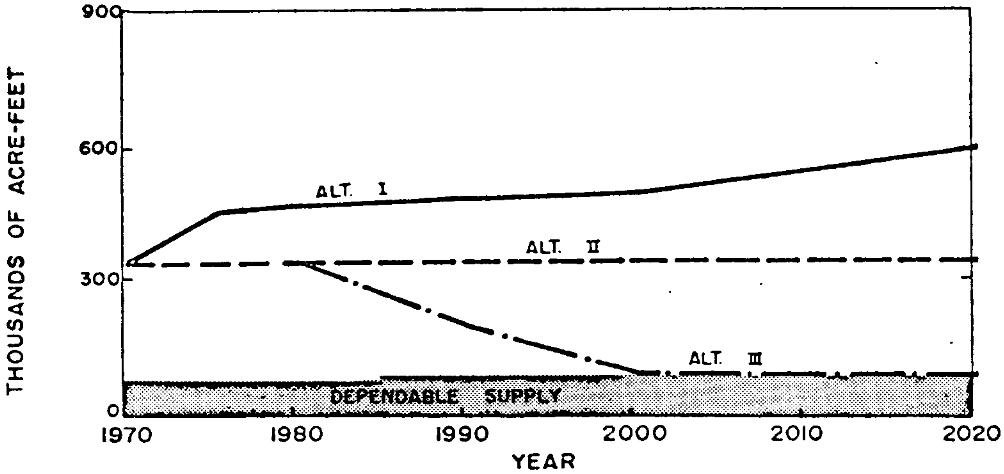
Water depletion in Arizona is serious, because it is pumping groundwater faster than it is collecting surface water and obtaining Colorado River water. Geothermal brines can be used for power plants needs, copper flotation and leaching, certain irrigation waters, and possibly heating and cooling applications. Alternative futures for water use in Cochise and Santa Cruz counties, respectively, are shown in Figures 12 and 13.

The utilization of geothermal energy for cooling systems is of vital interest, because Arizona consumes nearly 50 percent more electricity during the peak summer season due to electrical-driven air conditioning units. Geothermal-assisted heat pumps were shown to be economical for nearly all areas of Arizona, and are more reliable than air-to-air heat pumps. Further, the necessary low-temperature geothermal resource in the necessary narrow range of 15.5 - 26.6°C (60 - 80°F) is widely available, based on the known 3,000 thermal wells out of a total of about 30,000 irrigation wells. Geothermal-driven absorption systems is a second way to reduce electrical energy, but requires a geothermal resource above 105°C (220°F) in order to operate at a reasonable efficiency and capacity. Some areas of Arizona are believed to have such geothermal resources at economical depths, especially if one uses the geothermal energy content of the absorption effluent in a cascade system. More details are given in the specific report on cooling systems in Arizona, prepared as part of this project.

MATCHING GEOTHERMAL RESOURCES TO POTENTIAL USERS

Work performed in conjunction with the New Mexico Energy Institute (NMEI) modeled geothermal energy on line as a function of time over the next forty years. This model is discussed more fully in Appendix A. Figure 14 presents energy on line assuming a city-owned utility developed the resource; Figure 15 presents energy on line assuming private

