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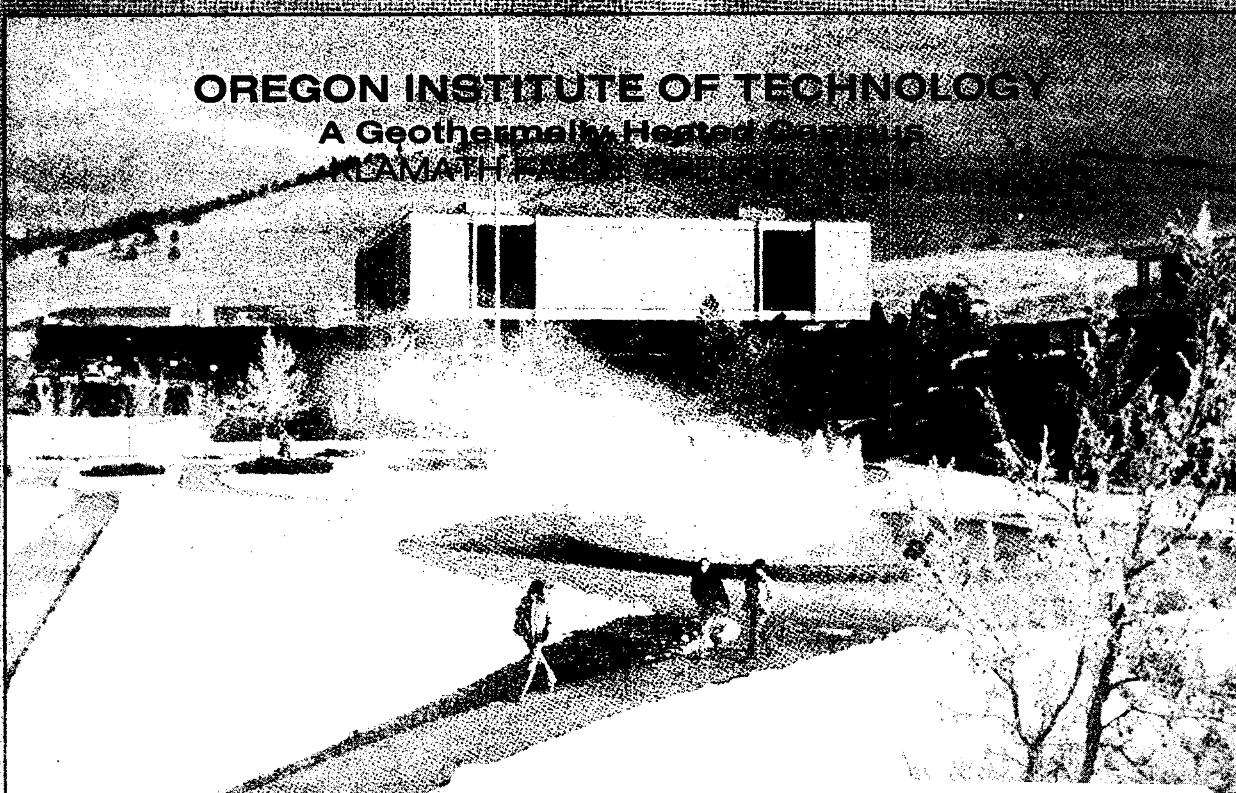

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GEOTHERMAL HEATING SYSTEM
for the
Children's Museum of Utah

July 1984

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GEOTHERMAL HEATING SYSTEM
FOR THE
CHILDREN'S MUSEUM OF UTAH
Salt Lake City, Utah

INTRODUCTION

The Children's Museum of Utah was opened in October 1983 in an old building located at 840 N. 300 W in Salt Lake City. The building was constructed during the early part of this century as a resort, housing two swimming pools, an Olympic size one and a smaller one, and a few guest rooms. This use of the building was discontinued in the fifties and the building was abandoned. It was becoming run down and dilapidated when taken over by the Museum. As of today, the Museum is using only some 4,500 square feet out of a total of about 35,000 square feet of floor area.

The plans for future utilization of the building are not at all firm. Work is underway to extend the museum into an approximately 3,500 square foot area on the first floor in the south end of the building. The big pool area, over 10,000 square feet, will be converted into a restaurant and the small pool area, approximately 2,000 square feet, is being planned as an auditorium. Both pool areas extend up through the building, but other parts of the building are two stories. The northwest end of the second level will provide for office space for the museum whereas the remaining second level space will be used for additional exhibits. A basement in the area underneath the south end of the building will probably be used as a work shop for the museum once it has expanded throughout the whole building (Lance Robson, Exhibits Committee, personal communication).

The building is located in the southerly part of the so called Warm Springs Fault geothermal area which is a strip approximately three miles long by 4,000 feet wide that parallels the western edge of the Salt Lake salient to the northwest of the Utah State Capitol Building (Murphy and Gwynn, 1979). The observed occurrences of warm water along the Warm Springs Fault are bound on the north by Beck Hot Springs and on the south by Wasatch Hot Spring (Figure 1). The

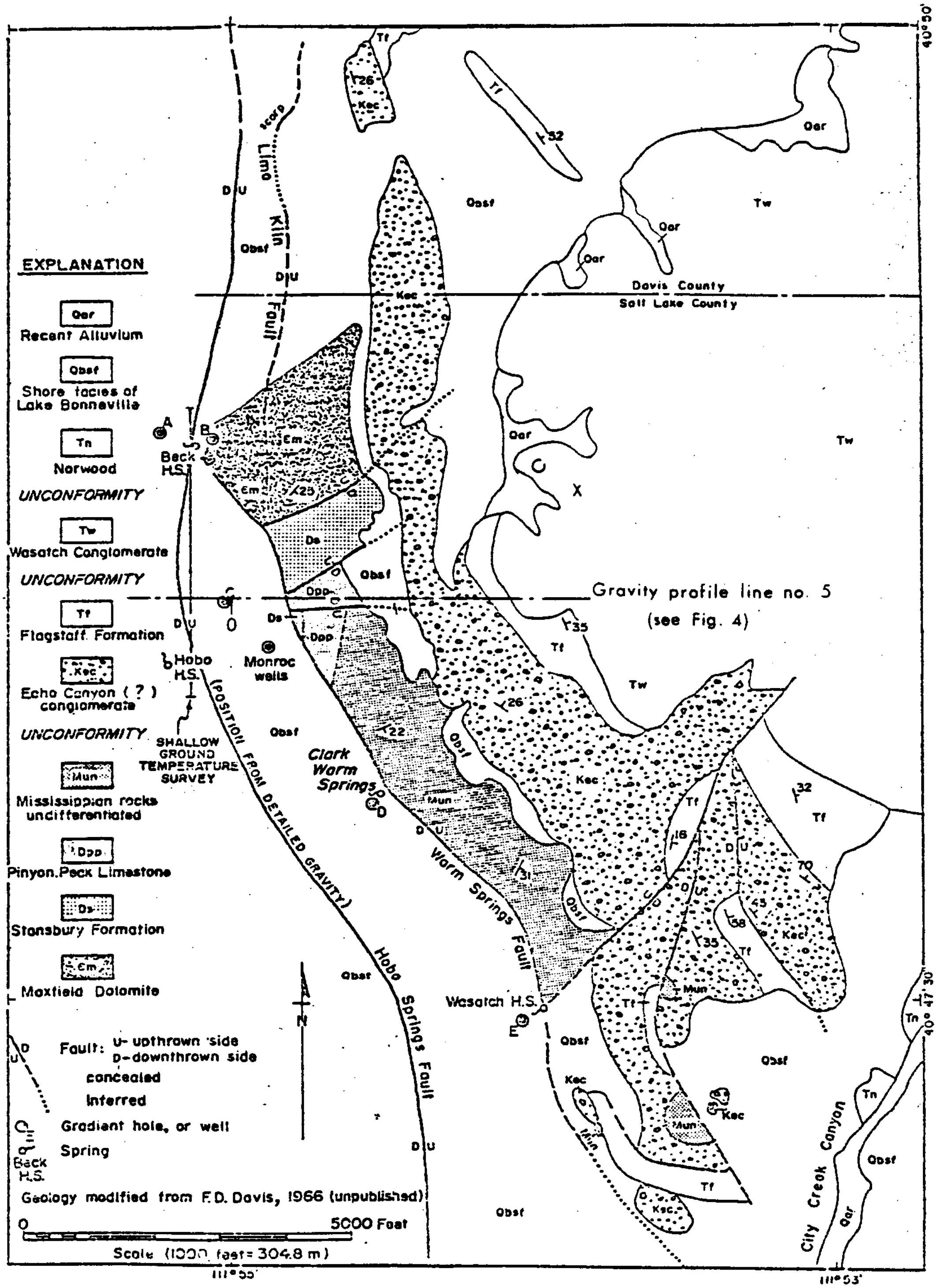

FIGURE 1

Geologic Map of Warm Springs Fault Area,
Salt Lake and Davis Counties, Utah
(from Murphy and Gwynn, 1979)

Wasatch Hot Spring supplied water to the swimming pools when they were in operation.

