OPEN-FILE REPORT NO. 81-3

APPENDICES OF
AN APPRAISAL FOR THE USE OF
GEOTHERMAL ENERGY IN
STATE-OWNED BUILDINGS IN COLORADO

*Section A: Alamosa
Section B: Buena Vista
Section C: Burlington
Section D: Durango
Section E: Glenwood Springs
Section F: Steamboat Springs

by

Richard T. Meyer
Barbara A. Coe
Jay D. Dick

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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
DENVER, COLORADO

1981

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ALAMOSA

Two state-owned building complexes have been evaluated within the city of Alamosa: Adams State College and the State Highway Department Buildings. The locations of these facilities are indicated in Figure 5.

The resource assessment for the Alamosa area is considered generally applicable to the City of Alamosa and the specific sites of the two facilities. For the purposes of this analysis, the drilling locations for the geothermal production wells are placed on-site at Adams State College and at the State Highway Department Buildings. The resource assessment indicates that 150°F may be available at flow rates of 1000 gpm per well, depths of 4000 feet, and possibly under Artesian pressure.

Two building retrofit engineering options are evaluated for Adams State College, both of which assume only partial replacement (approximately 50%) of the existing natural-gas-fired steam-boiler system. Partial replacement rather than total replacement of the steam heating system was chosen in order to provide for a first phase demonstration project and to allow for the on-campus drilling of both the production and reinjection wells. The two retrofit options for geothermal heating include (1) a high performance central heat pump for boosting the circulating heating water to 200°F for space heating and (2) a central heat exchanger for delivery of heating water at 145°F. The first option provides for continued usage of the existing hot water heating units in the campus buildings, with the exception of retrofit of the steam units in College Center. The second option provides for the addition of terminal hot water heating units in all of the buildings in order to adapt to 145°F heating water.

Retrofit engineering for the State Highway Department Buildings provides for the use of a central heat exchanger and the distribution of 140°F heating water to all building areas that are presently heated. The existing system of natural gas furnaces and unit heaters and of propane unit heaters can be retained for a back-up or peaking system.

The geothermal energy economics for Adams State College are evaluated for both the heat pump and the heat exchanger options. In addition, the following variations in parameters are provided: natural gas price escalation of 15 percent per year (through 2000) and of 12 percent/9 percent (through 1984/through 2000); production well pumping and circulation pumping of 8760 hours per year (100% operation) and of 4320 hours per year; and pumping depths of 100 feet and of 300 feet. The same variations are applied to the State Highway Department Buildings, except the operational period was confined to 4320 hours per year.

Results of the life cycle cost analysis for Adams State College strongly favor the geothermal system over the existing natural gas system, with either the heat pump or the heat exchanger option. This result is particularly true for the assumptions of 15% per year escalation on natural gas prices and for an aggregated period of operation of 4320 hours per year. The latter would require the use of an auxiliary heating system for the steam requirements of the cafeteria in College Center.

Figure 6. Regional gravity map of the eastern San Luis Valley showing major faults and structural features (adapted from Gaca and Karig, 1965). Hot springs and wells are shown herein and the outlined area is enlarged in Figure 7.

Source: Chaffee Geothermal, Ltd.

The economic analysis for the State Highway Department Buildings is generally unfavorable to the geothermal system. This result is primarily a consequence of the high capital costs and the high annual operating and maintenance costs associated with the production and reinjection wells.

Institutional and environmental issues are minimal for the two state facilities in Alamosa. In both cases, well drilling is proposed to take place on state-owned property, including the reinjection wells for disposal of the spent geothermal fluids.

Detailed information on the Alamosa facilities are provided in the following sections.

Resource Assessment for Alamosa Area

The San Luis Valley is one of the better known geothermal areas in Colorado with excellent geothermal low temperature agricultural and domestic potential. The San Luis Valley is the northern extension of the Rio Grande rift zone which is an area of extensive study, showing high heat flow measurements. Numerous hot springs and wells occur throughout the valley, some of which are shown on Figure 6. Valley View Hot Springs has a temperature of 99°F with a combined flow of approximately 250 gpm, Mineral Hot Springs has a temperature of 140°F with flows up to 200 gpm, the Sand Dunes Ranch warm water well is reported to be 4400 feet deep and producing at 111°F. The Mapco State 1-32 exploration well has a reported bottom hole temperature of 250°F at 9460 feet; the 2000 foot deep Splashland warm water well has a surface temperature of 104°F; and a domestic well in western Alamosa has a reported temperature of 112°F and is 3000 feet deep. Several oil and gas exploration wells have been drilled throughout the San Luis Valley and some have reported bottom hole temperatures of 235°F at greater than 10,000 feet (locations are confidential). Shaws Hot Spring in the western valley has a surface temperature of 86°F at very low flow rates.

The San Luis Valley is a large intermountain basin which is dissected by parallel faults. Several hot springs and wells are located immediately along these fault zones or within the deeper portions of the grabens. Initial geothermal projections of the San Luis Valley indicate that the valley may be underlain by geothermal fluids but those areas with the greatest geothermal potential may be along the bounding faults of the Alamosa Horst and within the Baca Graben.

For purposes of this study the geothermal resources within five to ten miles of Alamosa are being reviewed. As can be seen in Figure 6, the town of Alamosa is located midway between major fault zones. The area appears to have some geothermal potential but not as great as that along the faults. (In Figure 6, faults are shown as dashed lines).

