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Geothermal Energy Potential In the San Luis Valley, Colorado

by
Barbara A. Coe

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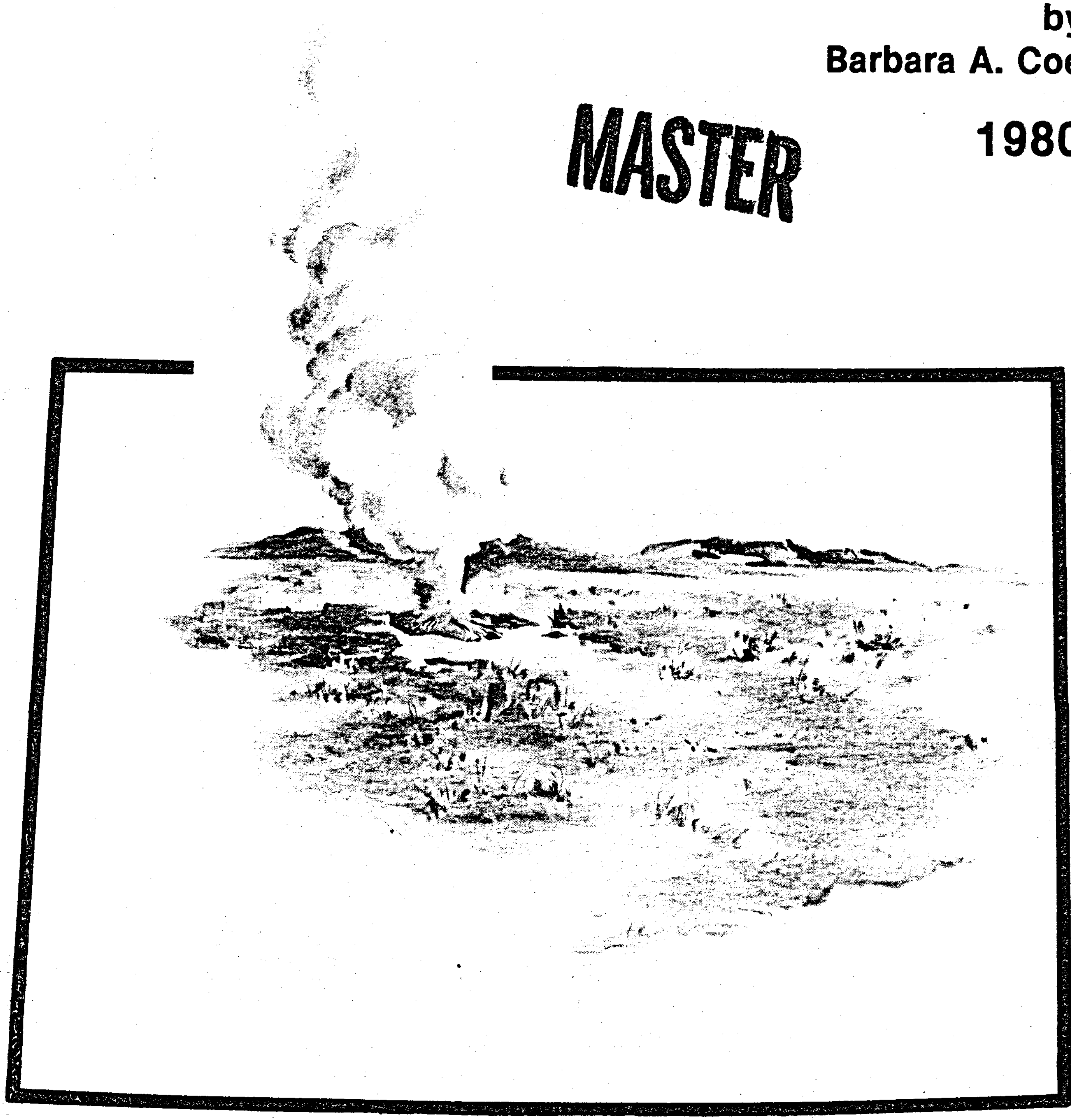

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GEOTHERMAL ENERGY POTENTIAL IN THE SAN LUIS VALLEY, COLORADO

BARBARA A. COE

1980

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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
Denver, Colorado

Prepared for the
U.S. Department of Energy
Division of Geothermal Energy

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PREFACE

Under a U.S. Department of Energy cooperative agreement, the Colorado Geological Survey is funded to conduct a Geothermal Energy Commercialization Project. That project has two primary facets: an outreach, or information and technical assistance facet, and an analysis facet. Inasmuch as the analytical phase can be conducted at site-specific, areal, or statewide levels, this document reports the results just of an area analysis of the San Luis Valley in Colorado.

Area analyses are directed toward several purposes. First, by analyzing all the primary conditions that affect geothermal energy development, an estimate can be made of the amount of energy that can be brought on line. This estimate in turn can indicate the potential value of efforts to aid the development process. It can also help rank sites so that priorities for activity can be established on the basis of the magnitude of the energy potential and the liklihood of development.

Secondly, constraints to development can be identified so that recommendations can be made for ways to overcome those constraints. Thirdly, the document itself can be used to help the geothermal energy market. This analysis addresses a large number of characteristics of the area and puts them together into a comprehensive framework to derive estimates for possible energy on line. Those estimates indicate geothermal energy could ultimately satisfy most of the thermal energy demand of communities throughout the San Luis Valley, as well as significantly aiding the economic development of the region. The primary constraint to such development that was identified in the study was the lack of knowledge of the economic advantages and of the resource itself. It is hoped that this report can help to fill the information gap.

Since the data for this report and the report itself were compiled in early 1979, some new information has been collected. Two investigations are currently underway. The Colorado Geological Survey is conducting preliminary resource exploration work, and Coury & Associates is conducting an evaluation of the potential of a number of sites for agriculture. These and other studies should be of enormous benefit in supplying the necessary information to help encourage the development of the valuable geothermal energy in the San Luis Valley.

I. INTRODUCTION

The San Luis Valley Region (Colorado Planning and Management Region 8) (Figure 1), south-central Colorado, is considered by many residents to be a prime area for geothermal energy development. Several very successful geothermal agricultural facilities are located there now (see Section III). This report attempts to indicate what amount of geothermal energy is currently used and what the long-range potential is for further development in the valley.

For this analysis, several kinds of investigations are conducted. The first is an investigation of the background of the area itself (Section II). The attributes considered are the geography, population, economy, and attitudes of the residents. Considered, too, are the energy demands of the area, specifically the moderate temperature thermal energy. Both existing and forecast demands are examined.

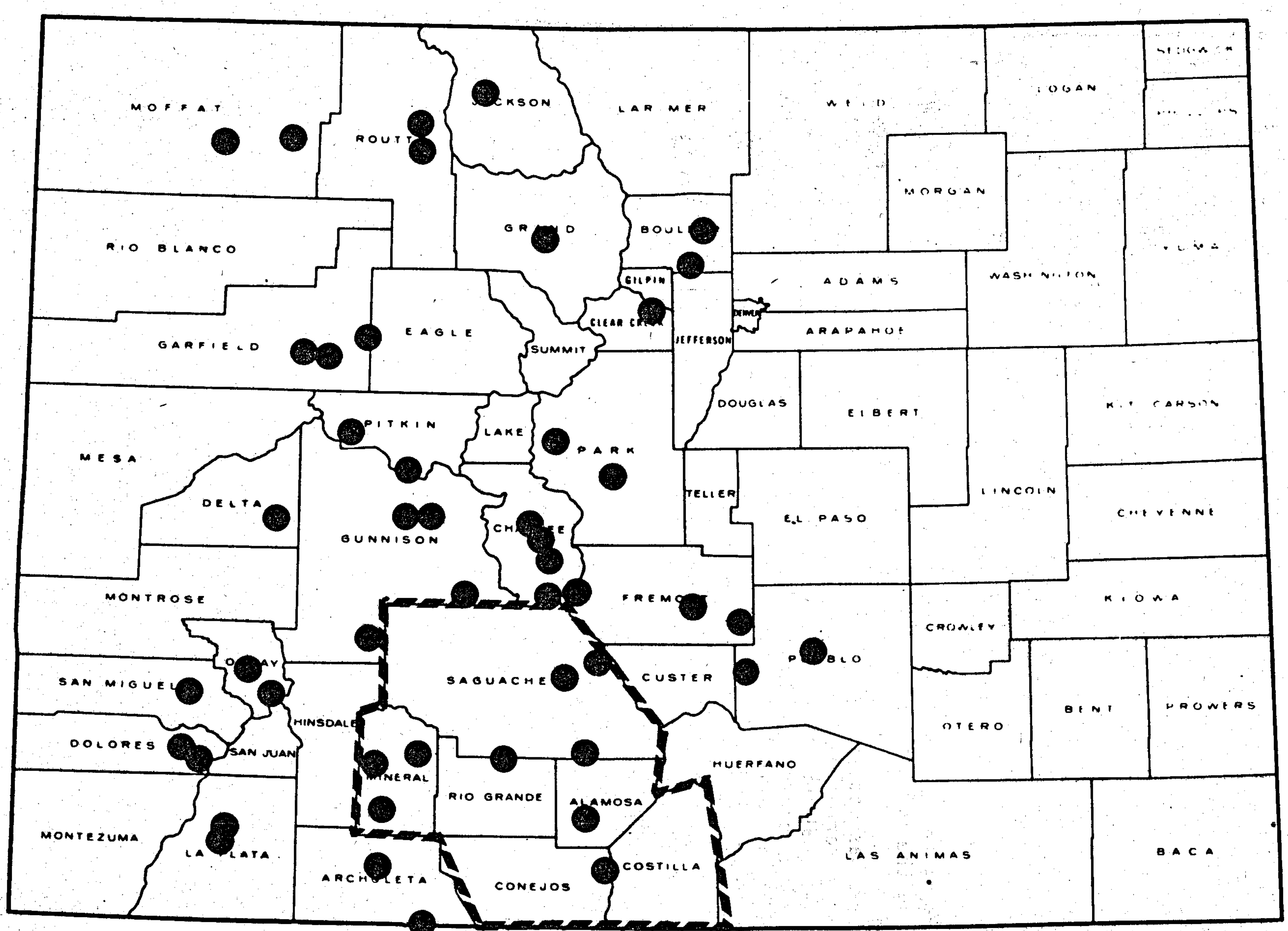


FIGURE 1. LOCATION OF COLORADO REGION 8 AND THERMAL WATERS.

Section III considers the requirements for geothermal energy development. These include socio-economic, institutional, and environmental conditions as well as some technical aspects that are possible to examine prior to a detailed investigation. Because economic considerations are critical elements in any development decisions, these are explored, albeit somewhat superficially.

In Section IV, the current, proposed, and potential geothermal energy developments are described. After the estimated usable thermal energy is matched with the estimated demand, a possible schedule of activities is hypothesized. It should be stressed, however, that this is but one scenario of many possible ones, and does not imply a prediction for the future. Although it is considered to be quite realistic, enterprising and innovative enterpreneurs may far exceed the existing indications. Conversely, lacking such entrepreneurs, the resource may remain comparatively undeveloped.

Section V is the summary and conclusions section of the report. An appendix describing the methodology follows.

This report was compiled, for the most part, from data obtained from secondary sources as referenced in the text. An attempt was made to avoid generating new data or duplicating the efforts of others. Few problems were encountered in obtaining the necessary data, although in some cases, a judgement was necessary about which of several sources would be most accurate. Also, it is most unfortunate that because of the schedule, this report could not wait for the results of two significant studies. One of them, Non-Electric Utilization of Geothermal Energy in the San Luis Valley, Colorado (Coury & Assoc., 1978a), has just been obtained and was, therefore, not used as a source for this report. The other, a comprehensive study of energy demand conducted by the Colorado Energy Research Institute, will be completed soon. Lacking this latter information, estimates were made of the energy demand. These and other analyses are described in the methodology section.

II. DESCRIPTION OF AREA

Region 8 is an 8,180 square mile area, including six counties: Alamosa, Conejos, Costilla, Mineral, Rio Grande, and Saguache. As Figure 1 shows, it is located in south-central Colorado. It is a huge, alluvial valley, called the San Luis Valley, bordered by mountain peaks on three sides and by the New Mexico state line on the south. As the topographic map of Figure 2 shows, the terrain varies dramatically among parts of the Region. The Rio Grande River originates in the western part of the region in Mineral County and flows through the lower valley.

Land Use and Ownership

A generalized land use map (Figure 3) by the San Luis Valley Council of Governments shows the land use in Region 8. As shown, irrigable cropland is the primary use in the central valley. Much of the western third is forested land. The eastern third is primarily salt desert shrub land. Small areas of pastureland are scattered throughout the region (SLVCOG, 1973).

