GEOTHERMAL DIRECT HEAT APPLICATIONS PROGRAM SUMMARY

SEPTEMBER 1981

SEMI-ANNUAL REVIEW MEETING
BOISE, IDAHO

DISCLAIMER

GEOTHERMAL

DIRECT HEAT APPLICATIONS

PROGRAM SUMMARY

PRESENTED

AT THE

SEMI-ANNUAL REVIEW MEETING

BOISE, IDAHO

SEPTEMBER 24-25, 1981

U.S. DEPARTMENT OF ENERGY

GEOTHERMAL AND HYDROPOWER TECHNOLOGIES DIVISION

2nd Printing

ACKNOWLEDGEMENTS

The project descriptions contained in this summary were prepared by the Project Teams of the direct heat application projects currently in progress throughout the United States. The Department of Energy gratefully acknowledges their assistance in providing this information which will assist other potential users in assessing the economic and technical viability of the direct use of geothermal energy. Additional copies of this summary can be obtained through the Department of Energy Offices listed on page 3.

At this review, the project presentations are organized according to the phase the project is in: reservoir confirmation, drilling and testing; financial and institutional concerns; system design; and system construction and operation.

CONTENTS

INTRODUCTION OF THE GEOTHERMAL DIRECT HEAT APPLICATION PROGRAM FOR THE GRC ANNUAL MEETING

Because of the undefined risk in the development and use of geothermal energy as a thermal energy source, the Department of Energy Division of Geothermal Energy* solicited competive proposals for field experiments in the direct use of geothermal energy. Twenty-two proposals were selected for cost-shared funding with one additional project co-funded by the State of New Mexico.

As expected, the critical parameter was developing a viable resource. So far, of the twenty resources drilled, fourteen have proved to be useful resources. These are: Boise, Idaho; Elko Heating Company in Nevada; Pagosa Springs, Colorado; Philip School, Philip, South Dakota; St. Mary's Hospital, Pierre, South Dakota; Utah Roses near Salt Lake City; Utah State Prison, Utah; Warm Springs State Hospital, Montana; T-H-S Hospital, Marlin, Texas; Aquafarms International in the Cochella Valley, California; Klamath County YMCA and Klamath Falls in Oregon; Susanville, California and Monroe, Utah. Monroe's 164°F and 600 gpm peak flow was inadequate for the planned project, but is expected to be used in a private development. Three wells encountered a resource insufficient for an economical project. These were Madison County at Rexburg, Idaho; Ore-Ida Foods at Ontario, Oregon and Holly Sugar at Brawley, California. Three projects have yet to confirm their resource. The Navarro College well in Corsicana, Texas is being tested; the Reno, Moana, Nevada well is being drilled and the El Centro, California well is scheduled to be drilled in January 1982. The agribusiness project at Kelly Hot Springs was terminated because a significant archeological find was encountered at the proposed site. The Diamond Ring Ranch in South Dakota, and the additional project, Carrie Tingley Hospital in Truth or Consequences, New Mexico both used existing wells.

The projects that encountered viable resources have proceeded to design, construct, and in the most advanced projects, to operate geothermal systems for district heating, space heating, grain drying and aquaculture.

The technical problems encountered by the engineers during designing and construction were within their capabilities but challenged their innovation. The standard engineering design guides did not contain sufficient information on well and reservoir production, material selection and deeply throttled system flow control. To assist future engineers, engineering design guides have been published: the Geothermal Resources Council Special Report #7, Direct Utilization of Geothermal Energy: A Technical Handbook; American Society of Heating, Refrigerating and Air Conditioning Engineers report - Direct Application of Geothermal Energy; and to-be-published, the design guide by the International District Heating Association. Individual state geology and energy offices have published detailed information for developers on the extent of geothermal resources and the potential market.

*Currenty the Division of Geothermal and Hydropower Technologies (DGHT).

The independent analysis performed by ICF has shown that the five projects thus far examined were economically viable as normal private business ventures. The projects at the Philip School, in Philip, South Dakota, St. Mary's Hospital in Pierre, South Dakota, Diamond Ring Ranch near Midland, South Dakota; the YMCA in Klamath Falls, Oregon and Pagosa Springs, Colorado were shown to compete favorably with lowest cost local present energy prices. Pagosa Springs, for example, has a minimum acceptable supply price (1980 dollars) of $2.56/MBtu which is less than the low price natural gas. An independent close examination of the economics of the other projects will occur this year and the results will be published.

The many elements of the direct use program came into focus while assisting these projects in their original formulation and continued through their development to operation. The state resource assessment efforts, the application feasibility studies, the technical assistance and the institutional studies, the across-the-board institutional and engineering studies, the engineering design guides and the management and technical assistance provided by the DOE Field Offices and their technical support contractors, have been instrumental in the progress of these projects. These projects represent a culmination of these efforts. Their successful completion and operation will provide a new impetus to development of geothermal energy by the private and local public sectors.

Eric A. Peterson, Program Manager
DOE/DGHT
12th & Pennsylvania Avenue
Washington, DC 20461
(202) 633-8760

DOE PROJECT OFFICES

Three Department of Energy Operations Offices are responsible for the management of the direct heat application projects. The offices and their respective projects are:

Office	Projects
DOE-Idaho Operations Office 550 Second Street Idaho Falls, Idaho 83401 Contact: Mike Tucker Project Coordinator (208) 526-3180 Technical Support: Frank Childs EG&G Idaho, Inc. Idaho Falls, ID 83415 (208) 526-9512	Boise Diamond Ring Ranch Elko Heating Company Madison County Ore-Ida Foods Pagosa Springs Philip School St. Mary's Hospital Utah Roses Utah State Prison Warm Springs State Hospital
DOE-Nevada Operations Office P.O. Box 14100 Las Vegas, Nevada 89114 Contact: Jim Cotter Director Energy Applications Division (702) 734-3424 Technical Support: Roland Marchand, EG&G Las Vegas Operations P.O. Box 1912 - M/S N20 Las Vegas, NV 89101 (702) 647-5211	Navarro College T-H-S Hospital
DOE-San Francisco Operations Office 1333 Broadway Oakland, California 94612 Contact: Hilary Sullivan Program Coordinator (415) 273-7943 Technical Support: George Budney Rockwell Energy Technology P.O. Box 1449 - Engineering Center Canoga Park, CA 91304 (213) 341-1000 ext. 6474	Aquafarms International El Centro Klamath Falls Moana, Reno Susanville

DIRECT HEAT APPLICATIONS

PROJECT DESCRIPTIONS

PROJECT SUMMARY

Project Title:

Field Experiments for Direct Uses of Geothermal Energy
Elko Heat Company, Elko, Nevada

Location:

City of Elko, NV

Principal Investigator:

Mr. Ira S. Rackley, P.E., Project Manager
Chilton Engineering, 702-738-2121

Project Team:

- Elko Heat Company, Elko, NV - Mr. Jim Meeks, President
- Chilton Engineering, Elko, NV - Mr. Ira S. Rackley, P.E. Project Manager, and Mr. Sheldon S. Gordon, P.E., Project Engineer

Project Objectives:

This project was selected to demonstrate the technical and economic feasibility of the direct use of geothermal brines from the Elko KGRA for the purpose of providing space, water, and process heat. In a more general sense, it is the aim of the project to generate information and approaches that will enable the proposers to develop the Elko resource as a viable alternative to the consumption of primary fuels for space, water and process heating in Elko.

Objectives related to this overall goal are:

- Develop adequate resource information to allow for the design of the geothermal process system.
- Use of this resource information to generate a plan for the continued development and use of this resource after the period of government support.
- Displace a significant portion of the primary fuel consumption in Elko for identified energy markets with geothermal energy.
- Determine the economics of the required investment and characterize the economics of a variety of applications of the resource.

Resource Data:

A gradient hole drilling program was initiated in April, 1980 with two holes being drilled within the business district of Elko. The location of the test holes was determined by the surface thermal survey conducted by Geothermal Surveys, Inc., Figure 1.

In September, 1980, two additional gradient holes were drilled on the wastern edge of the Elko Business District in an effort to gather more data on the complex faulting which seems to be controlling the heat flow from the Elko resource. A summary of the results of this drilling program is as follows:

Test Well EHC No. 1

Water Temperature @ 100'	15.4°C (60°F)
Average Temperature Gradient	3.73°C/100' (6.7°F/100')
BHT @ 995'	48.8°C (120°F)
Maximum Temperature Gradient observed	5.8°C/100'(10.4°F/100')
Water Quality	Good

Test Well EHC No. 2

Water Temperature @ 100'	14.5°C (58°F)
BHT @ 900'	36.4°C (98°F)
Average Temperature Gradient	2.74°C/100'(4.9°F/100')
Maximum Temperature Gradient observed	2.8°C/100' (5.0°F/100')
Water Quality	Good

Test Well EHC No. 3

Water Temperature @ 100'	61.9°C (143°F)
BHT @ 565'	71.2°C (160°F)
Average Temperature Gradient	2.97°C/100'(5.3°F/100')
Maximum Tenperature Gradient observed	2.97°C/100'(5.3°F/100')
Water Quality	TDS - 694 mg/L Silica - 56 mg/L

Test Well EHC No. 4

Water Temperature @ 100'	15.1°C (59°F)
BHT @ 625'	29.0°C (84°F)
Average Temperature Gradient	2.65°C/100'(4.8°F/100')
Maximum Temperature Gradient observed	2.65°C/100'(4.8°F/100')
Water Quality	unknown

The lithology of the gradient holes are similar, consisting of some brown sands and silts in the upper sections, lighter volcanic sands in the middle, and altered volcanics to intermixed clay lenses in the bottom.

It is theorized that test hole No. 1 and Test hole No. 3 are on the down thrust side of a controlling northeast-southwest fault line. Also, there appears to be cross faulting in the vicinity of test hole No. 3.

In July, 1981, the necessary permits were obtained and negotiations completed on geothermal rights for a production well in the vicinity of EHC #3. Paul Billings Drilling completed the production well drilling on August 7, 1981. The following tabulation summarizes the results of this effort.

EHC Production Well No. 1 (Figure 2)

BHT @ 845'		Estimated 194°F
Water Quality		Good: TDS-606 mg/L Ra-226 - 4.5 pc/L
Flow:	initial Artesian	935 gpm (59.0 L/s)
	sustained Artesian	485 gpm (30.6 L/s)
	Temp. Artesian	180°F (82°C)

A test pumping program was initiated in mid September, 1981 to determine well characteristics under pumped conditions. Results were not available for this publication.

It should be noted that the resource temperature is estimated to be (239°F) 115°C based upon silica geothermemetry.

Design:

The project team has recently started conceptual design work for the project. Due to parallel scheduling of work tasks relating to the confirmation of the geothermal resource (i.e., gradient hole drilling) the present effort of the design team has been directed primarily towards the preparation of an inventory and detailed description of the existing mechanical systems in the three selected buildings. See Figure 3 for distribution loop.

This effort is the first step in a system design and modeling effort which we feel is somewhat unique. The three selected buildings will be computer modeled using DOE-2, a detailed building loads and systems simulation model used to certify compliance to Title 24 of the California Administrative Code - Energy Conservation Standards. The building and process loads description generated by that modeling effort will then be used to drive a modified TRYNSYS simulation of the geothermal distribution system. This modeling effort will allow the design team to look at a number of options for the configuration of the geothermal distribution system and to design a system which may be expanded to meet future geothermal development needs of the community. The modeling tool will also have general applicability to the problems of design and performance estimation for geothermal district and process heating systems. The design team feels that a design tool of this nature will be particularly useful in the evaluation of system economics.

The buildings selected for retrofit to the geothermal source provide a wide variety of system types and configurations. These are described in more detail below. While the diversity of systems has posed a number of problems for the design team, it has also provided the opportunity for the retrofit applications. This experience will be useful in the effort at continued development of the resource.

Building Systems and Load Summary:

1. Henderson Bank Building

The fifty year old Henderson Bank Building is a four-story 21,000 sq. foot, brick or stone faced concrete building. The first floor (bank lobby) rises the equivalent of two stories. A mezzanine covers approximately one-third of the floor area and serves as bank office space. The second through fourth floors are office rental spaces. The basement is an unconditioned space and houses the primary energy conversion equipment.

The primary energy conversion equipment applicable to geothermal retrofit is a 200 HP hot water boiler. The boiler is coupled to a perimeter radiation distribution system. Cast iron radiators are located normally at each window. Each radiator is controlled by a thermostatically actuated modulating valve.

2. Vogue Laundry

The Vogue Laundry is a 17,300 sq.ft. building. The building construction is tilt-up concrete walls with a 25 ft. high beamed dome, which houses the dry cleaning and laundry facilities. A single story office space fronts the domed building.

Process loads make up the majority of the building energy demand. Internal gains from these process loads supply, in large part, the heat necessary to meet building loads. The primary energy conversion equipment are two 250 HP 125 PSIG steam boilers in parallel. Normally, only one boiler is fired at a time. The 125 PSIG steam is utilized directly by two commercial flat irons. A hot water generator converts the steam into 175°F hot water which is stored in a 5,000 gallon holding tank. This 175°F hot water is used by six commercial washing machines of a combined capacity totalling 3,130 lbs. Discharged wastewater from the washers is run through a heat recovery system to preheat makeup water into the hot water storage tank. The geothermal retrofit will be utilized to heat hot water for the washers.

3. Stockmen's Motor Hotel

The Stockmen's consists of several building components. First is the original motor court building. This is a two-wing, three-story, motel-type building with a heated swimming pool located in the court yard. Attached to the motor court is the two-story casino/restaurant. The first floor houses the casino/restaurant. The second floor houses air handling equipment and operates as a return plenum. In 1965 a two-story addition was built on top of the casino/restaurant section. These two floors consist of hotel rooms with a large glass-covered atrium court yard in the middle. Another addition was built off the casino/restaurant section in 1973. This two-story addition consists of a showroom, storage area, and four banquet rooms. Underneath the entire building is a basement/garage, which is used as office space, storage, parking, and to house mechanical equipment.

The primary energy conversion heating equipment consists of two 250 HP 60 PSIG steam boilers. Again, these boilers are piped in parallel with usually only one boiler on line at a time. The 60 PSIG steam is used as the main heat transfer medium to the steam coils or hot water generators.

There are several types of distribution systems which corresponds to the various building components. The original motor court is serviced by a modified, two-pipe hot/chilled water system, with individual terminal room fan coil converters. 180°F hot water is supplied to the system from a steam fired hot water generator.

The showroom addition has three types of systems. The majority of space conditioning is supplied by six air handlers. These air handlers are equipped with steam coils which utilize pressure reduced 10 PSIG steam. Two 30 PSIG unit heaters service the storage area. Lastly, a 30 PSIG baseboard system is used to heat a small portion of the addition.

Finally, three air handlers service the underground parking area and mechanical room. These air handlers are equipped with steam coils which utilize either 60 or 30 PSIG steam.

Cooling is accomplished by utilizing two centrifugal water chillers supplying chilled water to the various systems noted above. The feasibility of retrofitting the Stockmen's heating systems will be two-fold. First, all hot water systems will simply be tied into the geothermal source via heat exhangers. Secondly, all steam boilers, distribution piping, and coils will be retrofitted to hot water and connected to the geothermal source. This will be a major undertaking and requires extensive repiping.

Current Estimated Project Cost:

Total:	$1,234,720		
DOE Share:	$ 756,720	Participant Share:	$477,682
	61%		39%

Lessons Learned:

1. When considering project changes which effect permitting, determine if reprocessing of necessary permits may cause significant project delays. Find out if ammendments to existing permits may short-cut reprocessing or if you must start over. These constraints may effect your decision.

2. While geophysical techniques employed were successful in locating a producing fault zone for this project, improvements in techniques for locating faults and determining reservoir potential would be highly encouraging to potential developers in reducing risk and cost.

3. Before committing to a geothermal project, the developer should become familiar with laws in his state which govern the end-use of the resource. This would include possible classification of a district heating system as a utility and possible infringement on existing utilities "rights within a service area."

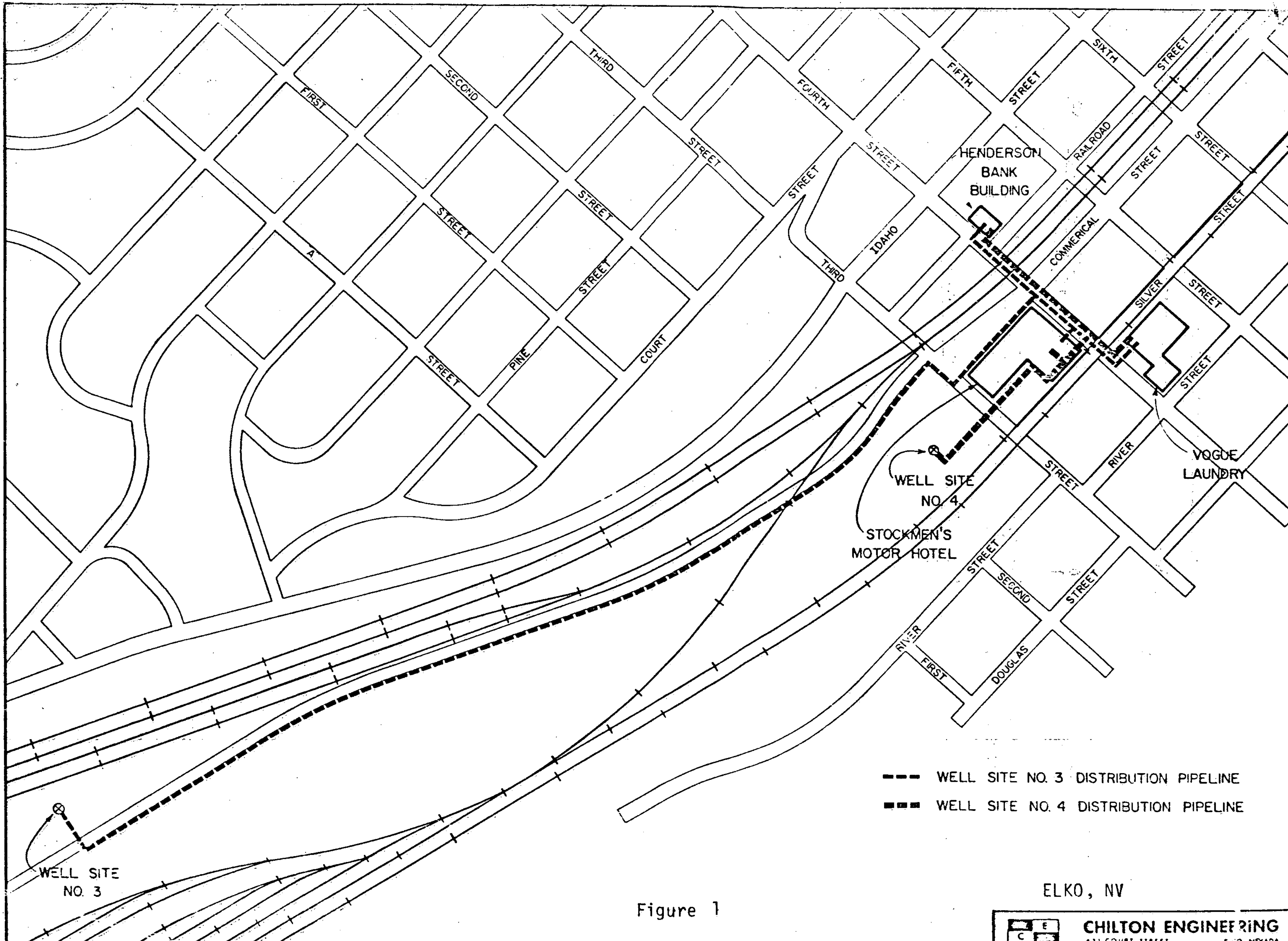
ELKO HEAT COMPANY PON REPORTS

(Cooperative Agreement No. DE-AC07-79ET27033)

1. Geothermal Surveys, Inc., Direct Use Geothermal Investigations Elko, Nevada, November 16, 1979, Contract No. DE-AC07-79ET27033

2. Elko Heat Company, Environmental Report, Elko Geothermal Project Contract No. DE-AC07-79ET27033, May 1979.

3. Geothermal Surveys, Inc., Thermal Survey For Ground Water, Elko, Nevada, September 16, 1977.



FIRST
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FOURTH
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RIVER
STREET
HENDERSON
BANK
BUILDING
VOGUE
LAUNDRY
WELL SITE
NO. 4
STOCKMEN'S
MOTOR HOTEL
STREET
SECOND
STREET
RIVER
FIRST
DOUGLAS
WELL SITE
NO. 3
WELL SITE NO. 3 DISTRIBUTION PIPELINE
WELL SITE NO. 4 DISTRIBUTION PIPELINE
ELKO, NV
CHILTON ENGINEERING
421 COURT STREET

Figure 1

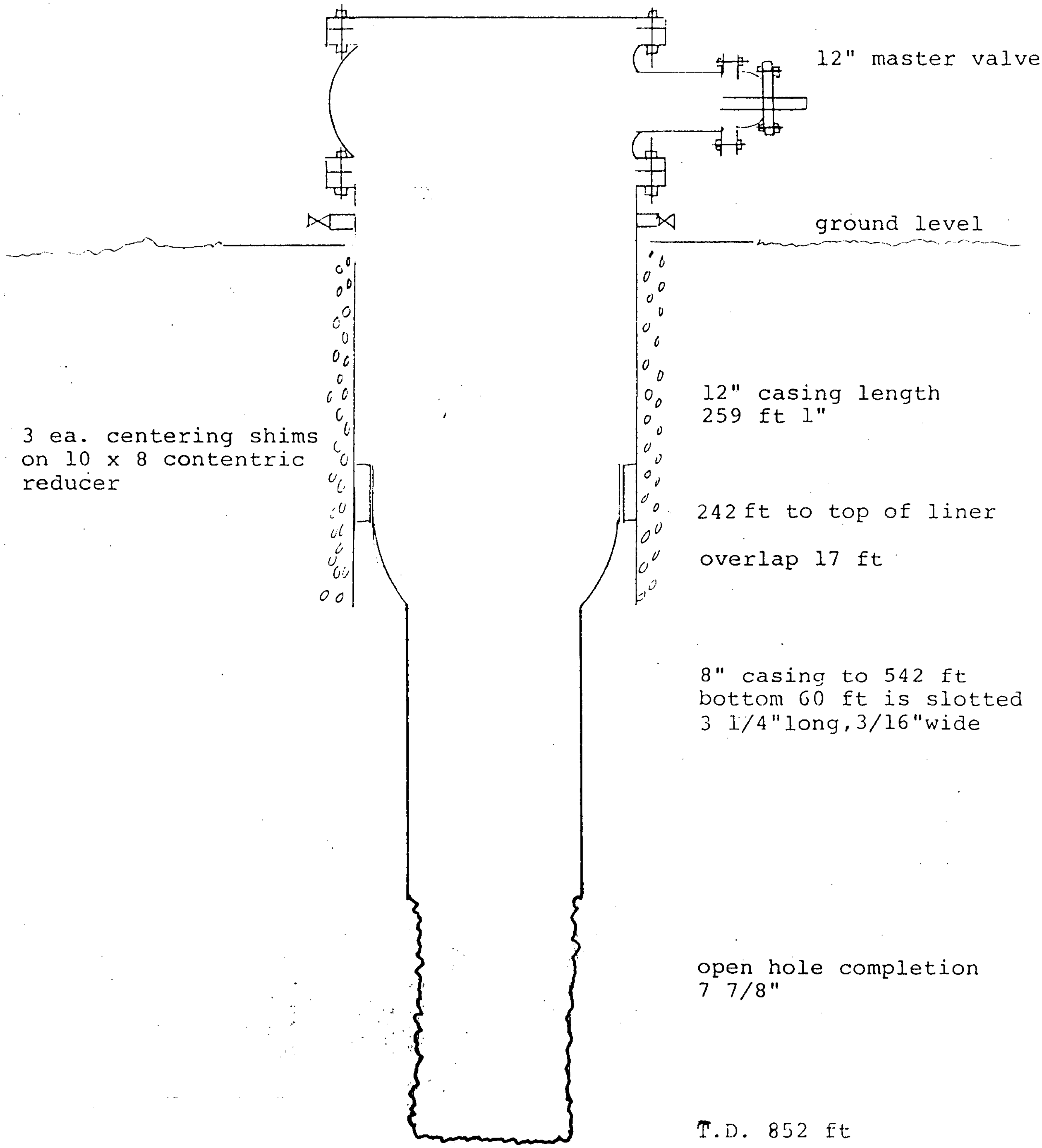
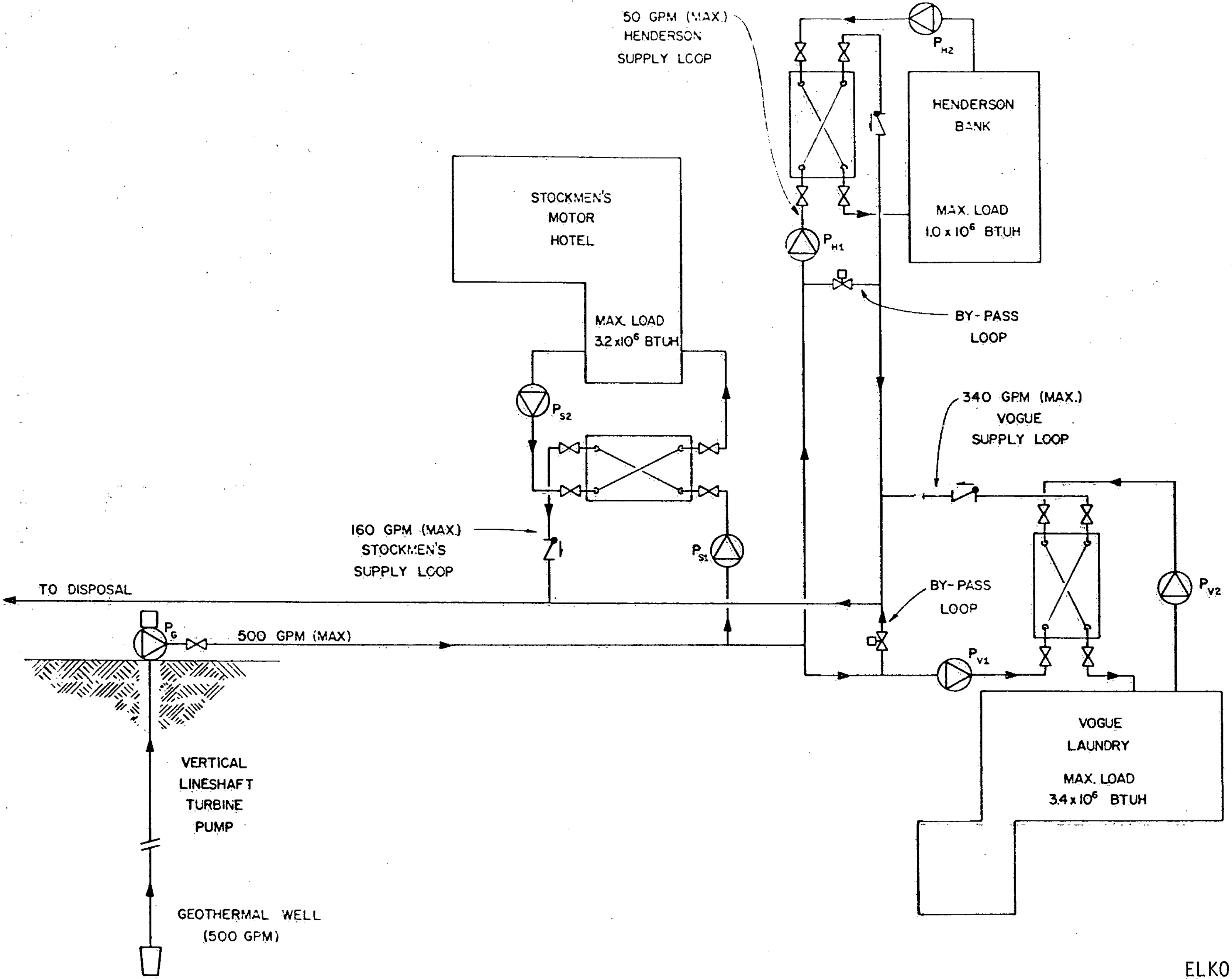


Figure 2. Elko Well, EHC GP-1



ELKO, NV

Figure 3. DISTRIBUTION LOOP SCHEMATIC

CHILTON ENGINEERING
421 COURT STREET ELKO, NEVADA

PROJECT TITLE: Madison County Geothermal Project

PRINCIPAL INVESTIGATOR: Dr. J. Kent Marlor, Chairman
Madison County
Energy Commission (208) 356-3431

PROJECT TEAM: Madison County (Owner)
Energy Services, Inc. (Engineer)

PROJECT OBJECTIVE: To demonstrate the economics and feasibility of using a low-termperature geothermal resource for food processing and space heating application.

LOCATION DESCRIPTION: Rexburg, Madison County, Idaho
25 miles (40 km) northeast of Idaho Falls, Idaho. T6N, R40E, S30.
Population: 10,773 (Rexburg)
Area Activities: Potato Processing, Agriculture and Trade Center. Junior College

RESOURCE DATA:

Well Depth: 3,950 ft (1,204 m)

Date Complete: (Not yet completed)

Completion Technique: Open Hole

Wellhead Temperature: Not applicable - 20°C from 2,400 ft level

Flowrate: 600 - 700 gpm (38-44 ℓ/s) pumped, 5 ft drawdown

Summary: Madison County is at the edge of the Snake River Plain, an area that has been characterized as a young volcanic rift. Northeast trending faults, concentrated along the plain boundaries are the source of many hot springs. The Madison County well intersected a fault at 3,000 ft (914 m). A failed packer on a liner hanger at 2,200 ft is allowing fluids from a porous formation at this level to enter the casing and has made it impossible to determine the formation temperature at depth. When pumping the well, only fluids from the 2,200 to 2,400 ft level are being produced. It has been impossible to sample fluids from below the casing (below 3,540 ft). In the natural condition, 20°C fluids have been entering the well at the 2,200 ft and flowing down and out the bottom of the casing at 8 ft/minute, cooling off the formation below the casing (3540 ft) for the last 16 months.

Madison County (Continued)

SYSTEM FEATURES:

Application: Potato processing and district heating were originally proposed. (American Potato Company was an original participant, but is awaiting results of the present well before obligating further).

Heatload (Design): 25×10^6 Btu/hr potato processing
(Proposed) 60×10^6 Btu/hr space heat

Yearly Utilization (Maximum): (Not applicable. Geothermal resource not confirmed to date). If used only for space heating, annual utilization will be nominally 40%. Food processing utilization would be 85% annually.

Energy to be Replaced: 1.8×10^{11} Btu/yr potato processing
4.5×10^{11} Btu/yr space heat (proposed)

Facility Description: Nine public buildings, various apartments and residences and the American Potato plant were originally proposed.

Disposal Method: One injection well was originally proposed.

Summary: The Madison County project is to be a combination district heating and industrial processing system. If temperatures of 250°F (121°C) can be found, the American Potato Company would replace 90% of its thermal energy use in blanching and drying operations. Cooler geothermal water and/or the discharge from the potato plant is to be used in a district heating system for the Rexburg business district. The well configuration and location are shown in Figure 1 and 2.

Madison County (Continued)

STATUS: Drilling below the 3,150 ft level, using water as the drilling fluid, proceeded without returns, and with severe lost circulation at a number of known depths. Bridging occurred at several locations, and the hole has never been logged in its open status below 3,480 ft. Originally drilled to 3,940 ft, when it was decided to stop drilling because cuttings were not being adequately lifted. Air lifted (pumped) well for 3 days at about 600 gpm. No drawdown and no change in wellhead temperature which never exceeded 70°F (21°C).

After learning of the hydrological situation in the well, plans were made to hang a liner from the bottom of the existing casing (then to 2,289 ft) to the level just above a suspected production zone around 3,600 ft. To keep the cost as low as possible, a workover rig was used. A 5½ inch liner (casing, K-55, 15.5 lb/ft) was hung with a liner hanger and packer from the 2,200 ft level. Cement was spotted around the bottom of the casing at 3,540 ft, and the fill in the hole was then drilled out to 3,950 ft, (10 ft deeper than originally drilled), leaving the bottom 400 ft as open hole formation. However, the flow ports on the packer failed to close, and thus negated making the desired seal at the 2,200 ft level. The attempted remedial action (installation of the liner) was completed in June 1981. An attempt to seal the failed packer using mechanical devices (lead and rubber seals), as shown in Figure 3, was made. Such a device was installed in August, but residual cement on the casing and packer-liner hanger walls prevented these seals from doing their job. Attempts are now underway (early September, 1981) to retrieve the first seal units and try a second time.

The significant downflow of 8 ft/minute is a very strong indication of a very permeable production zone below the liner (casing) - i.e., below 3,540 ft, and a reservoir under a different pressure and at a different temperature than that at the 2,200 ft level from which the in-flow is occurring. However, formation temperatures from the 3,600 ft and lower levels can never be obtained until the leak at 2,200 ft is repaired, for cold water has been flowing down the well, cooling off the bottom formation for the last 16 months.

CURRENT ESTIMATED
PROJECT COSTS:

Total:	$3,422.500		
DOE Share:	$1,677.025 49%	Participant Share:	$1,745,475 51%
Expenditures to date:		$865,000 (87% DOE, 13% Madison County)	

LESSONS LEARNED:

The $6,000 per day expense of the rig dictated that it be dismissed before the hydrological conditions in the well were completely understood. Remedial action to seal the upper zones with a liner hanger/packer using a workover rig failed because of a failed packer. Subsequent remedial expenditures now appear more than if rig had been allowed to remain on standby for several days to thoroughly evaluate the well.

Currently, the project is attempting to repair the leak in the casing caused by the failed packer. Mechanical lead and rubber seals are being fabricated in this attempt. The first such attempt in August, 1981, failed because of residual cement along the casing and inside the liner hanger/packer. Because of the significant downward natural flow, there is very strong suspicion that the zone below the casing (below 3,540 ft) is very porous and a producer of quite different (higher) temperature water than that entering the well at 2,200 ft.

A simple failure, of shear-pins not capable of being sheared in the packer, has created an extremely expensive and frustrating situation. Careful attention to quality control by the manufacturer and close discussion by engineer with the manufacturer prior to delivery and use of such devices is recommended. The latter did occur in this case, but did not prevent the delivery and use of a defective and expensive device.

MADISON COUNTY PON REPORTS

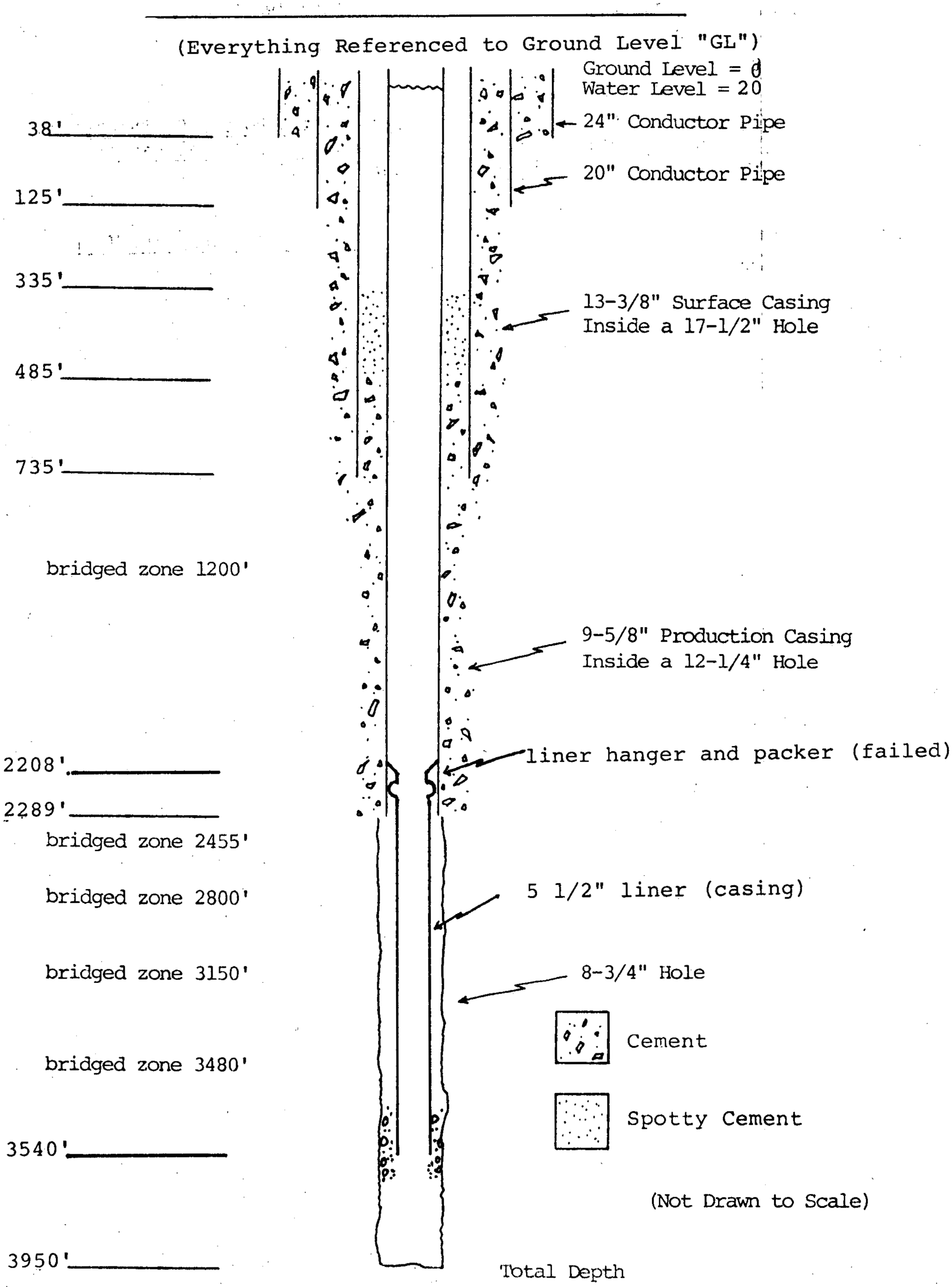
(Cooperative Agreement No. DE-FC07-79ET27028)

1. Energy Services, Inc., Madison County Rogers Potato Geothermal Space/Process Heating Project - Semi-Annual Technical Report February 1979 - August 1979, October 31, 1979.

2. Energy Services, Inc., Madison County Geothermal Project, Well Drilling Report (to be issued).

MADISON COUNTY WELL PROFILE 9/9/81

GEOTHERMAL WELL #1 FIGURE 1



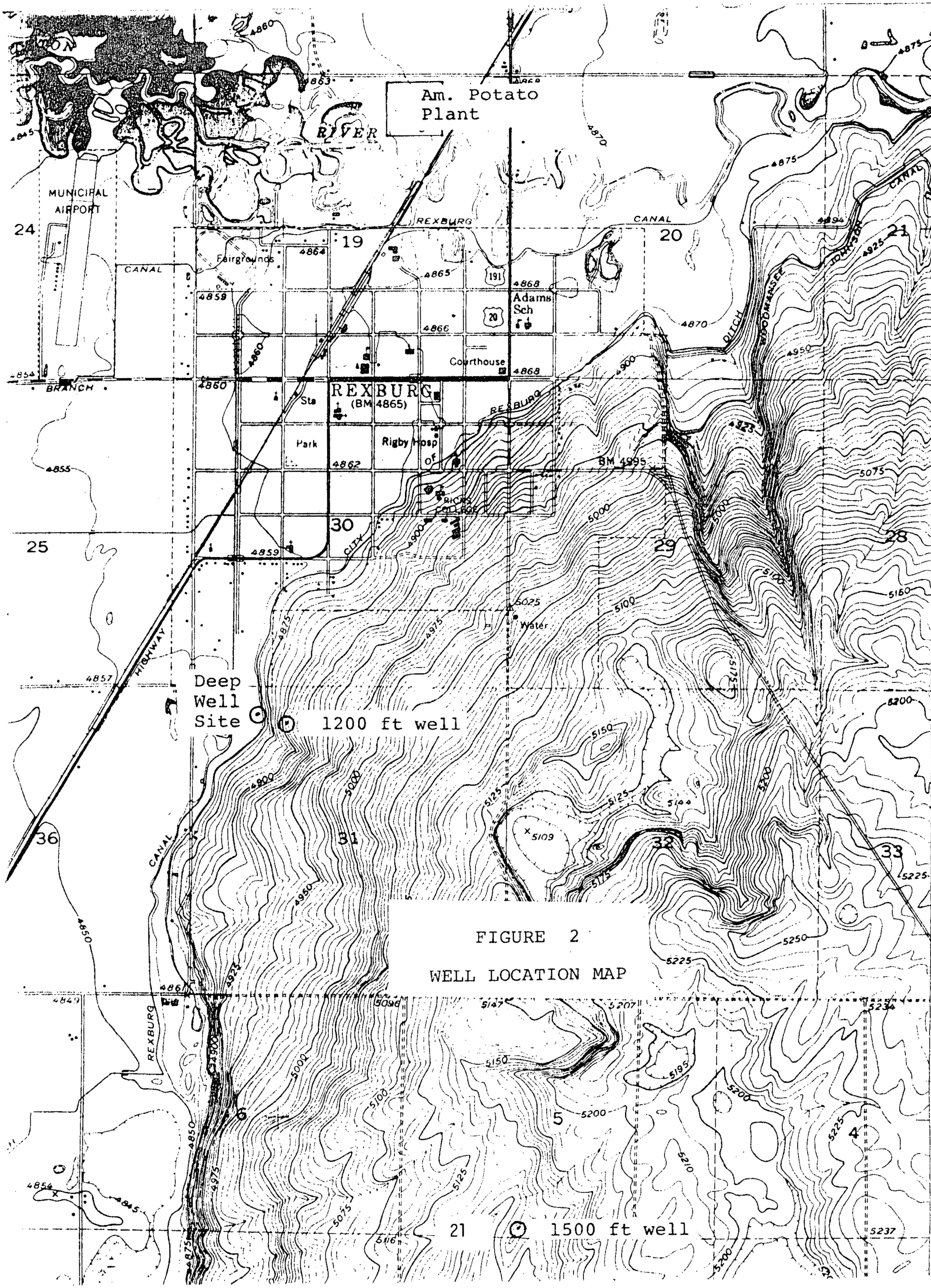
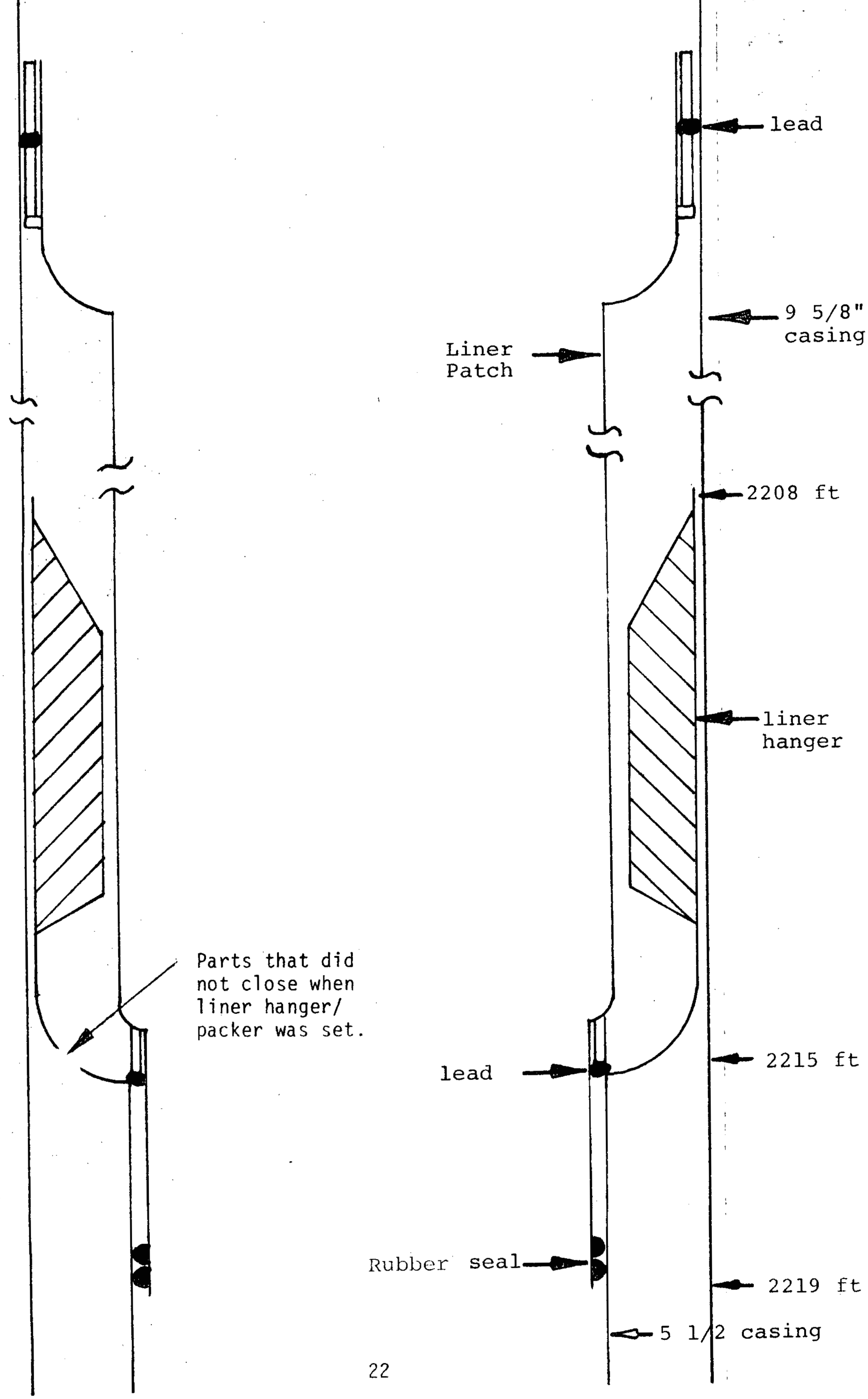


FIGURE 2

WELL LOCATION MAP

DETAILS OF THE LINER HANGER
AND PATCH TO REPAIR LEAKING PACKER

Figure 3



PROJECT TITLE: Multiple Use of Geothermal Energy at Moana KGRA, Reno, Nevada

PRINCIPAL INVESTIGATOR: Dr. David J. Atkinson, President
Hydrothermal Energy Corporation
(702) 323-2306; (213) 464-6446

PROJECT TEAM:

- Hydrothermal Energy Corporation, Developer and Heat Supplier
- S.A.I. Engineers, Engineering Design and Construction
- Water Development Corporation, Drilling
- Elliot Zais & Associates, Well Testing

PROJECT DESCRIPTION:

The Moana area of southwest Reno has been the site of small-scale direct use of geothermal heat for more than fifty years.

Between forty and fifty systems operate there. All of them are small, and most of them involve single family homes that use downhole heat exchangers for space heating. Two motels use the geothermal heat for space and pool heating, and a small apartment complex uses it directly as domestic hot water.

Until this time, the pattern has been one of piecemeal, haphazard development.

The extent of the resource is not yet well defined. The cool wells that surround the geothermal area are not close enough to map boundaries at this time.

Geologic conditions are quite straightforward. About 600 to 2000 feet of alluvial sediments, composed of sands and clays, and some gravels, overlie a "basement" of Tertiary volcanics, mostly andesitic in composition. Depth to the upper surface of these volcanics is clearly expressed in the gravity pattern of the region.

By combining the gravity data with detailed structural and hydrogeologic analysis, it can be seen that the area of shallow hot wells overlies an upfaulted basement block.

Most of these wells are only a few hundred feet deep. Some yield water at boiling point, but temperatures are more commonly between 140° and 190°F. The wells simply tap the top of the geothermal system in the shallow aquifers of the alluvial sequence of sands, clays and gravels.

These hot shallow aquifers are evidently fed from below through fractures propagating upwards from fault and fracture zones in the volcanic basement.

Low sun angle air photographs have been used to map the surface expression of these basement fault systems. From this work, and from geologic mapping, three fault systems have been recognized, trending N. 35°W., N., and N. 40°E.

Based on the sense of relative displacement and other structural evidence, the three fault systems are interpreted as two conjugate shears trending N. 35°W. and N. 40°E., bisected by a system of normal faults and extension fractures trending N. Faults of the latter system are interpreted to dip east or west at about 60°. Faults of the other two systems are steep or vertical.

From this interpretation, the best geothermal production would be expected from wells that intersect the N-trending faults and extension fracture zones, especially where additional fracturing has been produced at intersections with faults of the other systems.

Production from fracture permeability in the basement is likely to be greater than from the shallow sedimentary aquifers in the alluvial valley fill. However, the deeper drilling required to reach and penetrate the volcanic basement is, of course, considerably more expensive and difficult.

The thermal anomaly in the Moana district is centered around an area between the South Virginia/Moana Lane intersection and Wheeler Lake. Its general form is correlated with fault structures delineated in the geologic work we have done, and a string of hot artesian wells and the old Moana hot springs lie along one of the N.-trending fault zones.

In order to establish that this reservoir can be developed successfully on a large scale, our project is designed to supply space heating and domestic hot water heating to a large condominium complex in southwest Reno, the Salem Plaza Condominiums.

LOCATION DESCRIPTION

The site of the project is in a small section of southwest Reno between Plumb Lane and Moana Lane to the north and south, and between South Virginia and Plumas to the east and west.

RESOURCE DATA:

The first well is presently being drilled.

SYSTEM FEATURES:

Application:

Space and water heating of condominiums, with the addition of space cooling if the reservoir temperature proves to be high enough.

Heatload (Design), estimated: 6,000,000 BTU/HR.

Yearly Utilization: 15,600,000,000 BTU

30 Year Project Life: 468,000,000,000 BTU

Energy Replacement:

The fossil fuel energy replaced will be natural gas, amounting to about 468,000,000,000 BTU's over the thirty year life of the project.

Facility Description:

Salem Plaza is a 150-unit condominium complex, with a swimming pool. Their existing heating comes from two central boiler plants, fired by natural gas, that supply domestic hot water and space heat in a single system. This two-pipe circulating system provides space heat via heating coils and forced air. Domestic hot water is simply drawn from the same system.

Disposal Method:

The best method of disposing of spent fluids cannot be determined until drilling gives us the needed data on the chemistry of the geothermal fluid.

Alternatives include surface disposal by various methods, and reinjection.

Summary:

The project involves retrofitting a large existing residential complex, for space and domestic hot water heating, with the possible addition of space cooling.

The first production well is currently being drilled at the east edge of the property.

Buried, insulated pipelines will carry the geothermal fluid to and from the existing boiler facilities in the various buildings, which will be retrofitted with plate-type heat exchangers.

Disposal may be at surface or by reinjection. Additional use of available heat will involve whichever auxiliary applications prove most feasible after the space and water heating systems are operating.

STATUS:

The first steps of the project involved negotiation of the heat sale agreement with the Salem Honeowners Association, and obtaining environmental clearances.

Our environmental work showed that the two main problem areas would be the disposal of spent fluids after use, and the noise levels during drilling, close to the condominium units.

Special provisions were adopted to minimize difficulties with drilling noise. During the first phase of our drilling program not a single complaint has been received.

The fluid disposal problem cannot, of course, be resolved until the drilling has reached the stage where we are certain of the composition of the reservoir fluid. Other wells in the area typically yield sodium-potassium sulphate waters with only about 1100 ppm TDS. We therefore expect no particular difficulties in handling and disposing of these fluids.

Following the signing of the heat sale agreement, and the environmental work, we applied for and obtained the various permits required to drill for and use the resource, including water rights permits.

We then developed drilling plans based on the available geologic data, though the selection of a well site was mainly dictated by the need to use either the west or east parking lots of the condominium complex. The latter was selected as being larger and more useable and as being somewhat more favorable geologically.

Drilling of the first well began recently and has at this time reached a depth of 930 feet. A Portadrill RV-6 is being used, with the reverse circulation method, using water as the drilling fluid in order to avoid damaging potential production zones.

The first seventeen feet below the parking lot surface was composed of fill, with large cobbles (some up to 16" in diameter). A 24" hole was drilled with a Mohab bit and an 18" clamshell cobble bucket, to 19'6". There a 20" diameter conductor pipe 23'6" long was cemented in with two yards of cement grout (7 sack mix).

Below the conductor pipe we drilled an 18" hole; the cobble zones persisted to about 67', with other thinner zones in the next two hundred feet. Drilling in this upper section of the hole was thus slow and difficult. Some lost circulation problems were also experienced.

Below that, progress was much faster until a depth of about 850 feet was reached. In this lower section of the hole we were drilling in a friable claystone that frequently caved in. On some occasions as much as 90 feet had to be redrilled. (Our drilling was confined to the hours 8 am to 6 pm to avoid disturbing residents.)

After running electric logs, we placed 12" casing as a temporary guide casing to keep the hole open while we observed temperature and determined whether the hole needs to be deepened.

The most recent temperature logs show a temperature of about 147°F at 900 feet.

When the drilling of this well has been completed, and the temperature and flow characteristics have been assessed, we shall determine whether the hole is best used as a production or a reinjection well.

Additional drilling will follow to complete the production/disposal system.

Final design of the retrofit will be completed as soon as we have determined, from the drilling results, the temperature of the geothermal fluid we shall be using.

Buried, insulated pipes will be laid from the production well to the boiler rooms where plate heat-exchangers will be used to transfer heat to the existing heating system. The exchangers will be located where the return line from the building's heating system enters the boilers.

Acceptance and optimization tests will follow, to integrate the new geothermal system with the old natural gas system. The latter will remain as a permanent back-up, and for handling peak demand.

A detailed economic and engineering assessment of the operating system will follow as the final piece of research making up this project.

