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GEOTHERMAL DEVELOPMENT PLAN: COCHISE-SANTA CRUZ COUNTIES

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DISCLAIMER

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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 supplied with geothermal reserves which could potentially supplement the existing energy supplies. Consequently, planning efforts have concentrated on estimating the potential of geothermal energy utilization in Arizona and in providing information necessary for its prospective commercialization.

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

This ADP is concerned with geothermal potential in Cochise and Santa Cruz counties. A total of five hot springs and 25 thermal wells are located within the combined counties. The water discharged from these hot springs and wells may be suitable for applications such as process heat and space heating and cooling. Within Cochise County there are two large firms which are capable of using 70°C (158°F) geothermal water for their process heat requirements but the potential use of geothermal energy in Santa Cruz County is limited due to the absence of industry within the county. The amount of geothermal energy on line as a function of time under both private and city-owned utility development is also predicted using a computer simulation model.

AREA DEVELOPMENT PLANS

Arizona has been divided into seven distinct single or multicounty subdivisions for which Area Development Plans (ADPs) 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 ADP 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.

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

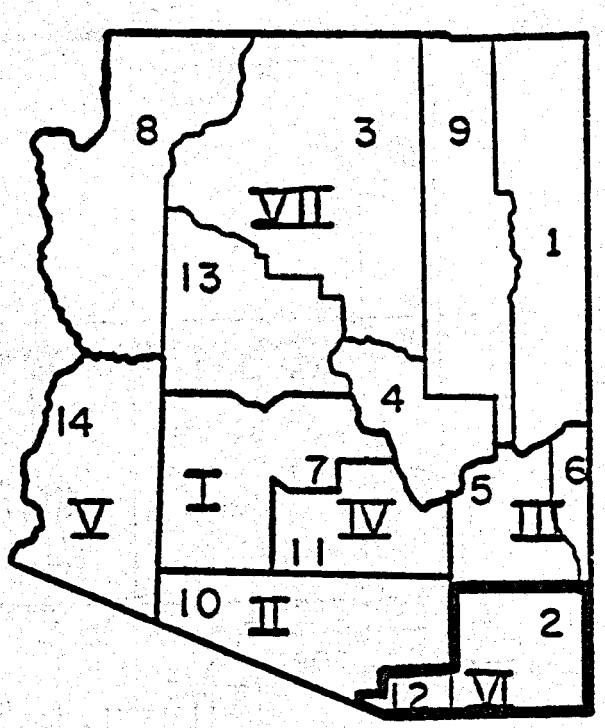
Temperature Conversions: $^{o}F = (1.8 \times {}^{o}C) + 32$

GEOTHERMAL RESOURCES

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. At least four areas known to store thermal water at relatively shallow depths of 1200 m (3940 ft) are located within these counties. Numbered boxes in Figure 2 identify the three areas; Table 2 gives the location of each of these areas along with rough depth, volume and temperature estimates.

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: Area Development Plans for Arizona.

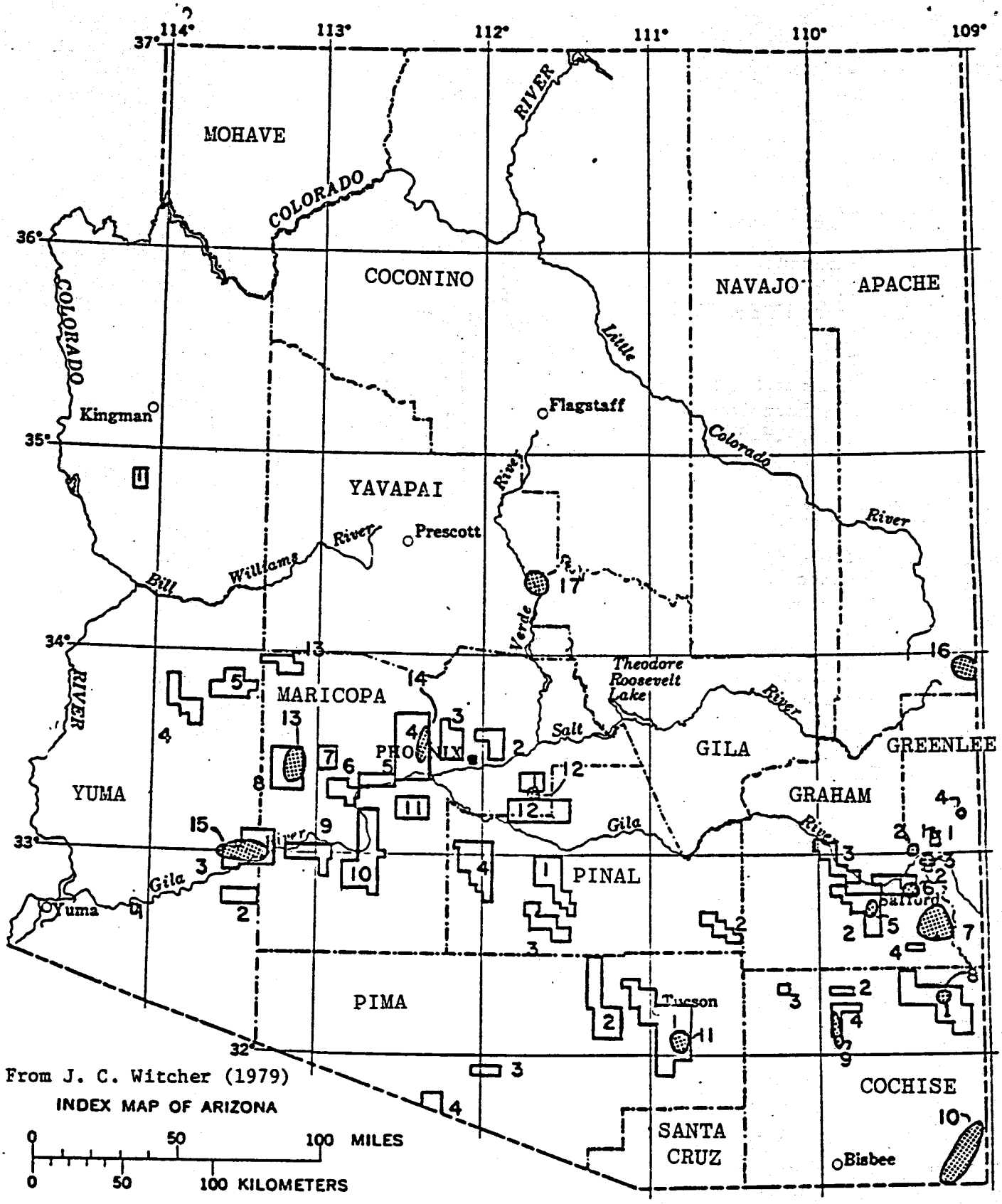


Figure 2: Arizona's Proven, Potential and Inferred Resources.