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY

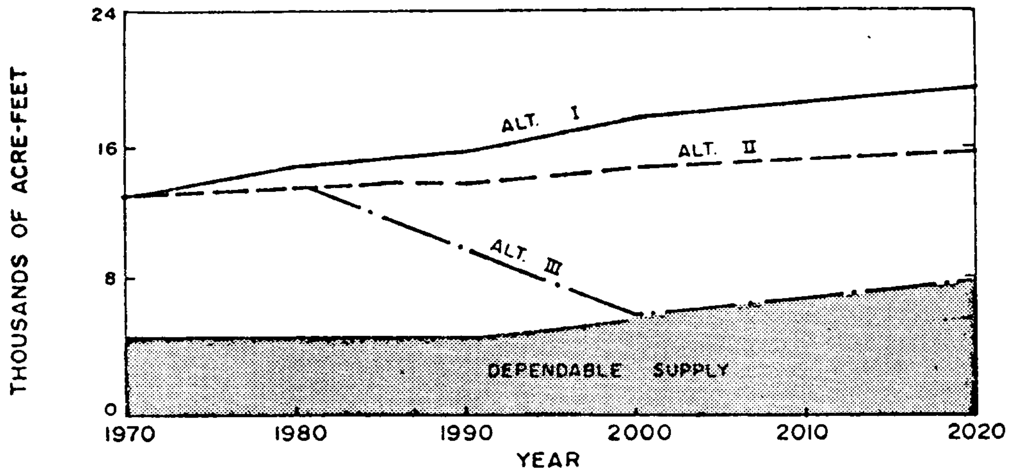


ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)		ALTERNATIVE FUTURES					
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	61.9	121.0	212.0	121.0	194.0	121.0	194.0
HARVESTED ACRES	118.0	172.0	213.0	118.0	118.0	68.0	7.2
URBAN DEPLETIONS AF/YR	8.9	13.6	22.0	13.6	20.2	13.6	20.2
STEAM ELECTRIC DEPLETIONS AF/YR	1.1	5.1	33.2	4.4	16.8	4.4	16.8
MINERAL DEPLETIONS AF/YR	8.0	25.0	55.0	14.0	43.0	14.0	43.0
AGRICULTURAL DEPL. AF/YR	335.0	455.0	506.0	313.0	280.0	180.0	17.0
TOTAL WATER DEPL. AF/YR	353	499	616	345	360	212	97
DEPENDABLE WATER AF/YR	85	97	97	97	97	97	97
SURPLUS SUPPLY (Def.)	(268)	(402)	(519)	(248)	(263)	(115)	0

Figure 12: Projected Alternatives for Water Use in Cochise County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY



ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)		ALTERNATIVE				FUTURES	
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	14.0	43.7	86.4	33.3	60.2	33.3	60.2
HARVESTED ACRES	3.0	3.3	3.5	3.0	3.0	2.0	0.5
URBAN DEPLETIONS AF/YR	1.8	3.3	6.3	2.6	4.4	2.6	4.4
STEAM ELECTRIC DEPLETIONS AF/YR	0	0	0	0	0	0	0
MINERAL DEPLETIONS AF/YR	0	1.0	2.0	1.0	2.0	1.0	2.0
AGRICULTURAL DEPL. AF/YR	11.0	11.7	11.4	10.6	9.8	7.0	1.6
TOTAL WATER DEPL. AF/YR	13	16	20	14	16	11	8
DEPENDABLE WATER AF/YR	5	5	8	5	8	5	8
SURPLUS SUPPLY (Def.)	(8)	(11)	(12)	(9)	(8)	(6)	0

Figure 13: Projected Alternatives for Water Use in Santa Cruz County. Source: Arizona Water Commission (1977)

