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1.0 INTRODUCTION

1.1 Report Format

This final report follows a general outline which was developed for all U.S. DOE Program Opportunity Notice (PON) geothermal projects. The intent of the outline is to provide general uniformity in reporting format and content. Since the scopes of the projects vary, some sections of the general outline may not be applicable to all projects. Sections not applicable to this report are so identified in those sections.

1.2 Objectives

1.2.1 U.S. DOE Program Opportunity Notice Solicitations

The private sector's use of geothermal energy for direct heating within the United States has been quite limited to date. Yet, there is a large potential market for thermal energy in such areas as industrial processing, agribusiness, and space/water heating of commercial and residential buildings. Technical and economic information is needed to assist in identifying prospective direct heat users and to match their energy needs to specific geothermal reservoirs. Technological uncertainties and associated economic risks have influenced potential user perception of profitability to the point of limiting private investment in geothermal direct heat applications.

In September, 1977, and April, 1978, the Department of Energy, Division of Geothermal Energy (now the Division of Geothermal and Hydropower Technologies), issued two Program Opportunity Notices. These solicitations were part of DOE's national geothermal energy program plan, which had as its objective the near-term research and development of hydrothermal resources by

the private sector. Encouragement was given to municipalities and the private sector by DOE offering to share a portion of the front-end financial risk in a limited number of field experiment projects. After competitive evaluations, 23 PON projects were selected from the two Program Opportunity Notice solicitations. Subsequent events caused four of these projects to withdraw from the program.

To assist future final report searches, a list of all 19 DOE Direct-Use Geothermal PON Projects that will be using this final report format is presented in Table 1-1. The DOE report number will be of the form DOE/ET/2XXXX-N where 2XXXX are the last five digits of the DOE contract number (given below) and N is the sequential order of reports issued by the subject project, printed by the federal government for general distribution, and available through the National Technical Information Service (NTIS).

This final report documents the DOE Direct-Use Geothermal PON Project in Corsicana, Texas.

1.2.2 Demonstration Project

The objective of this project was to demonstrate technical feasibility and to analyze economics of the direct-use of geothermal energy. To meet this objective, the geothermal resource was used to heat fresh water to raise shrimp (prawns), grow produce, and raise catfish at Navarro College in Corsicana, Texas.

TABLE 1-1.

Contract Number	Project Name	Location	DOE OFFICE
DE-FC07-78ET27054	Monroe	Monroe, Utah	ID
DE-FC07-78ET27080	Haakon School	Phillip, South Dakota	ID
DE-FC07-78ET28419	Diamond Ring Ranch	Haakon County, South Dakota	ID
DE-AC07-78ET28424	Ore-Ida Foods	Ontario, Oregon	ID
DE-FC07-78ET28441	St. Mary's Hospital	Pierre, South Dakota	ID
DE-FC07-79ET27027	Utah State Prison	Draper, Utah	ID
DE-FC07-79ET27028	Madison County	Rexburg, Idaho	ID

DE-FC07-79ET27030	Pagosa Springs	Pagosa Springs, Colo.	ID
DE-AC07-79ET27033	Elko Heat Company	Elko, Nevada	ID
DE-FC07-79ET27053	Boise	Boise, Idaho	ID
DE-AC07-79ET27055	Warm Springs State Hospital	W.S.S.H., Montanta	ID
DE-AC07-79ET27056	Utah Roses, Inc.	Sandy, Utah	ID
DE-AC03-78ET27154	Klamath Falls	Klamath Falls, Oregon	SAN
DE-AC03-79ET27029	Moana, Reno	Reno, Nevada	SAN
DE-AC03-79ET27040	Susanville	Susanville, California	SAN
DE-AC03-79ET27045	El Centro	El Centro, California	SAN
DE-AC03-79ET27047	Aquafarms	Dos Palmas Area, Calif	SAN
DE-AC08-78ET27059	T-H-S Hospital	Marlin, Texas	NV
DE-FC08-79ET27058	Navarro College	Corsicana, Texas	NV

DOE Direct-Geothermal PON Projects
Table 1-1

1.2.3 Project Location

Corsicana is the county seat of Navarro County, Texas and had a 1980 population of about 21,712. As depicted in Figure 1-1, Corsicana is situated 55 miles south of Dallas and 55 miles northeast of Waco. Figure 1-2 is a map of the city of Corsicana.

1.3 Pre-Project Background

Navarro College is a two-year comprehensive community college located in Corsicana, Texas on a 117 acre campus (Figures 1-1 and 1-2). This acreage is located over a medium temperature (130°F) geothermal reservoir 2,600 feet below the surface.

The college was founded in 1946 when a group of Navarro County citizens met to form a steering committee for the purpose of establishing a junior college. A public election was held on July 16, 1946, to elect the first board of trustees and authorize a local tax to support the newly formed college.

The first class of students entered in September, 1946. The initial college enrollment was 238 students. The first campus was located on

