# GEOTHERMAL DEVELOPMENT PLAN: YUMA COUNTY

Prepared by

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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 Yuma County. One hot spring and 33 wells drilled in the county discharge water at temperatures sufficient for direct-use geothermal applications such as process heat and space heating and cooling. Currently, one industry within the county has been identified which may be able to use geothermal energy for its process heat requirements. Also, a computer simulation model was used to predict geothermal energy on line as a function of time under both private and city-owned utility development of the resource.

## 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 Yuma County. 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

Yuma County lies entirely within the Basin and Range physiographic province which is characterized by numerous mountain ranges rising abruptly from broad valleys. At least five areas known to store thermal water at relatively shallow depths of less than 1200 m (3940 ft) are located within the county. 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.

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

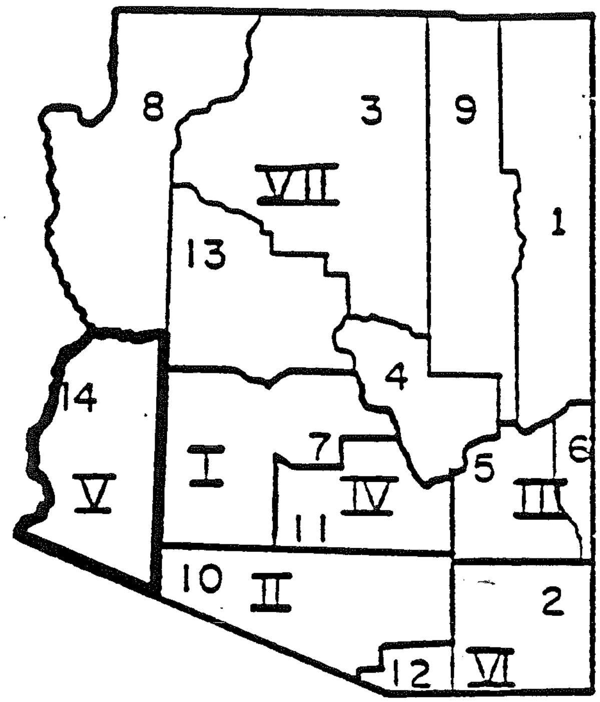



Figure 1: Area Development Plans for Arizona.