Slightly more than half of the land in the region is publicly-owned. As shown on Table 1 and Figure 4, federal and state land ownership constitute a total of 57 percent of the land in the six-county area. Even more significant than the

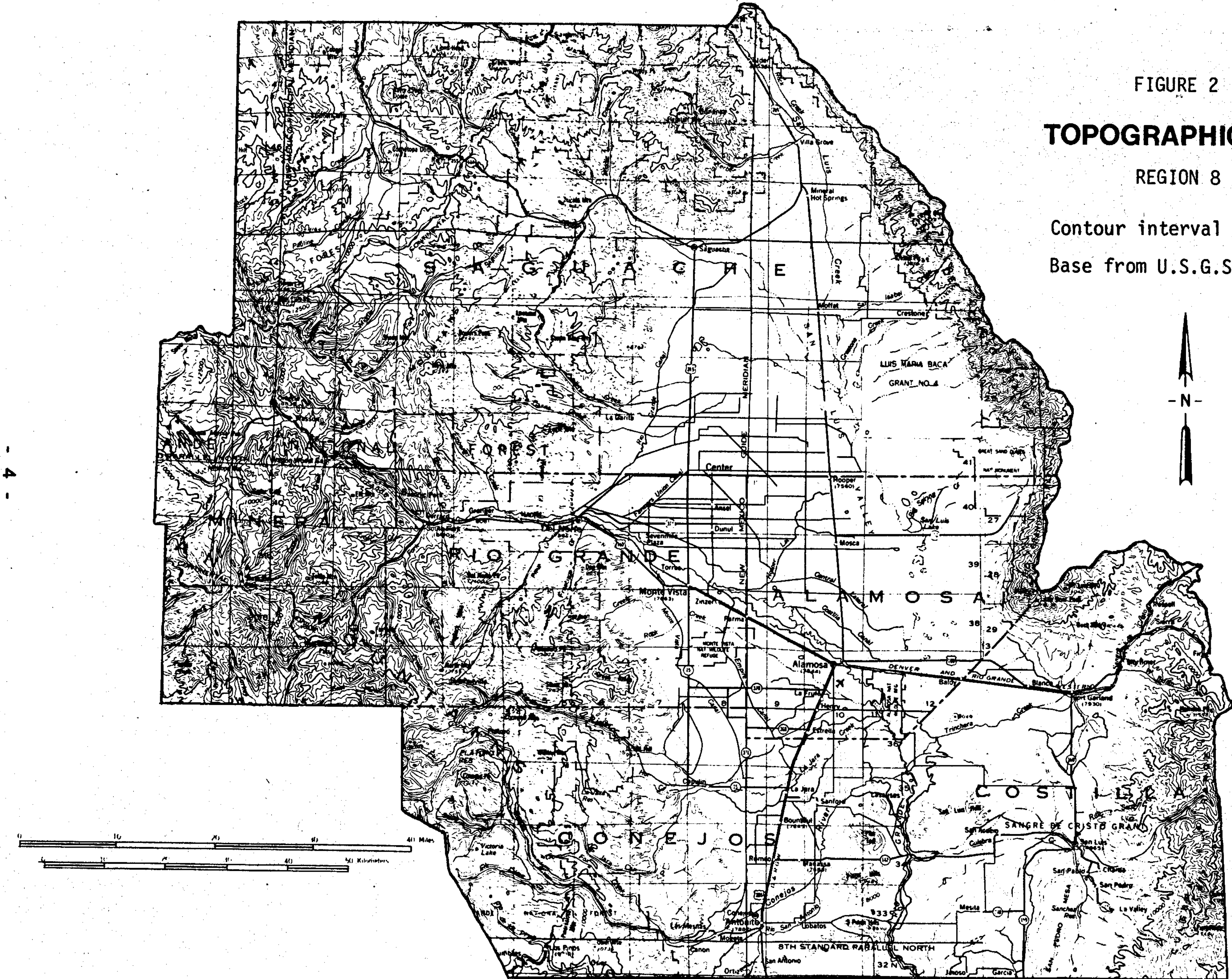


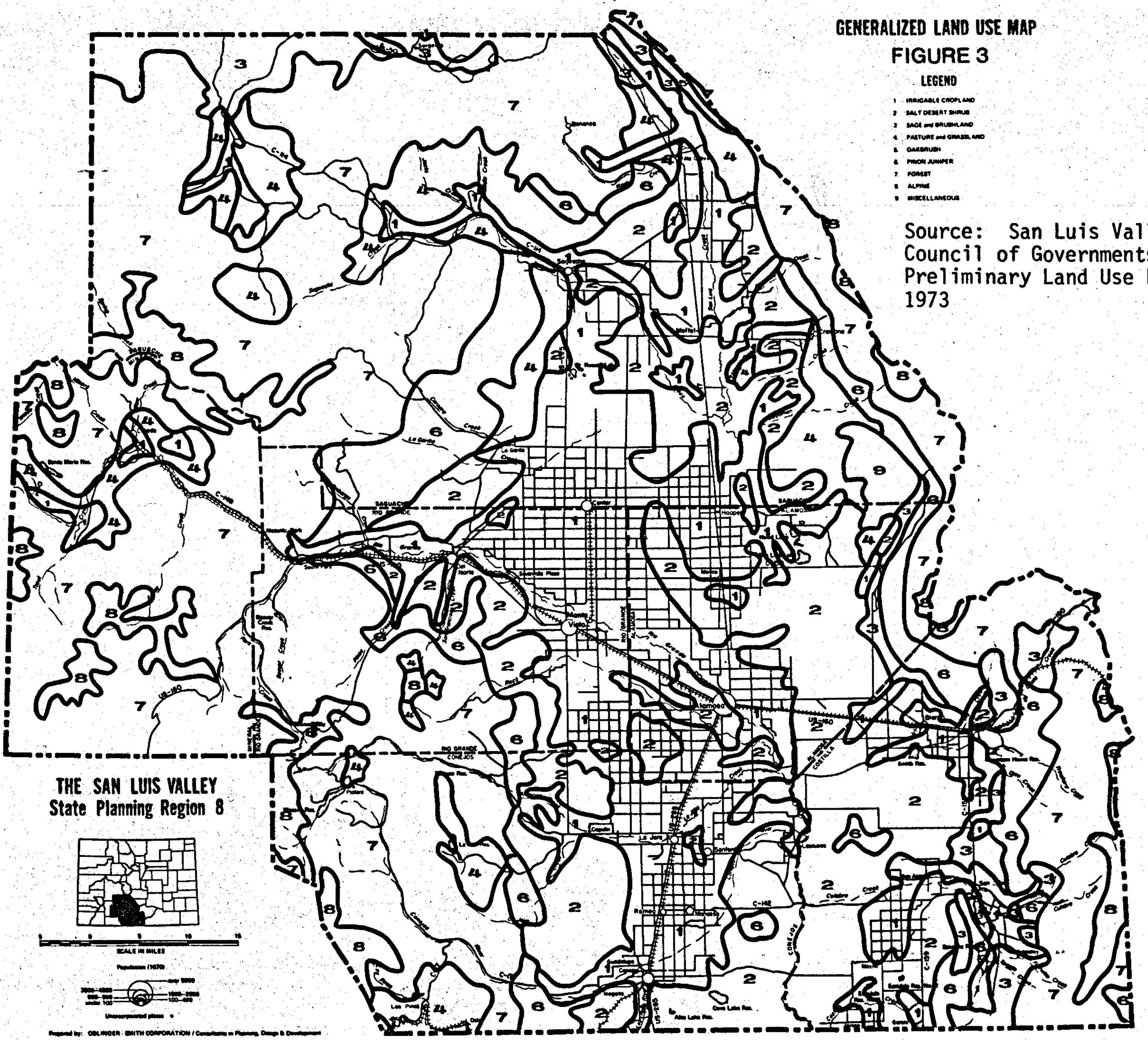
FIGURE 2

TOPOGRAPHIC MAP

REGION 8

Contour interval 500 feet

Base from U.S.G.S.



GENERALIZED LAND USE MAP

FIGURE 3

Source: San Luis Valley Council of Governments, Preliminary Land Use Plan, 1973

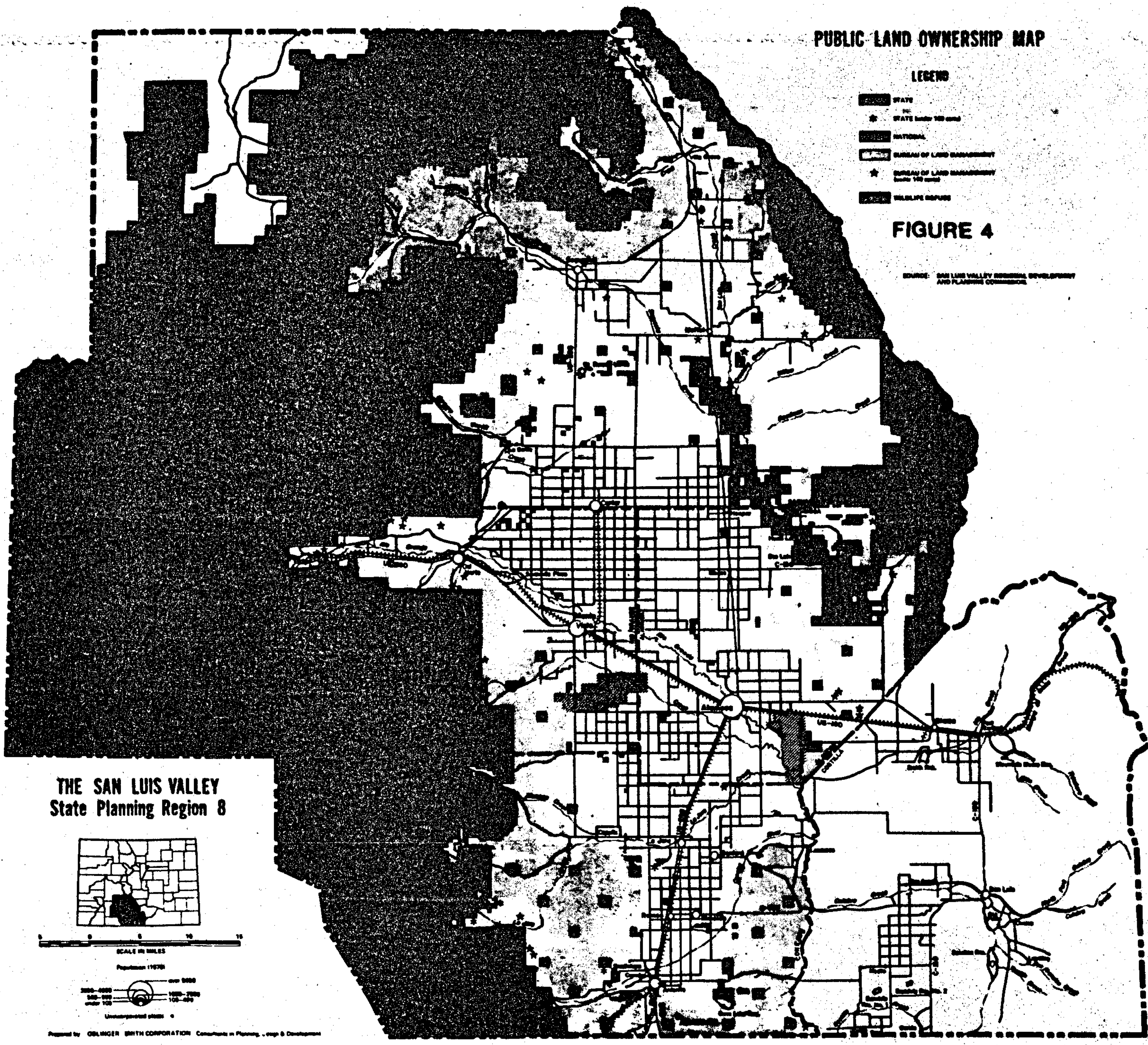

PUBLIC LAND OWNERSHIP MAP
LEGEND
STATE
NATIONAL
WILDLIFE REFUGE
THE SAN LUIS VALLEY
State Planning Region 8
SCALE IN MILES
US-160

FIGURE 4

TABLE 1
GENERALIZED LAND USE
SAN LUIS VALLEY REGION
(OWNERSHIP BY ACREAGE)

County	Private Land	Federal Land	State Land	County and Municipal	Total
Alamsoa	316,813	84,258	49,250	1,014	451,335 Acres
Conejos	272,149	459,952	57,954	140	790,195 Acres
Costilla	770,109	-	-	1,267	771,376 Acres
Mineral	35,630	525,287	60	3,472	564,449 Acres
Rio Grande	235,971	320,755	13,836	824	571,386 Acres
Saguache	590,693	1,329,876	95,195	180	2,051,944 Acres

Source: 1970 Colorado Marketing Manual (In Preliminary Land Use Plan, SLVCOG, 1973)

land ownership proportions may be the land ownership patterns. Where federal and state-owned lands or minerals alternate with private lands in a checkerboard fashion, an energy developer must often obtain federal or state leases in order to protect his investment in exploration and development.

Population

There are an estimated 42,000 residents in the region, the majority of them in communities. The 17 incorporated municipalities in the area range in size from 10 residents at Bonanza to 8,420 residents at Alamosa (Colorado Division of Planning, 1976). Although the rural population is a large percentage, one-third of the residents are located in the urban communities of Alamosa and Monte Vista and another 29 percent are in the remaining 15 non-farm communities (Div. Bus. Res., 1976). As Figure 5 shows, concentrations of population are generally congruent with the locations of identified thermal wells and springs.

Economic Activity

The economic basis of the San Luis Valley has historically been agricultural. Large percentages of the total state production of several crops are produced there, including 100 percent of the spinach, 83 percent of the potatoes, 85 percent of the lettuce, 20 percent of the carrots, and 38 percent of the barley. Hay, cattle, sheep, hogs and pigs are other important products (Div. Bus. Res., C.U., 1976).