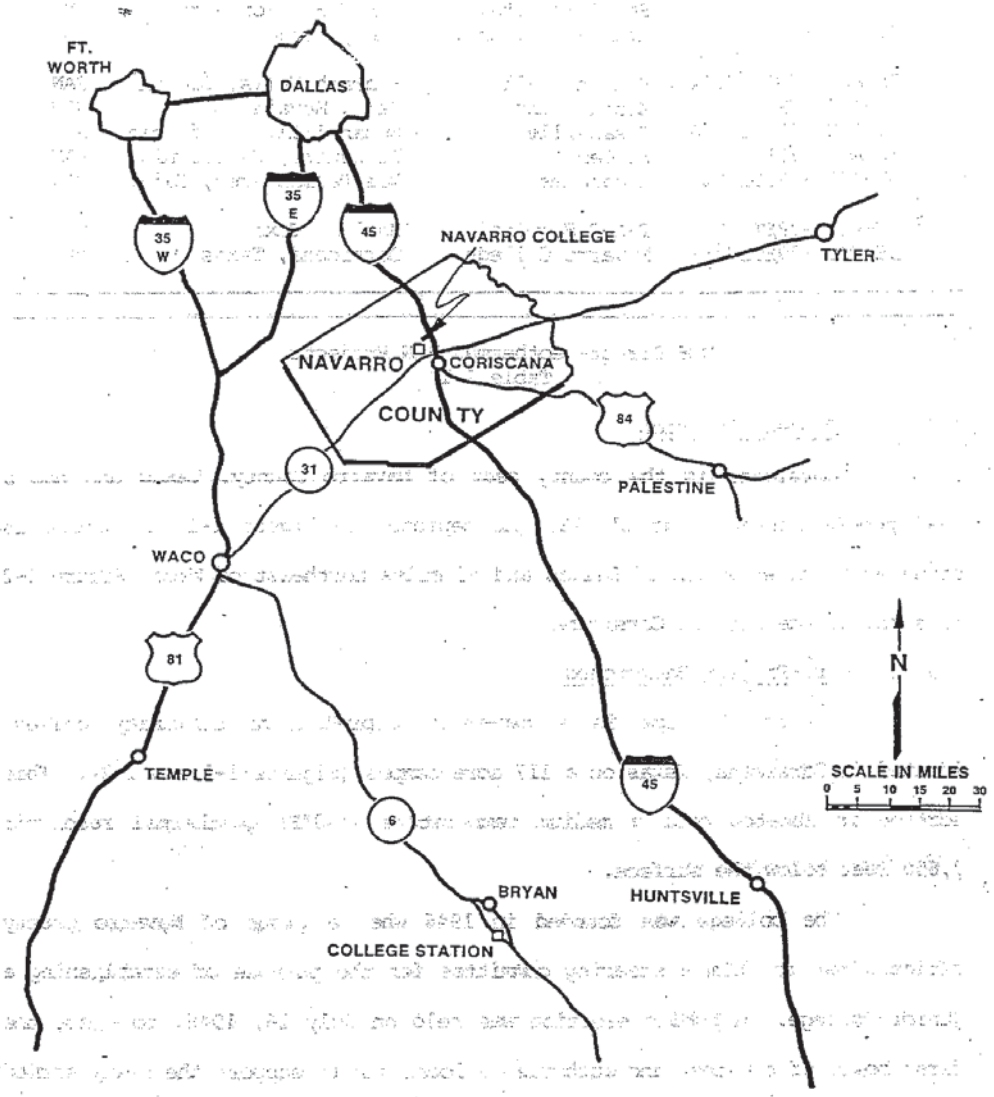

FIGURE 1-1. LOCATION OF CORSICANA, TEXAS

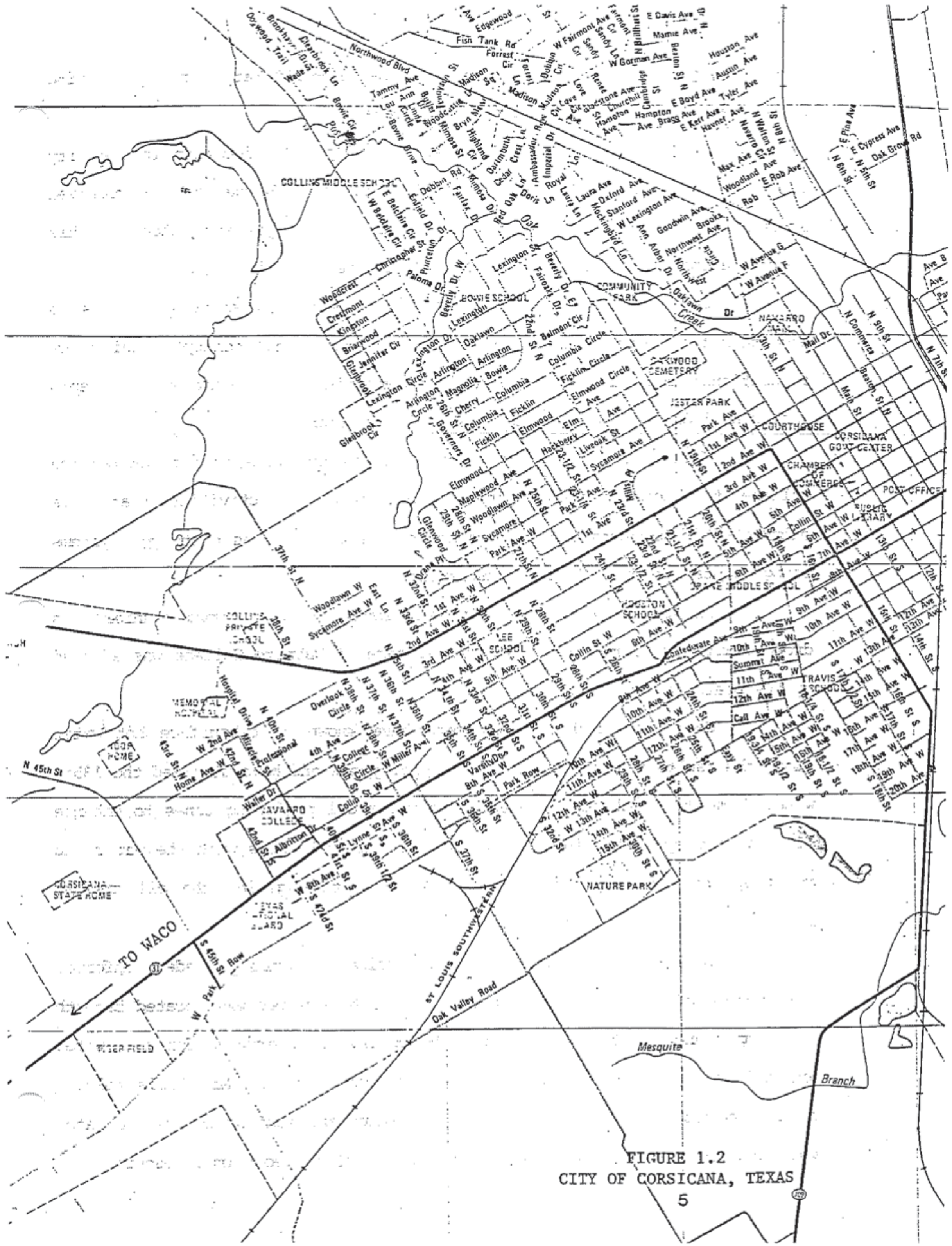

FIGURE 1.2
CITY OF CORSICANA, TEXAS

the property of the Air Activities of Texas, a World War II primary flying school facility, six miles south of Corsicana.

In 1951 the campus was moved to its present location in the city limits of Corsicana on State Highway 31 West. In 1954 the college received accreditation from the Southern Association of Colleges and Schools. This accreditation was reaffirmed in 1974 and will be again in 1985.

During 1974 the college broadened its philosophy and purposes to encompass the comprehensive community based educational concept, adding new occupational education programs and implementing new educational concepts including individualized and self-paced instruction.

This incorporation of new philosphies and concepts has enabled the college to become involved in numerous research activities that have culminated in projects and curriculum that have served as prototype systems being adopted at several other institutions.

In keeping with this new educational role, the word "Junior" was dropped from the name, and the official name of Navarro College was adopted by the Board of Trustees.

Geologists and oil producers have known of subsurface hot water along the faults near Corsicana for several years and have utilized the 135°F water from the Woodbine to inject into upper oil producing zones to enhance oil recovery by recharging the pressure in the oil zones with the water and reducing the viscosity of the oil with heat thus giving the oil greater mobility.

In 1978, Mr. Walter Erwin, a Corsicana community leader, informed the College of his belief that medium temperature water was located beneath the campus and he offered to assist the college in searching for this water and deliver it to the surface. Within one year, he and Mr. Louis Wolens, another community leader, provided the guidance and funding to drill a water well and prove the existence and location of a 130°F geothermal resource.

Based on this resource confirmation, the Department of Energy agreed to cost share a project to conduct research and development of the hydrothermal resource to determine the best methods of using the warm water to heat various spaces. Beginning research concentrated on utilizing the geothermal water to heat College buildings and a nearby hospital; however, because of the limited injection well capabilities, it was determined that the best utilization of the geothermal energy would be an application system where the energy and effluents pass through several use systems including an aquacultural, greenhouse, and farm pond operation. This design and application system has not only allowed for basic research on the economic and technical feasibility of a medium temperature resource, but it is anticipated that these facilities can be further utilized by the College as a continuing operation for educational training and curriculum development at Navarro College.

On March 9, 1979, the U.S. Department of Energy, Nevada Operations Office entered into cooperative agreement No. DE-FC08-79ET27058 with Navarro College to demonstrate the economic and technical feasibility of direct utilization of geothermal energy.

1.4. Project Scope

1.4.1 Original Scope

Originally the project scope was to show the feasibility of using the resource for space heating applications in one of the campus buildings and for the county hospital. Specifically the college was to perform the following tasks:

1.4.1.1 Drill a production well in the Corsicana known geothermal resource area and perform logging and production testing for a final reservoir confirmation.