This report presents the results of a study to determine the engineering and economic feasibility of using the Wasatch Hot Spring resource for space heating of the Children's Library building.

SUMMARY OF CONCLUSIONS

The Wasatch Hot Spring with a reported flow of about 63 gpm (240 ℓ/min) at an average temperature of 104°F is not capable of furnishing the needed heat for the Children's Museum building. The underground paths along which the thermal waters flow to their outlets at the Warm Springs Fault are not presently known. It is possible if the thermal water ascends from the deep layers of the earth along the Warm Springs Fault that increased geothermal flow at a higher temperature can be produced by drilling into the fault.

Assuming that sufficient geothermal fluid quantity is produced by drilling in the area, an analysis is made of a geothermal heating system for the building based on different fluid temperatures. It is assumed that the present and planned heating systems be left intact with the gas fired boilers taking over during cold periods when the geothermal system fails to provide sufficient heat. Economic analysis shows that the geothermal system is very attractive, even for the lowest geothermal fluid temperature considered (110°F).

In view of these results, it is recommended that an exploratory well be drilled in the vicinity of the Wasatch Hot Spring in order to establish the underground flow path. Only then can it be determined whether or not a geothermal heating system for the Children's Museum of Utah is feasible.

THE WASATCH HOT SPRING GEOTHERMAL RESOURCE

The Wasatch Hot Spring is approximately one mile northwest of the Utah

State Capitol Building between Victory Road and Beck Street. At one time the spring supplied water to the Wasatch swimming pools located in the building which now houses the Children's Museum of Utah. Over the years, when the swimming pools were in operation, a series of six tunnels were driven northeastward into cemented alluvium and tufa deposits in attempts to increase the spring flow. The tunneling usually increased the flow temporarily, but the discharge eventually decreased with time. The spring discharge also varies with seasonal and climactic variations. Temperatures ranging from 38°C to 42°C (100.4° to 107.6°F) have been reported (Murphy and Gwynn, 1979)(Cole, 1982, 1983), and the average discharge is 240 ℓ/minute (63.4 gpm, Cole, 1983).

The Wasatch Hot Spring constitutes the southernmost observed occurence of warm water along the Warm Springs Fault (Figure 1). The Warm Springs Fault geothermal system has been the subject of several studies (e.g. Murphy and Gwynn, 1979; Cole, 1982, 1983). Most of the information on the Wasatch Hot Spring presented below is drawn from these sources.

The total dissolved solids contents (TDS) of Warm Springs Fault thermal waters range from 6,000 to 14,000 mg/ℓ. In general, water with the highest TDS value is found at the northern end of the system. Beck Hot Springs, Hobo Hot Springs, and the Monroc water wells (Figure 1) all produce water in the TDS content range from 12,800 to 13,900 mg/ℓ. At the southern extend of the known warm water occurrences, Wasatch Hot Spring has a TDS value of approximately 6,000 mg/ℓ. Water from Clark Warm Spring is between these two extremes with a TDS content of approximately 9,700 mg/ℓ (Murphy and Gwynn, 1979).

Systematic chemical variations through time are characteristic of hot springs issuing from the Warm Springs Fault. The observed chemical contents will therefore depend on the time of year as indicated by Figure 2 which shows chemical data in mg/ℓ and temperature in °C sampled at the Wasatch Hot Spring for a period of more than a year and plotted against time in weeks. The figure indicates cyclical changes in water chemistry where chemical enrichment is observed during the summer months and depletions occur during fall and early winter months. These chemical variations are accompanied by corresponding

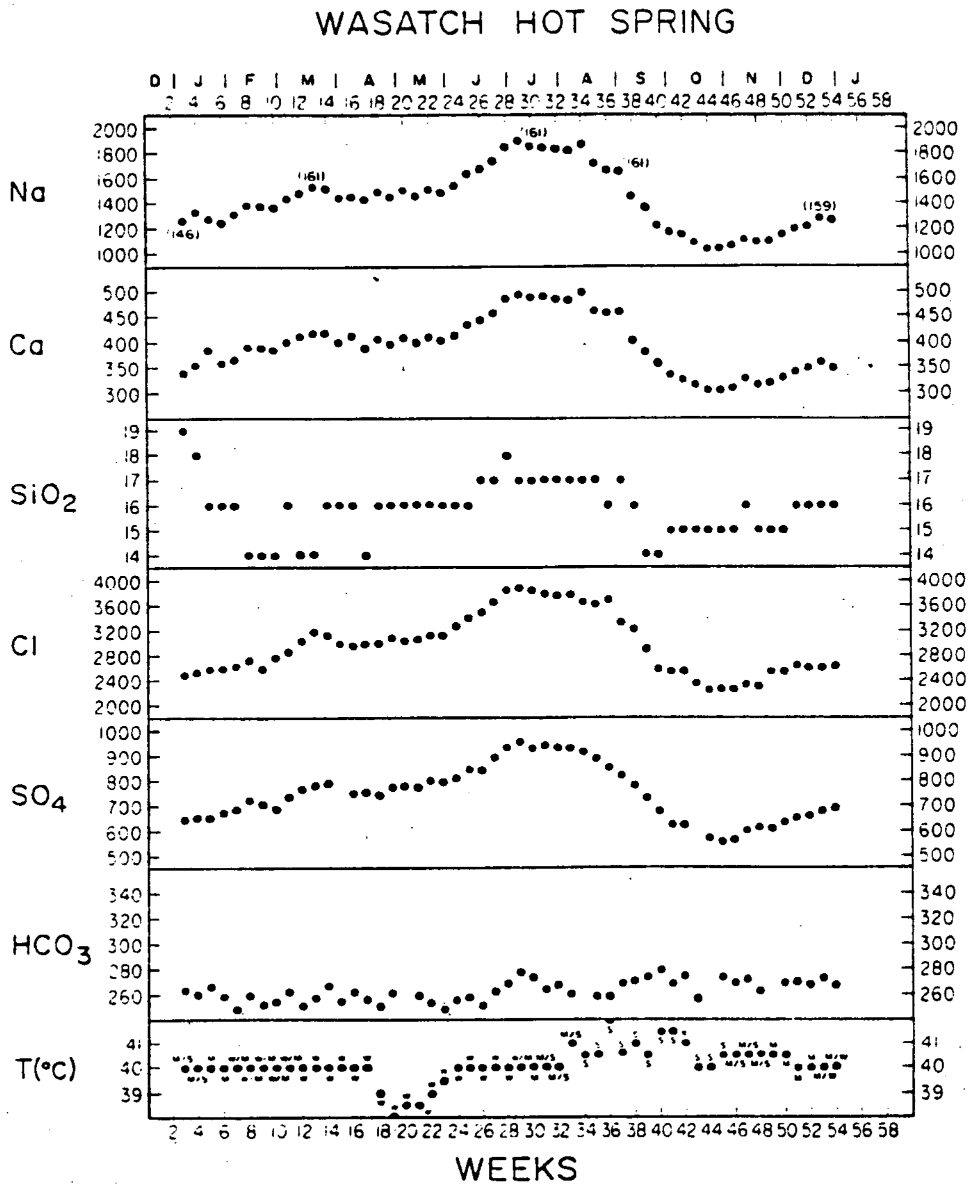

FIGURE 2

Selected Chemical Compositions and Temperatures for Wasatch Hot Springs Plotted Against Time in Weeks. The Numbers in ( ) are the Na/K/Ca Geothermometer Temperatures for Those Weeks. W = Weak Flow Rate; W/M = Weak to Moderate Flow; M/S = Moderate to Strong Flow Rate; S = Strong Flow Rate. From Cole (1983) changes in temperature and flow rates. For example, during the summer months at times of maximum flow, the hot spring exhibits its highest surface temperatures.

