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GEOTHERMAL DEVELOPMENT PLAN: GRAHAM-GREENLEE COUNTIES

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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 APP is concerned with geothermal potential in Graham and Greenlee counties, both of which contain significant quantities of geothermal energy that could be used for industrial, agricultural or residential use. Projections are made of geothermal heat on line under both private and city-owned utility development. Potential users of geothermal energy, however, are limited since this area is sparsely populated and lacks an industrial base. Only a couple of industries were identified which could use geothermal energy for their process heat needs.

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 Graham and Greenlee 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: $^{o}F = (1.8 \times {}^{o}C) + 32$

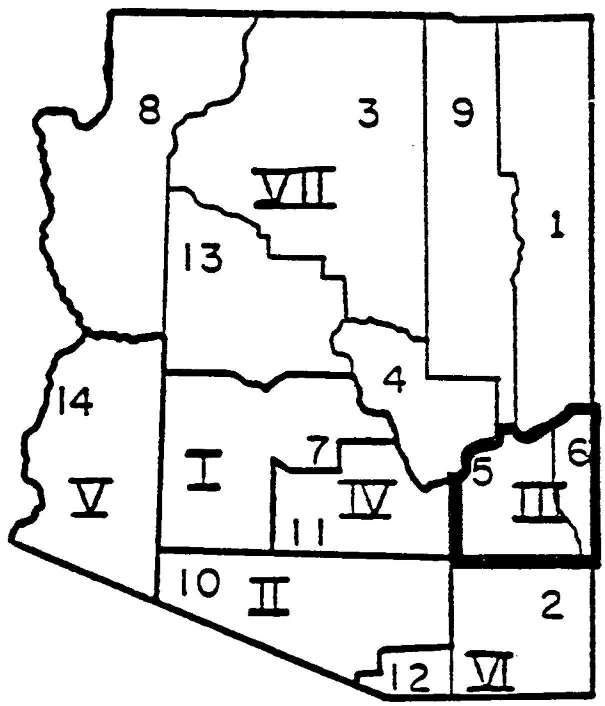
GEOTHERMAL RESOURCES

The areas of interest in Graham and Greenlee counties lie within the Basin and Range physiographic province which is characterized by numerous mountain ranges rising abruptly from broad valleys. At least six areas known to store thermal water at relatively shallow depths of less than 1200 m (3940 ft) are located within the two counties. Numbered boxes in Figure 2 identify these areas; Table 2 gives the location of each of these areas along with rough depth, volume and temperature estimates.

Graham and Greenlee counties have more hot springs than any other area of the state. Also, Safford itself is surrounded by proven and potential low temperature geothermal reservoirs, and the center of the Safford Basin

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.

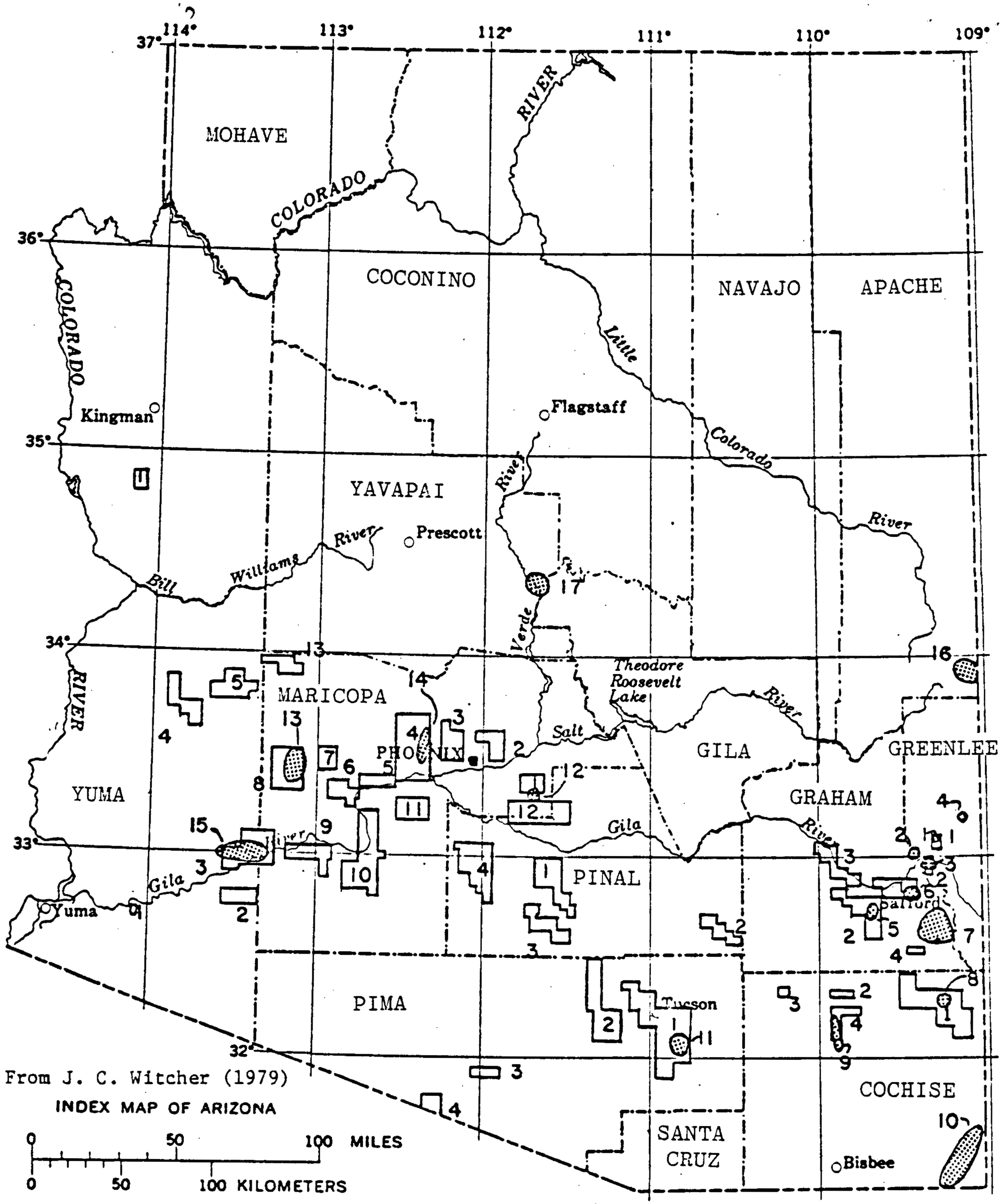


Figure 2: Arizona's Proven, Potential and Inferred Resources.

TABLE 2: PROVEN AND POTENTIAL RESERVOIRS OF GRAHAM AND GREENLEE COUNTIES OF LESS THAN 1.2 KM DEPTH

Modified from Witcher (1979) Tr - Average Reservoir Temperature

County/ Area	Location	Volume (km^3)	Measured (^oC) Temperature	Depth (km)	Tr(^oC)	Geothermometry Temperature(^oC)	Method
Greenlee 1	T4S, R30E	18.6	30-67	Surface	80	130-180	Quartz Mixing Model 2Na-K-Ca/mg corr.
Greenlee 2	T5S, R30E	18.6	30-83	Surface	80	130-140	Quartz, Na-K-Ca
Graham 1	T6-7S, R26-28E	61.9	30-50	<0.30	75	70-115	Quartz, Na-K-Ca
Graham 2	T7-9S, R24-26E	111.5	30-45	<0.61	70	30-90	Quartz, Na-K-Ca
Graham 3	T4-6S, R23-25E	71.2	30-60	<1.1	60	70-90	Chalcedony, Na-K-Ca
Graham 4	T10S, R28-29E	61.9	30-40	<0.61	60	90-110	Quartz, Na-K-Ca

may be as deep as 3000 m (9840 ft).

Intermediate temperature geothermal potential is inferred from presently available geological, geochemical and geophysical information (Witcher, 1979). The locations of several inferred potential reservoirs in Graham and Greenlee counties along with rough depth, volume and temperature estimates are presented in Table 3.

Figure 3 shows the locations of springs and wells having temperatures of over 30°C (86°F). Also shown are areas which are underlain by greater than 365 m (1200 ft) of basin-fill sediments.

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 on 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 population for combined Graham and Greenlee counties was 34,268. With a total land area of 6497 square miles, the two counties have a population density of five persons per square mile. The ethnic breakdown of the population is 57 percent white, 33 percent Hispanic, 7 percent Indian and 1 percent black.