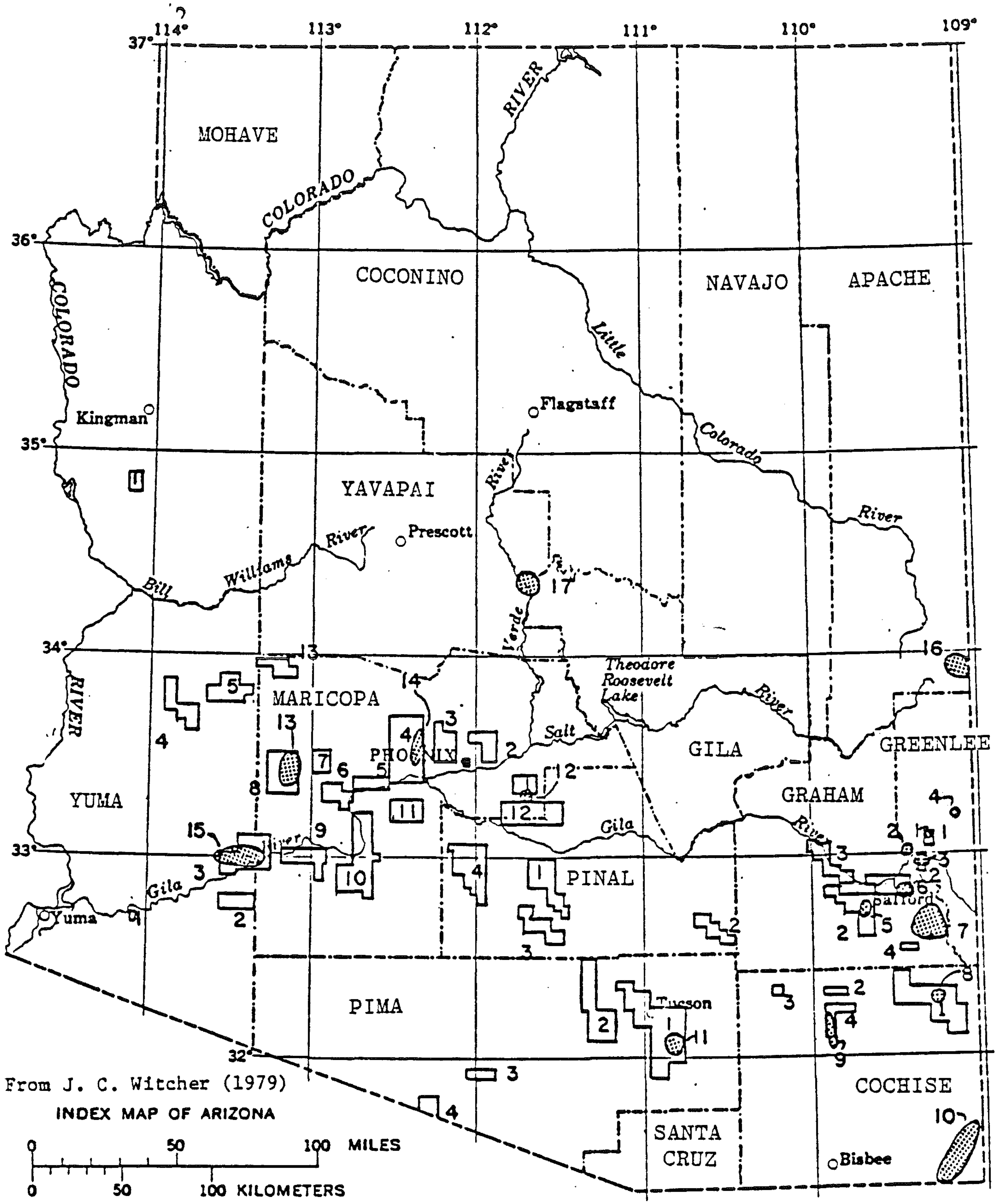



Figure 2: Arizona's Proven, Potential and Inferred Resources.

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

Modified from Witcher (1979) Tr – Average reservoir temperature

| Area | Location | Volume ($km^3$) | Measured (°C) Temperature | Depth (km) | Tr (°C) | Geothermometry Temperature (°C) | Method |
|---|---|---|---|---|---|---|---|
| 1 | T8-9S, R19W | 3.1 | 50-60 | <0.015 | 60 | 60-70 | Quartz |
| 2 | T7-8S, R11-12W | 65.0 | 30-40 | <0.21 | 65 | 40-70 | Chalcedony |
| 3 | T4-6S, R10-12W | 148.6 | 30-45 | <0.46 | 70 | 60-80 | Chalcedony |
| 4 | T3-6N, R14-16W | 83.6 | 30-45 | <0.46 | 60 | 40-70 | Chalcedony |
| 5 | T5-6N, R11-13W | 123.8 | 30-40 | <0.46 | 50 | 30-40 | Chalcedony |

One hot spring in Yuma County provides directly observable evidence of geothermal energy. Water discharged from the spring when it was flowing had a temperature of 60°C (140°F) and a total dissolved solids content of 2240 ppm.

Thirty-three thermal wells in the county discharge water at temperatures ranging from 35.0°C (95°F) to 42.5°C (108.5°F) and depths from 91 m (300 ft) to 602 m (1975 ft). Flow rates range from 2,271 to 12,665 liters per minute. Total dissolved solid content ranges from as low as 327 ppm to as high as 4450 ppm.

The Yuma area itself, located in the extreme southwestern corner of Arizona, lies principally in the Sonoran Desert subprovince of the Basin and Range physiographic province. A small portion of this area lies within the Salton Trough subprovince, a deep, sediment-filled structural basin extending through Mexico, Arizona and California. At least a dozen geothermal anomalies have been identified in the Salton Trough. These anomalies do not necessarily indicate a geothermal resource but they do indicate geothermal potential (Stone, 1981).

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 avialable in late 1981.

## ECONOMY

### Population

The 1980 population for Yuma County was 90,554. Total land area of the county is 9,991 square miles which results in a population density of 9 persons per square mile. However, over 50 percent of the population resides in the city of Yuma. Ethnic breakdown of the population is 65 percent white, 27 percent Hispanic, 4 percent Indian and 3 percent black.