The correlation of maximum and minimum surface temperatures with chemical enrichments and depletions, respectively, strongly suggests that mixing is the major process controlling the cyclic nature of the chemistry and temperature. The high concentrations of elements occur during periods when influx of nonthermal groundwater is the lowest. Significant declines in the concentrations of Na, Ca, SiO_2, Cl and SO_4 coincide with declines in surface temperatures. A nonthermal end member temperature of 22°C to 28°C (71.6° to 82.4°F) is required, assuming that it has a TDS of 500 mg/ℓ or less, which is typical of valley groundwaters adjacent to the Warm Springs Fault zone. If this cool water is derived initially from mountain snow packs, the duration of time from recharge to discharge is estimated to be four to six months. This estimate is arrived at by assuming that major recharge occurs during the spring thaw (April-May) and by noting that the pattern of major dilution in chemistry occurs in September and October (Cole, 1982, 1983).

In the fall of 1978 the Utah Geological and Mineral Survey (UGMS) contracted with Peterson Brothers Drilling Company of Salt Lake City, Utah, to drill 13 temperature gradient holes in northern Utah. Five of these holes were located along the Warm Springs Fault (marked A, B, C, D, E in Figure 1). The holes were logged by UGMS, samples were taken every 5 to 10 feet, and temperatures were measured in January-February, 1979 (Murphy and Gwynn, 1979).

Figure 3 shows the temperature profile in hole E which is located about 75 meters (246 feet) west of the Wasatch Hot Spring outlet. The hole was drilled through a series of sands and gravels containing varying percentages of clay. The generally elevated temperatures measured below five meters are the result of lateral flow of warm water through the sands and gravels from the spring system located to the east (Murphy and Gwynn, 1979).

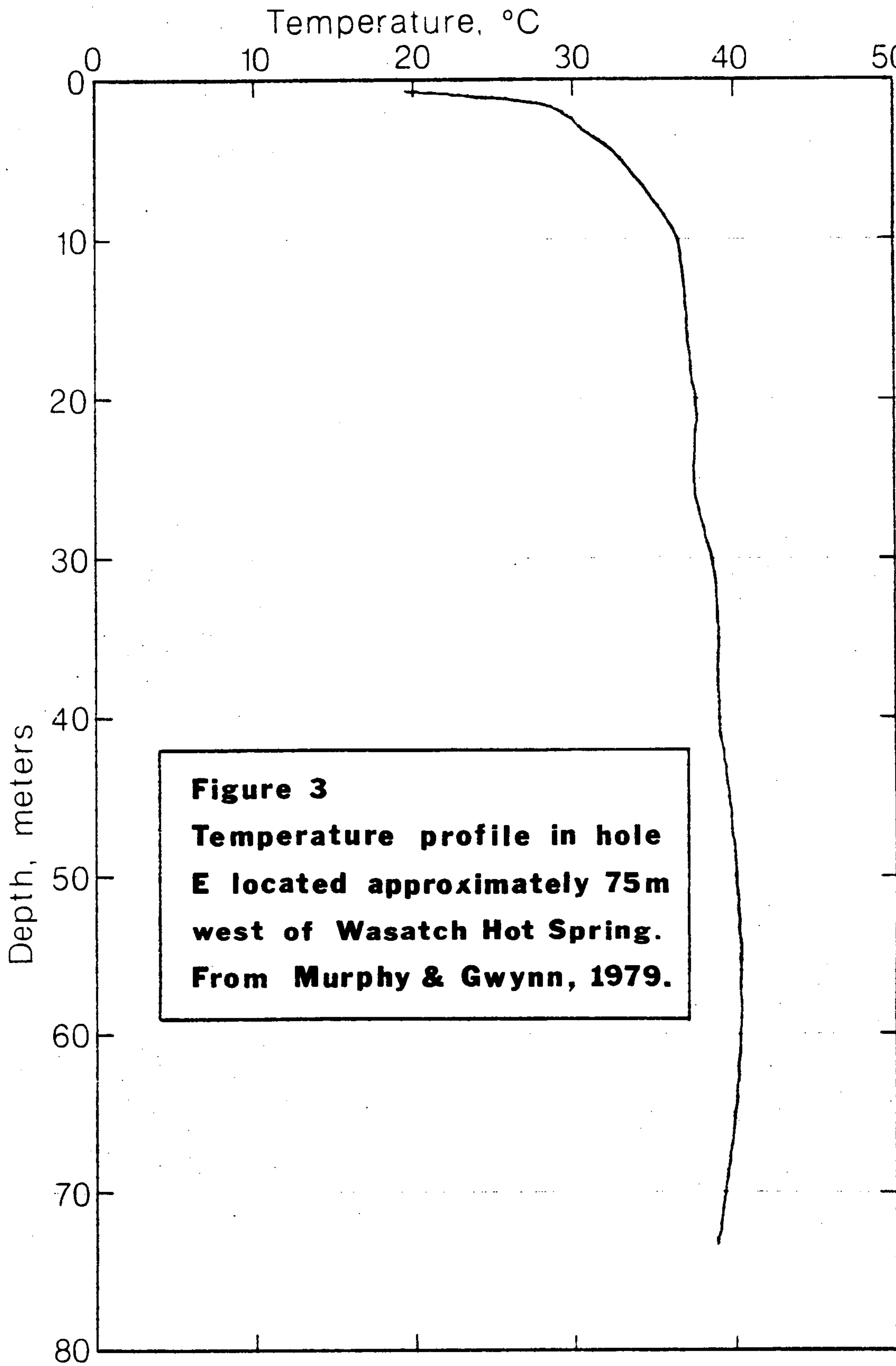

Figure 3
Temperature profile in hole E located approximately 75m west of Wasatch Hot Spring. From Murphy & Gwynn, 1979.

A detailed gravity survey of the Warm Springs Fault geothermal area was made for the UGMS in February 1979. The survey consisted of 12 east-west gravity lines along which stations were spaced at 500 to 1,000 feet intervals. One of the 12 gravity profiles, profile number 5, has been modeled using a three dimensional gravity modeling program. The observed gravity profile 5, the modeled gravity profile and a simple bedrock-alluvium model are presented in Figure 4. The actual location of profile 5 is shown in Figure 1. The model consists of two faults on the eastern edge, a deep alluvium filled graben and a horst block on the western edge. The easternmost fault corresponds to the Warm Springs Fault, and the downthrown block is covered by several hundred feet of alluvium. Approximately 1,500 feet to the west a single and almost vertical fault having approximately 4,000 feet of relief defines the eastern edge of the deep graben. This fault corresponds to the Hobo Springs Fault in Figure 1. At the western edge of the graben a horst block rises to within approximately 1,500 feet of the surface (Murphy and Gwynn, 1979).

Some variations in the shapes of the gravity profiles appear in the gravity survey but the general model described above appears to be applicable all along the Warm Springs Fault. The width of and depth to the downthrown block of the fault increase to the south of line 5 (see Figure 1), but displacement across the Warm Springs Fault remains minor in comparison to the Hobo Springs Fault to the west.

On the basis of the above observations, Murphy and Gwynn (1979) reached the following conclusions about the hot water system in the Warm Springs Fault geothermal area.

1. The occurrence of warm water in the area appears to be controlled by two main Basin and Range structures: a) the Warm Springs Fault striking northwest and dipping 65 to 70° to the southwest, and b) the Hobo Springs Fault striking subparallel to the Warm Springs Fault and dipping slightly to the southwest, close to 90°.