1.4.1.2 Prepare and submit to DOE an Environmental Report describing the potential environmental effects of the project.

1.4.1.3. Acquire the necessary disposal permits and design and construct an environmentally acceptable geothermal fluid disposal system.

1.4.1.4. Prepare a Preliminary Design Report to include an overview of the selected geothermal system, with a description of the major energy extraction and utilization subsystems, control(s), and components including auxiliary hardware, performance characteristics of the system and subsystems, and engineering drawings.

1.4.1.5. Prepare a Final Design Report to address total system design, including details of the geothermal energy extraction and utilization subsystems and controls, interfaces with the existing conventional energy system as appropriate, and an economic analysis. The economic analysis to provide sufficient detail to permit credible estimation of capital and life-cycle costs associated with the geothermal energy system including cost of conventional equipment modifications, estimated annual operation and maintenance costs for a five-year operation period, projected conventional fuel savings over the operating period, and estimated payback on the financial investment. All applicable construction drawings and specifications to be submitted for review and concurrence by DOE as part of this report.

1.4.1.6. Prepare an economic analysis (including life-cycle energy and cost savings) of the geothermal system versus a conventional energy system.

1.4.1.7. Determine performance requirements and design/procure/install and acceptance-test low-temperature geothermal heating systems to augment the Navarro College and Navarro County Memorial Hospital space and domestic water heating requirements.

1.4.1.8. Design and construct a geothermal fluid distribution system between the wellheads and the Navarro College Student Union Building, and the Navarro County Memorial Hospital.

1.4.1.9. Develop an Operations and Maintenance manual for the Navarro College and Navarro County Memorial Hospital geothermal system.

1.4.1.10. Plan and execute a public awareness program for the project.

1.4.1.11. Identify, coordinate, and resolve social, legal, environmental, and institutional factors which may effect the successful completion of the project.

1.4.1.12. During the initial operational period of the Navarro College and Navarro County Memorial Hospital geothermal system, provide for the attraction of, and information transfer to, potential users of similar systems.

1.4.2 Final Scope

The results of an injection test performed on the disposal well in October of 1981 revealed that the well would take fluid at approximately 60 GPM under gravity flow. This flow rate is insufficient for space heating of buildings. Therefore in July of 1982 the scope was changed from space heating to the cascade applications of geothermal energy. Specifically the College was to perform the following tasks:

1.4.2.1 Drill a production well in the Corsicana known geothermal resource area and perform logging and production testing for a final reservoir confirmation.

1.4.2.2 Prepare and submit to DOE an Environmental Report describing the potential environmental effects of the project, and supplement that report as required because of changes that occur in the project objective and scope.

1.4.2.3 Acquire the necessary disposal permits and design and construct an environmentally acceptable geothermal fluid disposal system.

1.4.2.4 Prepare a Preliminary Design Report to include an overview of the cascade application of geothermal energy for aquaculture, greenhouse and irrigation systems with a description of the major energy extraction and utilization subsystems, controls, and components including structures, fluid transport piping systems and hardware, performance characteristics of the systems and subsystems, and engineering drawings.

1.4.2.5 Prepare a Final Design Report to address total system design, including details of the geothermal energy extraction and utilization subsystems and controls, primary and support structures, schematic flow diagrams and other details and specifications as required to fully describe and specify the work to be performed to accomplish the Facilities Installation. The Report to include an economic analysis in sufficient detail to permit estimation of capital and life-cycle costs associated with the annual operation and maintenance costs for a five year operation period, and an estimated payback on the financial investment. All applicable facility drawings and specifications shall be submitted for review and concurrence by DOE as a part of this Report.

1.4.2.6 Procure and install facilities for the cascade application of geothermal energy in accordance with the approved Final Design Report and the facility drawings and specifications.

1.4.2.7 Develop an operations and maintenance manual for the aquaculture, greenhouse and irrigation systems and conduct a systems operational demonstration cycle of up to one year while gathering, recording, and evaluating data and observations for incorporation in the Final Technical Report.

1.4.2.8. Plan and execute a public awareness program for the project.

1.4.2.9. Identify, coordinate, and resolve social, legal, environmental and institutional factors which may affect the successful completion of the project.

1.4.2.10. During the initial operational period of the geothermal applications systems, provide for the attraction of, and information transfer to potential users of similar systems.

1.4.2.11. Prepare and submit reports as set forth in the Cooperative Agreement.

1.5. Growth Potential

The limiting factor of the project is the disposal well. Although production well tests show capabilities of producing up to 300 gallons per minute flow, the injection well acceptance rate, limits usage at the present time to 60 gallons per minute. Peak heating demands of the current project are scarcely accommodated by this capacity of the injection well.

Should an alternate method of disposal or better injection well become available, then the possibility of project expansion and/or space heating of buildings could be further investigated.

If the pilot project indicates that the operation should be expanded, alternatives include perforating the sands between 1730' and 1858', treatment of the upper Woodbine, and pumping the water into the injection well under pressure.

2.0 SUMMARY

The objectives of the Navarro College Geothermal Project have been: 1) to determine the technical feasibility of direct-use geothermal energy for a cascade system, 2) to use the project as a prototype system to encourage geothermal development by the private sector, and 3) to gather project data to analyze economic incentives for geothermal development. Table 2-1 briefly describes these activities and serves as a concise summary to the project and to this final report.

Activities of primary interest in Table 2-1 include system monitoring and economic analysis. It was from these efforts that projected natural gas savings and incentives for development by the private sector were derived.

As a prototype unit, the geothermal project at Navarro College has successfully demonstrated that initial planning and engineering have culminated in a technically feasible operation which extracts the maximum amount of available energy in a cascade application system. Crop items from each of the project elements were then used to establish the economic viability for projected commercial operations.

Two other elements affecting the economics of geothermal utilization in commercial enterprises include tax incentives and well utilization. Results indicate that tax incentives currently available have a significant impact on the economic incentive. Also, the economics could improve immensely if heating loads and well utilization were greater than those currently employed by the project at Navarro College. If the well, which is an expensive capital item, were utilized more fully, greater savings would be acheived at minimal additional costs, and economics would improve.

Table 2-1.

ACTIVITY	SUMMARY
° Resource Assessment	Based on historical evidence of geothermal resource in Corsicana and available geologic data, anticipated a highly productive 130°F resource having less than 8000 ppm TDS at a depth of 2600 ft.
° Well Drilling, Completion, and Testing	Instituted measures to prevent drilling noise from becoming an environmental problem. Drilled 2664 ft. well which produces 130°F water at 300 gpm. TDS content is 6000 ppm.
° Environmental and Institutional Issues	Drilled a second well to 4762 ft., trying to locate a hotter resource. Only a poorer quality resource found and the #2 well was plugged back to 2400 ft. to be used as the injection well. This injection well was required by state agencies to meet with environmental regulations and standards for geofluid disposal.
° System Design and Material Selection	Evaluated materials for their compatibility with the college geofluid. Prepared preliminary and final designs which use a cascade arrangement of energy use and which adhere to materials and process constraints.
° Bidding and Construction	Issued plans and specifications to candidate contractors through open bidding process. Selected contractor based on price and qualifications. Construction proceeded on schedule and system became fully operational in October 1983. Conducted Acceptance Test and prepared monitoring logs and Operations Manual for Navarro College personnel.
° Systems Monitoring and Dedication Ceremonies	Conducted a 1-yr, monitoring phase to monitor system performance, orient college personnel, and assist in troubleshooting as needed. No interruption of geothermal service has been experienced since system startup in October 1983. On October 27, 1983, Navarro College sponsored a dedication ceremony which was well attended by the press, Corsicana citizens, political figures and project participants.