Growth

The population of Greenlee County grew at an annual rate of 0.78 percent from 1940 to 1950. From 1950 to 1970, the population declined at an annual rate of 1.1 percent. Since 1970, population has grown at a rate of 1.5 percent annually. Graham county has also been one of the slower growing

TABLE 3: INFERRED INTERMEDIATE TO HIGH TEMPERATURE (>90°C) GEOTHERMAL RESERVOIRS OF GRAHAM AND GREENLEE COUNTIES OF LESS THAN 2.5 KM DEPTH

Tr-Average Reservoir Temperature

Name	County	Location	Depth km	Volume km^3	Tr - °C	Inferences based on
Clifton Hot Springs	Greenlee	T4S, R30E	2.0	2.5	170	1, 2
Eagle Creek Hot Springs	Greenlee	T4S, R28E	2.0	2.5	130	1, 2
Gillard Hot Springs	Greenlee	T4S, R30E	2.0	2.5	140	1, 2
Martinez Ranch	Greenlee	T3S, R31E	2.0	2.5	130	1, 2
Cactus Flat - Artesia	Graham	T7-9S, R26E	2.0	2.5	110	1, 2, 3
Buena Vista	Graham	T6-7S, R27-28E	2.0	2.5	120	1, 2, 3
Whitlock Mountains Area	Graham	T3-10S, R28-30E	2.0	2.5	110	1, 2, 3

(1) Geothermometry

(2) Structure

(3) Geohpysics/heat flow

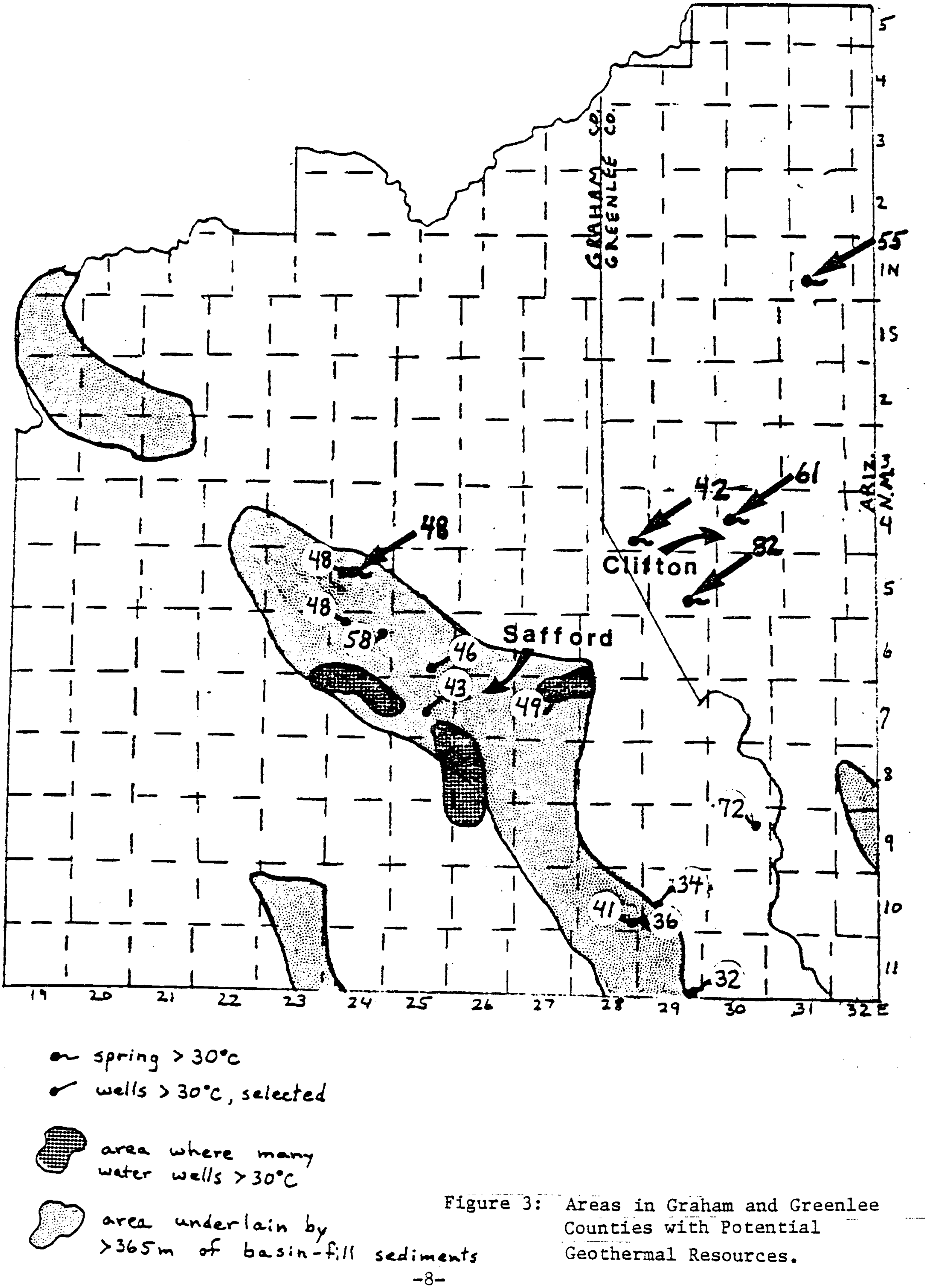


Figure 3: Areas in Graham and Greenlee Counties with Potential Geothermal Resources.

counties in Arizona. Between 1940 and 1970 the Graham County population grew at a rate of 1.1 percent per year. Since 1970, Graham County has grown at a three percent annual rate. As indicated in Figure 4, population projections for the combined counties place growth at an annual rate of 1.5 percent. The major towns are listed in Table 4 along with their projected populations to 2020.

TABLE 4: MAJOR TOWNS IN GRAHAM AND GREENLEE COUNTIES AND THEIR CURRENT AND PROJECTED POPULATIONS

Greenlee	1979	2020
Clifton	5770	9114
Duncan	1136	2501
Morenci	3422	1951
Residual	1472	1834
Graham	**1979**	**2020**
Safford	8381	21,246
Thatcher	3305	7127
Bylas	1409	780
Pima	1759	5284
Residual	6945	5963

Safford is the largest city in the two counties, the next largest being Clifton. The population of the Safford area is expected to expand to the north and to some degree to the south of the town. Most of Clifton is located in a canyon surrounded by state and federally owned land and privately owned Phelps Dodge land. The only direction for growth is to the south.

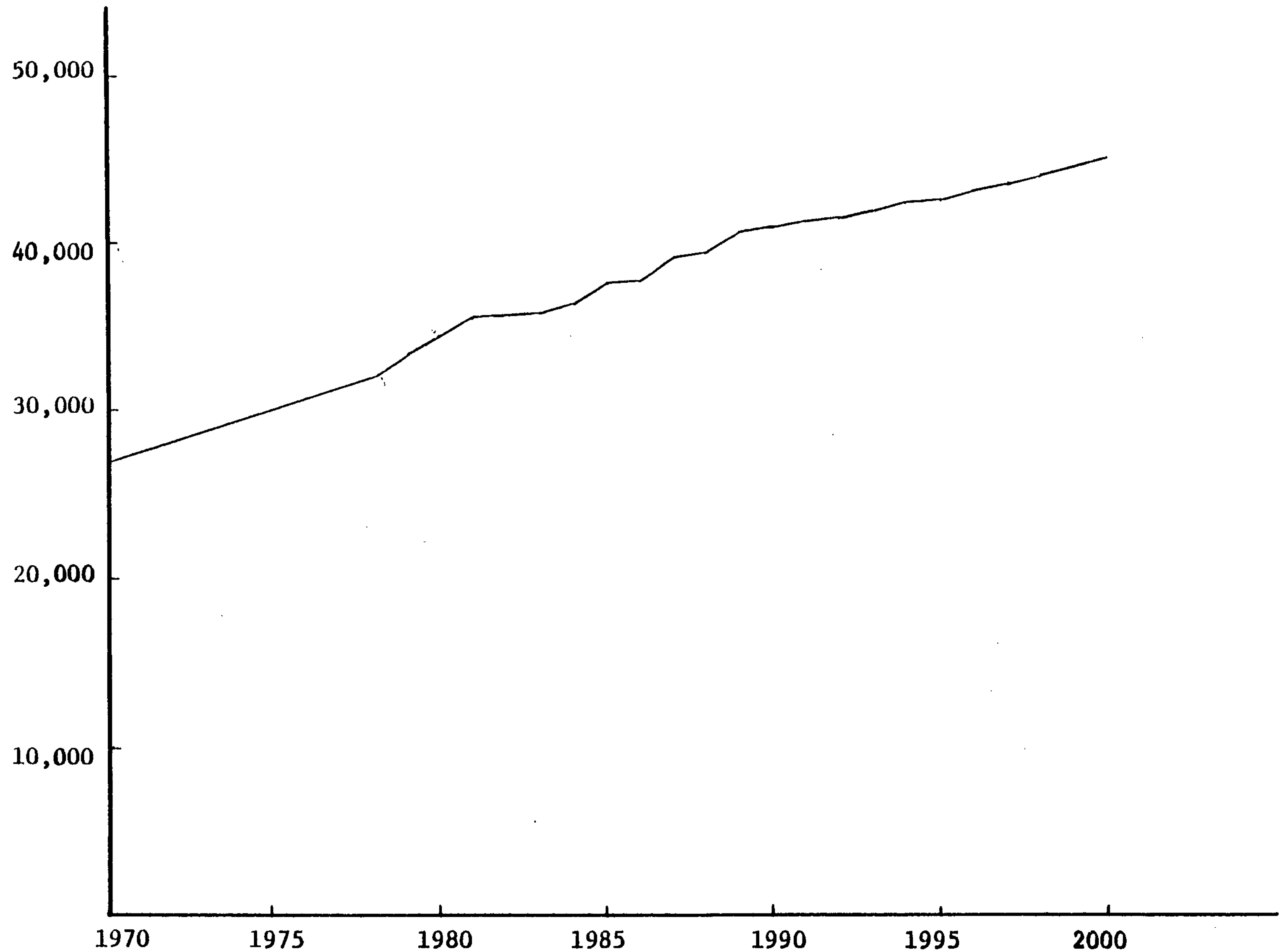


Figure 4: Population Projections for Graham/Greenlee Counties.
Source: Technical Advisory Committee (DES)

Industry and Employment

The major source of employment in Graham and Greenlee counties is mining. Most of this activity is concentrated in Greenlee County, the site of a large Phelps Dodge copper mine. Mining accounts for 25 percent of all jobs in the two counties with the value of mineral production exceeding $250 million in 1974. Future projections suggest a 2.3 percent annual growth rate in mining employment through 2000, implying that mining will continue to be the major employer in Graham and Greenlee counties.