CURRENT ESTIMATED PROJECT COST: $1,192,894

LESSONS LEARNED:

In developing a model heat sale agreement a considerable amount of pioneering was done in legal form and in the strategy and problems of marketing geothermal energy to the public.

A heat sale agreement was negotiated with the Homeowners' Association under which we are permitted to drill on appropriate portions of the Salem property, develop a geothermal system for them, and sell them the geothermal heat at a discount below the prevailing price of the natural gas that they currently use.

A long term agreement was critical, to ensure a sufficient return relative to the capital cost of exploration and development.

Various contingencies were important. Normally the geothermal developer needs a signed contract before he commits enough funds to carry his work to the stage of confirming the resource and confirming the economic and technical viability of his program. He needs to be able to withdraw without penalty if his work later shows the project is not practical.

The user, on the other hand, needs protection from a possible abandonment of the project that might leave his property scarred or in disorder.

For optimum reservoir development and management where there are several potential users, it is important to obtain the agreement of each that excess production from his property may be used to supply the others, and that the reverse is equally acceptable, so that his needs may be supplied by the excess produced on other users' properties. This gives the developer freedom to develop and utilize the resource in the best possible manner, without concern about arbitrary property boundaries.

Economically it is important to have agreements to supply base load heat to a group of users rather than to have to meet the peak load of one user for a few glorious hours each year, underutilizing the productive capacity of the system for the rest of the year.

It is also important to negotiate price on a basis involving a true comparison to alternative fuels. Geothermal heat will generally be metered as delivered heat, on the user's side of the heat exchangers. If "efficiency" could be said to have any meaning in that situation, it would be 100%. Natural gas or fuel oil boilers, on the other hand, will always have efficiencies well under 100% and often below 70%. Accordingly a geothermal price for a delivered therm that is 43% above the price of a "therm" of natural gas may in fact represent an exactly equal price in terms of delivered or usable energy.

Having the user maintain his pre-existing heating system (natural gas, fuel oil, etc.) is important for several reasons. First, it handles the user's doubts about the possibility that the geothermal reservoir may be used up. Along with that it covers the developer's worry that serious liabilities may arise from any interuption in the geothermal supply in the event of a pump failure or other maintenance problems. Lastly, and quite importantly, the ability to provide baseload heat from the geothermal supply, but to handle peak demand with the fossil fuel back-up system, is economically very significant. Eighty percent of a specific user's annual heat requirements can usually be supplied without exceeding 40% of the peak load; in that case, spreading baseload heating among two and a half users would then double the income from a given geothermal well, or group of wells $(0.8 \times \frac{100}{40})$.

In addition to our research on heat sale agreements and on marketing geothermal energy to the public, we worked on the details and importance of the broad-scale education about geothermal energy that is so critically needed. Our detailed surveys of public awareness have demonstrated how little the general public knows about geothermal energy, and have mapped out in detail the commonly held misconceptions, fears and doubts that need to be handled, and handled well, if broad-scale use of geothermal energy is to occur. A detailed program to accomplish this broad-scale education has emerged from our research in that area.

Our work has also included another critically important issue affecting private development of geothermal energy for direct use: whether or not the activity will be regulated as a utility. Such regulation could lead to a number of problems: costly interaction with a Public Utility Commission or Public Service Commission; conflicts with existing utility services, which are normally available and well established; possible difficulties in sustaining energy prices and profits at a high enough level to justify the risks involved in undertaking geothermal development; consequent disinterest from potential investors.

The utility issue is a State one. In Oregon, State legislation has greatly eased the development of geothermal energy, but in many other States the issue is still clouded with uncertainty.

As part of the institutional work that is an important component of this project, we took up this issue in 1980. At that time, the situation of our project was typical of any private enterprise geothermal development in Nevada. To be regulated by the Public Service Commission would raise the very serious problems enumerated above. Even worse was the uncertainty of whether such regulation would or would not be applied.

Earlier Nevada case law led to an ambiguous picture.

An opinion of the Attorney General in the matter of Taylor (January 31, 1968) had held that an owner/landlord of a shopping center supplying chilled air to his tenants was not performing a utility function, because "chilled air" was not specifically included in the Nevada statutes listing those commodities defined as utilities.

In another case, in the matter of the application of Mooney (January 3, 1967), an Attorney General's opinion held that a shopping center owner supplying electrical energy to his tenants was performing a public utility function. "Electrical energy" is included in the statute as a utility commodity. So is "heat".

Accordingly it appeared there was already established a strict interpretation of the statutes in this area and that a geothermal developer supplying heat via a geothermal fluid would be subject to PSC jurisdiction.

However, other Nevada cases provided some hope that utility regulation might be avoided if the entire geothermal system, from well to end-user, were located on private land; or if only a single user was supplied with heat.

This question then became critical: Is a Homeowners' Association a single user, or a group of customers?

Of course, such special conditions (single user, private land only) are unlikely to be met except in small geothermal developments. These problems might cramp large scale development, and discourage the critically important expansion of geothermal district heating.

This uncertainly, and the inability to predict whether PSC regulations would be applied after a project had begun, was in fact worse than the prospect of regulation.

Accordingly, our efforts were to push for clarification of the issue as a way to remove a major institutional barrier to geothermal development in Nevada.

We gave testimony before the Legislative Commission's Subcommittee to Study Geothermal Energy, emphasizing the need to encourage development with appropriate incentives, and to remove institutional roadblocks and uncertainties.

We pointed out that neither the large energy companies nor the utilities showed any interest in developing geothermal resources for direct use, and that this would be achieved, if at all, by small, presently little-known companies, eventually evolving into a new industry.

For such small companies the red tape of PSC regulations was a disproportionate burden, and the problem was not so much how to regulate them, but rather how to avoid discouraging them with additional regulatory problems.

Without careful regard to these very real problems, and to the necessity for encouraging investment by favorable tax treatment, low interest loans, and/or loan guarantees, the development of this resource (so important in an energy-poor State like Nevada) might never occur.

Our testimony went along with extremely effective work by John Nimmons of the Earl Warren Legal Institute, and by Ken Wonstolen of the National Conference of State Legislatures. It was well received and understood by the Legislative Commission's Subcommittee, which was chaired by Senator Lawrence E. Jacobsen.

In February 1981 the work bore fruit in the form of Nevada Senate Bill 164 by Senators Jacobsen and Getto, which was passed and signed into law.

This measure clarified the status of geothermal energy as groundwater, subject to appropriation doctrine and to administration by the State Engineer. It also established clear definitions of the resource and of the basic terms involved in activities related to it.

It ended the uncertainty about PSC regulation by providing amendments to Chapter 704 of the Public Utilities Code expressly stating that any entity providing heat from geothermal fluids <u>is</u> a utility. However, it set up separate and special requirements for obtaining a Certificate of Public Convenience and Necessity for a geothermal development, expressly limiting the requirements to a showing that an applicant developer has the ability and competence to perform the proposed services. The other requirements include certain annual reports and a small tax on geothermal revenues. The proposed contract for sale of geothermal heat must be filed for review and approval.

Another critical clarification is that the availability of some alternate form of heat from an existing Public Utility may not be grounds for denying an application for a geothermal development.

This legislation has provided what was needed: a clear statement of the procedures a prospective geothermal developer must follow, and a sufficiently viable framework in which to operate.

Dr. David J. Atkinson
HYDROTHERMAL ENERGY CORPORATION
Los Angeles; Reno

MOANA, RENO PON REPORTS

1. Atkinson, D. J., Multiple Use of Geothermal Energy at Moana KGRA, Reno, Nevada. In, Program Summary, Geothermal Direct Heat Applications Program, Semi-Annual Review Meeting, El Centro, California, April 15-17, 1980.

2. Atkinson, D. J., Multiple Use of Geothermal Energy at Moana KGRA. In, Program Summary, Geothermal Direct Heat Application Program, Semi-Annual Review Meeting, Las Vegas, Nevada, November 20-21, 1981.

3. Atkinson, D. J., Multiple Use of Geothermal Energy at Moana KGRA, Reno, Nevada. In, Program Summary, Geothermal Direct Heat Applications Program, Semi-Annual Review Meeting, Boise, Idaho, September 24-25, 1981.

4. Atkinson, D. J., Geothermal Development in Reno. In, Geothermal Resources Council, Transactions, Vol. 2, July 1978.

5. Atkinson, D. J., Marketing Geothermal Energy for Space Conditioning. In, Geothermal Resources Council, Transactions, Vol. 4, September 1980.

PROJECT TITLE: Direct Utilization of Geothermal Energy for Food Processing at Ore-Ida Foods, Inc.

LOCATION: Ore-Ida Foods Processing Plant, Ontario, Oregon

PRINCIPAL INVESTIGATOR: Mr. Robert W. Rolf, Vice-President, Technical Services, Ore-Ida, Inc.

PROJECT MANAGER: Mr. John Austin, CH2M HILL (208) 345-5310

PROJECT OBJECTIVE:

Locate and develop geothermal resource of 800 gpm at 320°F. Retrofit existing plant for potato processing, space heating, and hot potable water.

RESOURCE DATA:

Snake River Basin, (predicted) 320°F at 7,000 feet.

SYSTEM DESIGN FEATURES:

- Two Production Wells
- One Injection Well
- Central Heat Exchangers
- Fluid Transmission Pipeline
- Geothermal Fluid Temperature = 300°F (150°C)
- Injection Fluid Temperature = 130°F (55°C)
- Total Well Capacity = 800 gpm (50.5 L/s)
- Pipeline - Buried Insulated Steel
- Maximum Energy Utilization via Cascading
- System Capacity 64×10^6 Btu/hr
- Estimated Annual Fuel Savings - 97,200 MWh

PROJECT DESCRIPTION AND BACKGROUND

Ontario, Oregon, is located just across the Oregon-Idaho border, 57 miles northwest of Boise, Idaho. The existing Ore-Ida Foods, Inc., plant processes potatoes, corn, and onions. It is currently dependent on natural gas and oil for process heat. The plan for this demonstration program is to substitute geothermal energy for the potato processing heat and other heat loads of about 97,000 MWh annually (33.2×10^{10} Btu/yr).

The geothermal water will be transmitted from the production well field to the plant through a buried and insulated 10-inch (25.4 cm) steel transmission main. Under normal conditions the pipeline is expected to operate at a pressure near 100 psig (689 kPa). The transmission main will terminate at a building housing the heat exchangers.

The geothermal well pumps will be 150 hp (112 kW) deep well turbines suitable for continuous operation within the well environment, which may exceed 350°F (117°C) and is expected to be corrosive.

Plate heat exchangers will transfer the thermal energy from the geothermal water to the plant process water systems. This geothermal energy will supply the heat load requirements for several process operations which have temperature requirements below 300°F (150°C): hot and warm blanching, sugar drag, and drying of the food products. Generally in a geothermal system, operation and maintenance costs are not directly dependent on the amount of energy being extracted from the geothermal water. Therefore, due to the high capital costs, the user benefits by extracting as much thermal energy from the water as possible. This is usually accomplished by arranging heat loads in series. The geothermal water is distributed from processes which require the highest temperatures to those which use lower temperatures.

The conceptual design is based on the cascade principle - to extract as much of the energy from the 800 gpm (50 l/s) geothermal flow rate as possible. Figure 1 schematically represents the planned geothermal system. The hot and warm blanchers will drop the geothermal temperature from 300°F (150°C) to approximately 200°F (93°C). The sugar drags and peelers will further extract energy from the geothermal fluid to approximately 170°F (77°C). Space heating, domestic hot water, and process make-up water will subsequently lower the geothermal temperature to the 100°F (37°C) range. Fluctuations in the amount of energy required for these lower heat level cascades will cause the final geothermal fluid temperature to vary. The average reject temperature of the geothermal water will be approximately 130°F (54°C).

In the existing peelers and blanchers, live steam is injected directly into the process water as necessary to maintain the set-point temperature of the process water. Heat for the sugar drags is provided by steam coils located in the sugar drag tanks. The present steam systems will be retained to provide a secondary source of heat in the event the geothermal system is down for maintenance.

A majority of the equipment will be operated continuously whenever the product line is in operation. Water and product flow rates vary, however, making the energy requirements for individual pieces of equipment fluctuate. The actual amount of energy required for each process will be controlled by pneumatic valves which will modulate to maintain a set process water temperature.

The system will be fully instrumented with continuous pressure, temperature, and flow recorders to calculate and record accurately the actual amount of energy being derived from the geothermal source. The information thus obtained will be fed to a microprocessor which will calculate efficiencies, total energy usage, and energy costs.

Several secondary uses for the 130°F (54°C) geothermal water are also being considered. These include additional space heating in office buildings, maintaining temperatures in potato storage cellars, stabilizing wastewater temperatures for better treatment, and use in byproduct production. Potato storage requires maintaining the potato cellars at approximately 42°F (6°C) year around. The minimum heating required during the winter could be provided directly by geothermal water-to-air heat exchangers which would be located in the storage areas.

Additional uses of this low temperature geothermal water could include slab heating, greenhouse operations, and other suitable uses. When all of the useful energy has been extracted from the geothermal water, the spent fluid will be collected and transmitted by another steel transmission line to an injection well where it will be pumped back into the receiving aquifer.

Figure 2 represents the relative amount of energy supplied for simultaneous steady-state operation. The area indicated by each process is proportional to the amount of energy supplied.

The conceptual design indicates that approximately 50 percent of the present heat load can be provided by geothermal energy at 300°F (150°C) and below as illustrated. This represents approximately 89 $X10^6$ Btu/hr (25 MW).

Geothermal Resource

The Ontario, Oregon, site is located in the center of the western Snake River Plain geomorphic province. This province is an accurate structural and topographic depression which extends from about 25 miles (45 km) northwest of Ontario, eastward and northeastward across Southern Idaho, to the vicinity of Yellowstone Park, Wyoming. The western limb of the depression is referred to as the Snake River Basin. This basin is bounded on the north by the mountainous region of Central Idaho and on the south by the Owyhee uplift. At its northwest end, it is terminated against the Blue Mountains uplift of East-Central Oregon.

The existence of geothermal potential in the Snake River Basin is suggested by the history of late Cenozoic volcanism and tectonic activity. This general evidence is supported by the occurrence of thermal waters in springs and shallow water wells around the base margins. Further evidence occurs in the relatively high geothermal gradients encountered in some deep hydrocarbon exploratory test wells drilled in the basin.

A limited amount of geothermal exploration has taken place in the basin, consisting of temperature-gradient hole drilling, geochemical studies of thermal waters, and local geological and geophysical work. Apart from small-scale local uses of thermal waters from hot springs and shallow wells, no significant geothermal production has yet been established.

Several factors must combine to provide a geothermal resource of significant value. These include the existence of elevated temperatures and porous rocks capable of producing a useful fluid volume. In addition, these conditions must occur at depths at which they can be exploited with economic advantage.

The surface in the vicinity of Ore-Ida is covered by varying amounts of alluvium overlying poorly-lithified sediments of the Upper Idaho Group. Exposures of bedrock are too poor to permit field mapping of any structures that might be present. Interpretations of aerial photographs to define geomorphic lineaments of possible structural origin are not known to have been made in this area. On the basis of regional gravity data, the site is located on the west flank of the north-trending gravity high and at least 5 miles north of the major northwest-trending anomaly. Although the structural significance of these features is uncertain, it is probable that the site is in a relatively structurally low part of the basin, although not in one of the deep closed lows appearing on the gravity maps.

All of the detailed structural data related to the site were derived from six reflection seismograph lines surveyed for this project. The quality of the seismic data varies from excellent to poor. Seven possible faults were detected.

The well sites were selected based upon information obtained from a seismic survey that indicates there is a potential structural fault zone running northwesterly through the plant site. It is expected that the fault zone would be more permeable and produce more water than a location not associated with a fault.

The Ore-Ida Foods No. 1 well is located in the northeast quarter of Section 3, T.18 S., R. 47 E., in the town of Ontario, Malheur County, Oregon. The drilling contractor was Montgomery Drilling Company, Bakersfield, California, using a National 55 rig.

The well was spudded in at 9:00 a.m. August 18, 1979. A 17-1/2-inch hole was drilled 925 feet, where a 12-3/8-inch casing was set on August 22, Figure 3.

After installing the blow-out preventers, drilling resumed in a 12-1/4-inch hole from 925 to 7,154 feet, where geophysical logs and temperature surveys were run on September 18 to 20. Drilling continued to 7,958 feet, where a second set of geophysical and temperature logs were run on October 1 and 2. A 9-5/8-inch casing was run to 8,183 feet. Below 8,183 feet, an 8-1/2-inch hole was drilled to a total depth of 10,054 feet, reached on November 8. On reaching the total depth, geophysical and temperature logs were run from November 8 to 10, and a 7-inch slotted liner was suspended from 8,142 to 10,038 feet on November 13. The slots extended from 8,187 to 10,036 feet, are

125 mesh, in 8 rows, 2 inches long, with 6-inch centers. The testing operations were conducted from November 16 to 18 and from November 24 through 27.

The Ore-Ida Foods No. 1 well was drilled in order to develop a flow of 800 gpm of water at about 320°F. The actual conditions found are summarized as follows.

Equilibrium temperatures of 300°F occurred at a depth of about 7,000 feet in the Ore-Ida well. The gradient continued to increase at an average rate for the remainder of the hole to a total depth of 10,054 feet. The equilibrium temperature at total depth is estimated to be near 385°F. It appears that the project temperature requirements can be met at economically attractive depths in the Ontario area if an adequate fluid flow could be obtained.

The rocks most likely to contain reservoir potential within the depth interval of favorable temperature are basalt flows. Basalt units are interspersed through the Ore-Ida well section from a depth of 4,570 to 8,135 feet, and an aggregate of 1,425 feet of flows occurs in the 1,919-foot section below a depth of 8,135 feet. However, the depth to the top of this predominantly basalt section is approximately 2,000 feet deeper at the well site than had been inferred from reflection seismograph data. Although a thick section of basalt has been penetrated, no important zones of high porosity and permeability were encountered. Large basalt intervals have been included in formation tests, but there is no evidence that diffuse fractures are capable of producing an aggregate fluid volume approaching a useful level.

PROJECT STATUS

Numerous attempts to improve the flow characteristics of Ore-Ida No. 1 well have met with little success. The most recent action was performed in May 1981. Los Alamos National Laboratory performed a temperature log of the hole and participated in a fluid injection pump test. On May 19, the well was pressured to 1,400 psig and approximately 500 gpm pumped into the well in an effort to produce a mini hydrofrac in the lower zones below 7,000 feet. As indicated in the temperature profile shown on Figure 4, all of the pressurizing fluids were lost at the 5,900- to 6,000-foot interval. An unsuccessful attempt to seal these perforations was made before abandoning the test on May 20.

Presently, plug and abandon procedures are being outlined to seal the well. Additional funds required to set deep packers and conduct a second hydrofrac test do not appear to be available in the near future. It is recommended, however, that actual plug and abandon not be performed for several years in anticipation of additional funding and interest for stimulation of Ore-Ida No. 1 well.

CURRENT ESTIMATED PROJECT COST

TOTAL: $5,149,500

DOE SHARE: $2,556,000 (50%) Participant Share: $2,593,500 (50%)

Current contract value which covers government and participant costs through development or disposal of major production well.

LESSONS LEARNED

1. Geothermal resource development can be a high risk venture even with good geological indicators and carefully executed geophysical studies. This high risk continues to be a major deterrent to rapid geothermal development. Incentives need to be provided if significant geothermal development is to occur in the near future.

2. Drill the best geological site first.

3. Question service personnel extensively on their experience. They may not be familiar with all the services which their parent company provides. This is particularly necessary when you do not have extensive personal experience in the subject technology.

ORE-IDA FOODS PON REPORTS

(Cooperative Agreement No. DE-AC07-78ET28424)

1. CH2M Hill, Inc., Environmental Report for a Field Experiment: Food Processing Industry - Geothermal Energy, Contract No. ET-78-C-07-1725, October 1, 1978.

2. GeothermEx, Inc., Data Analysis and Drilling Site Selection for Ore-Ida Property Ontario, Oregon, October 1978.

3. CH2M Hill, Inc. Preliminary Design Report on the Conversion of Process Heat Load to a Geothermal Resource for Ore-Ida Foods, Inc., Ontario, Oregon, April 1980.

4. GeothermEx, Inc., Technical Report, Deep Well Test and Exploration Program for Ore-Ida No. 1, Ontario, Oregon, Volumes I, II and III, Contract No. ET-78-C-07-1725-GTX, May 1980.

5. GeothermEx, Inc., Well Log Analysis on Ore-Ida No. 1 Well, Ontario, Oregon, Contract No. ET-78-C-07-1725-GTX, March 1981.

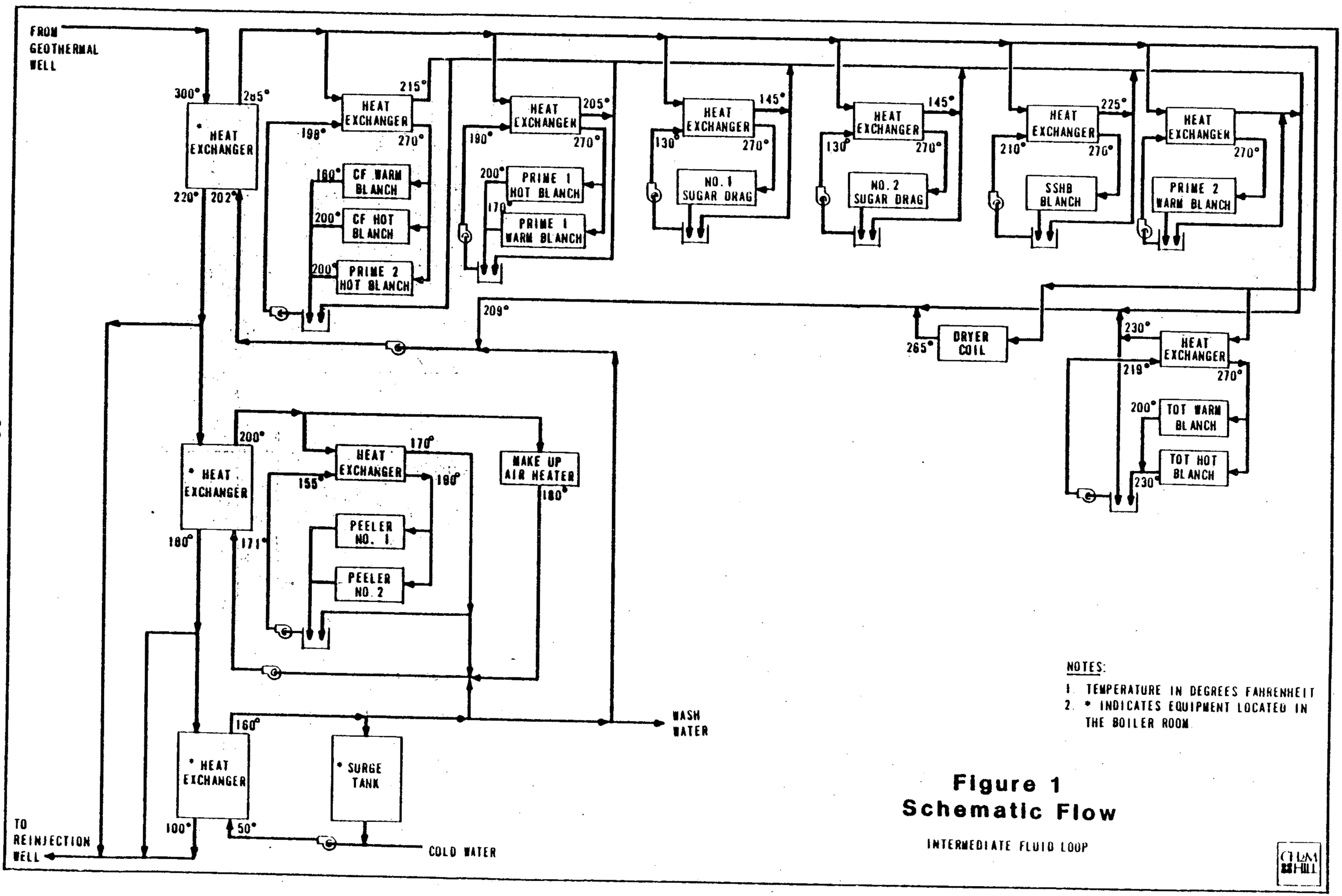


Figure 1
Schematic Flow

INTERMEDIATE FLUID LOOP

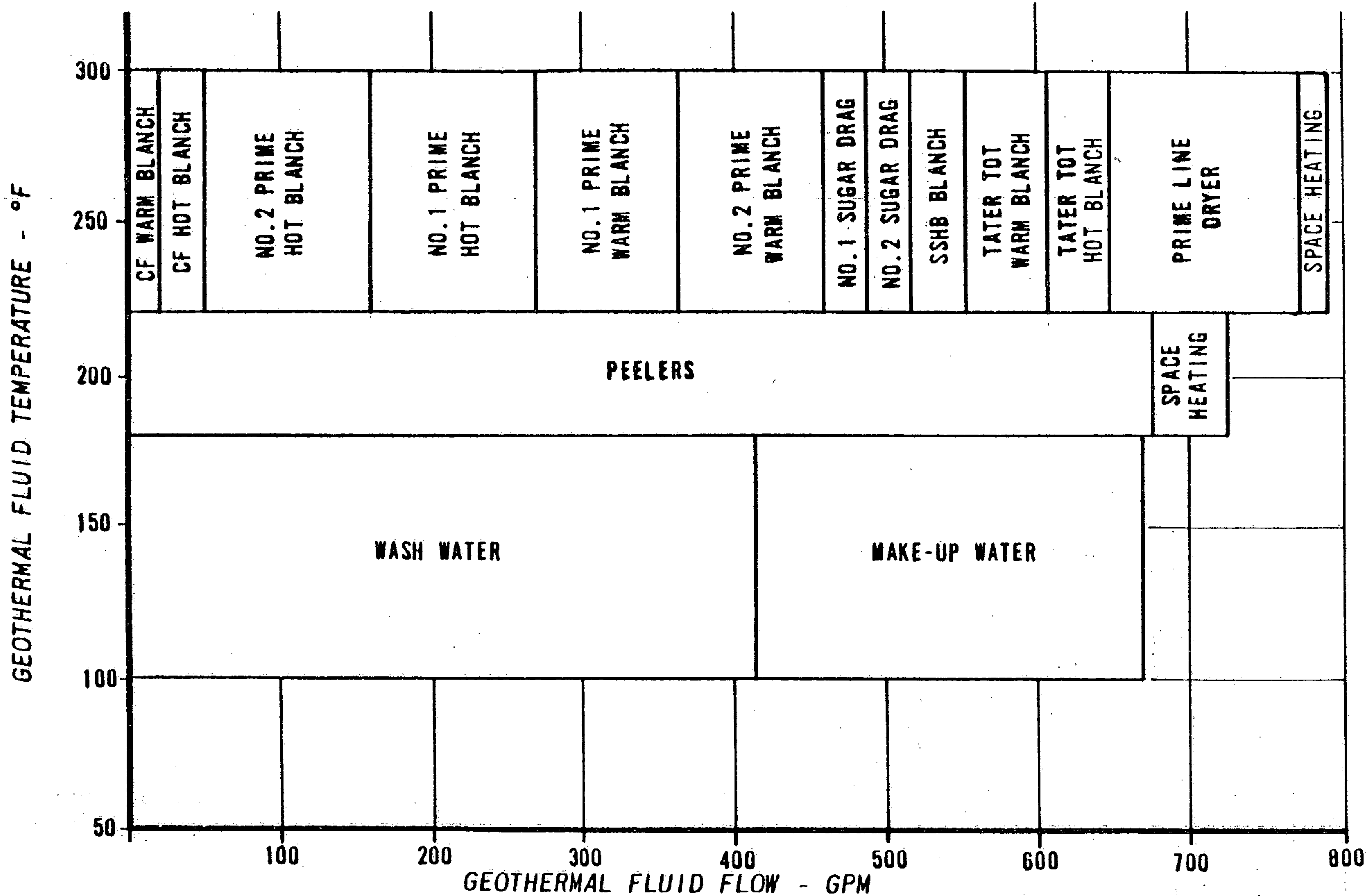


Figure 2
Energy Allocation

INTERMEDIATE FLUID LOOP

CH2M HILL

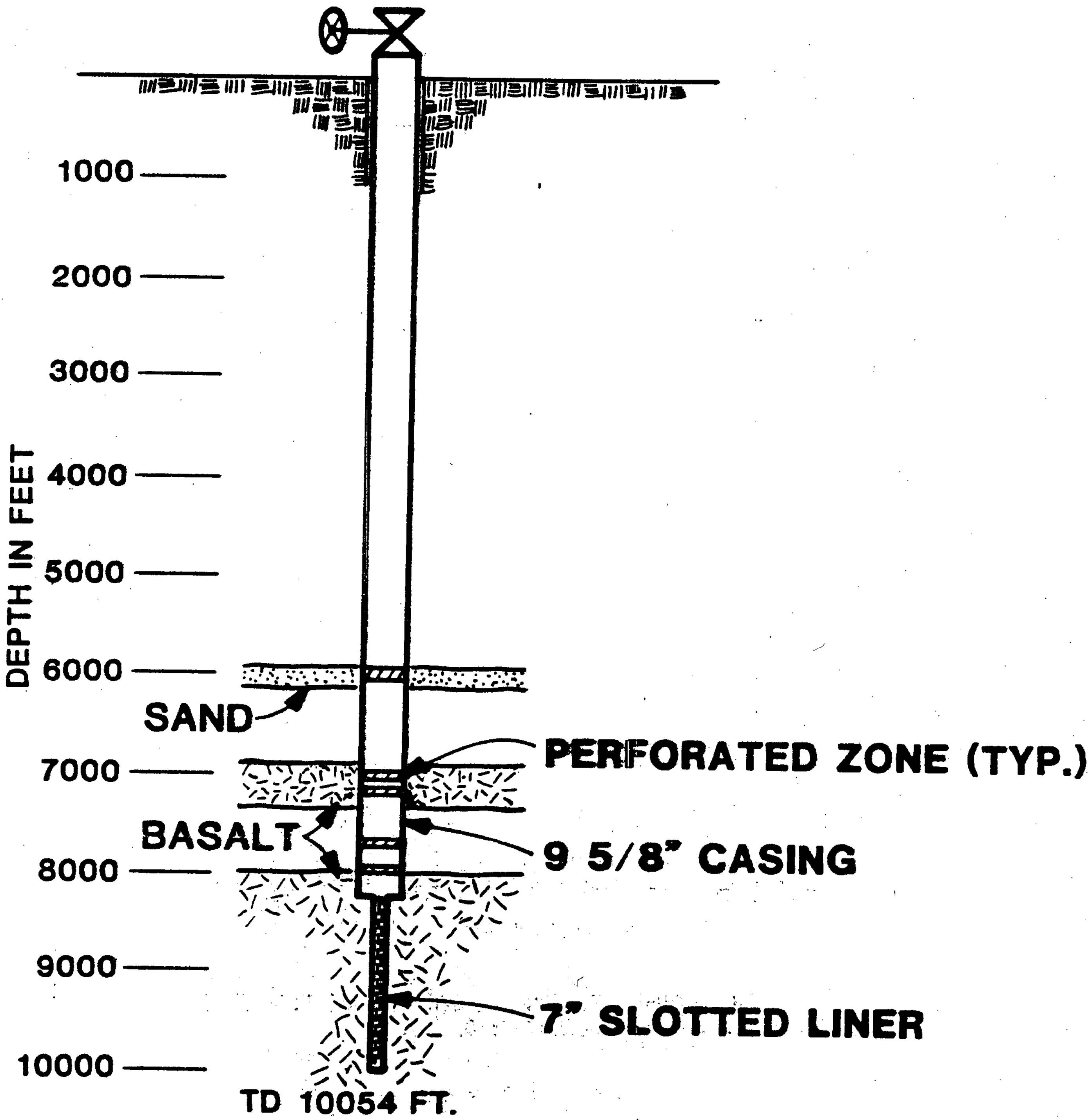
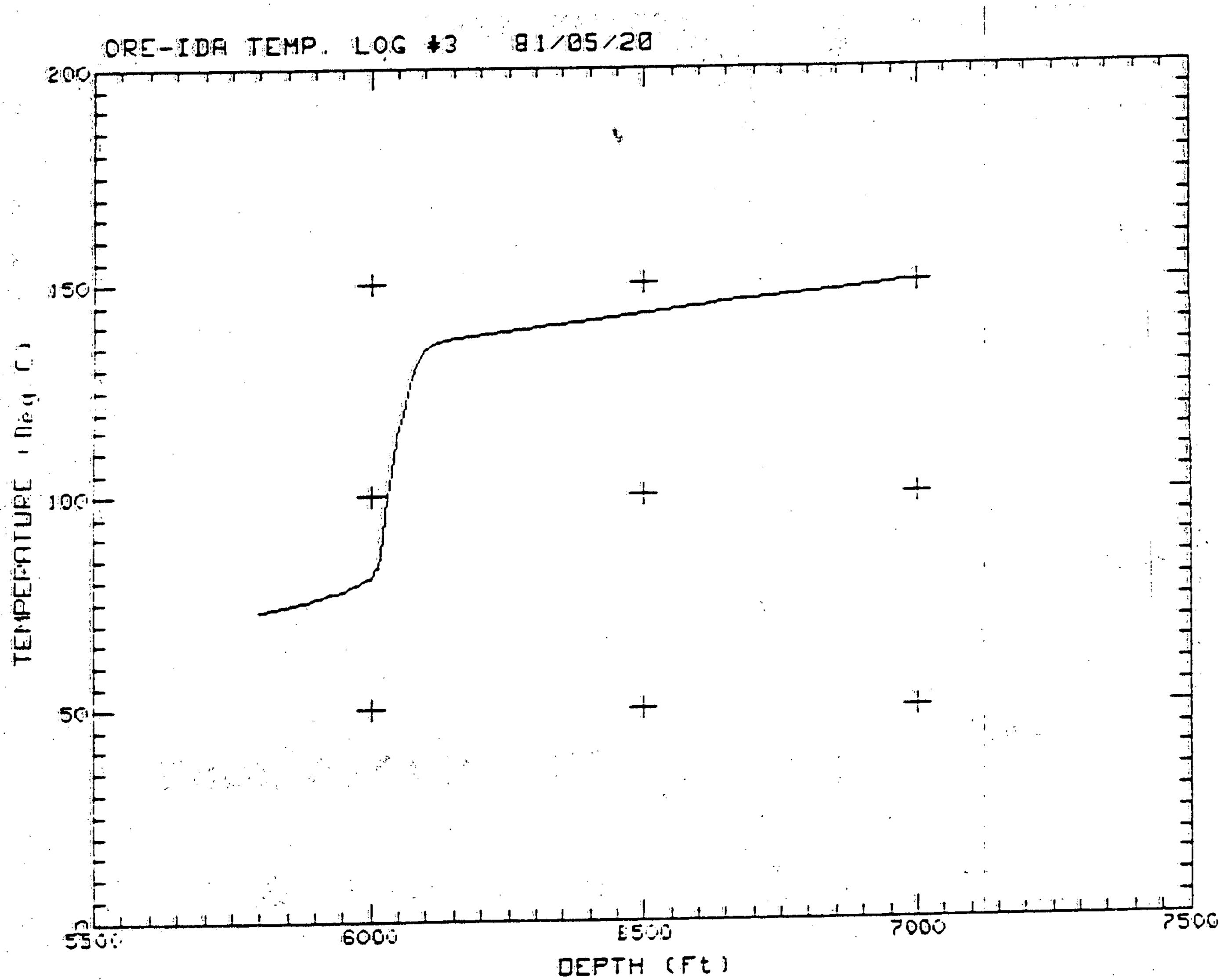


Figure 3. **ORE IDA NO. 1 CROSS SECTION**



WELL TEMPERATURE PROFILE DURING INJECTION TEST
COURTESY OF LANL

Figure 4

UTAH STATE PRISON

DIRECT UTILIZATION OF GEOTHERMAL ENERGY

FIELD DEMONSTRATION

AT

CRYSTAL HOT SPRINGS

GEOTHERMAL DIRECT HEAT APPLICATION PROGRAM

SEMI-ANNUAL REVIEW MEETING

BOISE, IDAHO

SEPTEMBER 24-25, 1981

JEFF BURKS

PROJECT MANAGER

UTAH ENERGY OFFICE

TERRA TEK, INC.

RESOURCE CONSULTANTS

CH_2M HILL

DESIGN ENGINEERS

1.0 PROJECT BACKGROUND

In July, 1978 the Utah Energy Office, on behalf of the State of Utah, submitted a successful proposal to the Department of Energy (DOE) in response to a Program Opportunity Notice (PON) for Direct Utilization of Geothermal Energy Resources.

The Utah Energy Office PON proposal proposed to develop the Crystal Hot Springs geothermal resource located on private property adjacent to the Utah State Prison at the southern end of the Salt Lake Valley. The objective of the PON was to demonstrate the economic and technical feasibility of providing sufficient geothermal water for use in a variety of direct applications at suitable sites within the Utah State Prison complex. A geothermal well, heat exchange system, and injection disposal well were proposed to form the initial demonstration of providing geothermal water for space heating and domestic water heating for the minimum security facility at the Prison.

Consisting of dorms, offices, a gymnasium, and a cafeteria, the 72,000 square foot minimum security facility was considered a good candidate for retrofit to geothermal energy for three reasons.

1. Due to its size and function, the facility consumed a large portion of the energy used at the Prison,

2. The minimum security facility's location as the nearest major prison building to the Crystal Hot Springs resource; a distance of only 400 meters, and

3. The existing building's space heating system was a hot water system and was considered to be a relatively easy retrofit for a geothermal heating system.

The initial demonstration of providing the minimum security facility with space and hot water heating was intended to form the nucleus of a system which potentially could be expanded to provide the bulk of the heating requirements for the entire Prison (Figure 1).

In order to meet the objectives of the PON proposal, the Utah Energy Office programmed the project into three phases consisting of:

<u>Phase I - Resource Assessment</u>

- Additional geophysical reconnaissance comprised of aeromagnetic and gravity surveys of the Crystal Hot Springs resource area.
- Resource monitoring program to establish baseline thermal, hydraulic, and chemical characteristics of the Crystal Hot Springs resource area.
- Selection of a drilling site on Prison property for a deep test well.

- Short term artesian flow testing program to assist in fixing a production well design and to provide information needed for completion of a preliminary heating system design.

Phase II - Resource Development

- Selection of a site on Prison property for drilling a production well.
- Detailed evaluation of well and reservoir characteristics.
- Investigation of disposal alternatives.
- Preliminary system design and economic and technical feasibilty assessment.

Phase III - Construction and Inspection of Demonstration

- Final system design.
- System construction.
- Commissioning and initiation of monitoring and performance verification program.

Work on the project was to begin in March, 1979, with the writing of the environmental report and culminate with the startup of the heating system in September of 1981.

The total estimated cost for the project is $637,326 with a cost share arrangement assigning $458,704 to DOE and $178,622 to the State of Utah.

2.0 PROJECT DESCRIPTION

2.1 Resource

Development is focused on the Crystal Hot Springs geothermal resource, the surface expression of which is located on private property adjacent to Prison property (Figure 2).

The Crystal Hot Springs geothermal system is a deep convective system located at the eastern margin of the Basin and Range physiographic province. The thermal springs are located north of an east-northeast trending horst that is perpendicular to the structural trend of Wasatch Front grabens. The horst, known as the Traverse Range, consists of highly fractured mid-Paleozoic quartzites and tertiary volcanics. Meteoric water enters the system in the adjacent ranges, circulates to depths of 3 Km, and is heated. The thermal fluids return to the surface along steeply dipping range front faults that bound the northern flank of the range. The thermal springs issue between two such faults that are buried beneath Tertiary and Quatenary age valley fill deposits. Highly fractured quartzite beneath the valley fill act as a near-surface reservoir for the thermal water that is being targeted for development.

The surface expression is defined by several hot water spring discharges contained within a 70 acre area. At the center of the Crystal Hot springs resource area springs issue to the surface through alluvium that is approximately 80 feet thick.

The maximum measured temperature at Crystal Hot Springs is 98° C, recorded in the bottom of the 410 foot Utah Roses well. The chemical quality of the thermal waters are excellent. The total dissolved solids content is between 1,500 - 1,700 ppm.

2.2 System Design

In the minimum security facility existing system, heat from steam supplied by the natural gas fired central boiler plant, is exchanged onto fresh water which is circulated through the building. This system will be modified by the addition of geothermal water/fresh water heat exchangers in series with steam/water units for both space and culinary water heating. Apart from supplementary pumping capacity, the rest of the system will be left essentially in tact.

To produce the necessary flows from USP/TH-1, the well will be pumped. A 50 hp vertical turbine pump, set at approximately 500 feet, capable of producing flows up to 288 gpm, is proposed. The pump discharge will connect to a 6-inch diameter epoxy-lined insulated asbestos-cement transmission pipeline, buried at a safe depth. The transmission pipeline will be routed as directly as possible to the two mechanical rooms in the minimum security facility.

Heat Exchangers

Located either within these mechanical rooms or just outside in their areaways, plate-type heat exchangers will transfer heat from the 175° F geothermal water into the existing space heating and domestic hot water systems that serve minimum security. The heat transfer would be accomplished through stainless steel plates that separate and completely isolate the hotter geothermal water from the space heating water and from the domestic hot water.

Control

Control of the geothermal flow would be regulated by two-way control valves that modulate in response to actual heating loads. Such a control system could minimize the geothermal flow, thereby conserving the resource and minimizing the geothermal discharge to the receiving stream.

Disposal Pipeline

After leaving the heat exchangers, the spent geothermal water, now 40° F to 50° F cooler, would be handled by a 6-inch diameter epoxy-lined asbestos-cement disposal pipeline, buried along the same route as the transmission pipeline. The buried disposal pipeline will continue past the production well through the Prison farm to a cooling pond located approximately 5,000 feet to the northwest.

- Short term artesian flow testing program to assist in fixing a production well design and to provide information needed for completion of a preliminary heating system design.

Phase II - Resource Development

- Selection of a site on Prison property for drilling a production well.
- Detailed evaluation of well and reservoir characteristics.
- Investigation of disposal alternatives.
- Preliminary system design and economic and technical feasibilty assessment.

Phase III - Construction and Inspection of Demonstration

- Final system design.
- System construction.
- Commissioning and initiation of monitoring and performance verification program.

Work on the project was to begin in March, 1979, with the writing of the environmental report and culminate with the startup of the heating system in September of 1981.

The total estimated cost for the project is $637,326 with a cost share arrangement assigning $458,704 to DOE and $178,622 to the State of Utah.

2.0 PROJECT DESCRIPTION

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Cooling Pond and Outfall

At the fully lined cooling pond, incoming spent geothermal water will be sprayed through the air into the pond to further cool the water to a temperature suitable for discharge. From the cooling pond, the cooled geothermal water would flow by gravity through a buried pipeline to a diffuser in the receiving stream.

2.3 Project Economics

To evaluate the economic benefit to the State Prison, natural gas consumption for heatng the minimum security facility was estimated based on an analysis of the building envelope, current operational procedures of the mechanical systems, and actual utility records. For both space heating and domestic water heating, it was estimated that 16,500 million BTU per year are required. Assuming an overall Prison physical plant efficiency of 60 percent, 27,500 million BTU per year input is required to meet that load.

This requires approximately 31 million cubic feet per year of natural gas. Since only a partial retrofit is proposed, the geotheraml system would not competely eliminate natural gas consumption for the minimum security facility, but approximately 66 percent could be saved, amounting to 21 million cubic feet per year.

To develop energy cost savings for the 20 year anticipated life of the project, the current natural gas price and estimated price escalations are as follows:

Current Price:	$2.26 per 1,000 cubic feet
Estimated Escalation:	18 percent per year for 1982 - 1986, then 12 percent per year for 1987 - 2001.

To assess operation costs for the geothermal system, which must be subtracted from the natural gas savings, electrical energy consumption by the production well pump was estimated. Current power prices and estimated price escalations are as follows:

Estimated Consumption:	170,000 kWh per year
Current Price:	$0.038 per kWh
Estimated Escalation:	15 percent per year for 1982 - 1986, then 12 percent per year for 1987 - 2001.

In addition to operation costs for the geothermal system, maintenance costs must also be subtracted from the natural gas savings.

Estimated Maintenance:	$5,900 per year in mid-1981 dollars
Estimated Escalation:	11 percent per year

By subtracting the operation and maintenance costs from the natural gas cost savings for each of the 20 years of anticipated operation, net cost savings are found. These are presented in Table 1, which is a 20 year cash flow for the partial retrofit of the minimum security facility.

An economic analysis cannot be considered complete without assessing the affect of the "time value of money." This has been accomplished by discounting the annual cost savings by a percentage that reflects this time value--assumed to be 10 percent throughout the anticipated 20 year life. This is included in Table 1 in the two right-hand columns.

It can be inferred from the cash-flow analysis that the cost of construction, estimated at $429,050, will have been recovered after approximately 9 years of operation. This can be found in the Cumulative Present Work column at the far right in Table 1. Sunk costs are ignored because it is only future costs which are germane to current decisions on the future of the project.

Since the State's current share of the project costs is approximately $135,000 ($60,000 of which is "in-kind services), its investment will have been recovered after approximately 3 years of operation.

3.0 PROJECT STATUS

3.1 Geophysical Reconnaissance

The geophysical reconnaissance program was designed to provide subsurface details of the geological structures controlling the thermal springs in the vicinity of the Crystal Hot Springs resource area. The program consisted of: a) a detailed gravity survey, and b) a detailed aeromagnetic survey; both conducted under the auspicies of the DOE/DGE State Coupled Geothermal Resource Assessment program.

Results of the detailed gravity revealed a complex faulted bedrock surface buried beneath the unconsolidated alluvium materials present on the valley floor. Interpretation of the gravity data identified an area north of the springs in the vicinity of the State Prison farm where fractured quartzite was present at approximately 275 feet below the surface. Because of the known association between the thermal springs and the near surface presence of quartzite at 275 feet, this intermediate depth bedrock was selected as a target for the test hole drilling program.

3.2 Test Drilling Program

The geophysical reconnaissance program provided the structural details needed to focus the exploration program on the most promising production targets available on Prison property. The purpose of the follow-up test hole drilling program was to test these targets for the presence of significant quantities of thermal water and to provide holes to be used for the purpose of preliminary reservoir assessment.

The test hole drilling program confirmed the bedrock model that resulted from the detailed gravity survey and confirmed the presence of significant quantities of thermal water within the fractured quartzite. A thermal gradient monitoring well, (SF-1) an existing hole, was deepened from 270 feet to 500 feet and flowed artesian at 300 gpm upon completion. A new test hole, USP/TH-1, was drilled to a total depth of 1,000 feet. USP/TH-1 penetrated 640 feet of quartzite and initially flowed artesian at between 800 - 1,200 gpm, Figure 3.

Results of the drilling program also suggest that the quartzite is not homogeneously fractured and that the upper portion of the quartzite is relatively impermeable.

3.3 Preliminary Well and Reservoir Testing

A testing program was designed and implemented to help fix a production well design and to provide information needed for completion of a preliminary heating system design. Specifically, data on noncondensable gas flash-point and drawdown were needed to assist in fixing the setting depths of downhole pumps. Data suggesting long-term reservoir productivity were also needed to establish the overall feasibility of the direct application project.

Noncondensable Gases

Noncondensable gas concentrations (CO_2) at wellhead conditions were found to range from .08 to .22 weight percent. Using soluability relationships and the measured gas concentrations, noncondensable gas flashpoints in the wellbore were calculated to range from 140 feet to 270 feet from the wellhead under hydrostatic wellbore conditions. These results imply downhole pump setting depths of at least 220 feet.

Artesian Flow Test

Analysis of surface and downhole/recovery data from well USP/TH-1, and drawdown/recovery data from well SF-1 yielded the following values for important well and reservoir parameters:

- Permeability = 1,570-4,340 milledarcy (hydraulic conductivity of 12.3-34.0 feet per day)
- Poiosity - Compressibility Product = 1.59 X 10^{-5} psi^{-1}
- Well Skin Factor = -1.51
- Reservoir Area = 4.5 X 10^6 ft^2
- Impermeable Boundary Location = 730 feet from well
- Well/Reservoir Shape Factor = .101

These parameters indicate a highly permeable reservoir of somewhat limited area. The well/reservoir shape factor and the inferred impermeable boundary location indicates that test well USP/TH-1 is completed within the periphery of the reservoir. The proximity of USP/TH-1 to reservior boundaries was evidenced by rapid transition from an infinate-acting to a pseudo-steady-state flow regime observed in the drawdown data.

Long Term Productivity

Predicted pressure drawdown (Figure 4) versus drawdown time for several different flow rates suggests that long term deliverability of USP/TH-1 is somewhat limited due to reservoir boundary effects. In its current configuration, USP/TH-1 would be capable of sustaining short term flows in excess of 100 gpm to meet peak load requirements.

Due to the Prison property's proximity to the reservoir boundary, it was determined that drilling a production well would not significantly enhance the Prison's chances of getting more productivity from the reservoir. USP/TH-1 will therefore be used as a production well, saving the PON the cost of drilling and lining an additional well.

Further testing is anticipated in the near term. The two-day artesian flow testing conducted during February was not conducted for a period of time sufficient to assess the effect of system recharge upon the performance of USP/TH-1. We have just begun initiating work for a long term (20-30 day) pump test of USP/TH-1 to verify the predicted long term drawdown characteristics and assess any system recharge effects.

3.4 Investigation of Disposal Alternatives

As outlined in the original proposal, the proposed method of disposal was injection into a well that would be drilled specifically for that purpose. Other disposal means were to be investigated, but injection disposal was the only assumed option for the project.

In May, 1981, CH_2M Hill was retained to investigate and develop disposal alternatives for the geothermal water. The options investigated for disposing of water from the proposed geothermal heating system were:

- Underground discharge (injection)
- Surface discharge (irrigation, perculation, evaporation)
- Sanitary sewer discharge
- Canal discharge
- River discharge

These options were considered individually and in combination from the following standpoints:

- Technical feasibility
- Economic feasibility.
- Institutional acceptability
- Environmental acceptabiliy

Based on the assessment of the disposal options for the Utah State Prison geothermal project, one viable option has been identified--to transport the geothermal water by pipeline, and discharge it into the Jordan River. Significant degradation of the quality of the Jordan River would not result from the geothermal discharge.

An application to surface dispose is currently pending action by the Bureau of Water Pollution Control. A decision will be made on this application on September 25, 1981.

3.5 Preliminary Design

The Preliminary Design Report is expected to be available for review September 23, 1981. Except for the surveying and preliminay scale drawings (which were put on hold until the disposal question is settled), this phase of the project is forecast to be 95 percent complete by that date.

For the past several months, our work on the preliminary design has been based on the assumptions that: 1) disposal by direct discharge to the Jordan River is the only viable option, and 2) well productivity is limited to a 100 gpm average for an 8 month season, with a maximum drawdown of 275 feet. If the results of the proposed pumped flow test indicate that these assumptions are not valid, adjustments in the proposed system (and perhaps construction budget) will be necessary during final design.

Component Sizing

Even though the results of the resource work to date suggest that the production potential is limited, the approach taken during preliminary design has been to provide flexibility in flow capacity for the major components. The pipelines have been sized to carry up to 300 gpm without substantial friction loss. Heat exchangers are proposed for both mechanical rooms, with the combined capacity to transfer 4.5 million BTU per hour.

Because the existing well is small in diameter, the well pump is the limiting component. Although the well casing size is adequate at 8 inches in diameter, the usable depth of the casing is not adequate (approximately 260 feet). Drawdown is anticipated to be 275 feet at maximum, and another 255 feet of submergence (water above the pump impellers) may be necessary to avoid noncondensable gas evolution during pumping. Therefore, a pump will have to be set at a depth greater than 500 feet. This means the pump will have to be extended into the 6-inch liner.

A vertical turbine lineshaft pump that will barely fit into the liner is proposed. Because the setting must be relatively deep, there is a limitation on the speed at which the pump should be driven--1,800 rpm is considered the maximum. A pump that meets these criteria will not produce a flow greater than 150 gpm at the maximum drawdown. However, at times when the water level in the well is relatively high, the pump could provide a peak flow of approximately 200 gpm.

If the results of the pumped flow test prove that the well's production potental is as limited as we have assumed, then a slight downsizing of the system to match pumping could be considered during final design. In that event, it might be desirable from a cost standpoint to retrofit only one of the two mechanical rooms in minimum security. The other mechanical room would continue to be served by steam only. Downsizing of the pipeline, especially the disposal pipeline, would not be recommended unless further geothermal resources development at the Prison were ruled out.

Disposal System

It is essential that the pressure in the geotheral system be held above the point at which the noncondensable gases evolve from solution. This is necessary to control scaling in the heat exchangers and the pipelines. Because a surface disposal permit will require cooling of the spent geothermal water, a cooling pond will be necessary. At the influent to the cooling pond, the pressure will be released, allowing the noncondensable gases to come out of the solution.

The spent geothermal water, cooled to approximately 35° F above the river temperature, will flow by gravity from the pond to the Jordan River in a pipeline oversized to provide excess diameter for scale build-up. High density polyethylene pipe is under consideration for the gravity pipeline.

Two important questions concerning the gravity pipeline will have to be settled before final design:

1. Because an irrigation canal must be crossed, the gravity piepline will have to be continuously sloped downward for freeze protection. Until a field survey is conducted, this will have to be assumed possible.

2. A right-of-way will be necessary for crossing under a railroad bridge over the canal. Investigation of this was not included in the preliminary design scope.

Another important question must be answered concerning the location of the cooling pond. All of the potential sites that are technically feasible will require land that is currently under cultivation. The area that will be required is approximately one fifth of an acre. The State has not had an opportunity to review the proposed location and determine is acceptability.