° Economic Analyses	Performed economic analyses to evaluate private sector incentives for continued development of Central Texas geothermal resource. Concluded that larger heating loads than those at the college are likely needed before economics become attractive for profit-making organizations.
° Public Awareness	Throughout the project, implemented stategies to inform general public about geothermal energy and the college project, and to attract potential geothermal users. Elements included press releases, fact sheets, site signs, tours, and audio/visual slide show.
° Materials Testing	During actual system operation, conducted 8-month corrosion test of common materials of construction in order to promote widespread use of the Central Texas geothermal resource. Identified suitable materials and confirmed the selections made for the Navarro College.

Summary of the Navarro College Geothermal Project
Table 2-1

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3.0 CONCLUSION AND RECOMMENDATIONS

The Navarro College Geothermal Project has encompased a broad range of technical, institutional, and economic activities, many of which have constituted pioneering efforts in determining practical applications of geothermal resources. Consequently, a great deal of the data acquired can be utilized for future geothermal development. A total of eleven conclusions and recommendations are presented below and are organized as technical, institutional/environmental, or economic.

3.1 Technical Conclusions and Recommendations

- The Central Texas geothermal resource near Corsicana can produce large quantities of relatively clean geothermal waters having temperatures at approximately 130°F. It is capable of supporting additional geothermal development.

- This project has demonstrated that substantial energy savings can be achieved for geothermal systems addressing water and space heating loads, even in mild Texas climates.

- Careful consideration of the geofluids corrosion and scaling tendencies must be given in the design stage if these maintenance hardships are to be prevented. Materials testing results from this project can aid future developers in planning their system and help reduce front end engineering costs.

- The Navarro College geothermal system has been in continuous operation since startup in October of 1983 and has not experienced any significant interruption due to engineering or design faults showing the system to be reliable and dependable.

- Piping, valves, heat exchangers, and associated components of the system which come into contact with the geofluids need to be closely specified in order to provide for a long-lived system.

- Geofluid disposal by injection requires careful planning of the production/injection wells couplet and careful design of the injection well. These efforts are essential if communication between wells and injectability problems are to be avoided. Injection well parameters play an important roll in system success. Limits of project scope are just as easily dictated by injection well acceptance rates as by production well flow rates.

3.2 Institutional/Environmental Conclusions and Recommendations

- Well drilling at Navarro College was accomplished at low noise levels and without complaints from nearby residents. Drilling noise should not be considered a deterrent to future geothermal projects.

- Obtaining appropriate permits for this geothermal system in Texas required interfacing and coordinating with several agencies, including the Texas Railroad Commission, the Texas Department of Water Resources, the Texas Department of Health, the Texas Air Control Board, the U.S. Environmental Protection Agency, and the U.S. Department of Environmental Quality. However, most of these permits were readily obtained and do not constitute a deterrent to potential geothermal developers. Potential users should, however, allow sufficient time to secure the permits, especially those related to environmental issues.

- The Operations Manual prepared for the Navarro College project has been used to familiarize college personnel with the operation and maintenance of these facilities. It is recommended that any potential geothermal developers also develop O & M Manuals for their operations.

3.3. Economic Conclusions and Recommendations

- Economic incentives currently exist for other organizations to pursue geothermal systems using the Central Texas Geothermal Resource, provided that the heating load is equal to or larger than that at the College. Larger heating loads can strengthen the incentives. It is recommended that facilities which can use substantial amounts of energy at or below 130°F investigate geothermal opportunities.

- The economic attractiveness of Central Texas geothermal development is due largely to the well defined resource, and the associated low risk involved in drilling a production well. Development of equipment, such as low temperature modine heat transfer units for greenhouses, makes the incentives even more apparent.

4.0 PROJECT DESCRIPTION

4.1 Task Breakdown

The principle tasks and sub-tasks are presented in Figure 4-1, which depicts the actual schedule of installation and utilization of each project segment of the Navarro College Geothermal Project at Corsicana, Texas. The lengthy schedule of this project can be attributed to several minor problems which caused numerous delays and extensions to the project's completion date.

Specific problems associated with this project included: (a) poor weather conditions which hampered drilling and workovers of both the production and disposal wells, (b) extensive time requirements by the architectural/engineers in preparing preliminary and final design reports, and (c) poor weather conditions during construction of the project elements.

4.2 Organization and Participants

Participating organizations and principals are presented in the Organization Chart; Figure 4-2. Dr. Lary Reed, Vice President for Campus Services, served as project director and coordinated the functions of all participants as well as interfacing with sponsoring entities.

Kenan Smith, Project Coordinator, presented information on the project to a number of community organizations, participated at DOE review conferences, kept the appropriate governmental agencies appraised of project status, and supervised systems operations.

4.3 Funding Breakdown

The cost of the project, depicted in Figure 4-3, was shared between the United States Department of Energy and Navarro College.