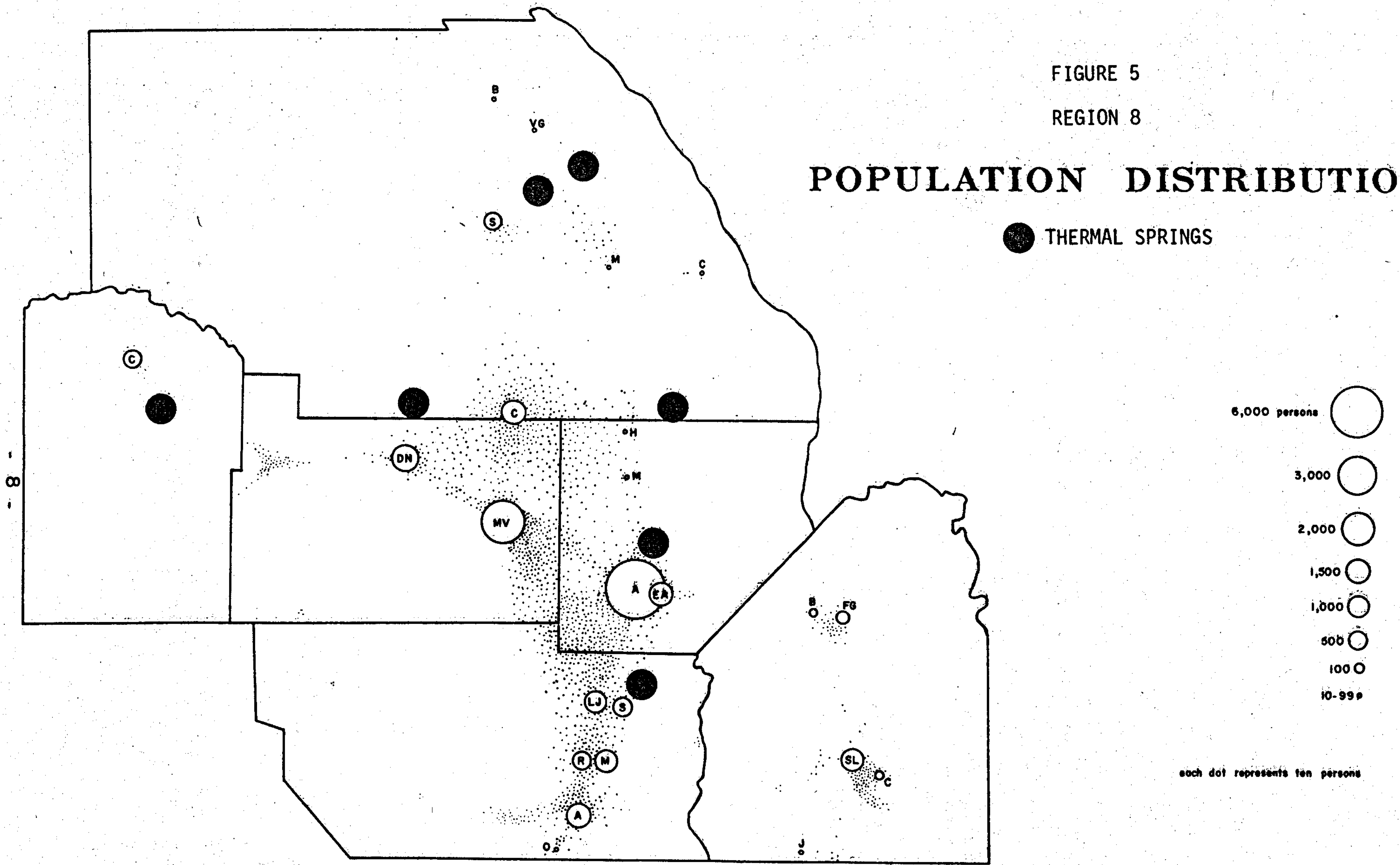
Mining is another important industry, especially in Mineral County, "one of the richest silver producers in Colorado history" (Div. Bus. Res., C.U., 1976). Recreation and tourism activity are growing, too, and have enormous growth

FIGURE 5

REGION 8

POPULATION DISTRIBUTION

THERMAL SPRINGS



Source: San Luis Valley Council of Governments, Preliminary Land Use Plan, 1973 potential. Natural attractions abound, including the Great Sand Dunes National Monument, the Wolf Creek Ski Area, three national forests, high mountain ranges, and a spectacular narrow gauge railroad trip. Cultural attractions include Spanish villages and the early mining town of Creede, which are enhanced by their festivals and museum displays (Div. Bus. Res., C.U., 1976).

Although the manufacturing sector employed only 6 percent of the region's labor force in 1974, it is the most rapidly expanding sector of the economy. Its expansion is encouraged as part of a region-wide goal to achieve balanced growth and development. To aid this goal, industrial parks and other plant locations are available throughout the valley. Industrial development corporations, revenue bonds, and Small Business Administration loans are available to assist in financing fixed capital requirements (Div. Bus. Res., C.U. 1976,). Because the area has a high unemployment rate and low incomes, environmentally-compatible economic development is being actively encouraged by numerous state, local, and federal organizations.

Unfortunately, the economic conditions which make economic development appealing also impose restrictions. Local governments are limited by the lack of strong revenue bases. The ability to provide the support facilities and services is then limited. It is further constrained by the diseconomies of scale of such facilities and services for very small communities (SLVCOG, 1977). In such settings, it is impossible, furthermore, to have large staffs of specialized professionals with the time and skills to handle numerous and diverse technical problems. The initiation of programs to share some services can overcome this restraint to a large degree but cannot remedy the problem of too small a demand for water and sewer services or geothermal heating to justify the cost.

Other conditions influence the location of new industry and residents and thus will indirectly affect the demand for geothermal energy development. These include the need for more efficient and economical transportation facilities and the need for sufficient electricity at reasonable rates. Furthermore, the capital and operating costs for fertilizer and farm equipment affect the development potential (SLVCOG, 1977).

Attitudes

The goals expressed by the San Luis Valley Council of Governments (SLVCOG), an organization of the local governments throughout the region, are amenable to geothermal development. As shown on Table 2, among the high-priority activities are the preservation of the agricultural industry, the development of agricultural processing plants, and the development of alternative energy sources (SLVCOG, 1977). Another source, the San Luis Valley Resource Conservation and Development Agency (SLVRC&D), suggests as objectives the identification of uses for timber by-products and the promotion of exploration, extraction and processing of metallic and nonmetallic ores in a manner that will preserve natural scenic values (SLVRC&D,1977). Geothermal energy might supply the energy necessary for processing such products.

TABLE 2

SUMMARY OF ECONOMIC DEVELOPMENT

PRIORITIES QUESTIONAIRE

SAN LUIS VALLEY COUNCIL OF GOVERNMENTS

The following is a list of economic projects ranked in priority order as determined by the Economic Development Questionaire:

Priority	Project	Total Points
1	Agricultural water projects	435
2	Community water and sewer projects	395
3	Solar energy demonstration projects for home and industrial use	389
4	Agriculture commodity processing firms	382
5	Increase availability of development or venture capital for new Valley industries	380
6	Fire and emergy medical care facilities and equipment	362
7	Expanded medical care for San Luis Valley	358
8	Moderate cost housing developments	341
9	Organizing new or supporting existing county development corporations for promoting new industries	335
10	Expanded vocational training programs and organizing rural development committees in each county to pursue and promote economic development	331
11	Development of geothermal deposits for home and industrial use	327
12	New or expanded electric generating facilities and bio-gas or other agricultural resource/energy plants	326
13	Regional industrial promotion and advertising	316

TABLE 2 (Cont.)

14	Regional tourism promotion and advertising	315
15	Small scale purchasing and selling cooperatives for smaller scale farm operators and other groups	313
16	Locating new State facilities in Region	303
17	Expanded public employment projects	294
18	Timber processing firms	287
19	New or improved industrial parks and Completion of major highway projects	285
20	Expanded recreation facilities for Valley residents	271
21	Small business management advisory service and Community curb, gutter and paving projects	266
22	Expansion of Adams State College enrollment/ facilities	264
23	Community/adult education projects	263
24	Rural public transportation system connecting Valley's municipalities	259
25	New winter sports areas, e.g., ski areas	245
26	Hiring an industrial development specialist	232
27	Speculative industrial building construction and Expanded airport facilities including jet service	223
28	Downtown shopping district renovations	207

Source: San Luis Valley Council of Governments, 1977.

Energy Demand

In order to estimate the potential for geothermal energy use, it is necessary first to investigate the existing consumption of energy and to forecast energy consumption for the future. Because natural gas is the primary fuel used to satisfy the energy demands for which direct thermal use of geothermal energy is appropriate, it is used as a basis for comparison. As shown in Table 3, natural gas is distributed in 13 communities, some of which are incorporated communities. Those remaining are unserved.

As Table 4 shows, a total of 1,594,400 Mcf was consumed in 1977 throughout the Valley, most of that being used by residential and commercial customers. To account for the thermal energy demand in those communities not served by natural gas, estimates were made based on consumption in served areas (see Appendix A - Methodology). Table 5 shows the estimated current and forecast residential and commercial thermal energy demand for selected communities in Region 8.

The industrial demand was identified from a list of all manufacturers in the region, their annual energy requirements, and process temperatures required (Table 6). From this list, manufacturers that might be candidates for geothermal energy use can be selected. The forecast industrial demand is treated separately (Section IV) because of the specificity of the process uses for which geothermal energy is appropriate.

Although 13 Region 8 communities have natural gas service, a moratorium on new natural gas taps was in effect from 1973 through 1978 (George Parkins, pers. comm., 1978). The supplier recently announced the lifting of that moratorium (Denver Post, November 29, 1978). While it was in force, long waits for gas taps forced some consumers to turn to electricity or propane for heat, both more expensive than natural gas (George Parkins, pers. comm., 1978). Even though the moratorium has been lifted, supplies are not expected to satisfy totally the demand. Futhermore, industrial users are often on interruptible service (George Parkins, pers. comm., 1978), and the energy dependency of the valley, which imports 45 percent of its electrical energy and all of its petroleum products, would seem to stimulate a demand for alternative forms of energy (SLVCOG, 1977).

III. REQUIREMENTS OF GEOTHERMAL ENERGY DEVELOPMENT

In order to speculate with any degree of realism about the geothermal energy development that could occur in Region 8, the requirements for that development must be investigated. This investigation is necessary, too, for understanding constraints that might be limiting such development. Among those considerations are institutional ones, which in this case are considered to be the policies and the practices of government agencies with which a potential geothermal developer must deal.

Institutional Considerations

Foremost among the institutional considerations that affect geothermal development are the leasing and permitting laws, regulations, and procedures of the federal, state, and local governments. Leases on public lands are often required for geothermal development, particularly in light of the checkerboard land ownership patterns discussed in Section II. Leasing on public lands in

TABLE 3
COMMUNITIES SERVED BY NATURAL GAS, 1977

Alamosa	Romeo
Antonito	Manassa
Conejos	Monte Vista
Capulin	Sanford
Guadalupe	Saguache
Del Norte	La Jara
Center	

Source: San Luis Valley Regional Planning and Development Commission, 1977.

TABLE 4

EQUIVALENT NATURAL GAS CONSUMPTION
SAN LUIS VALLEY
COLORADO
1977

	Residential		Commercial	
	MCF	Number of Customers	MCF	Number of Customers
Natural Gas Customers	794,879	5,050	689,719	936
Estimated Natural Gas Equivalent in Unserved Areas	143,496	925	123,407	165
Total Estimated Natural Gas Equivalent Consumption	938,375	5,975	813,126	1,101

Source: George Parkins, Public Utilities Commission and Estimates by Colorado Geological Survey.

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the San Luis Valley has been fairly extensive. However, a total of 39,744 acres of state leases and 1,163 acres of federal leases have been dropped in the past year (Colorado Land Board, U.S. Department of Interior, Bureau of Land Management, 1978). Since the focus of the lessees has been on electrical power generation, presumably the leases were dropped because evidence of high temperature resources was lacking. In spite of the dropped acreage, geothermal leases on 19,582 acres of state land and 12,670 acres of federal land are still in effect (see Table 7).