4.0 PROJECT SCHEDULE

Several major project decisions will be made in the next month. These decisions, based upon: a) the disposal method approved by the Bureau of Water Pollution Control, b) long term deliverability of well USP/TH-1 as estimated by Terra Tek, Inc., and c) costs to completion of construction; will ultimately determine the future disposition of the project and necessitate major adjustments to the program schedule.

Pending resolutions of these three items, a tentative program schedule for Phase III has been developed.

- Final Design - December, 1981-February, 1982
- Construction - April, 1981-September, 1981
- Startup - September, 1981-December, 1982

<u>UTAH STATE PRISON SPACE HEATING PON REPORTS</u>

(Cooperative Agreement No. DE-FC07-79ET27027)

1. Murphy, Peter and Gwynn, J. Wallace, <u>Geothermal Investigations at Crystal Hot Springs Salt Lake County, Utah</u>, Report No. DOE/ET/28393-1, Contract No. DE-AS07-77ET28393, October 1979.*

2. Terra Tek, Inc., <u>Environmental Report, Utah State Prison Geothermal Project</u>, Report No. TR 80-25, March 1980, revised July 1980.

3. Blair, C. K. (Terra Tek, Inc.), <u>Utah State Prison Space Heating with Geothermal Heat, First Semi-Annual Report for the Period 14 March, 1979 - 14 June, 1980</u>, Report No. DOE/ET/27027-1, Cooperative Agreement No. DE-FC07-79ET27027, July 1980.

4. <u>Specifications for a Geothermal Test-Drilling Program at the Utah State Prison, Draper, Utah</u>, June 1980.

5. Utah Energy Office, <u>Utah State Prison Space Heating with Geothermal Heat, Second Semi-Annual Report for the Period June 1980 - December 1980</u>, Report No. DOE/ET/27027-2, Cooperative Agreement No. DE-FC07-79ET27027, April 1981.

*For reference, not prepared under subject contract.

Table 1

20-YEAR CASH FLOW FOR A PARTIAL RETROFIT (66%) - RIVER DISPOSAL

Year**	Natural Gas Cost Savings[a] $47,300*		Additional Elec. Costs[b] $6,450*		Additional O&M Costs[c] $5,900*		Net Cost Savings	Present Worth[d]	Cumulative Present Worth
1	$55,814		-$7,418		-$6,549	=	$41,847	$38,043	$38,043
2	65,860		- 8,530		- 7,269	=	50,061	41,373	79,416
3	77,715		- 9,810		- 8,069	=	59,836	44,956	124,372
4	91,704		-11,281		- 8,957	=	71,466	48,812	173,184
5	102,708		-12,635		- 9,942	=	80,131	49,755	222,939
6	115,033		-14,151		-11,035	=	89,847	50,716	273,655
7	128,837		-15,849		-12,249	=	100,739	51,695	325,350
8	144,297		-17,751		-13,597	=	112,949	52,692	378,042
9	161,613		-19,881		-15,092	=	126,640	53,708	431,750
10	181,007		-22,267		-16,753	=	141,987	54,742	486,492
11	202,727		-24,939		-18,595	=	159,193	55,796	542,288
12	227,055		-27,931		-20,641	=	178,483	56,870	599,158
13	254,301		-31,283		-22,911	=	200,107	57,964	657,122
14	284,817		-35,037		-25,432	=	224,348	59,078	716,200
15	318,995		-39,242		-28,229	=	251,524	60,213	776,413
16	357,275		-43,950		-31,334	=	281,991	61,369	837,782
17	400,148		-49,225		-34,781	=	316,142	62,547	900,329
18	448,166		-55,132		-38,607	=	354,427	63,747	964,076
19	501,946		-61,747		-42,854	=	397,345	64,969	1,029,045
20	562,179		-69,157		-47,568	=	445,454	66,214	1,095,259
								$1,095,259	

[a]18 percent escalation for the first 4 years, then 12 percent.
[b]15 percent escalation for the first 4 years, then 12 percent.
[c]11 percent escalation for all 20 years.
[d]Discount rate is 10 percent.
*Mid-1981 costs.
**Starting with 1982-1983 heating season.

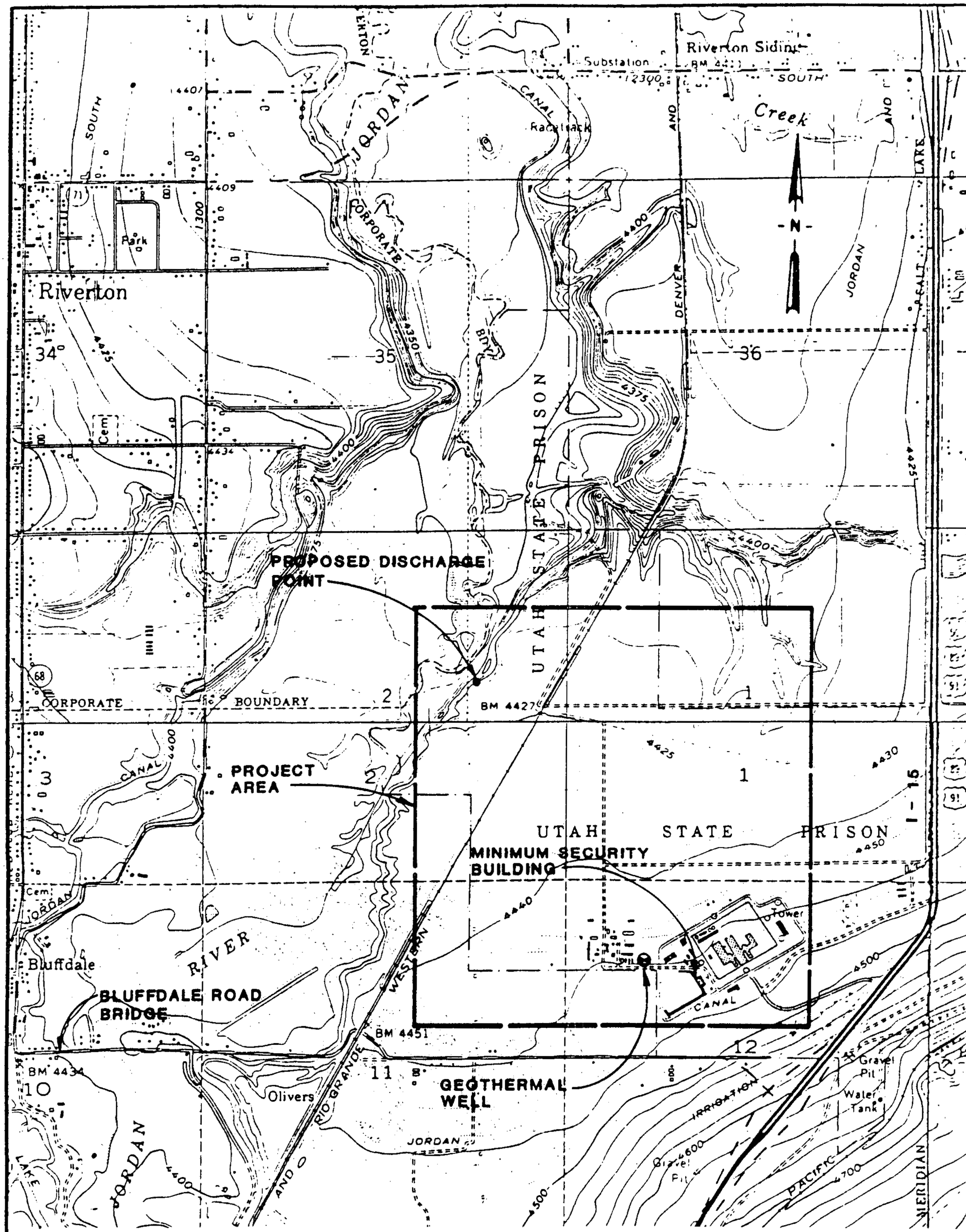


Figure 1

LOCATION MAP

0 — 1 Mile

B15051.A1

CH2M HILL

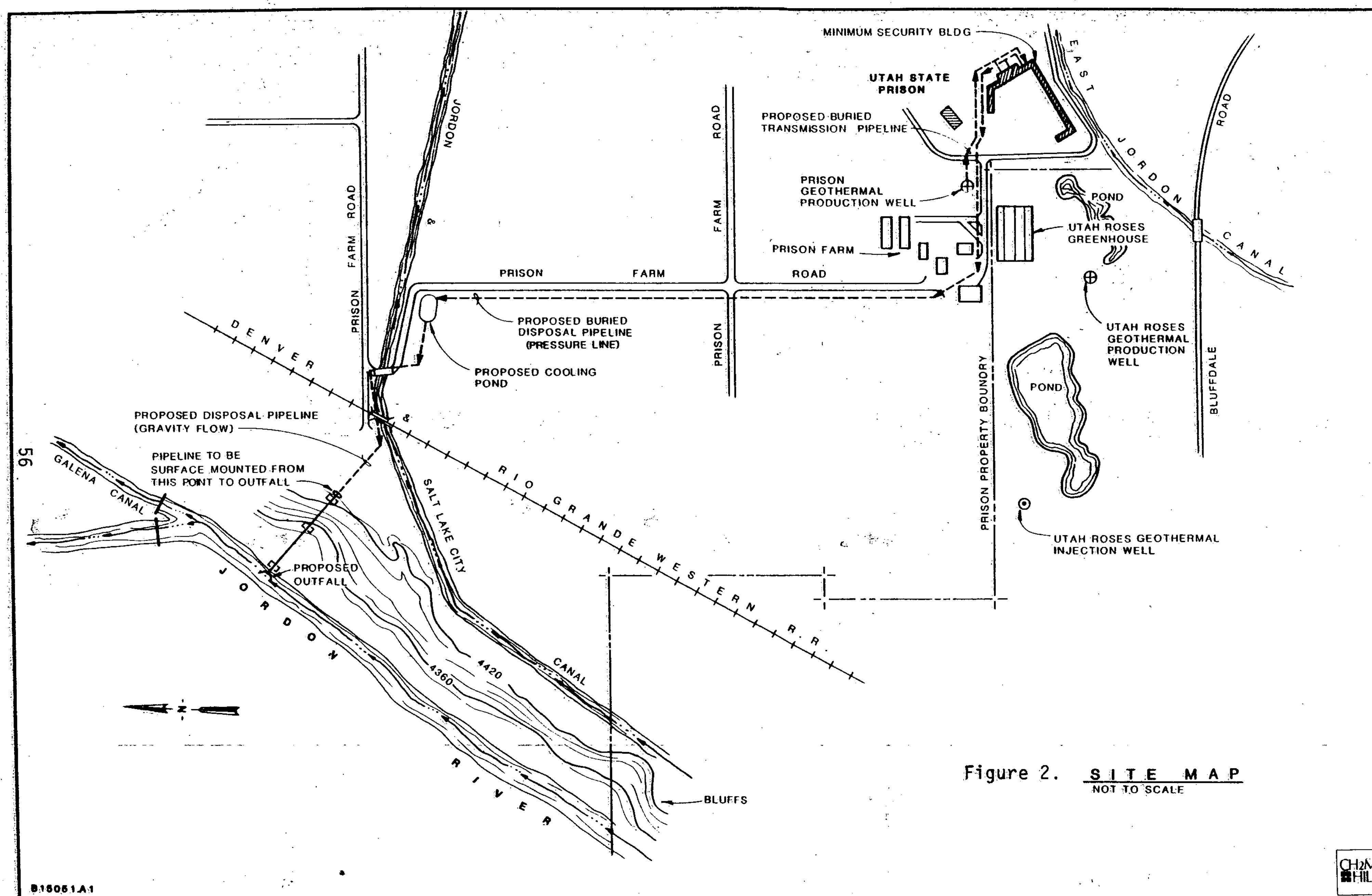
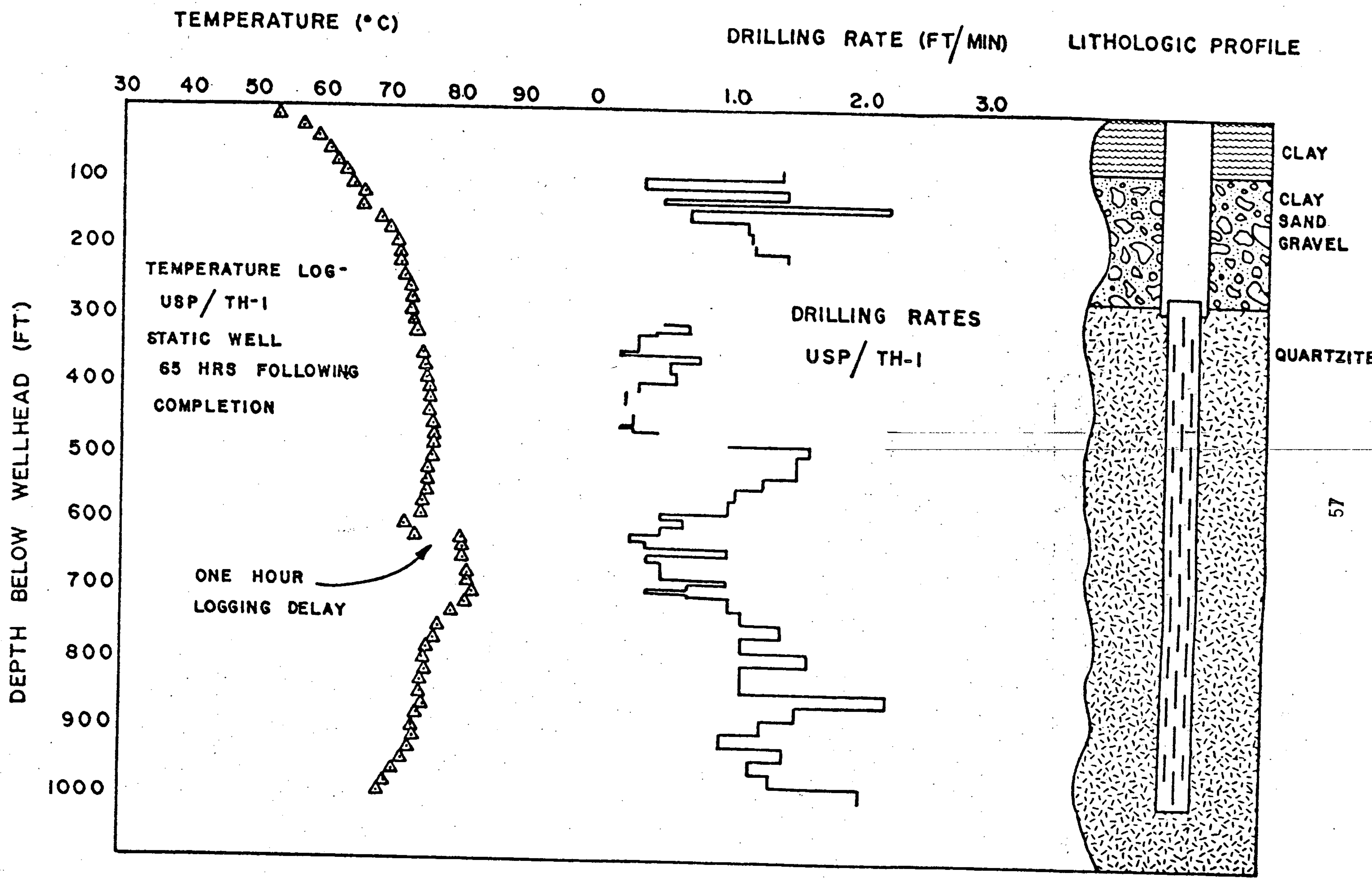


Figure 2. SITE MAP

NOT TO SCALE

FIGURE 3


TEMPERATURE (°C)
30 40 50 60 70 80 90
DRILLING RATE (FT/MIN)
0 1.0 2.0 3.0
LITHOLOGIC PROFILE
DEPTH BELOW WELLHEAD (FT)
100
200
300
400
500
600
700
800
900
1000
TEMPERATURE LOG-
USP/TH-1
STATIC WELL
65 HRS FOLLOWING
COMPLETION
ONE HOUR
LOGGING DELAY
DRILLING RATES
USP/TH-1
CLAY
CLAY
SAND
GRAVEL
QUARTZITE

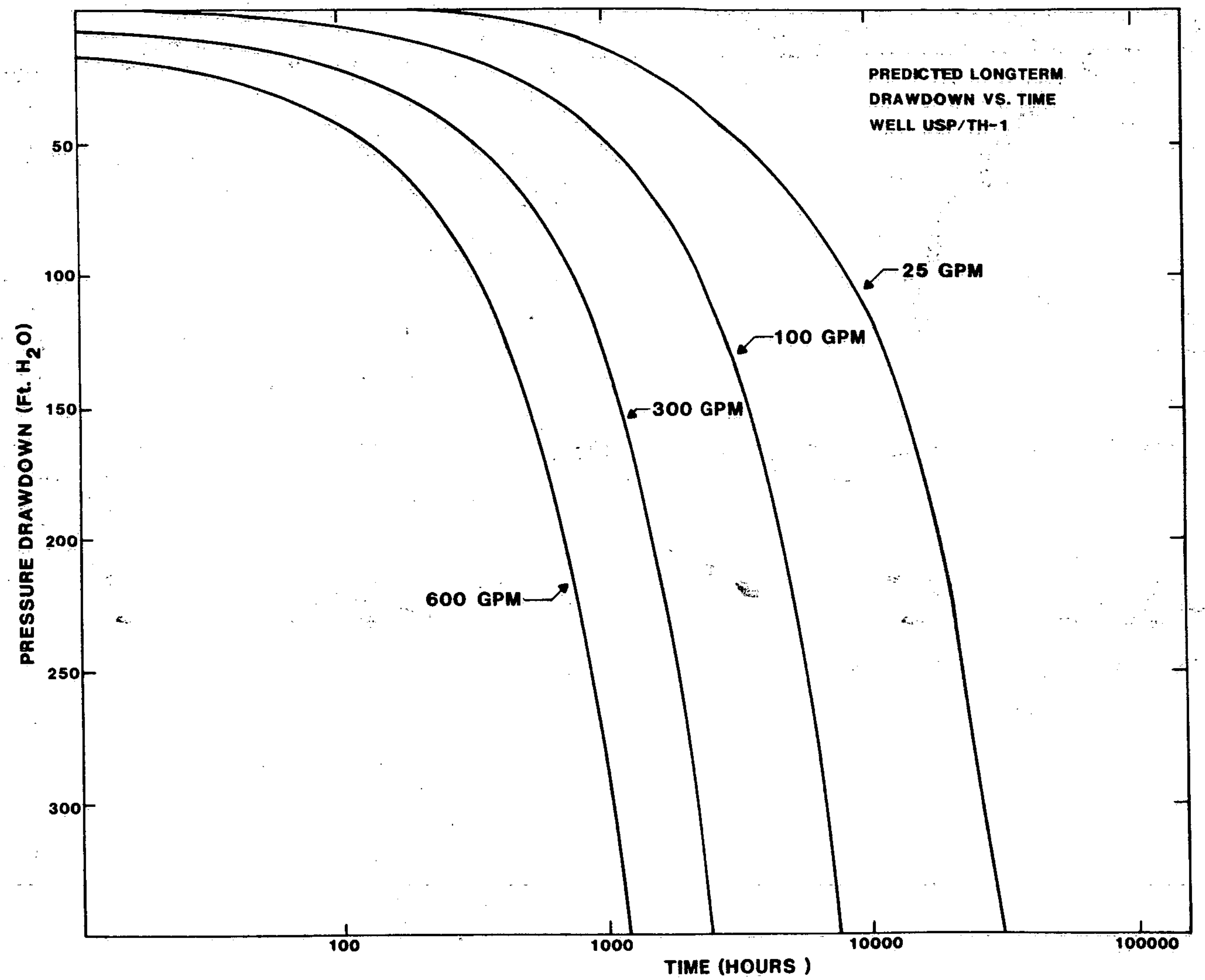


Figure 4. PREDICTED LONG-TERM PRESSURE DRAWDOWN CHARACTERISTICS FOR WELL USP//TH-1

EL CENTRO

GEOTHERMAL ENERGY UTILITY CORE FIELD EXPERIMENT

Principal Investigator: Abdel Salem
City Manager
City of El Centro, California

For information contact:
Daryl Avrit (714) 352-4391

Project Team: City of El Centro, WESTEC Services, Inc., Chevron Resources

1.0 PROJECT DESCRIPTION

The City of El Centro is conducting a geothermal energy utility core field experiment to demonstrate the engineering and economic feasibility of utilizing moderate temperature geothermal heat for space cooling, space heating, and domestic hot water heating. In this application, geothermal fluid at an anticipated temperature of about 250F (121C) will heat a secondary fluid (water). The secondary fluid will either be utilized directly or processed through an absorption chiller to provide space conditioning and water heating for the El Centro Community Center, a public recreational facility.

2.0 RESOURCE DATA

The pilot scale facility and well site for this experiment will be located on a parcel of vacant land located in the northeastern sector of the City of El Centro. The El Centro Community Center is located approximately one-half mile south of this parcel. The selected area is situated on the periphery of the 13.5 square mile Heber KGRA, estimated to contain 12.4 percent of the Imperial Valley's total geothermal resources.

According to geologic analyses prepared by Chevron Resources and Cascadia Exploration, shallow temperature gradient holes drilled in the area define a geothermal anomaly centered immediately south of the town of Heber. Reservoir temperatures from field wells are as high as 375F. There is further evidence that the anomaly decreases to the north in a radial pattern from Heber.

With specific reference to the El Centro drillsite, Chevron analyzed temperature data from its Hulse #1 well at Heber and the Magma Bonanza #1 well located about three miles northeast of the proposed site. Projecting this data, Chevron then prepared a thermal cross section of the area (Figure 1). Based on this cross section, the targeted temperature at the drillsite should be reached at a total depth of 8500 feet, Figure 2.

3.0 SYSTEM FEATURES

Once the wells have been completed and tested, the pilot hot water/chilled water plant at the well site will be constructed. Heat extracted from the brine will be transferred to the working fluid (water) through a conventional shell and tube heat exchanger. Pressure on the brine will be maintained to prevent flashing. City supply water was selected as the working fluid because of its relatively low cost and availability. The heated water will be used in the winter for space heating and domestic hot water needs. During the summer, the heated water will be used to operate a packaged lithium bromide absorption chiller for space cooling the Community Center. The chiller will require hot water at approximately 235F to produce chilled water at 42F during the cooling mode. The Center will be retrofit with heating/cooling coils for the space conditioning requirements, Figure 3.

A total of approximately 602 million Btu/yr of energy presently consumed by the El Centro Community Center is potentially replaceable by geothermal energy. For this demonstration, the geothermal hot/chilled water plant will be sized to handle approximately 97 percent of this annual load. This means that approximately 200,000 cubic feet of natural gas and 87,000 kilowatt hours of electricity will be replaced each year by geothermal energy.

After the usable heat has been removed, the geothermal brine will be disposed of by pumping the fluid down the injection well into a shallow, comparatively cool geothermal region. Reinjection temperature of the brine is expected to be at about 160F.

4.0 STATUS

At the last review meeting, the City had issued bids for drilling and for related supplies and services in connection with drilling. Responses received by the closing date of December 1, 1980 were legally insufficient for purposes of awarding a local governmental public works contract. Having complied with the requirement of the competitive bid process, the City was free to negotiate with selected companies. Several companies within each service category were contacted and responded. Selections have been made, and negotiations have been conducted.

A problem arose with respect to the casing procurement. The recent increase in domestic drilling has created a shortage of casing. After contacting numerous suppliers around the country, the City has firm commitments for all casing. Inspection and deliveries should be completed by the first week of October with drilling to begin mid-October.

In accordance with the City's contract with DOE, a well test plan was also submitted to DOE for approval in June. The purpose of this well test plan is to determine if the minimum performance standards required for the success of the project will be met by the geothermal production and injection wells. The minimum performance required from the two wells is basically the ability to produce geothermal fluid at a temperature of 250F and at a pumped production rate of 100 gpm and then reinject said fluid, after partial extraction of thermal energy, into a subsurface zone which is not in communication with shallow freshwater aquifers.

After the well is drilled to total depth (±4000 ft), but before casing is set, several temperature surveys and a complete suite of electrical well logs will be run. Utilizing temperature information, including the time elapsed since the previous temperature survey and since the last circulation of drilling fluid, Chevron reservoir engineering personnel will calculate a stabilized temperature profile for the well. Chevron will extrapolate this information to determine the probability of hitting the target temperature at target depth (±8500 ft) for the production well. Assuming a favorable decision to continue drilling, this phase of the project should be completed by the end of December.

5.0 CURRENT ESTIMATED PROJECT COST

Total Project Cost: $2,959,000

DOE Share: $2,794,000 (94%)

Participant Share: $165,000 (6%)

6.0 LESSONS LEARNED

1. Equipment and materials may be difficult to obtain from suppliers for small, one-time projects. This is particularly true when the items, such as well casing, are in short supply. Regular long-term customers get preferential treatment.

2. Regulatory approvals took longer than estimated. A local government is slowed by restraints associated with bidding and procurement which a private corporation would not have to address.

Direct Use Application Projects Bibliography

El Centro

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11. WESTEC Services, Inc., El Centro Geothermal Utility Core Field Experiment - Alternate Drillsite - Draft Environmental Impact Report and Draft Environmental Assessment, October 1979.

12. WESTEC Services, Inc., Drillsite Selection and Justification Report for the City of El Centro Geothermal Utility Core Field Experiment, October 1979.

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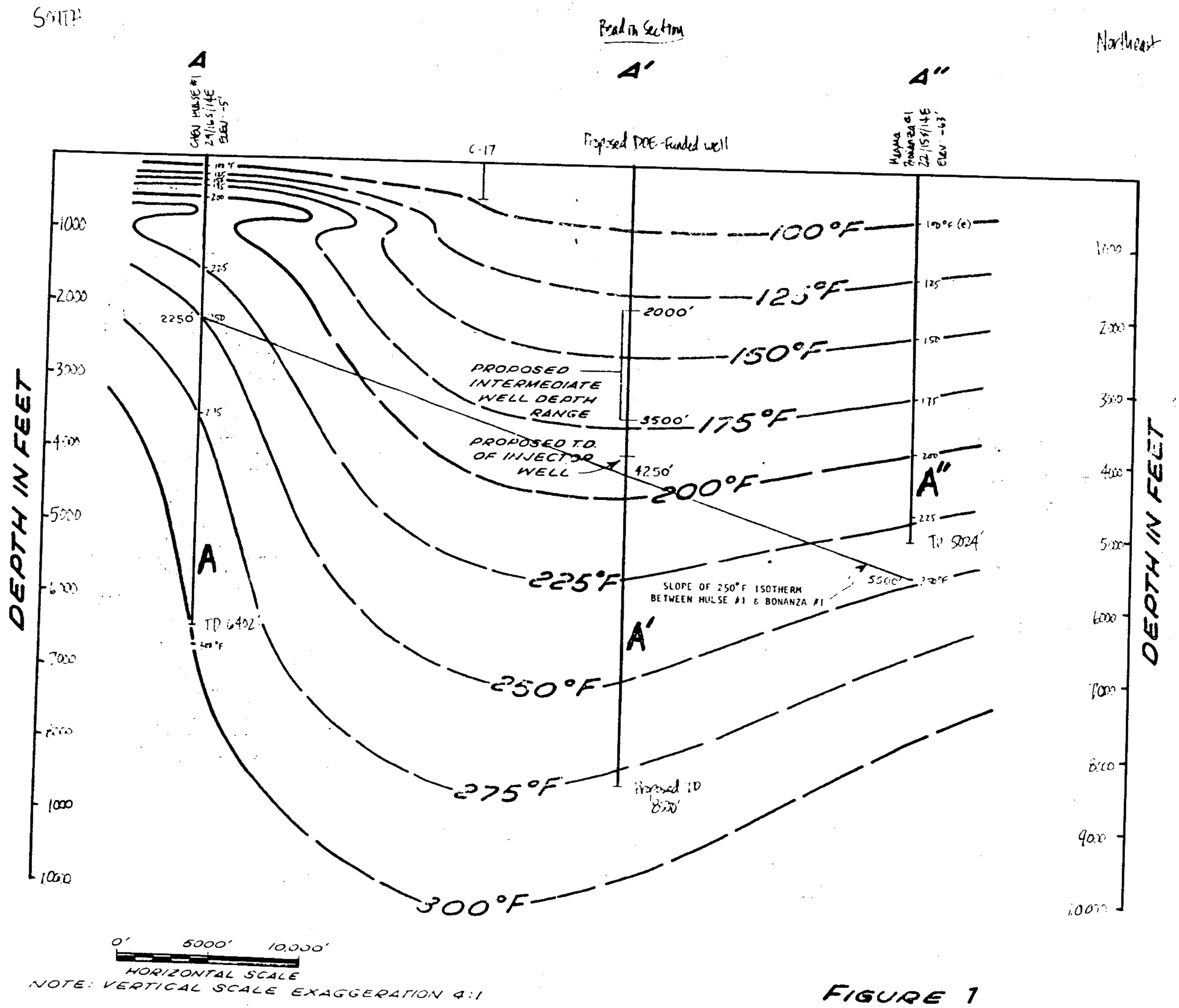
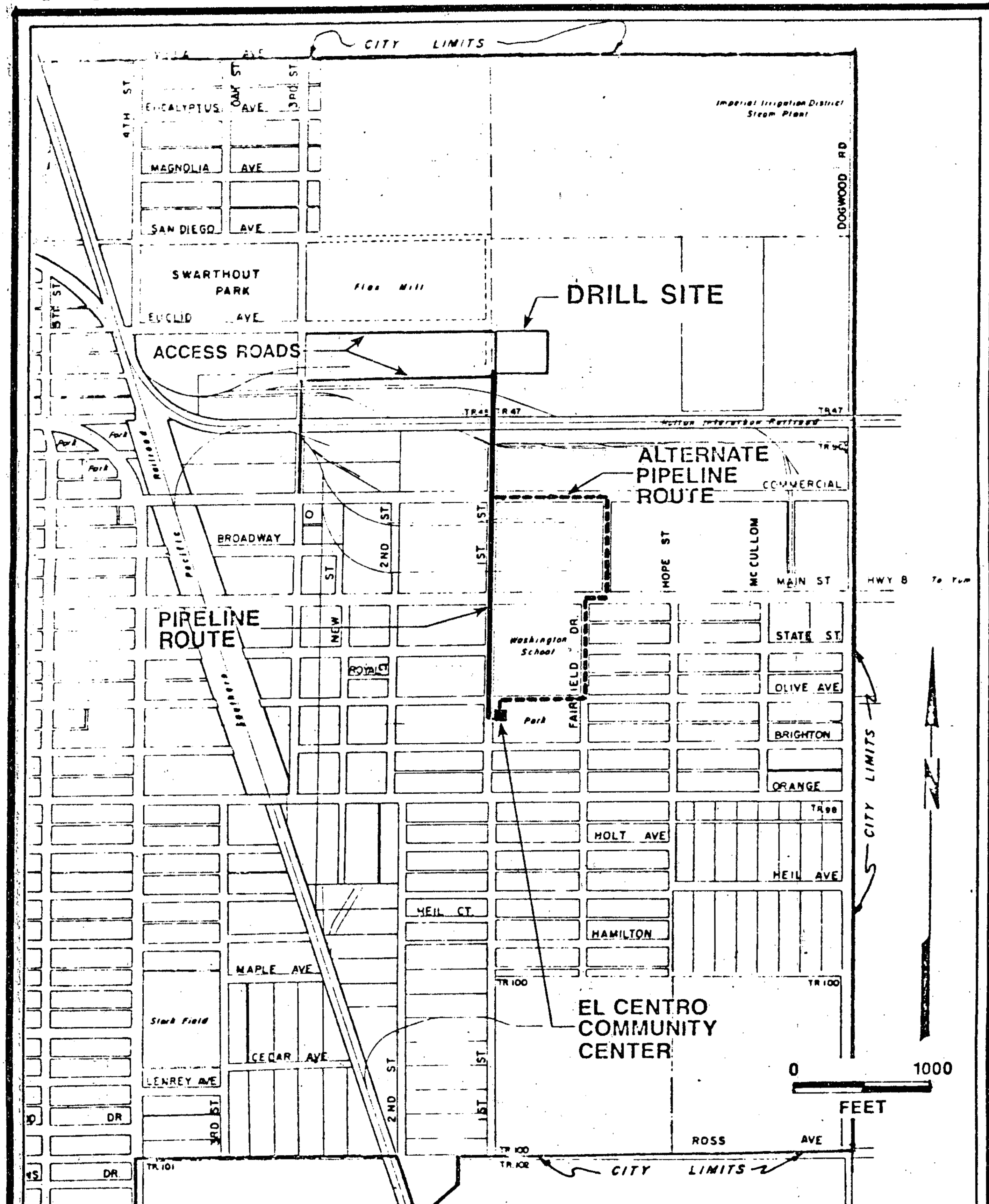


FIGURE 1

THERMAL CROSS-SECTION A-A''

TO ACCOMPANY LETTER BY R.W. BUTLER
DATED 3/14/80



El Centro
VICINITY MAP SHOWING LOCATION OF ACCESS ROADS

FIGURE 2

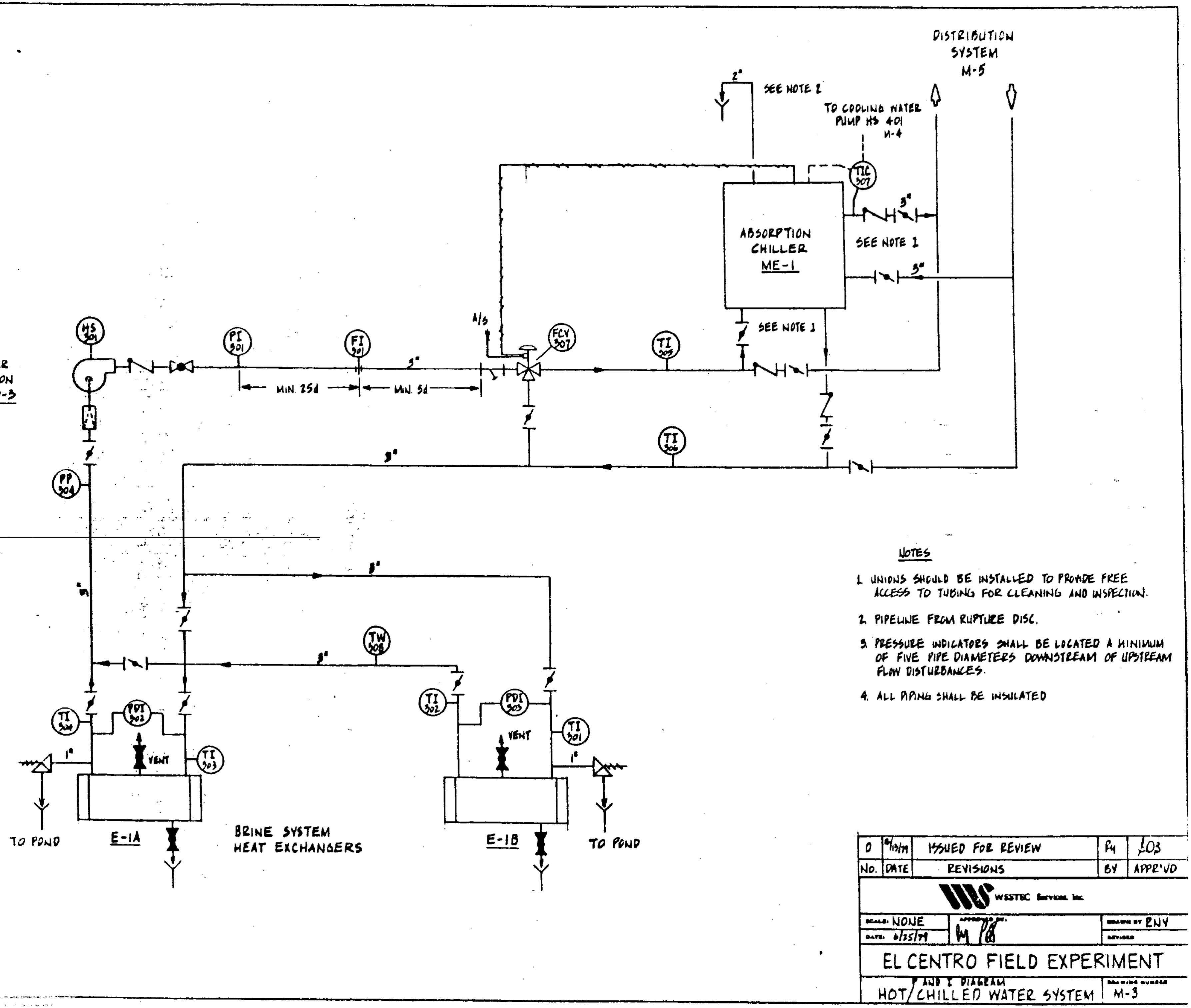


Figure 3. El Centro Hot/Chilled Water System

NAVARRO COLLEGE

Highway 31 West
Corsicana, Texas 75110

PROJECT TITLE: Multiple Direct Use of Geothermal Energy at Navarro College, Corsicana, Texas

PRINCIPAL INVESTIGATOR: Dr. Lary L. Reed, Executive Dean
Navarro College

PROJECT TEAM:

Prime Contractor:	Navarro College, Corsicana, TX
Geothermal Consulting Engineers:	Radian Corporation, Austin, TX
HVAC Consulting Engineers:	Ham-Mer Consulting Engineers, Austin, TX
Tubing:	Armco Steel, Houston, TX
Financial:	Wollens & Irwin, Corsicana, TX

PROJECT DESCRIPTION:

The purpose of this geothermal project is to retrofit several college buildings and a college aquaculture activity to directly utilize geothermal energy, thereby reducing their dependence on fossil fuels. The geothermal heating system will supply heat to domestic water systems, forced air heating systems and the aquaculture pond system.

Readily available commercial piping, pumps, valves, controls, plate heat exchangers, and insulation will be utilized in the system.

The final phase is a one-year operational demonstration phase during which potential geothermal users will be encouraged to visit and observe the geothermal system.

LOCATION DESCRIPTION:

Navarro College is located in Corsicana, Texas (population 22,300), approximately 45 miles south of Dallas (Figures 1 and 2).

RESOURCE DATA:

The production well (Well No. 1) is 2,664 feet in total depth and was completed in February 1979. The production zone is shot perforated in several intervals from 2,400 to 2,600 feet in the lower Woodbine Formation. Well pumping tests have produced sustained flow rates of 315 gpm fluid at 125°F with approximately 5,900 mg/l total dissolved solids (TDS). Hydrogen sulfide levels are minute and below human detection. Gross alpha activity of the water is approximately 80 pCi/l.

The source of the geothermal fluid heating is faulting associated with the Ouachita fold belt which outcrops in Arkansas and underlies much of Central Texas. Figure 3 shows a geologic dip section and emphasises the Woodbine Formation and its relationship to Corsicana. Hydraulic interconnection of deeper and shallow formations provided by the Mexia-Talco-Luling fault system is the factor most responsible for the area's low-temperature geothermal resource.

FLUID DISPOSAL:

Due to the fluid's gross alpha activity, surface disposal will not be pursued because of its possible uptake by biological systems.

Disposal will be done by injection, via Well No. 2, into the upper Woodbine. The upper Woodbine and the lower producing Woodbine are separated by many feet of shale. Thus the likelyhood of interference between the two is remote. The injection well is yet to be completed and tested (Figure 4).

SYSTEM FEATURES:

The production system will consist of a submerged pump set at 1,000 feet in Well No. 1. This pump will be sized to produce between 200 and 300 gpm, maximum, of 125°F fluid. To conserve geothermal fluid, production costs and injection costs, the pump will be run at a speed directly proportional to the system heating load. An electronic variable speed drive (VSD) unit will control the pump speed (and thus flow rate) according to the system discharge temperature set point of about 100°F. As the system load increases, the discharge temperature will tend to drop. A derived signal sent to the VSD will cause the unit to speed up the pump. The higher production rate will thus supply more heat to the plate heat exchangers (PHX) and the discharge temperature will also rise thus closing the loop.

At each retrofit building, a double-secondary PHX will transfer the geothermal heat to fan coil units and domestic hot water storage tanks. Although the prawns could exist readily in the geothermal fluid from a TDS standpoint, the prawns should not experience such elevated alpha activity. Therefore, a PHX will be used to separate the geothermal water from the pond environment.

Scale control is achieved by maintaining a closed geothermal loop under 5 psig, minimum, until injection. The ease with which PHX's can be disassembled and cleaned (defouled) also assures that potential scaling is efficiently dealt with. Corrosion control is achieved by: 1) precluding oxygen intrusion via a closed geothermal loop; and 2) selecting PHX plate materials that are known to resist corrosion in this water.

STATUS:

System design and thus system economics figures are awaiting the results of injection tests which are planned for October 1981.

Well No. 2 will be perforated at four shots/foot, using 0.5-inch shot, over the upper Woodbine interval. After hydraulic fracturing (with proppant) of the same interval, water from Well No. 1 will be produced and fed to an injection pump. Sustained injection at a planned 100 gpm will be conducted for at least 48 hours while careful data collection is made of pressure and flow rates versus time in order to determine reservoir parameters. During the last phases of the test, the injection flow rates will be increased to 200 gpm and 300 gpm levels.

PROJECT COST:

The total approved project cost is $1,075,000. This amount was underwritten in the following manner:

SOURCE	PERCENT
• US Department of Energy	80
• Navarro College Benefactors	8
• In-Kind and Other Services by Navarro College	12

LESSONS LEARNED:

1. Injection at minimum energy consumption proved to be more difficult than expected. It is recommended that an experienced industrial waste injection consultant be employed early in the project if injection disposal is likely to be needed.

2. There is no standard method of economic analysis. The assumptions used to arrive at any payback period or rate of return must be highly qualified to understand its significance.

3. The amount of time and effort required to turn a final design which is complete in terms of an engineering review into an acceptable bid package was much greater than expected. Overall, the time and effort required to get from completed design to negotiated construction subcontract was greater than planned. Intermediate steps were: generate bid package, reproduce and issue package, advertise, answer questions, evaluate bid, investigate contractor and negotiate to get final signed subcontract.

NAVARRO COLLEGE

(Contract No. DE-FC08-79ET27058)

1. Radian Corporation, An Environmental Report for the Geothermal Direct Utilization Project at Navarro College and the Navarro County Memorial Hospital, Corsicana, Texas, DCN 79-212-308-02, Agreement DOE/DE-FC08-79ET27058, May 1, 1979.

2. Radian Corporation, Geothermal Injection and Production Well Test Results, Navarro College, Corsicana, Texas, DCN 81-212-308-09, Agreement DE-FC08-79ET27058, February 4, 1981.

3. Thompson, Gerald L., Ground-Water Resources of Navarro County, Texas, Report 160, Texas Water Development Board, November 1972.

4. University of Texas at Austin, Bureau of Economic Geology, Geologic Atlas of Texas, Waco and Dallas sheets, 1972.

5. US DOE/NOO, Finding of No Significant Impact, Letter, June 12, 1979.

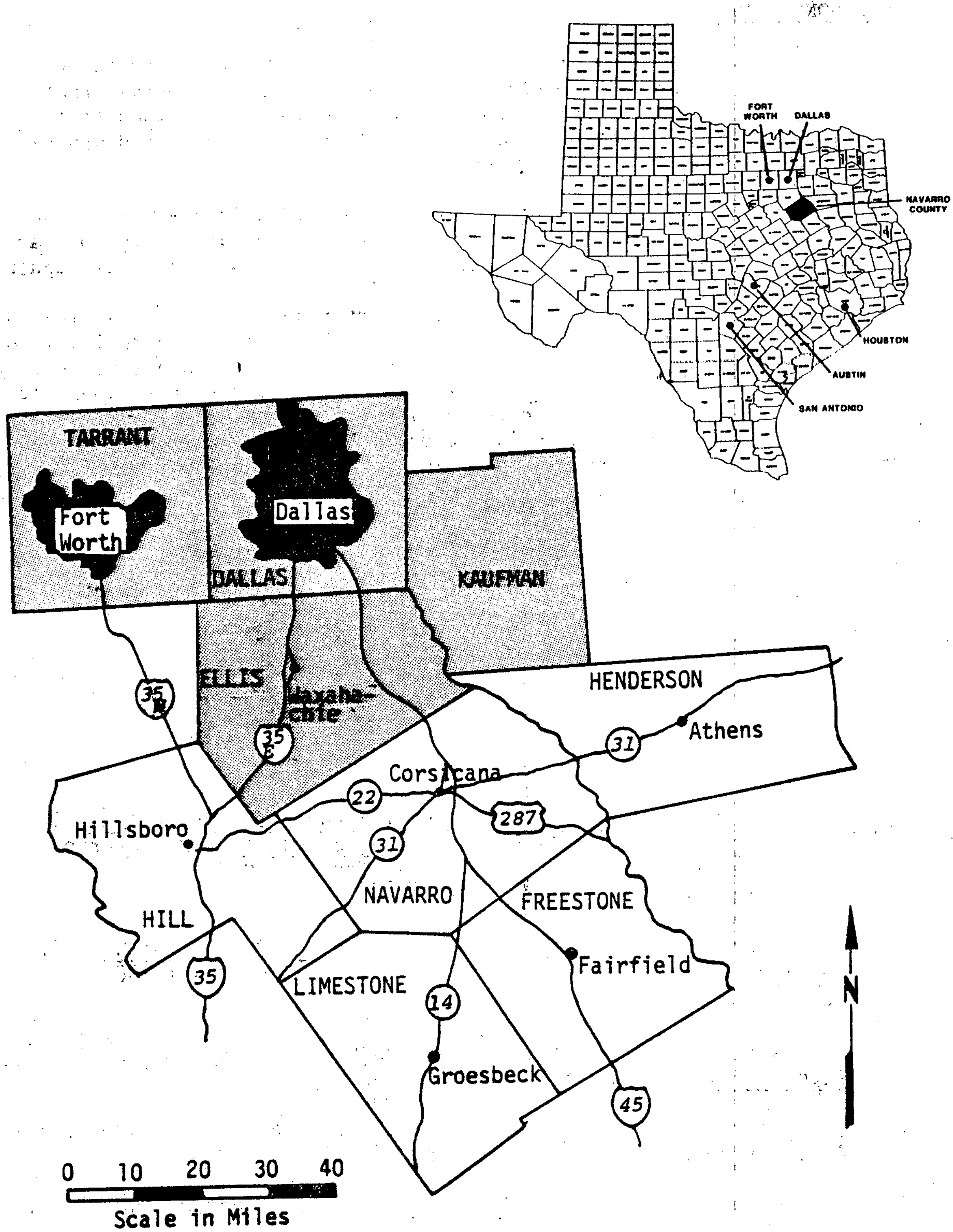


Figure 1. Geographic Setting of Corsicana and Navarro County, Texas

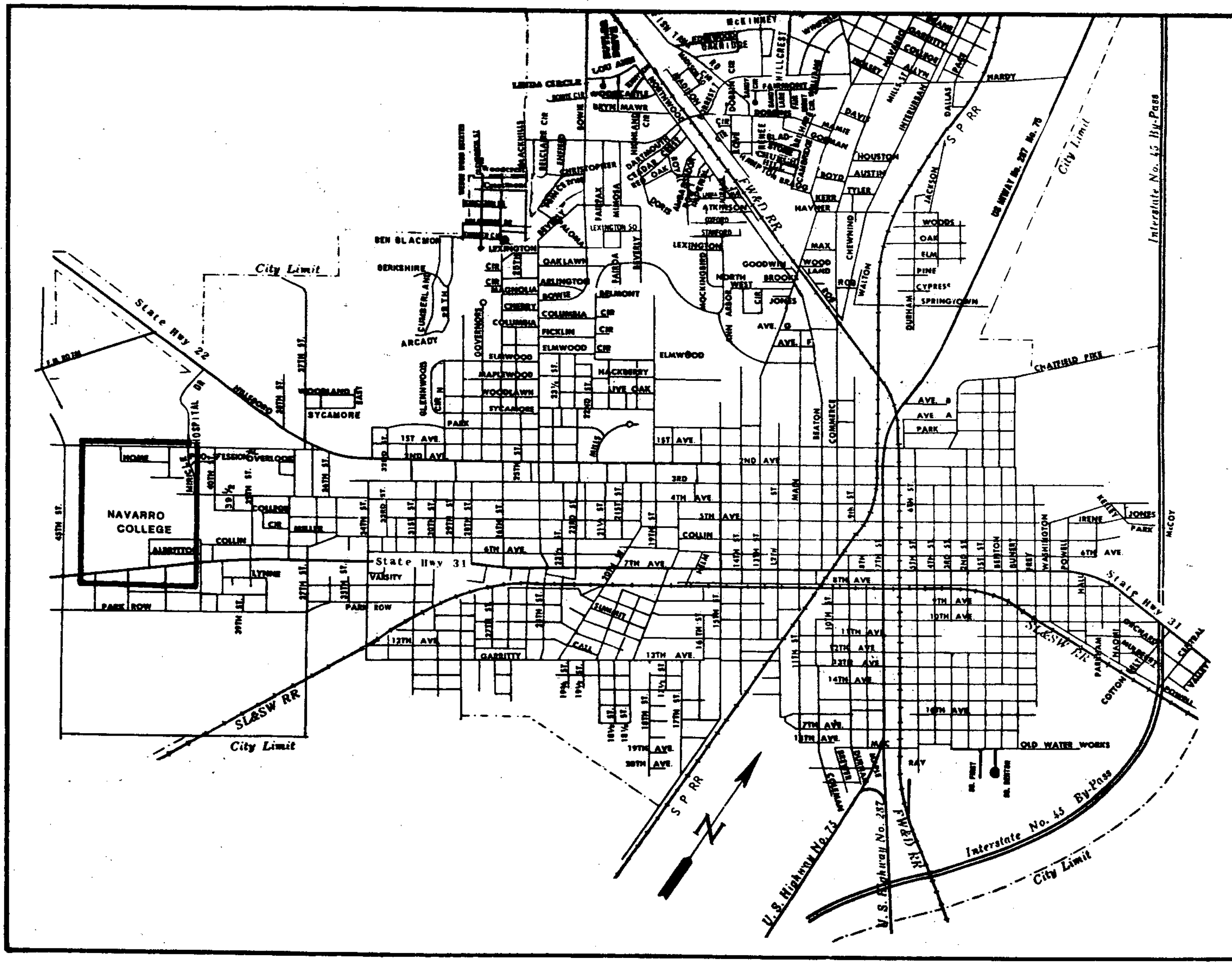


Figure 2. Navarro College Location in Corsicana

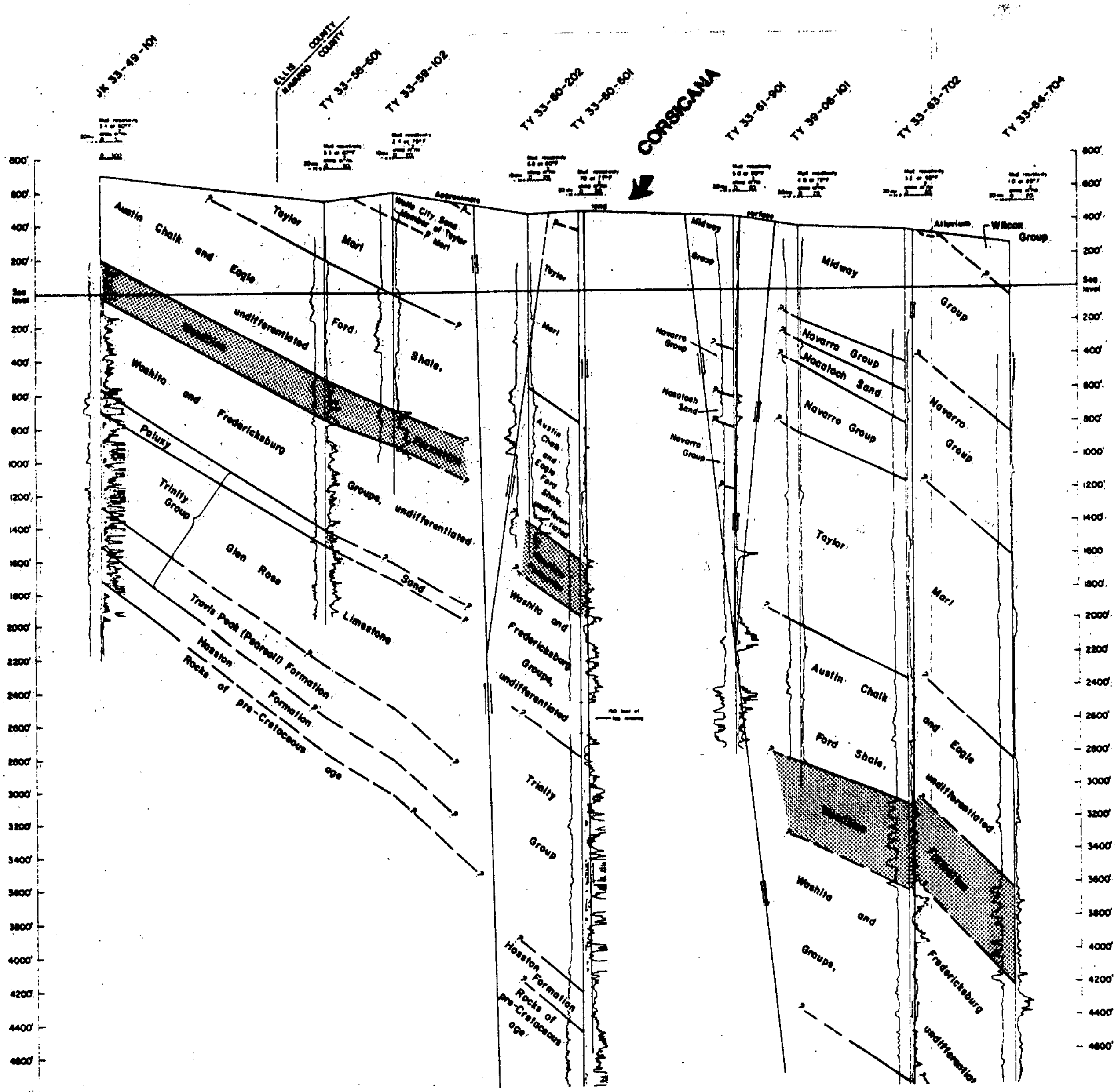


Figure 3. Generalized Geologic Cross-Section Across Navarro County

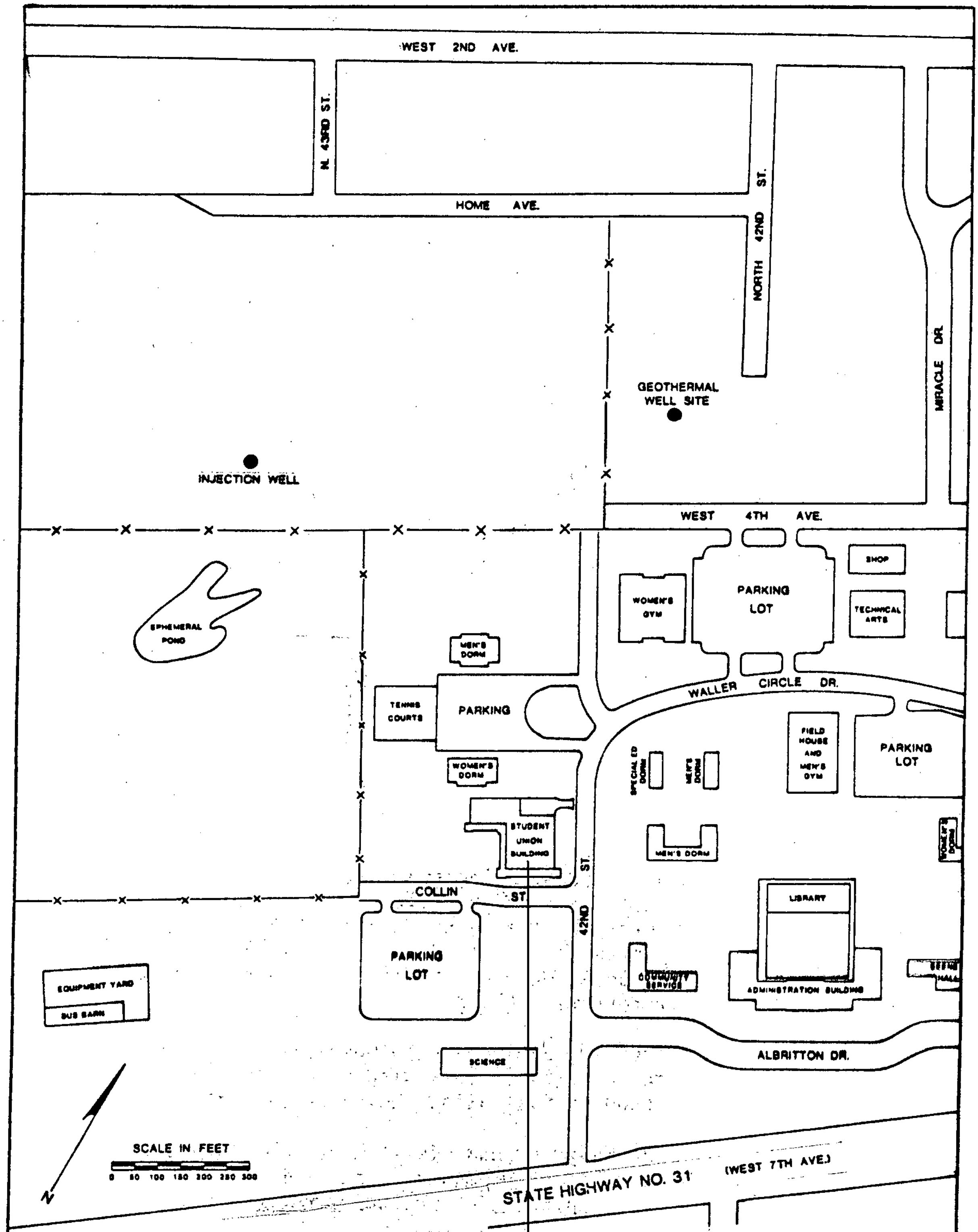


Figure 4. Location of Geothermal Production and Injection Wells on Navarro College Campus

Project Title: Geothermal Heating of Warm Springs State Hospital

Principal Investigator: Allan D. Miller
Montana Energy and MHD Research and Development Institute, Inc. (MERDI)
Phone: (406) 494-6350

Project Team: State of Montana
MERDI, Inc. (AKA: MultiTech, Inc.)
Energy Services, Inc.
CH_2M Hill, Inc.