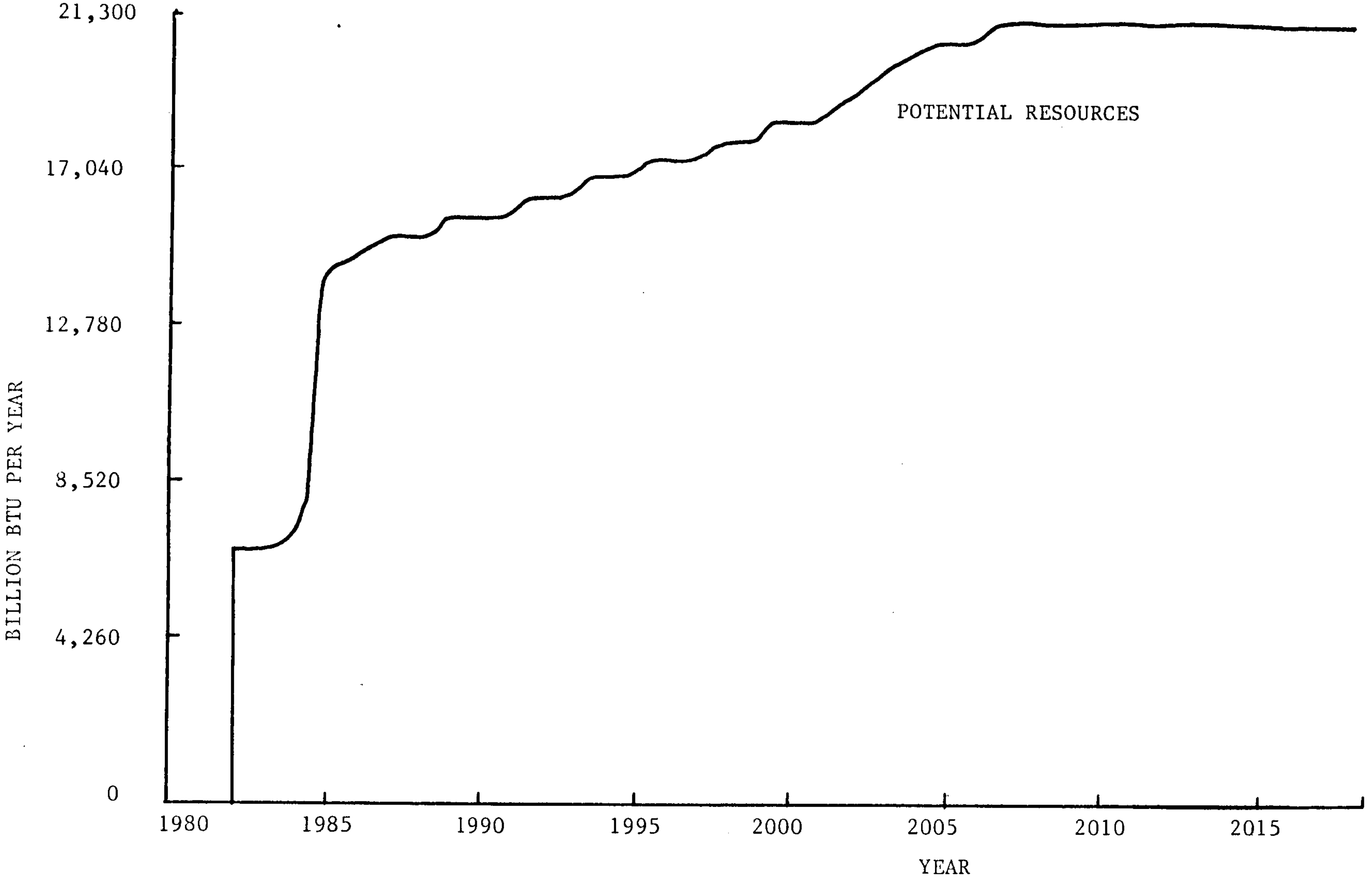


Figure 14: Projected Geothermal Heat on Line Under City Utility Development for Industrial Users.
Source: New Mexico Energy Institute