TABLE 5

ESTIMATED THERMAL ENERGY DEMAND
FOR SELECTED COMMUNITIES
IN REGION 8

COMMUNITY	ESTIMATED POPULATION 1975[1]	ESTIMATED DWELLING UNITS 1975	BTU'S X 10^{10} ESTIMATED RESIDENTIAL AND COMMERCIAL THERMAL ENERGY DEMAND 1975	FORECAST POPULATION 2020[4]	FORECAST DWELLING UNITS 2020	FORECAST RESIDENTIAL AND COMMERCIAL THERMAL ENERGY DEMAND 2020 BTU'S X 10^{10}	YEARLY ENERGY CONSUMPTION INCREASE
Baca Grande	300	107			218[5]		
Hooper	114	41		330	118		
Manassa	889	317		2,496	891		
San Luis	812	290		2,324	830		
Creede	624	223		1,083	387		
	2,739	978	15.213	6,233	2,444	38.016	0.46 (3%)
Alamosa	8,420	3,007		21,404	7,644		
Del Norte	1,788	639		2,713	969		
Sanford	667	238		1,754	626		
Center	1,594	569		2,424	866		
	12,469	4,453	69,266	28,295	10,105	157,183	2.03 (3%)
La Jara	796	284		2,298	821		
Romeo	332	118		883	315		
	1,128	402	6.253	3,181	1,136	17.671	0.25 (4%)
Monte Vista	4,487	1,602		6,783	2,423		
South Fork		204			445[5]		
Saguache	678	242		958	342		
Antonito	1,156	413		3,091	1,104		
GRAND	6,892	2,461	38.281	12,078	4,314	67.1043	0.76 (2%)
TOTALS	23,228	8,294	129.013	49,787	17,999	279.979	

[1]U.S. Bureau of the Census, 1978

[2]Based on average occupancy of 2.8 persons

[3]Based on 1977 residential and commercial consumption per residential customer

[4]Extrapolated from forecasts by Colorado Division of Planning

[5]Based on average region-wide community growth rate

TABLE 6
MANUFACTURERS
IN REGION 8
1976

Type[1]	SIC[1] Code	Number of Facilities	Btu's x 10^{10} Estimated Energy Need for each: SERI Data	Interplan Data	Low or Moderate Temp. Required(°C)
Meat packing plant	2011	2		1.831	177
Sausages and other prepared meats	2013	1		.451	177
Desserts	2024	1/2*	.964		77
Fluid milk	2026	1 1/2	1.590		77
Vegetables, soups	2034	1/2	6.610		177
Milk products	2041	1/2	1.039		121
Flour	2045	1/2	2.025	1.05	121
Wet corn milling	2046	1	2.025		121
Dog, cat, and other pet food	2047	1/2	3.701		121
Prepared foods	2048	1/2	2.849		274
Bread, cake, related products	2051	1	1.156		232
*Bottled and canned soft drinks	2086	1		.290	77
Food preparations & flour & other grain	2099	1 1/2	1.757		150
Leather & sheep lined clothing	2386	1/3	.233		121
Apparel belts	2387	1/3	.147		121
Apparel & accessories	2389	1	.182		121
Textile bags	2393	1/2	NA		
Logging camps	2411	2	NA		
Sawmills,planing mills	2421	5	.016		93
Bags, exc. textile	2643	1	1.520		149
Newspapers	2711	6 1/2	.216		149
Letterers	2751	1 1/2		.063	149
Lithographic	2752	2 1/2		.041	149
Fertilizers, mixing	2875	1/2		NA	200[1]
Agricultural chemicals	2879	1/2	4.401		149
Women's handbags and purses	3171	1/3	.164		93
Ready-mix concrete	3273	1/2	.001		66
Minerals, ground or treated	3295	4	22.127		1093
*Primary nonferrous metals	3339	1 1/2	17.085		
*Fabricated structural metal	3441	1	.792		93
*Sheet metal work	3444	1	.094		93
Fabricated metal products	3499	1/2	.481		93

TABLE 6 (Cont.).

Type[1]	SIC[1] Code	Number of Facilities	Btu's x 10^{10} Estimated Energy Need for each SERI Data	Interplan Data	Low or Moderate Temp. Required (°C))
Farm machinery & equipment	3523	1	NA		
Construction machinery	3531	1	3.081		1371
Conveyor & conveying equipment	3535	1/3		NA	
Blowers & fans	3564	1/3		NA	
Machine shops, jobbing & repair	3591	1/2		NA	
Motor vehicle parts & accessories	3714	1	3.081		1371
Truck trailers	3715	1/3	.960		316
Surgical appliances & supplies	3842	1	.520		93
Jewelry, precious metal	3911	3	.127		93
*Costume jewelry	3961	2	.202		93

Sources: [1]University of Colorado, Boulder, Business Research Division, Directory of Colorado Manufacturers, 1976; Interplan, Denver, Colorado, unpublished draft, 1978, and Solar Energy Research Institute, Denver, 1978, unpublished draft;

Note: Data from Interplan, (statewide averages), when average consumption values were available for Colorado; from SERI (nationwide average) when not available. Variations are wide.

*Where more than one activity was performed by a firm, the energy requirements were split proportionately.

Table 7
ACTIVE GEOTHERMAL LEASES ON PUBLIC LANDS
IN REGION 8, COLORADO
DECEMBER, 1978

Resource Area	Lease Number	Lessee	Lessor	Leased Acres	Description	County	Total for Area
Sand Dunes #34		General Geothermal	State	8,183.33	39N,12E, Sec. 5,6,7,18 39N,11E, Sec. 16 40N,11E, Sec. 25,26,27,34,35,36 40N,12E, Sec. 30: W1/2 E1/2, W1/2, 31.	Alamosa	
		General Geothermal	State	8,120.00	41N,10E, Sec. 13: N 1/2 NE 1/4 W 1/2, W 1/2 SE 1/4, 14,15,16,22,23, 24: S 1/2 NE 1/4; NW 1/4 NE 1/4; W 1/2; SE 1/4; 25,26,27,34,35,36	Saguache	16,303.33
Splashland #35		C. A. Underwood	State	1,120.00	33N,8E	Conejos	
		Geothermal Kinetics	BLM	1,000.60	37N,12E, Sec. 2, lots 3,4, S1/2 NW 1/4, SE 1/4 Sec 3: Lots 1-4, S 1/2 N 1/2 38N,13E, Sec. 30; Lots 1-4, Sec. 31: Lots 1-4	Alamosa	
		Geothermal Kinetics	BLM	827.31	38N,13E, Sec. 7: Lots 1-4 29S,73W, Sec. 7: Lots 1-4, E 1/2, E 1/2 W 1/2 (all)	Alamosa	
		Geothermal Kinetics	BLM	1,042.47	29S,73W, Sec. 17: all, Sec. 20: N 1/2, Sec. 31: Lot 2, NE 1/4 NW 1/4	Alamosa	
		Geothermal Kinetics	BLM	1,106.00	29S,73W, Sec. 18: Lots 1-4 E 1/2, E 1/2 W 1/2, Sec. 19. Lots 1, 2, NE 1/4, E 1/2, NW 1/4 Sec. 21: Lots 1,2, NW 1/4 NW 1/4	Alamosa	5,096.38

Mineral #31	Phillips Petroleum	BLM,USFS	329.50	46N,11E, Sec. 31: Lots 1-4, E 1/2 W 1/2	Saguache
	Phillips Petroleum	BLM	320.00	46N,10E, Sec. 33: NE 1/4, NE 1/4 NW 1/4, W 1/2 SE 1/4, NE 1/4 SE 1/4	Saguache
	Phillips Petroleum	BLM	1,120.00	45N,10E, Sec. 22: NE 1/4 Sec. 23; N 1/2 Sec. 25; All	Saguache
	Phillips Petroleum	BLM	1,644.50	46N,10E, Sec. 19: Lots 1,2,3, NE 1/4 SW 1/4, NW 1,4 SE 1/4 Sec. 21: All Sec. 27: All Sec. 29: NE 1/4	Saguache
	Phillips Petroleum		2,484.28	45N,9E; N.M.P. Sec. 2: Lots 2,3,4, S 1/2 NW 1/4, SW 1/4 Sec. 3: Lots 1,2,3,4, S 1/2 N 1/2, S 1/2 Sec. 10: N 1/2, N 1/2 SW 1/4, NW 1/4 SE 1/4 Sec. 11: N 1/2 Sec. 12: W 1/2 NW 1/4 46N,9E; N.M.P.M. Sec. 34: All	
			1,636.42	45N,10E; N.M.P., Sec. 1: Lots 1,2,3,4, S 1/2 N 1/2, SW 1/4, W 1/2 SE 1/4 Sec. 2: Lot 1, S 1/2 N 1/2, S 1/2 46N,10E; N.M.P.M. Sec. 35: N 1/2, N 1/2 S 1/2, S 1/2 SW 1/4	

TABLE 7 (Cont.)

Chevron	BLM	160.00	45N,9E, Sec. 13: E 1/2 NE 1/4 45N,10E, Sec. 18: E 1/2 NE 1/4	Saguache	
Earth Power	BLM	1,000.00	46 N,10E, Sec. 28: All Sec. 34: N 1/2 NE 1/4 NW 1/4, N 1/2 SW 1/4, NW 1/4 SW 1/4	Saguache	
C. A. Underwood	State	640.00	46 N, 10 E, Sec. 16 45 N, 9 E, Sec. 36		
General Geothermal	State	1,519.00	45 N,10E; Sec. 16: N 1/2; SW 1/4 SW 1/4; SE 1/2 SE 1/4 Sec. 1: Lots 1,2,3,4, S 1/2 N 1/2, SW 1/4, W 1/2 SE 1/4 Sec. 2: Lot 1, S 1/2 N 1/2, S 1/2 46N,10E, N.M.P.M. Sec. 35: N 1/2, N 1/2 S 1/2, S 1/2 SW 1/4		6,733.00

Sources: Colorado Land Board and U.S. Department of Interior, Bureau of Land Management, Colorado Office Lease Records, 1978.

Since the resource areas in Region 8 are concentrated for the most part near the center of the valley where the private land predominates, additional leasing of public lands may not be necessary for direct thermal geothermal development, at least initially. Obtaining a U.S. Forest Service right-of-way for a pipeline would most likely be necessary in order to transport the fluid to Creede. Leases from USBLM usually take a minimum of 3 months and lease applications sent for review by the US Forest Service in 1974 were still pending in 1978. (Craig Losche, pers. comm., 1978). In light of these time requirements, private leases would seem to be more attainable. The time required for those, however, is unpredictable and can vary appreciably, depending upon the individual owners.

When federal lands are designated as Known Geothermal Resource Areas (KGRA's), the leasing process is complicated and lengthened in such areas, because competitive rather than non-competitive leases are required, and leases are more costly because bonuses must be paid (Paul Summers, pers. comm., 1978). As shown on Table 8, three areas in the San Luis Valley have been designated as KGRA's.

In most if not all areas, various public authorities regulate development of various kinds. The time and extent of difficulty required in obtaining necessary permission affects the rate and magnitude of development. The state permits required for geothermal development require up to 6 months to obtain. The amount of time required to obtain leases on state lands is about the same (Coe, 1978).

Local jurisdictions, counties, or municipalities are allowed to control development within their boundaries (C.R.S. 1973, 24-65, 29-20, 31-23, 31-12). As an example, in Alamosa County, outside any municipal jurisdiction, a conditional use permit is required in order to construct pipelines or processing plants. Any new subdivision is subject to subdivision regulations. In addition, the geological hazards section of the regulations could allow for review and approval of any geothermal development. Application is made initially to the Alamosa County Planning Commission. Following review and a public hearing, the Board of County Commissioners will make the final decision about whether or not to allow the proposed development. About six months is generally required for the complete process (Marilyn Porter, pers. comm., 1979).

Environmental Considerations

Other considerations in assessing geothermal development opportunities include the potential for degradation of the physical environment. If serious environmental damage would result from geothermal development or from related activities, proposed development could be denied or delayed by local, state, and federal agency regulations. Studies by Coury & Associates (1978a) and by the Bureau of Land Management (USBLM, 1975) investigated some of the possible environmental impacts. Their studies have shown the following:

Air - Air pollution is one possible adverse effect of geothermal development. Although air pollution will not generally be the problem with hydrothermal resources that it can be with steam, the potential must be evaluated and steps taken to prevent the emission of intolerable amounts of toxic material into the air (Colo. Air Pollution Control Comm., 1977).

Table 8
KNOWN GEOTHERMAL RESOURCES AREAS IN SAN LUIS VALLEY, COLORADO

Leasing Unit No.	Description	Acreage
	ALAMOSA COUNTY KGRA	
1	T. 38 N., R. 12 E. Sec. 23: All Sec. 25: N 1/2, SW 1/4 Sec. 26: All Sec. 34: E 1/2	2080.00
2	T. 38 N., R. 12 E. Sec. 11: SE 1/4 Sec. 13: S 1/2 Sec. 14: NE 1/4 Sec. 24 NW 1/4, S 1/2 T. 38 N., R. 13 E. Sec. 18: Lots 1, 2, 3, 4 Sec. 19: Lots 1, 2, 3, 4	1480.93 (Bonus must be computed on basis of 1481 Acres)
	Total Acreage:	3560.93
	MINERAL HOT SPRINGS KGRA	
3	T. 46 N., R. 9 E. Sec. 22: W 1/2 NE 1/4, W 1/2 NW 1/4 SE 1/4, S 1/2 SE 1/4	520.00
4	T. 46 N., R. 9 E. Sec. 25: W 1/2 NE 1/4, W 1/2 NW 1/4 SE 1/4, S 1/2 SE 1/4	520.00
5	T. 46 N., R. 9 E. Sec. 34: All T. 45 N., R. 9 E. Sec. 2: Lots 2, 3, 4, S 1/2 NW 1/4, SW 1/4 Sec. 3: Lots 1, 2, 3, 4, S 1/2 N 1/2, S 1/2 Sec. 10: N 1/2, N 1/2 SW 1/4, NW 1/4 SE 1/4 Sec. 11: N 1/2 Sec. 12: W 1/2 NW 1/4	2484.28 (Bonus must be computed on basis of 2485 Acres)
	Total Acreage:	3524.28

TABLE 8 (Cont.)

VALLEY VIEW KGRA

6	T. 46 N., R. 10 E. Sec. 35: N 1/2, N 1/2 S 1/2, S 1/2 SW 1/4 T. 45 N., R. 10 E. Sec. 1: Lots 1, 2, 3, 4, S 1/2 N 1/2, SW 1/4, W 1/2 SE 1/4 Sec. 2: Lot 1, S 1/2 N 1/2, S 1/2	1636.42 (Bonus must be computed on basis of 1637 Acres)
7	T. 45 N., R. 10 E. Sec. 3: SE 1/4 Sec. 4: Lots 2, 3, 4 Sec. 10: E 1/2 Sec. 11: All Sec. 15: E 1/2, S 1/2 SW 1/4	1634.45 (Bonus must be computed on basis of 1635 Acres)
	Total Acreage:	3270.87

Source: U.S. Department of Interior, Bureau of Land Management, Colorado Office, 1978.

