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(DE85000463)

Energy

GEOTHERMAL

**DIRECT UTILIZATION OF GEOTHERMAL HEAT IN CASCADE
APPLICATION TO AQUACULTURE & GREENHOUSE SYSTEMS AT
NAVARRO COLLEGE**

Final Report for the Period March 1, 1979—September 30, 1984

By
Kenan Smith

September 1984

Work Performed Under Contract No. FC08-79ET27058

**Environmental Aquaculture Services
Corsicana, Texas**

**Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy**

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Navarro College
Geothermal Project

DOE/ET/27058-1
(DE85000463)
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NAVARRO COLLEGE
FINAL REPORT

DIRECT UTILIZATION OF GEOTHERMAL HEAT
IN
CASCADE APPLICATION
TO
AQUACULTURE AND GREENHOUSE SYSTEMS
AT
NAVARRO COLLEGE

SEPTEMBER 1984

Prepared for

NAVARRO COLLEGE

By

ENVIRONMENTAL AQUACULTURE SERVICES
Kenan Smith - Director
Corsicana, Texas

9578341

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
Nevada Operations Office

Under DOE Cooperative Agreement
No. DE-FC08-79ET27058

Highway 31 West/P.O. Box 1170/Corsicana, Texas/(214)874-6501

ABSTRACT

This final report documents the Navarro College geothermal use project, which is one of nineteen direct-use geothermal projects funded principally by DOE. The six-year project encompassed a broad range of technical, institutional, and economic activities including: resource and environmental assessment; well drilling and completion; system design, construction, and monitoring; economic analysis; and public awareness programs. Some of the project conclusions are that: 1) the 130°F Central Texas geothermal resource can support additional geothermal development; 2) private sector economic incentives currently exist which encourage commercial development of this geothermal resource; 3) potential uses for this geothermal resource include water and space heating, aquacultural and agricultural heating uses, and fruit and vegetable dehydration; 4) high maintenance costs arising from the geofluids' scaling and corrosion characteristics can be avoided through proper analysis and design.

ACKNOWLEDGEMENTS

The author is grateful for the encouragement, support, and leadership provided throughout this project by Dr. Kenneth Walker, President of Navarro College and by Dr. Lary Reed, Vice-President for Campus Services and the Geothermal Project Director for Navarro College.

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. W. Rushing	-	Dean of Academic Education -
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. W. Burkhalter	-	Agriculture Chairman - Navarro
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. C. Orsak	-	Director of Institutional Development -
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September 1984
Corsicana, Texas

Kenan C. Smith,
Environmental Consultant
Geothermal Project Coordinator

DOE DIRECT-USE GEOTHERMAL
PROGRAM OPPORTUNITY NOTICE (PON)
PROJECT

1. Project Title: Direct Utilization of Geothermal Heat in Cascade Application to Aquaculture and Greenhouse Systems at Corsicana, Texas

DOE CONTRACT INFORMATION - Contract/Cooperative Agreement

2. Number: DE-FC08-79ET27508
3. Former No. None
4. Period 03/01/79 to 09/30/84
5. Value: \$1,423,225
6. Shares:
 - U.S. DOE \$1,128,086
 - Navarro College \$ 295,139
7. Project Application: To investigate the technical and economical feasibility of utilizing the Central Texas geothermal resource for application to aquaculture and agriculture systems, and to encourage this utilization by the private sector.
8. Project Location: Corsicana, Texas; 55 miles south of Dallas, Texas
9. Well Name/Location: Well No. 1/A. Hicks Sur., A-335, 75 FWL - 887 FEL
10. Peak Heat Load: 962,500 BTU/Hr
11. Annual Heat Load: 3.6×10^9 BTU^S/Yr
12. Break-even 6 years*
13. Project Status: The geothermal heating system officially began operation in October 1983. Peak well temperature has reached 130°F. Operation of the complete system has been very satisfactory and has shown a 75% savings over natural gas utilization.
14. Principle Investigator: Navarro College, Dr. Kenneth Walker, President; Dr. Larry Reed, Project Director
15. Firm Address: Highway 31 West/P.O. Box 1170
Corsicana, Texas 75110
16. Telephone: (214) 874-6501 Extension 274
17. Other Participants: Environmental Aquaculture Services
Kenan C. Smith - Director/Geothermal
Project Coordinator
P.O. Box 3044
Corsicana, Texas 75110

* For Equivalent 10 acre Commercial Operation

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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

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 philosophies 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 achieved at minimal additional costs, and economics would improve.

Table 2-1.

ACTIVITY	SUMMARY
° Resource Assessment	Based on historical evidence of a 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 strategies 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

3.0 CONCLUSION AND RECOMMENDATIONS

The Navarro College Geothermal Project has encompassed 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 apprised 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/ft².

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 construction 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.
		Navarro	Macatoch Sand	202 884	Dark calcareous, sandy, glauconitic clay, & some beds of fine to medium-grained glauconitic sandstone, above & below the Macatoch. The Macatoch Sand includes four sandstone lenses interbedded with light gray shale.	The Macatoch 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.
			T Wolf City Sand Member	1,262	Calcareous & sandy, glauconitic fine-grained sandstone, & some impure chalk.	The glauconitic sandstone (Wolf 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 Washite and Fredrickburg (undifferentiated)		1,270	Limestone, shale, & calcareous, silty, & sandy shale.	Not a source of ground water in Navarro County.
			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 (Pearshall) Formation	662	Coarse-to fine-grained sandstone 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 formation.
		Coshulie	Nuevo Leon & Durango	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 ground 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

THE UNIVERSITY OF CHICAGO

Office of the President
The University of Chicago
Chicago, Illinois 60637
Dear Mr. [Name]:
I am pleased to inform you that your application for admission to the University of Chicago has been accepted. You will be joining a distinguished group of students who are pursuing their studies at this institution. The University of Chicago is a world-renowned center of learning and research, and we are confident that you will find it a stimulating and rewarding environment. You will be attending the [Term] session, starting on [Date]. Please contact the Office of the Registrar at [Phone Number] for further information regarding registration, housing, and financial aid. We look forward to welcoming you to the University of Chicago community.

Sincerely,
[Signature]
President, The University of Chicago

Enclosed for you are two copies of the University of Chicago Catalog, which provides detailed information about the university's programs, faculty, and resources. Please review the catalog carefully, as it will be an essential reference throughout your academic journey. Additionally, we have included a copy of the University of Chicago's policies on academic integrity and student conduct. We encourage you to read these documents thoroughly to ensure a successful and ethical experience at the university. If you have any questions or need further assistance, please do not hesitate to contact the Office of the Registrar or the Office of Student Support. We are committed to providing you with the resources and support you need to thrive at the University of Chicago.

Very truly yours,
[Signature]
President, The University of Chicago

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.

 

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 $\pm$ 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

9.0 RESOURCE TESTING

Production tests were performed during the summer of 1979. Results of these test are as follows:

- Static water level below ground surface (BGS).....421'
- Position of a TRW Reda 120 hp pump BGS.....1,000'
- Pumping rate - - gallons per minute (GPM).....315
- Drawdown BGS.....777'
- Water temperature at the surface.....125°F
- Estimated sustained maximum production (GPM).....400
- Average total dissolved solids (TDS).....± 6000 milligram per liter (mg/l)

The production well was reworked during the fall of 1980 and a more comprehensive test of the resource was performed on December 17, 18, and 19 of 1980 by two Radian Corporation hydrogeologists.

This test was used to define the well characteristics and aquifer parameters as listed in this section of the report. The results of this test were compiled and presented by Radian Corporation in a report entitled "Geothermal Injection and Production Well Results at Navarro College", February 14, 1981. A copy of this report may be obtained from the U.S. DOE Technical Information Office. A chemical analysis of the resource water is listed in the appendix.

9.1 Apparatus

A 40 horsepower submersible pump was installed in well number 1 and a temporary transformer installed to convert the available 1320 volts AC to 480 VAC required by the motor. Fifty feet of 3 inch PVC pipe was used to route the water over a small berm and away from the wellhead. Flow was controlled by a 2 inch gate valve at the wellhead.