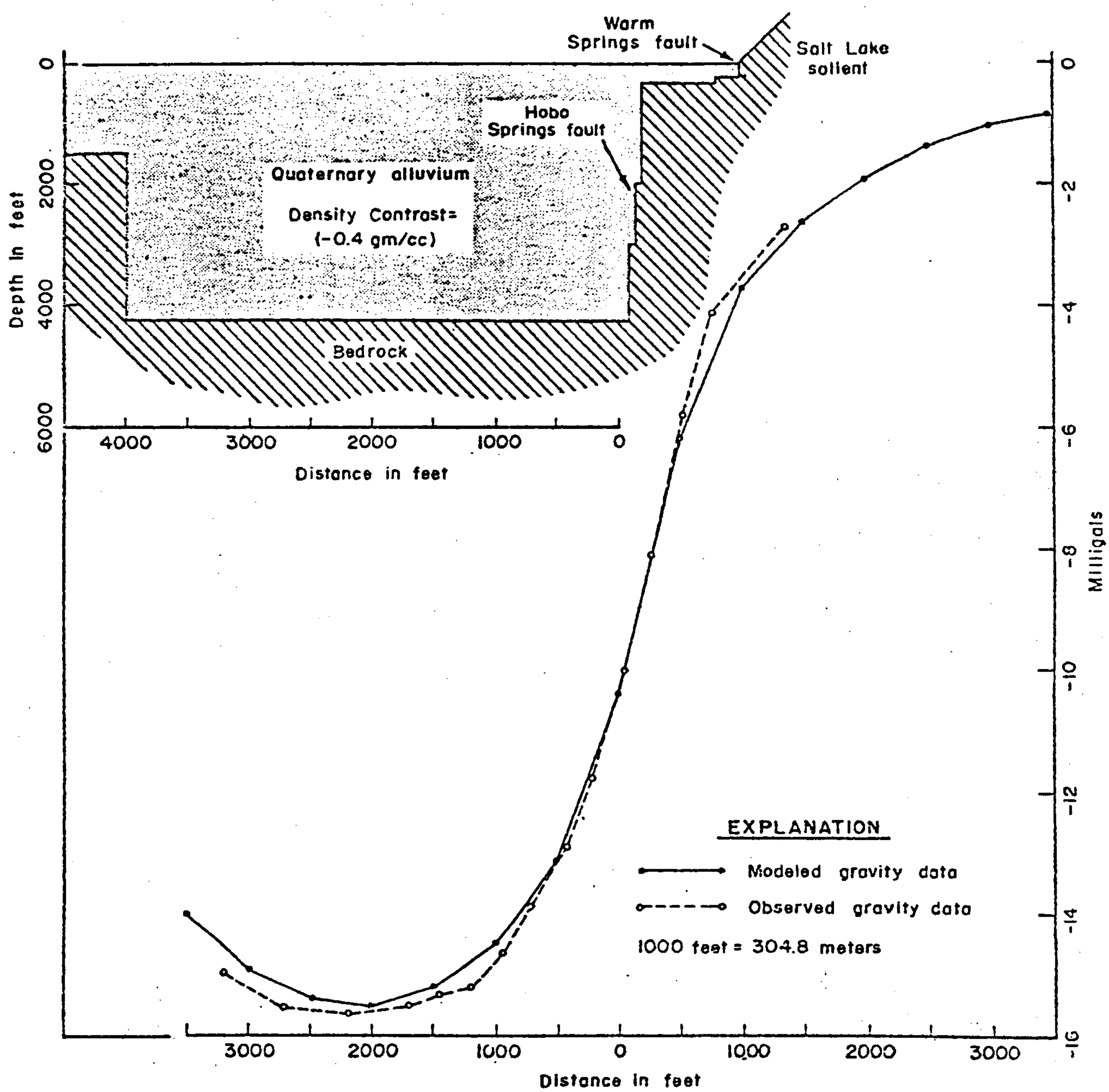

FIGURE 4

Model and Gravity Profiles for Line 5, Warm Springs Fault Detailed Gravity Survey, Salt Lake County, Utah (from Murphy and Gwynn, 1979)

2. There is little doubt that recharge to the Warm Springs Fault thermal spring system originates in the Wasatch Mountains east of the Salt Lake salient. Steeply dipping aquifers and numerous faults could easily transport the water to the required depth. The path by which the water actually descends to depth, however, is not presently known.

3. The Warm Springs Fault geothermal system is a convective system in which water is circulated to depth and heated by the relatively high geothermal gradient of the Basin and Range province. After being heated by the elevated temperatures at depth, the water rises quickly along faults to the surface where it is discharged into near surface aquifers, and to the surface as springs.

Cole (1983) found by geothermometer calculations utilizing either quartz (no steam loss), chalcedony, or Mg-corrected Na/K/Ca methods (Fournier, 1981) that most thermal springs in Utah have aquifer temperatures occurring in the range from 25° to 120°C (77° to 248°F). This temperature range suggests that fluid circulation along the steeply dipping faults which control hot spring activity is restricted to depths of three to four kilometers (9,800 to 13,000 feet), assuming thermal gradients ranging from 32° to 40°C/km.

The cyclic variation of the water chemistry in the Wasatch Hot Spring described by Cole (1983, see Figure 2) suggests mixing of cool groundwater with ascending thermal water as previously described. Where along the path of the flowing water this mixing takes place may be an important factor in deciding the usability of the thermal waters along the Warm Springs Fault. There are two different possibilities:

1. The thermal water which is circulated to depth and heated in the deep layers of the Basin and Range province flows laterally at depth and ascends along faults such as the Warm Springs Fault. As it nears the surface, it is mixed with the cool water which has traveled laterally from the mountains through the surface layers. This appears to be the model described in the papers by Murphy and Gwynn (1979) and Cole (1983).

2. The thermal water rises under the Range where it is mixed with the cool surface water. From there it flows laterally to its outlets along faults such as the Warm Springs Fault. Some investigators have expressed the opinion that this possibility is no less likely than the first (R. Klauk, UGMS, personal communication).

It is clear that the first of the above models offers a good chance of producing considerably warmer water than is now flowing from the Wasatch Hot Spring. This can be done by drilling a well down to the Warm Springs Fault below the downthrown block and casing off the overlying water bearing alluvium layer. A proposed design of such a well is shown in Figure 5. Figure 6 (from Gill, 1980) shows the location of the Children's Museum relative to the Warm Springs Fault. A well designed to cut the fault as shown in Figure 5 could probably be located within the city owned property line as shown in Figure 6.

If the thermal waters follow the path described by the second model, no temperature increase of the water is produced by drilling in the area. It is therefore of importance for the future utilization of the Warm Springs Fault geothermal field to establish the actual flow model for the area.

HEATING REQUIREMENTS IN CHILDREN'S MUSEUM BUILDING

Estimates of the heating requirements of the Children's Museum building are based on the following information received from Joseph Linton, Wayne Bingham, Architects, Salt Lake City, who prepared the plans for refurbishing the building for the Museum.

1. All exterior walls are poured concrete, 12 inches thick and uninsulated.

2. All floors between main and second levels and between basement and main levels are reinforced concrete with rigid insulation.