Most of the data on the geothermal potential specific to Alamosa are derived from local well data and from temperature gradient holes drilled by the Colorado Geological Survey during 1979. Bottom hole temperatures

were compared with the temperature recorded at 164 feet (50 meters) and a temperature gradient calculated for each gradient hole (Table 16). Data are also available on four warm water wells in the Alamosa vicinity (Table 16). The Splashland well has a temperature of 104°F, municipal wells in town have temperatures of 97°F and 103°F and a domestic well west of town (near the Gibson store) has a surface temperature of 112°F. Temperature gradients were calculated for these wells.

From the temperature gradient contours (Figure 7), the best geothermal areas appear to be west and east of town. If a geothermal well were drilled east of the city, the well depths estimated to be required are 3000 feet for a 150°F reservoir temperature and 4500 feet or more for 200°F reservoir temperature. A well drilled on the western margins of Alamosa would need to be 4000 feet or more for a 150°F temperature and greater than 5500 feet for a 200°F temperature.

Irrigation wells in the San Luis Valley have production rates ranging from several hundred gallons per minute up to 4000 to 5000 gpm. The hot water well near the Gibson store is producing at 600 gpm and several other wells in Alamosa have high flow rates. The geothermal reservoir in the San Luis Valley is within the sediments and valley-fill of the San Luis Basin which generally have very high permeabilities and porosities (those beneath the "Blue Clay" facies) that account for projected high flow rates. Production rates from deep geothermal wells at Alamosa could be 500 to 1000 gpm from each of several wells. The total dissolved solids content in this fluid production is expected to be a low 200 to 311 mg/l based upon chemical analyses of several other wells in the area.

The geothermal reservoir probably lies beneath all of the Alamosa area but the hottest reservoirs are bordering the fault zones. These hotter geothermal systems probably extend two to three miles either side of both fault zones and extend for numerous miles to the north and south. The overall areal extent of the prime geothermal systems near Alamosa is greater than 10 to 15 square miles.

The useable heat content (assuming no recharge) in the geothermal systems near Alamosa is projected by Pearl (1979) to be 93.1×10^{11} Btu. Since the reservoir projected herein is a bit larger than that of Pearl's, the estimate of the useable heat for Alamosa may be larger than this figure.

A summary of the projected geothermal resource characteristics (with the associated validity rating) at Alamosa is:

Reservoir temperature:	150°F (2)
Depth:	4000+ feet (2)
Production/well:	500 - 1000 gpm (2)
Areal extent:	10 - 15 square miles (3)
Formation:	Poorly consolidated sediments within volcanic flows
TDS:	300 mg/l
Useable heat:	93×10^{11} Btu. (2)

TABLE 16

Well Data and Temperature Gradient Calculations for Select Hot Water Wells and Temperature Gradient Holes Near Alamosa, Colorado.

Well Name	Depth	Bottom Hole Temperature	Temperature at 164'	Calculated Temperature Gradient	Other
GH-1	282'	60°F	55°F	4.24°F*	
GH-2	285'	59°F	55°F	3.31°F	
GH-3	272'	58°F	54°F	3.70°F	
GH-4	276'	55°F	52°F	2.68°F	
GH-5	289'	58°F	54°F	3.48°F	
GH-6	292'	59°F	54°F	3.91°F	
GH-12	276'	56°F	52°F	3.57°F	
GH-13	282'	56°F	52°F	3.39°F	
A-Splashland	2000'	104°F **	54°F	2.72°F	TDS = 311 mg/l
B-12th/River	1768'	103°F	54°F	3.05°F	hotter at 2000'
C-Lot 37	1648'	97°F	54°F	2.90°F	
D-Gibsons	3000'	112°F	54°F	2.05°F	TDS = 200 mg/l, 600 gpm

*°F/100'

** assumed bottom hole temperatures

Raw data on temperature gradient holes GH-1 through GH-13 is from the Colorado Geological Survey (Ringrose, 1980).

Figure 7. Temperature gradient profiles near Alamosa, Colorado. Contour intervals are in 0.5° F/100 feet isotherms. Well numbers and temperature gradients are shown on Table 1. The bounding faults of the Alamosa Horst are approximately at the borders of this figure.

SOURCE: Chaffee Geothermal, Ltd., 1980

Well number
●
°F/100'

Most of the San Luis Valley has geothermal potential, with the Baca area along the faults having the greatest. At Alamosa drilling would need to be deep to encounter useable geothermal fluids of 150°F but good production rates of 500 to 1000 gpm could be expected. Exploration for the geothermal resource is relatively risky and costly at Alamosa, but if the resource is located the geothermal potential is excellent.

Pipeline Right-of-Way

Geothermal wells to supply Adams State College and the State Highway Department Buildings may be located either on-site or up to 3.5 miles distant with the resource characteristics likely to be those specified above. The vertical relief for this zone is zero feet to $\pm$ 20 feet.

Production Well Costs and Well Engineering

Total costs for the drilling of production wells to a depth of 4000 feet are estimated at \$265,000 per well. Well engineering design and drilling procedures are basically similar to those described in Chapter VI for Glenwood Springs.

Building Retrofit Engineering for Adams State College

Brief summary descriptions of the present steam heating system, the assumptions made for the design of a geothermal system, the advantages and disadvantages of a geothermal system, and then the design specifications for the central heat exchanger and the central heat pump systems are presented below. A map of the campus of Adams State College is shown in Figure 8.

Present Steam Heating System Description

1. Central steam plant with steam distribution pipelines; natural gas fired boilers; three boilers (40,000 lb/hr, 35,000 lb/hr, and 20,000 lb/hr); maximum supply rate is 60,000 lb/hr (2 boilers only).
2. Most building heating is hot water with some being direct steam.
3. Steam distribution operates at 125 psi.
4. Present hot water operates at 200°F with 20°FΔT; outdoor reset is used (120°F water @ 60°F outside temperature).
5. Total campus load is 43.11×10^6 Btu/hr.