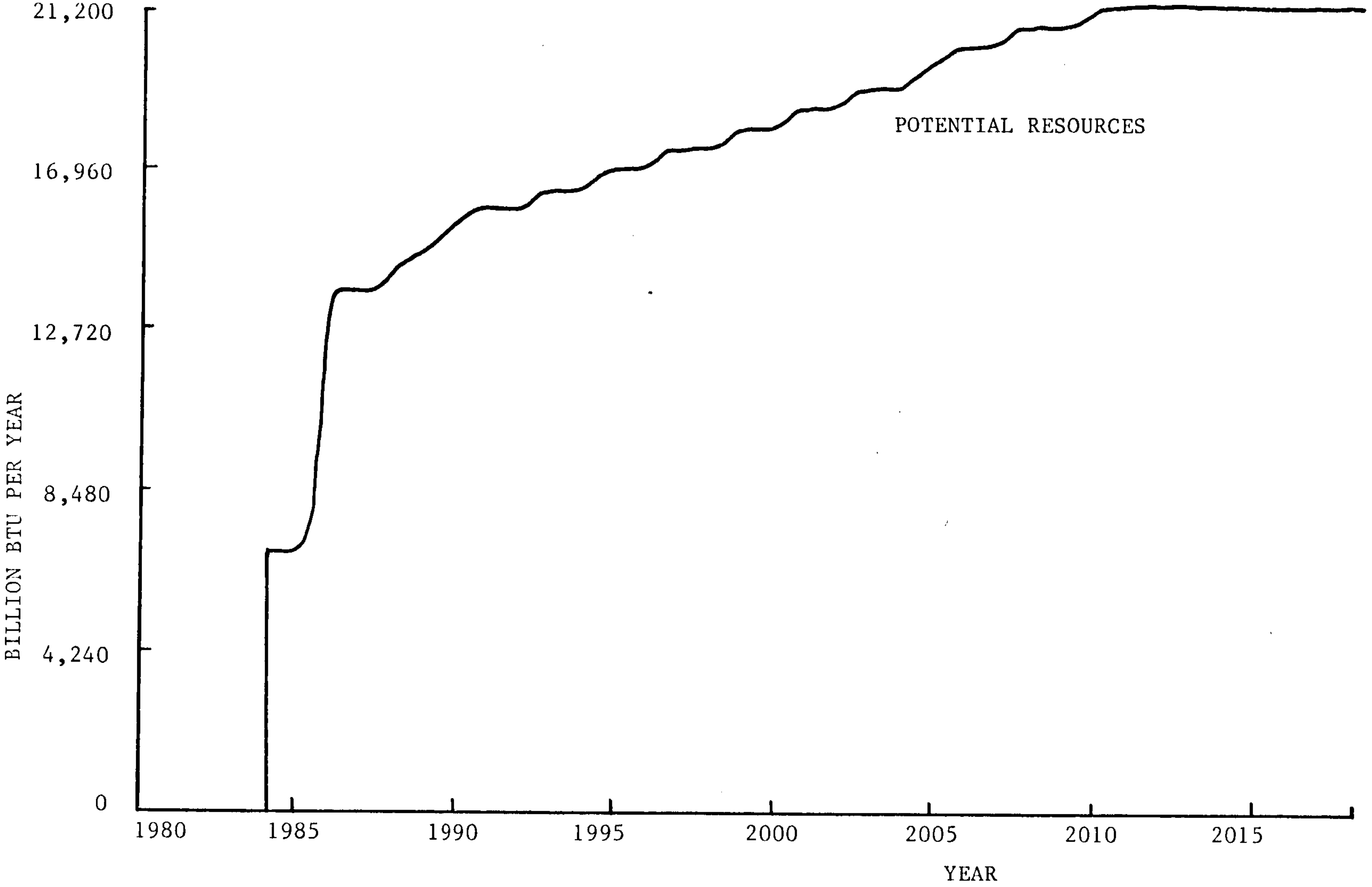


Figure 15: Projected Geothermal Heat on Line Under Private Industrial Development.
Source: New Mexico Energy Institute

development. The difference between the two cases is attributed to differing costs of capital.

Results from Figures 14 and 15 can be summarized as follows. Under private development, geothermal energy would come on line in 1984 and would climb rapidly until 2005. Under a city-owned utility, geothermal energy would also come on line by 1984 and would climb rapidly until 2006. Table 4 reports the results of the modeling in summary form in terms of barrels of oil replaced by geothermal energy annually. The table shows that in 1985, nearly twice as much geothermal energy would be on line under a city utility than under private development. After 1990, the amounts of geothermal energy on line would be about the same under both types of development.

TABLE 4: BARRELS OF OIL REPLACED BY GEOTHERMAL ENERGY PER YEAR
Process Heat Market
Cochise and Santa Cruz Counties

	1985	1990	2000	2020
Private Developer	1,216,071	2,696,428	3,250,000	3,785,714
City Utility	2,553,571	2,839,286	3,303,571	3,803,571

Similar modeling was performed for the residential and commercial space heating markets; however, these results have been omitted since it is believed that space heating without the capability for space cooling is not economically justifiable (see report on geothermal cooling systems).

Several industries in Santa Cruz County may be able to use geothermal energy for their space heating and/or process heat needs. These industries located in Nogales, include Chamberlain Manufacturing Corp., Charles E. Gillman Company, Irvine Industries, Incorporated, Pickett Industries, Prestini Musical Instruments Corporation and Roper Chain Saw Division.

Agribusiness and agricultural industries in Cochise County were identified. Most agricultural processing is concentrated in corn and sorghum; however, livestock processing is also important to the county's economy. Currently, many of the agricultural products are exported to California for processing. Geothermal energy might stimulate a local industry by providing a low-cost energy source suitable for agricultural and livestock processing.

APPENDIX A

The New Mexico Energy Institute at New Mexico State University has developed a computer simulation model, BTHERM, to assess the economic feasibility of residential and commercial district space heating, hot water heating and industrial process heating using low temperature geothermal energy. Another model, CASH, was developed to depict the growth of geothermal energy on line over the next 40 years as a function of price of competing energy sources. A major assumption of these models is that geothermal energy must be price-competitive with the lowest-cost conventional energy source in order to assure market capture.

Development of a geothermal resource is characterized by large capital outlays, but a long-term geothermal investment has the potential to provide relatively inexpensive energy at a stable price. Unlike natural gas and electricity, however, geothermal energy is an unknown energy involving certain risks such as price and reservoir life and the need for back-up systems. An analysis of the costs and economic competitiveness of geothermal energy must take these uncertainties into account. Thus, costs may be overestimated so that the benefits will not be overstated.