Project Objective: To develop geothermal resources at Warm Springs for domestic water and space heating.

Location Description: Warm Springs State Hospital
Deer Lodge County, Montana
15 miles (24 kilometers) south of Deer Lodge
Population: 10,700 (Deer Lodge County)
Area Activities: Mining, State Hospitals, and Agricultural

Resource Data: Well depth 1,498 feet (457 meters)
Date Complete: 12/5/79
Reworked: 4/20/81
Completion Technique: Slotted liner
Well Head Temperature: 168°F (76°C)

Flow Rate: 70 gpm (4.41 liters per second) required for system design.

Summary: Warm Springs is located adjacent to the State Hospital and discharges 168°F (76°C) water with a dissolved solids content of 1250 mg per liter. The source of the geothermal fluid is attributed to deep circulation in fault zones.

System Features: Application: Domestic water heating
Heat Load Design: 1.05 BTU per hour
Yearly Utilization: Maximum 9.2×10^9 BTU per year
Energy Replaced: Natural gas 10.8×10^6 ft^3/yr
Disposal Method: Surface discharge to migratory waterfowl wetlands

Status: The Warm Springs State Hospital Project was initiated in February of 1979 with an Environmental Assessment, Resource Evaluation, and a Legal/Statutory Review.

The Environmental Assessment addressed both human and natural environmental factors to determine the impact of the project on the surrounding area.

Status Continued:

The Legal/Statutory Review was conducted to determine legal requirements which must be met prior to, during, and after development of the project.

The Resource Evaluation was conducted to determine the most favorable geological location for siting of the well. The evaluation study consisted of 1) a gravity and resistivity survey by the Montana Bureau of Mines and Geology in the immediate area of the existing hot springs mound; 2) evaluation of existing reports, maps, surveys, and studies of the immediate Warm Springs area; and 3) review of two independent studies made of the Deer Lodge Valley which resulted in mapping of three probable faults running northeast to southwest and north to south.

In reviewing all of the above data, the well was sited northeast of the existing hot springs mound in the area of the facilities heating plant.

Drilling activities began in mid-October of 1979 and concluded in early December of 1979 at a TD of 1,498 feet (See Figure 2 for diagram of the well completion).

Logs run in the well were: 1) Dual Induction - Laterolog was run in the uncased section from 898 to 1501 feet; 2) Compensated Neutron Formation Density was run from 420 feet to 1501 feet; and 3) Temperature log run from 50 feet to 1501 feet. Also, two water samples were taken to determine Rw (formation water resistivity).

Some preliminary pump tests were run and then the decision was made to perform matrix acid treatment of the well. Based on an analysis of acid reaction to the well cutting, hydrochloric acid was chosen. The job consisted of pumping 4000 gallons of 15% hydrochloric acid down the drill pipe and displacing the acid by pumping fresh water down the annulus side. The pressure was bled off and the well was shut in for 24 hours. Several days later a pump test was conducted and the well flowed 200 gpm for 2 hours at 160°F. However, the test was stopped due to pump failure.

MERDI then contracted with a pump company to install a new Worthington line shaft vertical turbine pump. This pump was set at 830 feet. The pump consisted of 19 stages with spider bearings set on a stainless steel shaft every 10 feet. The pump test was plagued with vibration problems. One to two hours was the maximum running time of the pump during any single test. This lasted for several weeks for a total

Status Continued: running time of less than 52 hours. Actual cause of the vibration problem has never been settled.

In January 1981, Energy Services, Inc. of Idaho Falls, submitted a report to MERDI on their evaluation of the Warm Springs well. The conclusions in their report were recommending reworking the well and drilling an additional 50 feet into what they believed is a zone of hot water. Their recommendations were approved by the Department of Energy and work commenced on March 12, 1981. It was initially found that the bottom 220 feet was filled with drilling mud and rock chips. In addition, we retrieved a 12 foot piece of 3/8 inch steel pipe. After cleaning the well to the total depth, we hit a solid metal item in the bottom of the hole. Our best guess is that the metal at the bottom of the hole is a length of drill pipe lost previously. However, fishing attempts were unseccessful at retrieving the metal. Since we were unable to drill through or around the metal, the decision was then made to perforate the bottom 120 feet of casing. The well was then swabbed and cleaned for several days. The results were the artesian flow increased from an estimated 20 to 22 gpm to 32 to 35 gpm.

A 30 HP Reda G75 downhole submersible pump was installed on May 19, 1981 to a setting depth of 987 feet. The pump was test run by a Reda representative for approximately 1/2 hour. On May 23 long-term testing commenced.

The well was tested at rates of 50, 75, 95 and 110 gpm, for 100 hours each with required recovery time. After the final recovery of the 110 gpm test, a nine hour step drawdown of 25, 50, and 75 gpm was run for three hours at each gpm rate.

Results of the tests were:

Test Rate (gpm)	Test Time (hrs)	Maximum Drawdown (feet)	Recovery time (hrs)
50	100	815	3.4
75	100	900	3.8
95	100	870	2.9
110	100	860	2.5

The main purpose of the step drawdown test was not to determine well efficiency but to gather data on optimum pumping rate of the well. Since this is a devloping well, as evidenced by the data obtained, the test cannot give any valid conclusions about well efficiency.

Status Continued: From data obtained our recommendation has been:

1. No further remedial work is required on the well.

2. Maximum production should be limited to 90 gpm.

3. Expected temperature is 168°F.

4. Production of the well did not significantly affect the natural flow at the Warm Spring mound.

5. We recommend future development of the resources for space heating requirments.

Current Estimated Project Cost:

Total:	$1,166,755		
DOE Share:	$ 995,108	Participant Share:	$171,647
	85%		15%

LESSONS LEARNED

1. It can be important to have a project representative "sitting the rig" to observe unusual occurrences which may not show up in the drilling log records.

2. Initial pump testing of a resource should use a pump/control system capable of accurately delivering a wide range of flowrates.

3. Corrosion coupon tests or monitoring samples with new electronic corrosion detection equipment is good practice to avoid costly material failures and loss of reliability in the operational system.

4. Use reputable firms not only for basic site work but also for manufacturer's supplied equipment and engineering design.

5. Check with regulatory agencies on permits required and on their review requirements to avoid unexpected and costly delays.

6. Recognize site specific problems as they relate to the resource, waste water drainage or reinjection, electrical service, point of use location, and operational and maintenance requirements.

7. Generate plans and designs with adequate detail to assure obtaining desired product and to satisfy the cognizant agencies for their review and/or for bidding.

8. Coordinate all efforts with land owners and organizations which your work may impact.

WARM SPRINGS STATE HOSPITAL PON REPORTS

(Cooperative Agreement No. DE-FC07-79ET27055)

1. MERDI*, Environmental Report for the Geothermal Heating of Warm Springs State Hospital, Montana (Draft Report), MERDI Report No. 2DOE-MHD-D20, Agreement No. DE-FC07-79ET27055, April 1979.

2. Stoker, Roger C. (Energy Services, Inc.) Geothermal Resource Evaluation of the Warm Springs, Montana Area, MERDI Report No. 10-DOE-GEO-N10, Cooperative Agreement No. DE-FC07-79ET27055, June 1979.

3. McLeod, M. Eugene, Geothermal Heating of Warm Springs State Hospital, Warm Springs, Montana, Technical Progress Report, 1 February, 1979 to 1 August, 1979, MERDI Report No. 11 GEOWS-DOE-S79/3, Cooperative Agreement No. DE-FC07-79ET27055, August 31, 1979.

4. Stoker, Roger C. (Energy Services, Inc.), Well Drilling Specifications, MERDI Report No. 10DOE-GEO-N11, Cooperative Agreement No. DE-FC07-79ET27055, undated.

5. Carlson, Jon R., Drilling Report, Warm Springs State Hospital Production Well No. 1 (Draft), Montana Tech Foundation Mineral Research Center Report, undated.

*MERDI: Montana Energy and MHD Research and Development Institute (Environmental Division), Butte, Montana (AKA Multi-Tech, Inc.)

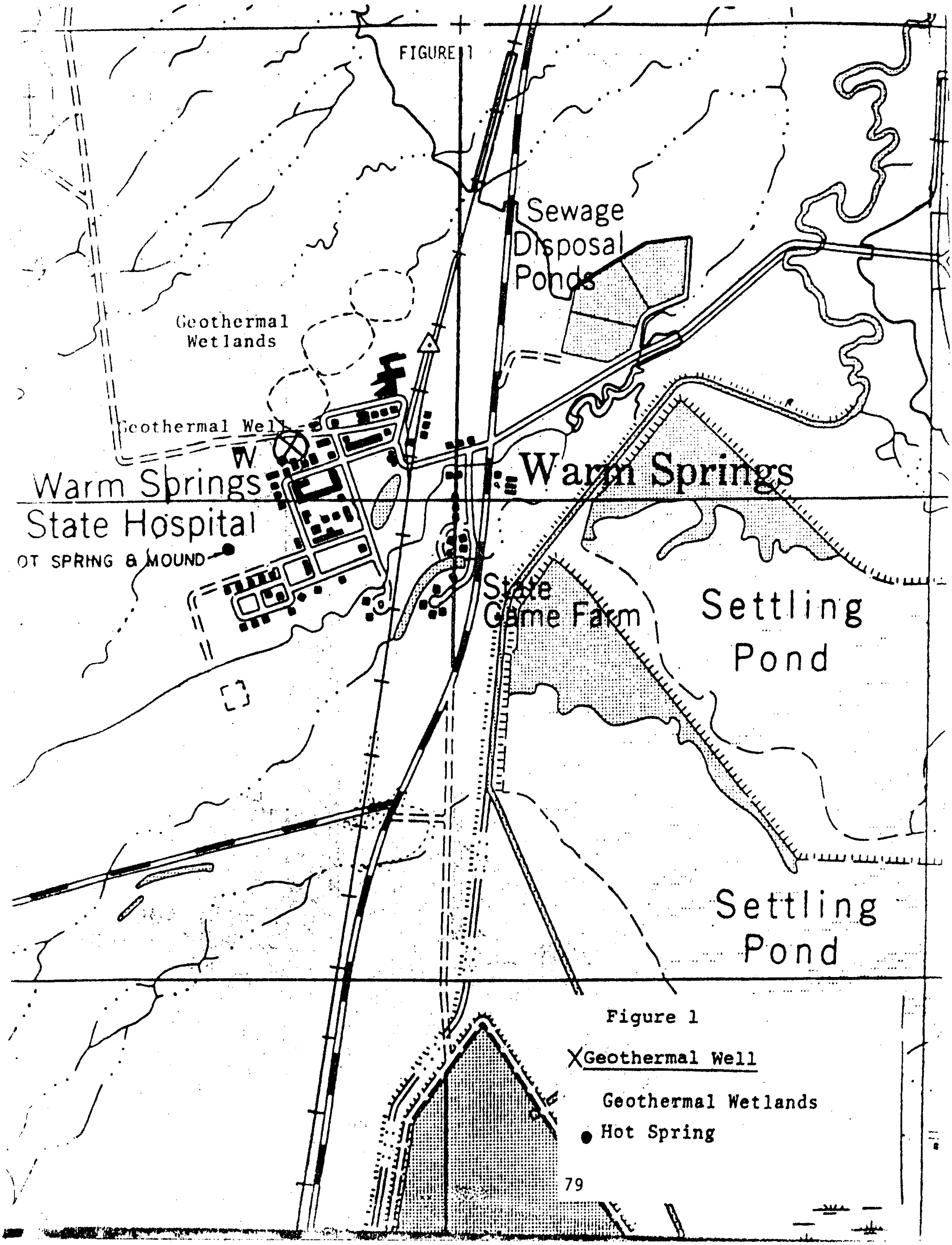
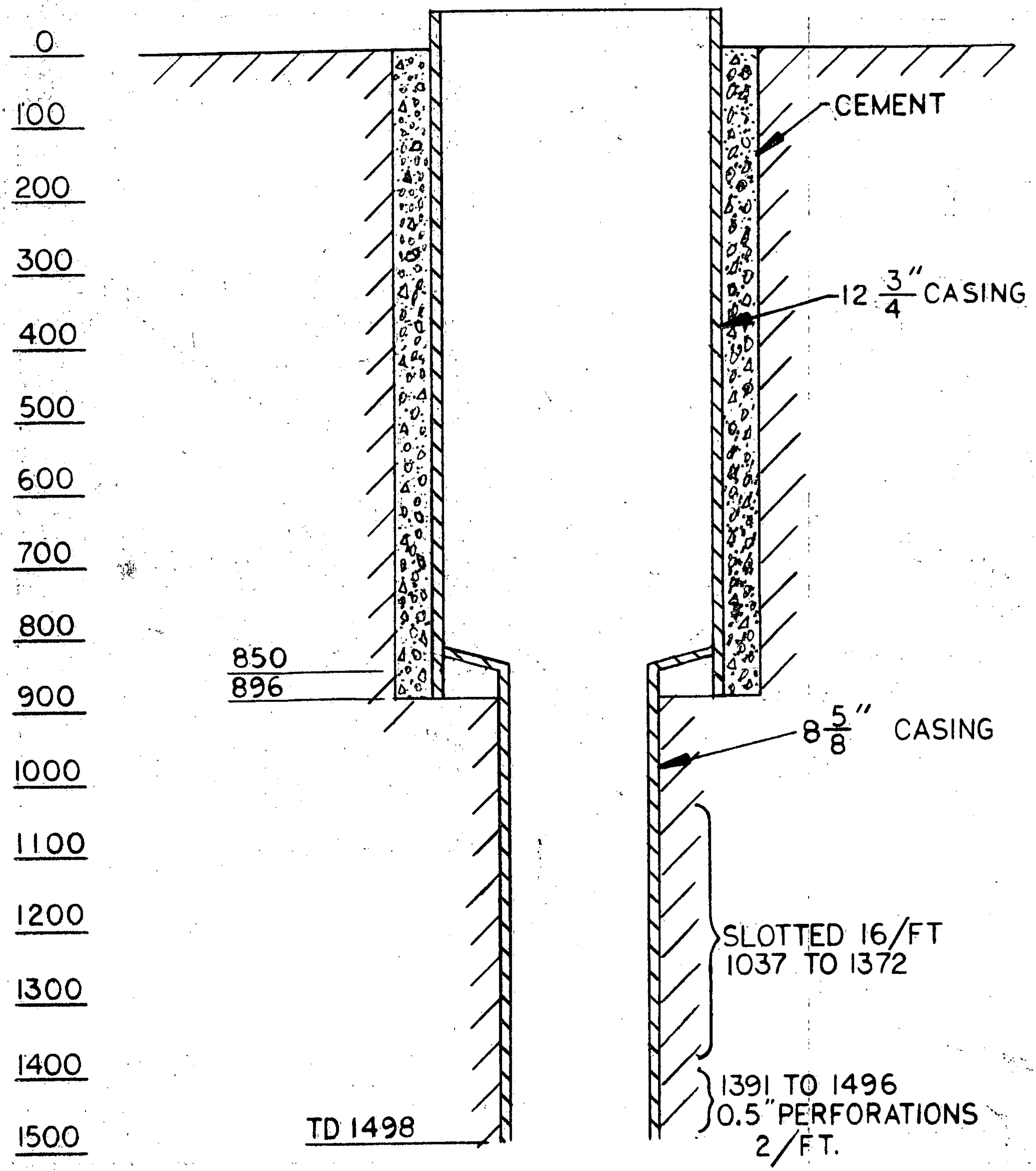


Figure 1

X Geothermal Well

Geothermal Wetlands

● Hot Spring



WARM SPRINGS PRODUCTION WELL
FIG. 2

PROJECT TITLE: Boise City - A Field Experiment in Space Heating

PRINCIPAL INVESTIGATOR: Phil Hanson, Director, Boise Geothermal
(208) 384-4013

PROJECT TEAM: Boise City
Boise Warm Springs Water District
CH2M Hill, Engineers

PROJECT OBJECTIVE: To develop a geothermal space heating system to serve the largest possible market in and around the Boise central business district.

LOCATION DESCRIPTION: Boise, Idaho
Population: 105,000
Area Activities: Commercial, governmental, manufacturing and recreational center

RESOURCE DATA: See geologic map of resource area, Figure 1.

A. Existing Boise Warm Springs Water District (BWSWD) Wells No. 1 and No. 2.
Well Depth - 400 feet (122 m)
Date Complete - 1890's
Completion Technique - Open Hole
Wellhead Temperature - 170°F (76°C)
Flowrate - 1,700 gpm combined flow of wells #1 & #2

B. New Boise Warm Springs Water District (BWSWD) Well No. 3.
Well Depth - 600 feet
Date Complete - June 5, 1981
Completion Technique - Closed Hole
Wellhead Temperature - 134°F (56°C)
Flowrate - Inadequate

C. New Boise Warm Springs Water District (BWSWD) Well No. 4 - PROPOSED.
Well Depth - 600 feet
Date complete - planned for summer 1981
Completion Technique - Open Hole
Well Head Temperature - 170°F (76°C)-Goal
Flowrate - 1,000 gpm (planned)

D. New Boise City Wells.
- Well Number 1 -
Well Depth - 2,010 feet
Date Completed - April 17, 1981
Completion Technique - Slotted Casing and Open Hole
Wellhead Temperature - 155°F (68°C)
Flowrate - None artesian (not yet pump tested)

- Well Number 2-
Well Depth - 800 feet
Date Complete - May 7, 1981
Completion Technique - Open Hole
Wellhead Temperature - 164°F (73°C)
Flowrate - 1,000 to 1,300 gpm artesian

- Well Number 3 -
Well Depth - 1,893 feet
Date Complete - June 4, 1981
Completion Technique - Slotted Casing and Open Hole
Wellhead Temperature - 165- 170°F (73-76°C)
Flowrate - None artesian (not yet pump tested)

- Well Number 4 -
Well Depth - 1,000 to 1,500 feet
Date Complete - Planned for August/September 1981
Completion Technique - Slotted Liner or Screen
Wellhead Temperature - 170°F (76°) - Planned
Flowrate - 1,000 to 1,300 gpm artesian

E. Summary:
The resource area is commonly referred to as the Boise Front. This appears to be fault controlled, with the source of water being the annual runoff in the mountains immediately behind Boise City. Two wells presently serve the existing BWSWD system and provide a peak flow rate of approximately 1,700 gpm. A third well was completed under the current project and was expected to increase that flow by 1,000 gpm. Results from this well were poor and are being reviewed for further well drilling plans. Three new City wells have been completed and a fourth is planned. Ultimate flow rates will depend upon further testing to be done but initial results from the City wells are very favorable based on large artesian flows.

SYSTEM FEATURES:

Application - District Heating
Heatload (Design) - 1 x 10^8 Btu/hour (29.3 MW/year)
Yearly Utilization - 2 x 10^{11} btu/hour (6.7 MW/year)
Energy Replaced- Natural Gas 2.92 x 10^8 cu. ft.
Facility Description - 500-1,000 residences and up to 2,000,000 square feet of office space
Disposal Method - Alternatives presently under review. Disposal to Boise River is preferred method.
Summary - The proposed Boise City and BWSWD systems will utilize the local geothermal resource, as described above. Production wells for the City system will be located approximately 1.5 miles (2.4 km) from the primary load located in downtown Boise. The pipeline will be sized for 4,000 gpm to allow for future growth, although initial production capacity is expected to be approximately 2,000 gpm. The BWSWD pipeline will be sized for 3,000 gpm. See pipeline maps, Figures 2 and 3.

STATUS:

Environmental Report	Completed
Geology Data Review	Completed
Well Siting Report	Completed
Preliminary System Design	Completed
Market & Rate Study	Completed
Customer Confirmation	In Progress

BWSWD Well Specifications	Completed
Boise City Well Specifications	Completed
Waste Disposal Report	Completed
Drilling Fund and Lease	Completed
Drill BWSWD Well #3	Completed
Drill Boise City Well #1	Completed
Drill Boise City Well #2	Completed
Drill Boise City Well #3	Completed
Drill Boise City Well #4	Completed
Final Design of BWSWD Pipeline	Completed
Final Design of Boise City Pipeline	Completed
Construction of BWSWD Extended System	Due: December 1981
Construction of Boise City System	Due: March 1982

PROJECT COSTS:

Total - $7,127,909 plus $700,000 contingency
DOE Share - $4,226,000 plus $700,000 contingency
Participant Share - $2,901,909

LESSONS LEARNED:

The area assigned to me is "institutional" with direction to discuss problems and resolutions over the past twelve months. Unfortunately, the institutional issues in Boise with which we have had to deal date at least to 1975. Since these issues have acquired layers of political, legal, and organizational fact and opinion I will simply define the problem for you, describe the form which our resolution of it is taking, and try to leave you with some general time boundaries.

1. Problem: The State of Idaho began working with geothermal, as a heat source for their buildings, about 1974. In 1978, they connected a 34,000 foot office building to the historic Warm Springs system. Other of their activities resulted in a $190,000 budget to retrofit buildings in the downtown Capitol Mall area, and a $105,000 budget to drill an exploratory well. The exploratory well was to be drilled downtown, on state property, to a target depth of 2,000 feet. The product of the well was to be used to heat major state buildings which were also candidates for the planned Boise Geothermal system. The well was to have been completed in June 1980, but was completed in November. The problem resulting from these circumstances was our need to know the States plans so that we could design a delivery/disposal system that either did or did not include the state buildings.

   Resolution - Time heals all wounds, almost. Our schedule,due to funding committees, product approval and task delay,slipped so that the states decision window will be close to ours. Unfortunately, the decision alternatives they face have very different impacts on our project. The decision options are:

   a. Connect their buildings to our distribution and disposal system.
   b. Connect their buildings only to our disposal system.
   c. Have no interface with their buildings.

   Their five buildings have a heat load of approximately 14.2×10^6 Btu/hour which would require about 600 gpm out of our initial production goal of 2,000 gpm.

2. Problem - Our original project was proposed to be about $9.5 million but DOE offered to provide only $4.9 million. This necessitated that the project be cut back and at the same time some additional funds were raised from EDA and the City. The end result was about $5.5 million available to the project. The problem is when preliminary engineering estimates were completed we needed a total of $8.3 million or $2.8 million more than we had, and the City did not have that kind of funds nor was the City Council, because of the 1% initiative, willing to try raising that amount through bonds or other conventional financial mechanisms available to cities. This problem was further complicated by DOE wishing to cut about $700,000 more out of their original committment.

   Resolution - The Boise Warm Springs Water District committed $625,000 toward the $2.7 million of which they have obligated and spent about $265,000 on new piping. The balance was raised through a drilling fund of about $2 million to develop production wells with the balance through a LID downtown. This resolution has raised the specter of another problem, i.e. the drilling fund being private capital will increase the price per therm of delivered energy even though it will benefit from risk of drilling for water of the right temperature and volume. A further problem was DOE action to cut "contingency" funds from the budget. The effect of this $700,000 cut will not be seen unless the project encounters "contingent" conditions in any of the tasks that have to be completed.

3. Problem - The Boise Geothermal project is a joint effort of Boise Warm Springs Water District, a special utility district of the State and Boise City a municipality. These two governments are totally separate and independent entities. They are sufficiently charry of each other so that in working on this joint project they have not wanted to relinquish any of their individual authorities to a common venture. The problem has been to determine how to make a two headed organization work.

   Resolution - The basic problem created by this dichotomous situation can not be totally resolved The attempt at resolution has involved a number of approaches.

   a. Develop an agreement on definite ground rules for interaction between the governments. This agreement helped to clarify the relationships but has no legal force and effect.
   b. Establish an Executive Committee with members drawn equally (total of four) from BWSWD and the City. This Committee reviews all activity and refers decisions, as appropriate, either to the Boise City Council or BWSWD Board.

4. Problem - The withdrawal of large volumes of water in other parts of the U. S. has resulted in problems of subsidence and interference. The geological engineering solution to this problem is to develop a monitoring program to track changes of ground or water levels. This solution is straight forward but costly. The institutional problem created is one of finding someone to assume technical and financial responsibility for monitoring. The City believes the State should assume this responsibility, and vice versa.

Resolution - The only action taken so far is toward a partial resolution of the problem. The State does not want to assume responsibility because they do not have sufficient financial resources for the purpose (up to $500,000 may be required), and to add insult to injury their budget was again cut in 1981. The absense of some monitoring system poses the future threat of litigation over interference or subsidence, and if that occasion should arise it is critical to have baseline data. The action taken by Boise Geothermal is partial in the sense that we are arranging monitoring equipment to be installed on those wells now in existence and over which we have some control, as well as those we are contemplating drilling in near future. If a complete program would really cost a half million dollars then our level of effort will be a very small fraction of that amount.

5. Problem - The use of a well drilling fund is a relatively efficient method of raising capital. The fund is predicated on committments by the City to purchase water at wholesale prices. These in turn are based on committments by building owners to purchase the water but building owners will not make committments until they know the delivered price of the water. These prices cannot be finally determined until firm bids, on which the price is based, are received for laying the pipeline and drilling the wells. But we cannot drill wells until the drilling fund raises money.

   This is further complicated by (1) the need for building owners to convince themselves that the retrofit and use of geothermal are to their financial benefit, and (2) the prevailing high interest rates.

   Resolution - The needed committments are being acquired in stages.
   a. A preliminary connection agreement has been prepared for signature by building owners. It provides the owners with a maximum price for the water and the drilling fund with a preliminary committment that can be used to raise funds for well drilling. The location and success of these wells will, to a certain extent, determine the pipeline route and cost.
   b. After the wells are proven and bids for the pipeline received a final connection agreement will be signed by building owners that specifies a definite price per therm. This will be backed up by a geothermal service ordinance.
   c. In 1981, in a effort to speed up building owners decision making process, we have offered technical assistance in completing a cursory technical review of in building equipment and financial requirements. This has resulted in no more than four hours per building to identify ballpark figures for retrofit costs and summary evaluations of financial feasibility.

6. Problem - We will be producing up to 2,000 gpm in the initial phase of our project which means, after use, we must provide for disposal of this amount of water. All of the options for disposal are under the regulatory authority of the Department of Water Resources, the U. S. EPA, State Health & Welfare, the Corps of Engineers, or/and the Bureau of Lands. The preferred disposal option is to return waste water to the river. In this case Health & Welfare and EPA would have principal responsibility. EPA requires preparation of an NPDES but, since the volume of water is small by their standards they will not be issuing a permit. On the other hand H & W will only grant

permission for disposal of a limited quantity for an indeterminate period of time. The problem is that we will have permission to dispose of some quantity revocable at any time.

Resolution - This problem is not yet resolved but we are planning some method, perhaps a contract, that will give us discharge permission for, hopefully, a large fraction of the planned useful life of the system. This formalized permission will be required before we invest large amounts of money burying pipes in the ground. We have filed a petition seeking permission to dispose of spent water into the river at a location close to downtown Boise, an action that, if granted, will save some of the cost of disposal pipe.

BOISE CITY PON REPORTS

(Cooperative Agreement No. DE-FC07-79ET27053)

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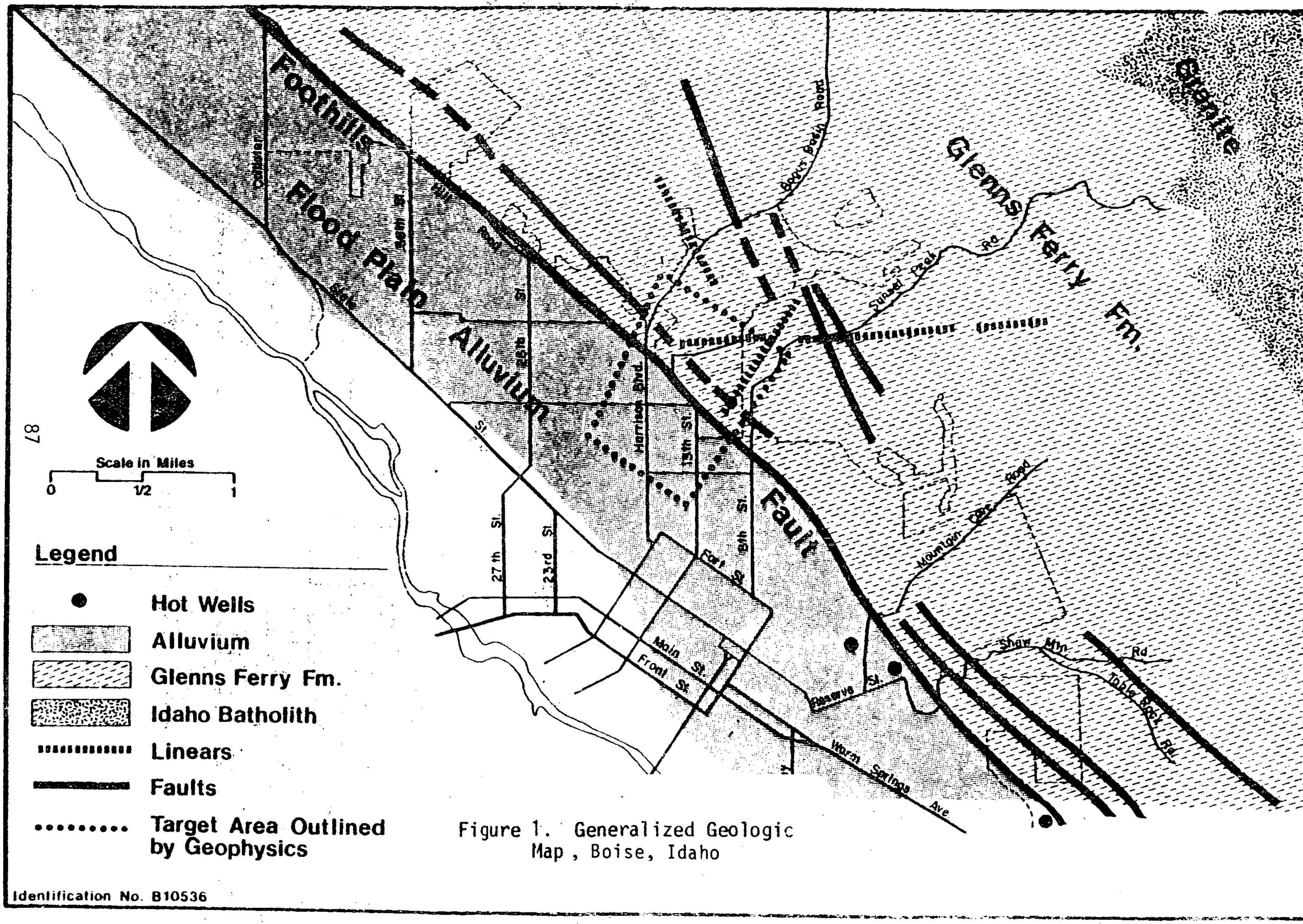

Figure 1. Generalized Geologic Map, Boise, Idaho

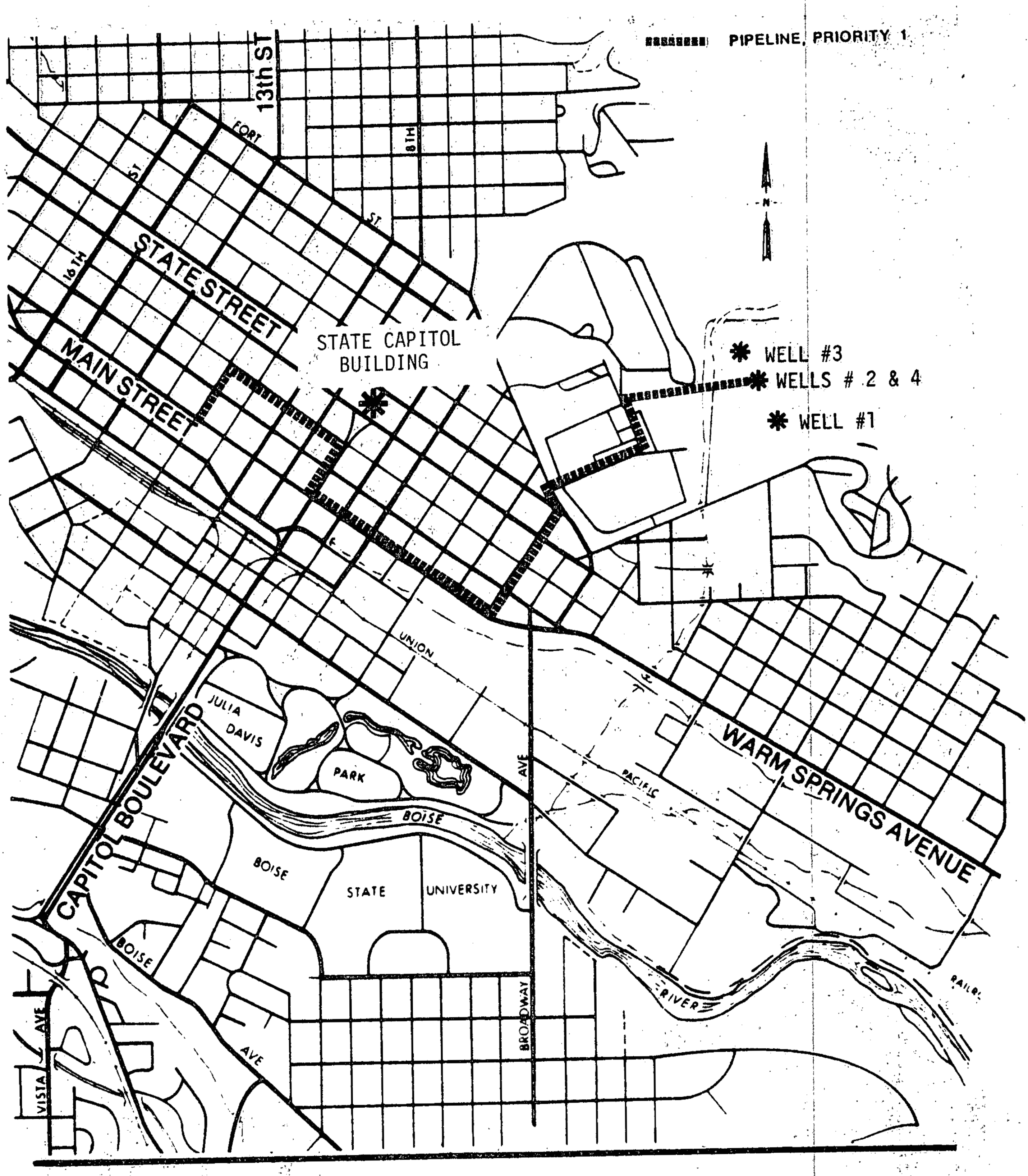

Figure 2. **BOISE CITY GEOTHERMAL SYSTEM PLAN**

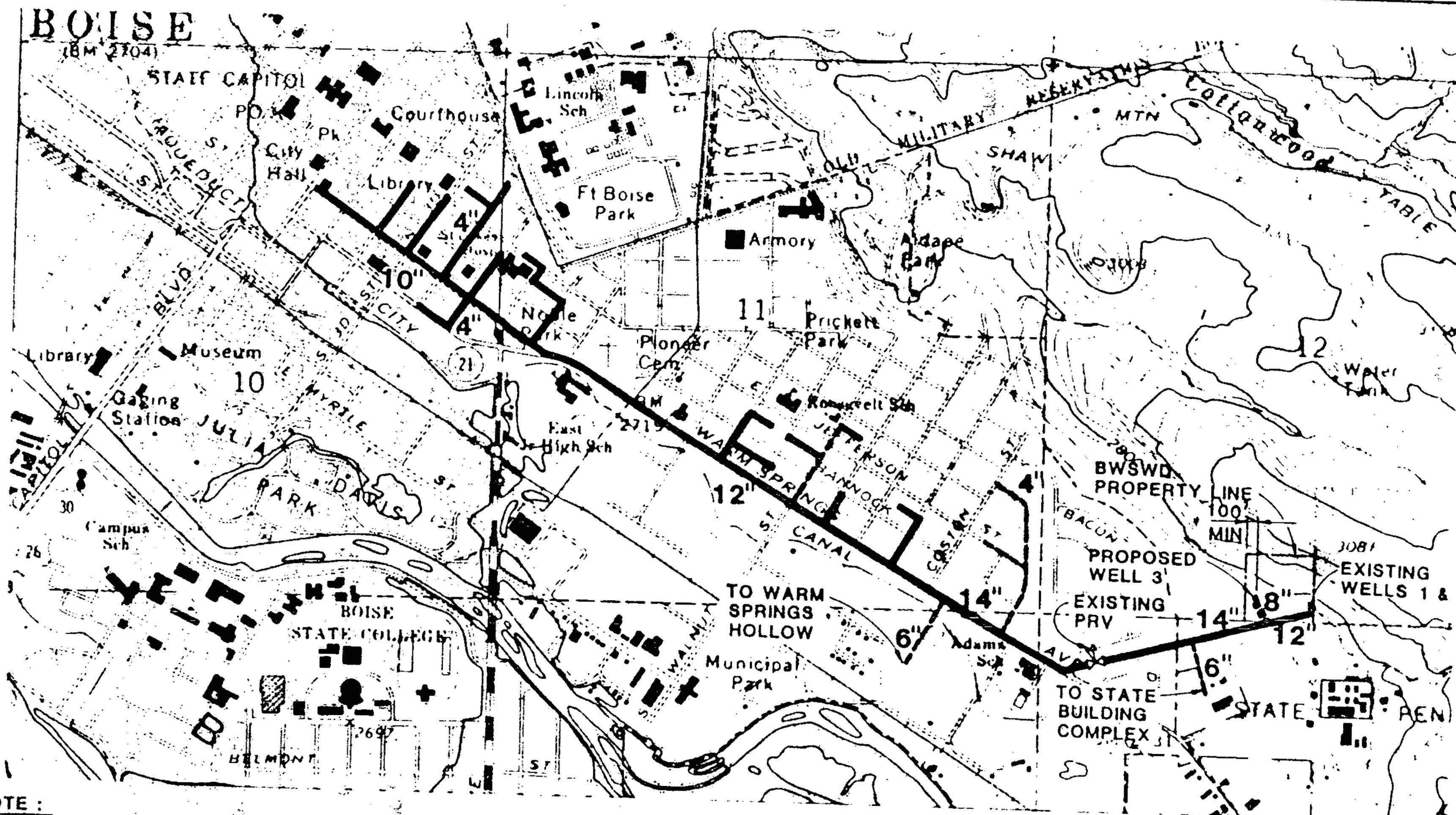
BOISE
(BM 2704)
STATE CAPITOL
Courthouse
City Hall
Library
Lincoln Sch
Ft Boise Park
Armory
Aldape Park
Prickett Park
Noble Park
Pioneer Cem
Library
Museum
Gaging Station
East High Sch
Roosevelt Sch
Campus Sch
BOISE STATE COLLEGE
Municipal Park
Adams Sch
Water Tank
MILITARY RESERVATION
SHAW MTN
Cottonwood
TABLE
AQUEDUCT
CAPITOL BLVD
JULIA DAVIS PARK
MYRTLE ST
WARM SPRINGS AVE
JEFFERSON
BANNOCK
CANAL ST
WALNUT ST
BELMONT ST
10
11
12
4"
10"
4"
12"
14"
6"
4"
14"
8"
12"
6"
TO WARM SPRINGS HOLLOW
BWSWD PROPERTY LINE 100' MIN
PROPOSED WELL 3
EXISTING PRV
EXISTING WELLS 1 & 2
TO STATE BUILDING COMPLEX
STATE PEN
NOTE :
UNLESS NOTED OTHERWISE ALL PIPELINES SHALL BE 2".
BWSWD GEOTHERMAL SYSTEM PLAN
N
LEGEND
NEW LINE
EXISTING LINE TO BE REPLACED
EXISTING LINE TO REMAIN
4" PIPE SIZE
PRESSURE REGULATING VALVE (PRV)
PROPERTY LINE
CH2M HILL

Figure 3.

KLAMATH FALLS GEOTHERMAL HEATING DEMONSTRATION PROJECT

Harold Derrah
Assistant City Manager, (503) 883-5317

ABSTRACT

The City of Klamath Falls is in the process of constructing a geothermal heating demonstration project for the heating of 14 government buildings. The project involves the installation of a primary pipeline to a central heat exchanger facility delivering the geothermal resource. A secondary pipeline will then be constructed with closed loop domestic water for delivery of heat to the 14 buildings all within the Klamath Falls commercial area. Additionally, the project also involved resource confirmation, district boundary identification, and economic evaluation.

PROJECT ACTIVITIES

1. Resource Evaluation

In order to facilitate design and construction of the project, resource evaluation had been completed by Lawrence Berkeley Laboratory and GeothermEx. Supportive data was compiled from research work completed by the U. S. Geological Survey. The data was complied through surface geological evaluation and through two pump tests, one completed in July 1978, and one completed in the fall of 1979. The first pump test was conducted in July 1978. The pump test was conducted to confirm resource potential within the proposed production area. The following is a summary of that test:

> During July, 1978, a pump test was performed on the 795-foot deep well in Site 1. This well has a 14-inch diameter casing to 229 feet and static water level at about 75 feet below the surface. Bottom hole fluid temperature has been measured at 234°F, and dry rock temperatures reported as high as 250°F.

It is estimated that this well is drilled into or is very near the major fault zone of the area. Twelve observation wells were selected within 1500 feet of the production well. Unfortunately, no well in the area extended to the same elevation depth as the production well.

Each of four phases of the test lasted 48 hours:

1. pumping without injection (water wasted to the sewer);
2. rebound;
3. pumping with injection; and
4. rebound.

Personnel from LBL and OIT students assisted in the project.

Observations:

1. Maximum production rate was 300 gpm at 100 foot drawdown.
2. Maximum surface flow temperature at the well head was 224°F.
3. There appeared to be no significant effect on adjacent wells when pumping without injection.
4. There appeared to be a measurable effect on adjacent shallow wells with pumping and injecting into a shallow well.
5. Flow of the production well was limited due to caving and filling of the well below the casing (estimated at 82 feet), which was determined after the test.

With completion of that test program, the decision was reached to proceed to the drilling of the production wells. The second pump test was conducted by the Lawrence Berkeley Laboratory on production well #1. That testing program was to determine the capabilities of well #1, and also to evaluate possible influence on existing wells within the production area. The pump test was conducted over a 15½ hour period at flows of 680 gpm with a discharge temperature of 218^{o}F. The conclusions of the testing program are as follows:

> The tests of the Klamath City Well-1 show that the shallow test aquifer is capable of sustained production of at least 680 at a temperature of about 218^{o}F. Rapid water level changes in the surrounding wells indicate a high degree of hydrodynamic reservoir continuity through several distinct lithologic units. This would indicate that a fracture network may possibly be controlling fluid movement in the reservoir. Calculated transmissivity values from the interference test indicate a permeability of approximately 100 darcies. When the pressure behavior over the 8-hour interference test are extrapolated to several years, drawdowns of 2 to 3 feet are predicted at a sustained production rate of 680. The departure of the data at later times from the Theis curve used for this analysis indicates that water level changes may be larger than the predicted values. At present no unique explanation can be given to account for this departure. To accurately predict the effects of sustained production over the lifetime of this project a longer test must be conducted to determine the effects of reservoir heterogeneity on the water level decline in surrounding wells. Present indications, from reservoir testing at the Klamath Falls, are that this system has a very promising potential for development of a large-scale district heating project, Figure 1.

With the information previously obtained through other studies, and verified by the pump testing program, the City then undertook the next phase of the project. That was completion of design of the pipeline facilities.

2. District Boundaries

A portion of the original grant project was to identify future potentials for commercial heating. In completing this exercise, initial data was collected for the establishment of boundaries for geographic pumping districting for geothermal fluid distrubution. In order to draw the boundaries, research was conducted in the areas of heat load requirements, natural topographical features, man-made features, political boundaries, and existing land uses. Additionally, marketing features, such as commercial uses versus residential uses, were evaluated for their ability to alternately, by time of day and expected times of use, supplement the residential and commercial activities. In establishing boundaries, determination was also made for future storage and peaking facilities. In concluding the boundary studies, the controlling factors that became evident were the natural and man-made features. They included two lakes, a river, a railroad, and an irrigation canal. All of the items mentioned above would have been very costly to cross and influenced the economic viability of the project, Figure 2.

3. Economic Evaluation

The following is the estimated project cost for completing the project:

Item Description	Amount	Status
Production Wells	63,965	Complete
Primary Pipeline	1,269,711	Complete
Secondary Pipeline	790,966	Construction in process
Engineering & Administration	205,468	
Total	$2,330,110 (Cost Share DOE 65%)	

For economic evaluation the lowest cost existing energy source available to the 14 buildings was used for comparison. That energy form is natural gas. Inflation rates were used through a ten-year period escalating natural gas costs to 82¢ per therm. The economic evaluation indicates that at 31¢ per therm the 14-building project would have a payoff in 6.2 years, based on a present worth of 8% and the cost of capital of 8%. A 20-year equivalent cost summary was also completed for the 11-block area. That equivalent annual cost summary, including operation and maintenance costs, shows an annual equivalent cost for geothermal of $216,096 per year versus $576,994 per year for natural gas. It should be noted that in completing the 20-year annual equivalent cost 82¢ per therm for natural gas was used. That figure, by current indications, seems to be very conservative and through the coming 20-year period should escalate considerably higher, placing the geothermal project in yet a more favorable position.

SYSTEM DESIGN

The system design for the project requires collection of the resource through a primary pipeline. The primary pipeline was 8" steel pipe with 2" of insulation (Figure 3). The primary pipeline ran a distance of approximately 4100 feet. The primary pipeline was housed in concrete conduit. The reasons for installing the primary pipeline in the concrete conduit were as follows:

1. Access to the pipes for future taps;
2. Access for future pipeline installation;
3. Other utilities may be readily installed;
4. Better assurance that ground water will not corrode pipe or damage insulation;
5. The lid of the duct is used as a sidewalk, with heat radiating from the pipes providing snow removal; and
6. Provides easy access for maintenance and repair.

The primary pipeline is to deliver the resource to the central heat exchange building. The central heat exchanger building houses the controls for the system, including telemetry to production wells and also various pumps on both the geothermal side and the domestic side. The wells work on both temperature and flow requirement basis, i.e., increased demand on the domestic side would, through telemetry, make known automatically the need for more resource from the geothermal side. The central heat exchanger building will also house the exchangers for the transfer of heat from the geothermal to the domestic. The exchanger used in the Klamath Falls project is the plate heat exchanger with the following characteristics:

Type - Single pass with 150
316 sst plates EPDM gaskets

Size - 9'3" long x 1'7" wide x 5' high
maximum platage

Geothermal side - 219^{o}F Inlet
176^{o}F Outlet
4.3 psig pressure drop
(1,000 gpm maximum flow
with full platage)
350 gpm flow

Secondary side - 200^{o}F Outlet
160^{o}F Inlet
3.7 psig pressure drop
(1,000 gpm maximum flow
with full platage)
378 gpm flow

Cost - $14,000 ea. - 2 required

The advantages and reasoning for going with the plate heat exchanger are as follows:

1. Their superior application for liquid to liquid heat transfer where close approach temperatures are desired;
2. Their excellent efficiency;
3. They need little floor space;
4. Ease of maintenance; and
5. Most importantly, the ability to accommodate changes in flow and temperature conditions by adding or removing plates.

The secondary, or domestic, pipeline is to be constructed of fiberglass reinforced plastic pipe, again with 2" of insulation. The secondary pipe line extends a distance of 7080 feet and is in parallel lines telescoping from a maximum diameter of 10" down to 3" as the line goes to the various buildings. The secondary line is to be direct buried because funds were not available to house it in concrete conduit, as was done on the primary pipeline. The secondary pipeline is sized to service all the buildings along its route should, at some time in the future, those buildings have the ability to receive the resource. The reasons for choosing the FRP pipe for the secondary loop were for cost advantages, low friction factor, corrosion resistance, and it does not require special equipment for expansion allowances.

CURRENT STATUS

The current status of the city's project is that construction is proceeding on schedule, and the primary pipeline and exchange building have been constructed. The secondary pipeline contracts have been bid and the contractor has initiated installation of the line. The anticipated completion of construction, depending upon climate, is for December 31, 1981.

While the engineering and construction have proceeded without any major complications, institutional and political problems have arisen concerning the use of the resource. Existing well owners have, through the Oregon initiative process, passed an ordinance which would require all water pumped from a geothermal well to be placed back in that same well. This particular ordinance is currently under litigation and a preliminary injunction has been issued against its enforcement. A hearing on a permanent injunction is scheduled for the fall of 1981. Regardless of the legality of the ordinance, the existing well owners have made it known that they do not wish the resource to be pumped and injected. Because of the complications surrounding the potential use of the resource from a pumping aspect, the city has developed a contingency plan. The contingency plan provides for the collection along the primary pipeline of existing geothermal fluids which are currently being dumped into the city sanitary and storm sewer systems. The city has identified 500 gpm of 175^{o}F fluids that can be collected into the primary pipeline and run through the exchanger building. It is anticipated that the city will implement this contingency plan for the heating of the 14 buildings.

To meet peaking requirements, the city will tie in the museum well, which was previously designated as the injection well, to provide additional fluids for peaking requirements. Additional backup to peaking requirements to be used with the waste-discharge collection plan is the city swimming pool well, which is directly adjacent to the primary pipeline. There is sufficient BTU's within the discharge fluids and the museum and pool wells to provide the resource to the 14 buildings; however, there will not be enough resource to expand beyond this project.

As indicated above, the project is anticipated to be completed with heat delivery to the 14 buildings in early 1982.