A four foot section of 4 inch pipe with a 2 inch free discharge orifice was attached to the end of the PVC pipe and used to measure flow. A 0.0625 inch hole was drilled in the top face of the orifice plate in an attempt to vent evolved gases from the upstream 4 inch pipe section.

Water levels were measured by use of a copper air line placed in the production well and attached to a pressure gauge.

9.2 Test Conducted

Data from this test was used in determining aquifer parameters of transmissivity, coefficient of storage, cone of depression, specific capacity, discharge temperature, chemical quality, and presence of dissolved gases.

The pump was turned on and allowed to clean and develop the well for twelve hours on December 17 and 18. The flow rate during development exceeded 100 GPM but was less than 165 GPM. The pump was turned off at 3 a.m. on December 18, 1980 and the water level in the well permitted to recover.

Based on the data collected, a 19 hour drawdown specific capacity of 0.99 and an estimated 19 hour recovery specific capacity of 1.03 were calculated. The average value being 1.0 gallons per minute per foot of drawdown (GPM/ft. dd). The water levels during the 3.6 days of pumping are recorded and shown in the following table and show no significant change with additional pumping.

TABLE 9.2-1.

Date/Time	Pump Test Discharge Temperature (°F)	Time Since Pumping Began (Hours)	Pumping Water Level (Feet Below Measuring Point)
18 Dec. 1980			
6:00 PM	Pump turned on @100GPM	0	491
6:15	103.1		
:30	111.2		
:45	114.8		
7:00	116.6	1	570
:15	118.4		
:30	121.1		
:45	121.1		
8:00	118.4	2	571.5
:15	118.4		
:30	118.4		
:45	119.3		
9:00	118.4	3	578
:30	118.4		
10:00	120.2	4	580.5
:30	122.0		
11:00	122.9	5	586
:30	119.3		
12:00 Midnight	118.4	6	578
19 Dec. 1980			
12:30 AM	118.4	7	
1:00	118.4	7	580.5
:30	117.5		
2:00	116.6	8	581
3:00	116.6		
4:00	122.0	10	583
5:00	120.2		
6:00	122.0	12	585
7:35	122.0		

TABLE 9.2-1 (Cont.)

Date/Time	Pump Test Discharge Temperature (°F)	Time Since Pumping Began (Hours)	Pumping Water Level (Feet Below Measuring Point)
10:06	122.9	16	587
11:00	116.6		
12:00 Noon	122.9		
1:00 PM	122.9		
1:01	Pump turned off	19	588
10:00	Pump turned on for further well development @ ±100GPM		
21 Dec. 1980			
11:00 AM	123.8	37	586
22 Dec. 1980			
11:30 AM	123.8	61.5	596
23 Dec. 1980			
11:15 AM	123.8	85.5	596
12:00 Noon	Pump turned off end of pumping development		

Discharge Temperature During Navarro
College Geothermal Well Test
Table 9.2-1

The temperature of the discharging geothermal fluid was taken at hourly intervals during the course of the pump test and are also shown in Table 9.2-1. At the end of the 19 hour pump test, the discharge temperature was 122.9 degrees F but recovered in later tests to 123.8 degrees F.

During the test, field specific conductances were determined for pumped fluid samples and are presented in Table 9.2-2 along with dissolved gas notations. A water sample was collected on December 19,

1980 upon completion of the 19 hour test. Analysis of the sample for total dissolved solids (TDS) indicated a value of 6080 milligrams per liter (mg/l). Two previously recorded values of TDS were at 5300 mg/l and 6820 mg/l.

TABLE 9.2-2.

Date	Time	Hours of Pumping	Field Conductance (mhos/cm)	Conductance Sample Temperature (°F)	Remarks
12-18-80	7 P.M.	1	13,100	105.8	Clear discharge some gas bubbles.
	8	2	13,100	116.6	Clear discharge.
	9	3	13,400	114.8	Clear discharge.
	10	4	13,200	109.4	Clear discharge.
	11	5	14,000	110.3	Clear discharge, gas.
	12 mid.	6	15,000	112.1	Clear discharge with bubbles, distinct odor.
12-19-80	1 A.M.	7	14,500	113.0	Clear discharge.
	2	8	14,750	113.0	Clear discharge, lots of gas in discharge with distinct odor.
	3	9	15,000	104.0	Clear discharge, lots of gas in discharge with distinct odor.
	4	10	15,700	113.0	Clear discharge.
	5	11	15,500	113.0	Clear discharge.
	6	12	15,500	113.0	Clear discharge.
	8	14	15,700	112.2	Clear discharge.
	10.15	16.25	14,700	113.9	Clear discharge.
	12 Noon	18	15,500	114.8	Clear discharge.
	12:55	19	14,700	113.0	Clear discharge.
12-17-80	1 P.M.	19	End of Pumping Phase of Test		

Field Specific Conductances of Pumped Geofluids
Table 9.2-2

The computed average transmissivity value determined from the drawdown and recovery data of the 100 GPM test is 1360 gallons per day per foot (GPD/ft). This value is lower than the average Woodbine value of 2300 GPD/ft reported for Navarro County by the Texas Water Development Board, report number 160, but does not appear unreasonable as the production well is perforated only in the lower Woodbine formation of 81 feet average thickness. From this the average permeability is computed at 16.8 gallons per day per square foot (GPD/ft²) (0.449 Darcy).

The coefficient of storage (a dimensionless number) is the amount of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. This parameter assists in determining how rapidly a cone of depression will expand with time. The average storage coefficient value computed from the test was 0.000024. Calculations indicate that the cone of depression caused by the pumping at the production well migrated radially out to about 2 miles during the course of the test assuming a practical sensible drawdown of 0.01 feet. No apparent hydrogeological boundaries were noted during the course of the test.

9.3 Results

All test objectives were met during the pump test of Well number 1 and no additional development is required. The geothermal fluid temperature of 123.8°F was within 2°F of the Spring 1979 test and is adequate to provide heating requirements of the cascade geothermal aquaculture system.

10.0 DISPOSAL WELL DRILLING AND LOGGING

10.1 Summary

During December of 1979, a second exploratory well was drilled on Navarro College property to determine if a hotter resource, of better quality, could be encountered. This would allow use of the first well as an injection well.

The second well was drilled to a total depth of 4762 feet. An electric log (see Appendix C) was run in the open hole from a depth of 4762 feet to within 2500 feet of the surface where previous logs had been run on the first well.

Only poorer quality resources were encountered and the hole was plugged back to a final depth of 2400 feet for use as the injection well. The well was then completed with perforations in the upper Woodbine Formation.

10.2 Completion

Prior to testing the disposal well at 3900 feet, a string of 8-5/8 inch casing was set and cemented at 4163 feet. Fluid yield and quality from this zone was not acceptable and the well was initially plugged back to 3300 feet and completed in the lower Woodbine Formation by perforating from 2452 feet to 2590 feet.

Testing was initiated to determine if there would be any interference with well number 1. When pumping in well number 2 was started, an immediate drawdown was noted in well number 1.

Because of this interference, well number 2 was plugged back to a depth of 2400 feet on December 23, 1981, for use as the injection well.

the plug was set, the well was perforated in the upper Woodbine Formation with 4 shots per foot in the intervals 2234 feet to 2256 feet and 2278 feet to 2292 feet. A total of 36 feet of sand was perforated with 133 shots.

A standard non-pressure wellhead was installed (Fig. 10-1)

10.3 Stimulation Method

In an effort to increase the rate at which the disposal well would accept fluids at a low pressure, a hydraulic fracture treatment was performed on the upper Woodbine Formation sands on October 23, 1981. The method employs hydraulic pressure to fracture the rock and the introduction of sand into the fractures, preventing their closing after the pressure is released.