3. Roofs are reinforced concrete and assumed to be uninsulated.

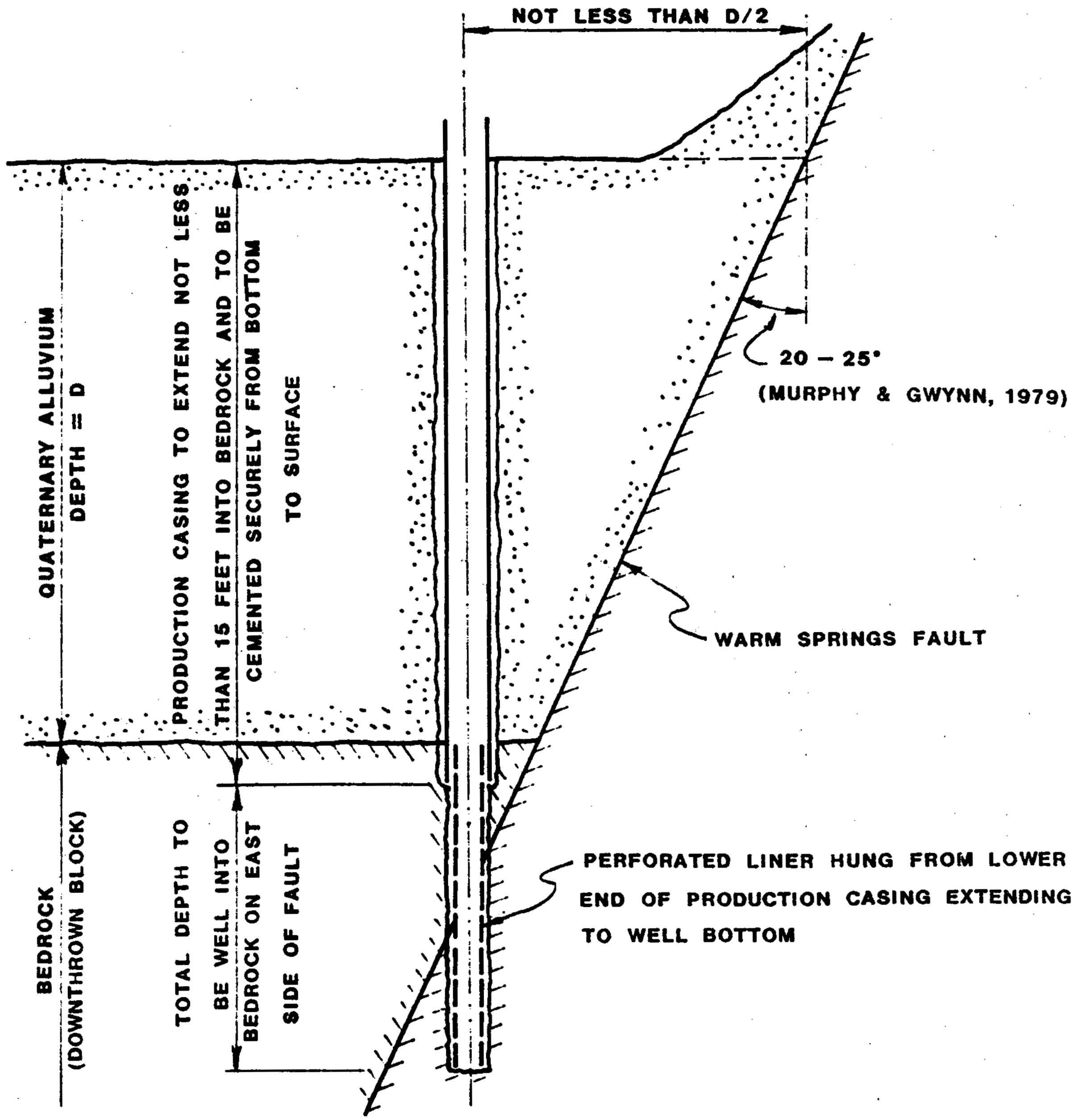

FIGURE 5

Proposed Positioning and Design of Well to be Drilled Near Children's Museum of Utah. Section Across Warm Springs Fault Looking North-Northwest

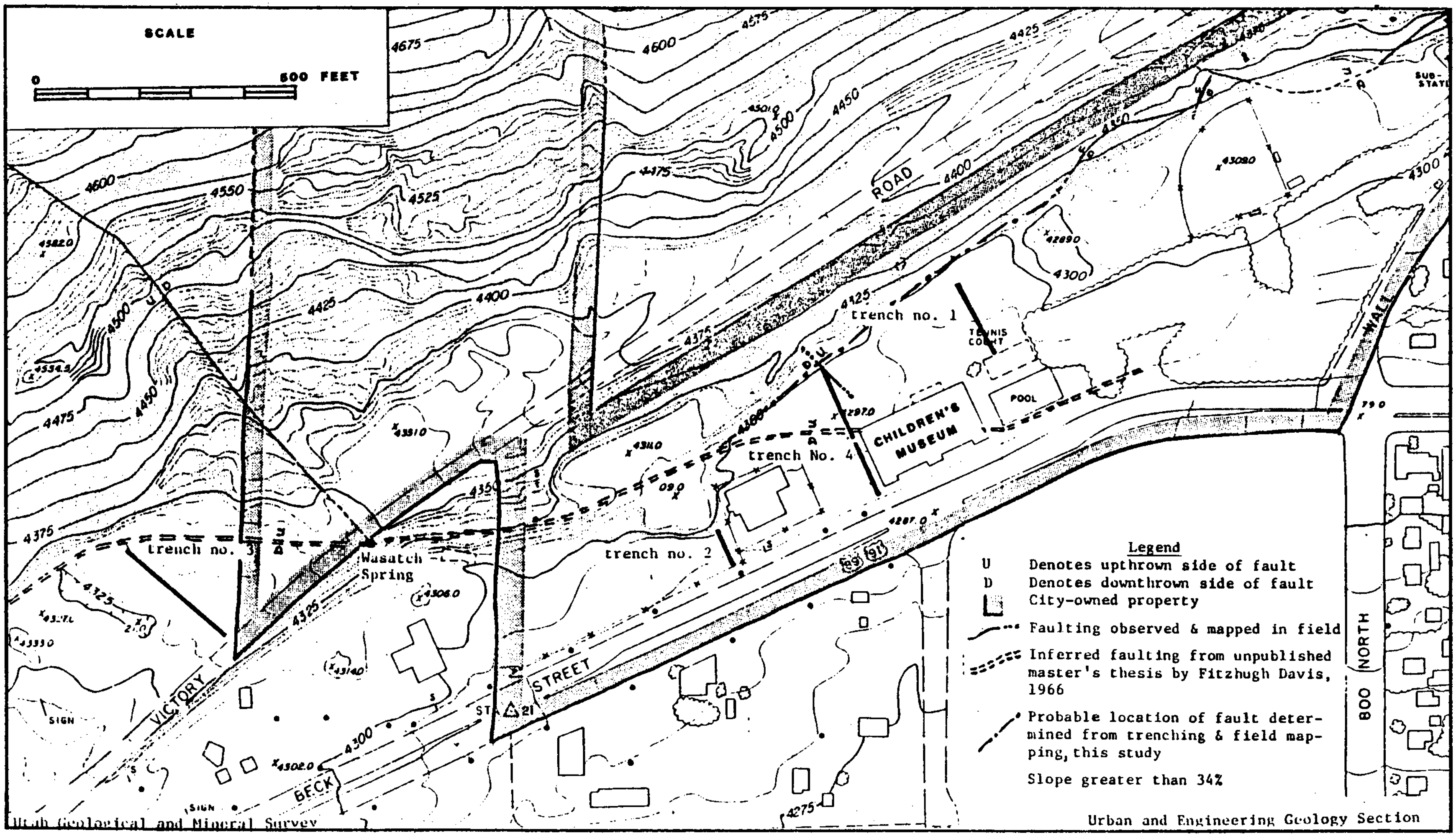

FIGURE 6

Location of Children's Museum of Utah in Relation to the
Warm Springs Fault and Wasatch Hot Spring (from Gill, 1980)

4. Windows are single pane, wood frame.

Outside design air temperature was chosen at 3°F (99% value, ASHRAE Handbook, 1977 Fundamentals, p. 23.14). It is assumed that the building will be taken into use in eight phases in order as listed below:

Phase 1: Main entrance with vestibule, lobby, reception, office, and rooms #1 and 2 as marked on Sheet no. A4, dated July 1982, prepared by Joseph Linton, Wayne Bingham, Architects. This is the part of the building already in use.

Phase 2: South end of building, main level. This is the area now being refurbished and will be opened in a few weeks.

Phase 3: Large pool area (restaurant).

Phase 4: Small pool area (auditorium).

Phase 5: Space in northwest corner of building on main level.

Phase 6: Northern end of second level, including space above main entrance.

Phase 7: Remaining part of second level.

Phase 8: Basement under southern end of building.

In calculating the heat loss for each phase it was assumed that phases not yet in use would remain unheated. The results of the heat loss calculations are presented in Table I.

The table shows a rather high heat loss per square foot of floor area. This is not unexpected since the building is uninsulated and because of the very great ceiling height in the two pool areas.