Assumptions for Geothermal System

1. Existing equipment will be used as much as possible in geothermal retrofit.
2. 150°F geothermal water is available.

Figure 8

Adams State College

ALAMOSA, COLORADO 81102

SOURCE: Adams State College

1. Art Building
2. Science and Industrial Arts Building
3. Richardson Hall (Administration)
4. Harry W. Zacheis Observatory-Planetarium
5. Business and Economics Building
6. Music Building
7. Pettys Hall
8. Delzell Hall
9. Leon Memorial
10. Education and Social Studies Building
11. President's Home
12. Casa Del Sol Apartments
13. KASF Radio Station
14. Speech and Hearing Clinic
15. Motor Maintenance Center
16. Maintenance Building and Warehouse
17. Day Care Center
18. Savage Hall
19. McCurry Hall
20. Houtchens Hall
21. Moffatt Hall
22. Married Student Apartments
23. Faculty Residences
24. Rex Field
25. Library
26. Rex Gymnasium
27. Steam Plant
28. Plachy Hall (Physical Education)
29. College Center
30. Girault Hall
31. Coronado Hall
32. Tennis Courts

3. Geothermal water cannot be used directly.
4. Constraint of maximum of two 1000 gpm wells on campus. This will not allow the entire campus to be heated.
5. Select clustered group of buildings to allow for approximately 20×10^6 Btu/hr load and to optimize distribution system.

Selection of Buildings for Geothermal Heating

1. Total load less than 20×10^6 Btu/hr.
2. Close proximity to each other and well location in order to optimize distribution system.

3. <u>Building</u>	<u>Square Footage</u>	<u>MMBtu/hr</u>	<u>Heating Mode</u>
Library	77,058	3,699	Hot water
Rex Gymnasium	22,600	1,084	Steam
Plachy Hall	92,270	4,429	25% steam, 75% hot water
College Center	93,905	4,507	Hot water
Grant Hall	34,377	650	Hot water and steam
Coronado	<u>101,973</u>	<u>4,895</u>	Hot water
	422,183	19,264	

Advantages of a Geothermal Retrofit

1. Large gpm is assumed to be available on the site.
2. Most buildings are presently heated with hot water.

Disadvantages of a Geothermal Retrofit

1. Present steam system cannot be used; new distribution system is required.
2. Steam heated buildings must be converted.
3. Only 150°F geothermal water is available; existing heating systems must be adapted to 150°F or 150°F must be boosted to 200°F.
4. High operating costs are prevalent if heat pumps are used.

Central Heat Exchanger Design Specifications

Proposed System and Modifications:

1. Heat a closed loop district heating system with 150°F geothermal water using a plate type heat exchanger (loop is 145°F).
2. Install a new hot water heating distribution system around the campus.
3. Replace the steam to water heat exchangers with a three-way valve and secondary pumping bridge.
4. Upgrade and/or add terminal units in the buildings to adapt to 145°F heating water.
5. Replace steam heating systems with water heating systems where necessary.
6. System designed to provide 20 million Btu/hr.
7. Geothermal wells (2-1000 gpm) to be drilled on site.

Engineering Design:

The new hot water distribution system is shown in Figure 9. Figures 10 and 11 provide the specifications for the central heat exchanger and for the retrofit a typical building to the hot water system, respectively.

Equipment Components and Cost Estimates:

	<u>Quantity</u>	<u>Unit Cost</u>	<u>Total Cost</u>
● Hot Water Distribution System			
Underground Pipe (Preinsulated/Prefab)			
8" Single line	460'	\$73	\$33,580
6" Single line	440'	59	25,960
5" Single line	1620'	57	92,340
4" Double line/1 Conduit	80'	83	6,640
3" Double line/1 Conduit	110'	68	7,480
Heat Exchanger (2000 gpm, 5°F Approach)	1	30,000	30,000
Pumps (1000 gpm @ 130 ft. hd.)	2	8,000	16,000
Air Separator/Expansion Tank	1	5,000	5,000
Miscellaneous Piping & Fitting	L.S.	8,000	8,000
Heat Exchanger/Pump Building	300 S.F.	25	7,500
Subtotal			\$232,500
Contingency (10%)			23,250
		Total	\$255,750

Figure 9

ADAMS STATE DISTRIBUTION SYSTEM

HEAT EXCHANGER SYSTEM

FIGURE 10

TYPICAL BLDG. RETROFIT
FOR GEOTHERMAL USE

FIGURE 11

● <u>Building Heating (145°F water)</u>	S.F. of Bldg.	Cost/ S.F.	Total Cost
Change steam heating to 145°F water system	47,600	\$6	\$ 285,600
Retrofit existing hot water heated building to handle lower temp water (add supplemental heat to existing equipment)	374,583	4	1,498,332
			<hr/>
	Subtotal		1,783.932
	Contingency (10%)		<hr/> 178,393
	Total		\$1,962,325
● <u>Geothermal Side (excluding well pumps)</u>			
10" Pipe to 2 wells	Assume 600 ft @ \$63/ft		\$37,800
	Contingency (10%)		<hr/> 3,780
	Total		\$41,580

Central Heat Pump Design Specifications

Proposed System and Modifications:

1. Heat a closed loop district heating system using a heat pump to extract heat from the 150°F geothermal water to heat the circulating water.
2. Install a new hot water distribution system around the campus (200°F).
3. Run the geothermal water directly through the evaporator side of the heat pump.
4. Replace the steam to water heat converter with a three-way valve and secondary pumping bridle.
5. Geothermal well is to be drilled on the site.
6. Replace steam heating systems with water heating system where necessary.
7. System to be designed to provide 20 million Btu/hr.