The formation broke down at a surface pressure of approximately 1500 pounds per square inch (PSI). Before all the sand could be pumped into the fractures, the formation quit taking the sand leaving a sand-gel mixture in the casing. The sand settled out of the gel and filled the casing to a point above the perforations.

On October 24, 1981, a coiled tubing unit was used to run a 1 inch outside diameter (O.D.) continuous tube into the well and nitrogen was employed to jet-lift the sand out of the casing. The sand was removed to a depth of 2309 feet, clearing all perforations.

NAVARRO COLLEGE GEOTHERMAL WELL #2 WELL HEAD

Figure 10-1

January 1st 1900
The first day of the new year
and the first day of the new
millennium. It is a day of
great significance and
importance. It is a day
when the world begins anew
and when the future is
before us. It is a day
when we can start afresh
and when we can make
our own destiny.

It is a day when we can
begin our journey towards
the future. It is a day
when we can start our
new year with a clean
slate and when we can
begin our new year with
a new heart.

11.0 DISPOSAL TESTING

On October 24, 1981, a pump truck was connected to the disposal well and water from a holding tank was pumped into the well. Pumping began at the rate of 255 GPM per minute at a constant pressure of 750 pounds. After 20 minutes of pumping at 750 pounds of pressure an attempt was made to determine the acceptance rate at gravity feed. A gravity injection rate of only 60 GPM was obtained. It was also determined that 500 pounds of pressure would be required to sustain an acceptance rate of 120 GPM.

12.0 APPLICATION ANALYSIS

12.1 Technical

The Geo-Heat Center at Oregon Institute of Technology was given the limitation of the injection well and requested to determine the most feasible application for this resource. Preliminary engineering and design details performed by the Geo-Heat Center indicated that the most feasible application would be in an aquacultural/agricultural operation.

The Geo-Heat Center was provided with information on average daily, monthly, and yearly temperatures at Corsicana, Texas, plus an expected energy yield from the resource of 1.6×10^6 BTU/HOUR at 60 GPM flow and they determined that sufficient energy was available to maintain 0.5 acres of covered aquaculture ponds at an optimum prawn growing temperature of 82°F. In addition to the aquaculture operation, the center advised that sufficient energy would exist in the effluent from these ponds to provide necessary heat for space heating requirements of a small greenhouse unit.

In an effort to increase the economic viability of the project, it was determined that all effluents could be captured in a two acre reservoir which could be utilized for a catfish production pond and possible irrigation of cropland.

With this preliminary engineering data available, Navarro College submitted a supplement to the original proposal in December of 1981 to the United States Department of Energy which received approval through Modification A005 to the original proposal, "Direct Utilization of Geothermal Energy at Navarro College, Corsicana, Texas".

This approval led to preparations of preliminary and Final Design Reports by a certified Architectural/Engineering Firm which were approved through the Department of Energy. These reports reflect a project that has been engineered as technologically feasible.

12.2 Economic

A preliminary economic analysis of the project was conducted by determining the projected income of all crop items from the research project plus potential income from new student enrollment due to incorporation of project elements into the Navarro College curriculum.

Due to the limited size of the project on campus property, and because of the restricted injection rate, it was recognized that this would be a pilot project only. As a pilot research project, a payback on investment was not calculated as it would be for a much larger commercial operation.

The chart below reflects a plot of the projected annual income from crop items and student enrollment income compared to the projected annual expenses for the first year of operation.

<u>PROJECTED ANNUAL INCOME</u>		<u>PROJECTED ANNUAL EXPENSES</u>	
Prawns - $\frac{1}{4}$ A x 4000 lbs./A/Yr.		Personnel:	
= 1000 lbs. x \$8./lb.	\$ 8,000.	1 FTE Aquaculturist	\$26,000.
		1 $\frac{1}{4}$ FTE Secretary	3,600.
Catfish - 2A x 1500 lbs./A		2 Pt. Time Laborers	3,700.
= 3000 lbs. x \$1.25/lb.	3,750.	Other Personnel Expenses	8,000.
Greenhouse Produce -		Utilities:	4,000.
10,000 lbs. x \$.50/lb.	5,000.	Maintenance:	1,500.
New Student Enrollment:	40,000.	Communications:	1,500.
		Supplies:	5,000.
<hr/>		<hr/>	
TOTAL ESTIMATED INCOME	\$56,750.	TOTAL ESTIMATED EXPENSES	\$53,300.

These income figures are based on a low end of production and student enrollment and would be considerably higher if yields and enrollment were greater.

13.0 OBTAINING USER COMMITMENT

No users other than Navarro College.

14.0 SYSTEM LOADS

This section describes the projected heating and cooling requirements of the project as calculated by an independent engineering firm.

Due to the nature of the project being exploratory and research oriented, very little data was initially available on heating and cooling requirements for aquacultural purposes in this area. Therefore, a vital part of this report has been directed at determining if calculated demands and flows would prove sufficient in this type of application.

14.1 Calculated Heating and Cooling Requirements

In designing the heating system for this project a calculation was determined on the maximum probable heat loss from the aquaculture ponds and greenhouse during a peak demand period. The heat losses experienced in this project consist of (1) heat transmitted through the walls, roofs, and other surfaces and (2) the heat required to warm outside air entering the heated space.

Heat loss for an area is computed by the equation $Q=UA (T_i-T_o)=UA \Delta T$ where:

Q = heat transfer rate from one area to an adjacent area (pond to air or air to building, etc)

U = heat transfer coefficient (BTU/Hr-ft²-°F)

A = heat transfer surface area (ft²)

ΔT = temperature difference between areas (°F)

This equation allows for calculation of heating or cooling requirements of each of the project elements listed below:

- A. Aquaculture ponds heat loss
- B. Aquaculture ponds heating water
- C. Heat exchanger parameters
- D. Aquaculture ponds heat gain during heating period
- E. Aquaculture facility ventilation rate
- F. Pond heat gain during cooling period
- G. Greenhouse heat loss and potential heat gain from pond effluents

A. AQUACULTURE PONDS HEAT LOSS

Enclosure Dimension - 204 ft. x 82 ft. x 12 ft.

$$\begin{aligned}\text{Total Exposed Area } (A_1) &= 2 (82 \times 12) + 2 (204 \times 12) \\ &\quad + (204 \times 82)\end{aligned}$$

$$A_1 = 1,968 \text{ ft}^2 + 4,896 \text{ ft}^2 + 16,728 \text{ ft}^2$$

$$A_1 = 23,592 \text{ ft}^2$$

Pond Dimensions - 185 ft. x 30 ft. x 4 ft.

$$\text{Total Pond Surface Area } (A_2) = 2 \times 185' \times 30'$$

$$A_2 = 11,100 \text{ ft}^2$$

Heat loss to sides and bottom of pond.

$$\begin{aligned}\text{Total Bank Area} &= (4 \times 185 \times 4) + (4 \times 30 \times 4) \\ &= 3,440 \text{ ft}^2\end{aligned}$$

Value of T water-bank = 25°F

$$U^*_{\text{Bank}} = 0.8 \text{ BTU/Hr-ft}^2\text{-}^{\circ}\text{F}$$

Let Q_3 = Heat Loss to Bank

$$Q_3 = 0.8 \times 25^{\circ}\text{F} \times 3,440 \text{ ft}^2$$

$$Q_3 = 68,800 \text{ BTU/Hr}$$

At equilibrium conditions, the pond heat loss will equal that of the enclosure heat loss.