TABLE 2: PROVEN AND POTENTIAL RESERVOIRS OF COCHISE COUNTY OF LESS THAN 1.2 KM DEPTH

Modified from Witcher (1979) Tr - Average Reservoir Temperature

Area	Location	Volume (km^3)	Measured (^oC) Temperature	Depth (km)	Tr (^oC)	Geothermometry Temperature (^oC)	Method
1	T12-15S, R28-31E	204.3	30-40	<0.30	60	60-85	Chalcedony, Na-K-Ca
2	T13, R24-25E	15.5	30-50	<0.61	60	60-70	Chalcedony
3	T12-13S, R21E	12.4	30-50	<1.1	60	50-90	Quartz, Na-K-Ca
4	T14-15S, R24-25E	80.5	30-40	<0.61	70	80-110	Quartz, Na-K-Ca

There are two hot springs located in Santa Cruz County. The water discharged from one of these springs has a temperature of 27°C (81°F) and a flow rate of 189 liters per minute with total dissolved solids of 450 parts per million. The other spring discharges 28°C (82°F) water at a flow rate of 190 liters per minute with total dissolved solids of 1000 parts per million.

There are three hot springs located in Cochise County. Water discharged from these springs has a temperature range of 25.5°C (78°F) to 52.0°C (126°F). Flow rates range from 4 liters per minute to 37 liters per minute, and total dissolved solids range from 120 to 300 parts per million.

There are a total of 25 thermal wells located within Cochise County. Water discharged from these wells has a temperature range of 35°C (95°F) to 54.4°C (130°F). Well depths range from 145 m (476 ft) to 1280 m (4200 ft) and total dissolved solids range from 231 to 1370 parts per million.

A forthcoming state geothermal map compiled by the Arizona Bureau of Geology and Mineral Technology and published by the National Oceanographic and Atmospheric Administration will provide 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 will be available in late 1981.

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 3.

TABLE 3: 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

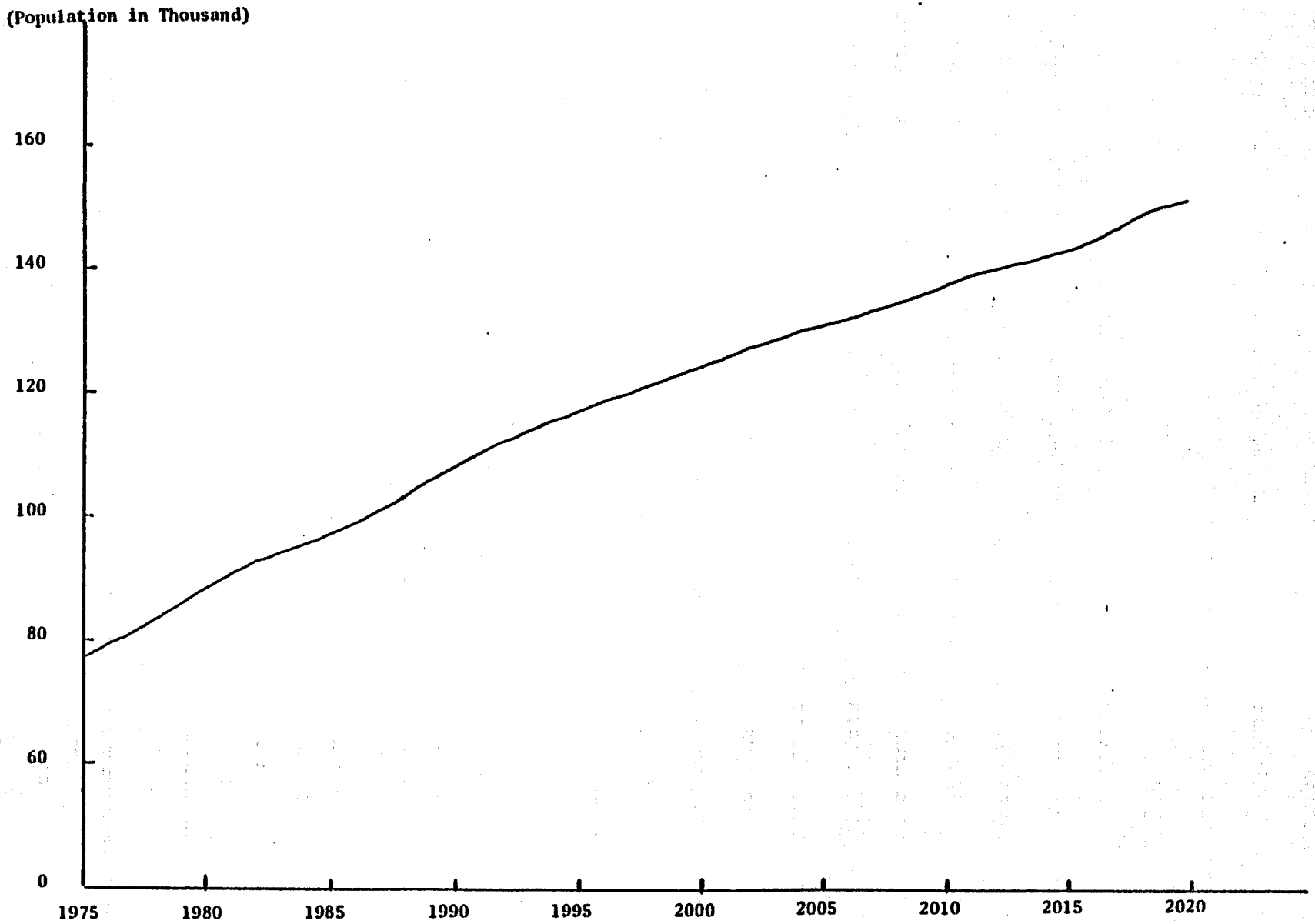


Figure 3: Population Projections for Cochise County.
Source: Technical Advisory Committee (DES)