As indicated in the USBLM report, dust from vehicular movement and construction activity and escape of gases when wells are vented during testing could be problemmatic (1975). However, as Coury & Associates (1978a) point out in their analysis of the environmental effects of development in the Baca Grant area, no significant quantities of noncondensible gases are present in the fluid or will be released into the atmosphere. Since this assessment cannot necessarily be generalized to the entire region, a site-specific analysis would be needed prior to any development.

Land - Another possibility for environmental damage is damage to the land. For instance, some subsidence could result from the extraction of geothermal fluid. Because the San Luis Valley is composed primarily of unconsolidated sediments, removal of large quantities of water could initiate compaction resulting in subsidence at the surface (Michael Galloway, pers. comm., 1978). As pointed out by Coury and Associates however, existing irrigation wells seem to have resulted in little subsidence. Furthermore, if subsidence should occur, it may or may not be detrimental, depending upon the location of such subsidence (Coury & Assoc., 1978a). Although a usual preventive measure is to reinject fluid, the proper procedure cannot be definitively known until after exploratory drilling and testing.

The Sangre de Cristo fault is probably the most active fault in Colorado. Because of this, the San Luis Valley is likely the most potentially hazardous area in the state for earthquakes (R.M. Kirkham & W.P. Rogers, 1978). Furthermore, there is significant potential for debris and mud flows in alluvial fan areas or bajada complexes, such as those found in parts of the Baca Grant (R.M. Kirkham, pers. comm., 1979). By state law, any proposed new subdivision is reviewed by the Colorado State Geological Survey to assure that potential hazards are adequately addressed (C.R.S. 1973, 30-28-137). But because of the presence of these geologic hazards, any development proposed to use the geothermal resource in the valley would probably require a careful site specific evaluation (R.M. Kirkham, pers. comm., 1978).

Soil erosion (primarily from vehicle movement and construction) is also mentioned by the USBLM (1975) as a potential negative environmental impact of geothermal development in the San Luis Valley. Although generally considered to be negligible, this, too, requires site-specific analysis to determine the severity of any problem.

Water - Water quality is another environmental aspect of geothermal development. The fluid must be disposed of in some manner after removing the heat. Whether reinjecting the fluid or discharging the fluid at the surface, the results must satisfy the criteria of the Environmental Protection Act (Water Quality Control Commission, pers. comm., 1977). The highest dissolved solids content that has been identified in the geothermal fluid of the valley so far is less than 1,500 mg/l (Barrett and Pearl, 1978). This is an indication that disposal of the fluid should not degrade the quality of surface or subsurface waters significantly. To minimize both the subsidence and the water pollution potential, however, Coury & Associates (1978a) recommend reinjection of the fluid "into aquifers similar to those from which they are produced".

Concerns about water quality include concerns about the disposal of waste from agricultural or industrial processes that might use the geothermal energy. The Regional Comprehensive Plan prepared by the San Luis Valley Council of Governments has indicated that the sensitive natural environment constrains industrial operations requiring extensive waste disposal (SLVCOG, 1974). Proposals to dispose of waste would be evaluated on a site- and use-specific basis.

Plants and Wildlife - Insignificant impacts to vegetation from geothermal development were predicted in the USBLM report. However, wildlife could be more severely affected. In particular, since thermal pollution of streams could cause trout losses, waste disposal must be carefully controlled. Extensive development in the winter could reduce antelope, elk, and deer populations (U.S. Bureau of Land Management,1975) so that indirect impacts related to geothermal development should be evaluated on a site-specific basis.

Ecological Interrelationships - If drilling were to cause natural hot springs to decline or cease discharging, several results could be anticipated, according to the U.S.B.L.M. report. As the report indicates, "Growing seasons would be shorter, aquatic plants and animals currently dependent upon the hot water would have smaller populations or die out, perishable archaelogic remains possibly located in the presently boggy drainage below the springs would lose their protective stable temperatures and wet conditions, and the effect of a winter oasis on the wildlife and nearby terrestrial plants would be greatly reduced or lost" (U.S. Bureau of Land Management, p. 26, 1975). Conversely, environments could be created in new areas, if desirable.

Human Values - Several possible adverse impacts on the community facilities in the valley were noted by Coury & Associates (1978a). Among these are possible overloads of sewer, water and utility systems and schools if a population increase should occur. Whether such a population influx would occur would depend upon the location and nature of the geothermal energy uses. Processing plants that would add large numbers of new residents to small communities would probably not fit the goals of the residents. Those that would provide jobs for some of the large numbers of unemployed workers should be quite popular, according to a survey recently conducted (SLVCOG, 1977).

Water Availability

The availability of water is an issue that arises whenever any significant development in the San Luis Valley is discussed. The Rio Grande River Compact requires that the Rio Grande supply certain amounts of water annually to New Mexico, Texas, and Mexico. Because of a previously-incurred deficit and to assure compliance with the Compact in the future, no new wells are allowed by the State Engineer except for domestic use because of the danger of drawing down the surface water (Fred Loo, pers. comm., 1978).

The only exception is wells in the shallow aquifer of the Closed Basin (Fred Loo, pers. comm., 1978), where the water table is extremely high, and about 1,000,000 acre-feet of water evaporate each year (SLVCOG, 1977). The minerals which are left behind degrade the values of the land for agriculture. The Closed Basin Project of the U.S. Bureau of Reclamation is designed to reduce the water table by drilling wells and diverting the water into the Rio Grande River (R. Pearl, pers. comm., 1978). This will help meet the Compact requirements, improve productivity of the land, and provide more water for the valley. Others have suggested diverting Closed Basin water to metropolitan areas (Charles Underwood, pers. comm., 1978).

The lack of water now and uncertainty for the future create a certain risk for potential developers. In particular, a large initial capital investment in agricultural processing plants requires the long-term availability of agricultural products. The products themselves rely upon water availability (SLVCOG, 1978). When a long-term water supply is not assured, developers may be reluctant to make investments. Another water issue is the possibility of diversion of water from agricultural to other uses. For example, the San Marco Pipeline Company's proposal to use valley water for coal slurry transport might divert water from existing uses. However, a study by Zorich & Erker, consulting engineers, has indicated that a second closed basin in the southwestern part of the valley could provide water to the pipeline with no impact on the other reservoirs or surface water (R. Pearl, pers. comm., 1979). Adding to the complexity of the water issues is the expressed goal of the San Luis Valley COG to keep valley water in the valley (SLVCOG, 1978).

Technical Considerations

Difficult or unusual technical requirements can preclude, slow, or at the least, add to the cost of geothermal development. As such, anticipating technical problems is helpful.

As indicated in the preceding section of the report, the requirements of federal, state, and local agencies for development must be met. As such, the disposal of waste products and the manner in which a resource area is developed must meet the requirements indicated by those agencies having jurisdiction. As previously noted, indications of the environmental reports are, however, that few conditions exist that would require unusual treatment. Low dissolved mineral content of the water would seem to indicate that corrosion and scaling problems that in some areas demand special alloys, heat exchangers, and other such materials or techniques could be negligible.

For several reasons, reinjection of the fluid was suggested (Coury & Associates, 1978a), which means that at least in some locations, injection as well as production wells would be needed, adding to drilling costs. Furthermore, drilling costs could be quite expensive if reservoirs are deep, as anticipated in some areas. They are estimated to be between 4,000 - 9,000 feet deep in the eastern and southeastern valley (Dick, 1978). In the northern part of the valley, however, expected reservoir depths of 1,100 - 5,000 feet, could make drilling in this area much more economical (Dick, 1978).

Other conditions could offset the cost of deep wells. The geothermal reservoirs in some parts of the valley are considered to be so large as to minimize the risk of failure of drilling programs to obtain geothermal fluid (Dick, 1978). Drilling through the relatively unconsolidated sedimentary formations could well be less expensive than drilling through more difficult strata (M. Galloway, pers. comm., 1979).

Economic Considerations

A detailed economic analysis of a geothermal market area is not within the scope of this study. However, some indication of the cost of development and how that cost compares with costs of alternative energy sources is needed for anticipating the motivation for developing geothermal energy. Energy costs for a barley-malting kiln estimated by Coury and Associates (1978b) were $2.63 per million Btu*(1978), and the total capital cost for such a plant would be between $3,159,000-$3,840,000. The study indicates that this would be competitive with available fossil (Coury & Associates, 1978b). They also studied the feasibility of producing ethanol for use in gasahol. That study showed a total energy cost of $2.29 to 5.14 per million Btu and a total capital cost of $3,401,000-$9,195,000 (Tables 9 through 11) (Coury & Associates, 1978b).

Costs of transporting geothermal water to southern Front Range cities in a 24-inch pipeline were assessed. That assessment showed a low of $4.00 per million Btu's for geothermal heat, compared with over $7.00 for electricity, $4.00 for propane, but $2.00 or less for natural gas. Although geothermal energy was, for the example given, higher than natural gas, some qualifications are necessary. First, since the geothermal costs quoted include the capital costs, natural gas costs should be calculated similarly. Second, natural gas is limited in quantity and may not be readily available to a new customer. Finally, natural gas is increasing in price in Colorado and may well be more expensive than geothermal energy over the life of a plant.

Insofar as the availability of capital is concerned, lessees, state economic development agencies, and consultants report that efforts to interest investors in geothermal projects have so far been unrewarded (Charles Underwood, Evan Metcalf and others, pers. comm., 1978).

However, one user of geothermal energy, Weisbart, Inc., located at Mineral Hot Springs south of Alamosa, was not constrained by any lack of investment capital. The owners explain that the reason is that the Weisbart operation is a well-financed, on-going operation. They developed the geothermal energy because they had a need for it at their existing location and could save on operating costs (Gary Weisbart, pers. comm., 1978).

*Btu = British thermal unit - that amount of energy required to raise the temperature of one pound of water one degree farendheidt.

TABLE 9

Capital Cost of Geothermal System for Corn or Wheat

Ethanol Process

Basis: Capacity of 7.4 million gallons ethanol per year
Brine temperature of 350°F

Distance between supply and use (miles)	1	5	10	20
Brine flow (1000 lb/hr)	334	334	334	334
No. of wells	4	4	4	4
Capital cost ($1000)				
Wells	4,000	4,000	4,000	4,000
Lines and Pumps	275	1,183	2,366	4,637
Additional equipment (grain cooker, flash tank)	42	42	42	42
	4,317	5,225	6,408	8,679

Capital cost of geothermal system for Sugar Beet

Ethanol Process

Basis: Capacity of 7.4 million gallons ethanol per year
Brine temperature of 375°F

Distance between supply and use (miles)	1	5	10	20
Brine flow (1000 lb/hr)	800	800	800	800
No. of wells	5	5	5	5
Capital cost ($1000)				
Wells	2,900	2,900	2,900	2,900
Lines and pumps	376	1,580	3,160	6,170
Additional equipment (extra heat transfer surface)	125	125	125	125
Total	3,401	4,605	6,185	9,195

Source: Coury and Associates, Inc. (1978)

TABLE 10

Geothermal Energy Costs for Corn or Wheat

Ethanol Facility

Distance between user and supply (miles)	1		5		10		20	
Total capital costs ($1000)	$4,317		$5,225		$6,408		$8,679	
Annualized capital cost (15%) ($1000)	648		784		961		1,302	
Annual heat load (10^{12} Btu)	.315		.315		.315155		.315	
Capital cost of energy (per million Btu)		$2.05		$2.49		$3.05		$4.13
Average brine flow rate (1000 lb/hr)	334		334		334		334	
Pump power requirement	150		150		250		250	
Annual pump power costs*($1000)	29.4		29.4		49		49	
Annual brine treatment costs**($1000)	73.1		73.1		73.1		73.1	
	102.5		102.5		122.1		122.1	
Unit utility costs (per million Btu)		0.33		0.33		0.39		0.39
Geothermal Energy cost (per million Btu)		$2.38		$2.82		$3.44		$4.52

* Costs .03/kwh electricity costs

** Brine treatment costs of $25 per million pounds

Source: Coury and Associates, Inc. (1978)

TABLE 11

Geothermal Energy Costs for Sugar Beet

Ethanol Facility

Distance between user and supply (miles)	1		5		10		20	
Total capital costs ($1000)	$3,401		$4,605		$6,185		$9,195	
Annualized capital cost (15%) ($1000)	510		691		928		1,379	
Annual heat load (1012Btu)	.312		.312		.312		.312	
Capital cost of energy (per million Btu)		$1.63		$2.21		$2.97		$4.42
Average brine flow rate (1000 lb/hr)	800		800		800		800	
Pump power requirement (hp)	150		150		250		250	
Annual pump power costs*	29.4		29.4		49		49	
Annual brine treatment costs**($1000)	175		175		175		175	
	204.4		204.4		224		224	
Unit utility costs (per million Btu)		0.66		0.66		0.72		0.72
Geothermal Energy cost (per million Btu)		$2.29		$2.87		$3.69		$5.14

* Costs .03/kwh electricity costs

** Brine treatment costs of $25 per million pounds

Source: Coury and Associates, Inc. (1978)

Small communities are interested in district space-heating with geothermal energy but are plagued by the lack of front-end capital for this as well as for many other kinds of projects. Because of the lack of tax revenue sources for local governments, construction of water systems, sewer systems, transportation systems, and housing has been thwarted for years in many areas. In many instances, only when federal funding has been made widely available for such projects, have they occurred in any timely and extensive fashion. So far, little federal or other public funding is available for developing geothermal district heating or industrial processing systems.