Let Q_1 = Enclosure Loss

Q_2 = Pond loss to enclosure space

T_o = 17°F Temp. outside (peak demand)

T_i = Temp. inside

T_p = 82°F Pond temp.

$$Q_1 = U_1 \times A_1 \times (T_i - T_o)$$

$$Q_2 = U_2 \times A_2 \times (T_p - T_i)$$

$$U_1 \times A_1 \times (T_i - T_o) = U_2 \times A_2 \times (T_p - T_i) \dots \text{Pond loss} = \text{Enclosure loss}$$

$$U_1 A_1 T_i - U_1 A_1 T_o = U_2 A_2 T_p - U_2 A_2 T_i$$

$$U_1 A_1 T_i + U_2 A_2 T_i = U_2 A_2 T_p + U_1 A_1 T_o$$

$$T_i = \frac{U_2 A_2 T_p + U_1 A_1 T_o}{U_1 A_1 + U_2 A_2}$$

$$U_1^* = 1.0 \text{ BTU/Hr-ft}^2\text{-}^{\circ}\text{F}$$

$$U_2^* = 1.0 \text{ BTU/Hr-ft}^2\text{-}^{\circ}\text{F}$$

* Source: White, Frank M. "Heat Transfer" copyright 1984 by Addison-Wesley Publishing Co., Inc.

$$T_i = \frac{(1 \times 11,100 \text{ Ft}^2 \times 82^\circ\text{F}) + (1 \times 23,592 \times 17^\circ\text{F})}{(1 \times 11,100 \text{ Ft}^2) + (1 \times 23,592)}$$

$$T_i = 37.8^\circ\text{F}$$

$$Q_2 = U_2 \times A_2 \times (T_p - T_i)$$

$$Q_2 = 1 \times 11,100 \times (82 - 37.8)$$

$$Q_2 = 490,620 \text{ BTU/Hr}$$

$$\text{Total Loss} = 490,620 + 68,800$$

$$= \underline{559,420 \text{ BTU/Hr}}$$

This calculation has assumed no infiltration loss and therefore the actual load will be somewhat higher.

B. AQUACULTURE PONDS HEATING WATER REQUIRED

$$\text{Pond Heat Loss} = 559,420 \text{ BTU/Hr} = 559,420 \text{ lb/hr-}^\circ\text{F} \times \frac{1 \text{ gallon}}{8.34 \text{ lb. 60 min/hr}}$$

$$\text{Heating Water Required} = \frac{\text{HEAT LOSS}}{500 \times \Delta T \text{ Geo-pond}^*}$$

(freshwater)

$$\begin{aligned} &= \frac{559,420}{500 \times 33^\circ\text{F}} \\ &= \underline{\underline{34 \text{ GPM}}} \end{aligned}$$

* Projects heating water enters at 115°F and pond temp is @ 82°F

C. HEAT EXCHANGER PARAMETERS

Geothermal water temp. entering exchanger = 125°F

Geothermal water temp. leaving exchanger = 70°F

Fresh water temp. entering exchanger = 62°F

Fresh water temp. leaving exchanger = 115°F

Geothermal Heat = 35 GPM x 500 x (125 - 70)

$$= 962,500 \text{ BTU/Hr}$$

$$\text{Freshwater GPM} = \frac{962,500 \text{ BTU/Hr}}{500 \times (115-62)}$$

$$= \underline{\underline{36 \text{ GPM}}}$$

D. AQUACULTURE PONDS HEAT GAIN DURING HEATING PERIOD

Heat gain = Solar gain + Transmission

$$\text{Exposed Area} = \quad \text{N} - 204 \times 9 = 1836$$

$$\quad \quad \quad \text{E} - 82 \times 9 = 738$$

$$\quad \quad \quad \text{S} - 204 \times 9 = 1836$$

$$\quad \quad \quad \text{W} - 82 \times 9 = 738$$

$$\quad \quad \quad \text{Hor} - 204 \times 82 = 16,728$$

$$\text{Solar Gain Factors} = \text{N} - 30 \text{ BTU/Hr-Ft}^2$$

$$\quad \quad \quad \text{E} - 77$$

$$\quad \quad \quad \text{S} - 72$$

$$\quad \quad \quad \text{W} - 90$$

$$\quad \quad \quad \text{Hor} - 205$$

$$\text{Solar Gain} = 1836 (30 + 72) + 738 (77 + 90) + 16,728 (205)$$

$$= 187,272 + 123,246 + 3,429,240$$

$$= \underline{\underline{3,739,758 \text{ BTU/Hr}}}$$

$$\text{Transmission Gain} = (2 \times 1836) + (2 \times 738) + 16,728 \times$$

$$1.0 \text{ BTU/Hr} - \text{Ft}^2 - ^\circ\text{F} \times 20^\circ\text{F}$$

$$= \underline{\underline{437,520 \text{ BTU/Hr}}}$$

$$\text{Total Gain} = 3,739,758 + 437,520$$

$$= 4,177,278 \text{ BTU/Hr}$$

E. AQUACULTURE FACILITY VENTILATION RATE

$$\text{Total Heat Gain} = 4,177,278 \text{ BTU/Hr}$$

If a max. temp. rise of 20°F in the aquaculture building is allowed,

$$\text{Vent rate} = \frac{4,177,278}{1.08 \times 20^\circ\text{F}} = 193,392.5 \text{ CFM}$$

$$\begin{aligned} 10 \text{ Fans used} &= 193,392.5 \div 10 \\ &= 19,340 \text{ CFM/FAN} \end{aligned}$$

F. POND HEAT GAIN DURING COOLING PERIOD

Assuming enclosure temp. is 120°F and water temp. is 82°F with an h-value of 1 BTU/Hr-Ft²-°F

$$\begin{aligned} \text{Pond Heat Gain} &= h \times A \times T \\ &= 1 \times 185 \times 60 \times 20 \\ &= 222,000 \text{ BTU/Hr} \end{aligned}$$

$$\text{Cooling water flow required} = \frac{\text{Heat gain}}{500 \times \Delta T}$$

$$\begin{aligned} \text{Cooling water} &= 222,000 \quad (500 \times 20) \\ &= \underline{\underline{25 \text{ GPM}}} \end{aligned}$$

G. GREENHOUSE HEAT LOSS AND POTENTIAL HEAT GAIN FROM POND EFFLUENT

$$\text{Enclosure area} = 30' \times 108'$$

$$\begin{aligned} \text{Surface area} &= N (2 \times 8' \times 108') + (2 \times 10' \times 30') + (30 \times 108) \\ &= 1728 + 600' + 3240 \\ &= 5568 \text{ Ft}^2 \end{aligned}$$

With a U-Factor of 1 BTU/Hr-Ft²-°F and a 30°F temp. difference (20° outside 50° inside)

$$\begin{aligned} \text{Heat Loss} &= 1 \times 5568 \times 30 \\ &= 167,040 \text{ BTU/Hr} \end{aligned}$$

Pond effluent temp. of 80°F and a flow at 30 GPM with a delta T through the Greenhouse Heaters.

Available heat = 30 GPM x 500 x 10

= 150,000 BTU/Hr

Due to additional infiltration loss, the Greenhouse will require additional heating but sufficient heat should be available for Spring and Fall heating requirements.

THE UNIVERSITY OF CHICAGO

 
100	100	100	100

15.0 PRODUCTION SYSTEM DESIGN

The production system of the Navarro College Geothermal Project includes the production well, the submersible pump and its control system, and the associated geofluid valving and piping to the heat transfer system located in the mechanical equipment building.

15.1 Materials Selection

The water quality, as presented in Table 15-1, was a critical factor that the project's architectural/engineering firm considered in properly designing the system.

TABLE 15-1

Constituent	Sample #1 (mg/l)	Sample #3 (mg/l)	Drinking Water Stds. (mg/l)	Irrigation Stds. (mg/l)
Total Dissolved Solids	6820	5300	500	5000
SO ₄ ⁻	2.4	38	250	-
Cl ₂ ⁻	3520	2560	250	-
F ₂ ⁻	1.6	-	2.4	1.0
HCO ₃ ⁻	-	1140	-	-
Na ⁺	1200	2020	-	-
Ag ⁺	.007	-	0.05	-
Si	11	-	-	-
Se ₂ ⁺	.005	-	0.01	-
Hg ₂ ⁺	.0005	-	0.002	-
Mg ₂ ⁺	-	5.6	-	-
Pb ₂ ⁺	.003	-	0.05	5.0
Fe ₂ ⁺	1.1	-	0.3	5.0
Cr ₂ ⁺	.005	-	0.05	0.10
Ca ₂ ⁺	-	13	-	-
B	14	-	-	-

Navarro College
Geothermal Water Quality Analysis
Table 15-1.