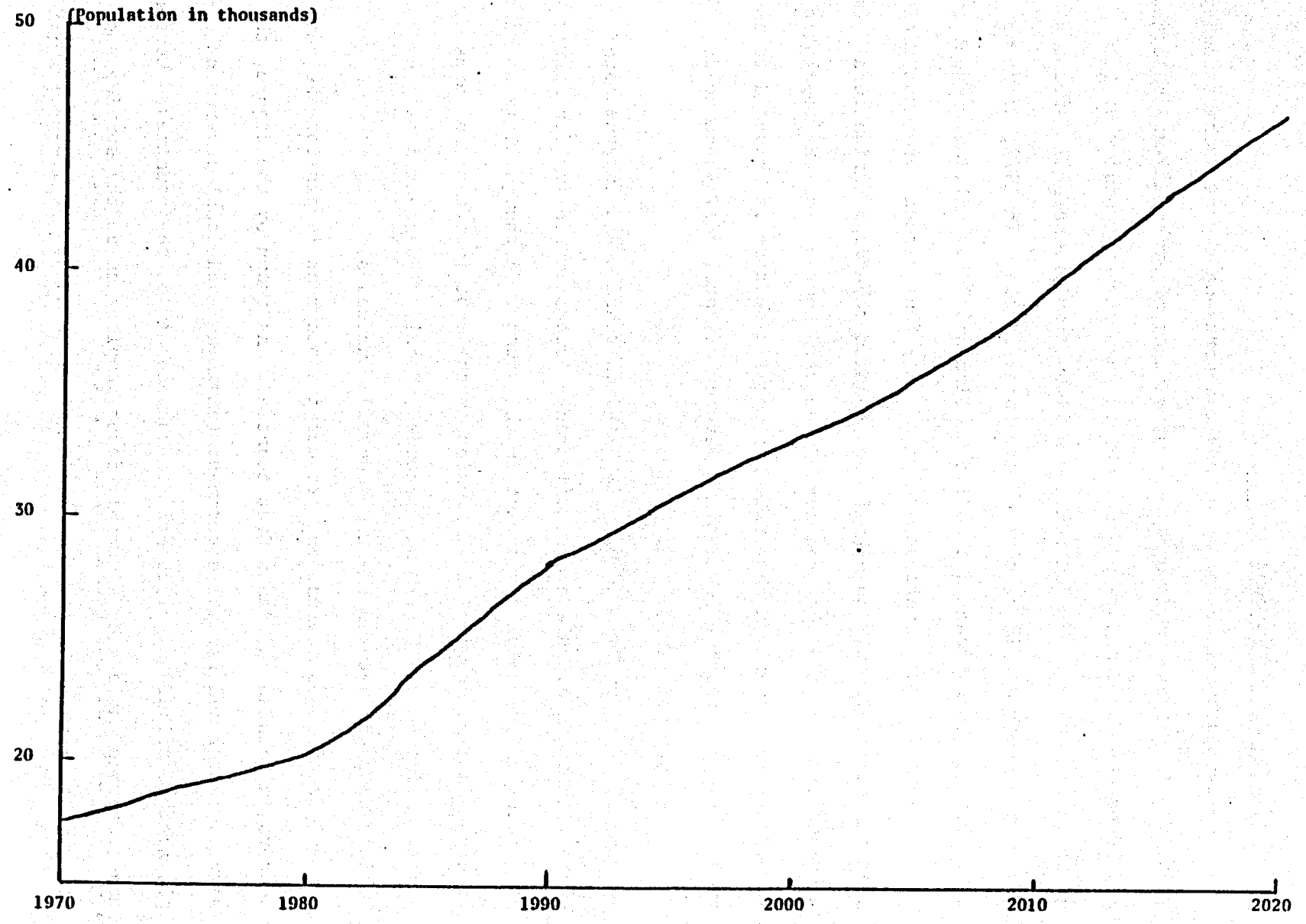


Figure 4: Population Projections for Santa Cruz County.
Source: Technical Advisory Committee (DES)

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

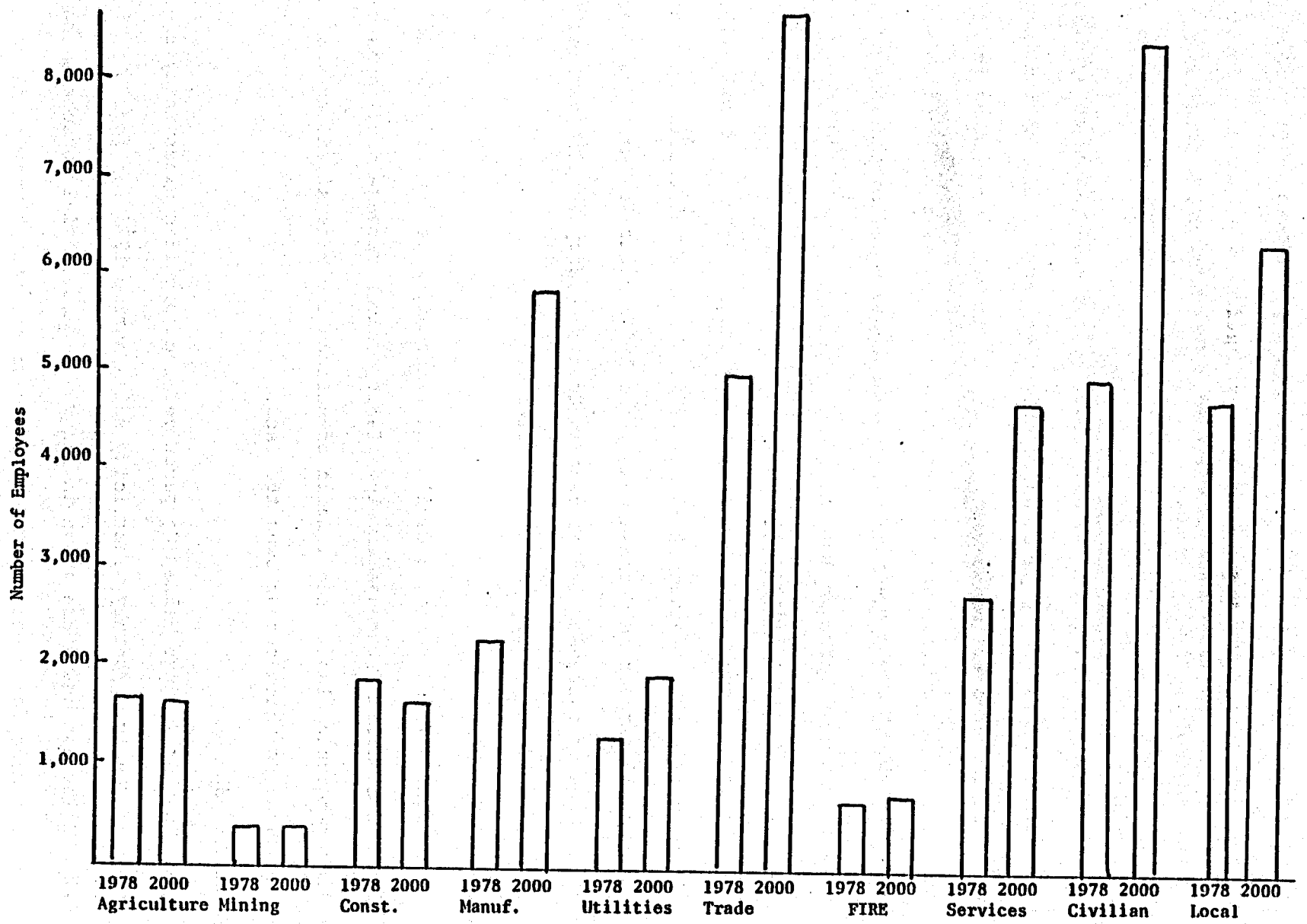


Figure 5: Employment Sector Projections for Cochise/Santa Cruz Counties.
Source: Department of Economic Security

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 4 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