The trade and service sectors and local government make up 47 percent of the total employment in the two counties. The trade and service sectors, expected to increase at a rate of over three percent per year to 2000, are projected to be the fastest growing sectors. Figure 5 shows current employment levels and projections to 2000.

Agriculture is also an important source of income for Graham and Greenlee counties despite the fact that employment in agriculture accounts for only 7 percent of the total. Principal crops in the two counties are cotton, alfalfa, sorghum and corn. No significant changes are expected regarding agricultural employment over the next 20 years.

Manufacturing and construction are not significant in either county. Manufacturing accounts for less than 1000 jobs in both counties and is only expected to grow at a 1.3 percent annual rate through the year 2000. Construction employment is expected to decline at a 1.4 percent annual rate.

Income

Both personal income and personal per capita income are considered strong indicators of the economic health of a region. Projections of the Planning Office of the Department of Economic Security show yearly increases in personal income for the next 20 years for both Graham and

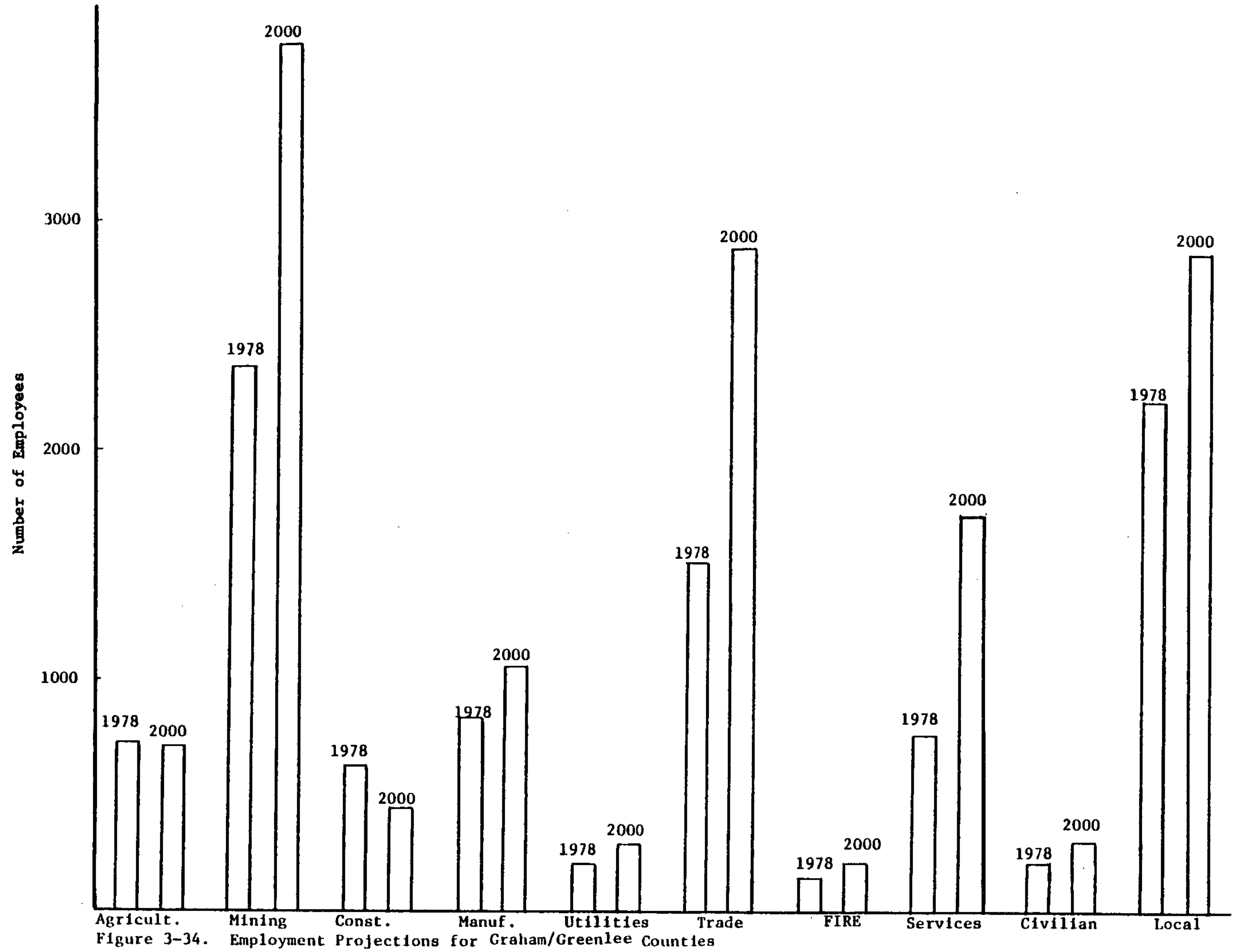


Figure 5: Employment Sector Projections for Graham/Greenlee Counties.
Source: Department of Economic Security

Greenlee counties. Projections of personal per capita income for both counties are presented in Figure 6. The annual growth rates of 2.3 percent and 3.0 percent for Graham and Greenlee counties, respectively, represent a slower rate of growth than is common in the more populous Maricopa and Pima counties. Also, the types of employment in Graham and Greenlee counties tend to pay lower wages than in the more industrialized counties.

Other Economic Indicators

Factors such as total retail sales and bank deposits are additional indicators of the health of the economy.

Between 1968 and 1978, both retail sales and bank deposits steadily increased in both counties. Graham County retail sales increased 236 percent over the ten-year period while Greenlee County retail sales increased 140 percent. Over the same period, bank deposits increased 185 percent in Graham County and 162 percent in Greenlee County.

In conclusion, Graham and Greenlee counties have typically been the slower growing counties in Arizona not only in population but also in the other gauges of economic welfare. Paradoxically, these two counties also exhibit the best potential for geothermal energy utilization in the state. Both counties exhibit an abundance of warm springs and wells ideal for direct-use applications. However, the sparse population and lack of an industrial base result in few potential developers of geothermal energy.

LAND OWNERSHIP

Figures 7 and 8 show general land ownership maps for Graham and Greenlee counties. Table 5 gives acreage breakdowns for each ownership class. Procedures for acquiring surface and mineral rights vary depending upon which sector owns the land.

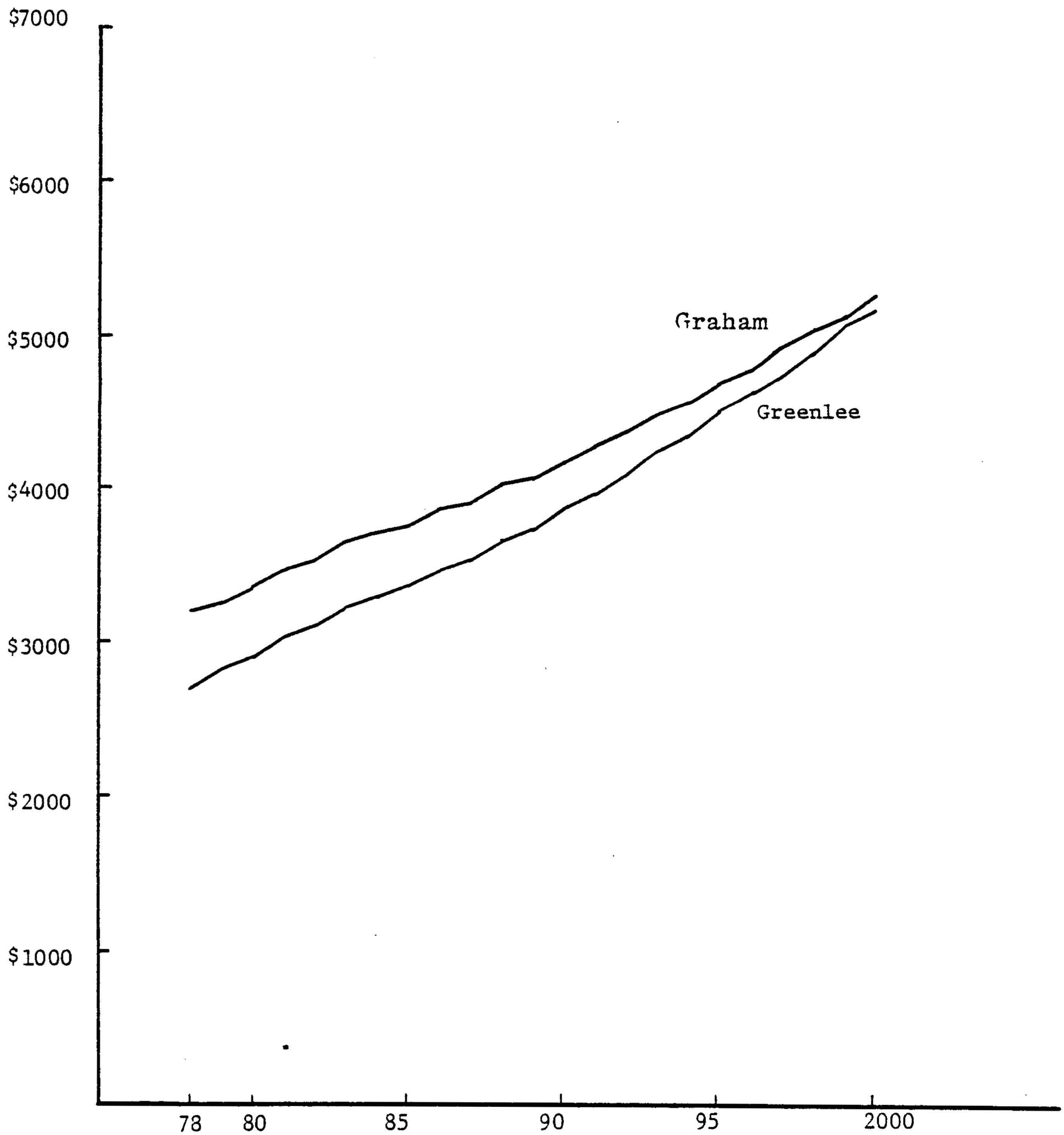


Figure 6: Personal Per Capita Income Projections for Graham and Greenlee Counties (1972 Dollars).
Source: Department of Economic Security