The geothermal water system, the freshwater transfer heating system, and greenhouse heating system needs were discussed with the A/E firm and with the McCormick Corporation, Water Treatment Specialists in Dallas, Texas, in an effort to eliminate any possible problem areas with facility operations.

Table 15-2 lists the components and selected materials recommended by the engineers.

TABLE 15-2

Component	Material Selected
Production and Injection piping (in the wells)	2 3/8" downhole tubing coated with an interior acrylic resin
Surface Piping (hot)	Schedule 80 CPVC
Surface Piping (cool)	Schedule 40 PVC
Valves	Rated 125 psi WSP each having a bronze body, with rising stem, solid wedge of ASTM Designation B-61 bronze, standard packing with bronze gland follower, and malleable iron wheel.
Pump Bowls	Flanged and bolted type made of close-grained cast iron. Flanges are of sufficient cross-section to prevent deflection, and are reinforced with four ribs (minimum), which are at least one-half the flange metal thickness. The diffuser portion of the bowl casting has a maximum cross-section to insure long life. Threaded bowl connections are not supplied but are provided with replaceable wear rings of SAE 64.
Pump Shaft	Made of AISI 416 Stn. Stl., rolled or forged, ground and sized to provide minimum deflection.

Pump Impellers	Enclosed type of bronze, secured to the shaft with SAE 1213 steel tapered deflection.
Plate Heat Exchanger	Gasket material of nitrile and flush-fitted design. Plate material of Type 304 stainless steel, not less than 0.6mm in thickness. Heat exchanger meets the requirements of applicable ASME and ANSI Codes and Standards, including the ASME Code for Unfired Pressure vessels, for which inspection, stamping and certification has been provided. Heat exchanger to be a unit consisting of an assembly of plates with flush-fitted gaskets supported in frames capable of being opened and reclosed, fitted with nozzles or ports that provide entrance and exit for the two heat exchanging fluid streams, and fitted with a special system of gas evacuation checks to prevent gas-vapor locking.

Navarro College
Geothermal Project Materials Selection
Table 15-2.

By using these materials for each of the project elements only minor scaling and corrosion have been noted during routine maintenance.

15.2 Production System Design

A schematic of the Navarro College geothermal production system is presented in Figure 15-1.

This system is composed of the production pump and controls, the downhole tubing, the CPVC piping, and the plate heat exchanger.

The production pump is a TRW Reda, multi-stage 540 series, submersible unit, with a low water level protector. It has been set on 660 feet of 2-3/8 inch tubing and has a pumping capacity of 30 gallons per minute.

Figure 15-1
Geothermal Production
System

The project has been designed so that all controls operate in an automatic on or off mode. This was accomplished by setting a 3°F differential in the shrimp pond temperatures. A pond temperature decrease to 79°F will activate the geothermal pump by means of a relay from the thermostats, and will then shut the pump down when the pond temperature has reached 82°F.

An ammeter chart is mounted in the pump control panel and provides a continuous record of pump on and off time. This plus the pump rate of 30 gallons per minute, provides the amount of energy used by the project during peak and non-peak demand periods.

Downhole tubing consists of 2-3/8 inch steel pipe coated on the interior with an acrylic resin to reduce scaling and corrosion problems.

The production line from the well to the mechanical building, where the plate heat exchanger is located, is Schedule 80 CPVC pipe. This type of pipe is resistant to scaling and higher (135°F) temperatures of the geothermal fluids. This line has also been covered with one inch of styrofoam insulation to reduce heat loss from the well to the plate heat exchanger.

The plate heat exchanger, a Baltimore Aircoil plate and frame unit measuring 5 feet by 1.5 feet by 0.5 feet, has plates composed of Type 304 Stainless Steel to reduce corrosion and scaling. This unit transfers the heat from the geothermal fluid to the freshwater which is used for project heating requirements.

 

16.0 DISPOSAL SYSTEM DESIGN

An injection well was required by state regulating authorities to avoid ground water contamination from the spent geothermal fluids (See Section 6.2). It was established through preliminary injection testing that this well would accept sufficient fluids at gravity flow to meet project demands (Section 10).

16.1 Materials Selection

In order to protect potential potable ground water aquifers and reduce corrosion of the casing in the injection well, tubing and a packer was installed. This unit (a Baker Packer - Model-1A) was set at 2200 feet and the 2-3/8" injection tubing was stabbed into it. This tubing was coated on the interior with an acrylic resin to reduce downhole scaling and corrosion. Piping from the plate heat exchanger to the injection well is Schedule 40 PVC (See Figure 19-1).

16.2 Design

Design of the disposal system is simple in concept:

Cool geothermal fluids (60° - 80°F) leaving the plate heat exchanger, exit the Mechanical Equipment Building through 2 inch schedule 40 PVC pipe to the injection well (approximately 300 feet). The fluid then enters the injection well head in the 2-3/8" down-hole steel tubing, gravity flows from the well head past the packer unit, through the perforations in the well wall, and into the Upper Woodbine Formation.

A pressure gauge is mounted at the well head in the 2-3/8" tubing. When salts begin to impede the flow of fluids into the formation, it will register on the pressure gauge.

Treatment of the injection well with 100 pounds of citric acid dissolved in water has been successful in removing these salt formations.

17.0 TRANSMISSION SYSTEM DESIGN

All aspects of the project are confined to a small location on one portion of the College campus area, this section of the report is not applicable to the Navarro College system.

18.0 DISTRIBUTION SYSTEM DESIGN

Navarro College is the sole user of this resource and the production and disposal wells are located on their premises, therefore this section is not applicable.

19.0 APPLICATION SYSTEM DESIGN

The application system for the Navarro College Geothermal Project was designed to utilize the maximum amount of available energy by cascading it through several uses.

This system consists of the heat energy transferred from the geothermal fluid to a fresh water source which is used for aquacultural and agricultural crop production.

19.1 Design

Based upon preliminary design concepts, the project's architectural engineers prepared a final design package for the project. In this system, shown schematically in Figure 19-1, geothermal fluids are pumped from the production well through the plate heat exchanger to heat fresh water. The cooled geothermal fluids then flow to the injection well.

The heated fresh water flows through a flow meter in the mechanical building which monitors instantaneous and cumulative flows to the enclosed shrimp ponds. Continuous records of geothermal and fresh water temperatures are maintained on strip chart recorders with thermocouple connections to the inflow and effluent pipes of the plate heat exchanger.

When shrimp pond temperatures decrease to 79°F, inflow valves open and the geothermal pump is activated. This allows heated fresh water to flow into the shrimp ponds until pond temperatures have increased to 82°F, at which time pond inflow valves close and the geothermal pump is deactivated. Constant records of pond temperatures are also retained on strip chart recorders.

Figure 19 - 1 Navarro College Geothermal Project Flow Diagram

As warm water flows into the shrimp ponds, cooler water flows out through the in-pond sluice boxes to a common collection box. Two 3/4 hp pumps at the collection box are activated by mercury float switches and pump the 80°F effluent from the collection box to two radiator fan units in the greenhouse. These units are controlled by thermostats located in the greenhouse and are activated at a set point of 60°F. When space temperatures in the greenhouse decrease to 60°F the fans are turned on to extract heat energy from the 80°F shrimp pond effluent to supplement the normal greenhouse heating system.

The water flowing through these heaters is then routed to the collection/catfish reservoir where residual heat energy is deposited. This reservoir is approximately two surface acres in size and has been stocked with 3,000 channel catfish fingerlings.

All aquaculture and agriculture crop items harvested are used in determining the economic viability of the project.

THE HISTORY OF THE

The first part of the history of the world is the history of the human race. It is a history of the progress of the human mind, of the growth of the human soul, of the development of the human spirit. It is a history of the human race, of the human mind, of the human soul, of the human spirit.