Engineering Design:

The new hot water distribution system is the same as that for the heat exchanger system, as shown in Figure 9. Figures 12 and 11 provide the specifications for the central heat pump and for the retrofit of a typical building to the hot water system, respectively.

HEAT PUMP SYSTEM

FIGURE 12

Equipment Components and Cost Estimates:

	<u>Quantity</u>	<u>Unit Cost</u>	<u>Total Cost</u>
● <u>Hot Water Distribution System</u>			
Underground Pipe (Preinsulated/Prefab)			
8" Single line	460'	\$73	\$33,580
6" Single line	440'	59	25,960
5" Single line	1620'	57	92,340
4" Double line/1 Conduit	80'	83	6,640
3" Double line/1 Conduit	110'	68	7,480
Heat Pumps (1605 nominal tons, COP=6.0)	1605	400	642,000
Pumps (1000 gpm @ 130 ft. hd.)	2	8000	16,000
Air Separator/Expansion Tank	1	5000	5,000
Miscellaneous Piping & Fitting	L.S.	8000	8,000
Heat Pump/Pump Building	300 S.F.	25	7,500
	Subtotal		844,500
	Contingency (10%)		84,450
	Total		\$ 928,950
● <u>Building Heating (200°F Water)</u>			
	<u>S.F. of Bldg.</u>	<u>Cost/ S.F.</u>	<u>Total Cost</u>
Change steam heating to 200°F water system	47,600	\$6	\$ 285,600
Tie in secondary/primary pumping bridle and three-way valves to existing system	L.S.		35,000
	Subtotal		320,600
	Contingency (10%)		32,060
	Total		\$352,660
● <u>Geothermal Side (excluding well pumps)</u>			
6" Pipe to well	Assume 200 ft @ \$63/ft		\$12,600
	Contingency (10%)		1,260
	Total		\$13,860

Building Retrofit Engineering for State Highway Department Buildings

The State Highway Department Complex at Alamosa consists of several buildings on one site. Both natural gas fired boilers for hot water heating and propane fired unit heaters are currently used. The proposed geothermal retrofit is to use a central heat exchanger with hot water distribution to replacement fan coil heaters and unit heaters throughout the complex. The retrofit specifications are outlined below.

Present Conventional Fuel Heating System

<u>Building</u>	<u>Square Footage</u>	<u>Fuel</u>	<u>Heating Equipment</u>	<u>Peak Heat Load (Btu/hr)</u>
Office Building	4,800	Natural gas	Water boiler, fancoils & radiators	1,621,000
Garage	10,260			
North Shed				
Materials Lab	2,400	Natural gas	Water boiler & radiators	217,600
Paint Shop	1,152	Propane	Unit heaters(2)	108,800
South Sheds				
Green Shed	2,400	Propane	Unit heaters(2)	163,200
Work Shed	1,600	Propane	Unit heaters(2)	108,800
Warehouse	4,000	Propane	Unit heaters(3)	326,400
Totals	26,612			2,545,800

Geothermal System Design Specifications

Proposed System and Modifications:

1. Replace existing fan coil units with new units capable of satisfying design loads with low approach temperatures.
2. Replace existing unit heaters with new units capable of satisfying design loads with low approach temperatures.
3. Plate-in-frame heat exchanger is required.
4. Circulation pump is required.
5. Air separator and expansion tank are required.
6. More sophisticated temperature control is required.
7. Use existing two-pipe and add two-pipe where necessary.
8. Assume 150°F geothermal water is available.

Engineering Design:

<u>Building</u>	<u>Design Peak Heat Load(Btu/hr)</u>
Office Building and Garage	1,625,000
North Shed	218,000
South Sheds	780,000
	<hr/>
	2,623,000

The design peak load can be accomplished utilizing 150°F geothermal hot water at 500 gpm, a ΔT of 10.5°F and a 2°F approach for the heat exchanger. Figure 13 shows the detailed engineering design for the entire complex.

Equipment Components and Cost Estimates:

<u>Component</u>	<u>Specifications</u>	<u>Quantity</u>	<u>Unit Cost</u>	<u>Total Cost</u>
Fan Coils	140°F EWT → 120°F LWT 72°F EAT → 90°F LAT 1200 CFM	4	\$750	\$3,000
Unit Heaters	140°F EWT → 120°F LWT 72°F EAT → 90°F LAT	21	750	15,750
Heat Exchanger	Plate-in-frame type 500 gpm 150°F → 140°F for geothermal side 250 gpm 140°F → 120°F for building side	1	10,000	10,000
Circulating Pump	250 gpm @ 60 ft. hd.	1	1,000	1,000
Air Separator and Expansion Tank		2	600	1,200
Piping	Twin pipe	1000 L.F.	16	16,000
Pipe Insulation		1000 L.F.	6	6,000
Temperature Controller				2,835
				<hr/>
			Subtotal	\$55,785
			Contingency (10%)	5,578
				<hr/>
		Total		\$61,363

Economic Evaluations

Adams State College

On the following pages are presented the itemized geothermal capital improvements costs, the annual operating and maintenance costs for both the geothermal systems and the conventional fuel system, and the results of the calculations of the four economic measures for the two geothermal options evaluated for Adams State College. Both options apply to only six buildings and about 50 percent of the annual heating load of the campus.

The total capital costs are \$3,674,678 for the central heat exchanger with Artesian flow and \$2,111,387 for the central heat pump with Artesian flow. The principal capital cost differences reside with the number of geothermal wells required, the high cost of the central heat pump, and the retrofit costs for the campus buildings. The total operating and maintenance costs for the two geothermal options are approximately equal in the first year and are less than the estimated annual costs for the conventional heating system.