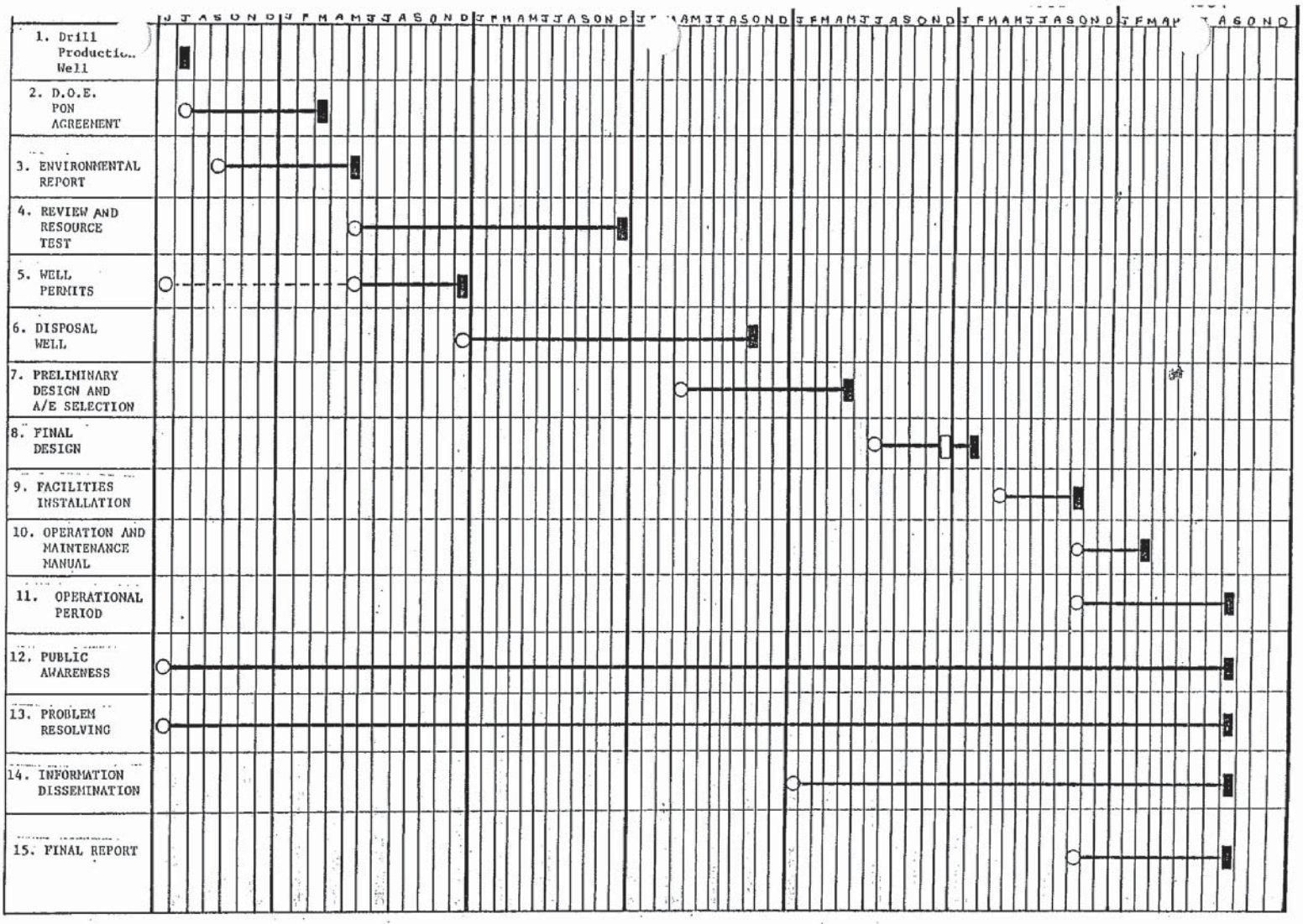


Figure 4-1 Project Schedule

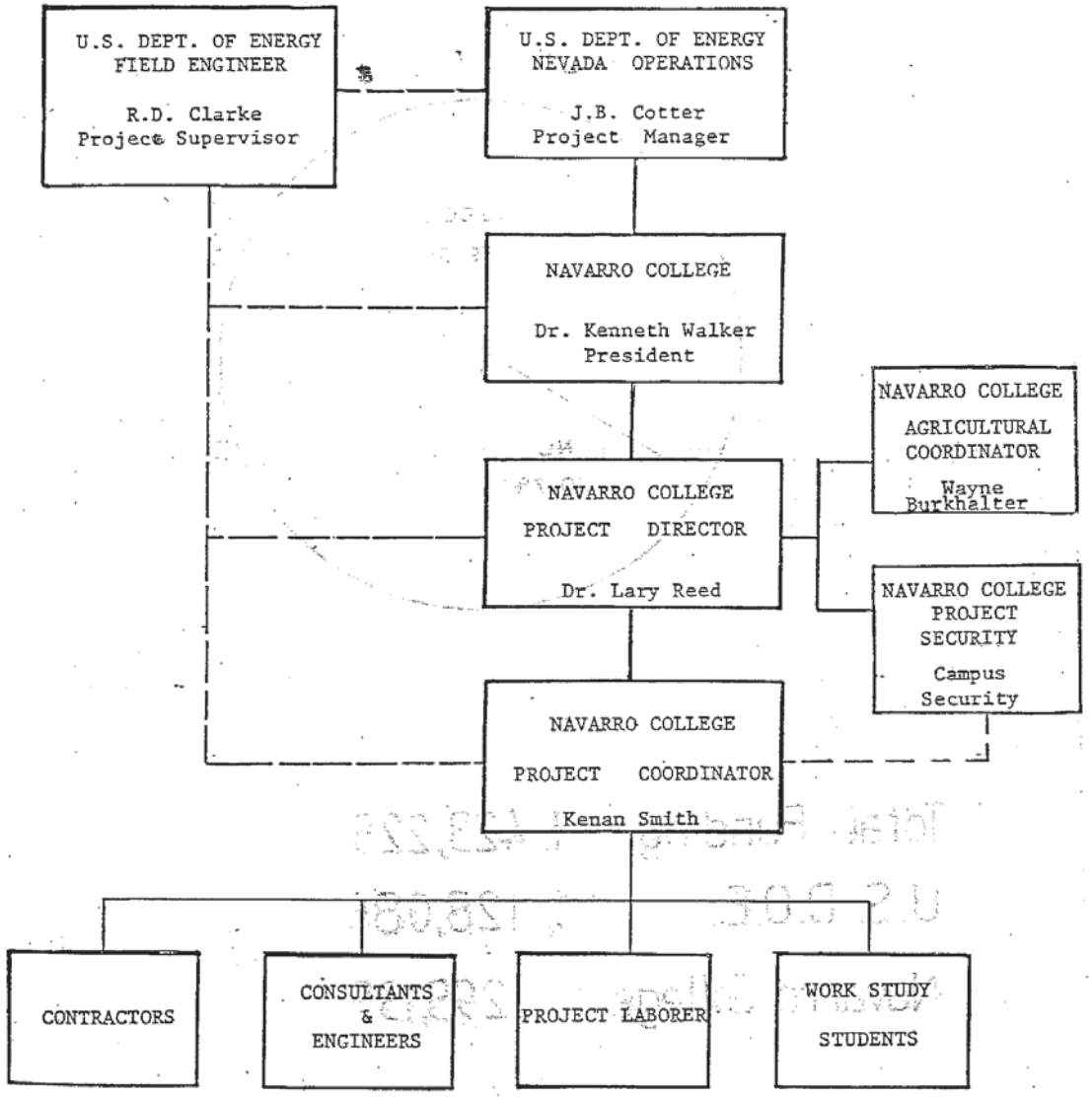
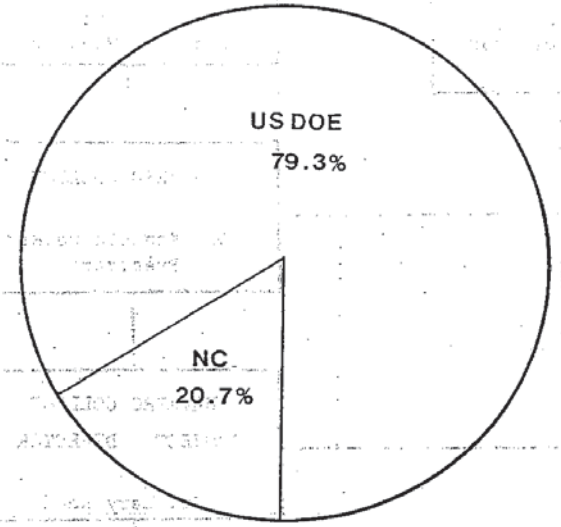


Figure 4-2
Organization Chart



Total Funding	1,423,225
U.S. D.O.E.	1,128,086
Navarro College	295,139

Figure 4-3
Cost Breakdown

5.0 RESOURCE ASSESSMENT

5.1 Pre-Project Assessment

For many years oil has been produced in and around Corsicana. Oil firms have utilized the 135°F geothermal resource from the Woodbine Formation as a supply of water for secondary oil recovery from upper zones in operational areas east of Corsicana.

5.2 Pre-Drilling Assessment

The Woodbine Formation is the shallowest unit in the Navarro County Area that contains water at elevated (greater than 90°F) temperatures. The formation occurs at a depth of approximately 2,250 feet at Navarro College. Based on a temperature log of the existing production well, the temperature of water over the perforated zone (2,450 to 2,560 feet) ranges from 116° to 119°F. The measured bottom-hole temperature is about 122°F. When the well was fully cleaned up and pumped at a flow of 330 gpm, the production zone temperature increased to 135°F.

On the basis of temperature gradient calculations, water in the deeper Trinity Group and Hosston Formation may have temperatures as high as 150° to 160°F. There are no wells completed in these deeper rocks in Navarro County.