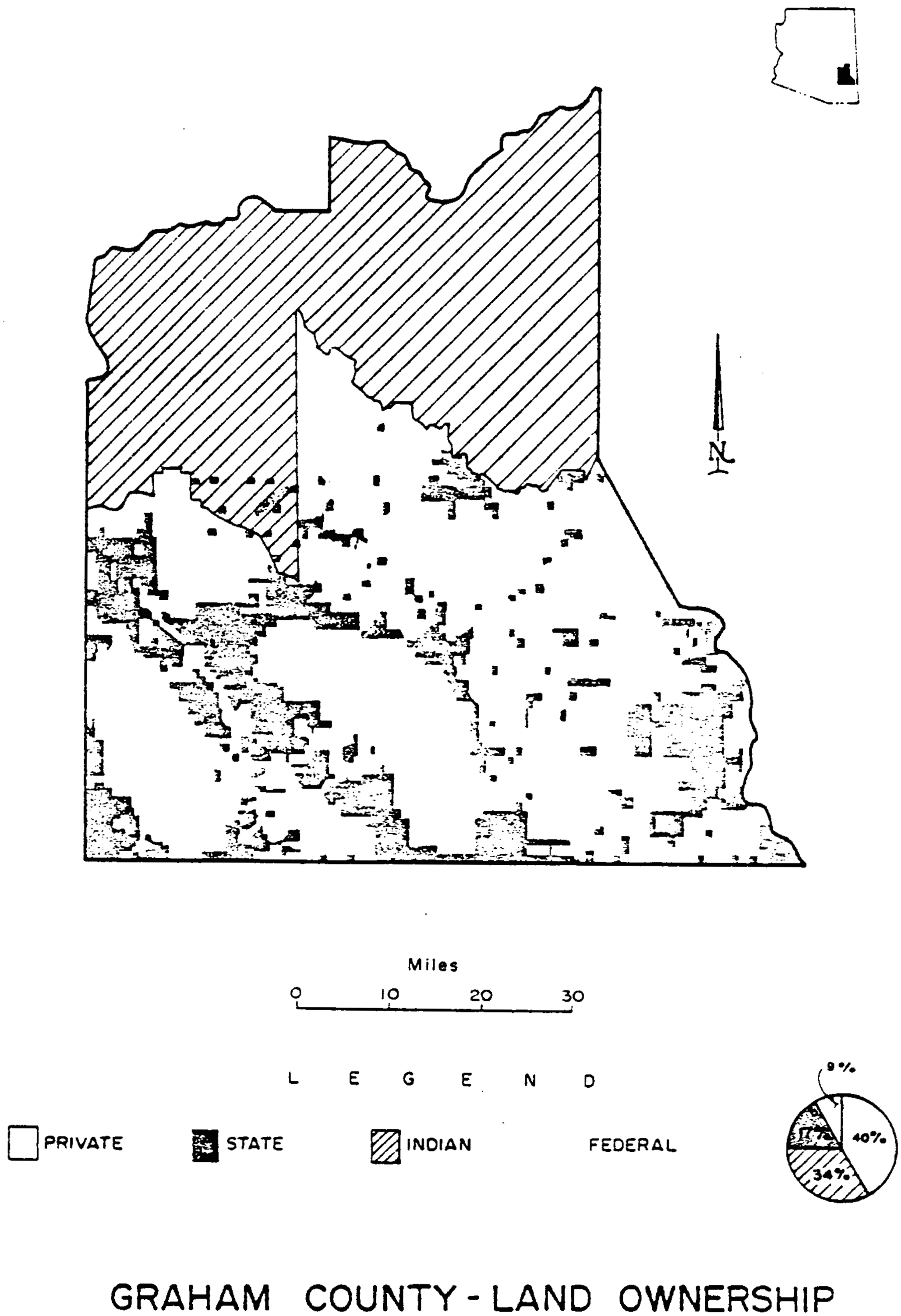


Figure 7: General Land Ownership Map for Graham County.
Source: Arizona Water Commission (1977)

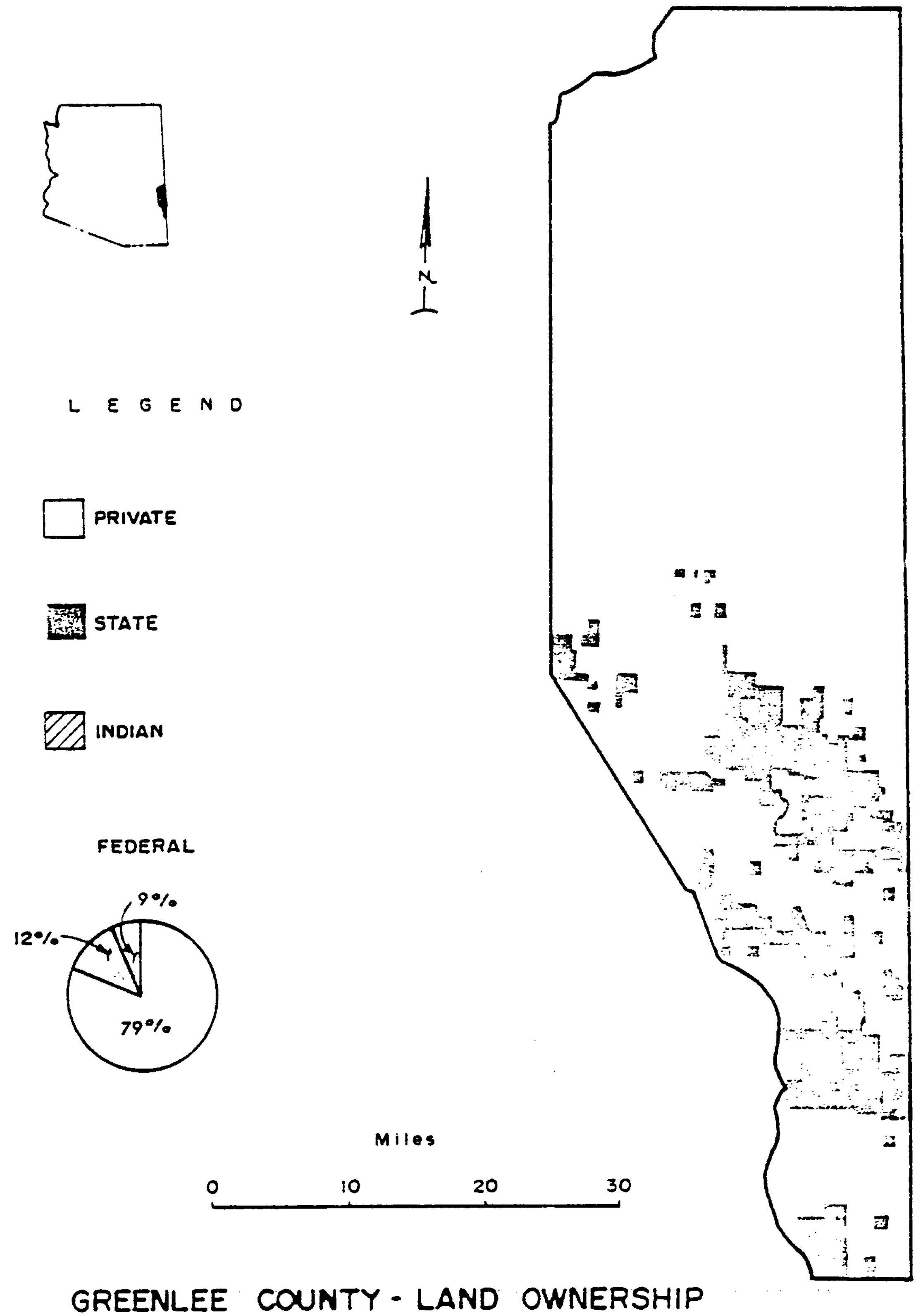


Figure 8: General Land Ownership Map for Greenlee County.
Source: Arizona Water Commission (1977)

TABLE 5: LAND OWNERSHIP IN GRAHAM AND GREENLEE COUNTIES

	Graham %	Total Acres	Greenlee %	Total Acres
Federal	40	1,180,000	79	947,210
State	17	501,500	12	143,880
Indian	34	1,003,000	0	0
Private	9	265,500	9	107,910
Total		2,950,000		1,199,000

ENERGY USE

Energy-use and energy-use projections to the year 2020 for Graham and Greenlee counties are presented by user class in Table 6.