The calculated economic measures (assuming fuel price escalation of 15% per annum) are summarized as follows:

	<u>Central Heat Exchanger</u>	<u>Central Heat Pump</u>
Simple Payback Period:	16 years	9 years
Total Annualized Cost:		
Geothermal:	\$658,049	\$476,912
Conventional:	\$720,535	\$720,535
Total Undiscounted Savings:	\$15,336,331	\$15,670,359
Total Present Value Savings:	\$4,096,455	\$4,194,979

Both geothermal options appear economically feasible, with the central heat pump system ranking higher than the central heat exchanger system.

CAPITAL COSTS

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Exchanger with Artesian Flow

A. Production Well System

	<u>Costs</u>
Exploration	\$ 53,000
Reservoir Engineering	106,000
Wells 2 @ \$265,000	530,000
Well Pumps (2) 2000 gpm, 380 ft-hd, 337 HP	134,800
Valves and Controls	5,000
Contingency Funds (10%)	<u>Included</u>
Subtotal	828,800
Engineering Design Fee (10%)	<u>Included</u>
Total	\$828,800

B. Transmission Line System

Piping (600 ft.)	37,800
Pumps () gpm, ft-hd, HP	N.R.
Contingency (10%)	<u>3,780</u>
Subtotal	41,580
Engineering Design Fee (10%)	<u>4,158</u>
Total	\$ 45,738

C. Central Distribution System

Heat Exchanger (2000 gpm)	30,000
Heat Pump	N/A
Auxillary Building	7,500
Valves and Controls	5,000
Piping (2710 ft)	166,000
Circulation Pumps (2)	16,000
1000 gpm, 130 ft-hd, 575 HP	
Miscellaneous	8,000
Contingency (10%)	<u>23,250</u>
Subtotal	255,750
Engineering Design Fee (10%)	
Total	<u>\$ 281,325</u>

D. Building(s) Retrofit HVAC System

Heating Units	1,498,332
Retrofit Plumbing	285,600
Valves and Controls	Included
Contingency (10%)	<u>Included</u>
Subtotal	1,783,932
Engineering Design Fee (10%)	<u>178,393</u>
Total	<u>\$1,962,325</u>

E. Reinjection/Disposal System

Reinjection Well(s): 2 wells @ \$ 424,000	424,000
Piping (1000 ft.)	30,000
Pumps ()	N.R.
Controls and Valves	5,000
Contingency (10%)	<u>46,900</u>
Subtotal	505,900
Engineering Design Fee (10%)	<u>50,590</u>
Total	<u>\$ 556,490</u>

F. Grand Total

\$3,674,678

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Exchanger with Artesian Flow

Geothermal System

<u>Cost Item</u>	<u>Electricity Cost</u>	<u>Maintenance Cost/ (% of C. C.)</u>
A. Production Well System Pump electricity	\$ 48,853	\$33,152 (4%)
B. Transmission Line System	-	457 (1%)
C. Central Distribution System Heat Pump electricity Circ. Pump electricity	- 16,680	2,813 (1%)
D. Building(s) Retrofit HVAC System		19,617 (1%)
E. Reinjection/Disposal System	-	11,130 (2%)
Total	\$ 65,533	\$67,169

Conventional Fuel System

Type of System: Natural Gas Fired Steam Boiler

<u>Fuel Cost</u>	<u>Maintenance Cost</u>
Total Annual Fuel Load $46,234 \times 10^6$ Btu/yr	Percent of Associated
1980-81 Estimated Fuel Price $\$4.16/10^6$ Btu	Capital Costs
1980-81 Estimated Total Annual Fuel Cost \$ 192,238	Estimated Capital Costs
	Estimated Maintenance Cost
	\$ 48,000
<u>Electricity Cost</u>	
1980-81 Estimated Total Annual Electricity Cost \$1,825	

ECONOMIC EVALUATIONS

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Exchanger with Artesian Flow

A. Simple Payback Calculation

Current Annual Conventional System Cost

Natural Gas	\$192,238
Electricity	1,825
Maintenance	48,000
Total	\$242,063

Geothermal System Cost

Capital Cost (1980 Dollars)	\$3,674,678
First Year Operating Cost	65,533
First Year Maintenance Cost	67,169
Total	\$3,807,380

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}} = 16 \text{ years}$

B. Annual Cost Comparison

(Assume 20-Year Life and 10% per Annum Cost of Capital)

<u>Cost Item</u>	<u>Conventional System Annualized Cost</u>	<u>Geothermal System Annualized Cost</u>
Capital Investment	\$ -	\$ 431,550
Electricity (9%/yr. escalation)	3,579	128,521
Maintenance (10%/yr. escalation)	70,017	97,978
Conventional Fuel (15%/yr. escalation)	646,939	-
Total Annualized Cost	\$ 720,535	\$ 658,049

ECONOMIC EVALUATIONS (cont'd)

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Exchanger with Artesian Flow