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20.0 PRODUCTION SYSTEM CONSTRUCTION

The production system construction at Navarro College was completed in two separate phases. The first effort was the 1978-79 tasks of well drilling, completion, and testing. These functions are described in Sections 8 and 9.

The second phase (1983), which included installation of the production pump, controls, and piping was concurrent with construction of the application system and part of the disposal system.

The production system, as installed, has only one deviation from that designed and specified in the original bid package. In the original specifications, the geothermal pump would require manual on and off operation. In order to reduce any waste in energy and costs, the system was modified by installing an automatic relay circuit from the pond thermostats to the pump control board. With this installation the pump is on only during a demand period and requires less labor costs in monitoring and operation.

The remainder of the production system was installed as designed and specified.

21.0 DISPOSAL SYSTEM CONSTRUCTION

The disposal system construction was done in two phases. The first phase, 1979-1981, included drilling of the disposal well, injection testing, workover, stimulation, and plugging back. These functions are described in greater detail in Sections 10 and 11.

The second phase of construction was concurrent with the application system construction. It involved installation of the disposal piping, tubing, and packer as per designs and specifications.

11/11/11

Dear Sir,

I am writing to you regarding the matter of the...

Yours faithfully,

[Signature]

22.0 TRANSMISSION SYSTEM CONSTRUCTION

Since the production and disposal wells are within a close proximity of each other, and are located entirely on College campus property, a transmission system was not needed. Therefore, this section is not applicable to the Navarro College project.

23.0 DISTRIBUTION SYSTEM CONSTRUCTION

Navarro College is the sole user of this resource, and the production and disposal wells are located on campus property, therefore this section is not applicable to the Navarro College project.

THE FUTURE OF THE WORLD

The future of the world is a subject of great importance and interest to all mankind. It is a subject that has been discussed for centuries, and it is one that will continue to be discussed for many years to come. The future of the world is a subject that is both complex and fascinating, and it is one that we must all strive to understand and control.

THE FUTURE OF THE WORLD

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24.0 APPLICATION SYSTEM CONSTRUCTION

The design and specifications for construction of the Navarro College Geothermal Project included not only the application system, but parts of the production and disposal systems. Therefore, the proposals and contractor selection discussed below applies to the complete facilities installation, which includes the entire application system, and the associated parts of the production and disposal systems.

24.1 Proposals and Contractor Selection

The construction requirements of the Navarro College Geothermal Project were varied and thus best accommodated by selection of a general contractor to operate as prime contractor. The prime contractor then employed the necessary electrical and controls subcontractors.

A "Request for Proposal" process was prepared to solicit candidate contractors. This procurement action was advertised in four area newspapers and the Commerce Business Daily.

Approximately 20 sets of plans and specifications were distributed to interested contractors during the proposal period. All of the contractors were encouraged to visit the site of the proposed project and any questions of the contractors regarding the plans and specifications were answered.

Three proposals were received. These proposals were opened on April 5, 1983 and are listed in Table 24-1.

Table 24-1.

<u>COMPANY</u>	<u>LOCATION</u>	<u>BASE PROPOSAL</u>
McKinney & Moore, Inc.	Jacksonville, TX.	\$350,700.00
Watkins Construction Co.	Corsicana, TX.	358,709.00
Lochridge-Priest, Inc.	Waco, TX.	361,838.00

Facilities Installation Proposals
Table 24-1

Based on qualifications and price, McKinney & Moore, Incorporated was selected as the prime contractor. The notice to proceed was issued to McKinney & Moore, Inc. on April 20, 1983, at a preconstruction meeting. On April 28, 1983, a ground-breaking ceremony was conducted at the proposed site. Participants at this ceremony included members of the Navarro College Board of Trustees, President of Navarro College Dr. Kenneth Walker, U.S. Department of Energy Representative Robert D. Clarke, and Mr. Walter Erwin, an original community sponsor for the project.

24.2 Construction Activities

System installation was scheduled to be completed by August 1, 1983. However, due to adverse weather conditions and delays in manufacturer's delivery schedules, project completion and acceptance by the College was postponed until October 3, 1983. The completion dates of major construction elements are listed in the following Table 24-2.

Table 24-2.

<u>PROJECT JOB DESCRIPTION</u>	<u>COMPLETION DATE</u>
Completed excavation of shrimp ponds	May 24, 1983
Production pump installed	July 6, 1983
Tubing & packer placed in injection well	July 7, 1983
Completed excavation of 2 acre reservoir	July 29, 1983
Aquaculture building completed	August 5, 1983
Mechanical equipment building completed	September 12, 1983
Completed electrical control systems	October 3, 1983

Construction Completion Dates
Table 24-2

Several modifications to the application system were made during construction and shortly after the facilities had been installed. These modifications included installation of a relay system which converted operation of the geothermal pump from manual to an automatic mode; replacement of inefficient modulating pond temperature control valves with solenoid valves; replumbing the boiler system to bring it on line as a back up heat source; and the addition of a recirculating fresh water pump to pump reservoir water to the shrimp ponds rather than using expensive city water for the shrimp. These modifications resulted in a final "Facilities/Installation" cost of \$398,953.00.

An Operations and Maintenance Manual was prepared by the Project Coordinator to assist college personnel who would operate the system after completion of the funded period. This manual describes the entire system and

lists the separate project elements in an operational procedure section. This will assist personnel in trouble-shooting the system and performing routine maintenance procedures. The manual covers the production and disposal system as well as the application system.

After completion of facilities installation, the system was stocked with plants and animals and was allowed to operate for a period of two months. At the end of the two month break-in period a testing and balancing firm (Delta-T from Dallas, Texas) was brought in to conduct a comprehensive analysis of the system. Results of these tests indicated that all systems and equipment were performing at a level equal to or better than anticipated. A copy of test results is included in Appendix E of this report.

An official project dedication ceremony was held at the college on October 27, 1983. The project history and results to date were given to those in attendance. The ceremony was attended by state and local political figures, a Department of Energy representative, local citizens, press, and project participants. A complete tour of the project was made following the ceremonies.

25.0 SYSTEM MANAGEMENT AND ORGANIZATION

Navarro College is the owner and sole user of the Navarro College Geothermal system. The college also manages and operates the system, and is responsible for all maintenance.

 

26.0 PRODUCTION SYSTEM PERFORMANCE

26.1 Performance Summary

Since production system start up in October of 1983, geofluid production for the Navarro College Geothermal Project has been maintained without interruption. The system has required a minimum of corrective maintenance (reinstallation of lightning arrester fuses) and has been operational with no problems. A high level of satisfaction has been experienced with this system.

26.2 Well and Pumping System Performance

The Navarro College well has a production capability to produce in excess of 150 gallons per minute with no appreciable drawdown (see Section 9 of this report). Since the present project has a demand for only 30 gallons per minute during operation, the geothermal reservoir will be capable of maintaining this level of production for a long period of time.

As discussed in sections 15 and 20, this system was designed to operate automatically. A 3°F drop in pond temperatures will activate the geothermal pump. This demand is for a full electrical load to the geothermal pump and maximum flow of the geothermal fluids through the plate heat exchanger. Once pond temperatures have increased to the thermostat's set point, the relay contact is opened and the geothermal production system is shut down. The percentage of time the system is on is dependant upon the ambient air temperatures which have a profound influence on pond temperature. This relationship is plotted in Figure 26-1.

As noted in Figure 26-1 the maximum heating requirements were during December of 1983, and January, 1984. It was during this time that record breaking low temperatures were registered for this area of the country.

26.3 Heat Exchanger Inspection

In mid June, 1984, following eight months of continuous production, the plate heat exchanger was disassembled for routine maintenance and inspection. The plates were visually inspected for pitting, corrosion, or scaling on the geothermal and fresh water sides.

This visual inspection showed the geothermal side to be essentially free of deposits, scaling, and corrosion; the surface had a glossy metallic appearance.