The principal factor responsible for the high temperatures of water in these rocks is the Mexia-Talco fault system. Where the Cretaceous rocks have been downdropped along the faults, water in these units co-mingles with the hotter connate waters of the rocks in the Quachita fold belt. These downfaulted Cretaceous units are hydraulically connected by faults to the same water-bearing units on the upthrown sides of the faults. Therefore, hot

waters migrate upward along the faults and mix with water in the shallower Cretaceous units, resulting in above normal water temperatures at shallower depths. (Fig. 5-1 through 5-3)

The Texas Department of Water Resources estimates that the transmissivity of the Woodbine in Navarro County is about 2,300 gpd/ft, based on a saturated sand thickness of 23 meters (76 feet) and hydraulic conductivity of 30 gpd/ft^2.

There are no other water wells producing drinking water from the Woodbine Formation at the present time in central or eastern Navarro County, due primarily to the poor quality of the water. Large quantities of brine have been pumped for over 50 years in conjunction with oil production from the Woodbine east of Corsicana. Production from the geothermal well represents only a small fraction of the brine production from oil wells.

5.3 Drill Site Selection

During 1978, and prior to the establishment of a cooperative agreement with the United States Department of Energy, local citizens expressed an interest in sponsoring the drilling of an exploratory well on the Navarro College campus. It was the intent of these sponsors that the well be located on the campus so that scientific research activities could be conducted in order to determine the feasibility of using this resource as an alternative to fossil fuels for heating purposes. Since the original intent for use of this resource was to heat a campus building and the county hospital, the first well site was selected in an open area on a northern section of the campus which was located between both the hospital and campus buildings. When the project had evolved further and the hospital was sold, this site was still conveniently located for installation of the disposal well and construciton of the present project.

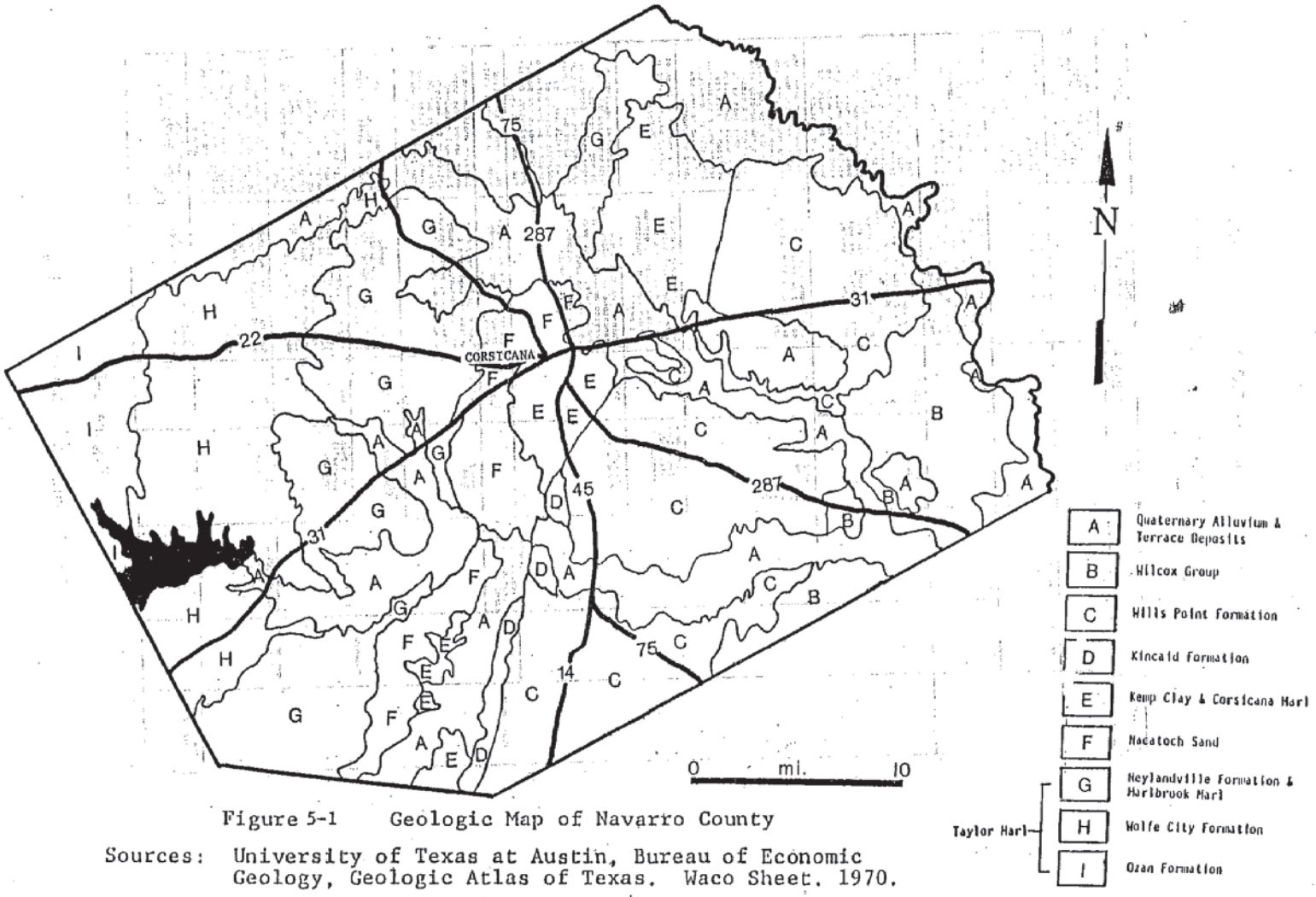


Figure 5-1 Geologic Map of Navarro County

Sources: University of Texas at Austin, Bureau of Economic Geology, Geologic Atlas of Texas. Waco Sheet. 1970.

University of Texas at Austin, Bureau of Economic Geology, Geologic Atlas of Texas. Dallas Sheet. 1972.