C. Total Savings and Payback Period

Year	<u>Conventional System</u>			<u>Geothermal System</u>		End of Year	Annual Savings	Present Value (i = 10%)
	<u>Fuel (15%)</u>	<u>Elect. (9%)</u>	<u>Maint. (10%)</u>	<u>Maint. (10%)</u>	<u>Elect. (9%)</u>			
1980						0		
1981	192,238	1,825	48,000	67,169	65,533	1	109,361	99,420
1982	221,074	1,989	52,800	71,431	73,886	2	130,546	107,883
1983	254,235	2,168	58,080	77,860	81,274	3	155,349	116,714
1984	292,370	2,363	63,888	84,867	89,402	4	184,352	125,912
1985	336,225	2,576	70,277	92,505	98,342	5	218,231	135,500
1986	386,659	2,808	77,304	100,831	108,176	6	257,764	145,508
1987	444,658	3,061	85,035	109,905	118,994	7	303,855	155,938
1988	511,357	3,336	93,538	119,797	130,893	8	357,541	166,793
1989	588,060	3,636	102,892	130,579	143,983	9	420,026	178,133
1990	676,269	3,964	113,181	142,331	158,381	10	492,702	189,937
1991	777,710	4,320	124,500	155,140	174,219	11	577,171	202,298
1992	894,366	4,709	136,950	169,103	191,641	12	675,281	215,145
1993	1,028,521	5,133	150,645	184,322	210,805	13	789,172	228,623
1994	1,182,799	5,595	165,709	200,911	231,886	14	921,306	242,580
1995	1,360,219	6,099	182,280	218,993	255,074	15	1,074,531	257,243
1996	1,564,252	6,648	200,508	238,703	280,581	16	1,252,124	272,462
1997	1,798,890	7,246	220,559	260,186	308,640	17	1,457,869	288,366
1998	2,068,723	7,898	242,614	283,603	339,504	18	1,696,128	305,133
1999	2,379,031	8,609	266,876	309,127	373,454	19	1,971,935	322,411
2000	2,735,886	9,384	293,564	336,948	410,799	20	2,291,087	340,456
Totals							\$15,336,331	\$4,096,455

Capital Investment \$3,674,678

	<u>Undiscounted</u>	<u>Present Value (discounted at 10%)</u>
Total 20-Year Savings	\$15,336,331	\$4,096,455
Payback Period	11-12 years	18-19 years

CAPITAL COSTS

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Pump with Artesian Flow

A. Production Well System

	<u>Costs</u>
Exploration	\$ 26,500
Reservoir Engineering	53,000
Wells 1 @ \$265,000	265,000
Well Pumps (1) 800 gpm, 300 ft-hd, 106 HP	42,400
Valves and Controls	5,000
Contingency Funds (10%)	<u>Included</u>
Subtotal	391,900
Engineering Design Fee (10%)	<u>Included</u>
Total	\$391,900

B. Transmission Line System

Piping (200 ft.)	12,600
Pumps () gpm, ft-hd, HP	N/A
Contingency (10%)	<u>1,260</u>
Subtotal	13,860
Engineering Design Fee (10%)	<u>1,386</u>
Total	\$ 15,246

C. Central Distribution System

Heat Exchanger, or	N/A
Heat Pump (1605 nom. tons)	642,000
Auxillary Building	7,500
Valves and Controls	5,000
Piping	165,950
Circulation Pumps (2)	16,000
1000 gpm, 130 ft-hd, 575 HP	
Miscellaneous	8,000
Contingency (10%)	84,450
Subtotal	924,950
Engineering Design Fee (10%)	92,495
Total	\$ 1,017,445

D. Building(s) Retrofit HVAC System

Heating Units	N/A
Retrofit Plumbing	285,600
Valves and Controls	35,000
Contingency (10%)	32,060
Subtotal	352,660
Engineering Design Fee (10%)	35,266
Total	\$ 387,926

E. Reinjection/Disposal System

Reinjection Well(s): 1 wells @ \$212,000	212,000
Piping (1000 ft.)	30,000
Pumps ()	N/R
Controls and Valves	5,000
Contingency (10%)	24,700
Subtotal	271,700
Engineering Design Fee (10%)	27,170
Total	\$ 298,870

F. Grand Total

\$2,111,387

ANNUAL OPERATING AND MAINTENANCE COSTS
(1980 Dollars)

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Pump with Artesian Flow

Geothermal System

<u>Cost Item</u>	<u>Electricity Cost</u>	<u>Maintenance Cost/ (% of C. C.)</u>	
A. Production Well System		\$15,676	(4%)
Pump electricity	\$ 15,366		
B. Transmission Line System		152	(1%)
C. Central Distribution System		20,349	(2%)
Heat Pump electricity	50,103		
Circ. Pump electricity	16,679		
D. Building(s) Retrofit HVAC System	-	4,056	(1%)
E. Reinjection/Disposal System	-	6,249	(2%)
Total	\$ 82,148	\$46,482	

Conventional Fuel System

Type of System: Natural Gas Fired Steam Boiler

<u>Fuel Cost</u>		<u>Maintenance Cost</u>	
Total Annual Fuel Load	46,234 x 10 ⁶ Btu/yr	Percent of Associated	
1980-81 Estimated Fuel		Capital Costs	
Price	\$4.16/10 ⁶ Btu	Estimated Capital	
1980-81 Estimated Total		Costs	
Annual Fuel Cost	\$ 192,238	Estimated Maintenance	
		Cost	\$ 48,000
<u>Electricity Cost</u>			
1980-81 Estimated Total			
Annual Electricity Cost	\$ 1,825		

ECONOMIC EVALUATIONS

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Pump with Artesian Flow

A. Simple Payback Calculation

Current Annual Conventional System Cost

Natural Gas	\$192,238
Electricity	1,825
Maintenance	<u>48,000</u>
Total	\$242,063

Geothermal System Cost

Capital Cost (1980 Dollars)	\$2,111,387
First Year Operating Cost	82,148
First Year Maintenance Cost	<u>46,482</u>
Total	\$2,240,017

$$\text{Simple Payback Period: } \frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}} = 9 \text{ years}$$

B. Annual Cost Comparison

(Assume 20-Year Life and 10% per Annum Cost of Capital)