Use of fresh water from the collection reservoir had resulted in a thin deposit of algae which coated the fresh water side of the plates, but a mild soap and water solution was able to remove this layer of material and restore the plates to a glossy metallic surface with no apparent pitting having occurred.

This inspection confirmed that the systems' design is efficient and will reduce or eliminate any high costs other than yearly routine maintenance and cleaning.

Percentage of Time The Geothermal Pump Was On in
Relation to Mean Ambient air temperature
Figure 26-1

27.0 DISPOSAL SYSTEM PERFORMANCE

Disposal of the spent geothermal fluids is accomplished by flowing these fluids into an injection well (see Section 16 and 27). All spent geofluids flow by gravity into the injection well and are dispersed into the Upper Woodbine Formation.

During the eight month period of system's operation, the injection well was treated with a hundred pounds of citric acid on four separate occasions to remove salt buildup in the Woodbine Formation. The salt formations block movement of the geofluids into the Woodbine Formation. Reduced flow registers as back pressure at a gauge mounted at the injection well downhole tubing. The citric acid treatment is quick and relatively inexpensive when compared to other methods and treatments.

Conclusions were that as long as this type of treatment breaks down the salt deposits and reduces back pressure in the injection well for more than three weeks, then cost effectiveness in maintenance and operation are achieved. No other problems have been noted in the disposal system performance.

28.0 TRANSMISSION SYSTEM PERFORMANCE

A transmission system does not exist in the Navarro College Project, this section is not applicable.

THE HISTORY OF THE UNITED STATES

 

BY

29.0 DISTRIBUTION SYSTEM PERFORMANCE

A distribution system does not exist on the Navarro College Project, this section is not applicable.

30.0 APPLICATION SYSTEM PERFORMANCE

When this system came into operation in October, 1983, two components with potential performance and economic problems were discussed with the contractor and project engineers. These components were the modulating pond temperature control valves and the plumbing to the backup boiler system. It was noted that the modulating valves were not designed to completely shut off and thus were allowing a constant flow of fresh water to enter the ponds even when the geothermal well was shut down. This affected the ponds by immediately causing a decrease in pond temperatures after they had been heated.

The second problem involved the plumbing design of the backup boiler system. If the geothermal pump were to break down or kick off due to an underload or overload, the old system would continue to allow unheated fresh water to enter the ponds until such a time that the system was manually switched to divert water through the boiler.

Both of these problems were corrected by the first of December, 1983, when the modulating valves were replaced with positive On/Off Solenoid Valves and a fresh water line was installed which allows fresh water to pass from the Plate Heat Exchanger to the backup boiler and then on to the shrimp ponds. If the fresh water is not heated through the Plate Heat Exchanger then the boiler is automatically activated.

These two corrective measures have resulted in the operators expressing satisfaction with the overall system performance.

A comparison of costs per BTU's of consumption is presented in Figure 30-1. This figure shows the actual costs of operating the geothermal system during peak demand periods in December, 1983, and January, 1984. These figures reflect the actual pumping costs for the geofluids and a comparable cost for an equal amount of BTU's from a natural gas boiler.

Energy Consumption Cost Comparison
Figure 30-1

Peak heating demands (Section 14.1) show that 962,500 BTU/Hr are available from the Plate Heat Exchanger and since the average operational time for December and January was 90%, this is equal to approximately 27 heating days or 648 hrs. of ON time. Energy amounts available to the ponds equals 648 hrs. x 962,500 BTU's or 623,700,000 BTU's.

Pumping costs for December, 1983, and January, 1984, were approximately \$600.00 each, which is equal to 1,039,500 BTU's/Dollar. Natural Gas prices in Corsicana are \$3.8958 per 1000 cubic feet of gas with 1,030,000 BTU's available per 1000 cubic feet. This equates to approximately 264,387 BTU's/Dollar.

This type of performance reflects a savings of about 75% when compared to a conventional gas boiler heating system. In addition to meeting the demands for the shrimp ponds, the effluents provide partial heating requirements to the greenhouse.

Energy cost savings and multiple energy applications satisfy the operators in terms of application system performance.

 

31.0 CONSTRUCTION COSTS

The total construction costs for the Navarro College geothermal systems is divided into two separate construction efforts. The effort reflects construction costs from 1978 through 1982 in drilling, completion, and testing of the production well. The second effort involved a bid process for facilities installation of the application system and was initiated during May, 1983. As presented in Section 24, the base bid was approximately \$350,700, but subsequent purchases and modifications resulted in a final contract price of \$398,953.

A breakdown of the construction cost totals is presented in Table 31-1.

Table 31-1.

Item	Amount	Subtotals
PRODUCTION SYSTEM		
° Well drilling, completion, & Testing*	\$ 72,698	
° Production Pump & Panel	<u>23,550</u>	
		\$ 96,248
DISPOSAL SYSTEM		
° Well drilling, completion, Testing, Plug-backs, & Stimulation	334,480	334,480
APPLICATION SYSTEM		
° Fencing & Mobilization	5,000	
° Catfish Reservoir Excavation	43,500	
° Site Work	7,000	
° Aqua-Pond Excavation	5,000	
° Aquaculture Building	123,000	

Item	Amount	Subtotals
° Aqua-Building Plumbing & Electrical	\$ 22,000	
° Mechanical Building Structure	30,000	
° Mechanical Building Plumbing & Electrical	20,000	
° Outside Plumbing & Electrical	40,000	
° Greenhouse Site Preparation	5,000	
° Concrete Work	35,000	
° Concrete Grade Beams	5,000	
° Controls & Modifications	42,953	
° Seeding of Grass	<u>3,576</u>	
		\$ 398,953
° Greenhouse Structure*		<u>30,000</u>
TOTAL CONSTRUCTION COSTS		<u>\$ 859,681</u>

*These Items Supplied by Navarro College

Breakdown of Navarro College Geothermal
System Construction Costs
Table 31-1

32.0 OPERATING AND MAINTENANCE COSTS

Operating and maintenance (O & M) costs include labor, utility, and repair or replacement of project materials.

Labor requirements have been projected for personnel to run the system and care for each of the project segments including cultivation and harvest of all crop items. The harvested items (shrimp, produce, and catfish) have been used as a resale item in determining the economics of the system (Section 33). Labor requirements are for one full time faculty member as system operator and supervisor with one half time laborer. The cost for these two positions, which includes fringe benefits and indirect costs, is approximately \$58,000.

Utility cost include parasitic electrical power, used primarily to power the system pumps and controls, and a limited supply of city water for use in the greenhouse. Electrical costs are approximately \$2700 per year while water costs are \$1000 per year.

The production pump and control circuits have a projected life expectancy of 10 years. A sinking fund allowance has been projected at this expectancy against a total cost of \$35,000 for a yearly cost of \$3500. In addition, repair or replacement of additional project elements has been estimated at \$2000 per year.

A summation of these O & M costs is presented in Table 32-1.

Table 32-1.

Item	Costs
° PERSONNEL	
One Full Time Operator & Supervisor	\$ 30,000
Fringe Benfits	7,800
Indirect Costs	15,000
One Half Time Laborer	<u>5,200</u>
° UTILITIES	
Electrical Costs	2,700
Water Supply	<u>1,000</u>
° REPAIR & REPLACEMENT	
Production Pump & Controls	3,500
Other Maintenance	<u>2,000</u>
TOTAL O & M COSTS	<u>\$ 67,200</u>

Summary of Yearly O & M Cost Estimates
For The Navarro College Geothermal Project
Table 32-1

33.0 SYSTEM ECONOMICS

The geothermal project at Navarro College is a prototype system which has been designed primarily to investigate the technical feasibility of direct utilization of geothermal energy in a cascade application system. Since this system is a prototype operation, it should be noted that the economics of this smaller scale system will not reflect a true picture of a larger commercial operation. It has always been recognized that development costs would be incurred in this project which need not be duplicated in future projects.