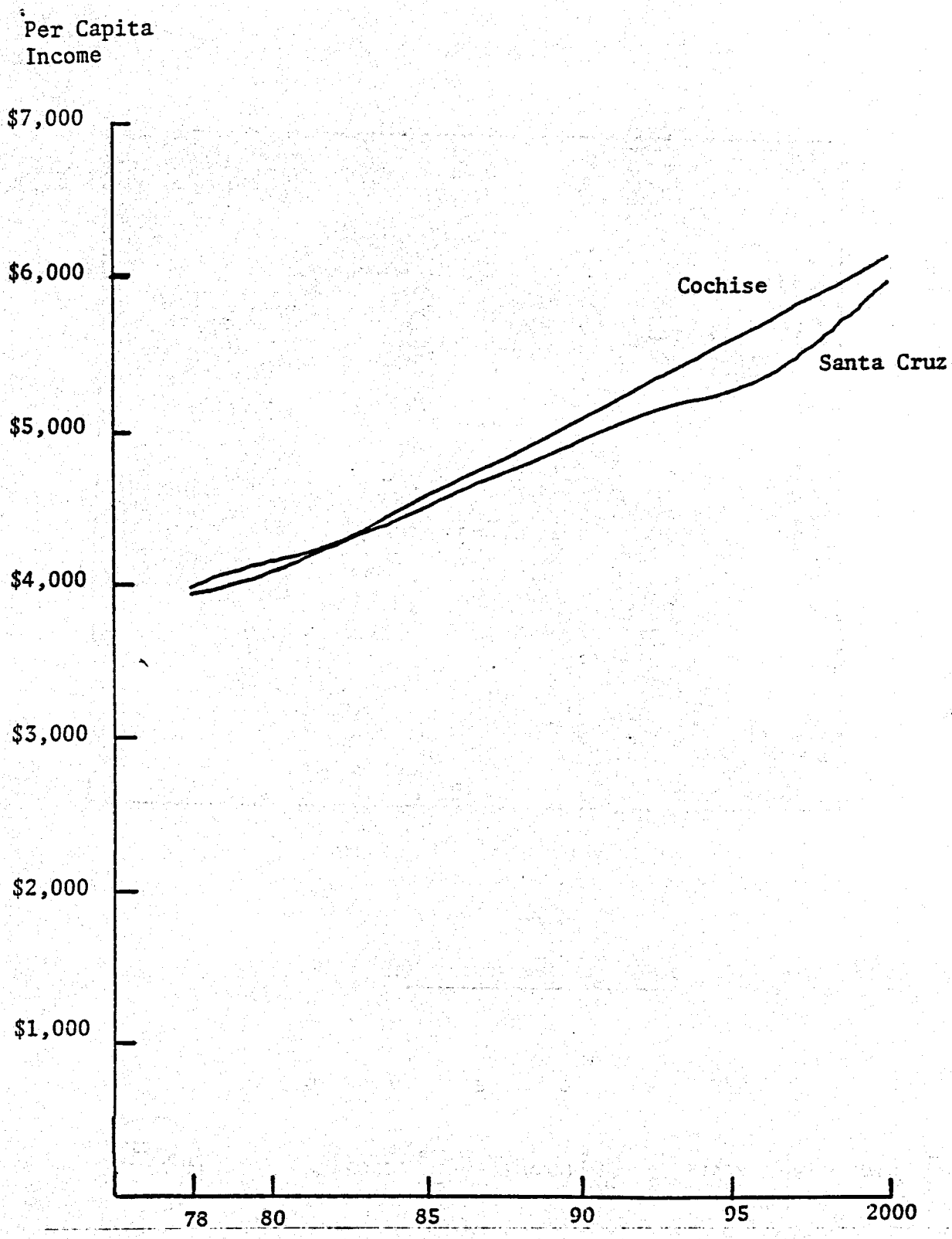


Figure 6: Projections of Personal Per Capita Income for Cochise and Santa Cruz Counties (1972 Dollars).
Source: Department of Economic Security

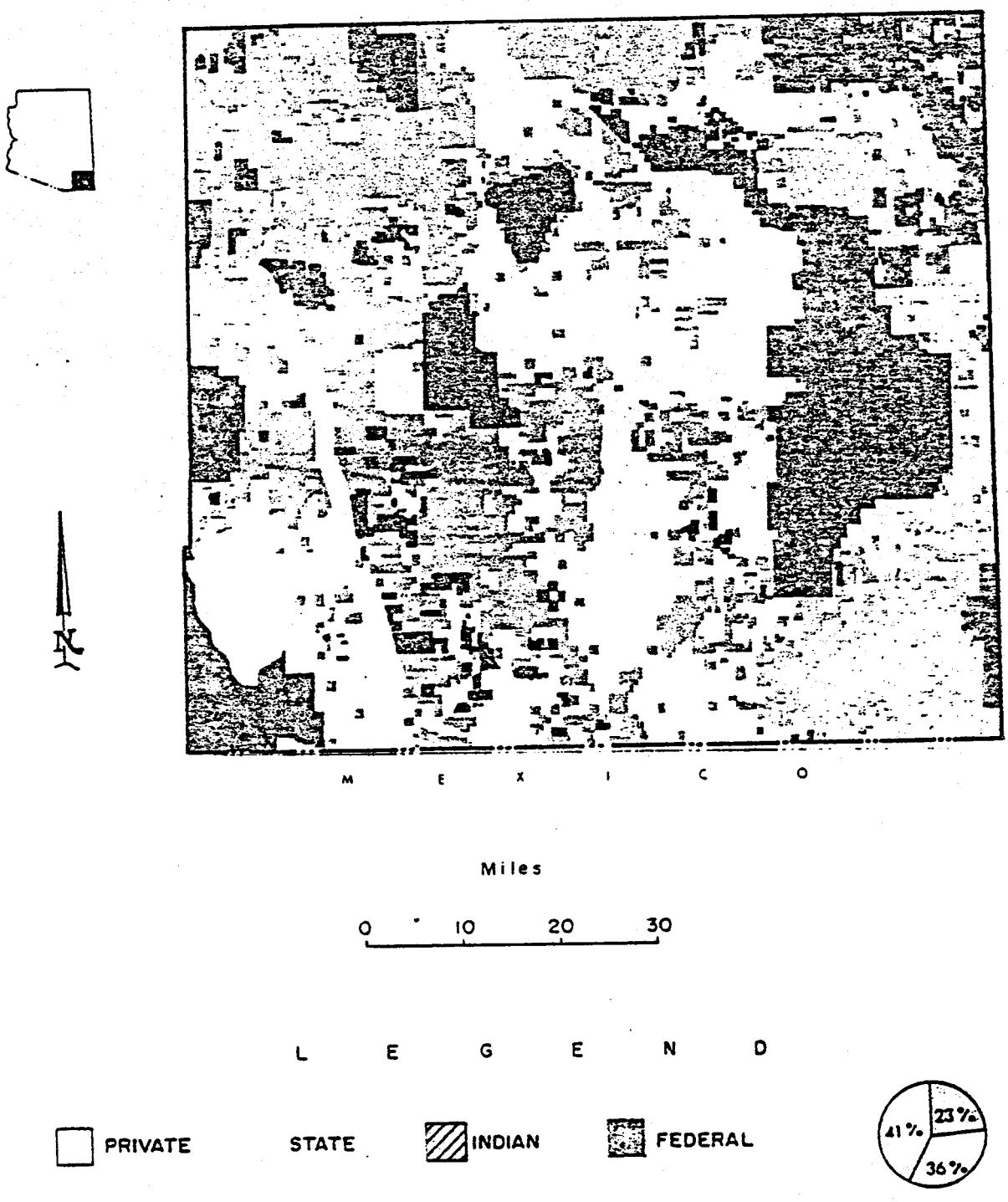


Figure 7: General Land Ownership Map for Cochise County.
Source: Arizona Water Commission (1977)