TABLE 6: ENERGY-USE PROJECTIONS FOR GRAHAM AND GREENLEE COUNTIES(1) (Trillion Btu)

	1978(2)	1985(3)	2000	2020
Residential	.815	.744	.65	.72
Commercial	.96	1.06	1.46	2.95
Industrial	2.13	2.26	2.82	4.29
Total	3.905	4.064	4.93	7.96

(1) Excludes transportation, line losses and conversion losses.

(2) Developed from Arizona Energy Use, 1978, by the Division of Economic and Business Research, University of Arizona.

(3) Projections derived from growth rates from state energy projections performed by New Mexico Energy Institute.

Electricity and natural gas are the two predominant types of energy consumed in the counties. Data on energy consumption for both electricity and natural gas appear in Table 7. These data do not represent total energy consumption for the counties but only that of the major cities of Safford, Thatcher, Clifton and Morenci as well as some rural areas. This information is also presented in Table 8 in terms of Btu equivalents.

TABLE 7: ENERGY CONSUMED BY USER CLASS, 1978

	Electricity (1) (MWh)	Natural Gas (2) (MCF)
Residential	26,203	156,767
Commercial	3,625	108,481
Industrial	2,194	57,995
Irrigation and Agriculture and Other	83	2,076
Total	32,105	325,319

(1) Sources are Sulphur Springs Valley Electric Cooperative, Morenci Water and Electric Co., and Town of Thatcher.

(2) Source is Safford Municipal Utilities for Graham County only.

TABLE 8: BTU EQUIVALENTS OF ENERGY CONSUMED (Btu x 10^{10})

	Electric	Natural Gas	Total
Residential	8.9	15.7	24.6
Commercial	1.2	10.8	12.0
Industrial	0.7	5.8	6.5
Agriculture and Other	0.03	0.2	0.23
Total	10.83	32.5	43.33

Average prices for energy types are presented by user class in Table 9.

TABLE 9: ESTIMATED 1978 AVERAGE PRICES BY USER CLASS (per MBtu)

	Residential	Commercial	Industrial	Agricultural
Electricity	$13.09-16.35	$8.80-18.00	$10.17-14.27	$8.80-13.83
Natural Gas	$ 3.24-4.29	$3.01	$ 2.86	----
Liquid Petroleum Gas	$ 6.04-6.77	Same	Same	----
Distillate	$ 4.90	Same	Same	----

Figure 9 presents monthly kilowatt-hour sales for the various utilities serving Graham and Greenlee counties. Though the August peak is rather severe, demand for electricity is not as pronounced as it is for counties such as Maricopa and Pima. A partial explanation for this type of monthly sale is the use of electricity for irrigation. However, due to lower personal income and a rural location, less electricity is consumed for space conditioning during the summer months in Graham and Greenlee counties than in the more populous Maricopa and Pima counties.

WATER

Figures 10 and 11 show projections of water availability and use for Graham and Greenlee counties, respectively. The three alternative futures presented in each figure take into account a variety of factors such as population growth, industrial development and consumer habits and life-styles that will have an effect on the future level of water use. The alternative future summaries for Graham and Greenlee counties show that water deficits are expected even under the most conservative water depletion alternative, Alternative III.

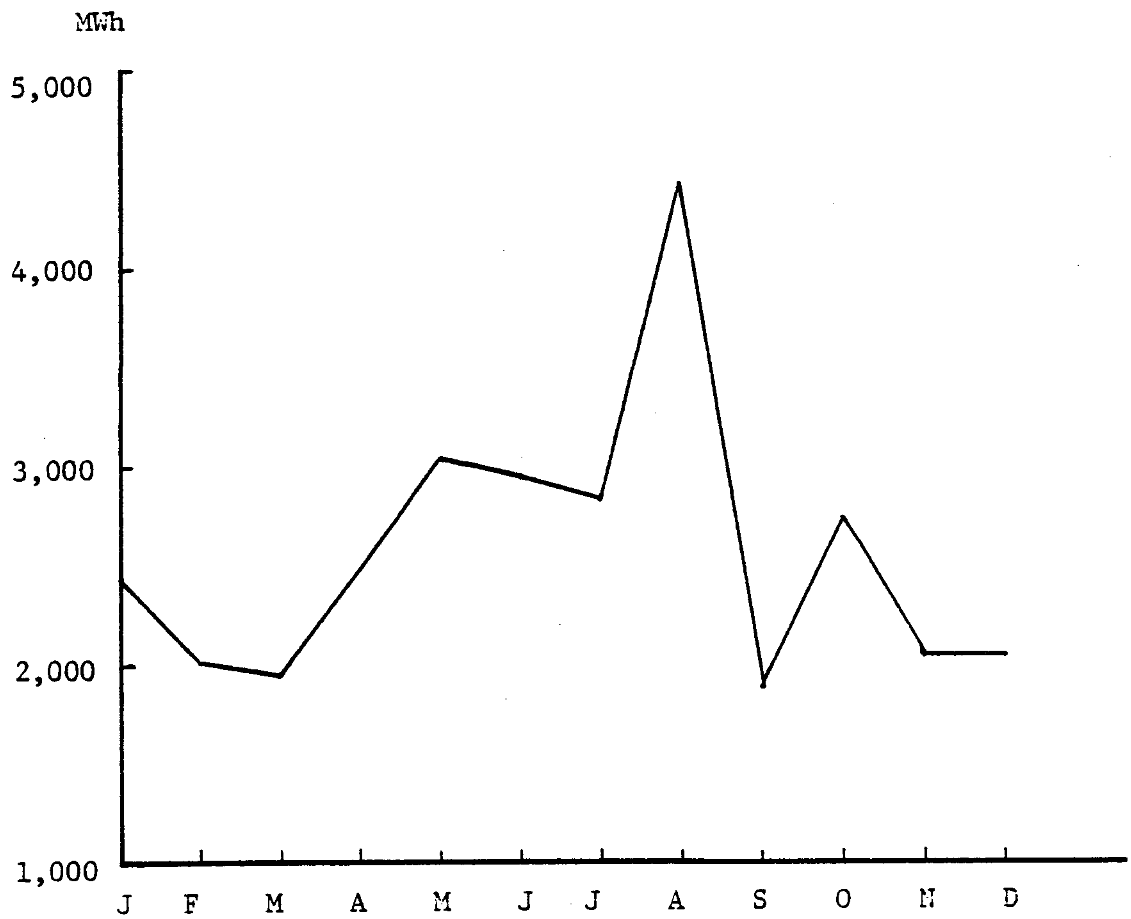
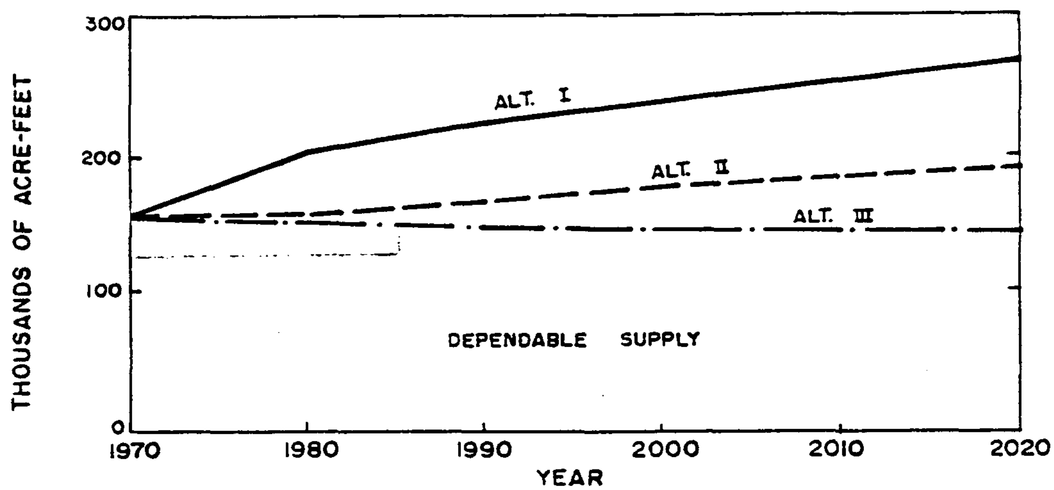


Figure 9: Monthly KWh Sales in Graham/Greenlee Counties.