LESSONS LEARNED

1. In the areas with high number of existing users, a fairly in-depth preconstruction survey of use and attitudes should be completed.

2. Existing users should be completely informed; if necessary, by personally delivering letters on pump testing results and on-going monitoring. Public hearings do not suffice in that turn-out of existing users does not develop until they feel threatened. From the City of Klamath Falls experience, once the existing users feel threatened, they cannot believe the data given to them by the Reservoir Engineer.

   Possible ways of information dissemination include:

   A. Establishing individual well recordings on an on-going basis where project representatives have direct contact with the well owners.

B. A newsletter distributed and mailed to all existing well owners providing information the project, on-going monitoring programs, production testing, and other pertinent data.

C. Neighborhood meetings in well owner areas with hand-delivered personal invitations to such neighborhood meetings. The meetings would then generally describe the information in the newsletter and also on an individual basis introduce the techniques involved in the program.

D. Make available personal and initial public presentations to civic organizations regarding the project on an on-going basis and specifically information obtained regarding the reservoir.

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2. Derrah, H., Klamath Falls Geothermal Heating Demonstration Project. In, Program Summary, Direct Heat Applications Program Semi-Annual Review Meeting, Boise, Idaho, September 24-25, 1981.

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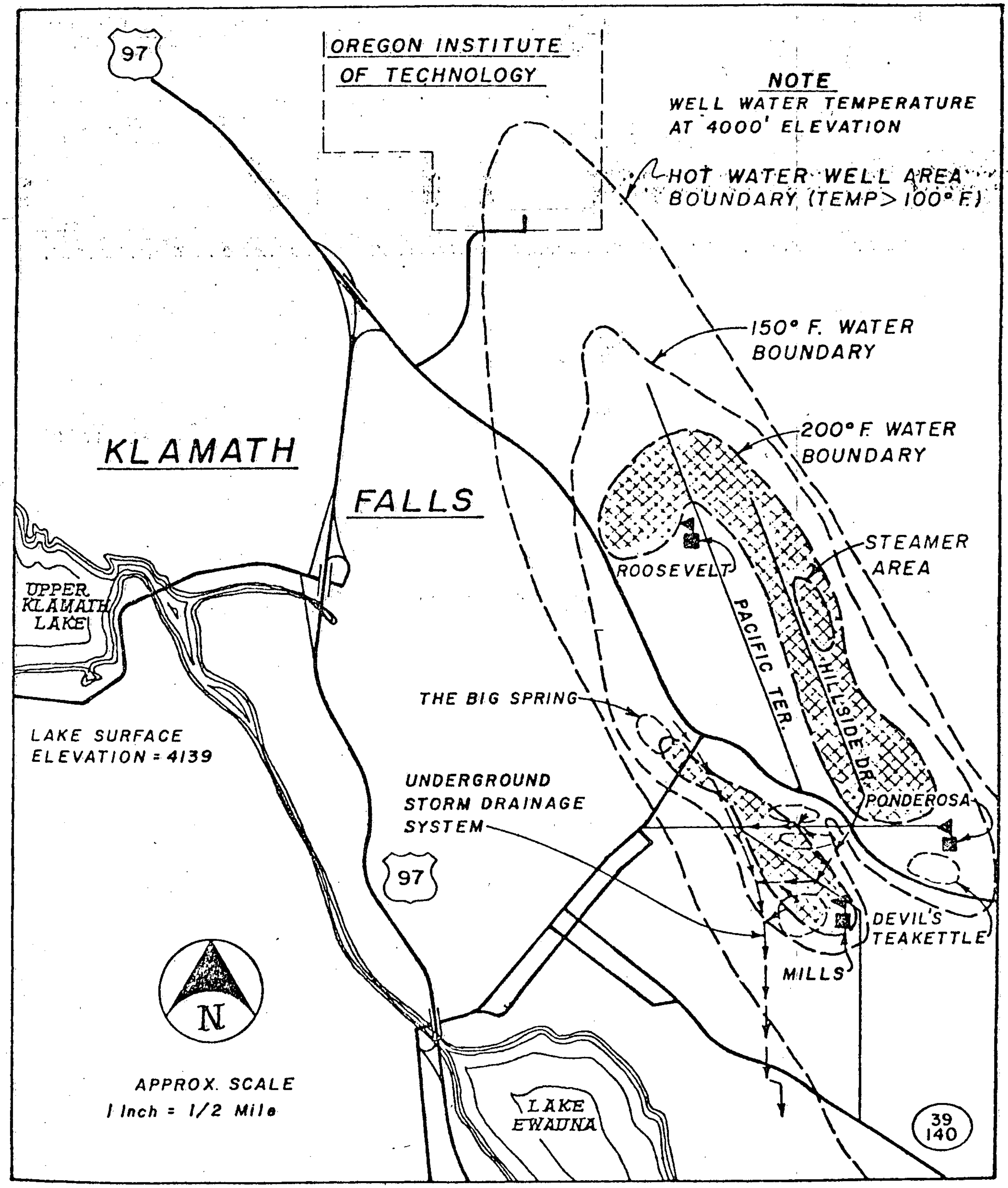

FIGURE 1. Well water temperature at 4000' elevation.

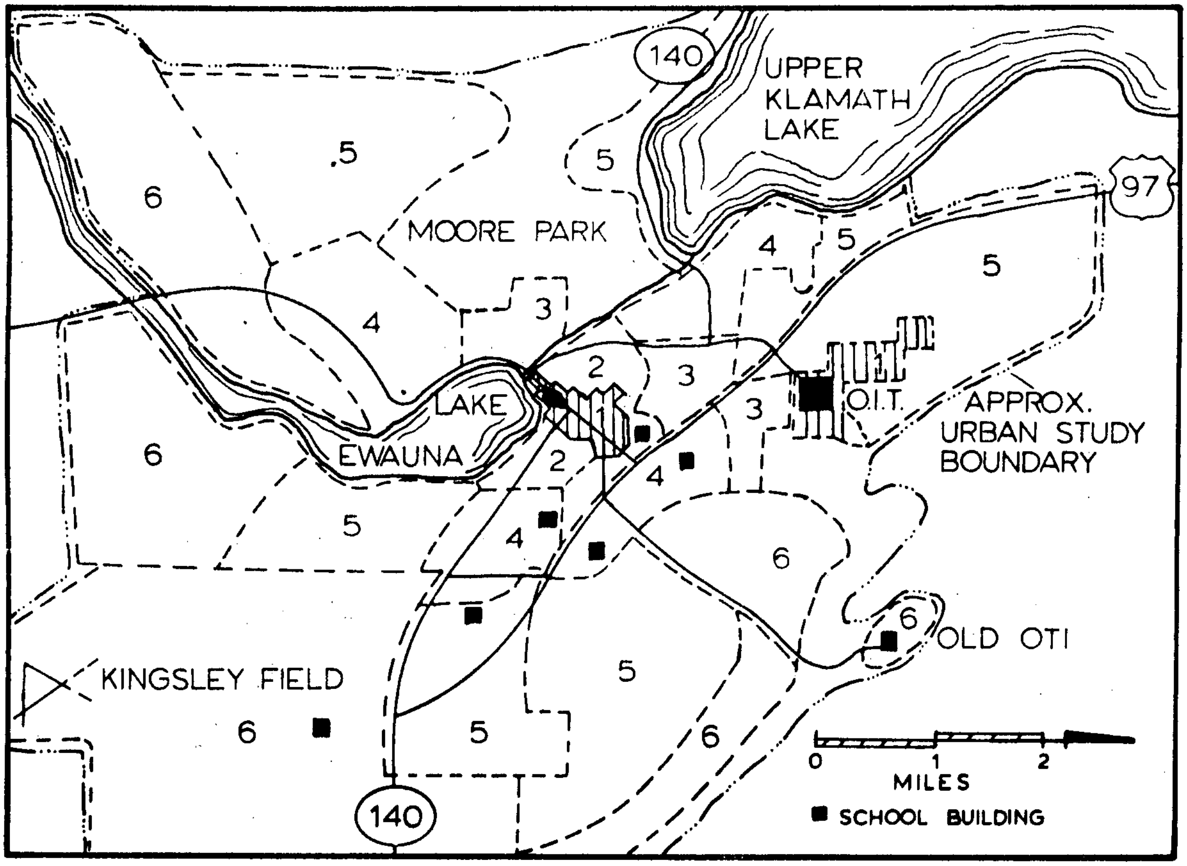

Fig. 2. District heating boundaries

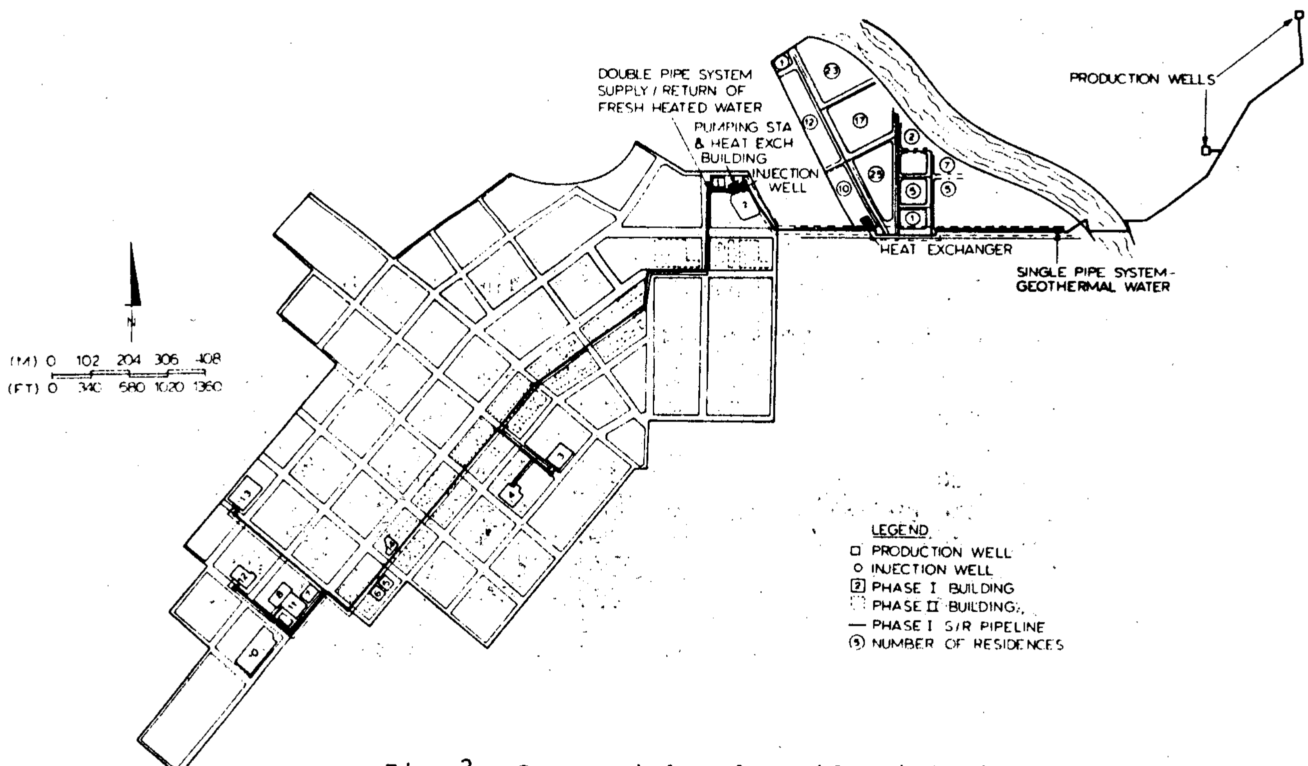

Fig. 3. Commercial and residential district network

SUSANVILLE ENERGY PROJECT

DIRECT UTILIZATION OF GEOTHERMAL ENERGY

LOCATION - NORTH END OF THE HONEY LAKE VALLEY - LASSEN COUNTY, CA

PRINCIPAL INVESTIGATOR: Philip A. Edwardes
66 North Lassen Street
Susanville, CA 96130
Tel: 916/257-7130

PROJECT TEAM

City of Susanville - Project Management
Lahontan, Inc. - Construction Management/Technical Assistance
Koepf & Lange, Inc. - Engineering
Aerojet Energy Conversion Company - Design and Engineering Review
GeothermEx, Inc. - Resource Assessment/Geologists
Energy Technology Engineering Center - Engineering Review

PROJECT DESCRIPTION

RESOURCE

Location The major portion of the identified resource underlays the Southern section of the City of Susanville. (See Figure I)

Production Well Development (Susan I) Drilling was commenced 10-15-80 and concluded 12-2-80. (See Table 1) The contract to drill was on a fixed price basis and, competitively procured, was awarded to the Water Development Corporation of Woodland for $112,600.00. GeothermEx of Berkeley were the geologists.

Based on drilling logs and formation logs, the following stratigraphic sequence was identified in this well:

alluvial section	-	0 - 23m	(0 - 75 feet)
lake beds	-	23 - 85m	(75 - 280 feet)
tuffs	-	85 - 213m	(280 - 700 feet)
lake beds	-	213 - 229m	(700 - 750 feet)
basaltic andesite	-	229 - 248m	(750 - 815 feet)
lake beds	-	248 - 273m	(815 - 895 feet)
basalt	-	273 - 279m	(895 - 915 feet)
lake beds	-	279 - 284m	(915 - 930 feet)

Drilling conditions were far more severe than anticipated resulting in numerous partial cave-ins of the uncased hole. Indications from two (Suzy 9 and 9A) temperature gradient wells drilled by the U. S. Bureau of Reclamation within 17m (55 ft) of the Susan I site had suggested that hard drilling through mildly fractured basalts should be expected.

A trailer-mounted Failing JEA-A Reverse Circulation Drilling Rig was used. Water for drilling was pumped from the Susan River into a pit located next to the rig. This water was the only fluid used - no mud, gel, foam or other lost circulation material was used. Table II shows final well design and dimensions. The permeable zones were defined in the 116 - 200m (380 - 656 ft) range and constitutes the prime production aquifer, contribution from minor permeable zones to total depth contribute to total flow.

Flow Rates and Temperature   Temperature throughout testing has remained at a constant 80°C (175°F).

Preliminary short-term pump tests of Susan I were conducted December 4 - 6, 1980 at rates from 9.5 - 44 L/s (150 - 700 gpm) with the major pump test conducted at 22 L/s (350 gpm). Further pump tests were initiated 8-15-81 and are currently continuing and confirm the results and interpretation of the initial tests. Constant flow at 44 L/s (700 gpm) causes a drawdown of 43m (140 ft). (See Table III). Drawdown stabilized in 1.5 hrs. and recovery was within 30 sec.

Conclusion   Although a fixed price contract causes costs to be somehwat higher than alternatives, in the case of the Susan I well, the decision on analysis was justified. Cost of the well was 10% higher than budgeted; however, the success of the test results indicate that a proposed second well is not necessary.

Fluid Chemistry   Table IV defines the chemistry of the geothermal fluids from Susan I well. Initial indications from the California Health Department suggest that the fluids fall within acceptable health limitations and may be used for direct consumption, opening up an interesting potential to utilize cascaded fluids in a mix with city domestic water supplies to raise the ambient temperature of water deliveries to homes in the winter months, thus saving considerably on electrical consumption throughout the City.

From earlier water analysis, no indications of H_2S or excessively high levels of sulphates had been evident and design and engineering had proceeded without major concern for water quality with recognition that changes might be necessary before the procurement process or as addendum to contract packages already in the procurement process.

DESIGN

The layout of the geothermal supply line is shown in Figure I. Table 5 depicts the buildings to be retrofitted and Table 6 identifies the various retrofit options for these buildings. Figure 2 shows climatological data for Susanville. Figures 3, 4, and 6 show proposed approaches for modifications of various existing heating systems, and Figure 5 shows the comparison of heat pump and fossil fuel boiler.

Unique Features The use of geothermal energy (a renewable energy resource) for: 1) Space heating and domestic hot water purposes; and 2) Economic development purposes by cascading the residual energy from the Heating District through an Industrial Park, thus displacing high cost fossil fuels and electricity.

System Economics A preliminary economic analysis of the project has been conducted that would indicate a selling price of $5.00 per million Btu for geothermal energy. No cost of money was considered and the following criteria utilized:

1) Depreciation -

Pumps and equipment	10 years
Wells	20 years
Pipeline, etc.	30 years

2) Normal administrative and maintenance cost
3) Electrical cost of 4¢/Kwh
4) A commercial A & E cost charged in proportion to the depreciation at 30% of capital cost
5) Two production wells producing 19 L/s (300 gpm) @ 30° F ΔT

6) Load factor of 40%
7) Well temperature of 76°C (170°F)
8) Oil price of $7.14 per million Btu

If one then charges geothermal energy to the retrofitted buildings at $5.00 per million Btu, it is possible to obtain a payback on the retrofit cost (without allowing for cost of money) within a 9-year period.

STATUS

Technical Scope   The objective was to develop one or two production wells capable of a total production of 42 L/s (660 gpm) at 70°C (160°F) anticipated not to exceed 275m (900 ft) in depth and requiring a 25 - 30cm (10 - 12 inch) casing cemented to prevent fresh water intrusion at 100m (328 ft). Injection will take place via a simple reinjection well situated in an area outside the main production zone.

Production from the one/two production wells will pass into a 50,000 L (13,000 gal) surge tank and be distributed to the main line via a transfer pump into a distribution system consisting of approximately 1,550m (5,000 ft) of insulated 15 - 20cm (6 - 8 in) main line with approximately 1,200m (4,000 ft) of return line consisting of 10 - 15cm (4 - 6 in) uninsulated transite. Fourteen public buildings along the route of the transmission line are to be retrofitted. (See Table 5)

Planning to eventually utilize the return effluent fluids from the Heating District in a Park of Commerce is concurrent with the anticipated DOE-funded construction phase. This effort is being carried out by the City of Susanville.

The originally proposed scope of the project envisioned three production wells, two injection wells and a distribution system encompassing at least 17 pbulic buildings. The major reasons for a cutback in anticipated scope arose from an enormous escalation in component cost due to inflation and the unanticipated high cost of retrofitting existing heating systems; particularly the low pressure steam systems that became apparent only through the design and engineering effort conducted in Phase I of the DOE Contract.

Schedule   The construction effort currently nearing completion is expected to go into a full system checkout and trail period commencing September 15, 1981 and be completed by October 15.

Costs The original proposal anticipated that at least 17 public buildings and associated distribution lines, resource development and associated software efforts could be accomplished for $2,372,378.00.

Bue to cutbacks, escalating costs and identified higher retrofit costs as a result of the design and engineering effort, it is anticipated that the $1.67 million available for construction will be sufficient for the reduced program scope.

Cost Share The cost share rates for Phase I was 97.77% DOE and 2.23% City of Susanville. The Phase II effort is anticipated to be at a similar level. Recent participation by the County of Lassen in the retrofit costs of their facilities will effect upward the level of local participation.

Areas of over/underrun The total project is currently expected to be completed within allocated funds.

PROCUREMENT PROCESS

Extensive use of Building Exchanges (10) and the Daily Pacific Builder (a California contractor daily newspaper), plus normal advertising in local newspapers and information dissemination to major pipeline, pump, heat exchanger manufacturers and to the construction industry caused above-average responses by contractors to the bid process.

A standard procurement package was developed:

Part A - contained City requirements and special conditions

Part B - addressed all Federal and State requirements

Part C - contained specifications

This allowed for a speedy approval process despite the many agencies involved.

Production Well (Susan I)

Fixed price	$112,600
Drilling commenced	October 15, 1980
Drilling completed	December 2, 1980
Contractor	Water Development Corporation, Woodland, CA

Pipeline

Fixed price	$347,369
Commenced	June 1, 1981
Completed	September 7, 1981
Contractor	Valley Engineers, Inc., Fresno, CA

Approximately 1,700m of 20cm (5,500 ft. of 8 in) Temptite transmission line, plus 1,700m of 10 - 20cm (5,500 ft. of 4 - 8 in) Transite return line direct buried 1 m (3 ft) below grade. Pipeline was surrounded by a 8cm (3 in) layer of 10mm (1/2 in) gravel. Fifteen major 1.2m x 1.2m x 2m (4' x 4' x 6') Valve Boxes are provided plus future takeoff points at each street intersection. Pipeline route was through existing streets requiring replacement of black top and tunneling underneath highway.

This contract was completed with a minor change order of $3,000 caused by the presence of an old motor car and sewerage pipe encountered in the tunneling of Main Street requiring the resetting of a Valve Box 0.6m (2 ft) lower than anticipated.

Overall, an excellent job completed on schedule.

Production Pump

Fixed price	$33,700
Ordered	April 15, 1981
Delivered	August 15, 1981
Contractor	E. E. Luhdorff Company, Woodland, CA

Supply of one Peerless Pump with capacity of 50 L/s (800 gpm) from a pump set of 49m (160 ft) and drawdown of 46m (150 ft) plus motor of 60 h.p. rating. Zinc free bearings throughout.

Installation and checkout completed, an excellent installation.

A long lead purchase item, factory delays caused further delivery problems. No cost changes.

Well Head Equipment, Electrical, etc.

Fixed price	$105,300
Construction commenced	May 11, 1981
Construction completed	September 15, 1981
Contractor	Dana W. Knudsen, Fort Jones, CA

Supply and installation of 50,000 liter (13,000 gal) insulated Surge Tank, two surface pumps, electrical control gear, temperature and flow meters, valving, etc.

Some delays in obtaining valves and recording equipment.

Cooling Tower

Fixed price	$10,000 installed
Ordered	December 17, 1980
Delivered	April 29, 1981
Contractor	Lassen Heating and Air Conditioning Susanville, CA

Supply of one Baltimore Cooling Tower for pump test to allow geothermal fluids to be disposed of in a local irrigation ditch by cooling fluids from 80°C - 55°C (175°F - 130°F) prior to disposal.

Tower performs to specifications and certainly provides a necessary safety factor. No cost changes.

Retrofit Lassen High School Complex (11 buildings)

Fixed price	$427,700
Awarded	June 29, 1981
Completion Estimate	September 30, 1981
Contractor	E. H. Morrill Company, Berkeley, CA

Retrofit existing space heating facilities and domestic hot water system.

Delay of 3 weeks caused by City's decision to change to stainless steel after award of contract in light of new water chemical analysis information. Additional cost of $15,000 incurred by this change.

Retrofit of Washington School Complex

Fixed price	$40,600
Contract awarded	June 29, 1981
Contract completed	September 15, 1981 (estimated)
Contractor	Lane's Builders, Burney, CA

Retrofit of space heating and domestic hot water system.

Heat Exchanger delivery caused 4 week delay.

Injection Facility Use of existing abandoned well with provision for second injection facility following full system checkout August 15, 1981.

Conclusion Construction, on the whole, has been completed within ancitipated time frame. Cost of retrofits have been considerably higher than anticipated. However, lower cost of pipeline and success of the first production well has allowed project completion to occur within projections.

Strong construction management and the ability of the Project Office to make decisions (thanks to the support of Hilary Sullivan and Rick Visoria) in a timely manner have kept change orders below 1% of project awards.

The quality of subcontractors has been most rewarding, certainly contributing to a relatively trouble-free construction effort.

LESSONS LEARNED - CONSTRUCTION PERIOD

Time allocated for the procurement process was underestimated. Review processes, particularly where cities are involved, tend to be lengthy.

In the current economy, nothing is available "off the shelf"; 6 to 8 weeks delivery for most mechanical components appeared to be the norm.

Standardization of bid packages saved considerable contract management and legal time.

Extensive use of the various Builders Exchanges and the Daily Pacific Builder considerably enhanced the number of responses to advertised bid packages.

Contracts with a face value of less than $400,000 failed to attract significant response, and therefore, limited competition in the bid process.

The use of a Construction Management Team was a definite benefit to the project and also appreciated by the subcontractors. Decisions, if necessary, could be made instantaneously in the field thus minimizing downtime.

Extensive detail in the specification packages minimize misunderstandings. Extensively detailed design drawings are possibly not necessary when specifications are extensive and definitive.

Excellent initial resource evaluation considerably enhanced program engineering and project progress.

Rampant inflation required license for creative thinking and decision making in order to remain within budget.

Conclusion Without extremely close communication between DOE-SANS Office, Project Team, Project Office and the Subcontractors, the timely review process conducted by DOE/SAN and ETEC, the Susanville project undoubtedly would have been in a serious overrun situation.

Direct Use Application Projects Bibliography

Susanville

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2. Susanville, City of, Susanville Energy Project - Direct Utilization of Geothermal Energy. Prepared for U. S. Department of Energy, July 1978. Proposal SG 071878, Vol. I - Summary Data and Technical Proposal. Vol. II - Business Proposal and Cost Proposal.

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Susanville (cont.)

13. Edwardes, P. A., Susanville Energy Project Direct Utilization of Geothermal Energy. In, Program Summary, Geothermal Direct Heat Applications Semi-Annual Review Meeting, Boise, Idaho, September 24-25, 1981.

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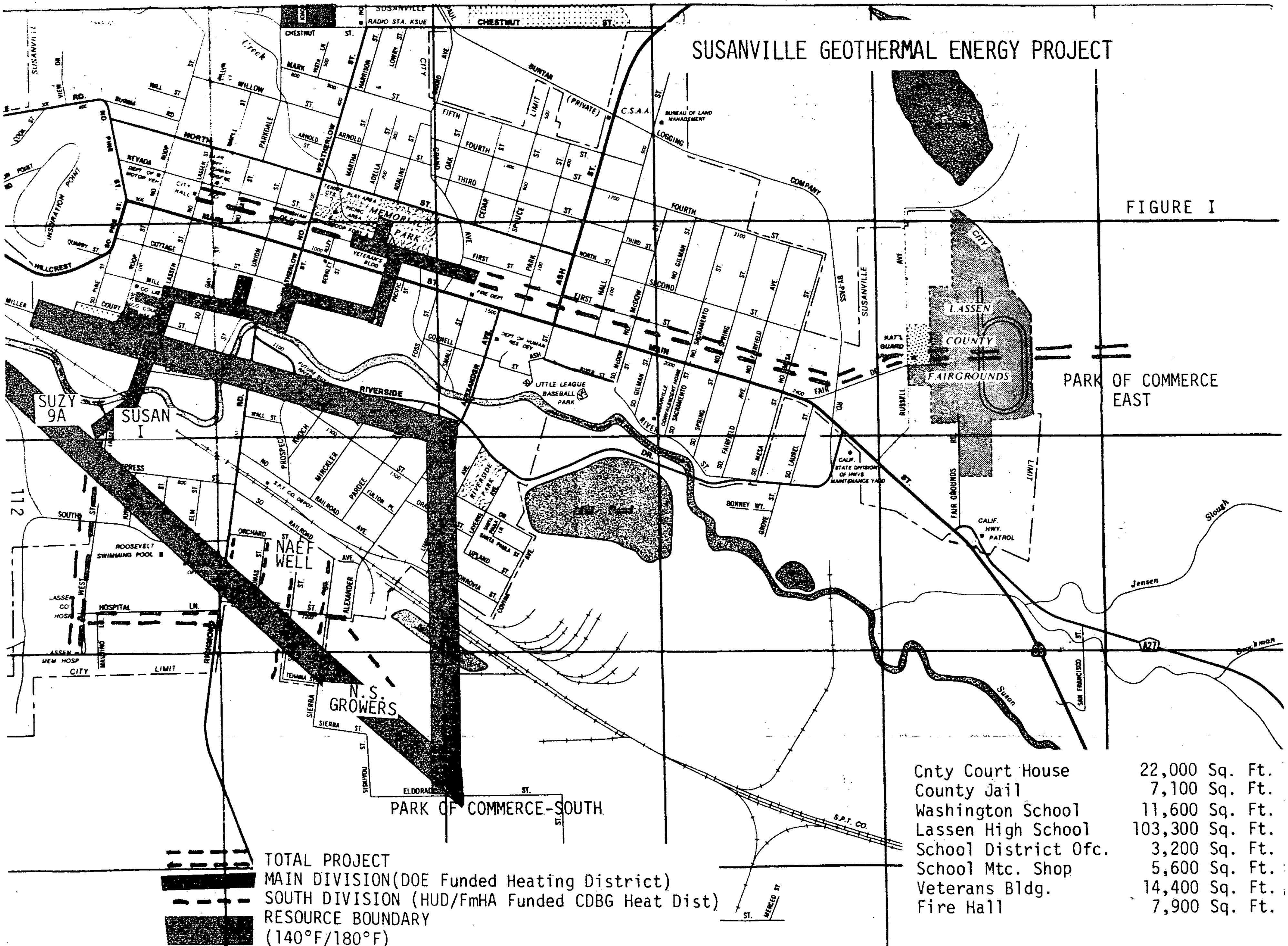


Cnty Court House	22,000 Sq. Ft.
County Jail	7,100 Sq. Ft.
Washington School	11,600 Sq. Ft.
Lassen High School	103,300 Sq. Ft.
School District Ofc.	3,200 Sq. Ft.
School Mtc. Shop	5,600 Sq. Ft.
Veterans Bldg.	14,400 Sq. Ft.
Fire Hall	7,900 Sq. Ft.

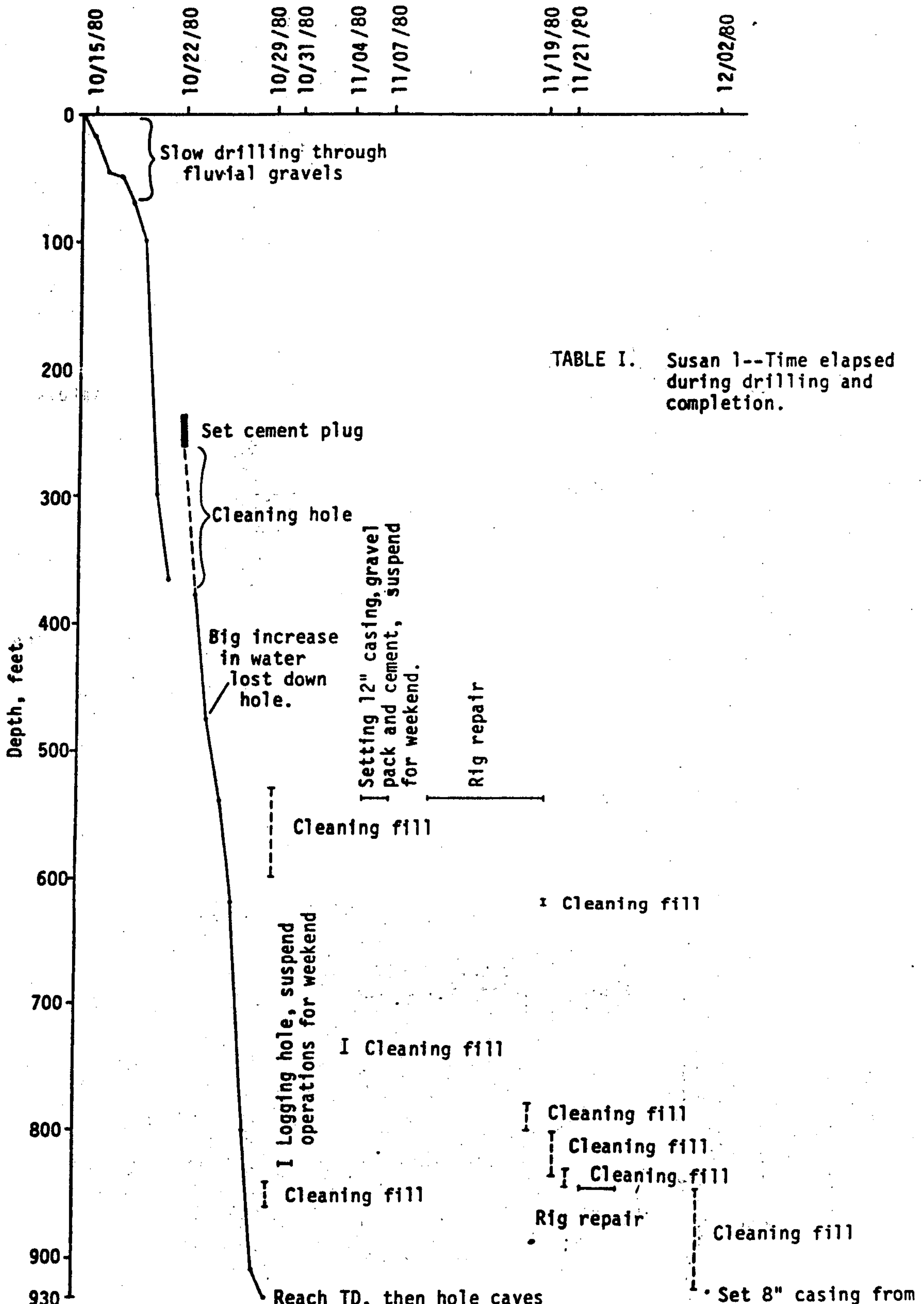
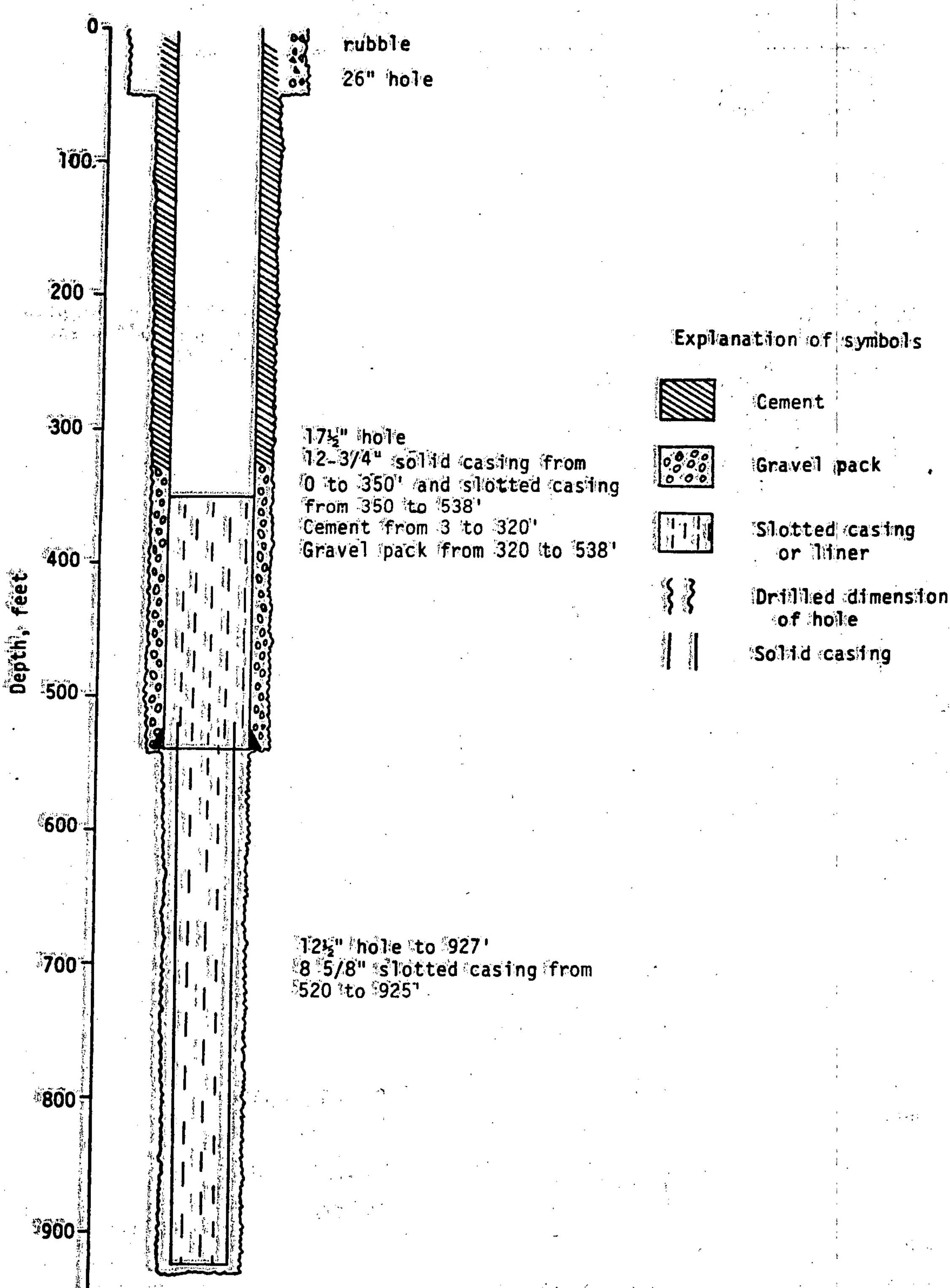


TABLE I. Susan 1--Time elapsed during drilling and completion.

GeothermEx, Inc., 1981

TABLE II. Susan 1 -- Final well dimensions.



GeothermEx, Inc., 1981

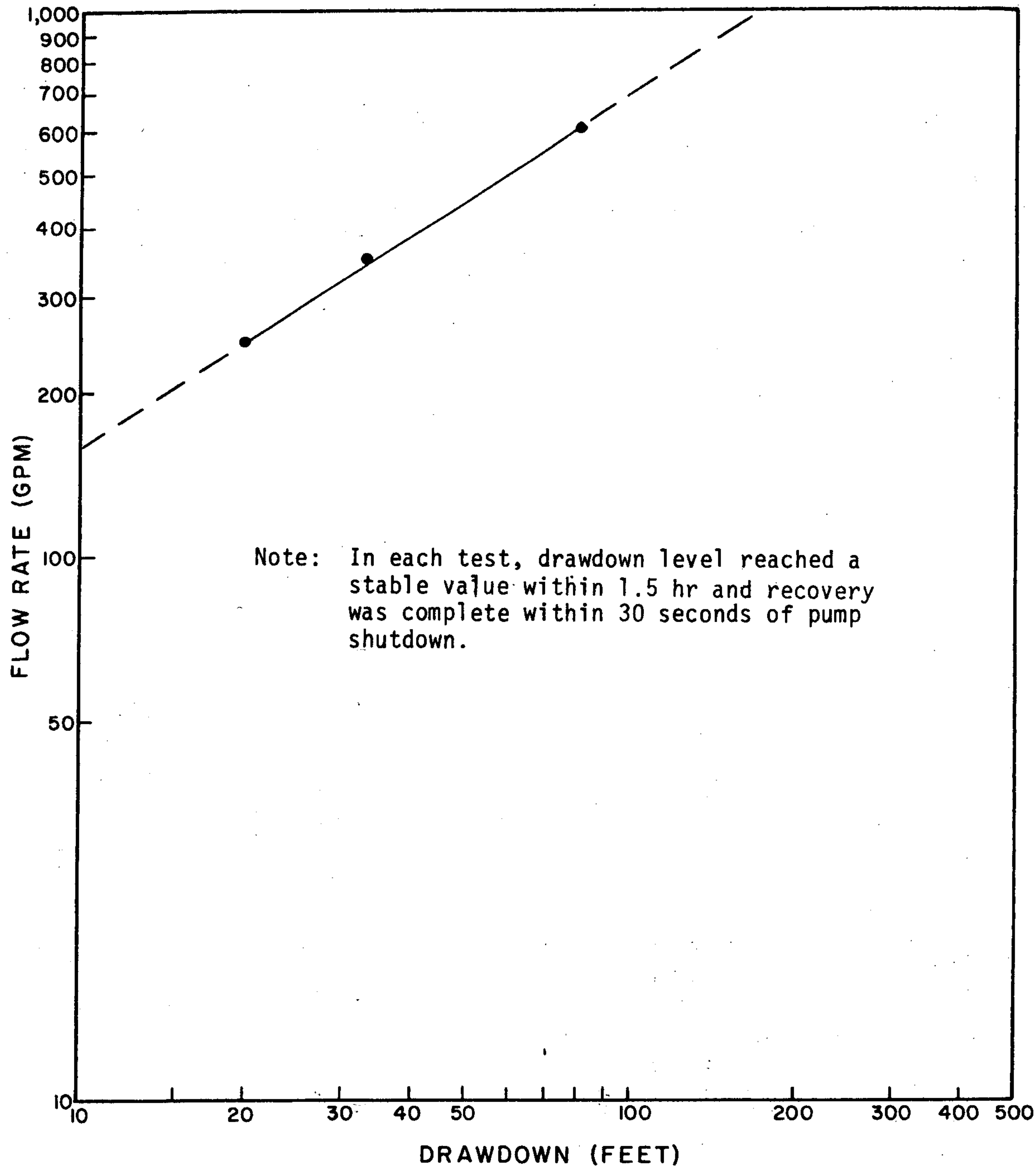


TABLE III. Deliverability of Susan 1.

(•)Short term flow test, 4 - 8 hours at each of 3 rates of flow.

TABLE IV.

Chemical analyses of water from Susan 1, Suzy 9A, and nearby wells.

Sample Number	Sample Date	Temperature, °F	Concentration, in parts per million											Calculated TDS	Field pH	Lab pH	Water Type
			Na^+	Ca^{++}	Mg^{++}	K^+	Cl^-	SO_4	HCO_3	CO_3	OH^-	B	SiO_2				
Suzy 9A-1	2/15/80[3]	165	215	76	2	5	120	320	34	0		2.00	-	757	6.5	8.1	
Suzy 9A-3	2/27/80[3]	165	205	32	1	6	120	294	37	1		3.08	-	680	6.5	8.4	
Suzy 9A-4	2/27/80[3]	165	203	30	1	6	119	294	35	1		2.46	-	674	6.5	8.4	Na>>Ca>>K SO_4>Cl>>HCO_3
Suzy 9A-5	2/27/80[3]	165	207	36	1	6	120	307	35	0		3.04	-	698	6.5	8.2	
Suzy 9A-6	2/27/80[3]	165	205	34	1	6	119	301	37	0		3.04	-	688	6.5	8.3	
Susan 1	11/23/80[4]	164	245	30	0.351	6.80	127	379		7.80	2.52		82.6	881		8.91	Na >>Ca>>K SO_4>Cl>>CO_3

TABLE 5

SUSANVILLE PUBLIC BUILDINGS

	SIZE SQ FT	YEARLY FUEL CONSUM GAL	TOTAL HEAT LOAD 10^6 BTU/HR	PERCENT GEO CONVERS %	GEO FLOW GPM
COUNTY COURT HOUSE	22,000	10,300	1.26	32	24
CITY AND COUNTY JAIL	7,100	7,700	.37	100	36
WASHINGTON SCHOOL	11,600	7,200	1.56	100	67
LASSEN HIGH SCHOOL	139,000	114,500	7.23	66	340
SCHOOL OFFICE	3,200	4,000	.21	100	11
SCHOOL MTC. SHOP	5,000	9,520	.76	74	28
VETERANS BLDG.	14,400	7,500	.6	67	20
FIRE HALL	7,900	8,000	.36	100	40
TOTAL	210,200	168,720	12.35	80	566

TABLE 6

SUSANVILLE PUBLIC BUILDING CONVERSIONS

BUILDINGS	RADIANT FLOOR PIPES DIRECT ATTACH THRU HEAT EXCH	PROPANE CEILING UNITS REPLACE W/HOT WATER UNITS	HOT WATER FORCED AIR ADD HOT WATER COILS	DIR FIRED FORCED AIR ADD HOT WATER COILS	STEAM-WATER FORC AIR DIRECT ATTACH OR HEAT PUMP AUGMENTATION	STEAM RADIATOR REPL W/ CONVECTORS OR HEAT PUMP
CO. COURT HOUSE						X
CITY & CO. JAIL			X			
WASHINGTON SCH.	X					
LASSEN HIGH (11 Bldgs)					X	
SCHOOL OFFICE				X		
SCHOOL MTC SHOP		X				
VETERANS BLDG.						X
FIRE HALL			X			

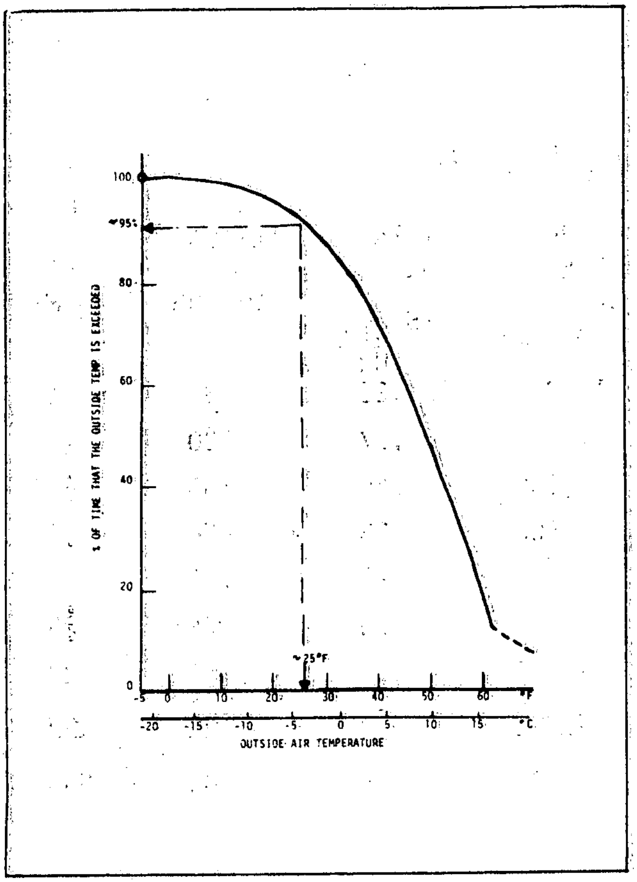


Fig. 2 Susanville climatological data

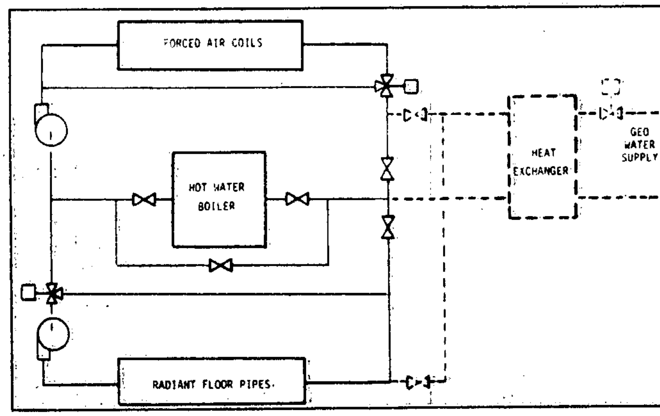


Fig. 3 Modification for radiant heating system

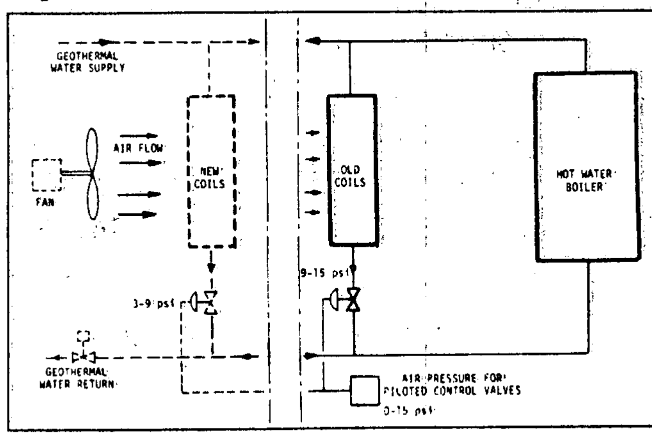


Fig. 4 Modification for forced air coils

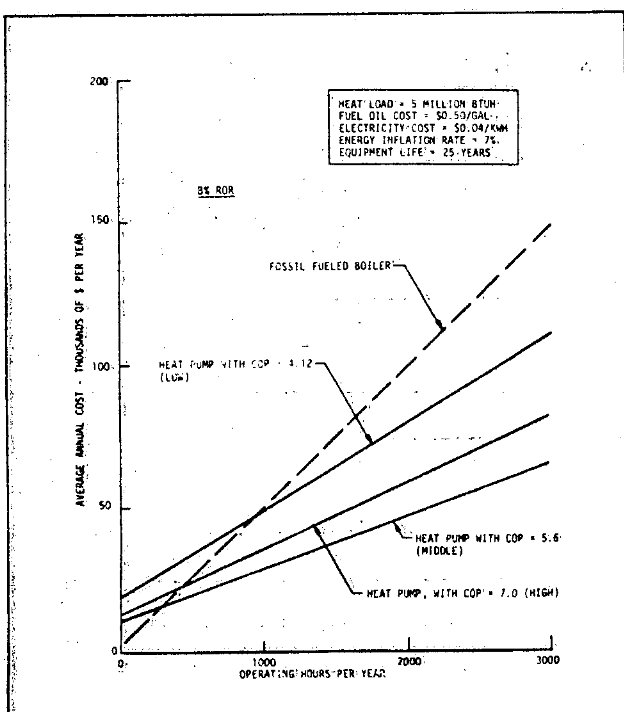


Fig. 5 Comparison of heat pump and fossil fueled boiler

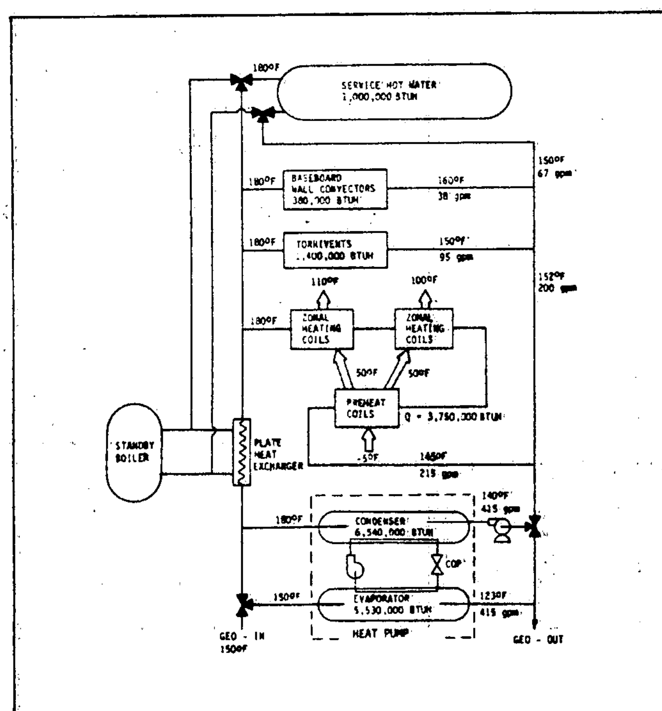


Fig. 6 Modification for additon of heat pump

PROJECT TITLE: Floral Greenhouse Industry Geothermal Energy Demonstration Project

PRINCIPAL INVESTIGATOR: Ralph M. Wright, Chairman of the Board
Utah Roses, Inc. (801) 295-2023

PROJECT TEAM: Utah Roses, Inc.
Energy Services, Inc.

PROJECT OBJECTIVE: To demonstrate to the public the potential offered by geothermal space heating in a highly populated area, by using geothermal heating in a commercial application.

LOCATION DESCRIPTION: Sandy, Utah (Figure 1)
13 miles (21 km) south of Salt Lake City
Population: 51,227; Metropolitan area of 50,000
Area Activities: Agriculture, light industry and commercial development

RESOURCE DATA:

Well Depth: 5009 ft (1527 m)

Date Complete: 12/8/79

Completion Technique: Slotted Liner

Wellhead Temperature: 124°F (51°C)

Flowrate: 230 gpm (14 l/s) with pumping

Summary: Several wells in the area of Utah Roses have shows of warm water, including one within 100 yards (91m) of the site, which has 93°F (34°C) water. The present well was drilled into loosely consolidated sandstone formations beneath the Utah Roses property, and encountered the primary production of 132 to 140°F water at 2800 to 3800 ft.

SYSTEM FEATURES:

Application: Greenhouse space heating

Heatload (Design): 4.9×10^6 Btu/hr. (1.44 MW) geothermal handles full load to 35°F outside temperature

Yearly Utilization (Maximum): 20×10^9 Btu (0.67 MW-Yr) estimated

Energy Replaced: Fuel oil – 40,000 gal. presently used only for peaking
Natural gas – 14×10^6 cu. ft.

Facility Description: Six acre (24,300 m^2) commercial greenhouse

Disposal Method: Surface discharge to adjacent canal.

Summary: The Utah Roses facility, in a rapidly growing suburb of Salt Lake City, used $130,000 of fossil fuels during the winter of 1979–80. It is anticipated that the well will provide 50% of the heating for the greenhouse which produces cut roses for the national floral market.

It had originally been expected that the geothermal well would provide 100% of the greenhouse heat. However, the relatively low temperature and flow limit the amount of heat available from geothermal to 25% of the peak heat load, which is estimated to provide 50% of the total annual load. However, Utah Roses has decided to replace the existing fiberglass greenhouse cover with a double-wall inflated polyethelene cover. This will reduce the required maximum heat load by 19%, thus allowing geothermal to provide 65 to 75% of the total annual requirement.

STATUS:

The well is completed. Approval for discharge of the geothermal fluids has been obtained from the Utah State Department of Health and the Utah State Engineer. The NPDES permit for surface discharge to the Jordan River has also been received.

The NPDES permit was delayed (see Lessons Learned, below) for a full heating season. The project schedule now calls for installation of the heating system in the greenhouse, the well pump and delivery system, the discharge system, and a part of the new greenhouse cover by Sept. 30, 1981. Operation of the system will commence at that time. Evaluation of the double poly cover on the greenhouse will be conducted in the winter of 1981–82, and installation of the balance of the cover will be done in the summer of 1982.

CURRENT ESTIMATED PROJECT COST:

Total:	$856,200		
DOE Share:	$478,312 56%	Participant Share	$377,888 44%

TOTAL EXPENDITURES TO DATE:

$435,733	$22,787

LESSONS LEARNED:

The project has been delayed for one full heating season by delays in obtaining state and federal discharge permits. The bulk of this delay came as a result of a misunderstanding of the proceedure followed by EPA in issuing the NPDES permit. The permit was applied for before the project began, and went through the normal 180-day period of public notice, public comment, and other administrative functions. During the 180-day period, EPA, through discussions with project personnel, was encouraged to at least issue temporary authority for discharging during well drilling and testing. This permission was given, just in time for each procedure to be conducted.