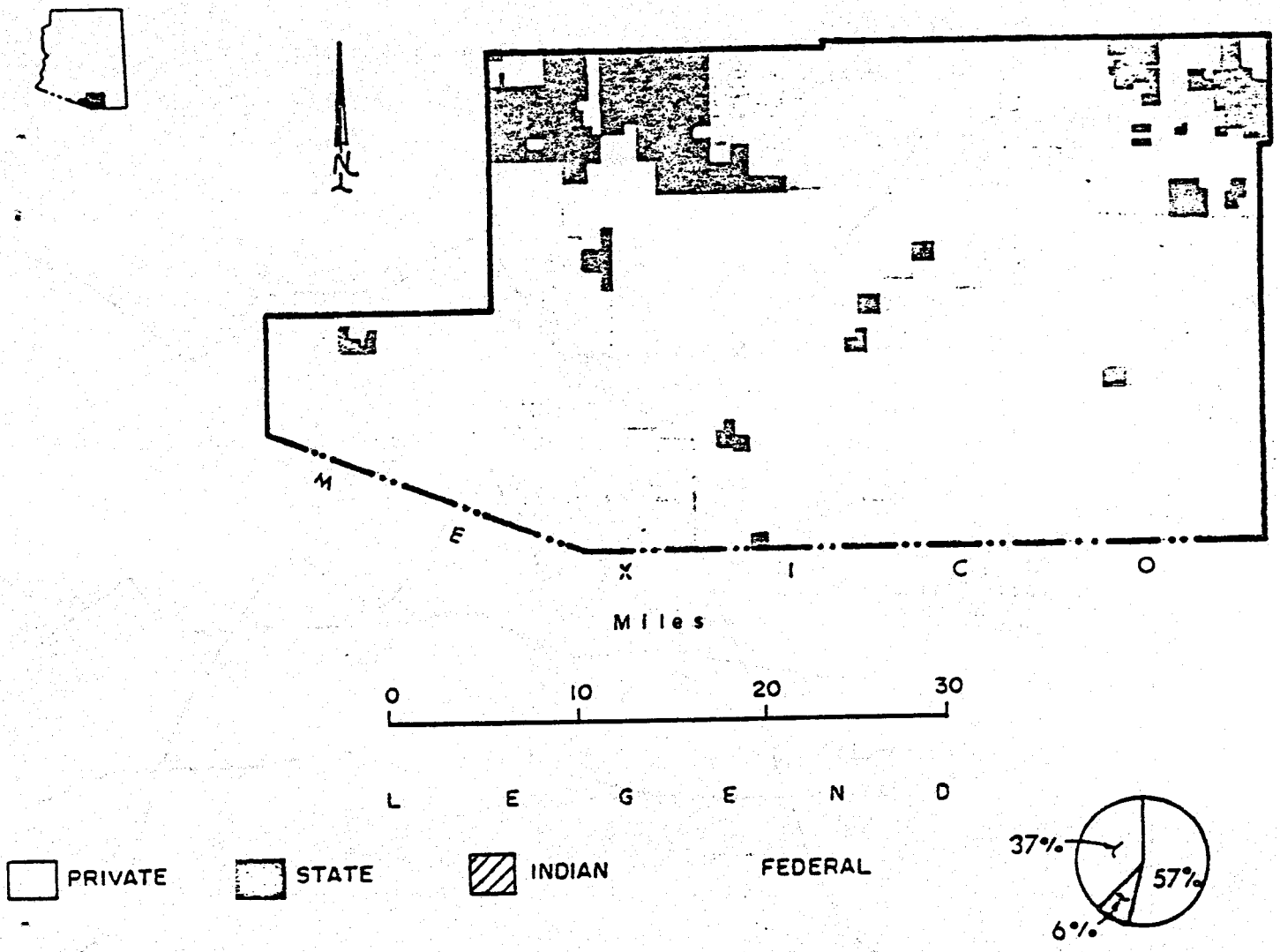


Figure 8: General Land Ownership Map for Santa Cruz County.
Source: Arizona Water Commission (1977)

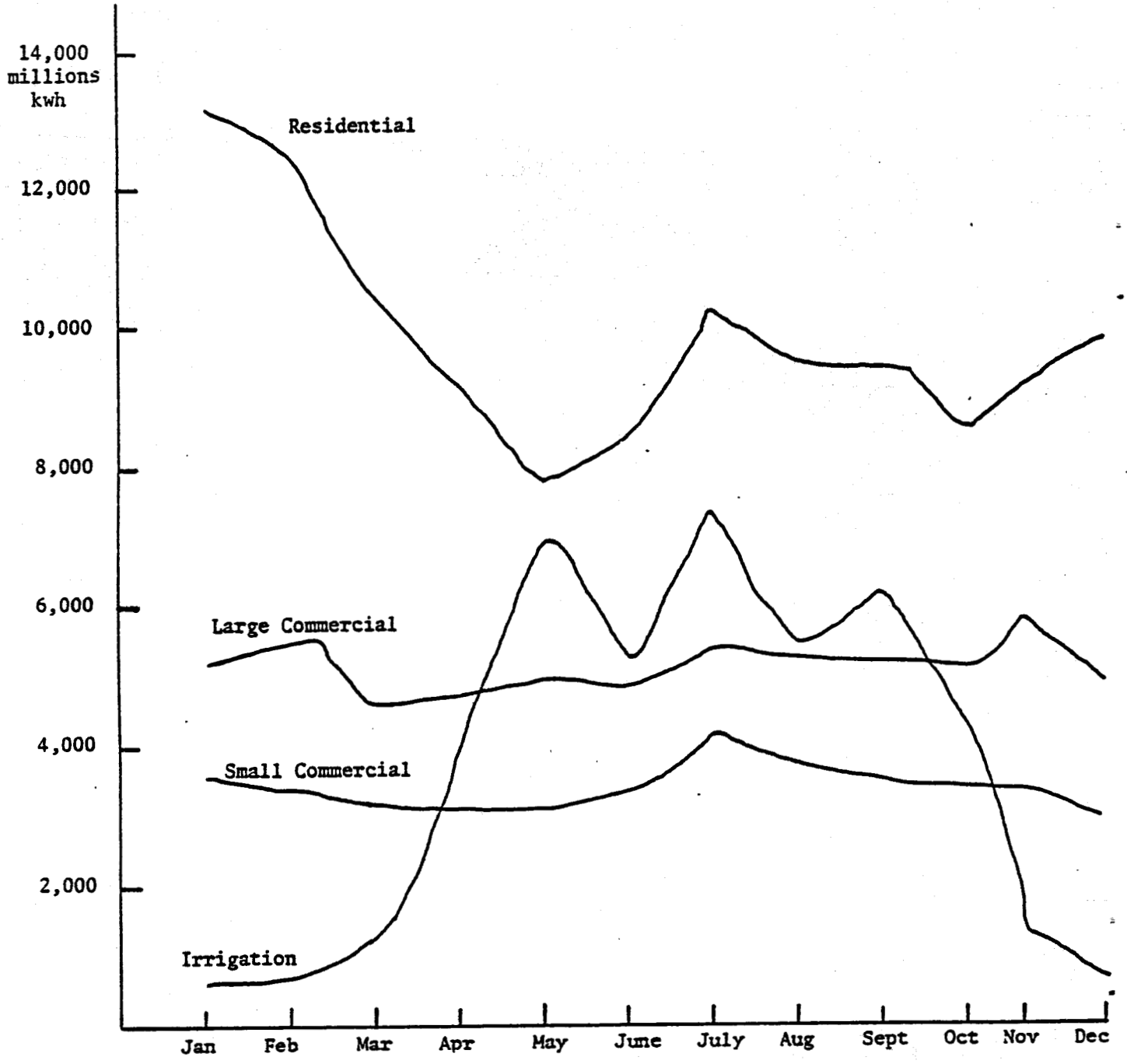


Figure 9: Electricity Sales for Sulphur Springs Valley Cooperative, Inc. in Cochise County.