LITHOLOGY AND WATER-BEARING CHARACTERISTICS

OF GEOLOGIC UNITS IN NAVARRO COUNTY

SYSTEM	SERIES	GROUP	GEOLOGICAL UNIT	MAXIMUM THICKNESS (FEET)	LITHOLOGICAL CHARACTER OF UNITS	WATER-BEARING PROPERTIES
Quaternary	Holocene Pleistocene		Alluvial deposits	55	Sand, gravel, silt, & clay.	Yields small quantities of fresh to slightly saline water to shallow irrigation wells along the Trinity River.
	Eocene	Wilcox		360	Fine to medium sands containing clay & silt.	Yields small quantities of fresh to slightly saline water to shallow dug wells for domestic & stock use in eastern part of county.
	Paleocene	Midway		820	Multishaded gray to black gypsiferous silty clay, siltstone, glauconitic calcareous sandstone, some sandy glauconitic limestone & concretionary limestone bed in upper part.	Yields small quantities of fresh to slightly saline water to shallow dug wells for domestic & stock use in eastern part of county.
Cretaceous	Gulf	Navarro	Nacatoch Sand	202 324	Dark calcareous, sandy, glauconitic clay, & some beds of fine to medium-grained glauconitic sandstone, above & below the Nacatoch. The Nacatoch Sand includes four sandstone lenses interbedded with light gray shale.	The Nacatoch yields small quantities of fresh water to slightly saline water to wells as much as 300 ft. deep for stock, domestic, & public supply use; & other beds of the Navarro yield very small quantities of hard water to shallow dug wells for domestic & stock use.
		TAYLOR MARL	Wolf City Sand Member	1,262	Calcareous & sandy, glauconitic fine-grained sanstone, & some impure chalk.	The glauconitic sandstone (Wolfe City Sand Member) yields small quantities of fresh hard water to a few shallow dug wells within the outcrop area for domestic & stock use; other beds yield very small quantities of fresh to slightly saline water to shallow dug wells for domestic & stock use in western third of county.
			Austin Chalk & Eagle Ford Shale, undifferentiated	928	Clayey limestone & chalk interbedded with silty & sandy shale, & dark shale containing beds of gypsum & thin beds of sandstone & limestone.	Not a source of fresh or slightly saline water in Navarro County.
			Woodbine Formation	592	Thin-to massive-bedded sandstone interbedded with varying amounts of shale & sandy shale. Upper part of formation contains clay, lignite, gypsum, & nodules of alunite.	A principal aquifer in western third Navarro County. Water from upper part of formation is more mineralized than from lower part. Formation yields small to moderate supplies of slightly saline water to drilled wells for public supply, industry, domestic, and stock use.
		unconformity Washita and Fredrickaburg (undifferentiated)		1,270	Limestone, shale, & calcareous, silty, & sandy shale.	Not a source of ground water in Navarro County.
	Comanche	Trinity	Paluxy Sand	120	Fine-grained, poorly consolidated sandstone & varying amounts of sandy clay, shale, some lignite, & nodules of pyrite.	Contains small amount of water having less than 3,000 mg/l dissolved solids in far western tip of County; but no known wells obtain water from formation in Navarro County.
			Glen Rose Limestone	1,363	Medium-to thick-bedded limestone & some sandstone, sandy shale, shale, and anhydrite.	Not a source of fresh or slightly saline ground water in Navarro County.
			Travis Peak (Pearsall) Formation	662	Coarse-to fine-grained sanstone in upper to lower parts & interbeds of sandstone, shale, & limestone in middle part. Shale & limestone increase in the middle part downdip.	Small to moderate supplies of slightly saline water are available in western quarter of the county, but no known wells in county obtain water from the form.
	Coahuila	Nuevo Leon & Durango	Mosston Formation	289	Sandstone & sparse interbeds of siltstone, sandy shale, red & green shale, calcareous silty shale, & thin limestone.	An important potential source of small to moderate supplies of slightly saline water in western third of Navarro County. No wells obtain water from the formation in the county.
		(major unconformity)				
Pre-Cretaceous				7	Shale, quartzite, limestone, & indurated sandstone.	Oil well tests in County indicate highly mineralized water in these rocks.

Figure 5-2

*Reconstructed by Navarro College

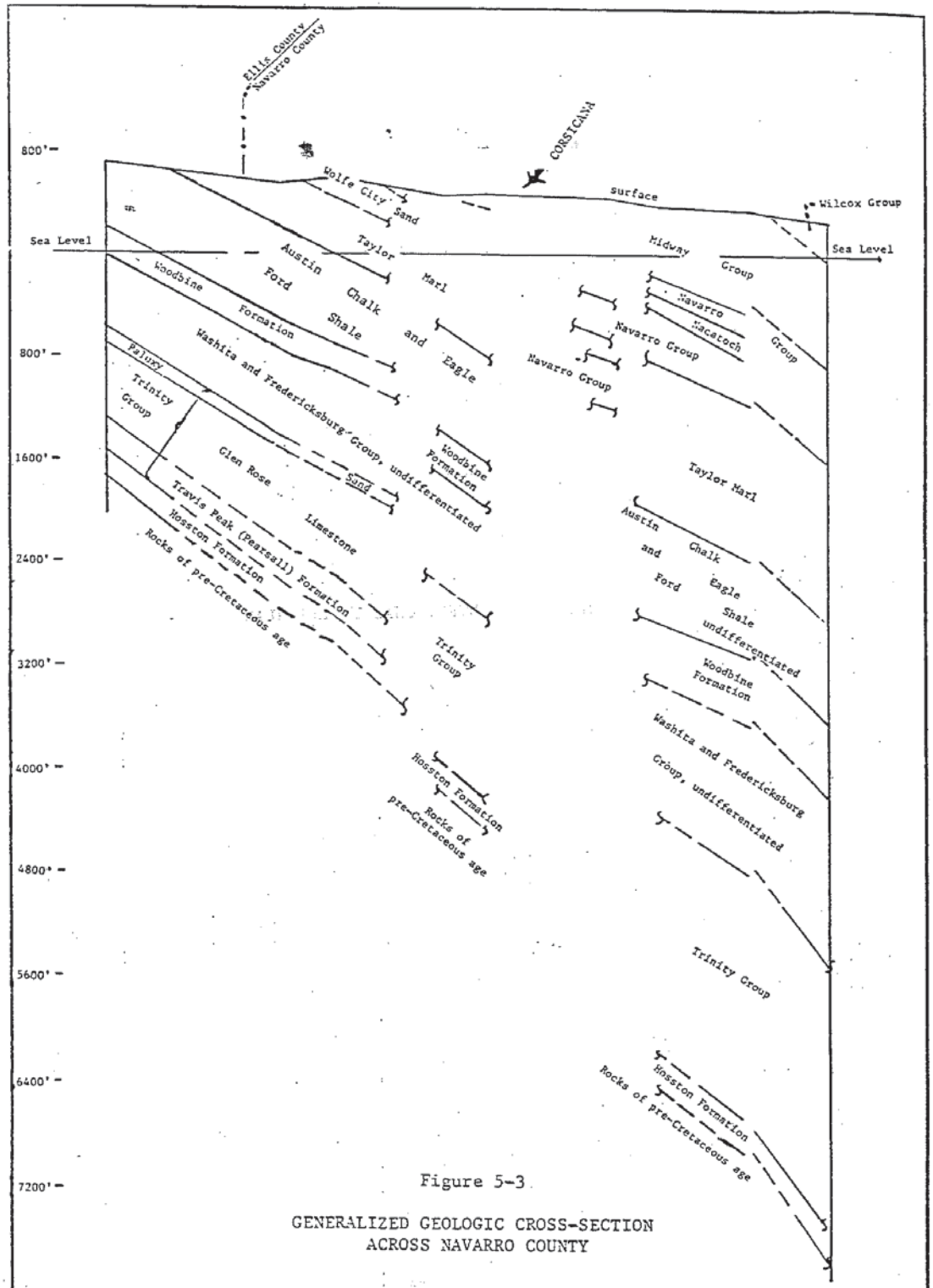


Figure 5-3

GENERALIZED GEOLOGIC CROSS-SECTION
ACROSS NAVARRO COUNTY

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6.0 ENVIRONMENTAL ISSUES

Under the original contract agreement, Radian Corporation was commissioned to develop an environmental report. The purpose of this report was to investigate the planning of the project and to assure that the project would be in compliance with federal, state and local laws regulating environmental impact as set forth in the National Environmental Policy Act (NEPA) of 1969. In addition, the report was to determine the environmental documentation necessary to remain in accordance with the implemented regulations published by the Council on Environmental Quality (CEQ) in November of 1978.

The tapping of this resource does not affect normal drinking water supplies since the well is cased and cemented to a depth of 238 feet to protect fresh water aquifers.

6.1 Pre-Drill

Prior to drilling the production well, normal permitting through the Railroad Commission of Texas was sought and approved. Other State entities, such as the soil Conservation Service and the Texas Department of Geology, (Fig. 5-1 - 5-3) were also contacted to assure that drilling and utilization of this resource would not present problems in relation to environmental impacts. (See Appendix A)

6.2 Post-Drill

Once the reservoir had been located and an analysis of the water (See Appendix B) completed, the Railroad Commission required that any spent geothermal fluids, not receiving treatment for the high dissolved solids

content, be reinjected rather than elimination of these fluids through surface disposal. This requirement was satisfied through completion of an injection well in October of 1981.