IV. GEOTHERMAL ENERGY DEVELOPMENT POTENTIAL

Geothermal Resource Characteristics

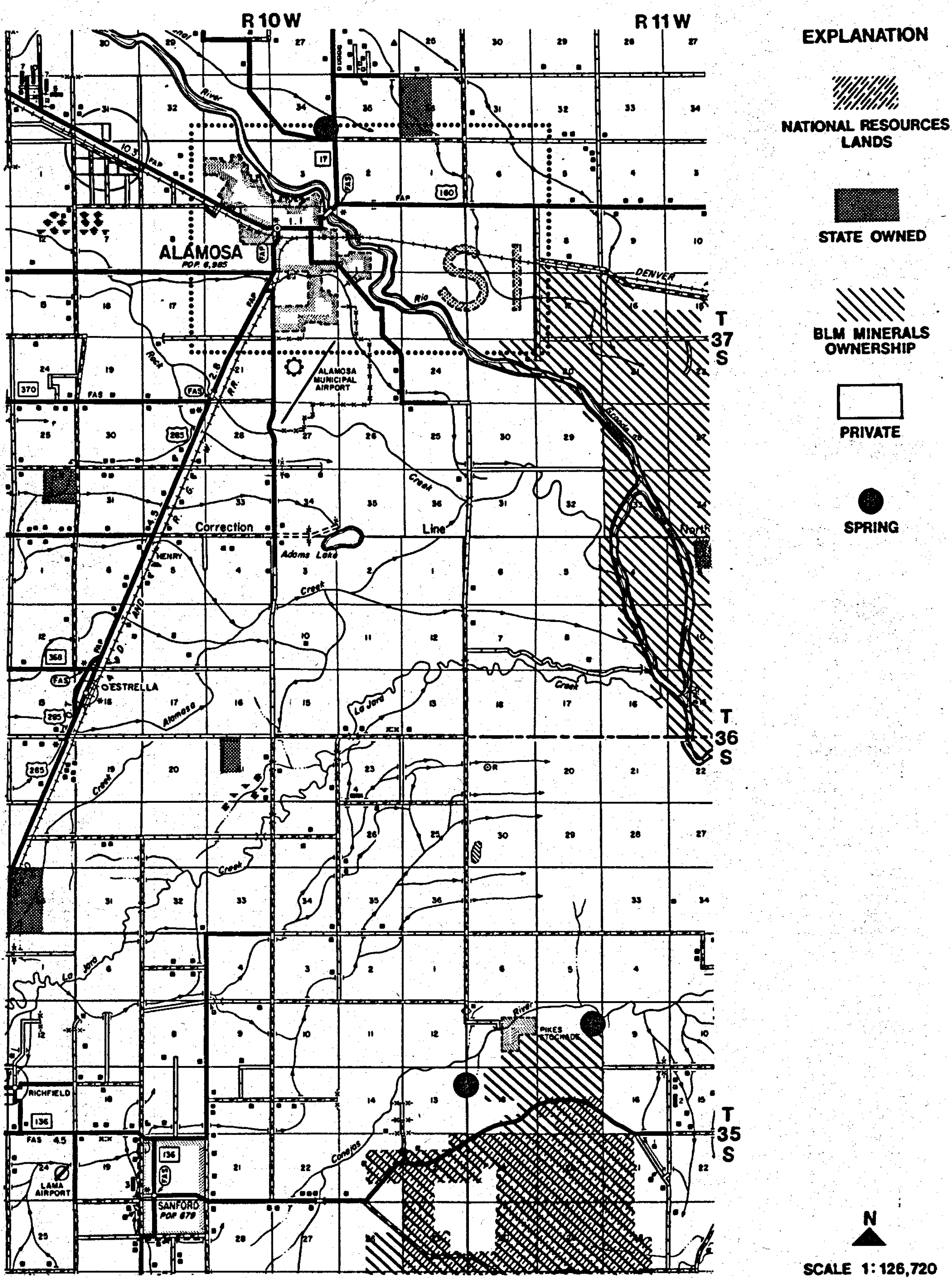
The energy demand in Region 8 was discussed in Section II. Those specific conditions that bear heavily upon the possibility of geothermal energy development have been investigated as well, as explained in Section III. The next step is to judge the extent to which geothermal development might be accomplished and the possible timing of that development.

Investigation of the currently available information about the resources shows the extent to which they seem capable of supplying part of the energy need.

In the valley six separate hydrothermal resource areas have been identified from hot springs or wells. These are shown on the maps (Figures 6,7,8, and 9) that follow. The Weisbart well was not included because of the lack of sufficient information. The areal extent of each of these areas is estimated to vary from 0.03 square miles to 10.1 square miles (or 32 square miles using a more optimistic estimate) (Pearl, 1979). Surface temperatures range from 35°C to 75°C and estimated subsurface temperatures range from 20°C to 68°C. Given these parameters, about 1.4270-6.2153 x 10^{15} Btu's (quads) heat are estimated to be contained in these reservoirs (Pearl, 1980). Table 12 shows the characteristics of each of the areas.

Since the energy must be first extracted from the ground and then used in some sort of application, the energy estimate must be reduced by factors which account for both. Realistically, the magnitudes of those factors cannot be known prior to exploratory drilling and testing. However, to obtain a rough estimate, 24 percent was assumed to be the amount of energy that could be extracted and 25 percent of that was assumed to be the percentage of the extracted energy that could actually be used. This resulted in estimated extractable energy of 0.342348 - 1.4917 x 10^{15} Btu's and the estimated usable energy of 0.0856 - 0.3729 x 10^{15} Btu's. This is more than 60 times the amount of natural gas consumed throughout the valley in 1977. If the thermal water were extracted at the rate of 1/30 per year, 0.0028 - 0.0124 quads of heat would be available each year.

Another important resource characteristic is the discharge rate of the water. As with some previously-mentioned characteristics, discharge rates cannot be known until wells are drilled and tested. Discharge rates can be estimated from the discharge rates of existing wells and springs, assuming they are discharging at an optimal rate. As Table 12 shows, in the San Luis valley the total fluid discharge of the measured springs and wells is between 299 and 459 gallons per minute. Unfortunately, discharge rates were not available for all of the springs and wells.