GRAHAM COUNTY
ALTERNATIVE FUTURES

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY



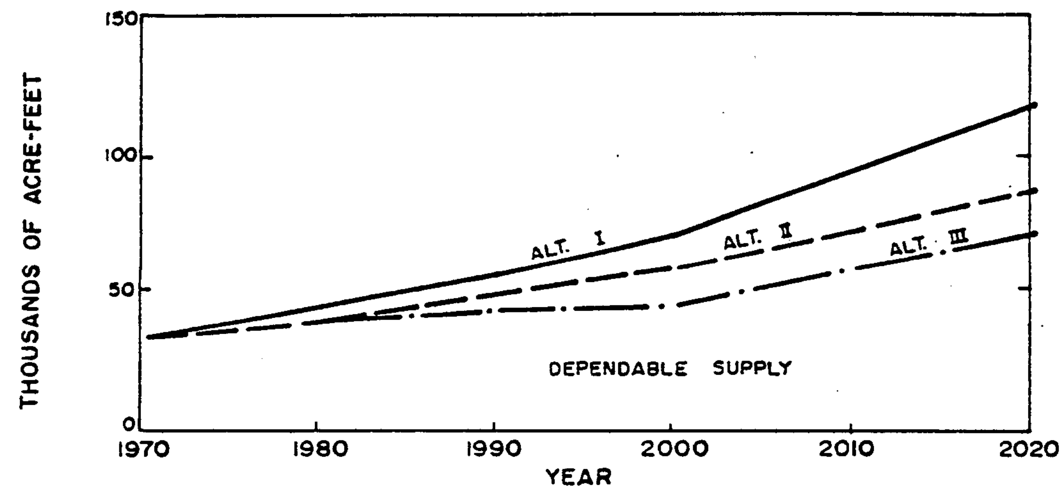
ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)		ALTERNATIVE				FUTURES	
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	16.6	37.8	69.0	23.8	30.9	23.8	30.9
HARVESTED ACRES	56.0	73.3	78.0	55.2	54.1	49.0	37.0
URBAN DEPLETIONS AF/YR	2.0	3.6	5.7	2.6	3.0	2.6	3.0
STEAM ELECTRIC DEPLETIONS AF/YR	0	0	0	0	0	0	0
MINERAL DEPLETIONS AF/YR	0	20.0	50.0	13.0	41.0	13.0	41.0
AGRICULTURAL DEPL. AF/YR	157.0	204.0	213.0	153.0	148.0	136.0	101.0
TOTAL WATER DEPL. AF/YR	159	228	269	169	192	152	145
DEPENDABLE WATER AF/YR	132	147	145	147	145	147	145
SURPLUS SUPPLY (Def.)	(27)	(81)	(124)	(22)	(47)	(5)	0

Figure 10: Projected Alternatives for Water Use in Graham County.
Source: Arizona Water Commission (1977)

GREENLEE COUNTY
ALTERNATIVE FUTURES

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	10.3	33.9	41.8	13.4	16.5	13.4	16.5
HARVESTED ACRES	5.0	5.6	5.8	5.0	5.0	3.0	0
URBAN DEPLETIONS AF/YR	1.7	3.6	4.4	1.6	1.8	1.6	1.8
STEAM ELECTRIC DEPLETIONS AF/YR	0	0	0	0	0	0	0
MINERAL DEPLETIONS AF/YR	14.0	36.0	99.0	32.0	72.0	32.0	72.0
AGRICULTURAL DEPL. AF/YR	17.0	17.7	16.5	15.9	14.2	9.6	0
TOTAL WATER DEPL. AF/YR	33	57	120	49	88	43	74
DEPENDABLE WATER AF/YR	33	43	41	43	41	43	41
SURPLUS SUPPLY (Def.)	0	(14)	(79)	(6)	(47)	0	(33)

Figure 11: Projected Alternatives for Water Use in Greenlee County. Source: Arizona Water Commission (1977)

In Graham County, the projected urban water uses are generally small in comparison to total use and the availability of dependable supplies. In Greenlee County, there is also adequate water to meet urban needs; however, projected water usage for mineral production exceeds projected supplies by substantial amounts. Future water use by the mineral industry alone may exceed the dependable supply of this county.

The Central Arizona Project is not expected to deliver large quantities of water to the area; however, Charleston Dam on the San Pedro River will increase dependable water supplies by approximately 12,000 acre-feet per year. Some additional water is assumed to be available to Graham and Greenlee counties through exchange of project water with downstream water-right holders on the Gila River, but unless further augmentation is achieved large reductions in water availability are inevitable.

DISTRICT HEATING

Because Clifton and Safford are located in a region of known geothermal potential, studies to determine the feasibility of using geothermal energy for district heating have been performed for both towns.

Clifton

Approximately two-thirds of all employed persons in the Clifton/Morenci area work for the Phelps-Dodge copper mining operation in Morenci. Despite the fact that Clifton has one of the most obvious and best understood geothermal resources in Arizona, the town has some major problems that would impede the development of a district heating system. These include confusion over who owns the land and mineral rights, concerns over too many regulations of the Environmental Protection Agency, a lack of city money and the existence of natural gas service from an investor-owned utility. Thus, near-term geothermal development is not realistic. Despite the problems currently faced by the town, the following economic analysis presents general results for establishing a geothermal district heating system in Clifton. This analysis assumes private rather than city development of the resource. Other assumptions necessary for the analysis are presented in Table 10.

TABLE 10: ASSUMPTIONS FOR CLIFTON DISTRICT HEATING SYSTEM

Variable	Value
Population	1475
Population Growth	0
Resource Temperature	60°C (140°F)
Depth	30 m (100 ft)
Flow Rate	1890 l/min (500 gpm)
Distance	1609 m (1 mile)
Heating Degree Days	3431
Peak Residential Heat Demand	14,750,000 Btu/hr
Peak Commercial Heat Demand	11,062,500 Btu/hr
Bond Rate (above inflation)	2%
Return on Investment (10%)	10%
Price of Natural Gas (per MBtu)	$3.30
Calculated Price of Geothermal (per MBtu)	$5.74

An itemized cost summary for the district heating system is presented in Table 11. Results of the analysis indicate that even though the depth to the resource is only 30 m (100 ft), the life-cycle cost of geothermal energy would not be competitive with natural gas until 1988. The majority of the cost is associated with the residential retrofit, the commercial conversion and the central system components. Central distribution system costs increase for low energy-use density systems such as this one.

TABLE 11: COST SUMMARY FOR CLIFTON DISTRICT HEATING SYSTEM

Category	Present Value of Capital Cost
Research Investment[(1)]	$ 18,022
Design	362,426
Wells[(2)]	26,874
Transmission	162,369
Distribution:	
Residential Retrofit	785,634
Residential Hookup	272,790
Commercial Conversion	414,913
Heat Exchangers	99,607
Central System	1,870,825
Total	$4,013,459

(1) Research Investment includes the cost of the first production well, injection well and pumps.

(2) Wells include cost of a second production and injection well, pumps and lease payments.

Although a district heating system appears unfavorable from an economic point of view, the time will come when geothermal energy will be the best energy alternative for the community. Cumulative future savings available by replacing natural gas with geothermal energy would be $4,647,000 to the year 2000.

Safford

With the assistance of the New Mexico Energy Institute, a preliminary feasibility study was performed for a downtown commercial heating district in Safford, Arizona. The study was based on the assumptions that the project life is 20 years, the cost of money is two percent above inflation and prices of electricity and natural gas would increase at three percent and five percent per year above inflation, respectively.

The Safford downtown commercial district consists of approximately 167 commercial buildings in an area one-half mile long by one-quarter mile wide. The estimated natural gas demand for heating and hot water is 62.4 x 10^9 Btu/yr. However, due to efficiency losses in the use of natural gas, the actual heat delivered would be 43.7 x 10^9 Btu/yr. Based on the relationship of average annual demand divided by average peak demand, peak demand for all the buildings is 38.5 x 10^6 Btu/hr. The average user peak demand is 230,550 Btu/hr.

In meeting the heating and hot water demand with a 17°C (30°F) temperature drop, a minimum flow rate of 2,565 gallons per minute (gpm) of 60°C (140°F) geothermal water is required. In this study three production wells each having a flow rate of 1000 gpm are assumed. Each well would be drilled to a depth of approximately 1065 m (3500 ft) and would be located in the downtown area. An injection well would also be drilled to a depth of 610 m (2000 ft).

In addition to the production and injection wells, 4.0 km (2.5 miles) of distribution pipe and 0.40 km (0.25 miles) of transmission pipe would be needed. The design also incorporates three well pumps, a heat exchanger, controls, a circulation pump and retrofit and hookup equipment. Table 12 presents a cost summary of the equipment required for the system.

TABLE 12: COST SUMMARY FOR SAFFORD DISTRICT HEATING SYSTEM

Wells	$ 1,170,000
Heat Exchanger	120,000
Piping	694,000
Well Pumps	160,000
Controls	20,000
Circulation Pump	12,300
Retrofit and Hookup	1,109,715
	3,286,000

In addition to the capital costs necessary to install the system, operating and maintenance costs were also estimated. Cost of electricity to power the system was estimated to be $83,960 per year based on a rate of 6.5¢ per kilowatt hour. Maintenance costs were estimated to be $32,860 per year or one percent of capital costs. Table 13 summarizes the operating and maintenance costs.

TABLE 13: OPERATING AND MAINTENANCE COSTS FOR SAFFORD DISTRICT HEATING SYSTEM

Well pumps (1360 hp)	1015 kw
Circulating pump (165 hp)	123 kw
Total	1138 kw
Hours of operation (per year)	1135
Annual electric cost ($.065/kwh)	$ 83,956
Maintenance costs (per year)	$ 32,860
Conventional fuel cost (1979)	$249,600

A summary of economic results using the net present value investment technique is presented in Table 14. Although the district heating system economic analysis shows a positive savings over 20 years, cost of the geothermal system would still be 85 percent of the conventional fuel cost. It is concluded that a 15 percent savings over 20 years would not justify the capital expense required for this project.