<u>Cost Item</u>	<u>Conventional System Annualized Cost</u>	<u>Geothermal System Annualized Cost</u>
Capital Investment	\$ -	\$248,004
Electricity (9%/yr. escalation)	3,579	161,106
Maintenance (10%/yr. escalation)	70,017	67,802
Conventional Fuel (15%/yr. escalation)	646,939	-
Total Annualized Cost	<u>\$720,535</u>	<u>\$476,912</u>

ECONOMIC EVALUATIONS (cont'd)

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Pump with Artesian Flow

C. Total Savings and Payback Period

Year	<u>Conventional System</u>			<u>Geothermal System</u>		<u>End of Year</u>	<u>Annual Savings</u>	<u>Present Value (i = 10%)</u>
	<u>Fuel (15%)</u>	<u>Elect. (9%)</u>	<u>Maint. (10%)</u>	<u>Elect. (9%)</u>	<u>Maint. (10%)</u>			
1980						0		
1981	192,238	1,825	48,000	82,148	46,482	1	113,433	103,122
1982	221,074	1,989	52,800	89,541	51,130	2	135,192	111,723
1983	254,235	2,168	58,080	97,600	56,243	3	160,640	120,689
1984	292,370	2,363	63,888	106,384	61,868	4	190,369	130,022
1985	336,225	2,576	70,277	115,959	68,054	5	225,065	139,743
1986	386,659	2,808	77,304	126,395	74,860	6	265,516	149,884
1987	444,658	3,061	85,035	137,770	82,346	7	312,638	160,446
1988	511,357	3,336	93,538	150,170	90,580	8	367,481	171,430
1989	588,060	3,636	102,892	163,685	99,638	9	431,265	182,899
1990	676,269	3,964	113,181	178,417	109,602	10	505,395	194,830
1991	777,710	4,320	124,500	194,474	120,560	11	591,496	207,319
1992	894,366	4,709	136,950	211,977	132,619	12	691,429	220,289
1993	1,028,521	5,133	150,645	231,055	145,880	13	806,569	233,663
1994	1,182,799	5,595	165,709	251,850	160,468	14	941,785	247,972
1995	1,360,219	6,099	182,280	274,516	176,515	15	1,097,567	262,758
1996	1,564,252	6,648	200,508	299,223	194,167	16	1,278,018	278,097
1997	1,798,890	7,246	220,559	326,153	213,583	17	1,486,959	294,120
1998	2,068,723	7,898	242,614	355,506	234,942	18	1,728,787	311,009
1999	2,379,031	8,609	266,876	387,502	258,436	19	2,008,578	328,402
2000	2,735,886	9,384	293,564	422,377	284,280	20	2,332,177	346,562
Totals							\$15,670,359	\$4,194,979

Capital Investment \$2,111,387

	<u>Undiscounted</u>	<u>Present Value (discounted at 10%)</u>
Total 20-Year Savings	\$15,670,359	\$4,194,979
Payback Period	9-10 years	13 years

State Highway Department Buildings

On the following pages are presented the geothermal capital improvement costs, the annual operating and maintenance costs for both the geothermal system and the conventional fuel system, and the results of the calculations of the four economic measures for the geothermal option evaluated for the Highway Department Building at Alamosa. The total capital cost is \$722,880 for the heat exchanger with Artesian flow. The first year annual operating and maintenance costs are \$32,936 for the geothermal system and only \$15,988 for the conventional fuel system.

The calculated economic measures (assuming fuel price escalation of 15% per annum) are summarized as follows:

<u>Heat Exchanger System</u>	
Simple Payback Period	47 years
Total Annualized Cost:	
Geothermal:	\$138,625
Conventional:	\$ 50,946
Total Undiscounted Savings:	(\$247,260)
Total Present Value Savings:	Negative

CAPITAL COSTS

Location: Alamosa

Facility: Highway Dept. Bldg.

Geothermal Option: Heat Exchanger with Artesian Flow

A. Production Well System

	<u>Costs</u>
Exploration	\$ 26,500
Reservoir Engineering	53,000
Wells 1 @ \$265,000	265,000
Well Pumps (1) 500 gpm, 340 ft-hd, 75 HP	30,000
Valves and Controls	5,000
Contingency Funds (10%)	<u>Included</u>
Subtotal	379,500
Engineering Design Fee (10%)	<u>Included</u>
Total	\$379,500

B. Transmission Line System

Piping (100 ft.) @ \$35/L.F.	3,500
Pumps () gpm, ft-hd, HP	N.R.
Contingency (10%)	<u>350</u>
Subtotal	3,850
Engineering Design Fee (10%)	<u>385</u>
Total	\$ 4,235

C. Central Distribution System

Heat Exchanger, or Heat Pump	10,000
Auxillary Building Valves and Controls	4,035
Piping 100 ft. @ \$22/L.F.	22,000
Circulation Pumps (1) 162 gpm, 40 ft-hd, 2.9 HP	1,000
Miscellaneous Contingency (10%)	3,704
Subtotal	40,739
Engineering Design Fee (10%)	4,074
Total	\$44,813

D. Building(s) Retrofit HVAC System

Heating Units 4 Fan Coils @ \$750 21 Unit Heaters @ \$750	18,750
Retrofit Plumbing Valves and Controls	-
Contingency (10%)	1,875
Subtotal	20,625
Engineering Design Fee (10%)	2,062
Total	\$22,687

E. Reinjection/Disposal System

Reinjection Well(s): 1 wells @ \$ 212,000	212,000
Piping (500 ft.) @ \$20/L.F.	10,000
Pumps ()	N.R.
Controls and Valves	2,500
Contingency (10%)	22,450
Subtotal	246,950
Engineering Design Fee (10%)	24,695
Total	\$271,645

F. Grand Total \$722,880

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Alamosa

Facility: Highway Dept. Bldg.