Base from Colo. Dept. of Highways

FIGURE 6

LAND AND MINERAL OWNERSHIP OF ALAMOSA AREA

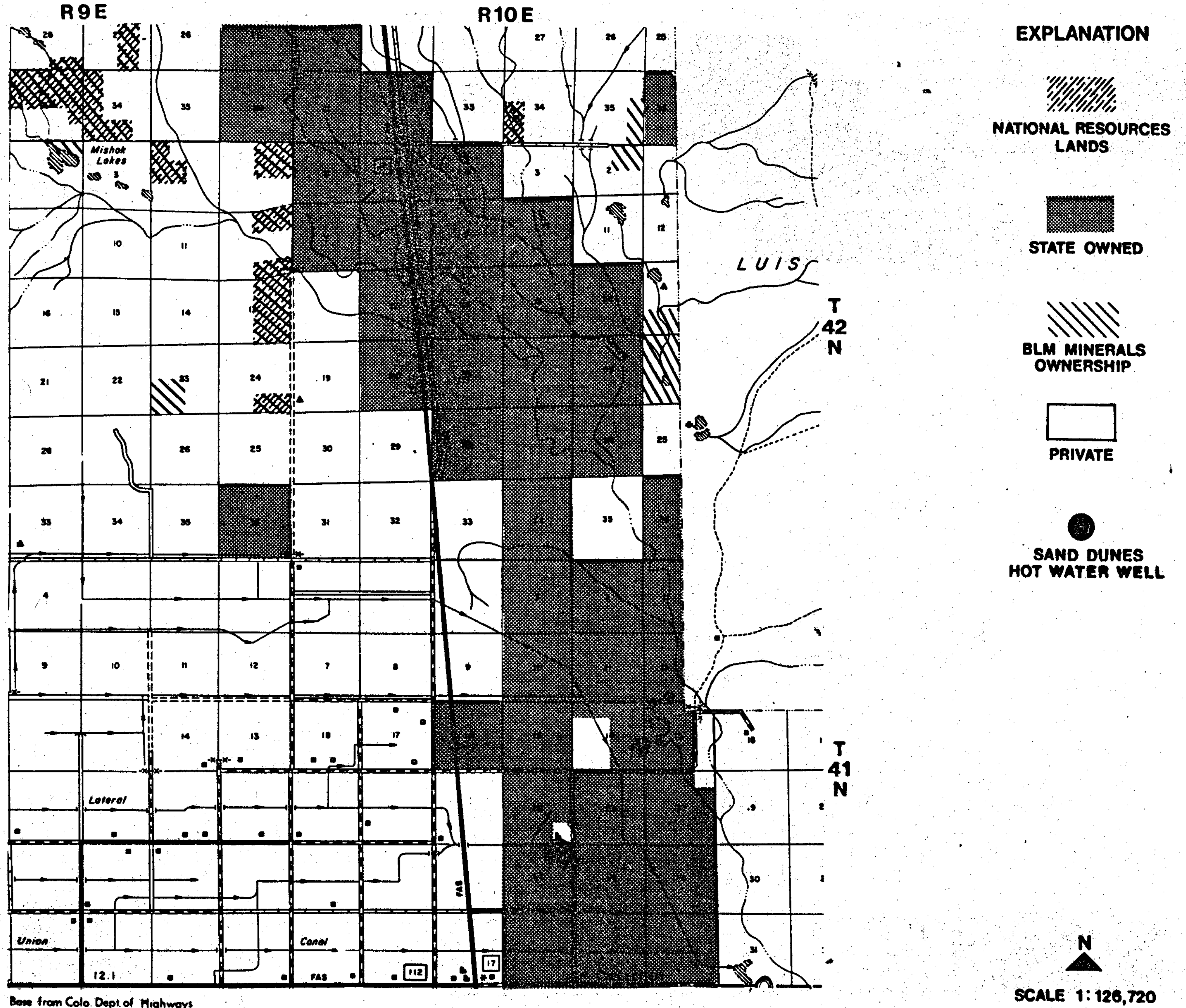


FIGURE 7

LAND AND MINERAL OWNERSHIP OF EAST CENTRAL SAN LUIS VALLEY AREA

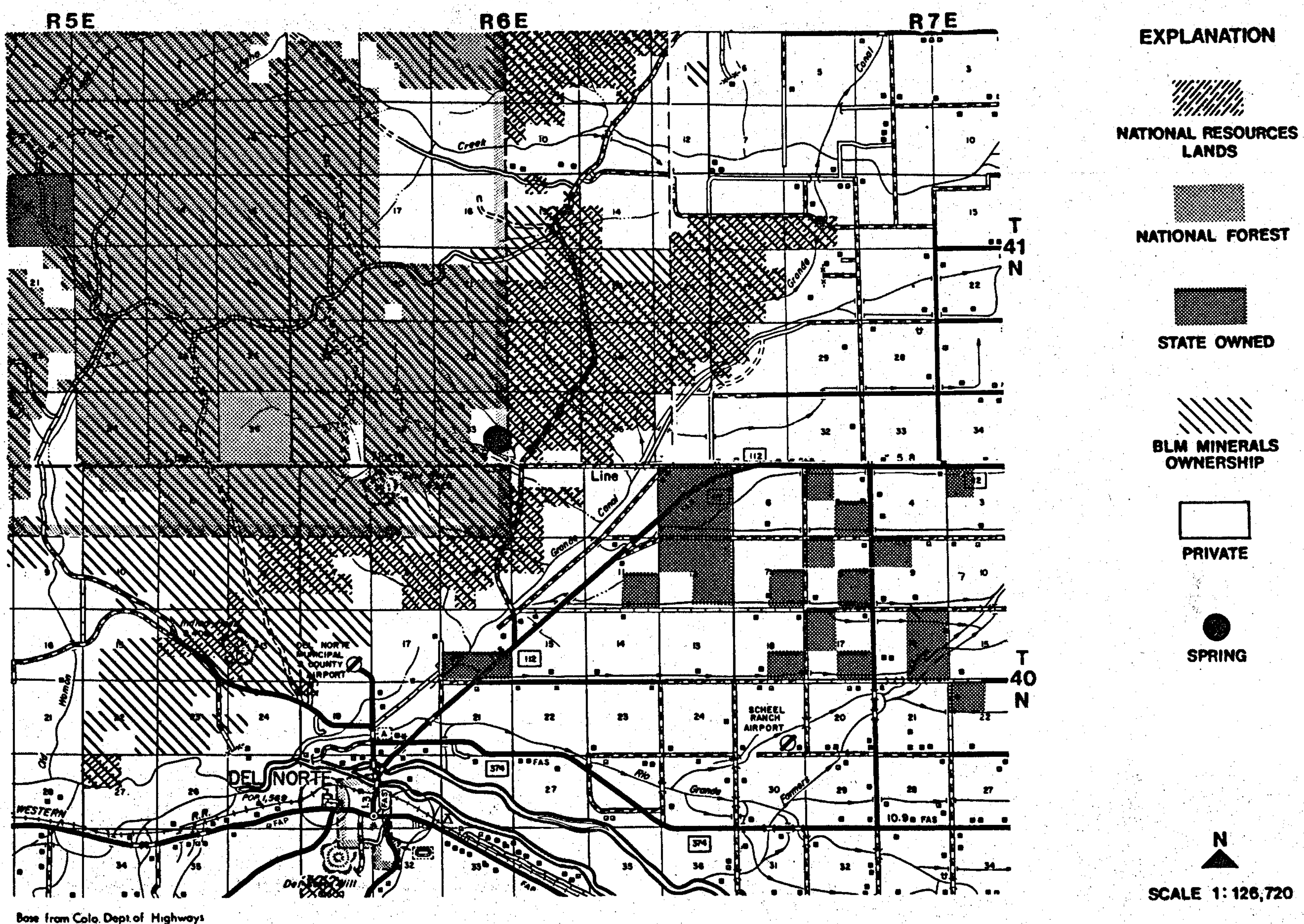


FIGURE 8

LAND AND MINERAL OWNERSHIP OF SHAWS WARM SPRING AREA,

SAN LUIS VALLEY

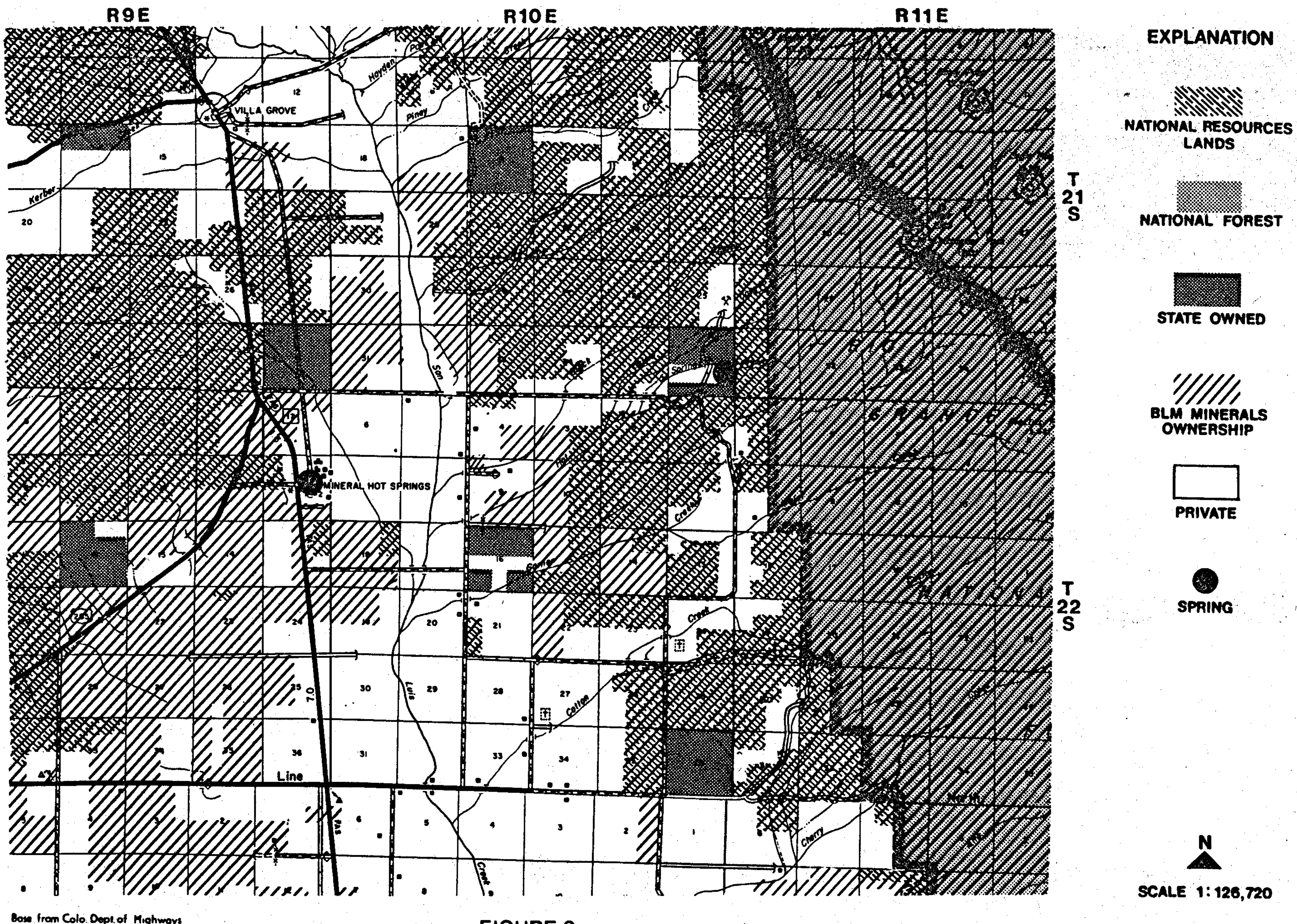


FIGURE 9

LAND AND MINERAL OWNERSHIP OF UPPER SAN LUIS VALLEY AREA

TABLE 12
GEOTHERMAL RESOURCE CHARACTERISTICS
SAN LUIS VALLEY, COLORADO

Resource Area Name & Number	Areal Extent (Square Miles)	Thickness (feet)	Surface Temperature °C	Estimated Subsurface Temperature Range °C	Discharge Rates Low-High Gallons per Minute	Dissolved Solids Mg/l Low-High	Estimated Energy Content Range Btu's x 10^{15}
Mineral #31	10-32	1000	60-140°F				
Spring A	--	--	--	70-90	70-167	639-663	0.9492-3,007
Spring C	--	--	--	70-90	--	723-723	
Spring D	--	--	--	70-90	5-5	648-690	--
Valley View #32	--	1000	--	--			0.0564-0.0564
Spring A	--	--	35-37	40-50	60E-60E	234-252	--
Spring B	--	--	32	40-50	--	234-234	--
Spring D	--	--	34-36	40-50	75-120	223-247	--
Shaws #33	.63	500	30	30-60	34-52	398-424	0.0148-0.0148
Sand Dune #34	1.5	1000	44	--	--	334-334	0.1551-0.1551
Splashland #35	1.5	1000	40	40-100	55-55E	--	0.0339-0.0339
Dexter/McIntyre #36,37	1.2	1000	20	20-50	299-459	3744-3878	1.3645-4.7868
Wagon Wheel Gap #43	7-16.	500		100-168			.0625-1.4285
4UR Spring			55-57		30-30	1550-1620	
CFI Spring			48-51		48-51	1470-1540	
TOTAL							1.4270-6.2153

Source: Pearl, R. H., 1979.

Note: Although wells are known to exist in northern Conejos County, insufficient information is available to include them.

Chemical analyses of the dissolved mineral matter contained in the thermal fluids are important for analyzing the likelihood of corrosion and scaling problems from mineralization. These analyses indicated a fairly low level of total dissolved mineral matter, ranging from 223 to 3878 milligrams per liter (Barrett & Pearl, 1978).

Historical Use of Geothermal Energy

Geothermal energy has been used in the San Luis Valley for years. At Valley View Hot Springs, a swimming pool which has since collapsed once used the resources. At Shaws Warm Spring and at Splashland the waters are used in swimming pools. At Sand Dunes, although the water was in the past used in a swimming pool, it is now used for heating a house and for cultivating catfish. Although the demand for catfish is sometimes believed to be too limited for its cultivation to be a profitable venture, in two nearby states where the fish are marketed, Texas and New Mexico, catfish is a popular delicacy (Putman, pers. comm., 1978).

The most extensive use of geothermal energy in the San Luis Valley occurs south of the city of Alamosa in Conejos County. A geothermal well provides preheated water for the hot water heating system of swine farrowing pens and nurseries at the Weisbart operation. Since a room temperature of 24°C is required for the young animals, a propane boiler heats the 26°C water to about 43°C before circulating the water through the floor system (Botsko, pers. comm., 1979).

When discharged from the heating system, the water then runs to fish tanks and raceways where talapia, an African perch, are cultivated. About 1 1/2 tons of the fish per week are produced. Whereas the fish, which are indigenous to the Sea of Galilee, are considered by devotees to be a delicacy, marketing them is difficult because of their relative foreignness. Owners hope that as more people become familiar with the fish, the market will expand.

Current Development of Geothermal Energy

Mineral Hot Springs, a former resort area that had mineral baths and a swimming pool, is now being developed to accommodate geothermally-heated swine pens for 30,000 head of swine and for a methane digester (Gary Weisbart, pers. comm., 1978). After heating the pens, using 200 gpm of 71°C water cooled to 24°C, the waste water will be used for watering the animals and slushing the pens. In addition, a system for producing methane is being designed. It will use about 100 gpm of water cooled about 10°C to produce methane, CO_2, heavy sludge for refeeding, and light water for growing algae. Experiments will use water at two different temperatures, 32°C and 63°C, to discover which is most effective. The total consumption of geothermal energy in the existing geothermal facilities in the San Luis Valley is expected to be about 10.0975×10^{10} Btu's (see Table 13).

Proposed Geothermal Energy Uses

The existence of geothermal energy in the San Luis Valley is well known. Numerous ideas have been presented and discussions have been held concerning the potential. The San Luis Valley Council of Governments indicates among its goals the encouragement of geothermal resource development (SLVCOG, 1977). Several state agencies, including the State Division of Commerce and Development and the Four Corners Regional Commission, show interest in

TABLE 13

EXISTING AND PLANNED
GEOTHERMAL ENERGY USE
REGION 8, COLORADO
1978

Industry	SIC Code	Number of Facilities	Heat Required (10^{10} Btu's/yr.)
		Existing	
Fish farms	NA	2	51.0000[1]
Swine pens	NA	1	2.1900[3]
Space heat-1 house	NA	1	.0089[4]
Total			53.1989
		Planned	
	Planned Geothermal Energy Development		
Swine pen	NA	1	7.4600[2]
Methane plant	NA	1	.4386[2]
Total			7.8986
Grand Total			10.0975

3 Estimated from information from Gary Weisbart, Owner, 1978.
4 Energy Conservation Office, 1978, Unpublished Data.

geothermal energy for process use to aid economic development in the valley Evan Metcalf and Ivo Roospold, pers. comm., 1978).

Studies have also been performed to assess the resources and development potential. Among the investigations are preliminary resource evaluations by Barrett & Pearl (1978) and Pearl (1979). Engineering and feasibility studies have been conducted to evaluate the potential of geothermal energy for processes such as barley malting, sugar beet processing, and alcohol production (Coury, 1978 a and b and Coury & Vorem, 1978). The potential for geothermal space heating and process heating in the Baca Grande development is also being explored (Glenn Coury, 1978 a,b,c). The State Division of Commerce and Development has conducted a feasibility study for potato processing in the San Luis Valley, a possible use of geothermal energy (Ivan Metcalf, pers. comm., 1978). And, the superintendent of schools for Alamosa has indicated interest in building geothermally heated schools (R. Pearl, pers. comm., 1978). At this point, however, only Mineral Hot Springs is being developed and no other areas are known to be planned for development.

Opportunities for Geothermal Energy Development

Existing demands also provide opportunities for using geothermal energy; space and water heating are among the most obvious. Those areas which are forced to rely upon propane or electric heat would be most likely to benefit economically from geothermal space and water heating in the near future, if retrofitting is not too costly. Even in those areas that have natural gas available, geothermal energy may be competitive now or in the future. New structures, particularly where the heating demand is sizeable, offer a prime opportunity for development of the geothermal energy because retrofitting costs may be avoided.

Some existing industrial processes could also use geothermal energy. Those heating processes for which the geothermal energy in the valley seems to be applicable are shown in Table 14. The possibilities include production of ice cream, milk, soft drinks, and ready-mix concrete and for wood products.

The economics of process uses may offer the most profitable opportunities for developing geothermal energy. Unfortunately, the geothermal resource sites in Colorado are generally in areas that have little industry. Even agricultural processing is very limited. Efforts to promote new industry in the San Luis Valley have had painfully slow results. As such, extensive industrial development cannot reasonably be postulated. However, with energy becoming an ever-larger percentage of the operating costs of a manufacturer, the availability of low-cost energy could enhance the geothermal process heat potential of the San Luis Valley. Because of the agricultural base, the most likely future industrial applications of geothermal energy would seem to be for cultivation and processing of agricultural products.

In the following possible development schedule (Figure 10), therefore, agricultural process uses are postulated for future geothermal development, along with space heating, water heating, and some other uses. It should be emphasized that these are ideas for development based on existing conditions, not forecasts. Some of the uses seem to have a higher probability of occurring than others, simply because of the interest already shown. It is assumed that the most economically competitive will come on line first; as indicated, the systems under construction are estimated for completion by early 1979. The swine pens, feedlot, methane plant, aquaculture facilities, and space heating by that time could be using an estimated 10.09×10^{10} Btu's of geothermal energy per year.

The second project that is hypothesized for development by 1980 is an industrial park that would include such proposed uses as a greenhouse, a barley-malting plant, a potato processing plant, and an ethanol plant. All using geothermal energy for processing heat, they are estimated to require about 80.00×10^{10} Btu's of heat per year (Table 14).

The next project envisioned is the space heating of several towns that currently lack natural gas service. These towns, Hooper, Manassa, San Luis, Creede, and the unincorporated Baca Grande development, are all within 10 miles of identified thermal wells and springs. By the year 1982 when these communities are hypothesized to have their geothermal heating systems in place, they will require an estimated 18.41×10^{10} Btu's per year for residential and commercial heating. Next, the expansion of the geothermal processing in the industrial park to three plants for drying fruit, seeds, and vegetables is postulated. This would put an additional 19.83×10^{10} Btu's of geothermal energy on line by 1982.