Growth

Between 1950 and 1960, the population of Yuma County increased at an average annual rate of 5.1 percent. From 1960 to 1970, the population increased at a rate of 2.7 percent per year. These increases were slightly below the state annual average rates of 5.7 and 3.1 percent for 1950 to 1960 and 1960 to 1970, respectively. Figure 3 presents population projections to the year 2020. The implied annual growth rate over the next 40 years is almost two percent.

Industry and Employment

Agriculture, the primary employment sector in Yuma County, accounted for 33 percent of the county's employment in 1978 and 12 percent of its personal income in 1977. Yuma County produced 47.5 percent and 45.0 percent of the state's major citrus crops during the 1976-1977 and 1977-1978 seasons, respectively. Principal crops are cotton, hay, wheat, corn, barley and sugarbeets.

Recently, there has been a decline in total cash receipts from agricultural products in Yuma County. From 1976 to 1977, there was a decline of approximately 11.4 million dollars or 5.1 percent of total revenue from agriculture. This decrease is attributed to the decline in livestock receipts. Crop and citrus fruit receipts, however, will continue to prosper.

Presently, Yuma County has several light industries. These include men's clothing, paper plates, photo processing equipment and ceramic

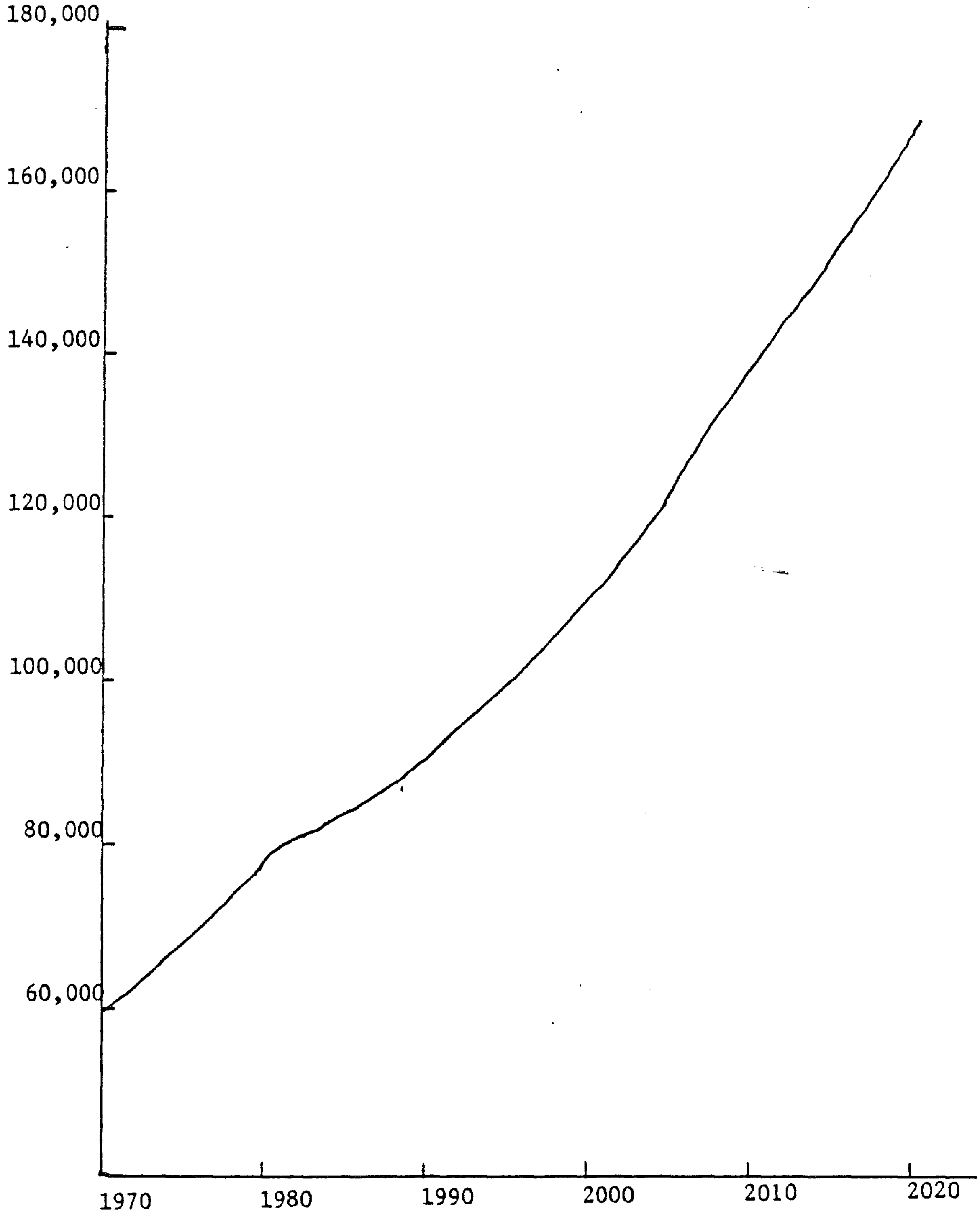



Figure 3: Population Projections for Yuma County to 2020.
Source: Technical Advisory Committee

highway markers. Yuma County also serves as a distributional center for McDonnell-Douglas Corp, Hughes Helicopter, Broder Machinery, and Lipe Clutel Division of Lipe-Rollway.

Yuma County's Chamber of Commerce is actively seeking and encouraging new industry. Several new industries are projected for the county.

LAND OWNERSHIP

Figure 4 presents a general land ownership map for Yuma County. The majority of the land is owned by the federal government. Table 3 shows acres owned by various sectors.

TABLE 3: BREAKDOWN OF LAND OWNERSHIP IN YUMA COUNTY

| Sector | Percentage | Total Acres |
|---|---|---|
| Federal | 81 | 5,176,710 |
| Private | 8 | 511,280 |
| State | 7 | 447,370 |
| Indian | 4 | 255,640 |
| Total | 100 | 6,391,000 |

ENERGY USE

Arizona Public Service Company provides both electric power and natural gas to Yuma County. The primary source of electrical power in the Yuma area is the 2,085-MW Four Corners Generating Station which is interconnected with the 161-KV United States Bureau of Reclamation transmission network at Parker, Arizona. One-third of the 75-MW capacity at the Yucca Plant in Yuma is allocated to the immediate Yuma area. Two 2.5-MW and two 60-MW natural gas turbines are used for peaking.