PRESENT AND PLANNED SPACE HEATING

New heating systems have been designed and installed in those parts of the Children's Museum building already in use and in the part which is now being

TABLE I

Heating Requirements of
Children's Museum Building by Phases

Phases in Use		1	1-2	1-3	1-4	1-5	1-6	1-7	All
Floor Area Heated, ft^2		4,450	7,923	18,239	20,520	22,107	26,496	31,696	35,224
Volume Heated, ft^3		44,722	79,452	378,098	429,888	445,758	480,873	522,471	554,223
Heat Losses by Phase Btu/hr	1	274,008	260,142	244,068	244,068	241,197	192,932	165,724	165,724
	2	-	282,500	275,715	275,715	275,715	275,715	213,826	151,937
	3	-	-	950,719	934,689	934,689	927,797	918,123	918,123
	4	-	-	-	316,703	313,478	309,612	309,612	309,612
	5	-	-	-	-	69,511	54,323	54,323	54,323
	6	-	-	-	-	-	258,067	255,703	255,703
	7	-	-	-	-	-	-	315,584	315,584
	8	-	-	-	-	-	-	-	62,245
Total Heat Loss, Btu/hr		274,008	542,642	1,470,502	1,771,175	1,834,590	2,018,446	2,232,895	2,233,251
Total Heat Loss, Btu/hr x ft^2		61.6	68.5	80.6	86.3	83.0	76.2	70.4	63.4
Total Heat Loss, Btu/hr x ft^3		6.13	6.83	3.89	4.12	4.12	4.20	4.27	4.03

refurbished, i.e. in phases 1 and 2. These systems have been designed by Dale R. Wilde Co./Engineers in Salt Lake City. The short description of the systems which follows is based on information furnished by the designers (Ray Wilde, engineer, personal communication).

Phase 1 heating system. The heating system in phase 1 consists of finned tube hot water radiators. The equipment is designed to operate at an entering water temperature of 200°F and a leaving water temperature of 160°F. Entering air temperature to the finned tube units is assumed to be 65°F. Most of the finned tube radiators are of the two tier type with a rated output of 2,110 Btu/hr x lf at design conditions.

Boiler room equipment consists of a gas fired Ajax water heating boiler rated at 675,000 Btu/hr input, 540,000 Btu/hr output, and a hot water circulating pump, Bell & Gossett, 36.8 gpm at 26 ft head, driven by an electric motor, 120/60/1, 3/4 HP, 1,750 rpm.

Phase 2 heating system. The installation of the phase 2 heating system is completed and this part will be taken into use in a few weeks. In this design the space above phase 2 (part of phase 7) and the basement below (phase 8) are grouped together with the phase 2 heating system. The system is of the same type as the phase 1 heating system, i.e. finned tube radiators and the design temperatures are the same, entering water at 200°F, leaving water at 160°F, entering air at 65°F.

Boiler room equipment consists of a gas fired Ajax water heating boiler, rated at 750,000 Btu/hr input, 600,000 Btu/hr output, and two hot water circulating pumps, Bell & Gossett, 15 gpm each at 45 ft head, driven by electric motors, 120/60/1, 3/4 HP, 1,750 rpm.

Remaining space. In order to make an economic evaluation of the heating cost of the building, it is necessary to make some assumptions about the heating systems to be installed in the remaining space. These have not yet been designed but according to the designing engineers the plan is to install the same type of hot water system wherever feasible in the remaining space as already is operating in phases 1 and 2. This means that all parts of the building except phases 3 and 4, the two pool areas, will have the same heating system. Due to the very great ceiling height and large heating requirements of the pool areas, the hot water finned tube radiators are not sufficient and will have to be supplemented by a forced air heating system.

It will be assumed that finned tube radiators supplying about 530,000 Btu/hr can be installed in the pool areas leaving about 700,000 Btu/hr to be supplied by the forced air heating system (see Table I). The total peak heat requirements of the building are then met as follows:

With finned tube radiators	1.54×10^6 Btu/hr
With forced air heating	0.70×10^6 Btu/hr

The installed boiler output capacity today is 114×10^6 Btu/hr. An additional 600,000 Btu/hr boiler will be sufficient for the finned tube radiator systems and about 800,000 Btu/hr should take care of the air heating system.

GEOTHERMAL SPACE HEATING POSSIBILITIES

It is clear that the Wasatch Hot Spring with a mean flow of 63 gpm (240 ℓ/min.) at a temperature of about 104°F (40°C) will not in any way be sufficient for space heating of the Children's Museum building. If geothermal is to be in the picture at all, some means must be found to obtain more geothermal water at a higher temperature. Two options come to mind in this connection.

1. Build a pipeline to transmit hot water from the Beck Hot Spring to the Children's Museum building. The Beck Spring has a discharge of about 230 gpm at 133°F (Cole, 1983).

2. Drill a well in the neighborhood of the Wasatch Hot Spring intersecting the Warm Springs Fault below the downthrown block of the fault. By blocking off the inflow of groundwater it may be possible to catch warmer water ascending along the fault (see Figure 3).

The first of these options is technically feasible but the cost is obviously prohibitive. The pipeline alone of the size and type needed (6" insulated and buried fiber reinforced plastic pipe) will cost over 10 times more than a drilled geothermal production well.

The second option is technically feasible if the path of the geothermal fluid is from the deep layers of the earth, where the fluid receives its heat, up through the fault. As discussed previously, scientists are not at all certain about the path of the geothermal fluid flow to the Warm Springs Fault.

The analysis which follows is based on the second option. A geothermal production well drilled to a total depth of 800 feet is assumed to be capable of producing the required flow of water by pumping. The temperature of the water, however, is unknown and will be left as a variable quantity in the analysis.

The analysis includes a reinjection well to dispose of the geothermal fluid after it is used. This well will be shallower and narrower than the production well.

In order to keep retrofitting costs to a minimum, the heating systems which already have been installed in the building will be left unchanged. The heating systems for the remaining parts of the building will be the same as discussed in the last section. This way the retrofitting of the building to geothermal heating is very simple, requiring only the installation of heat exchangers in the mechanical room for removing the required heat from the geothermal fluid.

With the hot water finned tube radiators designed for an entering water temperature of 200°F it is clear that the geothermal fluid will not supply all the needed heating energy unless its temperature is well above 200°F. For lower temperatures it will, therefore, be necessary to maintain the three finned tube system boilers. These will then take over when the outside temperature drops below a minimum value, which depends on the geothermal fluid temperature. It is, however, assumed that the geothermal system will be capable of handling the forced air heating system without the aid of a boiler. A schematic diagram showing this system is presented in Figure 7.

CAPITAL AND OPERATING COSTS OF GEOTHERMAL SYSTEM

Estimated capital and operating costs of the geothermal system are shown in Table II. As discussed in the last section, the temperature of the geothermal fluid is an unknown quantity so the estimates are made for several temperature values. A heat exchanger approach (difference between entering geothermal fluid temperature and leaving water temperature) of 5 to 6°F is assumed.

The capital cost items are independent of the fluid temperature except the plate heat exchanger cost. It increases with increased capacity (measured in Btu/hr). The heat exchanger, however, does not constitute a major cost item so that there is not a great difference in total capital cost between the highest and lowest fluid temperatures.

The maintenance cost of the geothermal system is independent of fluid temperature. The energy cost, on the other hand, is strongly influenced by the geothermal fluid temperature. The electricity is mainly that used for pumping the geothermal fluid from the production well through the heat exchanger. The fuel cost for the conventional operation of the heating system is reduced as the fluid temperature increases and the geothermal share of the heating of the building is increased.