MATCHING GEOTHERMAL RESOURCES TO POTENTIAL USERS

Graham and Greenlee counties have been found to contain significant quantities of geothermal energy which could be used for industrial, agricultural or residential use. However, the sparse population of the two counties results in few industrial matches with geothermal energy. Within both counties, only two industries were found which could use 105°C (221°F)

TABLE 14: ECONOMIC ANALYSIS FOR SAFFORD DISTRICT HEATING SYSTEM

	Nominal	Present Value
Capital Cost	$3,286,000	$3,286,000
Annual Operating Cost (20 years)	83,960	1,845,192
Annual Maintenance Cost (20 years)	32,860	548,054
Total		$5,679,246
Annual Conventional Fuel Cost (20 years)	249,600	6,666,859
Net Present Value		$ 987,613
Percentage of Savings		15%

geothermal water for process heat needs. The two industries are a bottling company and a manufacturer of sporting and athletic goods.

Projection of the amount of geothermal energy on line as a function of time resulted from work performed in conjuction with the New Mexico Energy Institute (NMEI). For modeling purposes, it was assumed that geothermal energy comes on line when its price becomes lower than that of energy alternatives. The amount of geothermal energy on line assuming both private development and city-owned utility development of the resource is presented in Figures 12 and 13, respectively. Comparison of the figures shows that development of geothermal energy by a city-owned utility would occur faster than it would under private development, the differences between the two cases resulting mainly from differing capital costs.

Results from Figures 12 and 13 can be summarized as follows: under both types of development, once geothermal energy came on line in 1983, the amount of geothermal energy on line would rapidly climb for 10 to 30 years. However, more geothermal energy would come on line by 1983 under city-owned utility development than under private development. Thus, city development of the resource occurs faster than private development. For comparative purposes,

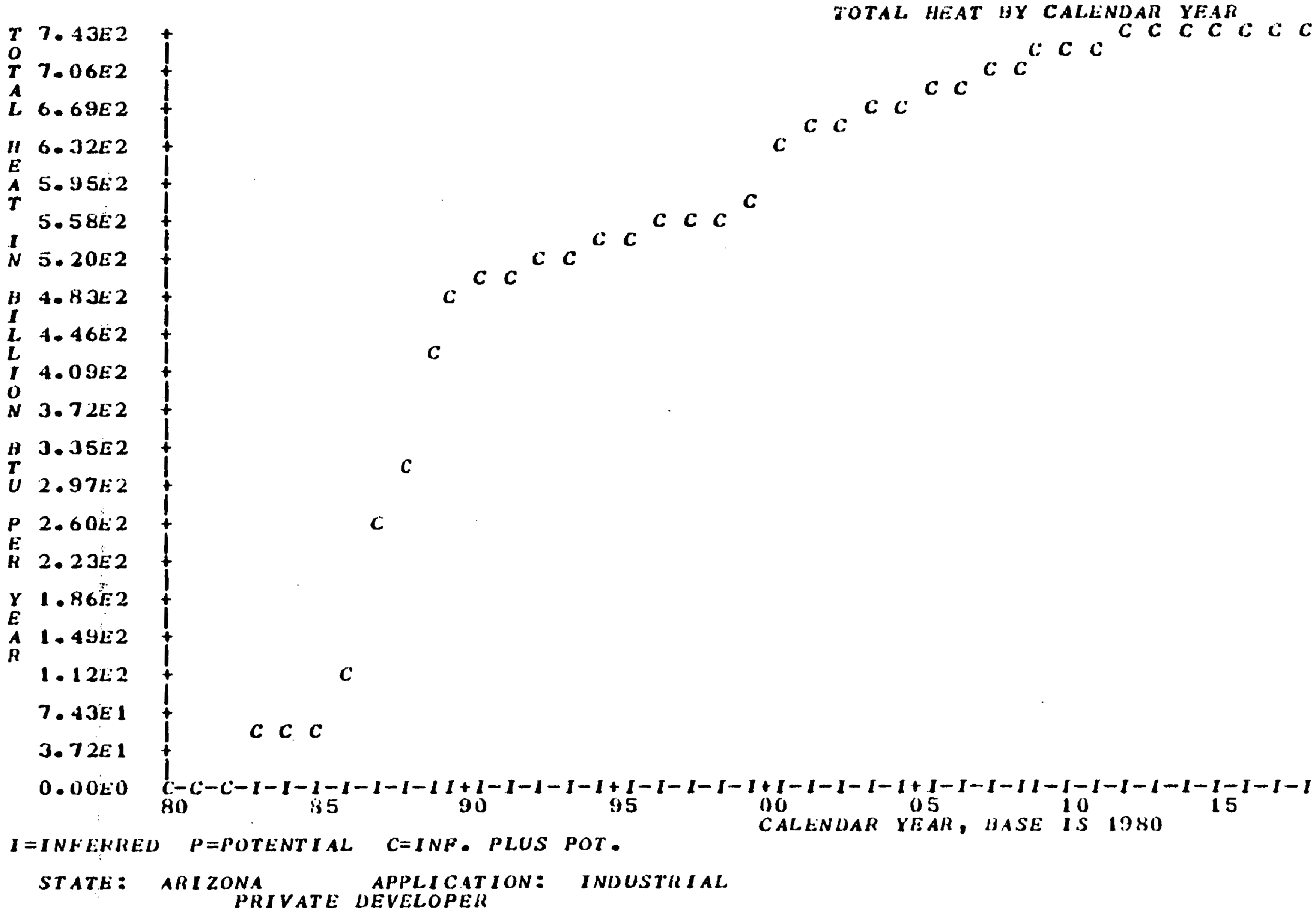


Figure 12: Projected Geothermal Heat on Line Under Private Development.
Source: New Mexico Energy Institute

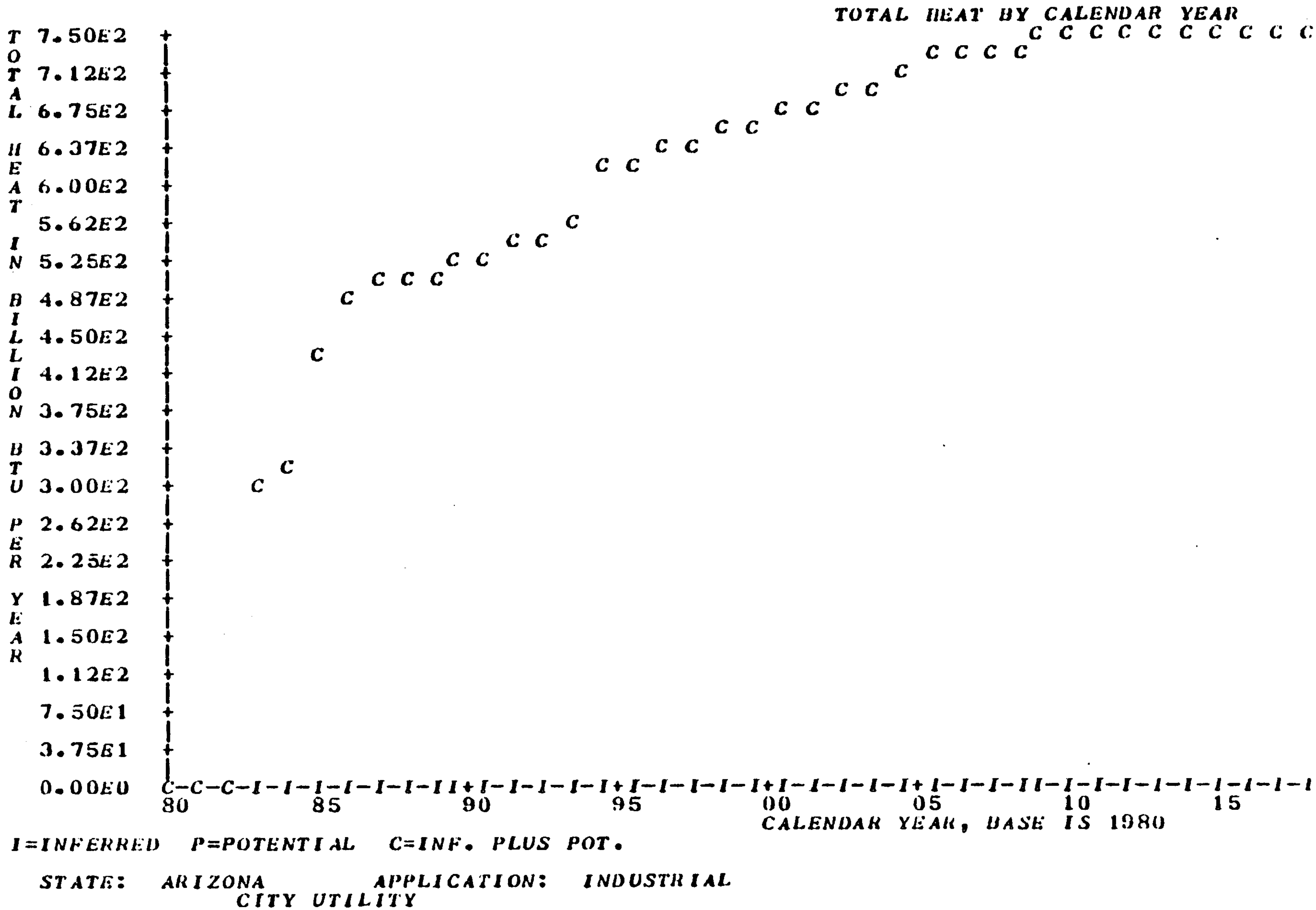


Figure 13: Projected Geothermal Heat on Line Under City Development.
Source: New Mexico Energy Institute

Table 15 reports energy on line in terms of barrels of oil replaced annually by geothermal energy.