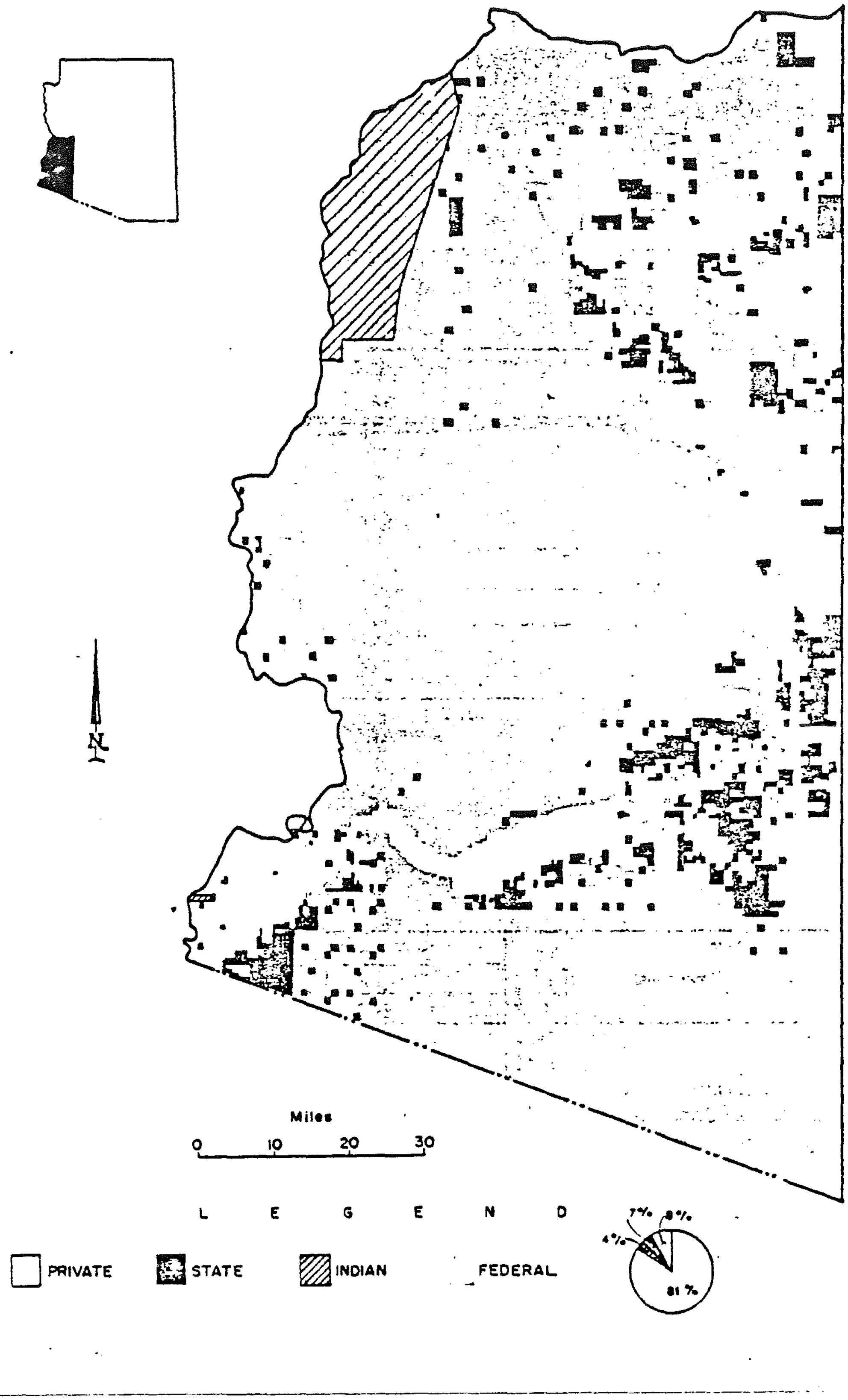



Figure 4: General Land Ownership Map for Yuma County.
Source: Arizona Water Commission (1977)

WATER

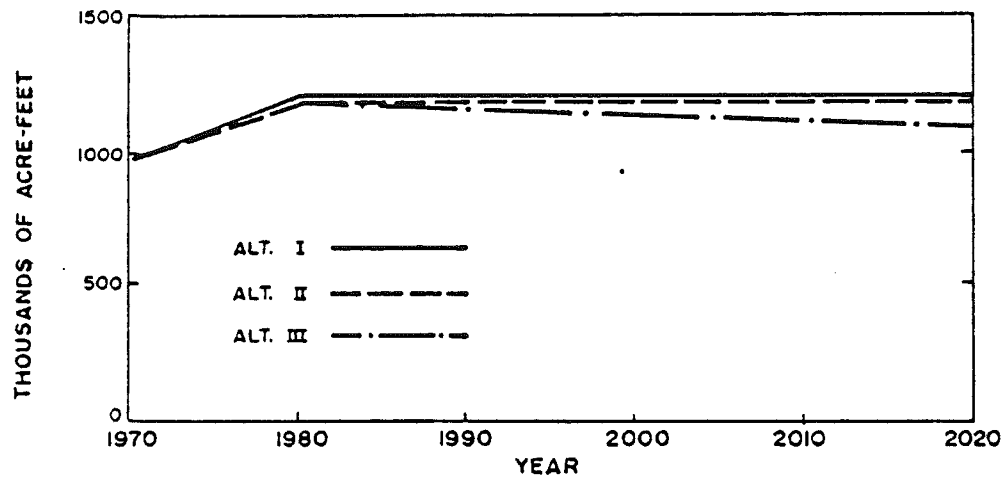
Three alternative futures for water depletion in Yuma County are presented in Figure 5. These alternatives provide a range of possibilities which might emerge depending on factors such as population growth, industrial development and consumer habits and lifestyles.

The rapid population growth projected for Yuma County will result in increased water depletion. However, water depletion associated with the projected population increase is relatively insignificant when compared to anticipated agricultural depletions. The data in Figure 5 show that urban use represents about two percent of total depletions under all three alternatives while agriculture accounts for approximately 95 percent.

Currently, only 900 acre-feet of water per year is consumed for steam electric power generation. Arizona Public Service is planning construction of another electric power generating facility near Bouse, Arizona. As a result, depletions for cooling steam electric power plants are projected to increase in Yuma County after 1990.

Dependable supplies along the Colorado River are projected to equal depletions. Although users along the river will have a dependable supply, other areas will experience groundwater overdraft. Thus, small deficiencies are projected under Alternatives I, II and III for Yuma County.

## PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY




## ALTERNATIVE FUTURES SUMMARY

| ITEM (Quantities in Thousands) | 1970 | ALTERNATIVE I 1990 | I 2020 | II 1990 | II 2020 | FUTURES III 1990 | III 2020 |
|---|---|---|---|---|---|---|---|
| POPULATION | 60.8 | 118.0 | 200.0 | 96.1 | 136.0 | 96.1 | 136.0 |
| HARVESTED ACRES | 247.0 | 301.0 | 318.0 | 298.0 | 318.0 | 288.0 | 295.0 |
| URBAN DEPLETIONS AF/YR | 13.0 | 18.1 | 29.3 | 15.1 | 20 6 | 15.1 | 20.6 |
| STEAM ELECTRIC DEPLETIONS AF/YR | 0.9 | 0.7 | 26.9 | 0.5 | 11.6 | 0.5 | 11.6 |
| MINERAL DEPLETIONS AF/YR | 0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 |
| ARGICULTURAL DEPL. AF/YR | 954.0 | 1170.0 | 1150.0 | 1160.0 | 1150.0 | 1120.0 | 1070.0 |
| TOTAL WATER DEPL. AF/YR[1] | 970 | 1219 | 1238 | 1206 | 1214 | 1166 | 1134 |
| DEPENDABLE WATER AF/YR[2] | 1086 | 1118 | 1127 | 1121 | 1127 | 1121 | 1127 |
| SURPLUS SUPPLY (Def.) | 116 | (101) | (111) | (85) | (87) | (45) | (7) |

[1] Includes 2 000 acre-feet depleted for fish and wildlife purposes in 1970 and 29 400 acre-feet in 1990 and 2020
[2] Dependable supply from the Colorado River is equal to depletions for all alternatives Off-river dependable supply was added to determine total county dependable supply Deficiencies only occur from off-river uses Dependable supply for 1970 includes unmeasured return flows

Figure 5: Projected Alternatives for Water Use in Yuma County.
Source: Arizona Water Commission (1977)

## MATCHING GEOTHERMAL RESOURCES TO POTENTIAL USERS

Some prospects for geothermal applications in Yuma County are indicated. Table 4 presents an estimate of industrial process heat requirements on an annual basis for the ready-mix concrete industry. Based on the assumed reservoir temperature of 70°C (158°F) this industry is considered a potential user of geothermal energy. It should be noted that industrial process heat requirements do not include energy consumed for space cooling or heating.

TABLE 4: ESTIMATED PROCESS HEAT ENERGY REQUIREMENTS
Assumed Reservoir Temperature: 70°C

| SIC Code | Industry Description | Process Heat Temperature | Energy Use $10^{10}$ Btu/yr |
|---|---|---|---|
| 3273 | Ready-Mix Concrete | 65°C | 0.85 |

Other industries in Yuma which may be able to use geothermal energy for their space heating and/or process heat needs include Blue Bell, Incorporated, The Gowan Company, Southwestern Ice and Coca-Cola Bottling Co. and Sun Printing Company.

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. For modeling purposes, it was assumed that geothermal energy comes on line when it becomes the lowest cost energy source. Figure 6 presents energy on line assuming a city-owned utility developed the resource; Figure 7 presents energy on line assuming private development of the potential resource. The differences result from differing costs of capital.