TABLE 4: 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 Co. 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.

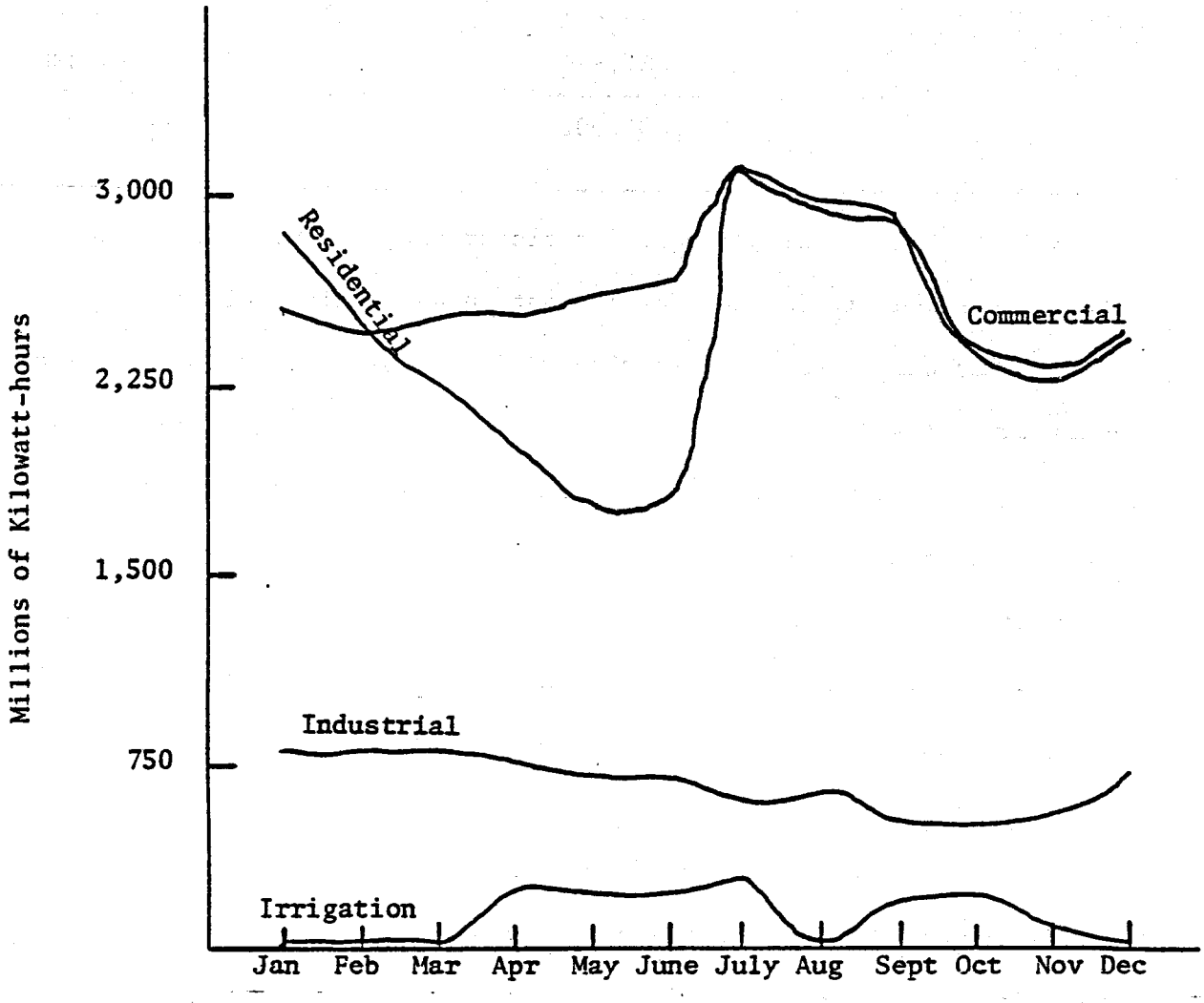


Figure 10: Electricity Sales for Citizens Utilities Company in Santa Cruz County.