Further details of the NMEI model for projecting geothermal energy on line are given in Appendix A.

TABLE 15: BARRELS OF OIL REPLACED BY GEOTHERMAL ENERGY PER YEAR
Process Heat Market

	1985	1990	2000	2020
Private Developer	9955	86,250	112,857	132,678
City Utility	86,964	93,750	113,750	133,928

Agribusiness and agricultural industries in Graham and Greenlee counties were also identified. Only a few such industries were found. Currently, most agricultural products are exported to California for processing. Geothermal energy might provide a low-cost energy source suitable for agricultural and livestock processing. Development of the processing industry in these two counties would have significant benefits for the local residents and farmers.

Lastly, the mining industry is quite important to the local economy. Copper is the principal metal which is being mined. Figure 14 presents a map of existing and potential dump leach operations in Graham and Greenlee counties, all of which are located in areas of proven or potential resources. Geothermal energy may be able to replace conventional energy sources used in these mining operations.

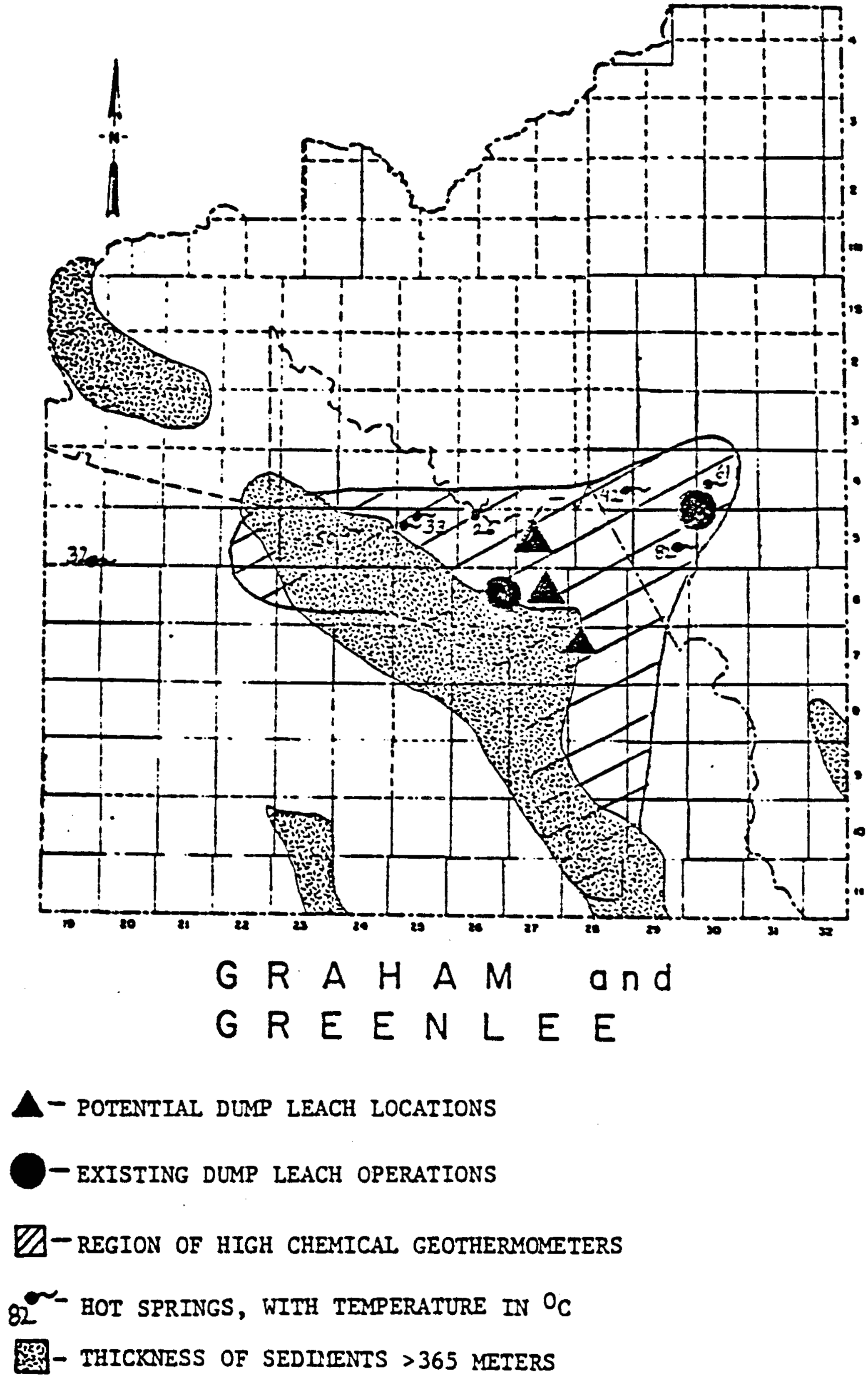


Figure 14: Potential for Integration of Geothermal Energy and Copper Dump Leachin

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 limitaiton 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 determining order-of-magnitude costs and potential benefits of geothermal energy development.

BIBLIOGRAPHY

References used in preparing the Area Development Plans

Arizona Agricultural Statistics 1978, 1979: Phoenix, Arizona, Arizona Crop and Livestock Reporting Service, 68 p.

Arizona Community Profiles, 1981: Phoenix, Arizona, Research Program, Arizona Office of Economic Planning and Development.

Arizona Statistical Review, 1979: Phoenix, Arizona, Valley National Bank of Arizona, 72 p.

Brown, K., 1978, Industrial Process Heat Demand Balance: Golden, Colorado, Solar Energy Research Institute, unpublished draft.

Climatograph of U.S. No. 81 Arizona, 1978: Asheville, North Carolina, National Climate Center.

Dunn, D. and Cox, D.C., 1979, Papers in Community Development No. 2 - Socio-Economic Indicators for Small Towns: Tucson, Arizona, Rural Information Center, 58 p.

Energy Analysis of 108 Industrial Processes, 1979: Philadelphia, Pennsylvania, Drexel University.

Energy-Saving Techniques for the Food Industry, 1977, M.E. Casper, editor: Park Ridge, New Jersey, Noyes Data Corporation, 657 p.

Frank, H.J., 1977, Arizona Energy Inventory: 1977: University of Arizona, Tucson, 100 p.

Gerber, L.A., Worden, M.A., and Dunn, D., 1980, Papers in Community Development No. 5 - Safford, Arizona: A Trade Area Analysis: Tucson, Arizona, Rural Information Center, 76 p.

Gibson, L.J., Worden, M.A., and Solot, M.S., 1979, Papers in Community Development No. 1 - A Citizen's Handbook for Evaluating Community Impacts: Tucson, Arizona, Rural Information Center, 65 p.

Hodgson, M.L., 1978, Arizona Job Scene 1985: A Labor Market Information Publication of the Arizona Department of Economic Security, 133 p.

Industrial Waste Heat Survey, 1978, Rocket Research Company.

Inside Phoenix 1979, 1979: Phoenix, Arizona, Phoenix Newspapers, Inc., 152 p.

Inside Phoenix 1981, 1981: Phoenix, Arizona, Phoenix Newspapers, Inc., 128 p.

1981 Directory of Arizona Manufacturers, 1981: Phoenix, Arizona, Phoenix Metropolitan Chamber of Commerce, 200 p.

Phase II - Arizona State Water Plan: Alternative Future, 1977: Phoenix, Arizona, Arizona Water Commission, 145 p.

Population, Employment and Income Projections for Arizona Counties 1977 - 2000, July 1978 & 1979: Arizona Department of Economic Security.

Population Estimates of Arizona as of July 1, 1979: Phoenix, Arizona, Arizona Department of Economic Security Report No. 12, 66 p.

Statistical Report for Financial Analysis 1969 - 1979: Phoenix, Arizona, Arizona Public Service Company, 24 p.

Stone, C., 1980, Preliminary Assessment of the Geothermal Potential at the Papago Farms, Papago Indian Reservation, Arizona: State of Arizona Bureau of Geology and Mineral Technology Open-File Report 80-6, 62 p.

Stone, C., 1981, A Preliminary Assessment of the Geothermal Resource Potential of the Yuma Area, Arizona: State of Arizona Bureau of Geology and Mineral Technology Open-File Report 81-4, 28 p.

Survey and Analysis of Solar Energy Process Heat Opportunities in Arizona, 1979: University of Arizona, Department of Nuclear Energy, Energy Management and Policy Analysis Group, Final Report prepared for Arizona Solar Energy Research Commission under Office of Economic Planning and Development Contract No. 458-78

Swanberg, C.A., Morgan, P., Stoyer, C.H., and others, 1977, An Appraisal Study of the Geothermal Resources of Arizona and Adjacent Areas in New Mexico and Utah and Their Value for Desalination and other Uses: New Mexico Energy Institute Report No. 6, 76 p.

Tucson Trends 1980, 1980: Tucson, Arizona, Valley National Bank of Arizona and Tucson Newspapers Inc., 88 p.

Witcher, J.C., 1979, Proven, Potential and Inferred Geothermal Resources of Arizona and Their Heat Contents: State of Arizona Bureau of Geology and Mineral Technology Open-File Report 70-5, 65 p.

Witcher, J.C., 1981, Geothermal Energy Potential of the Lower San Francisco River Region, Arizona: U.S. Geological Survey Open-File Report 81-7, 135 p.