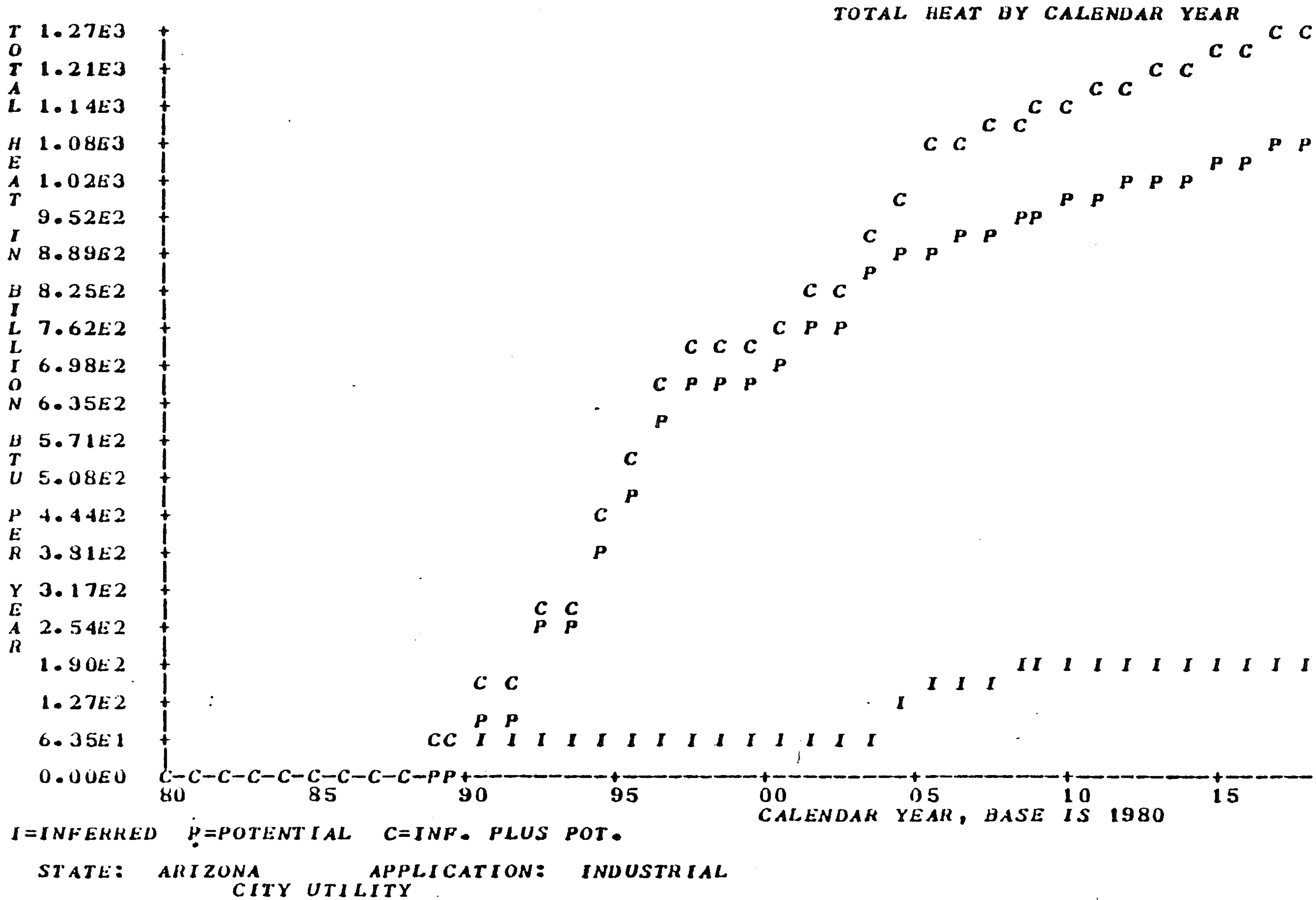



Figure 6: Projected Geothermal Heat On Line Under City Development.
Source: New Mexico Energy Institute