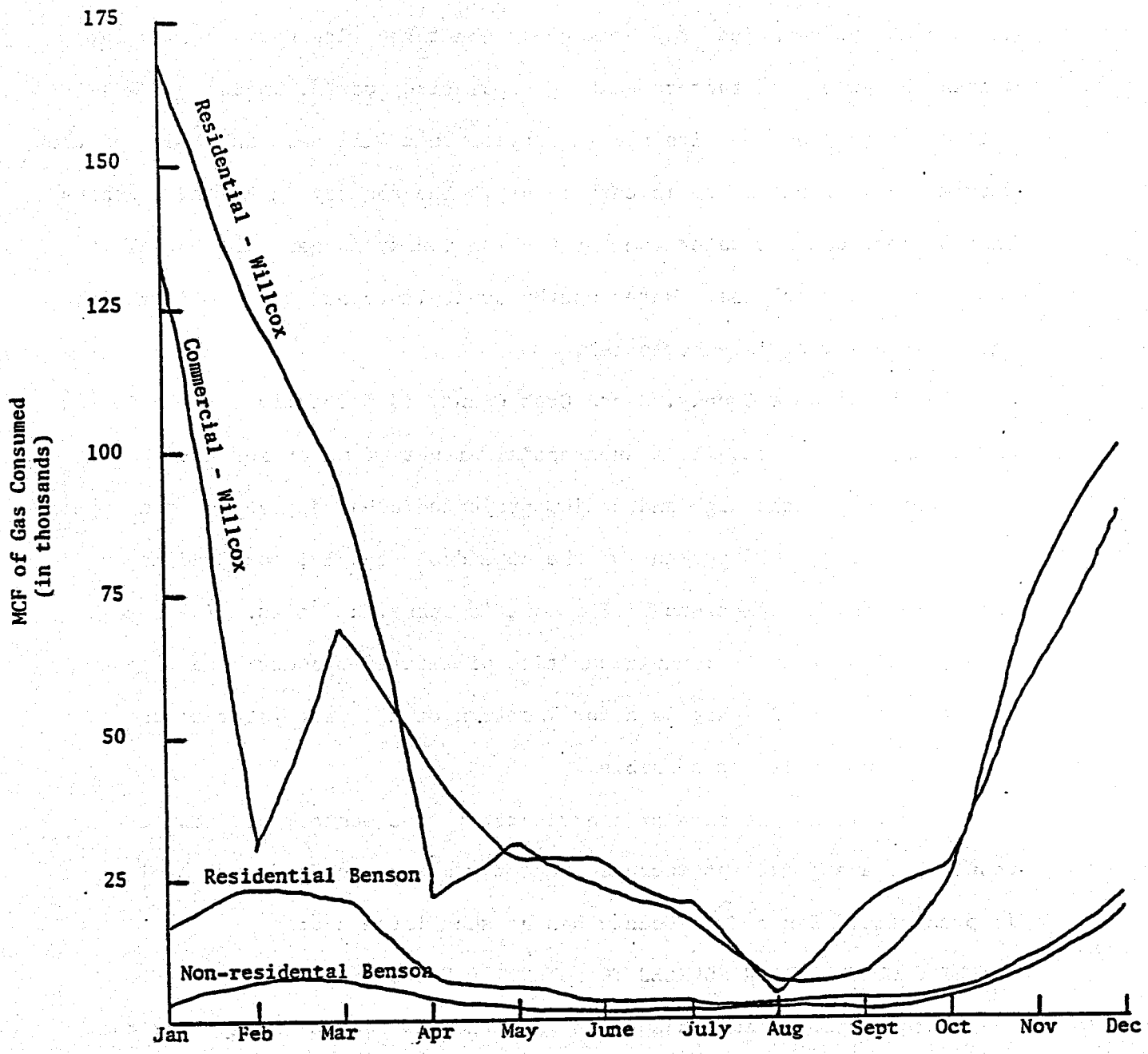


Figure 11: Estimated Monthly Natural Gas Sales in Cochise County by the Town of Benson and Willcox City Government, 1979.

WATER

Figures 12 and 13 present alternative futures for water use in Cochise and Santa Cruz counties, respectively. The three alternatives take into account a variety of factors such as population growth, industrial development and consumer habits and lifestyles that will have an effect on the future level of water use in each county. The summary in Figure 12 shows that projected urban water use for Cochise County is generally small in comparison to total use. Water use by agriculture and the copper mining industry, however, is substantial.

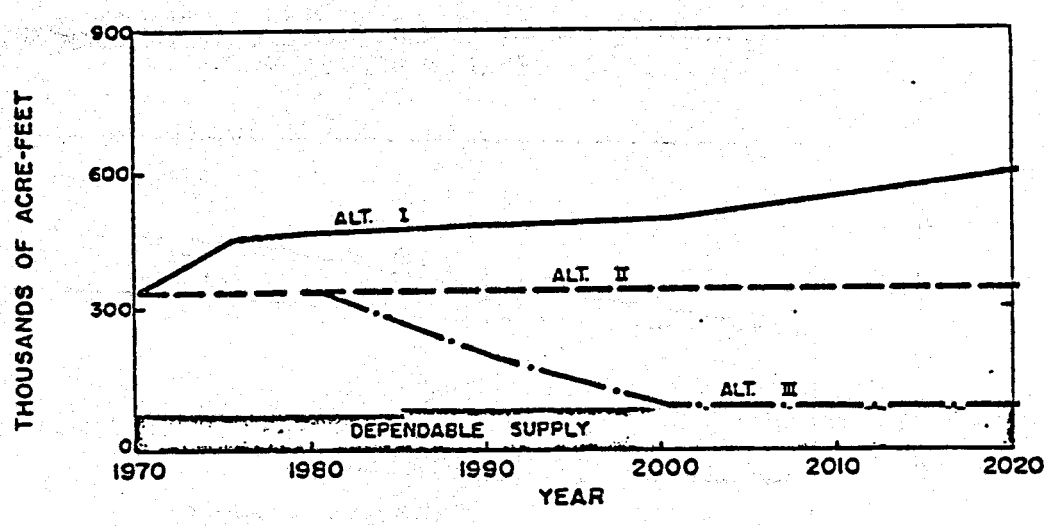
Unlike Cochise County, Santa Cruz County is primarily trade-oriented and is expected to require a substantial amount of water for urban water use. Generally, the high and medium projected urban depletions are expected to be in excess of 50 percent of the dependable supply; combined urban and agricultural depletions will result in annual deficits. The need for higher quality water for municipalities will further contribute to the county's water deficiency as a total return of the wastewater to the municipal supply is not possible.

Copper mining is a major contributor to the economy of Cochise County, so a significant increase in water use associated with mining is predicted. Santa Cruz County has no such large user.

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

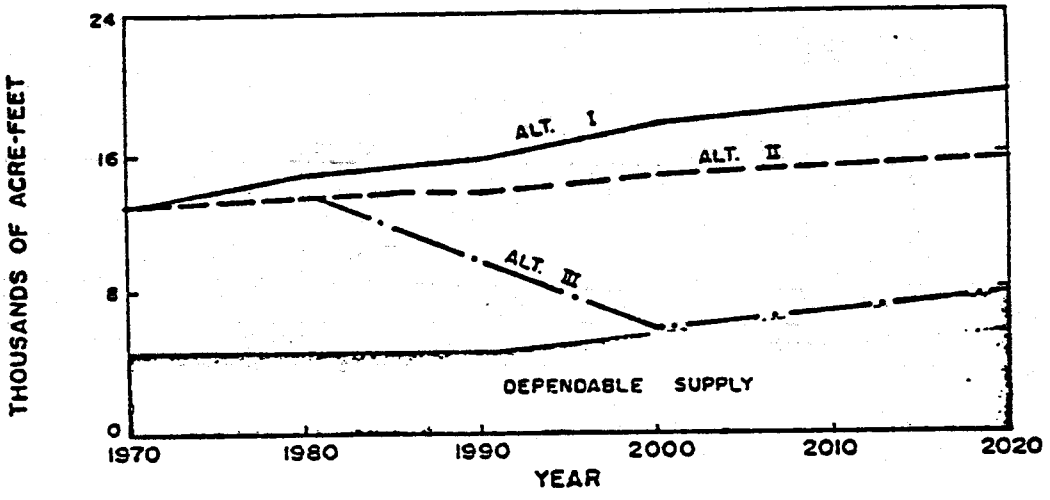


ALTERNATIVE FUTURES SUMMARY

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)