Upon completion of the well, the Utah State Dept. of Health was asked to give permission for the discharge, and the project manager was told that once Utah State had approved, the EPA would issue a permanent discharge permit (for a 5-year period, which is their maximum.) However, when the state approval was obtained in October, and EPA was asked to issue the NPDES permit, the project manager was informed that a new application would have to be processed by EPA. EPA would attempt to expedite the process in 90 days, but this effort failed. A permit was issued in May 1981. Also, it has been learned that this is not a new permit, but only a revision of the original temporary permit, and so the time period is not extended, but expires 5 years from the first issuance, which leaves only 3 years of heating seasons before the permit will become subject to review. One can only hope that any changes in the governmental regulatory philosophy in the next 3 years will be for the better.

UTAH ROSES FLORAL GREENHOUSE PON REPORTS

(Contract No. DE-AC07-79ET27056)

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6. Energy Services, Inc., Environmental Supplementary Analysis Pertaining to the Discharge of Geothermal Fluids from the Utah Roses, Inc., Geothermal Well at 567 West 90th South into the Galena Canal, (Utah Roses Report No. UR-G-79-1A, Contract No. DE-AC07-79ET27056), October 1980.

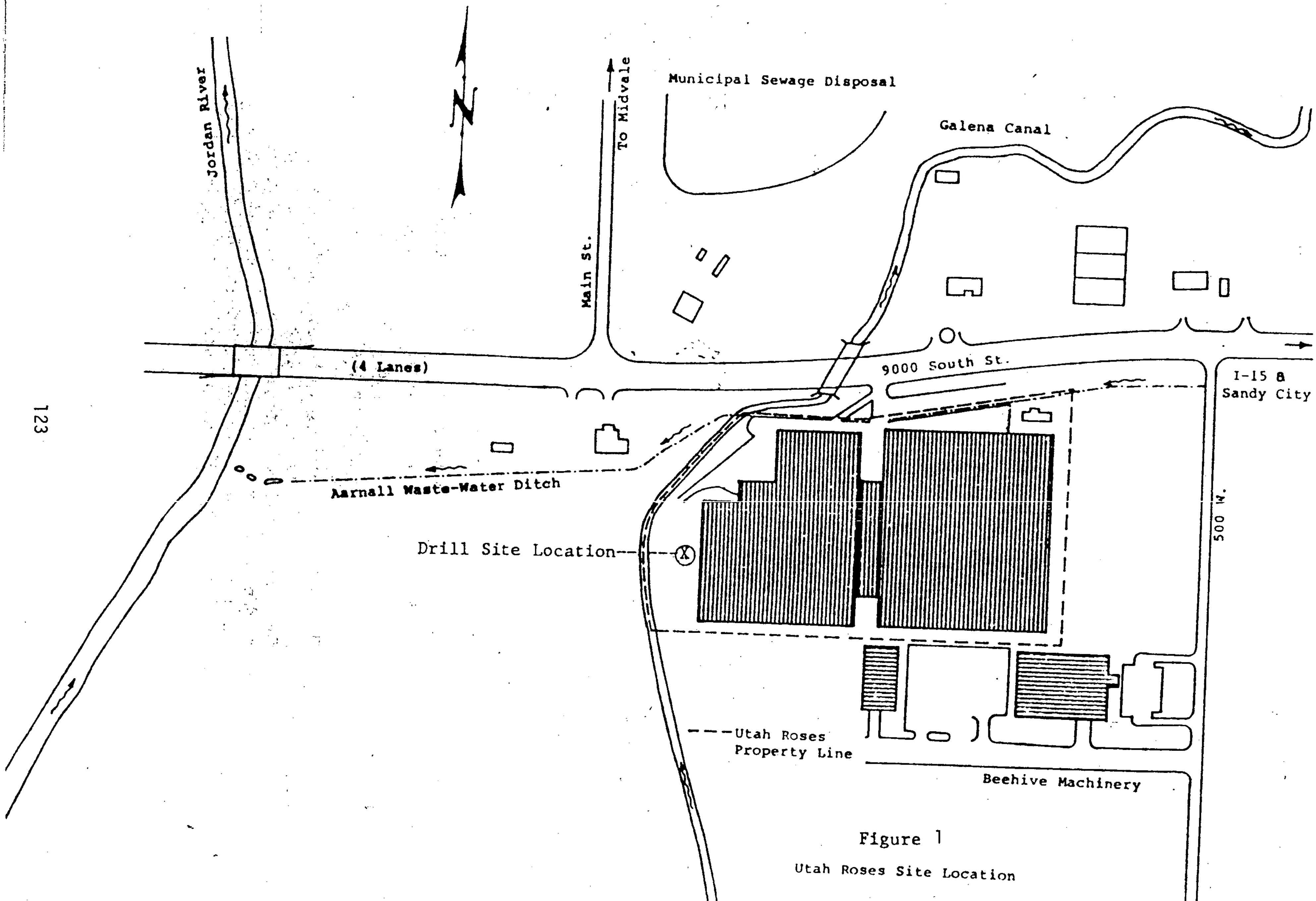


Figure 1

Utah Roses Site Location

PROJECT TITLE

Pagosa Springs Geothermal Heating and Distribution System

PRINCIPAL INVESTIGATOR

William A. Ray, Town Manager
(303) 264-5698

PROJECT TEAM

Town of Pagosa Springs
Archuleta County
School District #50-Joint
Coury and Associates, Inc.

PROJECT OBJECTIVE

To provide the community with a means of using its natural hydrothermal resource for space heating.

LOCATION DESCRIPTION

Pagosa Springs, Colorado
60 miles (97 km) east of Durango, Colorado
Population: 1500
Area activities: Ranching, lumbering, and tourism/recreation

RESOURCE DATA

	PS-3	PS-5
Well depth	300 ft (91 m)	275 ft (84 m)
Date complete	7/2/80	7/31/80
Completion technique	Open hole	Open hole
Wellhead temperature	131°F (55°C)	148°F (64°C)
Flowrate	600 gpm (38 l/s) for 12-hr test	1200 gpm (76 l/s) for 12-hr test

Summary: The geothermal resource in Pagosa Springs has been used since the early 1900's. Nearly 30 wells have been drilled for heating and recreation purposes. These wells are drilled to depths of less than 500 feet (152 m) and produce waters ranging in temperature from 130°F to 170°F (54°C to 77°C). The hydrothermal fluids are produced from a Dakota Sandstone acquifer, Figures 1, 2 and 3.

SYSTEM FEATURES

Application:	District heating
Heat load (design):	27 x 10^6 Btu/hr (7.9 MW)
Yearly utilization (maximum):	28.6 x 10^9 Btu/yr (0.96 MW-yr)
Energy replaced:	Natural gas--40.8 x 10^6 cu ft
Facility description:	10 public buildings, 54 businesses, 63 residences, and designed for future expansion
Disposal method:	The State of Colorado has agreed to discharge of the geothermal fluid to the San Juan River

Summary: The district system will provide heating for users located along U.S. Highway 160. For the proposed closed distribution system, two independent loops have been designed. The initial system will utilize 900 gpm (57 l/s) but will be capable of expansion to 1800 gpm (113 l/s), Figure 4.

STATUS

Technical Scope

The objective of this project is to demonstrate the engineering and economic feasibility of the utilization of a moderate temperature geothermal resource for space heating.

For the proposed closed distribution system, two independent loops have been designed, one for the east side of town and the other for the west side, to provide a safety factor in the event of a pipeline breakage. The east loop is designed to carry 1350 gpm. The west loop has been designed for 1000 gpm; however, initially, it will carry only 500 gpm. This is to permit future expansion of the distribution system into the growth areas of Pagosa Springs. A schematic diagram of the overall design is shown on Figure 5. Briefly, the system will operate as follows:

1. Clean city water will be heated with the geothermal fluid using two plate heat exchangers. The geothermal fluid leaving the plate heat exchangers is then discharged to the San Juan River.

2. The clean heated city water will be circulated in each of two closed loops by means of one to four pumps, depending on user demand. Each of the loops consists of large diameter asbestos-cement pipes, 6 to 10 inches, referred to as trunklines, and smaller diameter service pipes carrying the water to the individual users. Two parallel trunklines are in each loop. An insulated supply trunkline carries the heated circulating water, and an uninsulated return trunkline directs the cooled circulating water back to the heat exchangers.

3. At the terminal point of the supply line, in each loop, there will be flow control valves to ensure a minimal amount of hot water being circulated at all times.

4. The circulating water is collected in the return trunkline and then routed to the heat exchangers where the entire process is repeated.

DESIGN

Operating Conditions

Table 1 shows the design operating conditions for the heating system. The flow conditions will not be realized for the first several years, since initially the system is used to only partial capacity.

Table 1. DESIGN OPERATING CONDITION

	Geothermal Fluid			Circulating Fluid		
	Temp. (°F)	Pressure (psi)	Flow (gpm)	Temp. (°F)	Pressure (psi)	Flow (gpm)
Inlet heat exchanger	140	30	2000	107	60	1800
Outlet heat exchanger	114	15	2000	136	130	1800

The circulating water at the suction side of the pump is at a pressure of 60 psi. To assure the constant 60 psi suction pressure, city water supply will be cross-connected into the return lines of the distribution loops and maintained using a pressure-reducing valve. This will pressurize the system and also be the source of makeup water. Two back check valves are to be installed at this point to avoid the possibility of water backflowing into the city water supply system. Pressure release valves and vacuum valves will also be installed in the system.

The pumps at design flow rates add 70 psi of head, for a net of 130 psi. Valving and other losses drop the pressure to 133 psi and the heat exchanger further reduced to about 90 psi.

The heating system will not be operated at design conditions for the first several years since all users are not expected to be on-line. The system will be used to only 40% capacity when it is placed in initial service. This will not influence the normal operating conditions or the control scheme described below. The distribution system will be operating over a broad range of conditions that will fluctuate daily as well as seasonally. The seasonal flow ratios will vary from 200 to 2000 gpm, and daily fluctuations by 250%.

Control System

Operating over a broad range of conditions, the main intent of the control system is to minimize both the operating costs and manpower requirements to operate the system. The control scheme will control the four circulating pumps, the number of heat exchangers in operation, flow from the geothermal wells, and temperature of the circulating water leaving the heat exchangers. A system schematic diagram is shown on Figure 6.

The circulating pumps will be operated based on user demand plus 150 gpm, which will be continuously circulated through the piping system. The pumps will operate in the following sequence:

$500 \geq \text{flow} \geq 150$	1 pump
$1000 \geq \text{flow} \geq 500$	2 pumps
$1500 \geq \text{flow} \geq 1000$	3 pumps
$2000 \geq \text{flow} \geq 1500$	4 pumps

There will be manual switching for rotating the use of the pumps. This feature permits even utilization of all four pumps.

The flow requirements will be sensed by a flow indicator on the return portion of the piping network. In addition to determining the number of circulating pumps to be in operation, the flow instrument will control the number of heat exchangers in operation. At flow less than 1000 gpm, only one heat exchanger will be in service. At flows greater than 1000 gpm, both heat exchangers will be in service.

The flow indicator will also determine the number of geothermal pumps in operation. With flows of less than 1000 gpm, one well pump will be operational. At flows greater than 1000 gpm, both wells and associated pumps will be in operation. To minimize equipment wear and to allow the system to reach equilibrium operating conditions, there will be some minimum cycle time between on and off modes of the pumps and heat exchangers.

Flow from the goethermal wells will be controlled by the discharge temperature of the circulating fluid. This temperature controller will operate a throttling valve on the geothermal supply line to maintain a constant discharge temperature from the heat exchangers.

<u>Instrumentation and Data Collection</u>

A control panel monitoring the different components of the distribution system will be located in the building housing the heat exchangers and pumps. The panel will indicate which distribution pumps, well pumps, and heat exchangers are in operation.

The flow rates of both the geothermal and circulating fluids are to be measured and recorded. The flow rates will be indicated locally and will also be totalized to allow a comparison to be made with users' meter reading to act as a check. At the heat exchangers, the inlet and outlet temperature of the geothermal and circulating fluids will also be measured and recorded. The geothermal fluid discharge into the San Juan River will be measured and recorded continuously for temperature and flow. The two flow and nine temperature measurements will be recorded using a small computer. The computer will also be used for billing the system users.

Pressure gauges will be installed on inlet and discharge of each pump. Pressure gauges will also be installed on the upstream and downstream side of the pressure regulator in the city water supply line. Temperature gauges are to be installed on the geothermal wells, geothermal discharge, and all inlet and outlet points of the heat exchangers.

SCHEDULE

The wells required for the project were completed in the summer of 1979. Based on results from the well drilling program, the final design was completed in December. Construction is continuing with completion scheduled for the first week in October. A schedule of major completed and planned events is presented below:

1.	Completion of final design:	December 1980
2.	Send out bid documents:	April 1981
3.	Construction contracts:	June 2, 1981
4.	Construction:	July-September 1981
5.	System testing:	October 1-15, 1981
6.	System operation:	October 15, 1981

CURRENT ESTIMATED PROJECT COST

Total:	$1,364,280	
DOE share:	1,111,000	83%
Participant share:	227,500	17%*

*Includes $115,500 of existing facility credits.

LESSONS LEARNED

1. With the rapidly escalating costs of materials and labor, an appropriate contingency factor should be included in all cost estimates and should be acknowledged and accepted by grantor agencies. A good portion of our cost overrun from original agreement estimates made over two years ago are because of inflationary cost escalation during that time.

2. Keeping the public informed of project progress is important for successful acceptance, and to minimize erroneous information and rumors. Interviews by media reporters frequently result in partial, misleading information being published or broadcast. Carefully written news releases are best, but even then the media space or time limitations result in editing which often changes the context. If at all possible, a person should be designated to communicate with the media and the public on a regular basis.

3. Predicting the existence of geothermal fluid underground, and especially quantification, is not reliable even in close proximity to existing wells. It seems the only dependable way to determine the existence of, and to quantify, geothermal sources is by means of test holes.

   In our project, a new well located only 30 feet from a previously drilled test well produced fluid 10°F cooler than had been obtained from the test well at comparable depth. A second new well located 350 feet southwest of the first one did not produce fluid quantity or temperature comparable to the first new well, nor as expected from geological analysis of the substrata. The well could not be used and was cemented up. A third new well located 180 feet east of the first one, and about 30 feet south of an existing old well produced much greater quantity of fluid than either of them, and 17°F hotter and at a depth considerable less than predicted by geological analysis of the substrata.

4. Drilling geothermal wells, particularly artesian wells, presents problems and situations not encountered in usual water well drilling. This applies not only to the temperatures and pressures involved but also to the subsurface strata which may have been affected by the geothermal conditions. Anomalies from usual geologic situations should be expected.

5. Keeping state agencies and local government bodies informed on the progress of the project, and particularly about well drilling, is of great value in assisting various permitting and approval requirements.

6. If possible, a local contractor with interest in the project should be used. Since the contractor's reputation will be under close scrutiny, it is likely he will do a better job.

7. Extensive background checks should be made on all contractors by contacting the owner of their two or three most recent jobs. Past reputation may not always be accurate.

8. Many of the laws and regulations pertaining to geothermal are new and leave many holes regarding their interpretation. Can plan on spending much more time than initially anticipated in dealing with these. No precedence has been set for many of these new laws.

9. Work closely with area representative to introduce state legislation covering the existence and operation of community-owned geothermal heating districts.

PAGOSA SPRINGS PON REPORTS

(Cooperative Agreement No. DE-FC07-79ET27030)

1. Garing, Kenneth L., Direct Utilization of Geothermal Energy for Pagosa Springs, Colorado, Semi-Annual Progress Report, June-December 1979, Report IDO-7031-1, Contract No. DE-FC07-79ET27030.

2. Hydrosciences, Inc., Geohydrological Analysis of the Geothermal Reservoir, Pagosa Springs, Colorado, Cooperative Agreement No. DE-FC07-79ET27030, October 18, 1979.

3. Coury and Associates, Inc., An Environmental Report on the Construction and Operation of a Geothermal District Heating System in Pagosa Springs, Colorado, Revision 1, Contract No. DE-FC07-79ET27030, January 1980.

4. Coury and Associates, Inc., Chaffee Geothermal, Ltd., and Hydrosciences, Inc., Geothermal Resources Report Pagosa Springs, Colorado, (Cooperative Agreement No. DE-FC07-79ET27030), January 1980.

5. Coury and Associates, Inc., Direct Utilization of Geothermal Energy for Pagosa Springs, Colorado, Preliminary Design Report, Contract No. DE-FC07-79ET27030, February 1980.

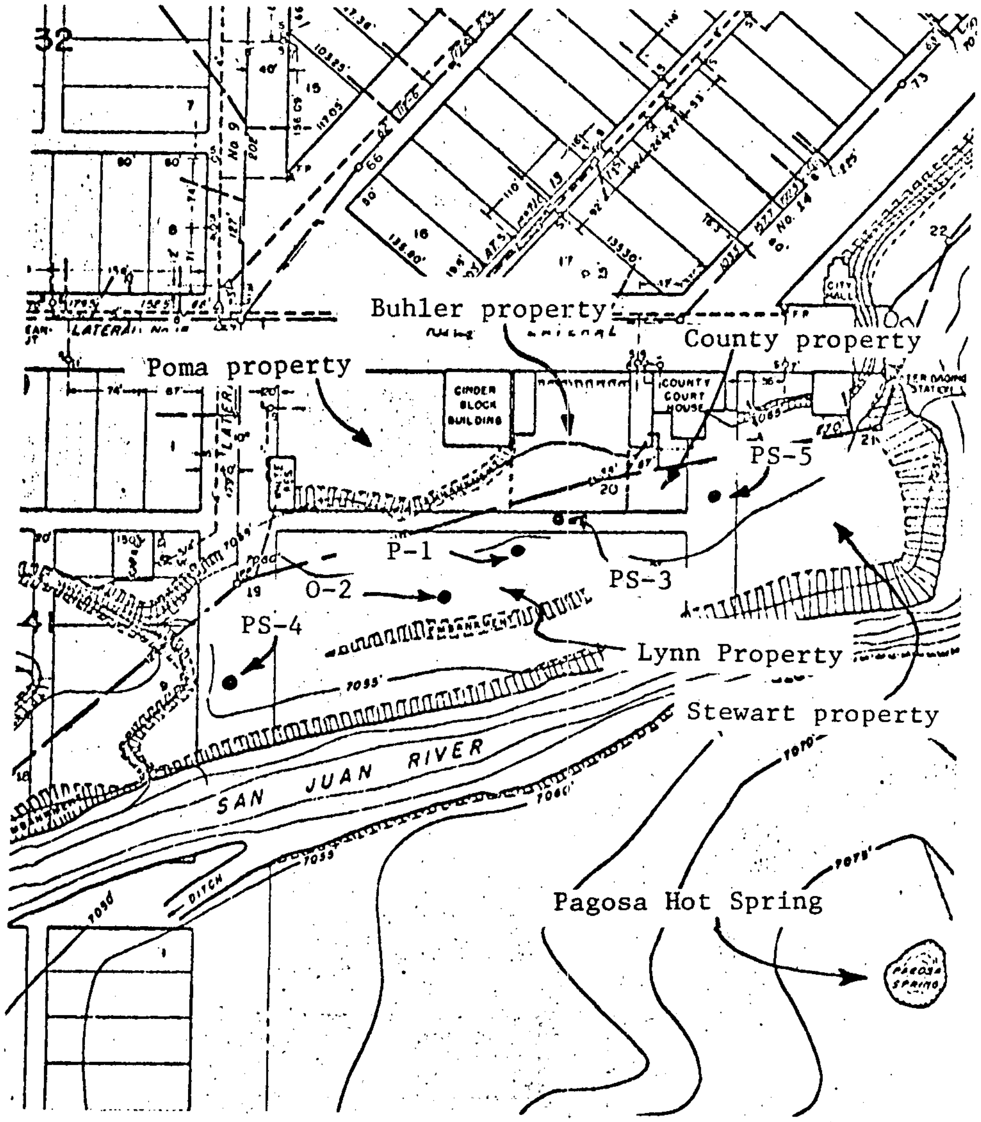


Figure 1. Location of wells drilled by this project (PS-3, -4, and -5) and wells drilled previously by the Colorado Geological Survey (P-1 and O-2). Also shown are the landowners within 100 feet of the new wells.

Pagosa Springs, CO

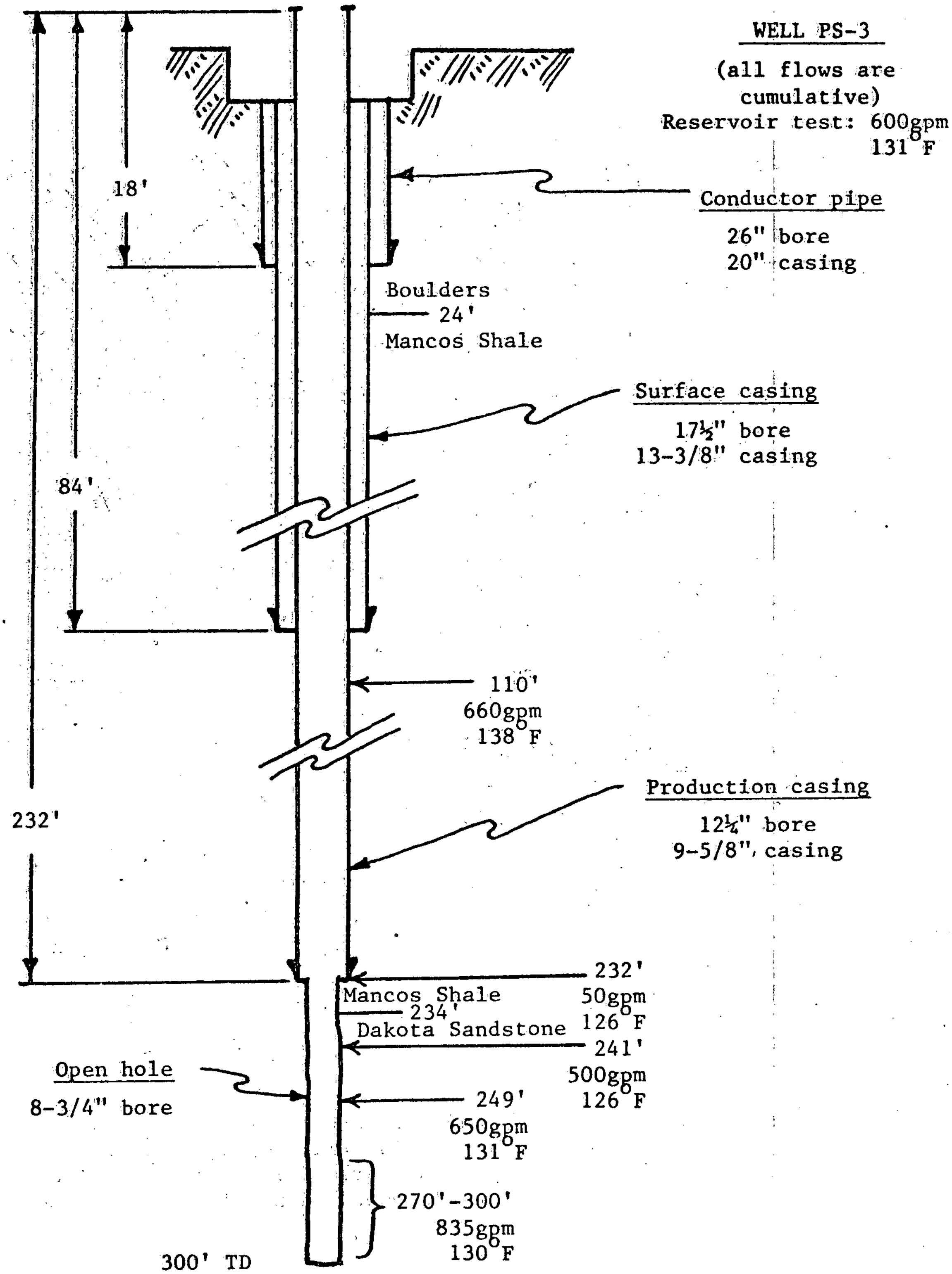


Figure 2. Completion and casing profile of well PS-3, Pagosa Springs, Colorado.

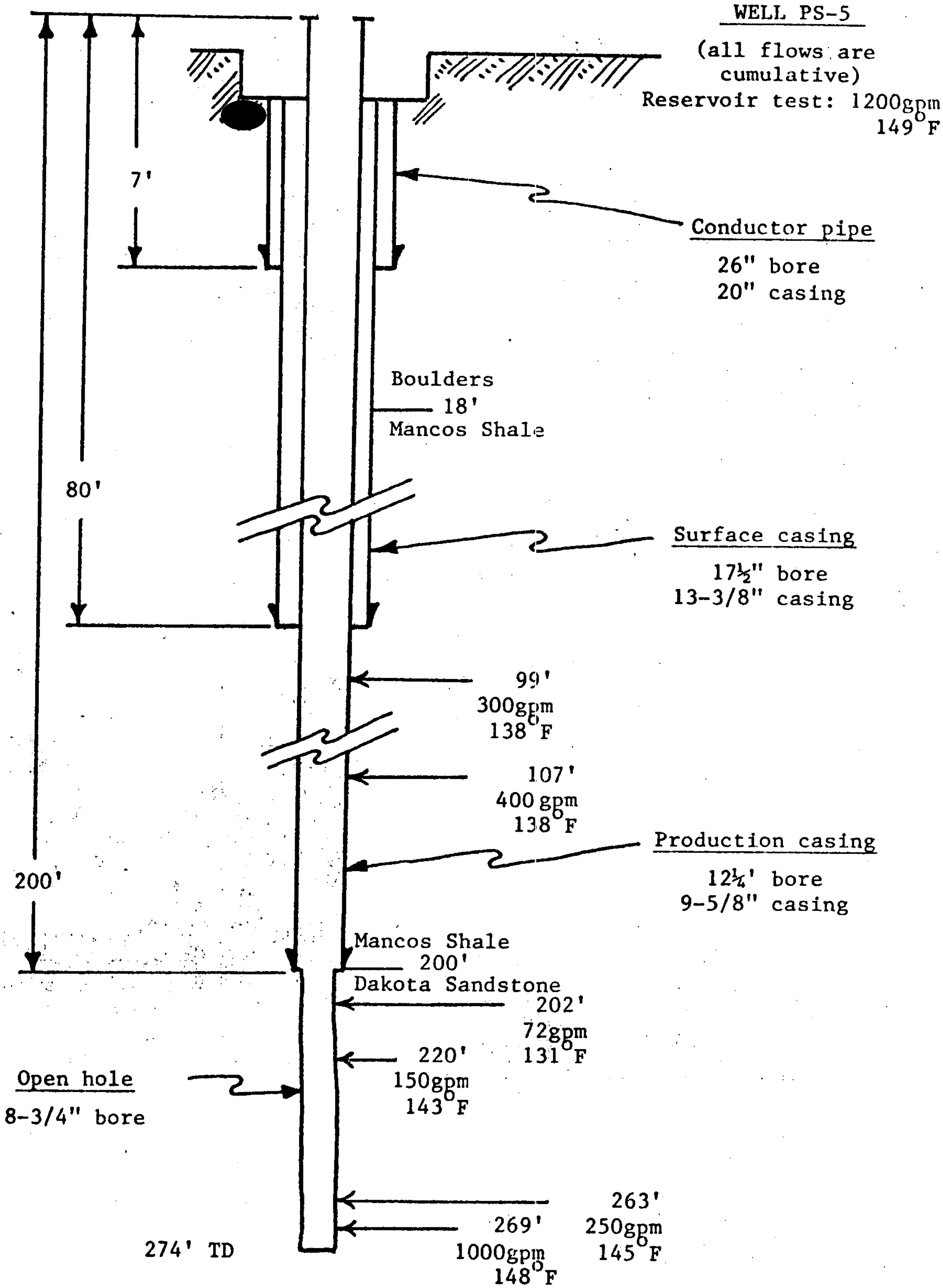


Figure 3. Completion and casing profile of well PS-5, Pagosa Springs, Colorado

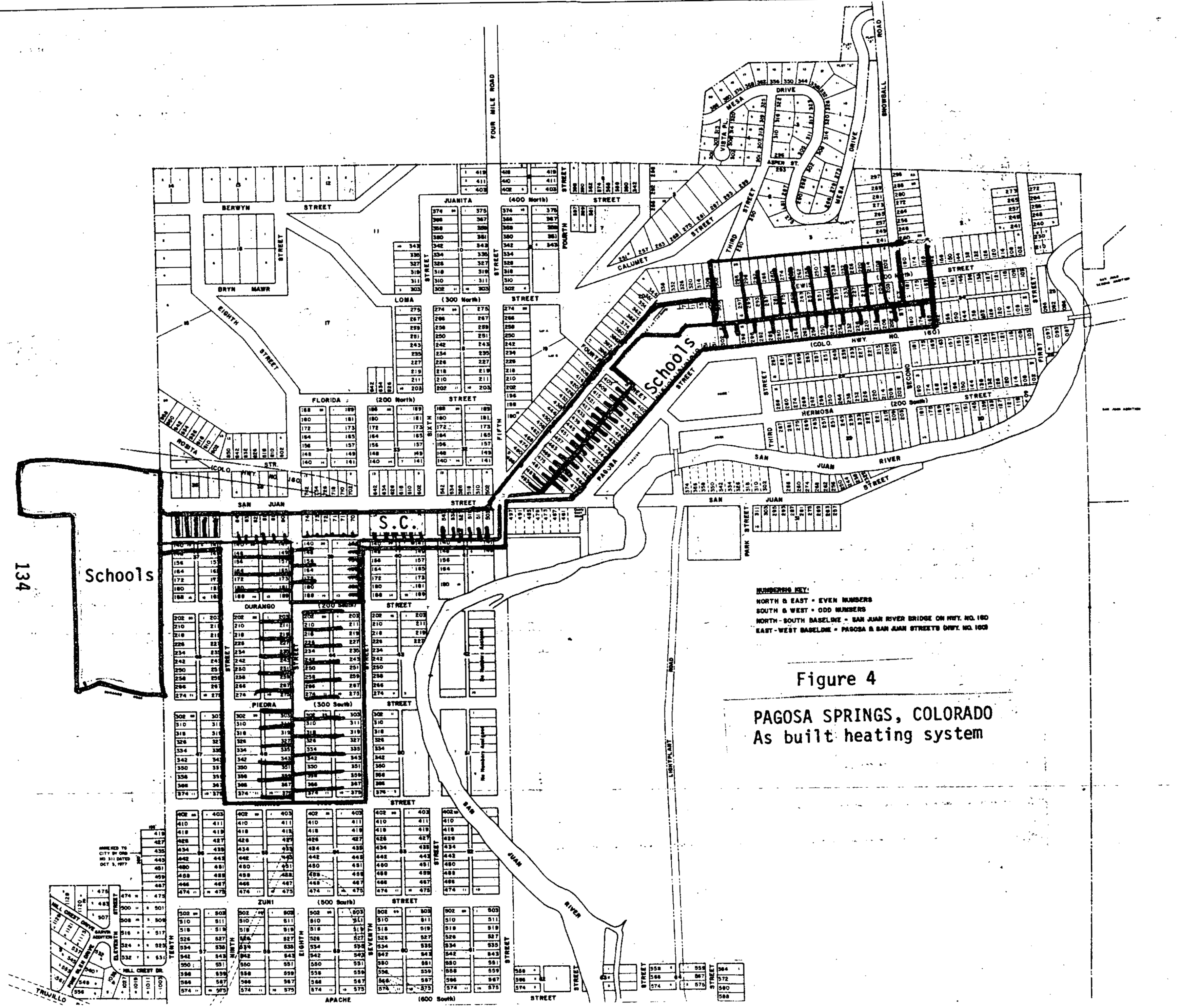
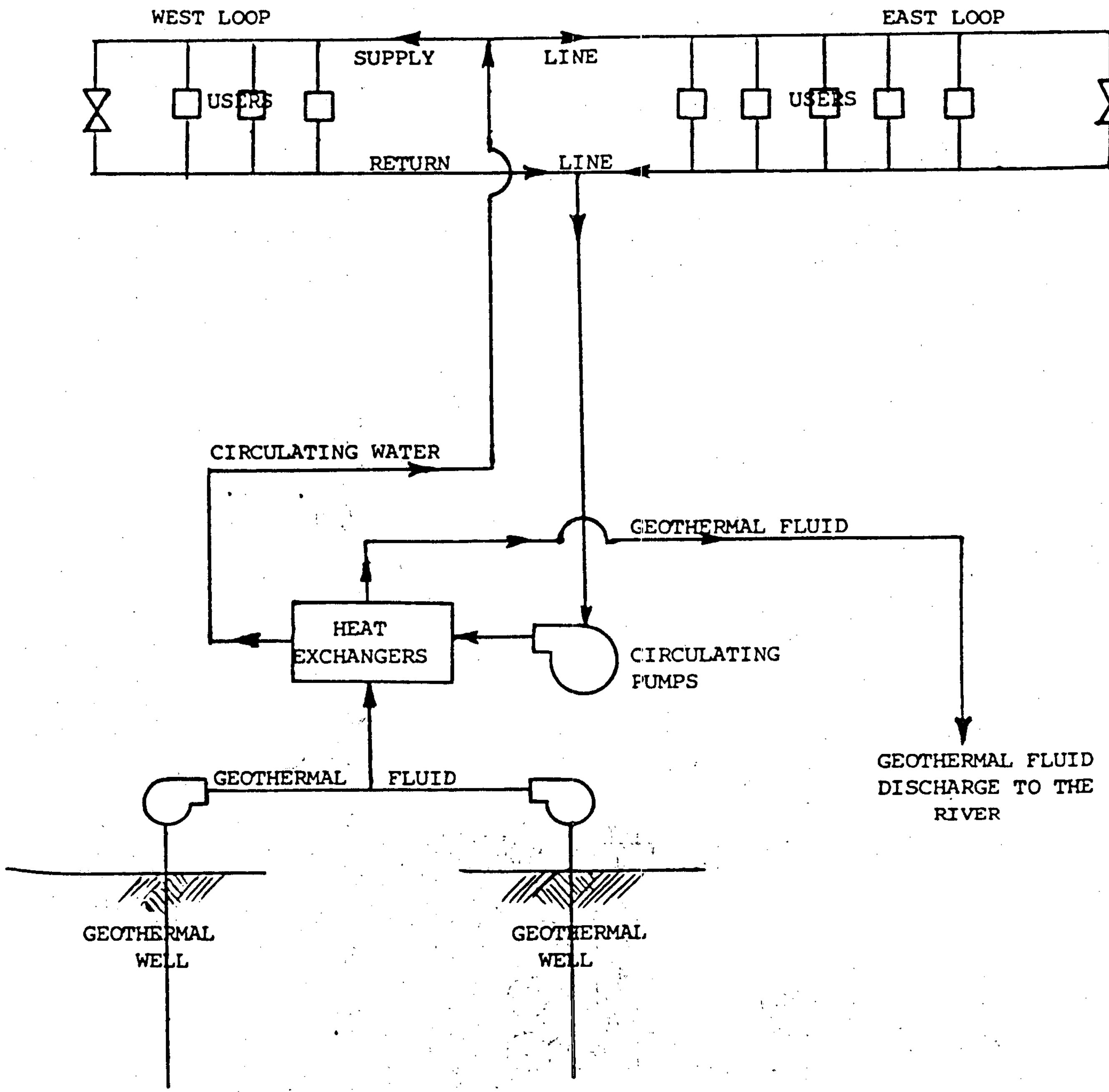


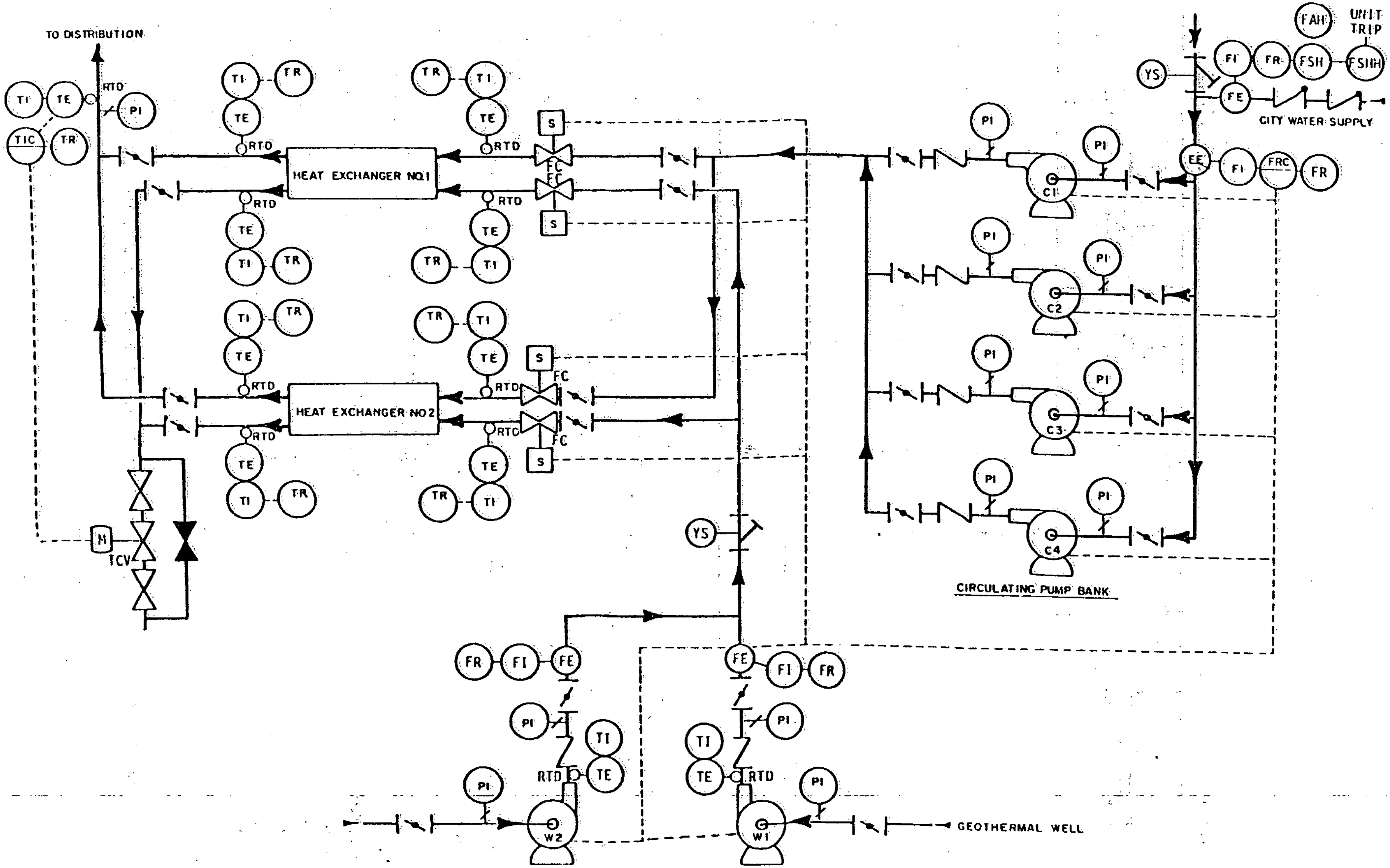
Figure 4

PAGOSA SPRINGS, COLORADO
As built heating system



SCHEMATIC DIAGRAM OF THE TOWN GEOTHERMAL HEATING SYSTEM

FIGURE 5.



INSTRUMENTATION AND CONTROL SCHEMATIC

NO SCALE

Figure 6.

Torbett-Hutchings-Smith
Memorial Hospital

322 Coleman Street Telephone: 817-883-3561
Marlin, Texas 76661

PROJECT TITLE: Direct Utilization of Geothermal Energy at Torbett-Hutchings-Smith (THS) Memorial Hospital, Marlin, Texas

PRINCIPAL INVESTIGATOR: J. D. Norris, Jr., Administrator, THS Memorial Hospital

PROJECT TEAM:

Prime Contractor:	THS Memorial Hospital, Marlin, TX
Geothermal Consulting Engineers:	Radian Corporation, Austin, TX
Architects:	Spencer Associates, Austin, TX
HVAC Consulting Engineers:	Ham-Mer Consulting Engineers, Austin, TX
Drilling and Completion:	Layne Texas Company, Dallas, TX
Constructors:	Lochridge-Priest, Inc., Waco, TX
Surface Disposal:	City of Marlin
Community Coordination:	Marlin Chamber of Commerce
Legal:	J. Welch, Marlin, TX
Accounting:	W. M. Parish & Co., Marlin, TX

PROJECT DESCRIPTION:

The purpose of this geothermal project is to retrofit the 130-bed hospital space and water heating systems to use geothermal energy, thereby reducing its dependence on fossil fuels. The geothermal heating system will supply heat to the hospital domestic water system, as well as to the space heating and outside air preheating systems. At present, heat input to these systems is accomplished via steam provided by a low-pressure, natural-gas-fired boiler. This boiler system will remain in place as backup and augmentation. Readily available commercial piping, pumps, valves, controls, plate heat exchangers, and insulation will be utilized.

The final phase is a one-year operational demonstration phase, during which potential geothermal users will be encouraged to visit and observe the geothermal heating system.

LOCATION DESCRIPTION:

THS Memorial Hospital is located in Marlin, Texas (population 6,350), approximately 30 miles southeast of Waco, Texas (Figures 1 and 2).

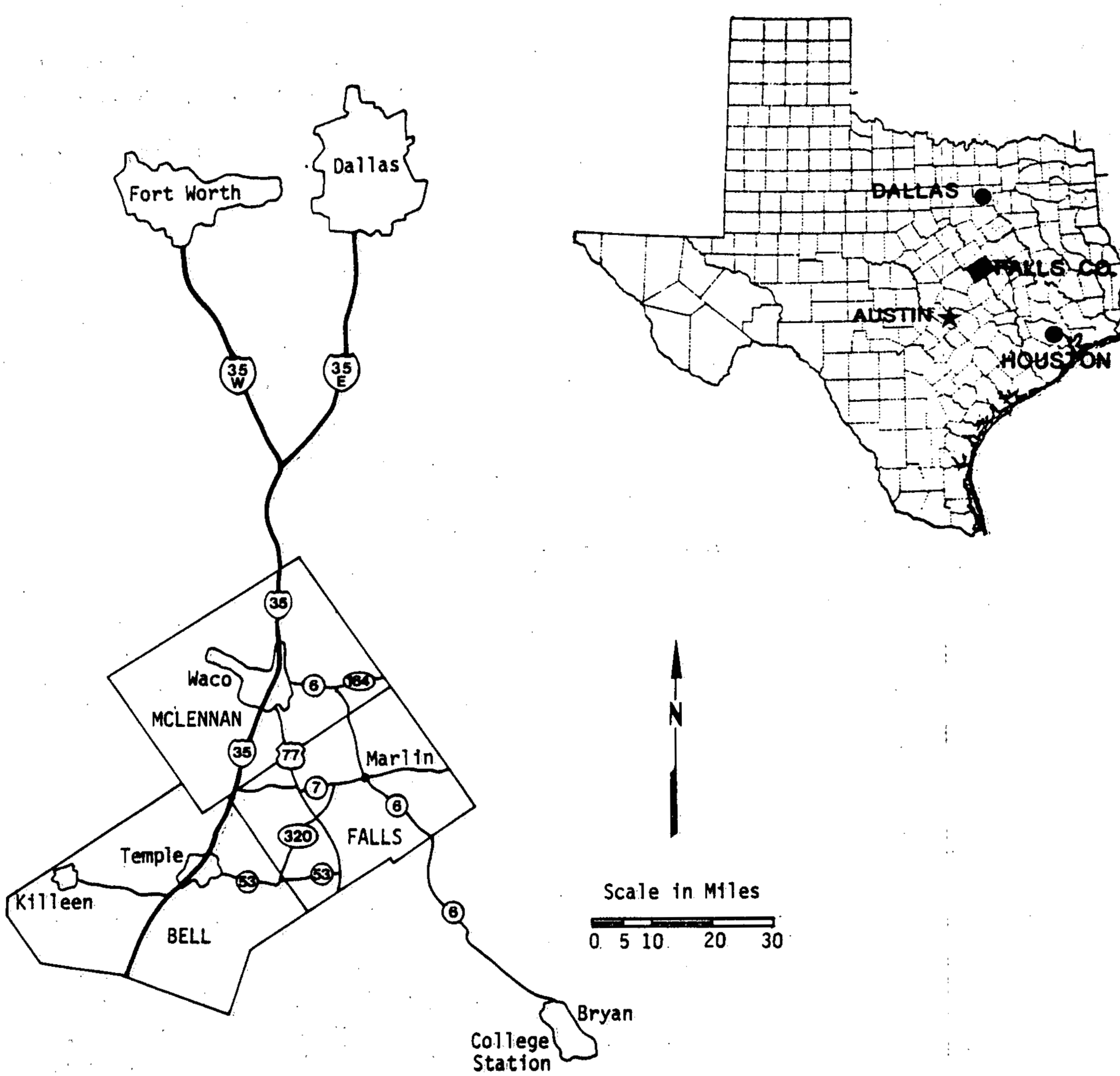


Figure 1. Geographical Setting of Marlin, Texas

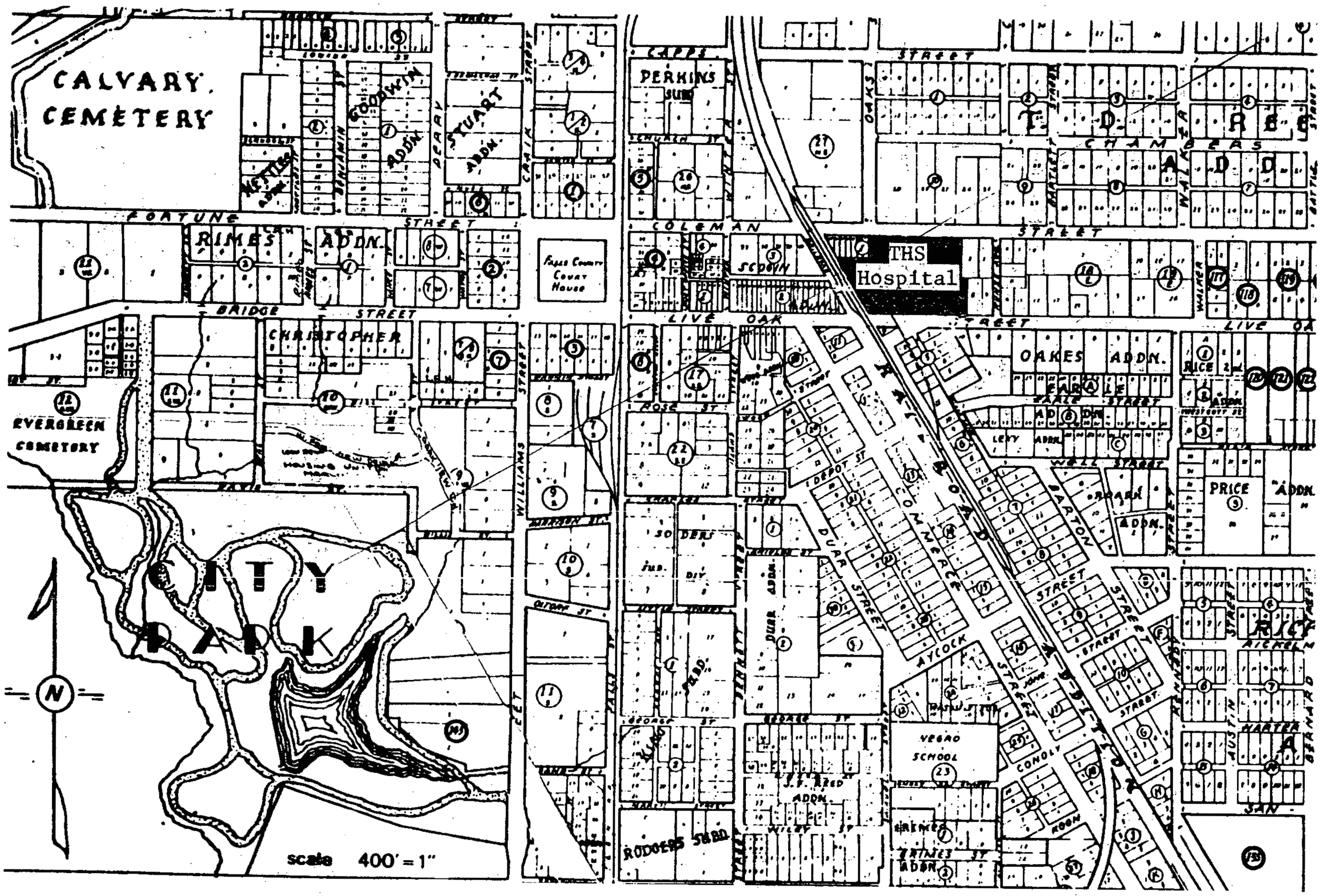


Figure 2. THS Memorial Hospital Location in Marlin

RESOURCE DATA:

The production well, shown in Figure 3, is 3,885 feet in total depth and was completed in July 1979. The production zone is screened (5-1/2" O.D. mill slot screen) from about 3,613 to 3,883 feet. Pump testing of the well has produced flow rates of 315 gpm of 153°F fluid containing less than 4,000 mg/1 total dissolved solids (TDS). Hydrogen sulfide levels are minute. Gross alpha activity is less than 2 pCi/1.

The source of the heat is faulting associated with the Ouachita fold belt, which outcrops in Arkansas and underlies much of central Texas. The coarser-grained sandstones (especially the Hosston member of the Travis Peak formation) are the groundwater reservoirs that define the aquifer shown in Figure 4. The factor which is responsible for the area's geothermal value is the hydraulic interconnection of deeper and shallow sandstones provided by the Mexia-Talco fault system.

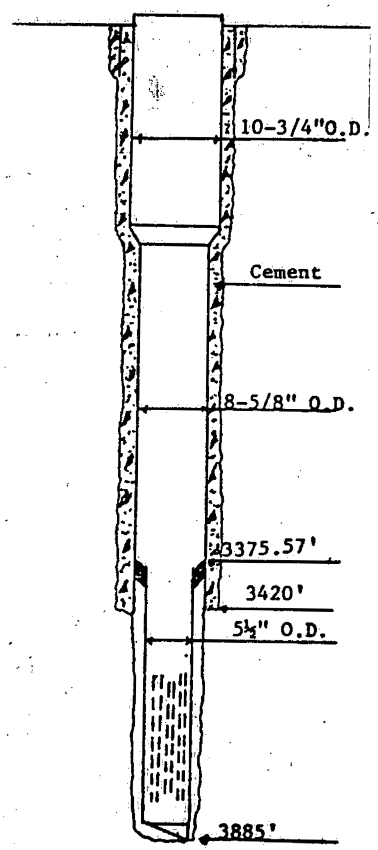


Figure 3. THS Production Well No. 1 Sketch

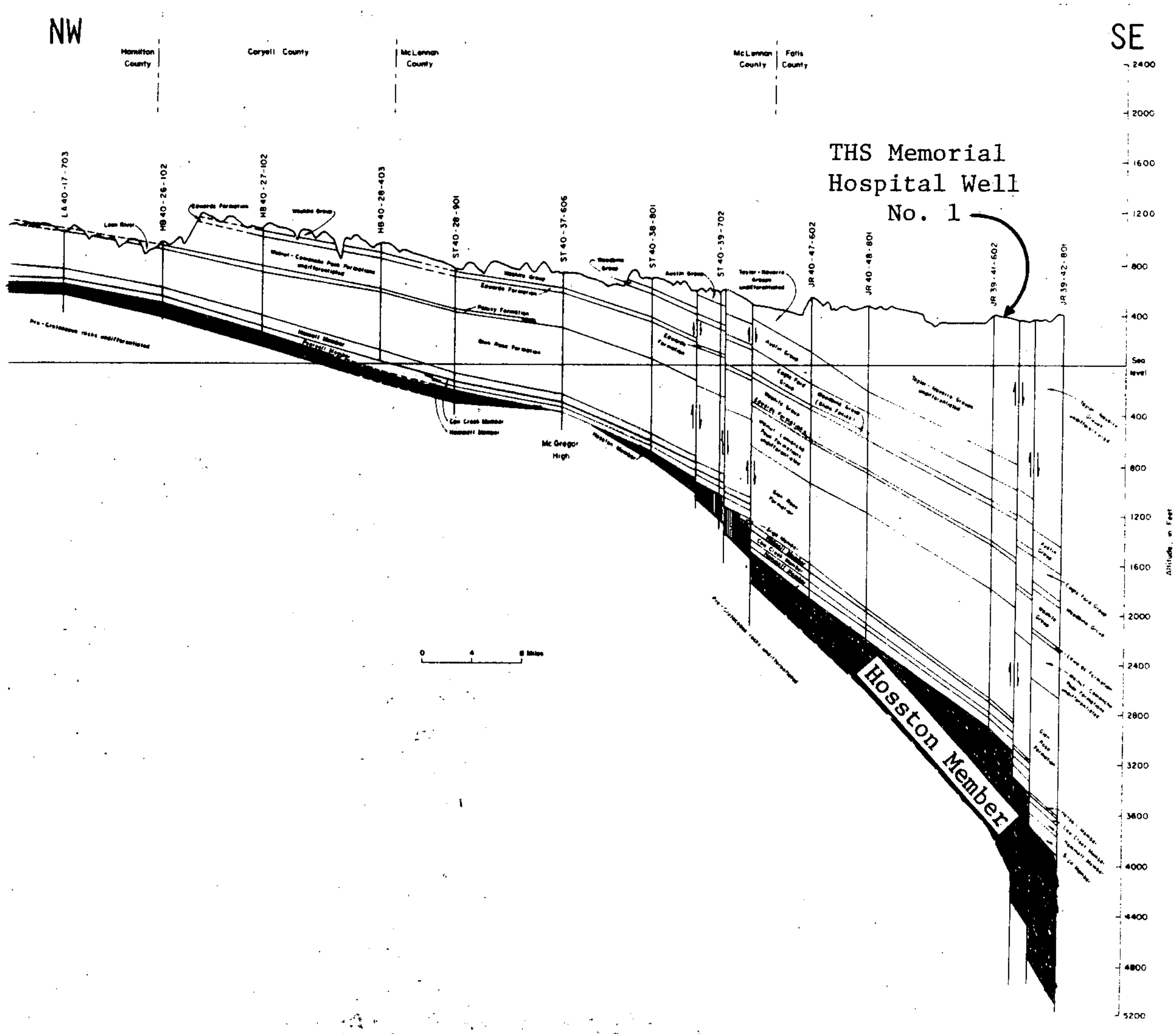


Figure 4. Geologic Dip Section Showing Hosston Member Passing Through Marlin, Texas

SURFACE DISPOSAL:

An environmental assessment of the disposal route showed that surface disposal of the 4,000 mg/1 TDS THS Memorial Hospital geothermal water would not present an unacceptable environmental impact. Both the Texas Railroad Commission (which regulates saline water disposal) and the EPA issued disposal permits.