BTHERM models the residential, commercial and industrial sectors of a typical city, each sector having unique energy costs and energy system physical parameters as well as different growth rates. The model possesses the ability to model each sector individually and can analyze the application of geothermal energy to new growth only, to conversion of existing structures or to a combination of both. The model also has the capability to model both private and city-owned utility development of the geothermal resource.

Output of the model includes the levelized price per million Btu of delivered energy, the discounted present value of investment necessary and the undiscounted values of investments for policy studies. Also, from input of the price and price growth rate of conventional energy, the model determines the discounted or undiscounted values for federal and state taxes, tax credits, royalty rates, property taxes and consumer savings due to conversion from conventional energy to geothermal.

Certain limitations of the model have already been suggested. Costs, for example, may be overestimated due to safeguards built into the model to take into account the risks associated with geothermal energy. This overestimation of costs might result in the exclusion of a potential use of geothermal energy. Another limitation is that the price of natural gas is taken as the price of competitive (conventional) energy, but not all users have access to natural gas.

The output of the model is not a substitute for detailed engineering design studies but it is useful for determing order-of-magnitude costs and potential benefits of geothermal energy development.

APPENDIX B

STATE LEGISLATIVE UPDATE AND AGENCY CONTACTS

In 1979, an Arizona Geothermal Institutional Handbook was prepared which outlined all of the state agencies involved in geothermal energy development, procedures and regulations promulgated by these agencies and geothermal legislation as of 1979. Since 1979, several changes in agency heads and legislation have occurred. The following appendix serves as an update for legislative and agency personnel changes.

The most significant legislative change is pending approval in the Arizona legislature as of March, 1982. In general, if passed, the legislation would modify the current geothermal exemption from the groundwater laws of Arizona. As proposed, the Oil and Gas Conservation Commission would be responsible for issuing geothermal drilling permits and for determining whether a resource is geothermal energy. Once designated as geothermal, probably based on a use and temperature criteria, the Department of Water Resources would issue a geothermal effluent permit, which will regulate the use of the geothermal fluid once the heat has been extracted. The legislation recognizes geothermal effluent as groundwater to be allocated, acquired, used or disposed of in a manner consistent with the groundwater laws of the state. Developers interested in producing geothermal fluid should contact the Department of Water Resources for specific permit applications, regulations and reporting requirements after March, 1982.

The following section lists the principal state agencies likely to be involved in geothermal development in the future. The list is an update of a previously published list and is current as of July, 1982.

Administrative Agencies

1) Arizona State Land Department, 1624 West Adams, Phoenix, AZ 85007

Hal Susie - Manager of Minerals and Energy (602) 255-4628

The State Land Department leases state lands for geothermal purposes.

2) Oil and Gas Conservation Commission, 1645 West Jefferson, Suite 420, Phoenix, AZ 85007.

A. K. Doss - Executive Director (602) 255-5161.

The Oil & Gas Conservation Commission issues drilling and injection permits for geothermal drilling.

3) Department of Water Resources, 99 E. Virginia Street, Phoenix, AZ 85007

Wesley E. Steiner - Director (602) 255-1550.

The Department of Water Resources manages the state's water resources and issues geothermal effluent permits (tentative).

4) Department of Health Services, 1740 West Adams, Phoenix, AZ 85007

Arthur A. Aymar - Director of Air Quality Control (602) 255-1140

Dr. Ron Miller - Director of Water Quality Control (602) 255-1252

The Department of Health Services issues environmental permits for geothermal development.

5) Arizona Department of Transportation, 206 South 17th Avenue, Phoenix, AZ 85007.

Juan Martin - Director of Motor Vehicles Division (602) 261-7426

The Department of Transportation issues encroachment and oversized vehicle permits.

6) Power Plant and Transmission Line Siting Committee, Arizona Attorney General's Office, 1700 West Washington, Executive Tower, Phoenix, AZ 85007.

Tom Prose - Attorney General's designee to Power Plant and Transmission Line Siting Committee (602) 255-1620.

The Power Plant and Transmission Line Siting Committee determines what effect proposed electrical generating plants and transmission lines will have on the environment. They also issue Certificates of Environmental Compatibility.

7) Arizona State Parks Board, 1688 West Adams, Phoenix, AZ 85007

Ann Pritzloff - Historic Preservation Officer (602) 255-4174

The Arizona State Parks Board issues archeaological clearances for improvements in archeaological areas.