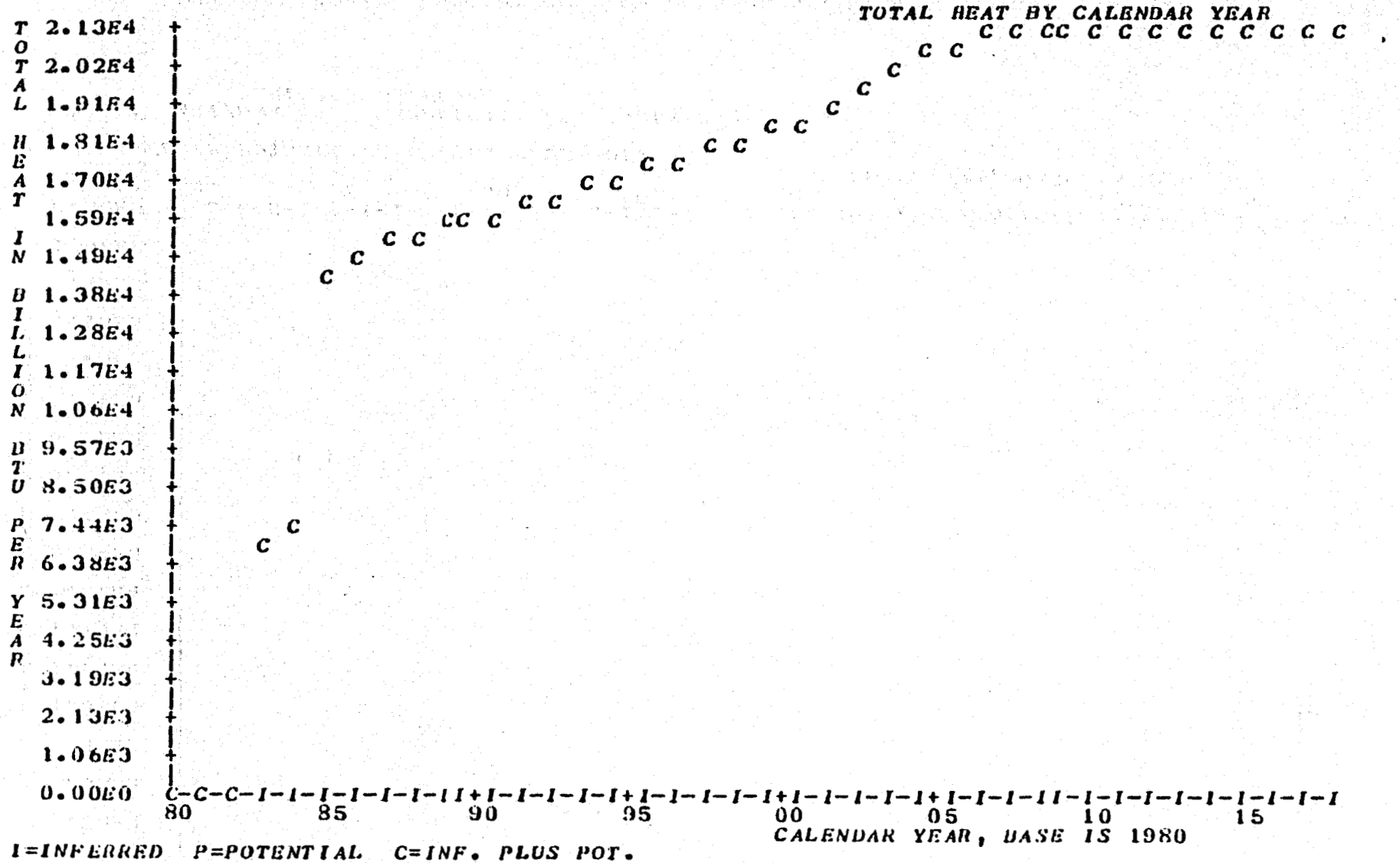


Figure 14: Projected Industrial Geothermal Heat On Line Under City Development for Cochise/Santa Cruz Counties.
Source: New Mexico Energy Institute

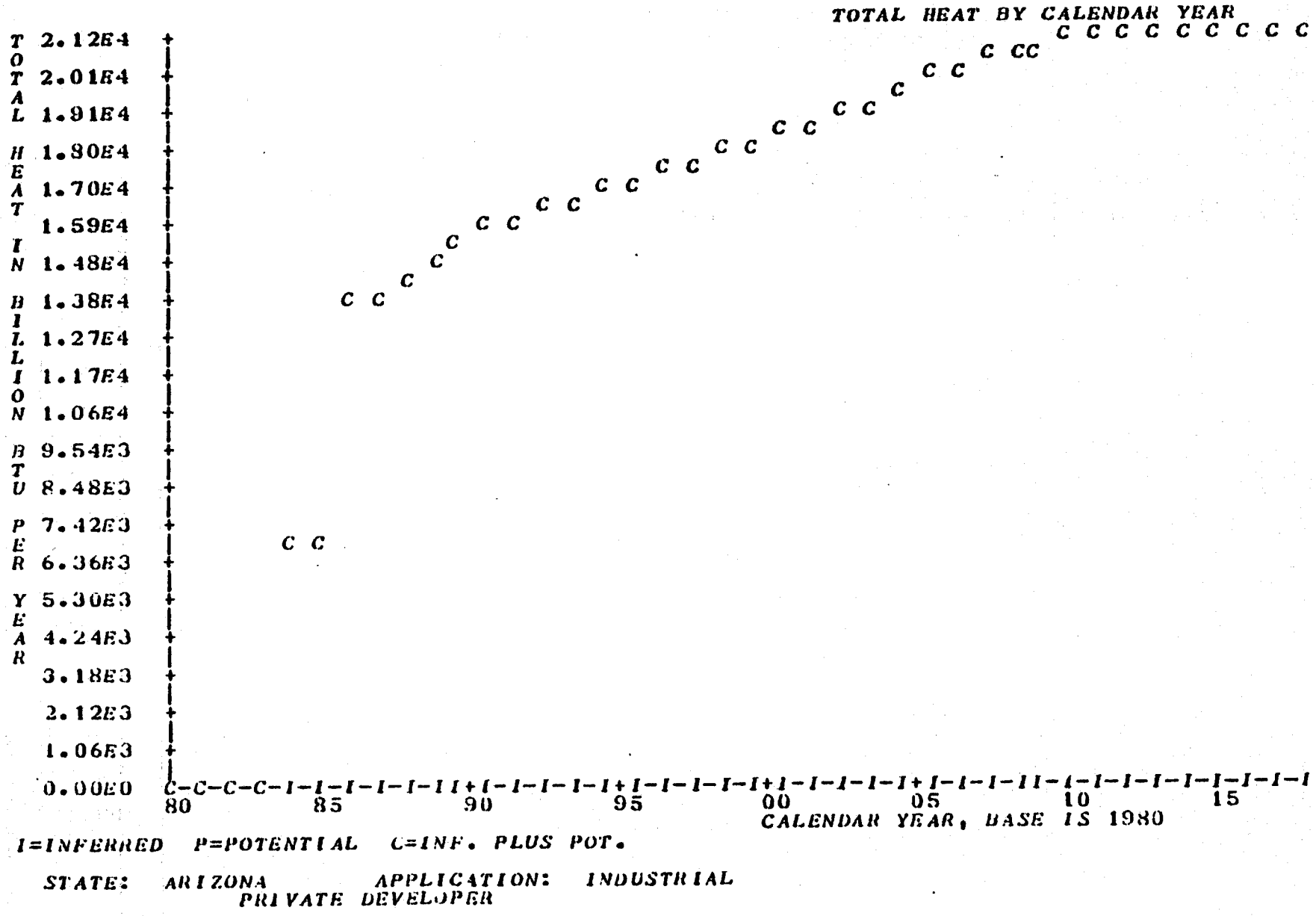


Figure 15: Projected Industrial Geothermal Heat On Line Under Private Development for Cochise/Santa Cruz Counties.
Source: New Mexico Energy Institute

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 5 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 5: 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.

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.

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