Figure 5 presents an overview of the disposal route from the 5-acre City Park Lake on to the Brazos River via Bean Branch and McCullough Slough--a distance of about five miles. Figure 2 shows a more detailed view of the hospital's relationship to City Park Lake which is about a half mile away.

System discharge enters into the city storm sewer at the hospital. A cascading waterfall at the lake entrance aerates the sewer outfall. Since the lake is a storm water basin, dilution of the geothermal water will occur before discharge to Bean Branch. The traverse to the river is through open grain fields. A discharge of 160 gpm (peak) is judged to present no impact on the river which has a 150,000 to 24,000,000 gpm annual flow.

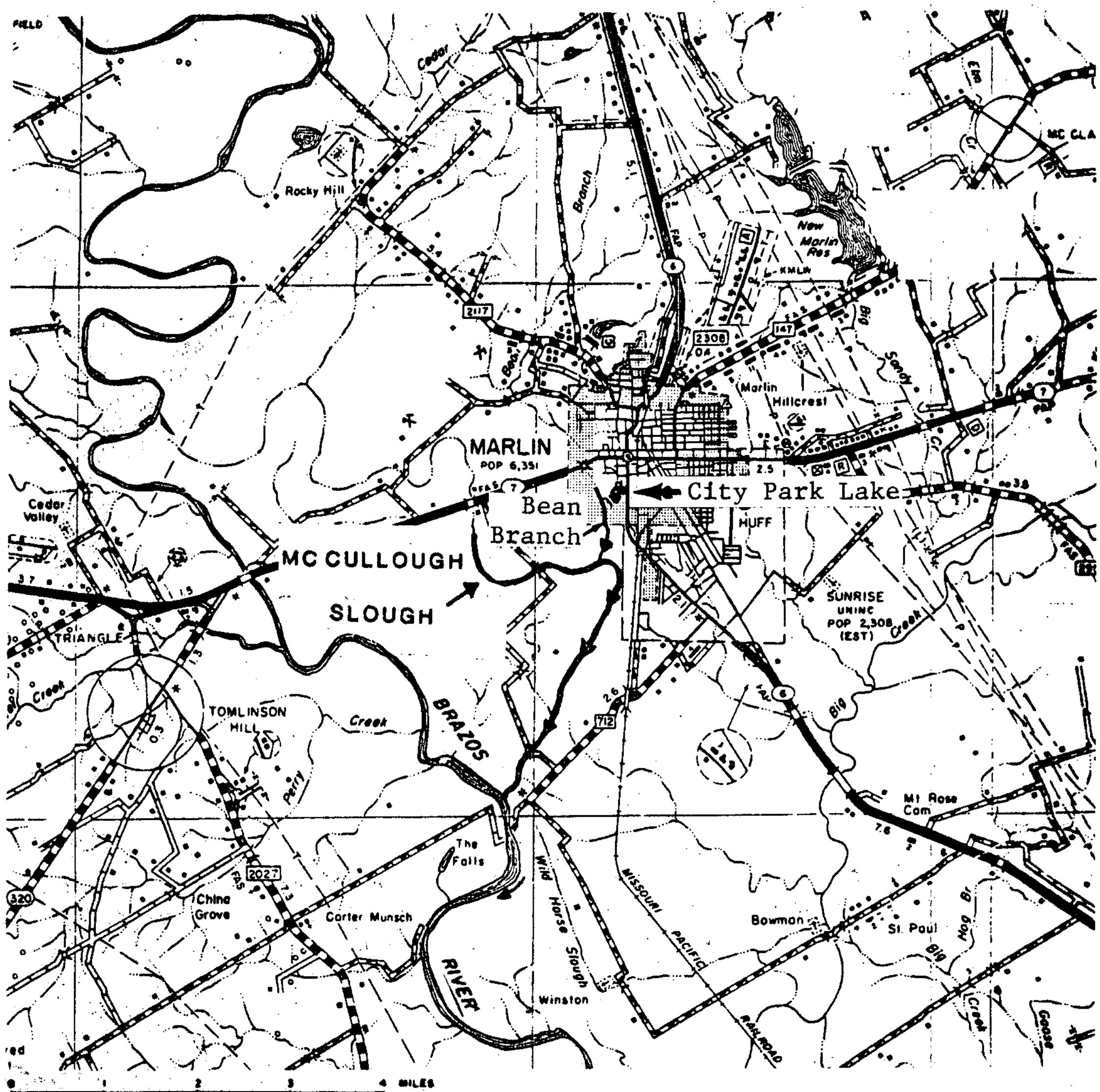


Figure 5. Surface Disposal Route from City Park Lake to the Brazos River

ESSENTIAL PERMITS AND EXEMPTIONS:

- DOE/EA: EIS Negative Declaration — August 8, 1980
- Texas Railroad Commission: Approval for Off-Lease Surface Discharge of Geothermal Discharge Water — March 17, 1980
- Environment Protection Agency: National Pollution Discharge Elimination System (NPDES) Permit No. TX0086321 — June 14, 1981
- Texas Air Control Board: Permit Exemption — August 3, 1981
- Texas Department of Health: Reviewed — May 15, 1981

SYSTEM FEATURES:

Figure 6 shows the geothermal fluid production system. A submerged pump, that requires less than 10 HP at the design maximum flow rate of 160 gpm will be set at 200 feet and used to supply 150°F geothermal fluid to the plate heat exchangers (PHX). To conserve the geothermal resource and electric pumping energy costs, the pump will be run at a speed directly proportional to the system heating load. An electronic variable speed drive (VSD) unit will control the pump speed (and thus flow rate) according to the system discharge temperature set point of about 100°F. The VSD unit is mounted in the geothermal equipment room with the PHX's. As the system load increases, the discharge temperature will drop and a signal sent to the VSD will cause the VSD to speed up the pump. The higher flow rate will supply more heat to the PHX's and the discharge temperature will thus rise closing the loop. Geothermal fluid flow rate will be monitored by a flow meter.

Four PHX's are located in the geothermal equipment room. One PHX will supply heat to the domestic water heating system. A conductance measuring system monitors the output of the heated potable water to insure that if geothermal water has leaked, within the PHX, from the primary to the secondary side, an operator alarm is activated and such water heating is automatically terminated. Two PHX's supply heat to the building heating

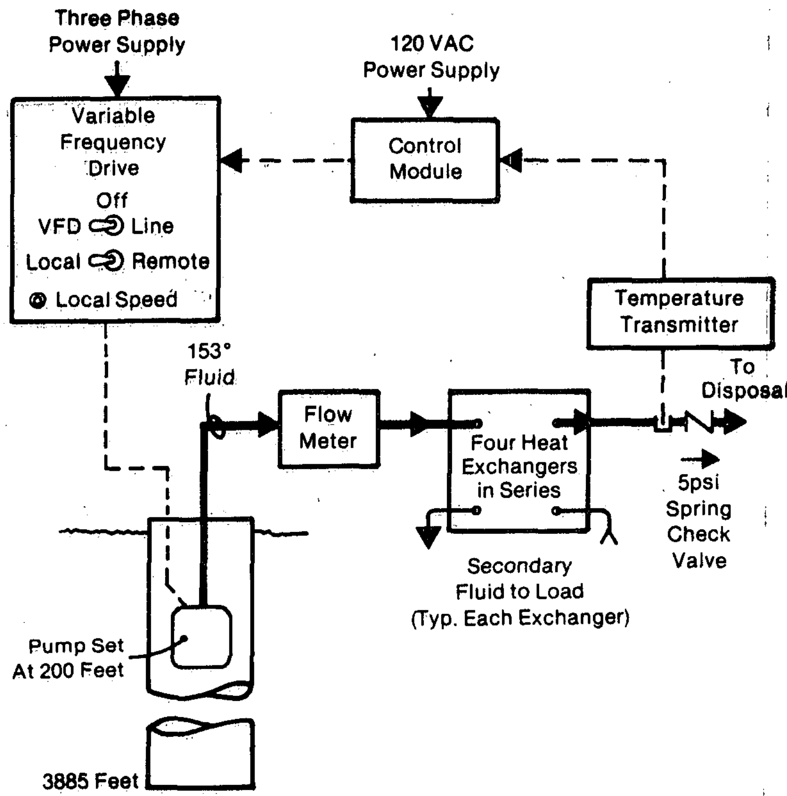


Figure 6. THS Hospital Geothermal Fluid Production System

system, and the fourth PHX supplies heat to the outside-air-preheating system. Other auxillary functions such as laundry driers, office heaters and surgery room air handling will also receive geothermal heat. The existing low-pressure steam boilers will remain in place and will automatically activate to augment the geothermal heating system. Or, the boilers will heat the hospital when it is necessary to shut down the geothermal system for O&M activities.

Scale control is achieved by maintaining a closed geothermal loop, which is maintained at 5 psig, minimum, until discharge. A backwash feature for the PHX primary side, coupled with the ease of PHX disassembly and plate cleaning (defouling), assures that potential scaling is efficiently dealt with. Corrosion control is achieved by: 1) precluding oxygen intrusion via a closed geothermal loop; 2) selecting Type 316SS PHX plates which are known to resist corrosion in the Marlin fluid; and 3) utilizing CPVC piping for all the geothermal pipes.

STATUS:

Advertising for construction bids was accomplished on March 1, 1981, with a 30-day response time. Response to the bid advertising was outstanding. More than 15 construction firms expressed interest in the project by requesting plans and specifications during the response period. The following four bids were received and opened on April 2, 1981:

• Jacobs-Cathey	$689,000
• Emerson Construction	$490,000
• Grunau	$430,936
• Lochridge-Priest, Inc.	$365,544

Lochridge-Priest's bid was within 15% of the estimated cost and was the obvious winner in all respects.

As of September 2, 1981, the construction phase is over 50% complete with the following items accomplished:

- Geothermal Equipment Building Erected
- PHX's On-Site
- Air Heating Coils On-Site
- Pneumatic Control Tubing Pulled
- Steel Piping 75% In Place
- Roof Improvements

The construction phase is progressing smoothly and no change-orders have surfaced. System operational date is December 1, 1981. The constructors are subject to a $100 per day penalty after that date.

PROJECT COST:

The total approved project cost is $995,900. This amount was underwritten in the following manner:

SOURCE	PERCENT
• US Department of Energy	82
• Texas Energy and Natural Resources Advisory Council	8
• In-Kind Services by the THS Memorial Hospital and City of Marlin	10

LESSONS LEARNED:

1. The number of permits required and the effort necessary to obtain them were significantly underestimated in the initial project planning.

2. There is no standard method of economic analysis. The assumptions used to arrive at any payback period or rate of return must be highly qualified to understand its significance.

3. The amount of time and effort required to turn a final design which is complete in terms of an engineering review into an acceptable bid package was much greater than expected. Overall, the time and effort required to get from completed design to negotiated construction subcontract was greater than planned. Intermediate steps were: generate bid package, reproduce and issue package, advertise, answer questions, evaluate bid, investigate contractor and negotiate to get final signed subcontract.

T-H-S MEMORIAL HOSPITAL
(Contract No. DE-AC08-78ET27059)

1. Klemt, William B., Robert D. Perkins, and Henry J. Alvarez, Ground-Water Resources of Part of Central Texas With Emphasis on the Antlers and Travis Peak Formation, Volume I, Report 95. Austin, Texas. Texas Water Development Board, November 1975.

2. Radian Corporation, An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas, DCN 78-200-300-02 (Rev. A), Contracts DOE/ET-78-C-08-1554 and TENRAC/G-3-1, August 15, 1978.

3. Radian Corporation, An Exhibit for a Special Request for Exception to SWR 8 to Permit Off-Lease Discharge of Geothermal Water at the Torbett-Hutchings-Smith Memorial Hospital at Marlin, Texas, Contract DOE/ET-78-C-08-1554, November 13, 1979.

4. Radian Corporation, Preliminary Design Report for the T-H-S Memorial Hospital Geothermal Heating System at Marlin, Texas, DCN 79-212-300-15, Contracts DOE/ET-78-C-08-1554 and TENRAC/G-3-1, December 20, 1979.

5. Radian Corporation, Final Design Report for the T-H-S Memorial Hospital Geothermal Heating System at Marlin, Texas, DCN 80-212-300-16, Contracts DOE/DE-AC-08-78ET27059 and TENRAC/G-3-1, September 17, 1980.

6. Railroad Commission of Texas, Exception to Statewide Rule 14(B)(2), T-H-S Memorial Hospital, Inc., (02282) Lease, Well(s) No. 1, Wildcat Field, Falls County, Texas, Letter, July 7, 1981.

7. Texas Air Control Board, Permit Exemption X-2672 Geothermal Heating Facility, Marlin, Falls County, Letter, August 3, 1981.

8. Texas Department of Health, Torbett-Hutchings-Smith Hospital #517, Marlin, Texas HFC-AH80-0401-021, Review, Letter, May 15, 1981.

9. US DOE, Enviornmental Assessment, Geothermal Direct Heat Project, Marlin, Texas, DOE/EA-0117, August 1980.

10. US DOE, Environmental Assessment DOE/EA-0117, Geothermal Energy, Direct Heat Applications Program, Torbett-Hutchings-Smith Memorial Hospital, Marlin, Falls County, Texas (July 1980) and Findings of No Significant Impact, Letter, August 8, 1980.

11. US EPA/Region VI, NPDES Determination, Permit TX0086321, May 13, 1981.

DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR PHILIP SCHOOL BUILDINGS AND DISTRICT HEATING SYSTEM

Location: Philip, South Dakota
Principal Investigator: Charles A. Maxon, Superintendent of Schools
Project Team: Haakon School District 27-1
Hengel, Berg & Associates, Architects - Engineers
Rapid City, South Dakota

ABSTRACT

The primary objective was to use Geothermal Energy to heat the Haakon School District Buildings at Philip, South Dakota. Secondary use included heat for a district heating system for the City of Philip. The existing city well 2½ miles north of the city is free flowing and provides water at 154 F. A new well closer to the school provides water for the school and the district heating system. The description of the system and the status of the project follows.

MAJOR SUBCONTRACTORS AND SPECIALTY:

Francis-Meador-Gellhaus, Inc., Consulting Engineers, Rapid City, South Dakota	Specifications for well drilling
Mintech, Inc. Research and Testing Rapid City, South Dakota	Water and Corrosion Testing
Northern Wyoming Drilling Company	Drilled new well
EG&G Idaho & CH M Hill	Reviewed plans and specifications
Brady Engineering Consulting Engineers Spearfish, South Dakota	Plans and specifications for Barium Chloride treatment plant
Wolff's Heating & Plumbing Commercial & Industrial Contractors Spearfish, South Dakota	Construction of Geothermal Conversion and Boiler Replacement Haakon School District Buildings
Ramstad Inc.	Geothermal Distribution Pipeline

PROJECT DESCRIPTION

Resource

Well Depth: 4,266 feet (Madison Formation)
Well Type: Open hole
Fluid Temperature at Wellhead: 157 degrees F.
Fluid Flowrate: 340 gpm (maximum) artesian
Note: Sulfates in fluid contain Radium 226 at level of 105 pico curies per liter. EPA standards for drinking water: 5 pico curies per liter.

SYSTEM FEATURES:

Application: Space, water and district heating
Heatload (Design): 5.5×10^6 BTU/hr
Yearly utilization (Maximum): 9.53×10^9 BTU/yr
Energy Replaced: Electricity - 122,989 kWh @ $0.036/kWh = $ 4,428
Fuel Oil - 54,729 gals. @ $1.132/gal = 61,953
Propane - 23,858 gals. @ $0.563/gal = 13,432

Facility Description: 5 school and 8 business district buildings

Disposal Method: Surface discharge to the Bad River after treatment to remove Radium 226.

Summary: The school heating project has stimulated the development of a business district heating system, Philip Geothermal, Inc. In Addition, Little Scotchman Industries, the city water plant and county maintenance building use geothermal fluids from other wells for space heating, Figure 1.

Design

A single pipe line carries the geothermal fluid from the well head to the Armory High School Building. This line continues to the Elementary School building and a return line carries the fluid which passes through two plate type heat exchangers in the Armory to the Elementary building. There the fluid used in its two heat exchangers is introduced into the line which then becomes the single supply line to the District Heating System which presently serves eight business buildings. Separate supply and return lines serve the District and Terminate at the City Fire Station where controls maintain flow in response to outside air temperature. A single line carries the fluid to the treatment plant where the sulfates which contain the Radium 226 are precipitated and allowed to settle in one of the two cells of the holding pond from which the fluid then flows into the North Fork of the Bad River.

The Armory High School building had a single oil-fired steam boiler which heated service water and provided steam for the space heating terminal units. This boiler was replaced by modular hot water boilers and the terminal units and pipe were converted to use water. The geothermal fluid is extremely corrosive and plate type heat exchangers transfer heat from the fluid to the service water and the space heating systems of both the Armory and Elementary school buildings.

The project was divided into two bid packages. One included the piping from the well head to the school, the distribution pipe line to the Heating District and the discharge line to the treatment plant, the barium chloride treatment plant and the discharge line to the river.

The other bid package included the geothermal conversion of the school buildings heating systems and the boiler replacement.

A two pipe supply and return system was designed and constructed through the business district, with tees for each business desiring to utilize the geothermal energy. Eight commercial buildings with a design load of 1.80×10^6 BTU/hr and an annual load of 3.24×10^9 BTU have converted their heating systems to use the geothermal fluid for space heating.

Economics

Original estimate of project costs:

Item	DOE	School	Total
Total Project Estimated Cost	$ 936,199	$ 269,605	$1,205,804
Current Costs:			
Well	$ 169,365	$ 47,770	$ 217,135
Geothermal Distribution Pipe Line	340,614	96,071	436,685
Geothermal Conversion	258,203	72,826	331,029
Reports, Conferences & Misc.	4,147	1,170	5,317
Engineering	58,146	16,400	74,546
Total	832,408	234,781	1,067,189

The bid for the Geothermal Distribution Pipe Line was $490,700 and was reduced by negotiation to a contract amount of $436,685. The bid for the Geothermal Conversion was $346,500 and was reduced by negotiation to $331,029. The work under both of these contracts is substantially complete except for adjustments and balancing the flow of fluid through the system.

The construction phase of the project was substantially completed November 17, 1980. Since that date the geothermal fluid has been used to heat all of the school buildings. In the district heating system, the entire space heating loads of Ringer Refrigeration Appliance (60,000 Btuh at design conditions) and Philip Motor Company (520,000 Btuh at design conditions) were provided by the geothermal fluid, as were the loads of Dorothy Brothers Garage (375,000 Btuh), Kennedy Implement (350,000 Btuh) and Hanson's Super Value grocery store (154,500 Btuh) for several months of the heating season.

LESSONS LEARNED:

Conduct more extensive tests of the results of the barium chloride precipitation process before installing such a process in the system. This could possibly have eliminated the sulfate deposits in the pipe downstream from the point of introducing the barium chloride into the system.

Provide BTU meters or continuous temperature and flow recorders in order to accurately measure the quantity of heat used by each sub-system.

Explore other methods of removing the sulfates which contain the Radium 226. These include: 1. Delay the reaction which occurs when the barium chloride is introduced into geothermal fluid until the fluid passes the static mixer. 2. Try mixing the barium chloride by using two ninety degree elbows in a disposable pipe line in lieu of the static mixer. 3. Try introducing the barium chloride into the fluid in an open well set in the settling pond. 4. Change the electro-magnetic potential between the fluid and the pipe.

Provide convenient method of removing all valves downstream from the barium chloride treatment plant to facilitate removal of sulfate deposits which prevent operation of some valves.

PHILIP SCHOOL PON REPORTS

(Cooperative Agreement No. DE-FC07-78ET27080)
(Previously No. ET-78-F-07-1728)

1. Maxon, C. A., Direct Utilization of Geothermal Energy for Philip Schools, Six Month Progress Report - July - December 1978.

2. Hengel, Berg & Associates, Environmental Impact Assessment, Geothermal Heating of Philip School Buildings for Haakon School District No. 27-1, August 25, 1978.

3. Maxon, C. A., Direct Utilization of Geothermal Energy for Philip Schools, Three-Month Progress Report - January - March 1979, Cooperative Agreement No. DE-FC07-78ET27080, April 1979.

4. Ibid, April - June 1979, June 1979.

5. Ibid, July - September 1979, October 1979.

6. Ibid, October - December 1979, January 1980.

7. Maxon, C. A., Direct Utilization of Geothermal Energy for Philip Schools, Three-Month Progress Report - January - March 1980, April 1980.

8. Ibid, November 1980 - January 1981, January 1981.

ARMORY-HIGH SCHOOL BOILER ROOM

Month: February Year: 1981 Instantaneous instrument readings.

DAY	HOUR	1 Entering Geothermal Pressure	2 Entering Geothermal Temperature	3 Domestic hot water Return Pressure	4 Temperature of geothermal fluid entering domestic hot water heat exchanger	5 Temperature of geothermal fluid returning from space heating heat exchanger	6 Temperature of space heating water returning from building	7 Temperature of space heating water supply to building	8 Temperature of geothermal fluid leaving boiler room			Outside Temperature
2	3:00	52	150	50	140	132	132	150	142			18
3	6:30	64	150	60	140	140	138	150	138			19
3	3:20	10	150	8	142	128	134	150	148			22
4	6:35	16	150	4	102	142	140	150	142			11
4	3:25	10	150	6	144	112	128	150	150			34
5	6:30	12	150	4	142	126	132	150	148			26
5	3:00	10	150	6	142	118	132	150	148			29
6	6:25	12	150	6	134	138	140	150	148			9
6	3:10	10	150	6	140	122	122	130	150			33
9	6:35	20	150	8	124	142	140	150	144			0
9	3:40	16	150	8	128	142	138	150	142			5
10	6:40	18	150	6	140	142	138	150	140			-11
10	3:45	20	150	6	140	144	138	150	140			-6
11	6:20	20	150	10	142	148	140	150	142			-4
11	3:30	10	150	2	142	132	138	150	148			3
12	6:35	14	150	2	124	142	140	150	142			12
12	2:35	10	150		144	132	120	150	150			30
13	6:25	10	150	4	144	122	132	150	148			32
16	6:30	12	150	4	144	120	122	150	150			40
16	3:15	2	150	+	94	96	102	150	150			65
17	6:40	10	150	4	144	118	130	150	150			33
17	3:25	4	150	+	148	106	112	150	150			52
18	6:35	10	150	4	144	118	132	150	150			36
19	6:40	10	150	4	144	108	130	150	150			35

GRADE SCHOOL BOILER ROOM

Month: February Year: 1981 Instantaneous instrument readings.

DAY	HOUR	1 Entering Geothermal Pressure	2 Entering Geothermal Temperature	3 Temperature of Geothermal after leaving space heating heat exchanger	4 Temperature at modulating valve	5 Temperature of space heating water supply to building	6 Temperature of space heating water return from building	7 Temperature of domestic hot water to building	8 Temperature of domestic hot water from building	9 Pressure of Geothermal fluid leaving domestic water heater	10 Temperature of geothermal fluid after leaving boiler room
2	6:45	20	142	118	140	124	116	118	86	18	140
2	3:00	50	148	124	146	140	144	132	122	48	146
3	6:35	60	148	122	144	138	130	134	136	60	142
3	3:10	8	148	104	150	138	130	120	120	6	146
4	6:45	10	150	132	148	148	138	140	138	4	148
4	3:05	8	150	114	150	132	120	130	128	2	150
5	6:35	10	148	120	150	138	124	130	128	4	152
5	3:10	10	150	120	150	138	124	132	130	4	148
6	6:35	10	148	132	150	142	120	132	128	4	148
6	3:15	10	150	124	150	138	124	130	138	4	148
9	6:45	20	148	138	144	150	132	120	120	6	140
9	3:45	8	150	132	146	148	134	136	132	2	146
10	7:10	18	148	138	140	140	130	132	130	4	146
11	6:40	20	150	140	142	150	132	130	130	8	142
11	3:45	10	150	138	140	140	134	136	130	2	148
12	7:00	10	150	142	130	144	136	132	98	2	148
12	2:30	6	150	106	150	124	120	124	120	2	150
13	7:00	10	150	140	134	146	138	136	120	2	150
16	6:40	10	150	142	130	142	134	134	122	4	150
16	3:10	4	150	96	150	100	102	92	92	+	150
17	7:00	10	150	118	150	120	122	128	124	2	150
17	3:30	4	150	100	150	118	112	96	90	+	150
18	6:40	10	150	140	150	140	132	136	122	4	150
18	4:00	4	150	100	150	112	108	96	94	5	150
19	7:00	12	150	112	150	128	122	132	132	4	150

WELL HOUSE

Instantaneous instrument readings. Month: Feb. Year: 1981

DAY	HOUR	STATION Temp	Flow	Head Press.	Mod. Valve Pressure	Pressure Out				Cummulative Gallons
2	3:05		240	68	54	52				42,174,400
3	6:20		220	75	62	62				42,377,900
3	3:15		330	30	18	12				42,455,000
4	6:30		320	35	22	18				42,764,400
4	3:30	36	330	32	18	12				42,925,800
5	6:25	10	330	30	18	12				43,220,900
5	3:20	24	320	30	18	12				43,388,200
6	6:15	12	330	30	20	14				43,686,600
6	3:30	36	330	30	20	14				43,859,000
9	6:20	2	320	40	24	20				45,068,200
9	3:50	8	330	30	20	18				45,297,600
10	6:30	-10	310	40	26	20				45,523,000
10	3:50	0	310	40	26	20				45,692,800
12	6:30	12	330	36	20	16				46,426,700
12	3:30	1	330	32	17	12				46,605,100
13	8:10	32	330	30	18	12				46,928,600
13	2:30	52	150	98	2	2				47,014,400
16	6:20	30	340	40	18	12				48,057,900
16	3:20	68	150	100	6	5				48,183,400
17	6:25	35	330	25	20	16				48,439,700
18	6:30	34	330	30	18	10				48,860,700
18	4:00	58	150	100	5	5				48,975,000
19	6:30	35	330	30	18	10				49,256,500
19	3:30	66	150	100	6	4				49,351,900

REPORT OF ION EXCHANGE EXPERIMENT FOR REMOVAL OF SULFATES CONTAINING RADIUM 226

Start of Experiment: August 11, 1981, 9:18 P.M.
End of experiment: August 13, 1981, 9:47 P.M.
Length of time of experiment: 60 hours 27 minutes

Column: 4" I.D. PVC Pipe
Cross Sectional Area: .393 ft^2
Exchange Media: Barium Sulfate

SAMPLE NO	RADIUM 226 (pico curries per liter)	% OF RADIUM 226 REMOVED	ACCUMULATIVE VOLUME THROUGH COLUMN WHEN SAMPLE TAKEN (gals)	CROSS SECTIONAL FLOR RATE (gpm per sq.ft.)
1.(Ref. Sample)	119 ± 2	0	0	0
2.	.02 ± 0.06	99.9	100	6.16
3.	3.7 ± 0.3	97.14	500	19.1
4.	10.7 ± 0.05	91.6	1015	14.3
5.	33.0 ± 1.9	72.4	2000	13.3
6.	26.1 ± 1.9	81.9	2476	12.4
7.	34.4 ± 2.2	73.9	2912	11.4
8.	41.7 ± 2.3	67.6	3500	10.3
9.	37.8 ± 1.2	73.7	4000	10.3

SUMMARY OF RESULTS:

Initially the barium sulfate ion exchange system was very effective in the removal of the Radium 226, reducing the content from 119 to less than 0.02 pico curies per liter. The EPA allowable with allowance for background is ten (10) pico curies per liter. However, the reaction degraded to background level after approximately 1,200 gallons of fluid had passed through the system. However, the annual cost of the barium sulfate is estimated at $118,000 which prohibits further consideration of this system at this time.

Table 1

ALFA-LAVAL Plate Heat Exchanger for Space Heating
Haakon School District 27-1, Armory - High School

		Side 1	Side 2
		Geothermal Fluid	Treated Water
Duty Requirements			
Fluid Flowing			
Mass Flow Rate	Lb/Hr	75000.0	75000.0
	US GPM	152.8	152.2
Flow Type		Counter Current	
Inlet Temperature	Deg F	155.0	116.0
Outlet Temperature	Deg F	131.0	140.0
Physical Properties			
Specific Heat	BTU/LB-F	0.997	0.997
Specific Gravity		0.981	0.985
Thermal Conductivity	BTU/FT-HR-F	0.378	0.373
Viscosity	CST	0.462	0.525
Viscosity Wall	CST	0.486	0.496
Performance Data			
Heat Transferred	BTU/HR	1794224.	
LMTD	Deg F	15.0	
Effective Area Reqd	Sq. Ft.	108.5	
Heat Transfer Units	Reqd/Act	1.60/ 1.60	1.60/ 1.60
Press. Drop Allowed	PSI	10.0	10.0
Press. Drop Actual	PSI	5.0	4.8
5% EXTRA SURFACE INCLUDED			
Plate Data Per Unit			
Pass Arrangement		1	1
Plate Material		AISI 316/0.6	
Gasket Material		Nitrile	Nitrile
Construction Data			
Design Pressure	PSI	150.	
Test Pressure	PSI	225.	
Gasket Design Temp.	DEG F	240.	
Cover Material		SA 515-70	
Bolting Material		Carbon Steel	
Carrying Bar Mtrl.		Stainless Steel	
Nozzle Material		CS	CS
Nominal Nozzle Diam.	IN	2.0	2.0
ASME Code Construction Section VIII Div. 1.1977			
Dimensions (Nominal)			
Total Area of heating surface	square feet	119.6	
Overall length	inches	46	
Overall width	inches	14.5	
Overall height	inches	35.75	

Table 2

ALFA-LAVAL Plate Heat Exchanger for Space Heating
Haakon School District 27-1, Elementary School

		Side 1	Side 2
Duty Requirements		Geothermal	
Fluid Flowing		Fluid	Water
Mass Flow Rate	Lb/Hr	50000.0	50000.0
	US GPM	101.9	101.5
Flow Type		Counter Current	
Inlet Temperature	DEG F	155.0	116.0
Outlet Temperature	DEG F	131.0	140.0
Physical Properties			
Specific Heat	BTU/LB-F	0.997	0.997
Specific Gravity		0.981	0.985
Thermal Conductivity	BTU/FT-HR-F	0.378	0.373
Viscosity	CST	0.462	0.525
Viscosity Wall	CST	0.486	0.496
Performance Data			
Heat Transferred	BTU/HR	1196149.	
LMTD	DEG F	15.0	
Effective Area Reqd	Sq. Ft.	73.6	
Heat Transfer Units	Reqd/Act	1.60/ 1.60	1.60/ 1.60
Press. Drop Allowed	PSI	5.0	5.0
Press. Drop Actual	PSI	4.4	4.4
5% EXTRA SURFACE INCLUDED			
Plate Data Per Unit			
Pass Arrangement		1	1
Plate Material		AISI 316/0.6	
Gasket Material		Nitrile	Nitrile
Construction Data			
Design Pressure	PSI	150.	
Test Pressure	PSI	225.	
Gasket Design Temp.	DEG F	240.	
Cover Material		SA 515-70	
Bolting Material		Carbon Steel	
Carrying Bar Material		Stainless Steel	
Nozzle Material		CS	CS
Nominal Nozzle Diam.	IN	2.0	2.0
ASME Code Construction Section VIII Div. 1 1977			
Dimensions (Nominal)			
Total Area of Heating surface	square feet	80.6	
Overall length	inches	34	
Overall width	inches	14.5	
Overall height	inches	35.75	

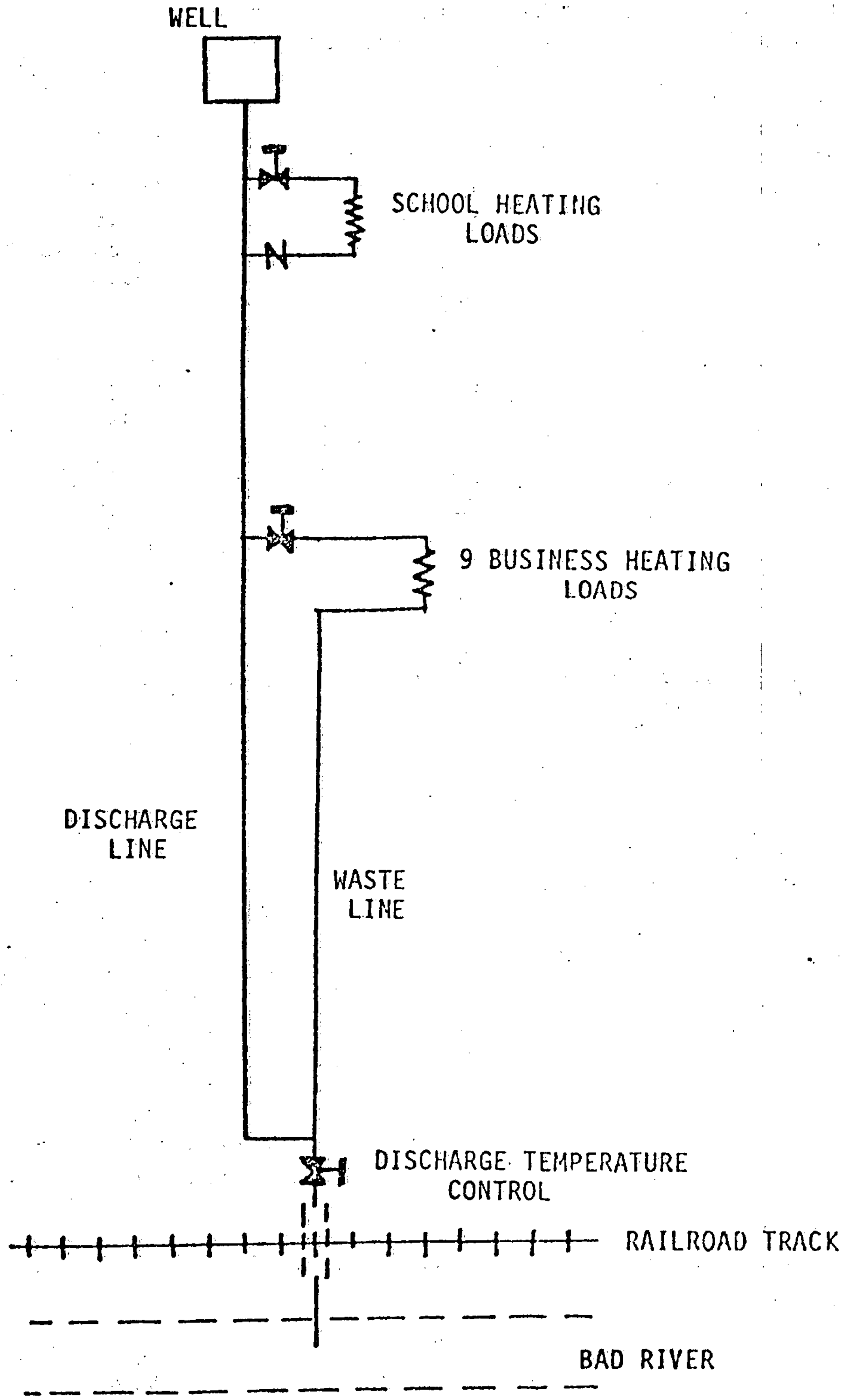


Figure 1. Simplified Philip Schematic

PROJECT TITLE

Direct Utilization of Geothermal Energy in
Western South Dakota Agribusiness
(Diamond Ring Ranch Geothermal Demonstration
Project)

PRINCIPLE INVESTIGATOR

Dr. S. M. Howard - (605) 394-2341
Professor of Metallurgical Engineering
South Dakota School of Mines and Technology
Rapid City, South Dakota 57701

PROJECT TEAM

South Dakota School of Mines and Technology
Rapid City, South Dakota
Stanley M. Howard
Dan D. Carda

RE/SPEC, Inc. (Design)
Rapid City, South Dakota
Thomas Zeller
Bill Grams

Diamond Ring Ranch (Site Owner)
Midland, South Dakota
Gene Armstrong

PROJECT OBJECTIVE

The objective was to utilize an existing geothermal well to

1) produce hot air for grain drying in a conventional grain dryer and

2) produce hot air for space heating four homes, a shop, and a hospital barn.

RESOURCE DATA

Well Depth: 4112 ft (1253 m)

Date Complete: 1959

Completion Technique: Open hole

Wellhead Temperature: 152°F (67°C)

Flowrate: 170 gpm (10.7 ℓ/s) artesian

Summary: The Madison Aquifer extends under the western half of South Dakota and into the bordering states of Wyoming, Montana, and North Dakota. Most Madison wells in South Dakota are naturally flowing with temperatures varying from 110°F (43°C) to 170°F (77°C). Figure 1 shows the Madison's extent and temperatures in South Dakota.

SYSTEM FEATURES

Application: Space heating and grain drying

Heatload (Design): 3.35 x 10^6 Btu/hr (.98 MW)

Yearly Utilization (Maximum): 7.87 x 10^9 Btu/yr (.26 MW-Yr)

Energy Replaced: Electricity - 185,288 kWh/yr
Propane - 49,415 gal./yr

Facility Description: 6 bldgs. and a 700 bu/hr grain dryer use geothermal water with disposal to stock watering pond.

Summary: Two stainless steel plate-type heat exchangers are used to heat recirculating water. One of these exchangers is located at a 700 bushel/hr grain dryer and one in the shop. The exchanger at the grain dryer supplies a hot, inhibited propylene glycol-water mixture to a water-to-air exchanger through which the grain dryer fan pulls hot, dry air. Unlike conventional combustion grain dryers, the moisture content of the air is not increased as a consequence of heating.

The exchanger in the shop is used to heat water recirculating in two conventional hydronic loops supplying water-to-air exchangers. One loop feeds the two mobile homes and the hospital barn. The second loop feeds the shop, owner's home, and the employee's home. Temperature sensors at each end-use exchanger can start the recirculating pump in the shop to maintain hot water in each line. This reduces the response time when the space thermostat calls for heating.

Inhibited ethylene glycol will be added to the space heating loops upon completion of a successful pressure check.

Figure 2 is a schematic of the system layout. BTU meters have been installed at the mobile homes, shop, employee's home, owner's home, and hospital barn. The system layout is shown in Figure 3.

STATUS

The grain drying system is operable and provides hot air for grain drying as designed.

The space heating loop operated normally during the 1979-80 winter and until February of the 1980-81 winter at which time a power failure caused freezing in the normally recirculating water lines causing the rupture of two water-to-air exchangers. The repaired exchangers will be reinstalled in September 1981.

The BTU meters for monitoring are all installed and the system will be charged with antifreeze this September to protect against power failure and other hazards which otherwise could cause freezing of the working fluid.

CURRENT ESTIMATED PROJECT COST

Total:	$403,098		
DOE Share:	$250,725	Participant Share:	$152,373
	62%		38%

LESSONS LEARNED

1. The 4,000-ft. long pipeline carrying geothermal water to the isolation heat exchangers has three high spots along its length which could have been avoided only at greatly increased pipeline expense. A degasser at the wellhead proved insufficient to prevent gas pockets from forming in the line's high spots. This problem was eventually overcome by installing PVC air vent valves at the first two of the high spots.

2. The space heating system is comprised of a plate-type isolation heat exchanger used to heat recirculating water to six structures: four homes, a hospital barn, and a shop building. These structures are supplied by two loops with the return water mixing as it re-enters the isolation exchanger. The problem of freezing arises in the event of a power failure. Freezing is most likely in the barn and shop since these structures have low thermal mass unlike the homes. To prevent freezing, the recirculating system will be charged with antifreeze. The cost of the antifreeze would have been substantially reduced by use of smaller recirculating lines (2 inch rather than 3 inch) and by dividing the isolation exchange into two units so as to put the structures subject to freezing all on one loop. It should be noted that this would have increased the capital cost but lowered operating cost assuming the antifreeze is lost several times during the system's life.

3. All systems using recirculating water subjected to freezing temperatures should be protected with antifreeze. One should not rely on auxiliary power or trained personnel to drain threatened equipment. This is particularly true for projects in remote locations such as the Diamond Ring Ranch.

4. Dividing the exchangers as described above would also have allowed subjugating the heating demands of the barn and shop to the other space heating demands. This would be a distinct advantage since the ambient temperatures of those structures are lower.

DIAMOND RING RANCH PON REPORTS

(Cooperative Agreement No. DE-FC07-78ET27158)

1. Howard, Dr. Stanley M., Environmental Report, Demonstration Project for Non-Electric Applications of Geothermal Energy, Contract No. ET-78-F-07-1729, August 10, 1978.

2. Howard, Dr. Stanley M., Direct Utilization of Geothermal Energy in Western South Dakota Agribusiness, First Quarterly Report, June 30, 1978 - September 30, 1978, Contract No. ET-78-F-07-1729, (October 1978).

3. Ibid, Second Quarterly Report, October 1, 1978 - December 31, 1978, (January 1979).

4. Ibid, Third Quarterly Report, January 1, 1979 - March 31, 1979, (April 1979).

5. Ibid, Fourth Quarterly Report, April 1, 1979 - June 30, 1979, (July 1979).

6. Ibid, Fifth Quarterly Report, July 1, 1979 - September 30, 1979, (October 1979).

Was previously DE-FC07-78ET28419.

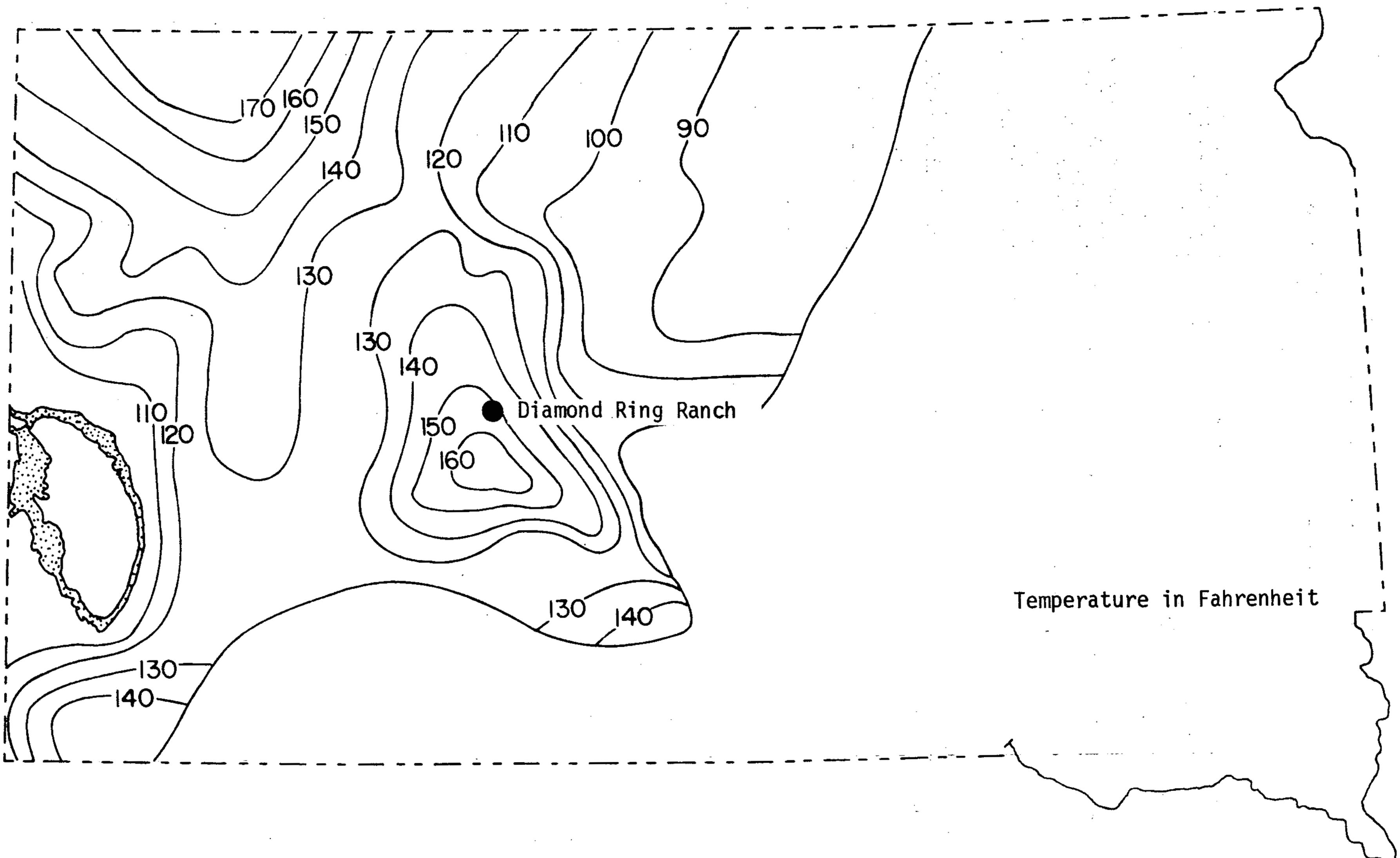


Figure 1. Isothermal Map of the Madison Aquifer in South Dakota

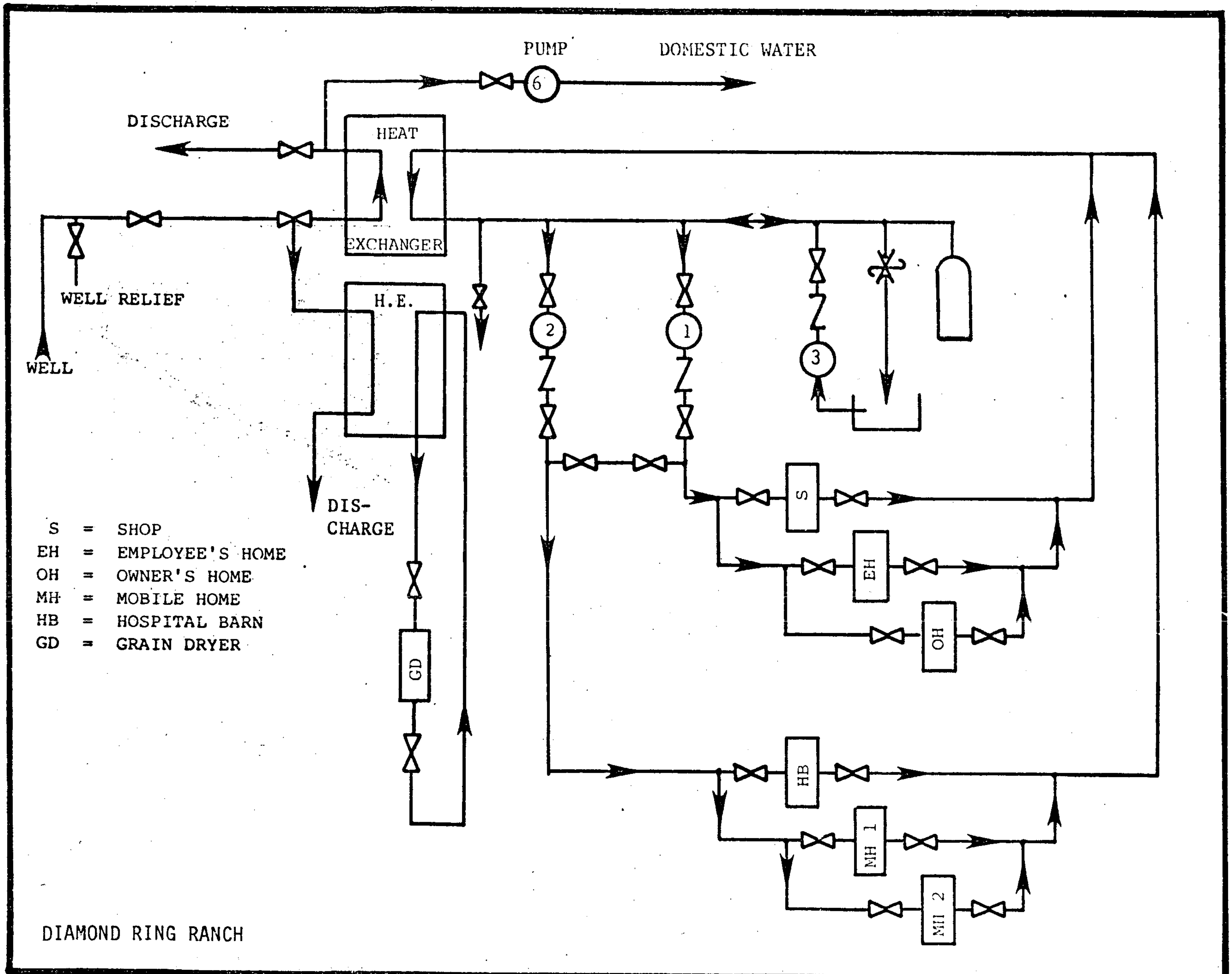


FIGURE 2. SCHEMATIC DIAGRAM OF GEOTHERMAL SYSTEM

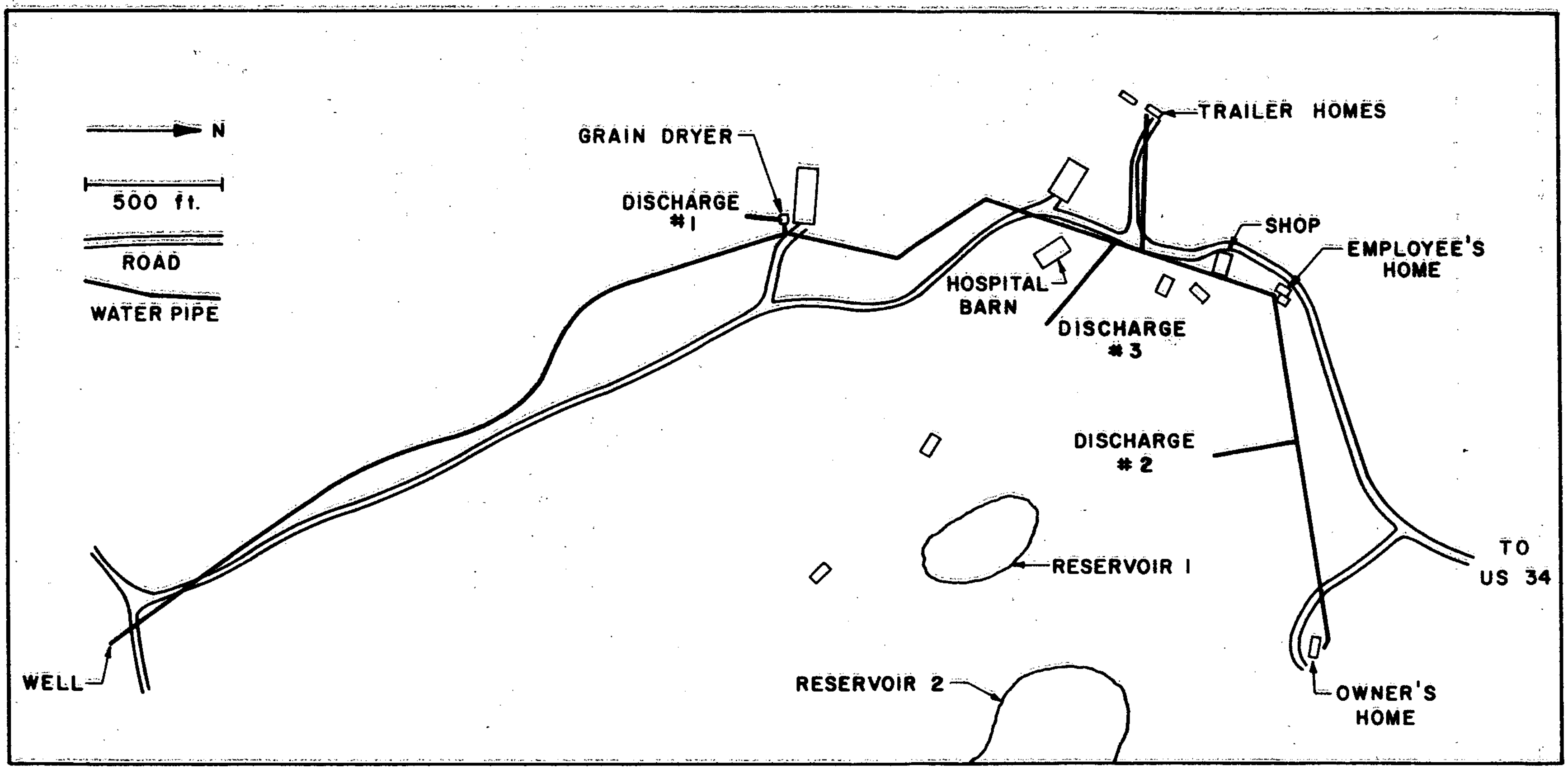


Figure 3: Layout of the Diamond Ring Ranch Geothermal Project

PROJECT TITLE: Project of Raising Prawns with Geothermal Water in the Cochella Valley, California.