Geothermal Option: Heat Exchanger with Artesian Flow

Geothermal System

<u>Cost Item</u>	<u>Electricity Cost</u>	<u>Maintenance Cost/ (% of C. C.)</u>	
A. Production Well System			
Pump electricity	\$10,872	\$15,180	(4%)
B. Transmission Line System	-	42	(1%)
C. Central Distribution System		872	(2%)
Heat Pump electricity	-		
Circ. Pump electricity	418		
D. Building(s) Retrofit HVAC System	minimal	227	(1%)
E. Reinjection/Disposal System	-	5,433	(2%)
Total	\$11,290	\$21,646	

Conventional Fuel System

Type of System: Natural Gas & Propane

<u>Fuel Cost</u>		<u>Maintenance Cost</u>	
Total Annual Fuel Load	5097 x 10 ⁶ Btu/yr.*	Percent of Associated	
1980-81 Estimated Fuel	Nat. Gas \$3.88/10 ⁶ Btu	Capital Costs	2%
Price	Propane \$1.15/10 ⁶ Btu	Estimated Capital	
1980-81 Estimated Total		Costs	75,000
Annual Fuel Cost	\$ 14,488	Estimated Maintenance	
		Cost	\$1,500

<u>Electricity Cost</u>	
1980-81 Estimated Total	
Annual Electricity Cost	\$ 0

* 62% Natural Gas, 38% Propane

ECONOMIC EVALUATIONS

Location: Alamosa

Facility: Highway Dept. Bldg.

Geothermal Option: Heat Exchanger with Artesian Flow

A. Simple Payback Calculation

Current Annual Conventional System Cost

Natural Gas	\$14,488
Electricity	-
Maintenance	<u>1,500</u>
Total	\$15,988

Geothermal System Cost

Capital Cost (1980 Dollars)	\$722,880
First Year Operating Cost	11,290
First Year Maintenance Cost	<u>21,646</u>
Total	\$755,816

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}} = 47 \text{ years}$

B. Annual Cost Comparison

(Assume 20-Year Life and 10% per Annum Cost of Capital)

<u>Cost Item</u>	<u>Conventional System Annualized Cost</u>	<u>Geothermal System Annualized Cost</u>
Capital Investment	\$ -	\$ 84,909
Electricity (9%/yr. escalation)	0	22,142
Maintenance (10%/yr. escalation)	2,190	31,574
Conventional Fuel (15%/yr. escalation)	48,756	-
Total Annualized Cost	<u>\$50,946</u>	<u>\$138,625</u>

ECONOMIC EVALUATIONS (cont'd)

Location: Alamosa

Facility: Highway Dept. Bldg.

Geothermal Option: Heat Exchanger with Artesian Flow

C. Total Savings and Payback Period

Year	<u>Conventional System</u>			<u>Geothermal System</u>		<u>End of</u>	<u>Annual Savings</u>	<u>Present Value</u> (i = 10%)
	<u>Fuel (15%)</u>	<u>Elect. (9%)</u>	<u>Maint. (10%)</u>	<u>Elect. (9%)</u>	<u>Maint. (10%)</u>	<u>Year</u>		
1980						0		
1981	14,488		1,500	11,290	21,646	1	(16,948)	
1982	16,661		1,650	12,306	23,811	2	(17,806)	
1983	19,160		1,815	13,414	26,192	3	(18,631)	
1984	22,034		1,996	14,621	28,811	4	(19,402)	
1985	25,340		2,196	15,937	31,692	5	(20,093)	
1986	29,141		2,416	17,371	34,861	6	(20,675)	
1987	33,512		2,657	18,934	38,347	7	(21,112)	
1988	38,538		2,923	20,639	42,182	8	(21,360)	
1989	44,319		3,215	22,496	46,400	9	(21,362)	
1990	50,967		3,537	24,521	51,040	10	(21,057)	
1991	58,612		3,891	26,728	56,144	11	(20,369)	
1992	67,404		4,280	29,133	61,759	12	(19,208)	
1993	77,514		4,708	31,755	67,934	13	(17,467)	
1994	89,142		5,178	34,613	74,728	14	(15,021)	
1995	102,513		5,696	37,728	82,201	15	(11,720)	
1996	117,890		6,266	41,124	90,421	16	(7,389)	
1997	135,573		6,892	44,825	99,463	17	(1,823)	
1998	155,909		7,582	48,859	109,409	18	5,223	
1999	179,296		8,340	53,256	120,350	19	14,030	
2000	206,190		9,174	58,049	132,385	20	24,930	
Totals							(\$247,260)	\$ Negative

Capital Investment \$722,880

	<u>Undiscounted</u>	<u>Present Value (discounted at 10%)</u>
Total 20-Year Savings	(\$245,141)	Negative
Payback Period	-	-

Institutional Requirements

To provide geothermal energy in Alamosa, wells could be drilled on-site or 2 to 3 miles east or west of the City. If wells were drilled on-site, the State would have control of the drill site. If a well or wells were drilled some distance away, surface leases on private land would be required. Similarly, were a well site some distance away from the site of use, private geothermal leases would also be required. If right-of-way is needed, it could probably go along State Highway 160, then along city street R.O.W., depending upon the exact well site (Coe and Forman, 1980). City building permits are required before retrofitting the heating systems (Don Park, pers. comm., 1981).

Environmental Considerations

Based on a review of available information, no significant environmental constraints to geothermal development in the Alamosa area can be identified. The geothermal fluid from existing wells is quite pure. Arsenic (a toxin) and magnesium (a corrosive) are present in high but not excessive concentrations.

Some potential for subsidence and seismic activity may exist but is not considered likely to be significant (Coe, 1980).