ECONOMIC ANALYSIS

In order to make an economic comparison between the geothermal heating system

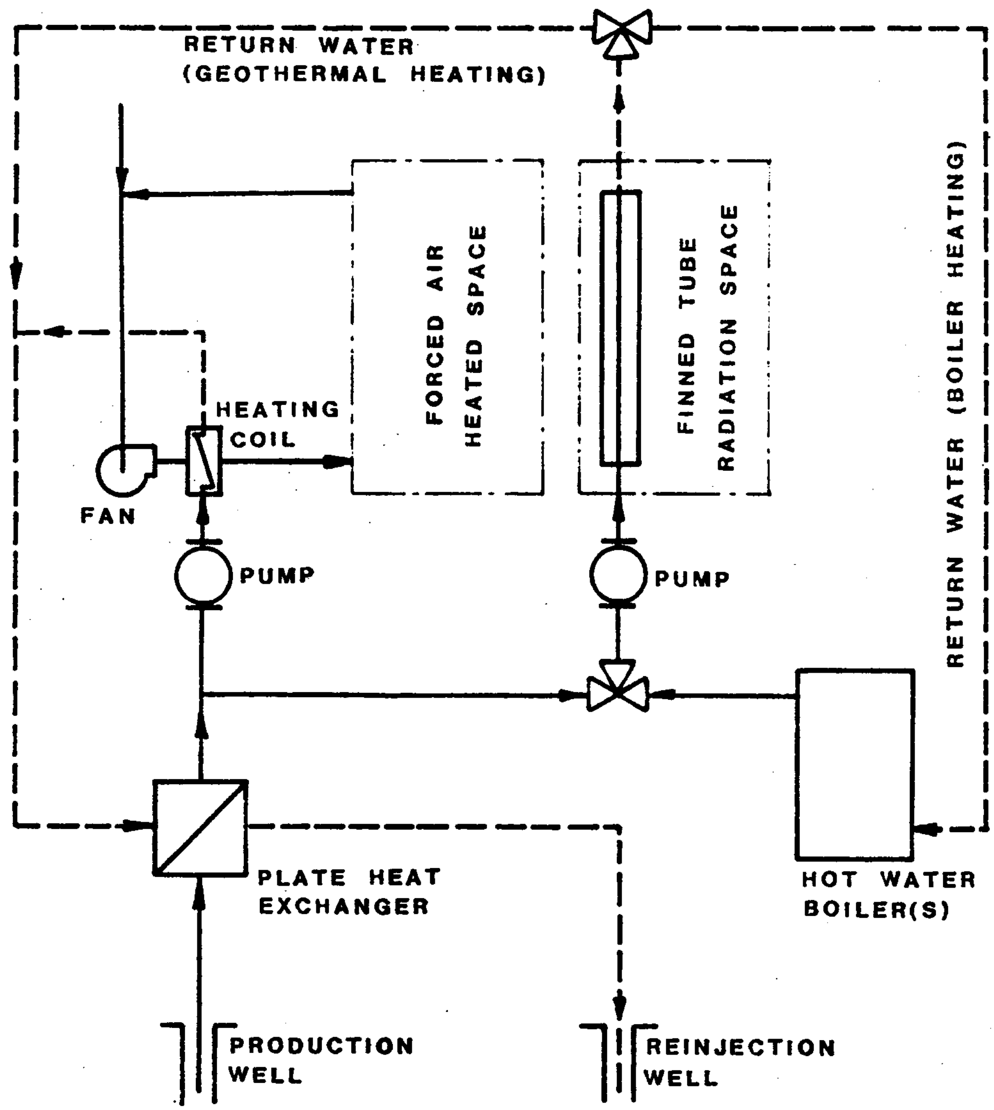

FIGURE 7

Schematic Flow Diagram of Proposed Hookup
for Geothermal Heating of Children's Museum of Utah

TABLE II

Capital and Operating Cost Estimates for Geothermal Heating System for Children's Museum of Utah

Geothermal fluid temp., °F	110	133	157	181	206
Average heating water temp., °F *	100	120	140	160	180
Low outside air temp. w. geoth., °F	57	45	32	18	3
A. Capital Costs:					
Production well, 800'	26,000	26,000	26,000	26,000	26,000
Injection well, 400'	10,000	10,000	10,000	10,000	10,000
Downhole pumps & drive	32,000	32,000	32,000	32,000	32,000
Wellhead building	3,000	3,000	3,000	3,000	3,000
Plate heat exchangers	3,500	4,400	5,500	6,600	7,800
Misc. piping, mechanical & electrical	25,000	25,000	25,000	25,000	25,000
Engineering, 10%	10,000	10,100	10,200	10,300	10,400
Subtotal	109,500	110,500	111,700	112,900	114,200
Contingency	11,000	11,100	11,200	11,300	11,400
TOTAL CAPITAL COST	120,500	121,600	122,900	124,200	125,600
B. Operating Costs:					
Maintenance	2,500	2,500	2,500	2,500	2,500
Energy cost: Electricity	4,100	2,500	3,100	3,000	2,500
Natural gas	27,000	20,600	9,400	1,700	0
TOTAL OPERATING COST	33,600	25,600	15,000	7,200	5,000

*At geothermal peak load.

and the conventional system the annual savings with the geothermal system must be evaluated. As discussed previously it is assumed that the complete conventional system for the finned tube radiators be left intact since the geothermal system fails when the outside air temperature drops below a given value. On the other hand, the geothermal system is assumed to be capable of furnishing sufficient heat to the forced air heating system without the assistance of a peak load boiler. For the conventional system the forced air heating boiler must therefore be added and its cost taken into account in the economic comparison of the two systems.

The cost of a hot water boiler of the size needed for the forced air system installed and including a burner, expansion tank, and other accessories, is about $10,000 (Means Mechanical Cost Data 1984). This cost is subtracted from the geothermal system capital cost for net payback evaluation. Maintenance cost of other parts of the conventional system are assumed to be the same with or without the geothermal system. The annual savings at present are then estimated as shown in Table III.

In order to arrive at cost figures over the 20 years assumed life of the proposed geothermal heating system some assumptions must be made of rates of inflation and price escalations of operating cost items. For this analysis the forecast figures recently published by the California Energy Commission (CEC, March 1984) are used. These are as follows:

Year	General Inflation	Natural Gas	Electricity
1984	1.0000	1.0000	1.0000
1985	1.0895	1.0857	1.1761
1986	1.1535	1.1434	1.2221
1987	1.2212	1.2745	1.2444
1988-2004	6.5% per year	10.23% per year (average)	7.03% per year (average)

TABLE III

Estimated Annual Savings with
Geothermal Heating of the Children's Museum of Utah

Geothermal fluid temp., °F	110	133	157	181	206
Ave. heating water temp., °F	100	120	140	160	180

Conventional heating:

Electricity, 5300 kWh	445	445	445	445	445
Natural gas, 82,000 therms	43,050	43,050	43,050	43,050	43,050
Total annual cost	43,495	43,495	43,495	43,495	43,495

Geothermal heating:

Maintenance	2,500	2,500	2,500	2,500	2,500
Electricity	4,100	2,500	3,100	3,000	2,500
Natural gas	27,000	20,700	9,400	1,700	0
Total annual cost	33,600	25,600	15,000	7,200	5,000

Annual savings (present)	9,895	17,895	28,495	36,295	38,495

Maintenance cost of the geothermal system follows the general inflation rate.

The projected heating costs and savings with geothermal heating of the Children's Museum building over the 20 year period are shown in Table IV for the water temperature values considered. The total savings with the proposed geothermal system are shown in the last four columns of the table. It is seen that even at the lowest geothermal temperature, 110°F, the project appears to be economically feasible with simple payback obtained in less than six years. Discounted payback at 12% is obtained in a little over 9 years. It must be considered, however, that this temperature, 110°F, is at the lower limit of what is technically feasible with the hot water radiator system in the building. Higher temperatures are preferred and the table shows that the payback period is rapidly reduced as the temperature is increased making the project very attractive indeed.

It should be borne in mind that the foregoing analysis is based on the assumption that sufficient amount of geothermal fluid (about 120 gpm) can be produced from a well drilled into the Warm Springs Fault. As discussed in the section on the Wasatch Hot Spring resource, the path along which the thermal water flows to its outlet is not known at present. It is not at all certain whether drilling in the area will result in added flow or higher temperature of the geothermal fluid. In view of the results of this study, it is recommended that an exploratory well be drilled in the vicinity of the Wasatch Hot Spring in order to establish the underground thermal water flow path. Only then can it be decided whether or not a geothermal heating system for the Children's Museum of Utah is feasible.