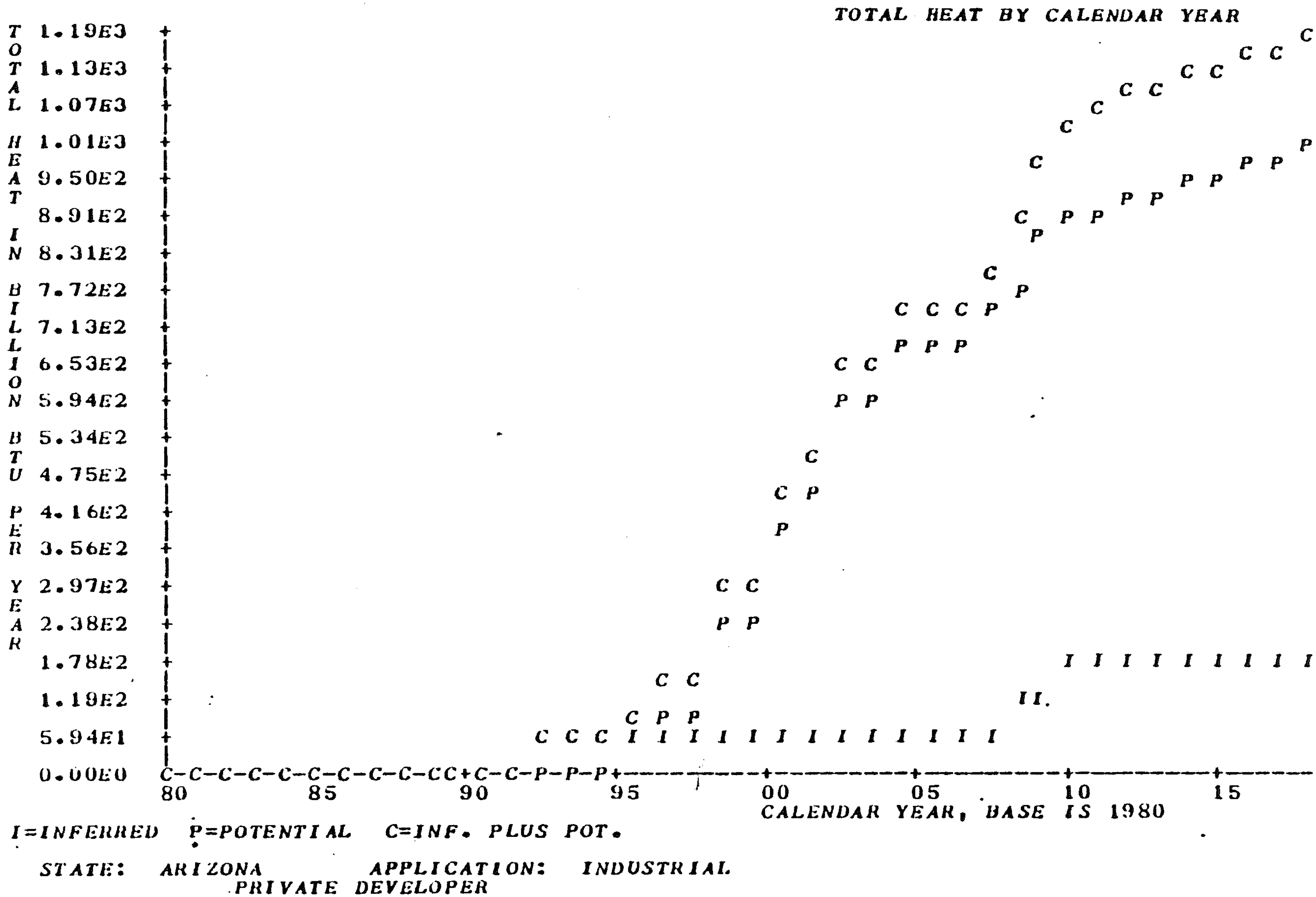



Figure 7: Projected Geothermal Heat On Line Under Private Development.
Source: New Mexico Energy Institute

Results from Figures 6 and 7 can be summarized as follows. Under private development, geothermal energy would come on line by 1993 and would grow steadily until 2020. Under city utility development, geothermal energy would be cost competitive by 1989. Thus, city utility development results in faster development of the resource. Table 5 reports energy on line in terms of barrels of oil replaced by geothermal energy annually. It is apparent that in the process heat market, geothermal

TABLE 5: BARRELS OF OIL REPLACED BY GEOTHERMAL ENERGY PER YEAR
Process Heat Market

| | 1985 | 1990 | 2000 | 2020 |
|---|---|---|---|---|
| Private Developers | 0 | 0 | 53,393 | 212,500 |
| City Utility | 0 | 9196 | 132,142 | 226,785 |

energy could replace a significant number of barrels of oil by the year 2020.

The NMEI model for predicting geothermal energy on line is discussed more fully in Appendix A.

Modeling comparable to the above work was also performed for the residential and commercial sectors. However, the scope of work was confined to space heating energy requirements. The use of space heating in Yuma County is limited to a few winter months and would not justify the establishment of district heating systems. Thus, results from the residential and commercial sectors have been omitted.

Agribusiness and agricultural industries in Yuma County were also identified. Most agricultural processing is concentrated in citrus crops and in raising livestock. Future expansion of agricultural processing in Yuma County would have significant benefits for local residents and farmers. Geothermal energy might stimulate a local industry by providing a low-cost energy source suitable for agricultural and livestock processing and irrigation.

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

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