PRINCIPAL INVESTIGATOR: Dr. Dov Grajcer, Aquafarms International Inc. (AII)

PROJECT TEAM: Rick Visoria, DOE, Oakland
Ken Zahora, DOE, Oakland
Dr. Dov Grajcer, President, AII
Rebecca Broughton, Deputy Project Director

AII's Technical Staff: Vincent Price
Rodney Chamberlain
Mary Price
Dennis Fulks
Stanley Fulks

Dr. Tsvi Meidav, Geothermal Consultant, Meidav Assoc.

Kreiger Inc., Accounting, Palm Desert

PROJECT DESCRIPTION:

Aquafarms International, Inc., a small California corporation, has developed a 50 acre prawn farm on its property in the Dos Palmas area, on the east side of the Cochella Valley. By utilizing geothermally heated water, AII intends a continuous, year round prawn farming operation. The specie of prawns being grown is Macrobrachium rosenbergii. Figure 1 shows the layout of the ponds.

LOCATION DESCRIPTION:

AII's headquarters is located off of California State Highway 111, near North Shore (mailing address: P.O. Box 157, Mecca, CA 92254). DOE project site: Dos Palmas area, Cochella Valley, CA.

RESOURCE DATA:

WELL A-1*:

The well was drilled to 910 feet during January 1980. It was completed with 1-inch diameter casing since it was specifically constructed as a thermal gradient hole. Geophysical logging was conducted including: S.P., resistivity and gamma-ray. Thermal gradient measurements were also made. The thermal gradient actually measured was more than twice the mean global thermal gradient, i.e., over 75°C/km (4.1°F/100 ft). This indicated that a favorable thermal gradient for direct heat uses extends all the way to the north end of the property. On the other hand, the piezometric surface at the north end is about 11 feet below the ground surface. Pumping is, therefore required.

WELL A-2:

This well was drilled to 100 feet during February 1980. Attempts to control the artesian flow with a high-density barite-rich drilling fluid failed because of inadequate pumping capacity. To prevent a potential collapse of the hole, it was decided to develop it as an agricultural well, rather than a geothermal well. A 15hp centrifugal pump has been installed at this location. The water temperatue for this well is 82°F.

WELL F-1:

This well was drilled to a depth of 325 feet during June 1980. The well was completed with a double casing to two depths, as two distinct water temperatures were available at two separate depths. The greater flow, located at the shallower depth, was 79°F. The deeper portion has been fitted with a 7.5hp centrifugal pump, in order to utilize the 92°F water during cold climatic conditions to maintain the critical life temperatures for the prawns. The advantage of this well is that the cooler water can be used year round; undiluted during normal periods and as diluent water for moderating the temperature of the high temperature section when necessary.

WELL F-2:

This well was completed to 180 feet during July 1980. Water from this well (83°F) can be pumped through a series of pipes to ponds constructed during the project period. This well was drilled, cased, cemented and redrilled through the cement cap; allowing maximum control of the artesian flow. Its water chemistry nearly duplicates that of Well A-2. Water from this well is currently being utilized to support an actively growing prawn population.

WELL F-3:

This well was drilled to a depth of 800 feet during July 1980. The best geothermal potential exists at this site, wellhead temperature was 107°F. Well cave-in occurred and attempts to redevelop the well did not succeed. The site is being held for future consideration.

WELL F-4:

This well was drilled to 125 feet during February 1981. Water temperature was 86°F. Water from this well is currently being used to maintain grow-out ponds located on the southeast portion of the site.

WELL TF:

This well was originally initiated as A-1 in January of 1980. However, due to squeeze clay effects and partial hole collapse, drilling was halted, and a new A-1 site was chosen (A-1*). Because of information gathered previously, the site was redeveloped as an agricultural well. It has been cased to 100 feet and a submersible pump installed.

SYSTEM FEATURES:

APPLICATION: The water is being used directly to supply ponds for the prawn grow-out facility.

YEARLY UTILIZATION: The geothermal fluid will be used throughout the year as the desert is subject to extreme temperatures as well as extreme temperature fluctuations. This use of the geothermal fluid will enable these temperatures to be mitigated.

ENERGY REPLACED: If fossil fuels were to be used to heat irrigation water, a total of 170 billion Btu/Yr would be requied per year for a 50 acre farm. As the pond heating is to be 100% geothermal, that amounts to approximately 30,360 barrels heating fuel/yr (heat value 5.6×10^6 Btu/bbl) replaced.

FACILITY DESCRIPTION: The prawn grow-out facility is located on approximately 250 acres of land. The northern part of this area has been developed into 50 acres of ponds. Seven wells have been completed during this contract, two of which are double cased. However, three additional wells exist which predate the contract. The water from these wells is distributed via a piping system to the prawn ponds. Where appropriate, ponds include valved delivery systems and drop box drainage systems. Pond banks act as both impoundment features and roadways. Electricity is available to all pumping sites. A drive through, low maintenance feed storage facility was constructed. Other equipment necessary for daily operations includes: pond maintenance equipment, portable feed containers, harvest nets (several types), aerated transfer/transport systems and water quality monitoring equipment.

DISPOSAL METHOD: When AII's water resources reach a point that a disposal procedure must be adopted, several techniques can be employed. Much water is lost to evaporation and some is percolated through the pond substrate. Surplus water could be impounded and recycled.

SUMMARY: With the direct use of geothermal water it seems to be possible to develop an economically sound 50 acre prawn farm in the Cochella Valley, Dos Palmas area. At today's prices this project is not feasible if fossil fuel were used because the gross product income is less than the cost of the fossil fuel.

STATUS:

A substantial schedule slippage was caused early in the contract by a very slow reaction to and often ambiguous requirement of various environment related agencies. Therefore, in order for a cost overrun not to be incurred, AII, with cooperation and advice from the DOE, chose a time extension at no additional cost. Through efficient management and a highly qualified total capability team, we have been able to complete some tasks under budget. The reserved funds were channeled into tasks in which inflation made the largest inroads. An extension to August 15 enabled us to complete facility development. The final handbook/report is being drafted.

CURRENT ESTIMATED PROJECT COST:

Total:	$575,266	
DOE Share:	$363,000	(63%)
Participant Share:	$212,266	(37%)

LESSONS LEARNED:

1. Projects that are some distance from an agricultural or industrial center should plan, from the beginning, to include within their resident team persons capable of construction and maintenance. This assures satisfactory job performance, adherence to schedule, good response to project needs and helps minimize project costs.

2. Drilling and completing relatively shallow artesian geothermal wells was a problem for local water well drillers. This problem was resolved by setting and firmly cementing a 20 inch dia conductor casing from surface to 50 ft depth. Local water well drillers needed to be educated on conductor casing use.

3. Heat transfer losses were large and temperature was somewhat difficult to control with the original pond design (100 ft wide by 5 ft deep and varying lengths from 300 to 800 ft). The surface area of new ponds has been cut in half (50 ft wide by 10 ft deep and similar lengths). Performance of the new ponds will be evaluated during the 1981-82 winter.

AQUAFARMS PON REPORTS

1. Broughton, R., Demonstration Project of Raising Prawns with Geothermal Water in the Coachella Valley, California. In, Program Summary, Geothermal Direct Heat Applications Program, Semi-Annual Review Meeting, Las Vegas, Nevada, November 20-21, 1980.

2. Broughton, R., Project of Raising Prawns with Geothermal Water in the Coachella Valley, California. In, Program Summary, Geothermal Direct Heat Applications Program, Semi-Annual Review Meeting, Boise, Idaho, September 24-25, 1981.

3. Aquafarms International, Inc., A Proposal to Support Demonstration of Raising Prawns with Geothermal Water in the Coachella Valley, California. Vol. I Summary Data/Technical Proposal, July 16, 1978. Vol. II Business Proposal/Cost Proposal, July 16, 1978.

4. Aquafarms International, Inc., Environmental Assessment Report - Demonstration Project of Raising Prawns with Geothermal Water in the Coachella Valley, California. DOE Contract No. DE-AC03-79ET 27047, October 1979.

5. Aquafarms International, Inc., Geothermal Resource Assessment Report - Demonstration Project: Raising Prawns with Geothermal Water in the Coachella Valley. DOE Contract No. DE-AC03-79ET 27047, November 1979.

6. Aquafarms International, Inc., Development Planning Demonstration Project: Raising Prawns with Geothermal Water in the Coachella Valley, (No Date). DOE Contract No. DE-AC03-79ET 27047.

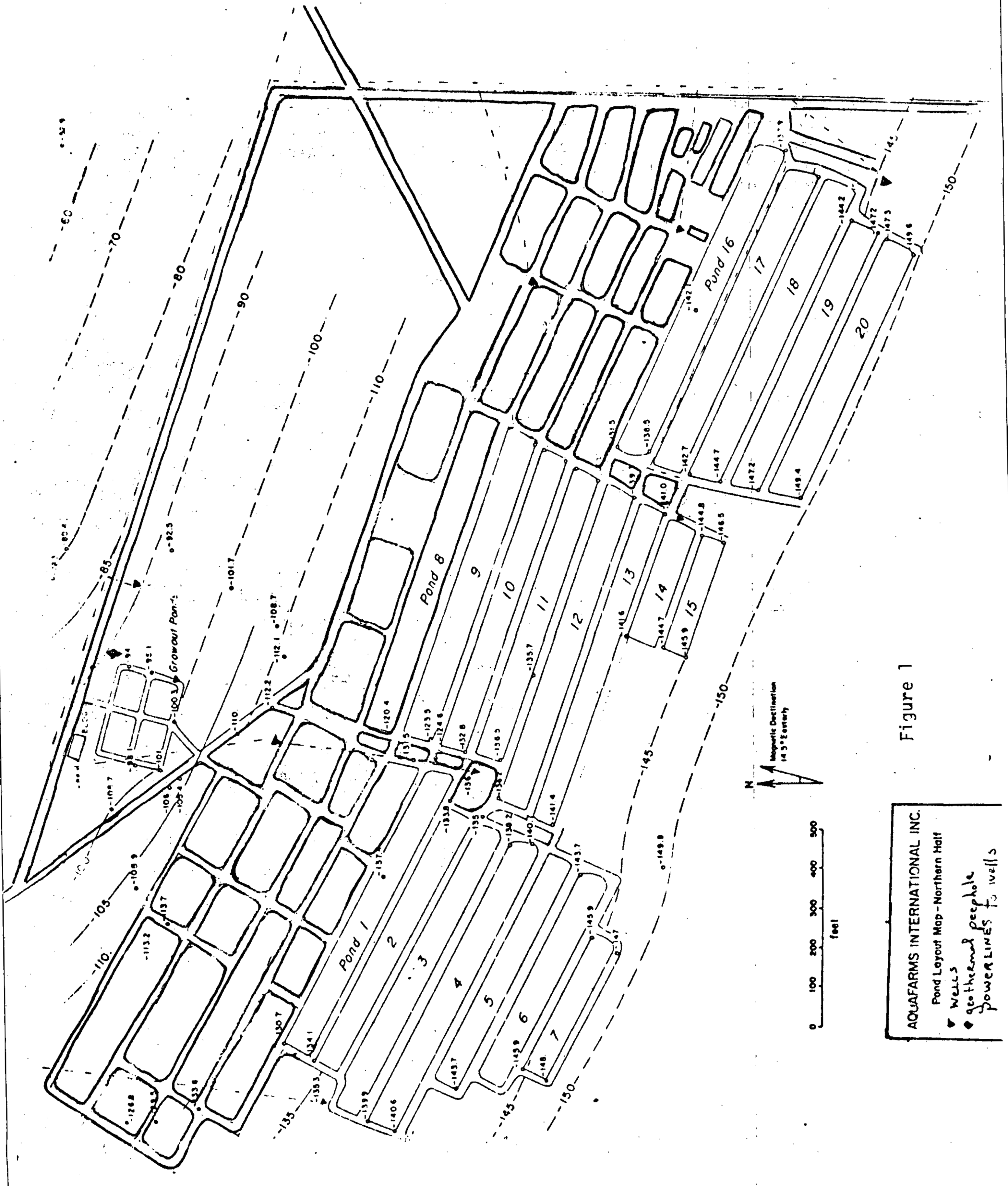

AQUAFARMS INTERNATIONAL INC.
Pond Layout Map-Northern Half
wells
geothermal peephole
power LINES to wells
Pond 1
2
3
4
5
6
7
Pond 8
9
10
11
12
13
14
15
Pond 16
17
18
19
20
Growout Ponds
Magnetic Declination 14.5° Easterly
N
feet
0
100
200
300
400
500
60
70
80
85
90
100
105
110
135
145
150

Figure 1

Geothermal Direct Heat Application

St. Mary's Hospital

Pierre, South Dakota

Principal Investigator

James Russell, Administrator

Dale Moss, Director of Support Services

(605) 224-3100

Project Team

Kirkham, Michael and Associates, Engineers

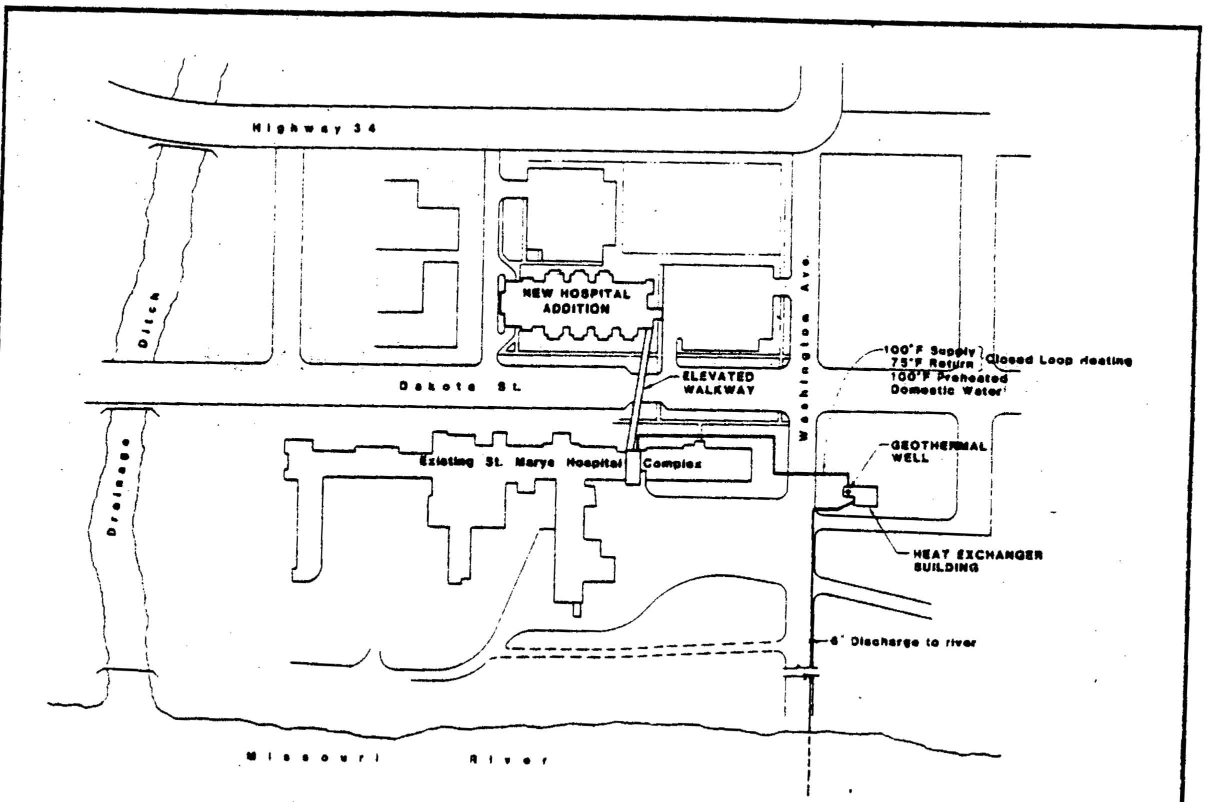
Sherwin Artus, Reservoir Consultant

Dr. J.P. Gries, Geologist

I. PROJECT DESCRIPTION

Resource

This project is located in central South Dakota within the City of Pierre. The Hospital served by the Geothermal well is located on the south side of Pierre approximately 1,000 feet north of the Missouri River which flows around the south edge of the City. The Geothermal energy will be utilized in an 83,000 sq. ft. existing hospital and also in a 65,000 sq. ft. hospital addition which is presently under construction.



St. Mary's Hospital Pierre, South Dakota

The well is located on hospital property in a vacant lot across the street east from the hospital. The well is drilled to a depth of 2,174 feet into the Madison aquifer.

The temperature of the water out of the well is 106° F. The well flow is artesian and flows at a rate of 375 gallons per minute with a residual pressure of 27 psig at the well head. The pressure at the well head with zero flow obtains a maximum of 480 psig.

The well water discharged from the heat exchangers is directed through a 6 in. poly vinyl chloride pipe approximately 1,100 ft. south to the Missouri River. The water will be dispersed through 40 ft. of perforated pipe which extends from a distance of 150 ft. to 190 ft. into the river.

The heat exchangers are in accordance with the following design conditions:

No.	Function	Fluid	Flow gpm	Ent °F	Leav °F
1.	Building Heat	Geothermal	= 350	105	80
		Closed Loop Heating Water	= 350	75	100
2.	Preheat Domestic hot water utilizing thermal discharge from Exchanger #1	Geothermal	= 350	80	75
		Domestic Water	= 76	55	78
3.	Preheat Dom HW (boost from #2 and full preheat when #1 is unloaded)	Geothermal	= 97	105	70
		Domestic Water	= 76	55	100

A corrosion and water quality report indicated that Type 316 stainless steel be the material used for the thin wall plate fin type heat exchangers.

Underground Distribution

The underground closed loop heating water supply and return and the preheated domestic hot water piping from the exchanger building to the hospital facilities is a preinsulated piping system. This piping system consists of a filament wound fiberglas carrier pipe surrounded by 1½" thick poly urethane insulation and jacketed with a poly vinyl chloride pipe. The calculated heat loss in the approximate 450 ft. of underground supply line indicates an average temperature drop in the 100° F. supply water of less than ½° F.

End Use of Heat in Existing Hospital

The 100° F. preheated domestic hot water is connected to the supply to the existing water heater and the existing hospital steam system provides further heating as required.

The closed loop heating water serves two existing systems:

1. Heating of building makeup air for ventilation.

2. Space heating in existing room fan coil units.

The water from the well has a total dissolved solids of 2,084 ppm and a hydrogen sulfide content of 0.7 ppm. Complete water analysis as follows:

TABLE I: WATER ANALYSIS FOR ST. MARY'S WELL

Species	PPM	Species	PPM	Species	PPM
(TDS)*	2084	Ca	402	Pb	0.8
HCO_3^-	124	Mg	86	Zn	0.02
Cl	75	Fe	0.3	Cd	0.05
SO_4	1445	Mn	0.25	Hg	0.005
SiO_2	27	B	1.63	HS^-	0.7
Na	50	Cu	0.1	0	1.0
K	21	AG	0.25		

*Total Dissolved Solids

pH = 6.80

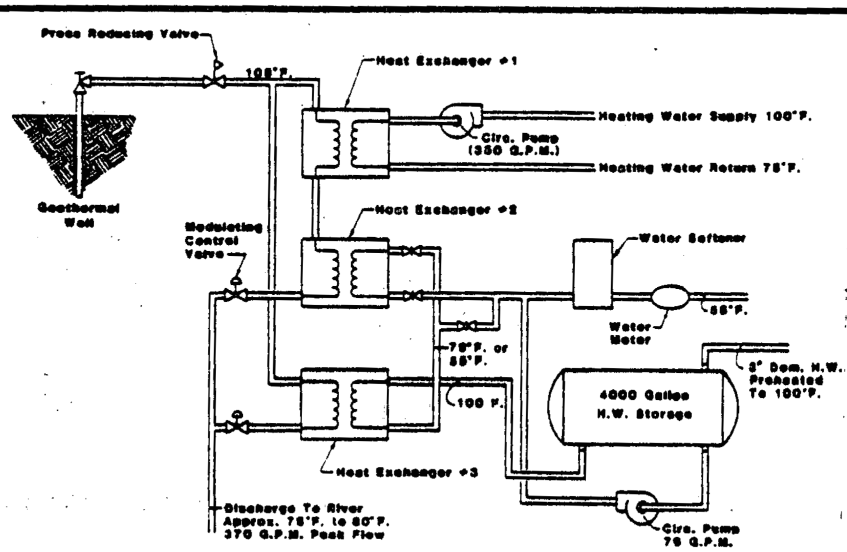
T = 106°F

Design

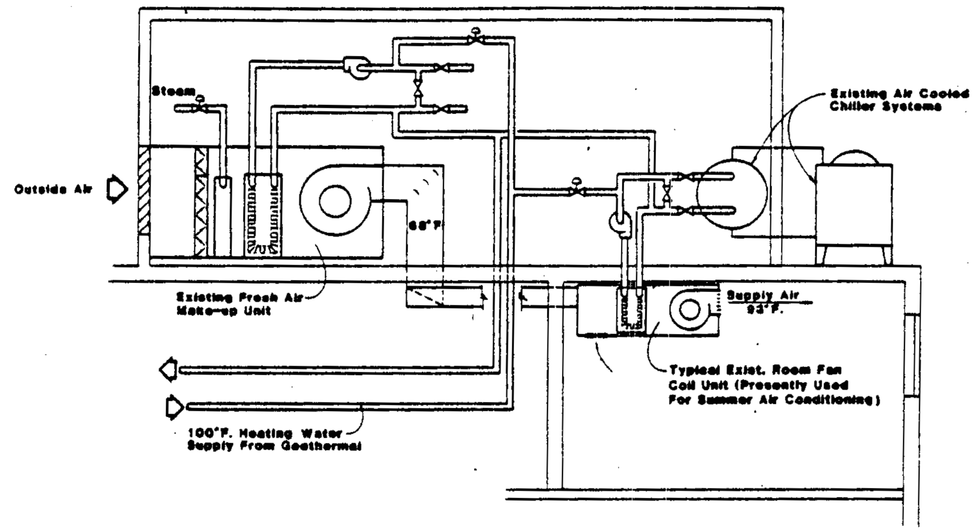
The heat is extracted from the Geothermal water by three heat exchangers located inside a small building at the well site.

The heat used from Heat Exchanger #1 is by a closed loop system circulated by a centrifugal pump which delivers 100° F. to the building heating systems.

The domestic water, which is preheated by Heat Exchangers 1 and 2, is stored in an insulated 4,000 gallon tank located within the heat exchanger building and made available for use upon demand.



WELL HOUSE AND EXCHANGER BUILDING SCHEMATIC



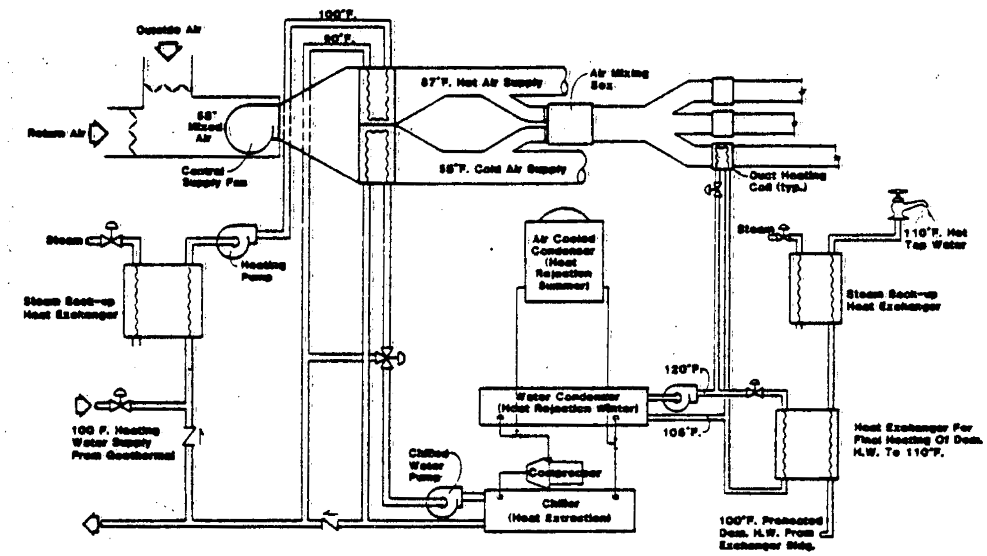
EXISTING HOSPITAL DIRECT HEAT APPLICATIONS

The existing makeup air handling of 15, 650 cfm capacity is located in a penthouse above the hospital. A six row chilled water coil existing in this unit will be supplied with the 100° F. water from the closed loop. Under a peak heating condition of heating this 15,650 cfm air from -30° F. to 68° F., 90 GPM of 100° water entering the coil would leave the coil at 63.2° F.

The present heating system in the existing hospital is basically steam perimeter radiation. A fan coil system has been added to provide air conditioning. Chilled water at the average temperature of 50° F. is circulated in the summer to provide approximately 57° to 59° supply air off the coils. In the winter time, 100° F. water will be provided to these coils to produce 90° F. heated air which is adequate to heat the spaces served during outside temperatures of approximately 2° F. and above.

New Building Addition Application

155 gpm of 100° F. water from Heat Exchanger #1, representing 2,000,000 BTUH, will be available for use in the new hospital addition that is presently under construction. The new heating system is designed to utilize the Geothermal heat source.



NEW BUILDING HEATING SYSTEM SCHEMATIC

The Geothermal energy is utilized directly in the hot deck coil of the main building air handling units. As the outside temperature drops and the demand for heat increases, further energy is extracted from the Geothermal by directing a portion of the approximate 80° F. return water from the hot deck into the chiller. Heat is then taken from the condenser or hot side of the chiller in the form of 120° F warm water for use in individual space heating coils. This condenser water is also utilized to add heat to the 100° F. preheated domestic hot water to raise it to a final use temperature of 110° F.

Instrumentation

Meters and recording equipment are being furnished to provide visual indication and seven day recording chart for the following:

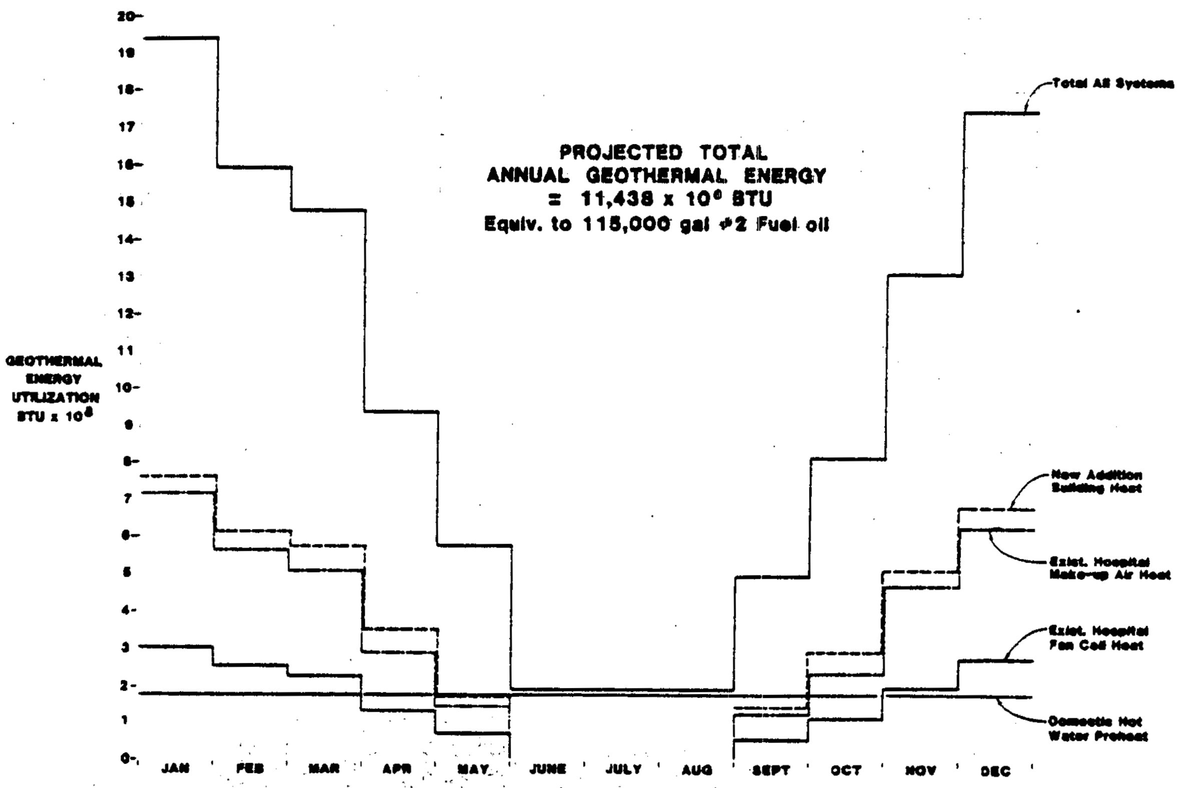
1. Well head pressure (500 psig max. to 10 psig min.).
2. Well supply temperature 106° F ±10° F.
3. Well discharge after heat exchangers (60° F to 106° F).
4. Well flow rate (0-400 gpm range).
5. Closed loop heating water supply temperature.

BTU computer to indicate BTU rate and BTU totalizer for both the total Geothermal flow and for the closed loop heating water system.

By subtracting the BTU's used in the closed loop from the total used, the amount utilized for domestic hot water heat is obtained.

System Economics

The projected month by month Geothermal energy utilization for the building heating system's calculation are plotted on the following graph.



Geothermal Energy Utilized

Fuel oil is the present source of heat energy for St. Mary's Hospital. Energy from the Geothermal source is expected to reduce the hospital's future demand for fuel oil by 115,000 gallons per year.

Based on a simple payback formula of initial cost divided by annual cost savings, the project economics are as follows:

ECONOMIC DATA

• TOTAL PROJECT COST	:	$718,000
• ANNUAL FUEL OIL SAVINGS	:	115,000 Gal.
		X.95/Gal.
TOTAL	:	$109,250
• ANNUAL OPERATION & MAINTENANCE COSTS		
Added Pumping Energy Cost	:	$840
Annual Maintenance Cost	:	10,000
Operational Cost	:	20,000
TOTAL	:	$ 30,840

• OVERALL PROJECT SIMPLE PAYBACK

$$\frac{\$718{,}000 \text{ Total Cost}}{(\$109{,}250 \text{ Annual Fuel Saving} - \$30{,}840 \text{ Oper.\&Maint. Cost})} : 9.15 \text{ YEARS}$$

• PAYBACK TO OWNER
@ 25% SHARE OF TOTAL COST

$$\frac{\$718{,}000 \times .25}{\$109{,}250 - \$30{,}840} : 2.3 \text{ YEARS}$$

The flow demand on the well will vary in direct relation to the system demand for energy from a peak requirement of approximately 360 gpm during the coldest winter month to approximately 96 gpm during the summer for domestic hot water preheating. The calculated total annual well water consumption is 51.1 million gallons.

II. STATUS

The well was completed in April of 1979. The original flow rate was approximately 250 gpm. After further perforations of the well casing and by pumping 8,000 gallons of 20 percent HCL solution into the well, the flow rate was increased to the present level of 375 gpm.

The construction work for the application of the Geothermal resource to the existing hospital and the new addition was completed September, 1980. The systems were put into operation in mid October of 1980. System performance when put into operation exceeded the anticipated capability as follows:

Anticipated	Actual
Well Supply Temp. = 106°F	108°F
Closed Loup Supply Temp. = 100°F	104° to 105°F
Domestic Hot Water Supply = 100°F	106°F

The system has been in operation approximately one year. The first year fuel oil savings equalled 60,000 gallons. The system was out of service for a period of time due to malfunctioning of the pressure reducing valve on the geothermal supply water.

III. LESSONS LEARNED

1. An economic space-heating system with good payback can be obtained with only a 106°F geothermal resource.

2. The flat plate and frame heat exchangers have worked very well and the project's A/E firm uses them more often now than previously.

3. The preinsulated reinforced fiberglass pipe (PVC cover over eurethane insulation) performed satisfactorily in this application.

4. The Madison Aquifer in this region, apparently will not produce more than 400 gpm even after stimulation of the well by acidizing, and therefore, the well and system designs should be scaled to this flow limit per well.

5. The design of the well should permit later protection of the interior surfaces of the casing from corrosion.

6. The design and the materials used for piping and other components should be selected to minimize corrosion due to exposure to the geothermal water. Material coupon tests should be performed in the specific geothermal fluid which will be used.

7. When discharging fluid into a river from a perforated pipe along the bottom of the river, do not shut off the discharge for more than two days at a time. Silting over of the pipe may force mechanical removal before discharge can be restarted.

8. Find out about, and make allowances for, permitting requirements as early in your project planning as possible.

9. Provide a contingency in any drilling budget since it is unlikely drilling will go according to plan except within a well established drilling field.

10. Exercise care to assure proper installation of flow control and pressure balance devices when using multiple water feed systems.

11. Be sure to determine if purchased pressure regulators were "factory set" to your specified pressure or just "factory tested" to determine that they worked at a random set point when assembled.

ST. MARY'S HOSPITAL PON REPORTS

(Cooperative Agreement No. DE-FC07-79ET28441)
(Previously No. ET-78-F-07-1731)

1. Aesco, Inc., Environmental Report, St. Mary's Hospital Geothermal Project, (Cooperative Agreement No. DE-FC07-79ET28441, formerly No. ET-78-F-07-1731), July 1978.

2. Kirkham, Michael and Associates, Hydrothermal Retrofit Program, St. Mary's Hospital, Pierre, South Dakota, First Quarterly Report July 1, 1978 - October 1, 1978, Contract No. ET-78-F-07-1731, (October 1978).

3. Ibid, Second Quarterly Report October 1, 1978 - January 1, 1979, (January 1979).

4. Ibid, Third Quarterly Report January 1, 1979 - April 1, 1979, (April 1979).

5. Ibid, Fourth Quarterly Report April 1, 1979 - July 1, 1979 (July 1979).

6. Petroleum Supervision and Management, Inc., Drilling Prognosis, St. Mary's Hospital Hot Water Supply Well #1 Pierre, South Dakota, (Cooperative Agreement No. DE-FC07-79ET28441), March 1979.

7. Howard, Dr. Stanley M. and Carda, Dr. Dan D., Corrosion and Water Chemistry Analysis for the St. Mary's Geothermal Well at Pierre, South Dakota, (Cooperative Agreement No. DE-FC07-79ET28441), June 8, 1979.

8. Kirkham, Michael and Associates, Specifications and Contract Documents, St. Mary's Hospital, Pierre, South Dakota, (Cooperative Agreement No. DE-FC07-79ET28441), August 1979. (Includes drawings, 14 sheets and Addendum No. 1, September 27, 1979.

PROJECT TITLE: Carrie Tingley Hospital (Not a PON project; cost shared with the state)

PRINCIPAL INVESTIGATOR: George Scudella, New Mexico Energy and Minerals Department

PROJECT TEAM: State of New Mexico, Energy and Minerals Department, BDM Corporation, Arthur J. Mansure, Project Manager, Coupland, Moran & Associates - Mechanical Design

PROJECT OBJECTIVE:

The objective of the project was to demonstrate the use of a low temperature resource by using an existing resource to preheat the hospital's domestic hot water.

LOCATION DESCRIPTION:

Carrie Tingley Hospital, Truth or Consequences, New Mexico.

RESOURCE DATA:

Existing well that also supplies therapeutic pools.
Depth: 212 ft.
Maximum Flow Rate: 90 gpm
Temperature: 105°F

SYSTEM FEATURES:

Geothermal water is pumped through the tube-side of a shell-and-tube heat exchanger and discharged to the therapeutic pools at approximately 93°F. Domestic water is circulated through the shell side of the heat exchanger and back to a storage tank. On demand, 103°F water is extracted from the storage tank and fed to the hospital's existing hot water boiler where it is heated to 180°F. The Figure 1 shows the system schematically.

STATUS:

Monitoring and operation of the system began in October 1980. During the nine month monitoring period, natural gas was displaced at the rate of 0.69 MBtu/day. During this peirod, the hospital was in the process of being relocated in Albuquerque. This resulted in a lower demand for hot water than the system was designed to provide. The final report for the project has been issued.

PROJECT COST:

Total: $101,227

LESSONS LEARNED:

1. Do not overlook potential problems from scaling and corrosion on the domestic water side of the system. In this system, heat exchanger scaling is more of a problem on the domestic side than on the goethermal side.

2. Use insulating anions when connecting dissimiliar metals in a piping system handling high-conductivity water.

3. Subcontractors were selected on the basis of technical qualifications for installation of the geothermal system to industrial standards. The additional costs associated with travel time and daily expenses for Albuquerque-based firms were more than off-set by the high caliber of workmanship.

CARRIE TINGLEY HOSPITAL REPORTS

(Cooperative Agreement No. DE-FC07-79ET27245)

1. The BDM Corporation, Carrie Tingley Geothermal Project, Final Report, BDM/A-81-435-TR, July 31, 1981.

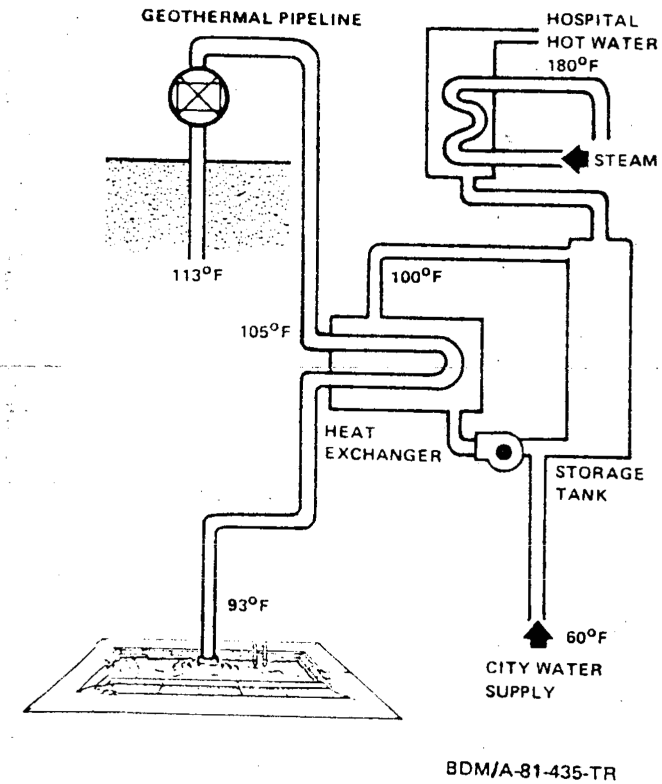


Figure 1. Carrie Tingley Hospital System Schematic

PROJECT TITLE: Research and Development of Information on Geothermal Direct Heat Application Projects

PRINCIPAL INVESTIGATOR: Mr. William C. Stitt
President, ICF Incorporated
(202) 862-1100

CONTRACTOR LOCATION: 1850 K Street, Northwest
Washington, D.C. 20006

PROJECT OBJECTIVE: The objective of this study is to compile, analyze, and make available necessary investment-decision information for direct-use geothermal projects using data from current application projects.

PROJECT SCHEDULE: October 1980 through September 1983

PROJECT DESCRIPTION

The project consists of four major tasks:

- compilation of a data base,
- evaluation and analysis,
- identification of barriers,
- technical reporting.

Task 1: Compilation of Data Base*

The data items will be project-specific and include project scope, project status, project size, project costs, fuel displaced, geological review, well construction, application, delivery system, disposal system, produced fluids, environmental issues, leasing, legal and institutional.

Task 2: Evaluation and Analysis

A series of analyses will incorporate data collected in conjunction with data base development. The issues addressed in these cross-cutting analyses emphasize economic, financial, and institutional aspects of the project experience.

*Formal data base may be reduced or eliminated due to current funding reduction, and inability to maintain in the future.

Only those projects with relevant experience are included in each analytic exercise. For instance, the first analysis has emphasized the cost experience of several operational or advanced projects and the comparative economics of geothermal versus conventional energy supplies (see project activities section, below).

Task 3: Identification of Barriers

Where appropriate, ICF will analyze geothermal direct heat applications to identify the technical, programmatic, economic, environmental, and institutional barriers to widespread adoption of the particular uses of geothermal energy covered by the projects. Additionally, we will investigate methods of alleviating, circumventing or removing these barriers. One issue receiving special attention is federal tax treatment of geothermal investments.

Task 4: Technical Reporting

ICF will prepare a series of topical reports geared toward assisting potential investors and developers of geothermal direct heat applications. The first of these reports was issued in June 1981 (see project activities section). It addressed the economics of geothermal direct heat. Related reports and professional papers will be prepared to communicate project results to a broad set of relevant audiences. An annual series of technical progress reports will also be prepared. The first technical progress report will be issued in October.

PROJECT ACTIVITIES

At the November 1980 semi-annual review meeting, a shift in this project's emphasis began in response to anticipated changes in federal geothermal energy policy. This change de-emphasized the development of a comprehensive computerized data base for direct heat application projects. Instead, the study has focused on taking maximum advantage of the information gained from several applications projects that have advanced to operation or are close to implementation. The project activities are summarized by task.

Task 1: Compilation of Data Base *

Activity concerned with compilation of a data base on geothermal direct heat applications has included two major elements. First, ICF has sought to identify the types of information of greatest importance to potential investors and developers. Second, ICF has also collected selected data from a limited number of application projects.

With respect to the identification of potentially useful data, ICF spoke with a limited sample of financial institutions and others active in geothermal energy and with DOE and other project or contractor personnel. The financial institutions' interest centered on "the bottom line," that is, whether or not such projects could operate profitably. This view was

*Formal data base may be eliminated due to current funding reduction, and inability to maintain in the future.

interpreted as reflecting the major concern of potential investors. The data requirements of the others whose opinions were sought were assumed to represent the broader interests of potential developers and other important audiences.

ICF developed an extended data collection form set up to collect data on:

- basic project information,
- pre-project activities,
- leasing and permitting,
- resource assessment,
- planning,
- well development and performance,
- transmission pipelines,
- heat extraction and distribution,
- disposal of geothermal fluids,
- environmental safeguards,
- project costs,
- project management,
- operations,
- project results/achievements.

Several reviewers of this comprehensive project review suggested that this data form could provide a useful basis for preparation of each Program Opportunity Notice (PON) project's final report. EG&G and DOE staff have pursued this concept because it would provide an ideal means of achieving several goals, including:

- a comprehensive review of each PON project's experience;
- development of project data in a format that provides treatment of important subjects in a manner that is consistent across projects;
- obtaining data without causing undue interruptions of PON project personnel by analysts not familiar with a particular project.

Some data have already been collected on twelve application projects. This has included, in some instances, review of project reports (including quarterly and monthly reports and subject-specific reports such as corrosion, environmental, geological, and design reports), invoices, and project specifications.

The greatest emphasis on data collection to date, however, has been on cost and financial data. These data for five advanced projects provided the basis for the comparative economic analysis described below.

Task 2: Evaluation and Analysis

The initial analytic effort of this project addressed the economics of geothermal direct heat applications as evidenced in the results of several advanced projects. The synopsis of the analysis presented here is based upon the interim topical report and the paper prepared for the Geothermal Resources Council meeting.

The analysis examined the five projects summarized in Table 1. The approach used to compare the projects was a discounted cash flow analysis. The costs of the different projects were adjusted to account for the particular financial situation faced by each of three types of investors:

- private, for-profit firms;
- non-profit organizations without tax-exempt bond authority; and
- local governments (or non-profit organizations with tax-exempt bond authority).

TABLE 1

PROJECT DATA SUMMARY

Project (Sponsor Status)	Application	Well Depth (feet)	Fluid Temperature (°F)	Start-up of Operations	Planned Project Life a/ (years)	Capital Cost (1980 Dollars)	O&M Cost (1980 Dollars)	Annual Energy Delivered (10^9 Btu)
Diamond Ring Ranch (private firm)	grain drying; space & water heating	4100	152°F	1979	20	$ 489,000b/	$ 5,000	7.9
Klamath YMCA (private, non-profit)	institutional space & water heating	1400	147	1980	25	285,000	2,100	7.0
Pagosa Springs (local government)	district heating	275 300	131 148	1981 c/	30	1,462,000	50,400	56.7
Philip, S.D. (local government)	district heating	4300	157	1980	30	1,188,000	4,000	14.8 d/
St. Mary's Hospital (non-profit, tax-exempt bonds)	institutional space & water heating	2200	106	1980	30	769,000	10,800	11.4

a/ Period prior to major capital re-investment.

b/ Adjusted to include cost of building new well and exclude costs of extending pipeline to existing well site.

c/ Planned.

d/ Data not available from project; estimated from energy displacement data.

The costs of all the alternatives for each investor type were then converted to a levelized unit cost (in constant dollars) of conventional energy displaced over the projected life of the geothermal project. Conventional fuel prices were estimated based on a recent DOE world oil price forecast in which oil prices increase about three percent annually.

Subsequently, a sensitivity analysis was performed to assess the effect of changes in the original assumptions. The assumptions which were altered in the sensitivity analysis included project costs, geothermal fluid flow over time, financing, federal tax policy, and world oil prices.

The analysis estimates the geothermal supply costs that each of the three types of investors would face in providing geothermal direct heat energy given a set of standard assumptions concerning taxation and financing of a project. Assumptions made in the analysis of development by a private, for-profit firm include the following:

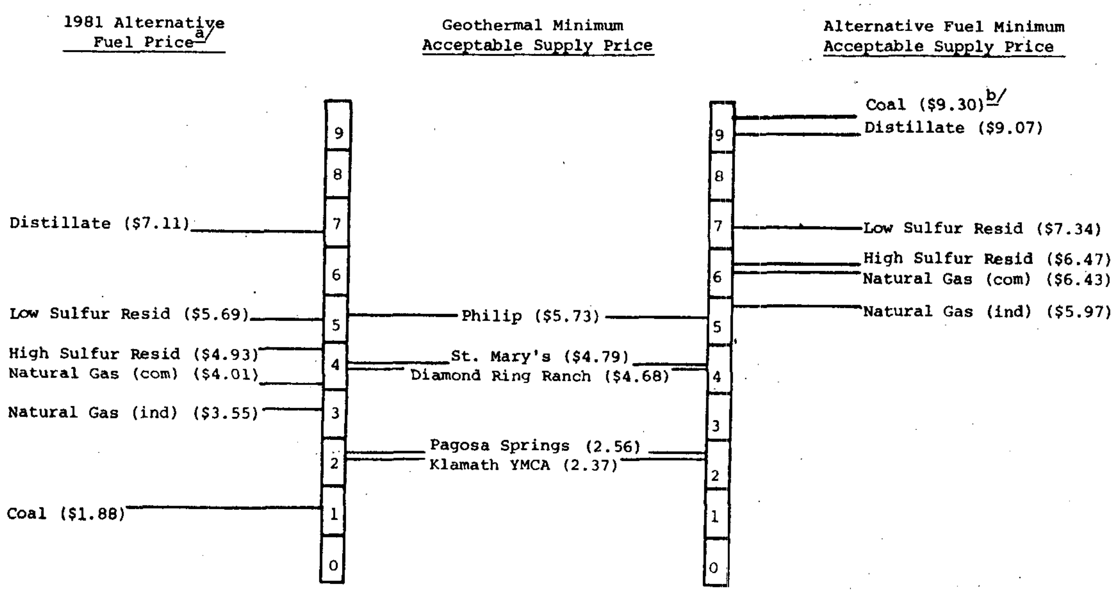
- 15 percent energy tax credit;
- federal and state income and local property tax rates (46%, 5%, and 2%, respectively);
- 10 percent royalty;
- initial debt/equity ratio of 50/50;
- 3 percent real corporate interest rate;
- 9.5 percent real return on equity.

For the private, for-profit developer, geothermal costs vary from $2.37 to $5.73 per million Btu. Because the taxation and financial assumptions were standardized for these base case estimates, the differences in unit costs result entirely from the range of variations encountered for the physical characteristics associated with the resources and applications at each project. Well depth appears to be especially important to cost differences. Fluid temperature, well capacity factor, and other factors may affect geothermal costs but additional data must be gathered before conclusive statements about these variables are possible.

Figure 1 shows that for the assumptions listed above, each project is economically superior to conventional alternative fuels on a lifecycle basis. Compared to current conventional fuel prices, however, levelized geothermal costs are not nearly as attractive.

FIGURE 1

BASE CASE COMPARISON OF
GEOTHERMAL AND CONVENTIONAL ENERGY COSTS
(1980 Dollars per Million Btu)



a/ Fuel only.
b/ Capital, O&M, and fuel costs.

A sensitivity analysis was performed for the Philip project, the most costly of the five. Although this approach "biased" the analysis against geothermal by using a high-cost project, geothermal energy remained economically superior to distillate fuel oil for all cases examined and superior to natural gas in many cases. Under the gas price assumptions used for this analysis, however, natural gas would be superior to Philip geothermal if the required real return on equity increased by 25 percent, the initial equity share grew to 75 percent, capital costs increased (perhaps to provide an injection well), or the energy tax credit were removed. Table 2 lists the levelized unit costs of the Philip geothermal project and of distillate fuel oil and commercial natural gas for selected sensitivity analysis cases.

The economic assessment performed in this study indicates that geothermal energy can provide an economical alternative to conventional fossil fuels in low temperature heating applications. The cost estimates developed should be applicable to similar projects when the geothermal resource to be used is known to resemble the resources used in the projects examined. Consequently, potential investors in geothermal direct heat applications can use the results of this study to evaluate the economic attractiveness of proposed projects in some specific locations.

This analysis' generally favorable preliminary findings about the economic attractiveness of geothermal energy indicates the need for additional efforts along several avenues of inquiry. First, the preliminary findings based on projects using known geothermal resources should be confirmed using data from other advanced projects. Second, the economic assessment must expand its scope of analysis to include the costs associated with identifying and

TABLE 2

SELECTED SENSITIVITY ANALYSIS

Parameter	Parameter Change	Philip Geothermal MASP b/ ($/million Btu)	Minimum Acceptable Supply Price a/ Distillate ($/million Btu)	Minimum Acceptable Supply Price a/ Natural Gas (Commercial) ($/million Btu)
Capital Cost	25% Increase	$7.10	$9.07	$6.43
	25% Decrease	4.35	9.07	6.43
Yearly Production Rate	Declining to 1/2 initial Rate c/	6.40	8.78	6.22
	Declining to 0 c/	7.26	8.42	5.96
Debt/Equity Ratio	25/75	7.22	9.07	6.43
	75/25	4.23	9.07	6.43
Real Return on Equity	25% increase	6.80	8.79	6.20
	25% decrease	4.72	9.40	6.68
Tax Treatment	Remove energy tax credit	7.19	9.07	6.43
	"10-5-3" accelerated depreciation	3.88	9.07	6.43
Royalties	Remove royalty charge	5.15	9.07	6.43
Project Sponsor Status	Private, not-for-profit (no tax-exempt debt)	3.68	10.12	7.17
	Local government (tax-exempt debt)	2.65	10.61	7.48

a/ Conventional fuel prices are levelized assuming the same energy quantities and applying the same discount rate as the corresponding geothermal project costs.

b/ Minimum acceptable supply price.

c/ Linear decline beginning year 6.

confirming a commercial geothermal resource. The effects of new tax regulations and potential changes in the regulation of natural gas prices also deserve attention.

The validity of the study's results would be enhanced by improving both the geothermal and the conventional energy cost estimates. The geothermal cost estimates can be improved by expanding the geothermal direct heat project data base with data from additional projects. For conventional fuel costs, future work should refine the estimates of heating equipment efficiency and examine the likelihood of different fuel price escalation rates in greater detail. Refinements would also incorporate the results of the changes in Federal business taxation.

The identification of a geothermal resource and the confirmation of its quality requires an analysis of the costs and risks of such activities and the means to finance them. The act of identifying and confirming the quality of a geothermal reservoir may or may not lead to an exploitable resource. Future work on the economics of geothermal direct heat applications should estimate the costs of identifying and confirming the required resources and the risks at each stage that a resource could prove unacceptable. Means of reducing the effective costs of such activity through full use of the tax advantages available and through creative financing approaches should also be explored.

Task 3: Identification of Barriers

The economic analysis has shown that the potentially most important barrier to commercial success, an inability to achieve economic competitiveness, has already been overcome for several geothermal direct heat applications. One closely related issue that could hinder geothermal development, tax policy towards geothermal energy, received special attention in the economic analysis. The results of that effort are reported in an appendix of the interim topical report. The subject of tax policy, especially recent major changes in the treatment of capital investments, is expected to receive further attention in this project.

Task 4: Reporting

An interim topical report, "Economic Assessment of Geothermal Direct Heat Technology: A Review of Five DOE Demonstration Projects," DOE/ID/12099-1, was published in June 1981. The results were also reported to DOE and national laboratory personnel at a briefing at DOE, Washington, April. At DOE's request, a paper, "Economics of Geothermal Direct Heat Applications," was submitted for presentation at the Geothermal Resources Council annual meeting in Houston, Texas in October 1981.

PROJECT STATUS

ICF, DOE and EG&G, Idaho personnel are in the process of identifying the next subjects for topical report preparation. Work continues to support development of the data base in its revised format.

LESSONS LEARNED

The geothermal direct heat application projects reviewed so far have uniformly provided an economical source of alternative energy. This has proven true not only under special circumstances (e.g., with Diamond Ring Ranch's existing well) but also for more typical conditions that a new project with similar geothermal resources might face.

The cost data development effort for the economic analysis confirmed the value of collecting data through the use of a detailed form filled out by project staff. ICF found that no reported information, including detailed monthly vouchers, provided cost data in the breakdown required to properly account for the major variations in the tax treatment of various project segments and types of equipment. When ICF explained the cost element distinctions required to calculate taxes correctly, project staff quickly provided the information. Moreover, project staff did not indicate that these requests imposed any inconvenience.