Regulatory Agencies

1) Arizona Corporation Commission, 222 W. Encanto Blvd., Phoenix, AZ 85009

Bud Tims - Chairman of Commission (elected) (602) 255-3935

Jim Weeks - Commissioner (elected) (602) 255-3933

Diane McCarthy - Commissioner (elected) (602) 255-4143

Neill Dimick - Utilities Director (602) 255-4251

The Corporation Commission regulates public utilities and sets rates. In addition, they issue Certificates of Public Convenience and Necessity.

Advisory Agencies

1) Arizona Solar Energy Commission, 1700 West Washington, Executive Tower, Room 502, Phoenix, AZ 85007

James Warnock - Director

Dr. Frank Mancini, Associate Director (620) 255-3682

The Arizona Solar Energy Commission provides information relating to solar energy and other renewable energy sources.

2) Arizona Bureau of Geology and Mineral Technology, 845 North Park Avenue, Tucson, Arizona 85719

Dr. Larry Fellows, Assistant Director and State Geologist (602) 626-2733

The Bureau of Geology and Mineral Technology provides geologic information for geothermal resource development.

By referring to the Arizona Geothermal Institutional Handbook, people interested in geothermal development will find details on each of the above mentioned agencies. In addition, federal regulations are outlined in the Institutional Handbook along with agency contacts. Copies of the Institutional Handbook can be obtained by writing to the National Technical Information Center, P. O. Box 62, Oak Ridge, Tennessee 37830. The contract number for the Institutional Handbook is DOE/ID/12015-2.

As a final note, county or city regulations regarding geothermal development have not been mentioned. The majority of regulations for geothermal development in Arizona are state level rules. Local governments have a minor role in geothermal development. However, people interested in developing geothermal resources in Arizona should contact local planning and zoning boards to confirm their role in regulating development.

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2. Goldstone, L.A. and White, D.H., 1982, Geothermal Development Plan: Pima County, prepared for the U.S. Department of Energy, Contract No. DE-FC03-80RA50076 and the Arizona Solar Energy Commission: State of Arizona Bureau of Geology and Mineral Technology Open-File Report 79-9.

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Open-File reports can be obtained by writing to:

State of Arizona Bureau of Geology
845 N. Park Avenue
Tucson, Arizona 85719

or to

Arizona Solar Energy Commission
1700 W. Washington, Room 502
Phoenix, AZ 85007

In addition, reports prepared for the U.S. Department of Energy can be obtained by contract number from

U.S. Department of Energy
Technical Information Cneter
P.O. Box 62
Oak Ridge, TN 37830

GLOSSARY OF GEOLOGICAL TERMS

Anomalously shallow depth - unusually or unexpectedly shallow depth.

Basin-range graben bound by deep faults - an area usually ten to hundreds of km^2 in area that has been down dropped along deep faults relative to the surrounding mountains; the grabens become filled with sediments to become valleys.

Curie-depth - the depth at which rocks become hot enough to lose their magnetic properties, ~ 525°C. Curie temperature within 5-10 km of the surface are an indicator of geothermal resource potential.

Deep circulation - the natural movement or flow of ground water, as a result of convection, whereby it descends and becomes heated at depth and then rises toward the surface.

Deep sediment-filled, faulted basin - see basin - range graben.

Depth of Curie-isotherm analysis - technique used to estimate depth to the Curie temperature.

Hot dry rock production - a method for extracting useful heat in a deep dry hole; accomplished by fracturing the hot rock between two deep holes, and pumping cold fluid into one and bringing hot fluid out of the other.

Geothermometer - an empirical formula, based on the temperature-dependent solubility of certain minerals, used for estimating deep fluid temperatures in a geothermal reservoir.

Magnetotelluric survey - an electromagnetic method in which natural electric and magnetic fields are measured. Models of the crust can then be constructed and resistivities at great depth can be predicted.

Major range bounding faults - fractures or fracture zones along which mountains have risen relative to down dropped grabens.

Shallow magmatic intrusion - a body of magma that has intruded its way upward into shallower crust.

Na-K-Ca geothermometer -- (also, quartz geothermometer, chalcedony geothermometer) - see geothermometer.

Tectonic history - the cycle that relates the larger structural features of the Earth's crust to gross crustal movements and to the kinds of rocks that form in the various stages of developments of these features.