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TABLE IV

Heating Costs and Savings with Geothermal Heating at Children's Museum of Utah

	Natural Gas Convent'l System	Electricity Convent'l System	Natural Gas Geothermal System	Electricity Geothermal System	Maint. Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
A. Geothermal Fluid Temperature 110°F									
Present cost	43050	445	27000	4100	2500				
Year									
1985	56826	523	35640	4822	2725	14162	14162	12645	12645
1986	59838	544	37529	5011	2884	14958	29120	11924	24569
1987	66719	554	41845	5102	3053	17273	46394	12295	36864
1988	73541	593	46123	5461	3251	19299	65692	12265	49129
1989	81061	634	50839	5844	3462	21549	87241	12227	61356
1990	89349	679	56038	6255	3687	24048	111290	12183	73540
1991	98485	727	61768	6694	3927	26823	138112	12133	85673
1992	108555	778	68083	7165	4182	29903	168015	12077	97750
1993	119655	832	75045	7668	4454	33320	201335	12016	109766
1994	131890	891	82718	8206	4744	37112	238447	11949	121715
1995	145375	953	91176	8783	5052	41318	279765	11878	133593
1996	160240	1020	100499	9400	5380	45981	325746	11802	145395
1997	176625	1092	110775	10060	5730	51151	376897	11723	157117
1998	194685	1169	122102	10767	6103	56882	433778	11639	168757
1999	214591	1251	134587	11523	6499	63232	497011	11552	180309
2000	236533	1339	148348	12333	6922	70269	567279	11462	191771
2001	260718	1433	163517	13199	7372	78063	645343	11369	203141
2002	287377	1533	180236	14127	7851	86696	732039	11274	214415
2003	316761	1641	198666	15119	8361	96257	828296	11176	225591
2004	349150	1756	218979	16181	8904	106842	935137	11076	236667
Total	3227975	19940	2024514	183721	104543	935137		236667	
						Simple Payback			5.97
						Discounted Payback			9.06
B. Geothermal Fluid Temperature 133°F									
Present cost	43050	445	20700	2500	2500				
Year									
1985	58826	523	27324	2940	2725	24360	24360	21750	21750
1986	59838	544	28772	3055	2884	25670	50030	20464	42214
1987	66719	554	32081	3111	3053	29028	79058	20662	62876
1988	73541	593	35361	3330	3251	32192	111250	20459	83334
1989	81061	634	38977	3564	3462	35692	146943	20253	103587
1990	89349	679	42962	3814	3687	39564	186507	20045	123632
1991	98485	727	47355	4082	3927	43848	230355	19834	143466
1992	108555	778	52197	4369	4182	48585	278939	19623	163089
1993	119655	832	57534	4676	4454	53823	332762	19409	182498
1994	131890	891	63417	5004	4744	59615	392378	19195	201692
1995	145375	953	69902	5355	5052	66019	458397	18979	220671
1996	160240	1020	77049	5732	5380	73099	531496	18763	239434
1997	176625	1092	84928	6134	5730	80925	612421	18546	257980
1998	194685	1169	93611	6565	6103	89574	701995	18329	276309
1999	214591	1251	103183	7027	6499	99133	801128	18111	294420
2000	236533	1339	113734	7520	6922	109696	910824	17894	312314
2001	260718	1433	125363	8048	7372	121368	1032192	17677	329990
2002	287377	1533	138181	8614	7851	134264	1166457	17460	347450
2003	316761	1641	152310	9219	8361	148512	1314969	17243	364693
2004	349150	1756	167884	9867	8904	164251	1479220	17027	381721
Total	3227975	19940	1552127	112025	104543	1479220		381721	
						Simple Payback			4.01
						Discounted Payback			5.40
C. Geothermal Fluid Temperature 157°F									
Present cost	43050	445	9400	3100	2500				
Year									
1985	56826	523	12408	3646	2725	38570	38570	34438	34438
1986	59838	544	13066	3788	2884	40643	79214	32401	66839
1987	66719	554	14568	3858	3053	45794	125008	32596	99434
1988	73541	593	16058	4129	3251	50696	175704	32218	131652
1989	81061	634	17700	4419	3462	56114	231819	31841	163493
1990	89349	679	19509	4729	3687	62102	293921	31463	194956
1991	98485	727	21504	5062	3927	68719	362640	31085	226041
1992	108555	778	23703	5417	4182	76030	438670	30707	256748
1993	119655	832	26127	5798	4454	84109	522779	30330	287079
1994	131890	891	28798	6205	4744	93034	615812	29954	317033
1995	145375	953	31743	6641	5052	102893	718705	29579	346612
1996	160240	1020	34989	7107	5380	113784	832490	29206	375818
1997	176625	1092	38566	7607	5730	125814	958303	28833	404651
1998	194685	1169	42510	8141	6103	139100	1097403	28463	433114
1999	214591	1251	46856	8713	6499	153774	1251177	28094	461208
2000	236533	1339	51647	9325	6922	169978	1421155	27727	488935
2001	260718	1433	56928	9980	7372	187871	1609026	27362	516297
2002	287377	1533	62749	10681	7851	207629	1816656	27000	543297
2003	316761	1641	69165	11431	8361	229445	2046100	26640	569937
2004	349150	1756	76237	12235	8904	253530	2299630	26283	596220
Total	3227975	19940	704831	138911	104543	2299630		596220	
						Simple Payback			2.74
						Discounted Payback			3.42

TABLE IV cont'd.

D. Geothermal Fluid Temperature 181°F

	Natural Gas Convent'l System	Electricity Convent'l System	Natural Gas Geothermal System	Electricity Geothermal System	Maint. Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Present cost	43050	445	1700	3000	2500				
Year									
1985	56826	523	2244	3528	2725	48852	48852	43618	43618
1986	59838	544	2363	3666	2884	51468	100320	41030	84648
1987	66719	554	2635	3733	3053	57852	158173	41178	125826
1988	73541	593	2904	3996	3251	63983	222156	40662	166489
1989	81061	634	3201	4276	3462	70755	292911	40149	206637
1990	89349	679	3528	4577	3687	78236	371147	39637	246274
1991	98485	727	3889	4898	3927	86497	457644	39127	285401
1992	108555	778	4287	5242	4182	95622	553266	38620	324021
1993	119655	832	4725	5611	4454	105697	658963	38116	362136
1994	131890	891	5208	6005	4744	116824	775787	37614	399751
1995	145375	953	5741	6427	5052	129109	904897	37116	436866
1996	160240	1020	6328	6878	5380	142674	1047571	36621	473487
1997	176625	1092	6975	7361	5730	157651	1205221	36129	509617
1998	194685	1169	7688	7878	6103	174184	1379406	35642	545258
1999	214591	1251	8474	8432	6499	192437	1571843	35157	580416
2000	236533	1339	9340	9024	6922	212585	1784428	34677	615093
2001	260718	1433	10296	9658	7372	234826	2019254	34201	649294
2002	287377	1533	11348	10337	7851	259375	2278628	33729	683023
2003	316761	1641	12509	11063	8361	286470	2565098	33261	716284
2004	349150	1756	13788	11840	8904	316374	2881473	32798	749082
Total	3227975	19940	127469	134430	104543	2881473		749082	

Simple Payback 2.24
Discounted Payback 2.72

E. Geothermal FLuid Temperature 206°F

Present cost	43050	445	0	2500	2500				
Year									
1985	56826	523	0	2940	2725	51684	51684	46147	46147
1986	59838	544	0	3055	2884	54442	106126	43401	89548
1987	66719	554	0	3111	3053	61109	167236	43496	133044
1988	73541	593	0	3330	3251	67553	234789	42931	175975
1989	81061	634	0	3564	3462	74669	309458	42369	218344
1990	89349	679	0	3814	3687	82527	391985	41811	260155
1991	98485	727	0	4082	3927	91203	483188	41256	301411
1992	108555	778	0	4369	4182	100782	583969	40704	342115
1993	119655	832	0	4676	4454	111358	695327	40157	382271
1994	131890	891	0	5004	4744	123033	818360	39613	421885
1995	145375	953	0	5355	5052	135921	954281	39074	460959
1996	160240	1020	0	5732	5380	150148	1104430	38539	499498
1997	176625	1092	0	6134	5730	165852	1270282	38009	537507
1998	194685	1169	0	6565	6103	183185	1453467	37483	574991
1999	214591	1251	0	7027	6499	202316	1655783	36962	611953
2000	236533	1339	0	7520	6922	223430	1879213	36446	648399
2001	260718	1433	0	8048	7372	246731	2125944	35935	684334
2002	287377	1533	0	8614	7851	272446	2398390	35429	719763
2003	316761	1641	0	9219	8361	300822	2699212	34928	754690
2004	349150	1756	0	9867	8904	332135	3031347	34431	789122
Total	3227975	19940	0	112025	104543	3031347		789122	

Simple Payback 2.16
Discounted Payback 2.60

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