The Railroad Commission was contacted on June 20, 1982 and the project scope was discussed to determine if additional permits would be required. Since the project would have a small flow and be reinjecting the spent geothermal fluid, additional permitting through the Railroad Commission was not required.

In order to determine if any other federal permits were required to meet with the environmental issues, the project was discussed with the Environmental Protection Agency (EPA) in Dallas, Texas on June 19, 1982. After reviewing the project it was determined that permitting was not required by the EPA.

Due to the high degree of design and utilization techniques employed in this system, a minimum of environmental impacts and the associated permitting requirements have been imposed on the project. The Environmental Report entitled An Environmental Report for the Geothermal Direct Utilization Project at Navarro College was completed by Radian Corporation on May 1, 1979. The results of this report can be obtained upon request from the U.S. DOE Technical Information Center.

7.0 INSTITUTIONAL ISSUES AND PERMITS

Permits required for this project were limited and did not present any significant problems. Federal permits and requirements were met through the environmental report and approval from the Environmental Protection Agency.

State permits and approvals have been supplied through the Texas Railroad Commission and the Texas Water Board Commission (see Appendix A), while normal building permits satisfied the local requirements of city and county codes.

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8.0 PRODUCTION WELL DRILLING AND LOGGING

8.1 Summary

During July of 1978 an exploratory well was drilled on Navarro College property to investigate the potential of geothermal water believed to exist in the Woodbine Formation.

The well was drilled to a depth of ± 2664 feet and an electric log (see Appendix C) was run in the 9-5/8 inch open hole from the total depth of 2664 feet to the bottom of the 10-3/4 inch surface casing at 238 feet.

A 130°F resource was confirmed in the Woodbine Formation and the hole was cased with 7 inch casing from 2664 feet to the surface. The well was then completed with perforations in the lower Woodbine sand from 2454 feet to 2560 feet.

8.2 Completion

A 17½ inch hole was drilled to 238 feet and 10-3/4 inch casing was set and cemented from 238 feet to the surface. A 9-5/8 inch hole was then drilled from 238 feet to 2664 feet and 7 inch, 23#, K-55, R3 steel casing was set and cemented from 2664 feet to the surface (Fig 8-1).

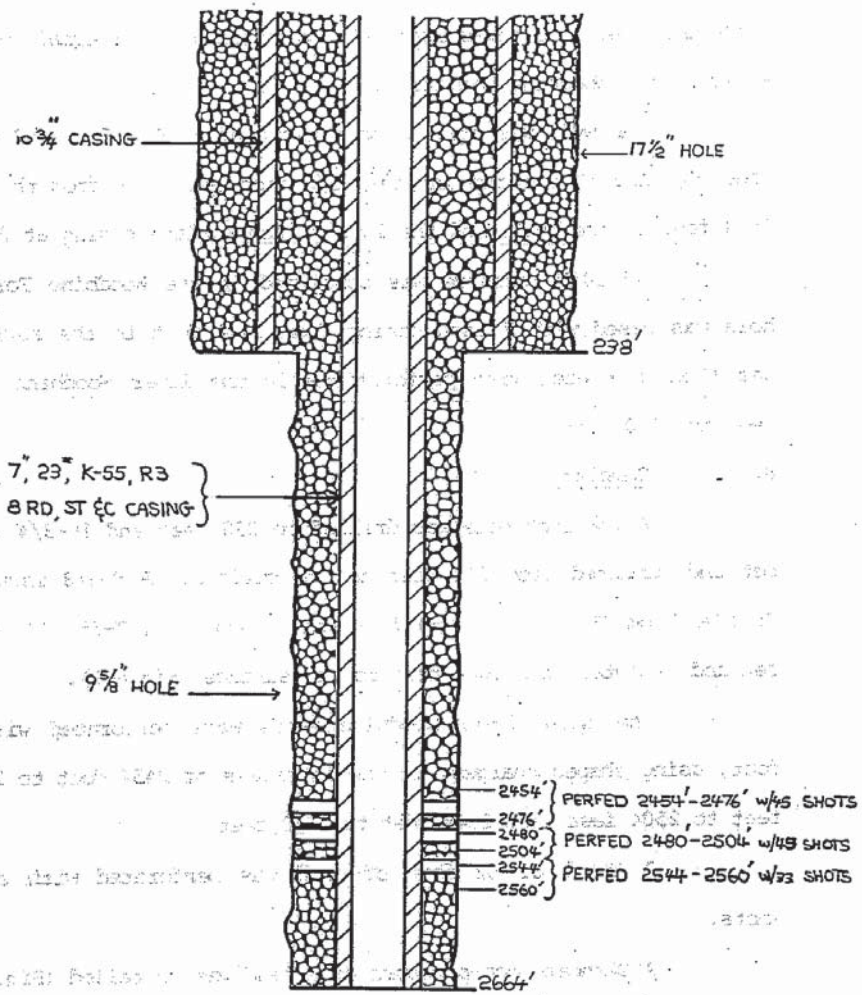
The three lower Woodbine sands were perforated with 2 shots per foot, using shaped charges, in the intervals of 2454 feet to 2476 feet; 2480 feet to 2504 feet; and 2544 feet to 2560 feet.

A total of 62 feet of sand was perforated with a total of 127 shots.

A standard non-pressure well head was installed (Fig. 8-2).

NAVARRO COLLEGE GEOTHERMAL WELL # 1

completion schematic



well completed July 1978

figure 8-1

NAVARRO COLLEGE
GEOTHERMAL WELL #1

Well Head

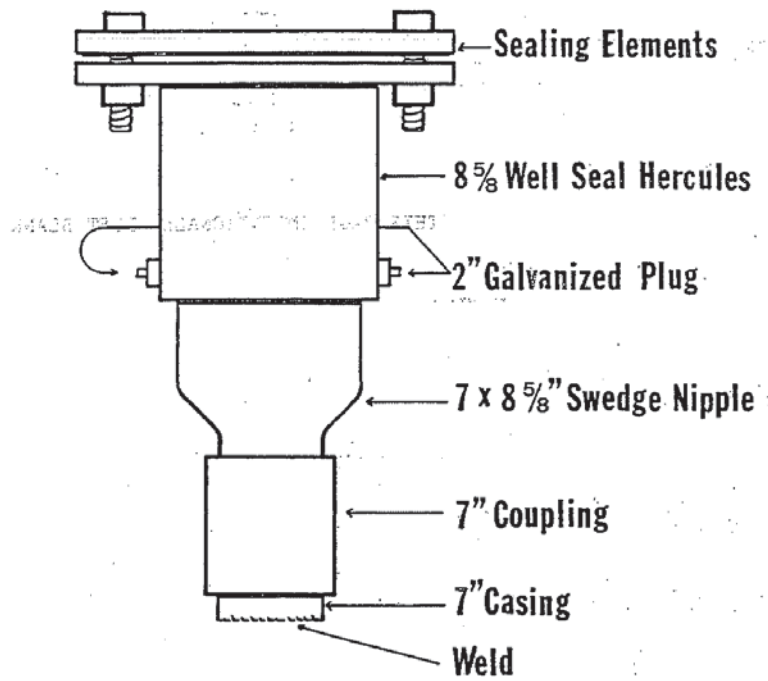


Figure 8-2

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