TABLE 14
POTENTIAL INDUSTRIAL AND AGRICULTURAL PROCESS
USERS OF GEOTHERMAL ENERGY
REGION 8, COLORADO
1976 Manufacturers

Industry	SIC Code	Number of Facilities	Low-Grade Heat Required (10^{10} Btu's)/yr
	Potential for Existing Industries		
Ice Cream & frozen desserts	2024	1/2*	0.4820[2]
Fluid milk	2026	1 1/2	2.3850[2]
Bottled and canned soft drinks	2086	1	0.2900[1]
sawmills, planing mills	2421	5	0.0800[1]
ready-mix concrete	3273	1/2	0.0007[2]
			3.2377
	Proposed Industrial and Agricultural Industries[3]		
barley-malting	2082	1	22.00[4]
potato processing	2034	1	6.00[5]
ethanol production	2869	1	50.00[2]
greenhouses (acre)	NA	1	2.00[4]
			80.00

*Where a facility has more than one process, the heat requirements were split proportionately.

[1] Interplan, Inc., unpublished data, 1978.

[2] Solar Energy Research Institute, draft, may be refined later.

[3] Unpublished data from the San Luis Valley Council of Governments, 1978.

[4] Simmons, 1977

[5] Breindel, Harris, Olson, 1978

FIGURE 10

POSSIBLE DEVELOPMENT SCHEDULE

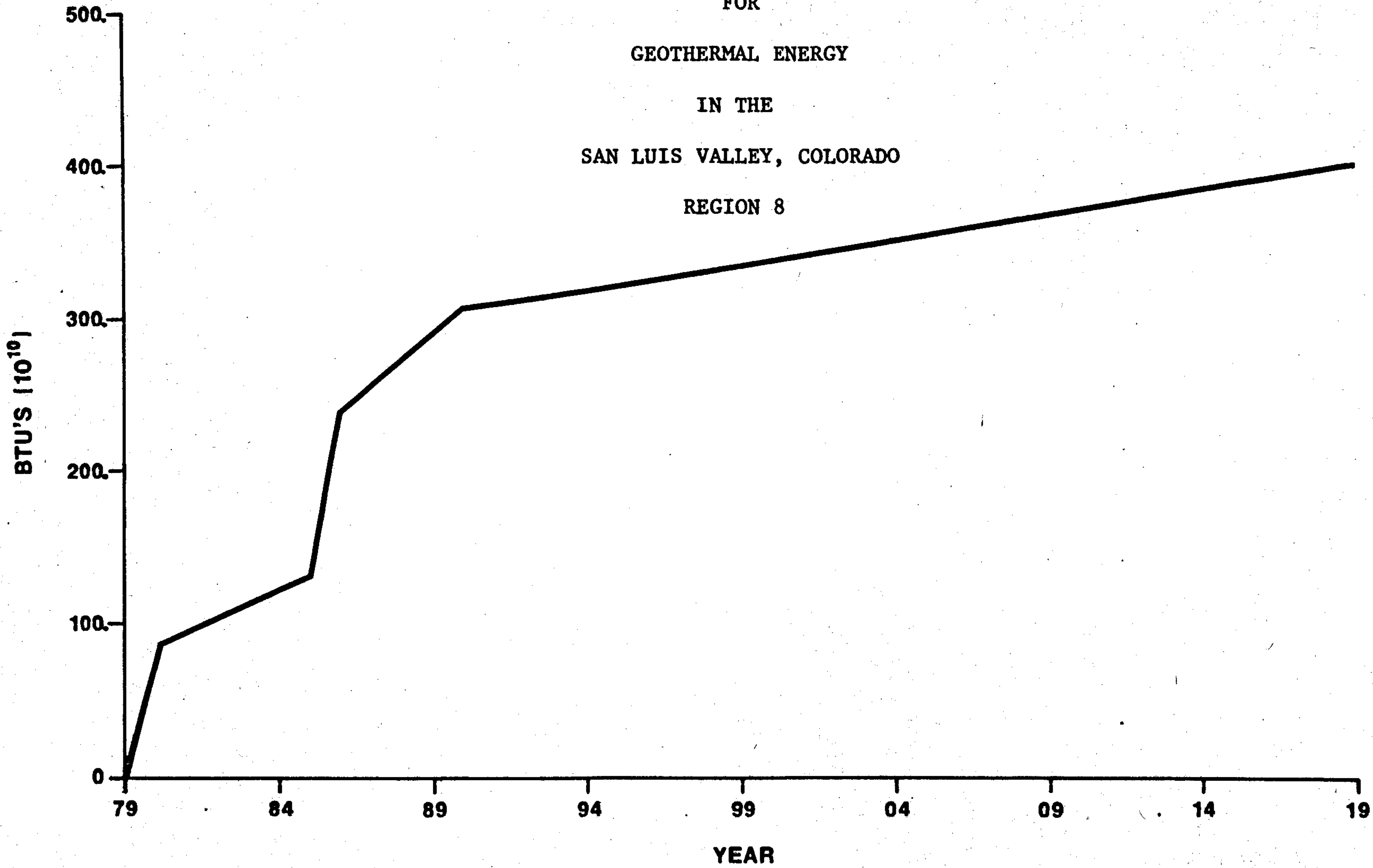
FOR

GEOTHERMAL ENERGY

IN THE

SAN LUIS VALLEY, COLORADO

REGION 8



Also, by 1982 those towns near identified geothermal wells or springs that have natural gas service may start to develop district heating systems. They are the towns of Alamosa, Del Norte, Sanford, and Center. By 1986, when these sytems are conjectured to be on line, their demand would be about 92.13 x 10^{10} Btu's/year. The bottling and dairy plants in Alamosa are also assumed to convert to geothermal energy at that time, adding another 3.03 x 10^{10} Btu's/year.

By 1986, the Sanford heating system could be extended to La Jara, and the Manassa heating system could be extended to Romeo for an additional 9.00 x 10^{10} Btu's on line.

By about 1990, existing industrial processors in towns more remote from known surface expressions might convert to geothermal heat. These towns, which include Monte Vista, South Fork, and Saguache, could be using about 9.92 x 10^{10} Btu's for industry by 1990. Finally, these towns are conjectured to convert to geothermal for space heating as well, bringing another 50.44 x 10^{10} Btu's on line by 1990. By that time, it is assumed that almost no natural gas would be in use in the valley. The graph, Figure 10, shows the amount of postulated geothermal energy development over time. Given these hypothesized developments, this scenario would result in a total of 305.25 x 10^{10} Btu's in the year 1990 and about 370 x 10^{10} Btu's by the year 2009. This is within the range of hydrothermal energy estimated to be available per year if systems become depleted over the 30-year period. More than likely, however, the use of geothermal energy could continue for an indefinite period.

V. SUMMARY AND CONCLUSIONS

If the energy content of the geothermal reservoirs in the San Luis Valley is similar to that that has been estimated, the potential energy supply is significant indeed. The lowest estimate indicates that the usable geothermal energy could be more than 60 times the amount of natural gas consumed in the valley in 1977 and more than 19 times the 2020 estimated thermal energy demand of the valley's communities A market for the energy includes not only water and space heating of existing and future residential and commercial structures, but proposed new agricultural facilities. The San Luis Valley has been known to have the agricultural products, including barley and potatoes, the labor force, the community support, and a reasonably convenient location to encourage such processing. If the geothermal energy can be demonstrated to be a valuable source of energy for these and other facilities, the economic development of the area could be greatly enhanced. Requirements for geothermal development have been identified. They include institutional, environmental, technical, and economic considerations and water availability. Of all these, only the availability of water presents potentially difficult hurdles. Even a constrained water supply can, however, be overcome by using various techniques for removing the heat from the geothermal fluid and not consuming the water. Economic studies that have been performed show the costs for developing geothermal energy to be competitive with natural gas.

The primary constraint to develop part of the San Luis Valley's geothermal energy at this stage is lack of knowledge--of the economic advantages and of the resource. If more resource information were obtained, the next step would be to find funding or investor sources for development.

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APPENDIX A

METHODOLOGY

As indicated in the Introduction, most of this report was compiled from secondary sources of information. Following is a description of the methodology used when those data required interpretation, manipulation, or supplementation.

Population and Energy Demand

To estimate the role that geothermal energy could play in the San Luis Valley required an estimate of the thermal energy demand, both present and future. The first step in making such estimates was to obtain actual natural gas consumption figures and numbers of customers for 1977 by residential, commercial, and industrial sectors. Then the demand for thermal energy was estimated for all residential and commercial structures in concentrated population areas, including those that have no natural gas service. This required calculation of the mean natural gas consumption for residential and commercial sectors per residential customer. This was then multiplied by a factor of .9 to eliminate the small amount used for cooking and by .7, an efficiency factor. Finally, a Btu content of 850 Btu's per cubic foot of natural gas was assumed. These calculations resulted in an estimated 155.5 million Btu's per residential customer. The result can then be used to estimate the total thermal heat needs of each of the communities.

The next step was to obtain population estimates for 1975 for the communities in the region. The Region 8 average of 2.8 occupants per dwelling unit (SLVOG, 1974) was used to estimate dwelling units in each of those communities. The number of dwelling units in two unincorporated areas were also reported. About 100 dwelling units are located in the Baca Grande Subdivision (Coury, 1978 a, b) and 140 in the South Fork area (Hundley, pers. comm., 1979). The energy demand for each community was then estimated using the estimated demand per dwelling unit and estimated number of dwelling units.

To forecast future energy demand, population forecasts for the year 2000 from the U.S. Census Bureau were extrapolated to the year 2020. The dwelling unit occupancy rate and the proportionate split among the communities were assumed to remain constant. The thermal energy consumption per dwelling unit was also estimated to remain constant, for two reasons. First, the promotion of energy conservation is assumed to be effective. Secondly, new energy consuming devices generally use electricity, not thermal energy.

After estimating the thermal energy for residential and commercial space and water heating demand for the year 2020, the increase from the year 1975 was distributed equally to each of the intervening years.

The energy demand for scattered rural structures was considered to be irrelevant, because economic use of geothermal energy is assumed to require a concentration of users. The incorporated towns of Blanca and Bonanza were also excluded because of their small size and distance from identified geothermal resource areas.

The industrial demand for geothermal energy was analyzed on a use-by-use basis, as described in Section IV.

Geothermal Energy Available

Another type of information necessary is the amount of usable geothermal energy. Although this information cannot be confirmed until wells are drilled and tested, it has been estimated. Pearl (1979) recently completed an assessment of the probable and possible content of each of the geothermal reservoirs underlying those thermal wells and springs that have been identified so far in Colorado Region 8. That assessment was based on reservoir volumes and estimated subsurface temperatures as described in Coe (1978) and Pearl (1979). The estimated energy content of from 1.4270-6.2153 x 10.015 Btu's multiplied by a factor of 0.24 was then used to estimate the energy extractable from the ground, an estimated 0.3425 - 1.4917 x 10^{15} Btu's. This is then multiplied by a factor of .25 to estimate the heat that would actually be used in a geothermal heating facility, an estimated 0.0856 - 0.3729 x 10^{15} Btu's.

Unfortunately, estimating the reservoir volume cannot indicate the rate at which the energy can be consumed. Since the hydrologic system will recharge, a facility will usually be designed to equalize the discharge with the recharge. Mining of water is not considered to be desirable (Pearl, pers. comm., 1978). In lieu of data that can only be obtained from drilling wells, an estimate of the possible rate of energy use was required. To avoid being overly optimistic, the removal of a portion of the energy was assumed to deplete the energy supply by that much, as though the heat were being mined. To obtain an average of the amount of energy available each year, the total usable energy may be divided by 30, based upon a commonly-used gauge of equipment life of 30 years. The estimated usable energy per year that results is between 0.0029-0.0124 x 10^{15} Btu's per year.

For the sake of comparison, another analysis assumed that existing flows are optimal and therefore avoids an assumption of mining the water. For some of the resource areas in the San Luis Valley, discharge rates were measured, ranging between 299 and 459 gpm. These flow rates can be multiplied by minutes per year, by the weight of the water, and then by the degrees of heat (F) extracted in order to yield usable energy. Assuming a midpoint discharge rate and extraction of about half of the heat, the San Luis Valley areas are estimated to yield only about 1.1092 x 10^{10} Btu's/year of usable energy, much less than that estimated using the previous method.

Of these results, the former calculations seem to be the most appropriate. For one thing, discharge rates are lacking for the Sand Dunes and Splashland areas. Secondly, the assumption that the geothermal discharge is indicative of the rate of recharge of the system is tenuous. The valley is comprised of horizontal, sedimentary layers and is very large. For these reasons, thermal waters could be migrating laterally for many miles, rather than erupting at the surface. Also, thermal waters could mix with cold ground waters, cooling prior to surfacing. In a fault-controlled system, particularly if it is believed to be quite confined, using the discharge to estimate the energy content might be appropriate, but in this case, the former method seems more valid (Galloway, pers. comm., 1978)

Possible Development Schedule

The background of Region 8 and the area's requirements for geothermal energy development were analyzed in order to devise a reasonable hypothetical schedule for geothermal energy development. As such, the time required is incorporated into the schedule and assumptions about probable uses are based upon current economic activities and trends, population distribution, and expressed interests. Deciding exactly how these elements might fit together involves making judgements, and as such, any number of different plans could be devised. This is only one of numerous possible plans, not a prediction for the future.

In postulating the kinds and timing of geothermal development, several assumptions were made. First, it was assumed that the nature of the economy in the San Luis Valley would not change drastically. Then, it was assumed that those activities that are generally the most economically competitive would come on line first. This means that new, single facility, large users, namely agricultural processing plants, would be first to develop and use the energy. These and subsequent developments would act as demonstrations for additional developments. Because electricity and propane are expensive, the second major use is assumed to be residential and commercial space and water heating in those communities that lack natural gas service. Then, as natural gas prices continue to rise, existing residential and commercial and then industrial users would have greater incentives for conversion to geothermal energy.