To account for these development costs and to provide a truer picture of private sector incentives, capital costs for an "equivalent" system are used in the economic analysis. The first part of this analysis (33.1) will compare O & M costs of the Navarro College project to the income generated from harvested crop items. The second part of this section presents the projected system economics for a larger commercial operation.

It is also important at this point to address the fact that a significant impact on the economic attractiveness of geothermal system utilization lies in tax incentives and benefits available to commercial developers. These incentives are listed in Table 33-1.

Table 33-1.

Cost Category	Tax Treatment ¹
◦ Tangible Well Equipment ²	Capitalized and Depreciated; Eligible for ITC and ETC ³ .
◦ Intangible Drilling Costs ⁴	Expensed (or capitalized, at taxpayers option).

° Design, Planning, & Bidding	Capitalized and Depreciated; apportioned among the appropriate categories and treated accordingly.
° Pump Houses & Other Equipment	Capitalized and Depreciated; eligible for ETC only.
° Disposal Equipment	Capitalized & Depreciated; eligible for ITC, assumed eligible for ETC.
All Other Construction Costs	Capitalized & Depreciated; eligible for ITC & ETC.

¹ Extracted from Hederman 1981, Economic Assessment of Geothermal Direct Heat Technology: A Review of Five DOE Demonstration Projects.

² Physical well property such as casing, valves, etc.

³ ITC = Investment Tax Credit (10%), ETC = Energy Tax Credit (15%)

⁴ Includes labor, fuel, repairs, hauling, supplies, etc.

Tax Treatment for Commercial Developments
Using Geothermal Energy
Table 33-1

33.1 Geothermal Economics at Navarro College

In assessing the potential success of any geothermal operation, several factors need to be considered once the type of operations has been established. If the type of operation is one of space heating for buildings, then a savings over fossil fuels or electrical heat must be realized which offsets the cost of installation of the geothermal equipment. The projected pay-back on this equipment is dependent upon specific factors of the resource itself, such as quantity and quality of the geothermal fluids available. Due to these limitations it can be quickly assessed that larger operations with high energy demands which have access to large quantities of a high quality geothermal resource will

prove to be more economically feasible than small prototype operations such as the one at Navarro College. The development costs incurred for this project would not show a pay-back on investment for this small of a scale operation. Yet, projections are presented in Section 33.2 which show that a larger operation would be economically feasible for this type of cascade application. Therefore, in assessing the economics for the Navarro College geothermal project, construction costs have not been considered and the following table (33-2) compares only the income from project crop items and increased student enrollment to the O & M costs.

Table 33-2.

Income From Project Elements		O & M Costs	
° Aquaculture Crops		° Personnel	\$ 58,000
Shrimp (750 lbs.)	\$ 6,240	° Utilities	3,700
Catfish (4500 lbs.)	5,625	° Repairs & Supplies	3,500
		° Other	<u>2,000</u>
° Greenhouse Crops			
Tomatoes (9600 lbs.)	7,200		
Cucumbers (2400 lbs.)	1,200		
Other	900		
° Projected New Student Enrollment Due To Facilities On Campus			
25 New Students	<u>50,000</u>		
TOTALS	\$71,165		\$ 67,200

Navarro College Geothermal Project Costs
And Income Comparison
Table 33-2

33.2 Larger Scale Aquaculture Operation Economics

The following information is based on a study to develop a 10 acre aquaculture operation requiring 2500 gallons per minute of 150°F geothermal water of potable quality.¹ The facilities include three fully cased 2,000 foot wells with pumps; 40 one fourth acre ponds with necessary piping, valves, and controls; and a hatchery and harvesting equipment. The yield on capital investment (before taxes) based on a 20 year life cycle will probably be 19.6%. A pessimistic analysis yields 9.4%, and optimistic analysis yields 31.0%. Capital investment for the project is \$1,000,000 and excludes housing or amenities for employees.

33.2.1 Capital Cost

Table 33-3 summarizes capital cost, which total \$1,000,000.00. Major cost items are the wells, (\$270,000.00) and the deep well turbine pumps with variable speed drivers, (\$200,000.00).

33.2.2 Operating Cost and Income Summary

Table 33-4 shows the first year operating cost to total \$111,913.00. This will increase as labor and material cost inflate over the operating years.

Income is shown for three different levels: pessimistic (\$175,000.00), probable (\$245,000.00), and optimistic (\$343,000.00). The difference in dollar amounts is the results of the particular combination of yield and price used as shown in Table 33-4.

¹ Geo-Heat Center, Oregon Institute of Technology 1981; "Geothermal Aquaculture Project".

33.2.3 Simple Payback

Table 33-6, showing six to eleven year simple payback periods, is evidence that geothermal systems can be attractive to commercial developers, not only for application in space heating, but for development in the fields of aquaculture and agriculture as demonstrated by the 75% savings over natural gas costs for equivalent amounts of heat energy. These results definitely indicate that commercial development of the central Texas geothermal resource can indeed be economically attractive.

Table 33-3.

Wells, 3 required, cased, 2,000 ft. deep		\$270,000.00
Well pumps, 3 required, 100 hp motor, variable speed drive		200,000.00
Domestic water well and water system		10,000.00
Piping, polybutylene supply, polyvinyl chloride drain		130,000.00
Well head buildings, 3 required		20,000.00
° Ponds		
Clearing and grubbing	\$ 2,000.00	
Dike construction	122,000.00	
Bottom grade and compaction	4,000.00	
	<u>\$128,000.00</u>	128,000.00
° Access Roads		
Clearing, excavation, and grading	\$ 2,000.00	
Gravel	8,000.00	
Culverts	2,000.00	
	<u>\$ 12,000.00</u>	12,000.00
° Machinery (including office and lab)		
750 sq. ft. building	\$ 13,000.00	
Equipment (including four 250 gallon tanks, aerators, filters, misc.	7,000.00	
	<u>\$ 20,000.00</u>	20,000.00

° Initial stocking (1.5 post larvae prawns per ft ² @ \$35/1000		22,000.00
° Other equipment		
Nets and seining material	\$ 1,500.00	
Recording instruments and chemicals	1,500.00	
Packing and shipping cartons	2,000.00	
	\$ 5,000.00	5,000.00
° Engineering fees		30,000.00
° Misc. mechanical and electrical		15,000.00
	Subtotal	\$ 862,000.00
	Contingency	138,000.00
	Total capital	\$1,000,000.00

Capital Cost Summary
Table 33-3

Table 33-4.

OPERATING COST

° Electricity	836,230 KWH/year		\$ 17,676.00
° Consumables			
	Nets and seining material	\$ 750.00	
	Chemicals	500.00	
	Packaging and shipping cartons	2,000.00	
	Feed @ \$5.00 per day, per acre	\$18,250.00	
		<u>\$21,500.00</u>	\$ 21,500.00
° Labor			
	1 man @ \$22,000/yr	\$22,000.00	
	2 men @ \$12,000/yr	24,000.00	
		<u>\$46,000.00</u>	\$ 46,000.00
° Maintenance			
	Piping	\$ 763.00	
	Pumps, hatchery, bldgs.	14,086.00	
	Ponds and roads	1,643.00	
		<u>\$16,491.00</u>	\$ 16,491.00
° Property taxes and insurance			\$ <u>10,246.00</u>
° Total operating cost (1st year)			\$111,913.00

INCOME (1ST YEAR) 3 CASES

1. Minimum yield, minimum price (pessimistic) 35,000 lbs/year @ \$5.00/lb =	\$175,000.00
2. Maximum yield, minimum price and/or minimum yield, maximum price (probable) 49,000 lbs./ year @ \$5.00/lb. =	\$245,000.00
35,000 lbs/year @ 7.00/lb =	\$245,000.00
3. Maximum yield, maximum price (optimistic) 49,000 lbs/year @ \$7.00/lb. =	\$343,000.00

Operating Cost and Income Summary
Table 33-4

33.2.4 Cost Analysis

Life Cycle Cost Analysis was completed for the Aquaculture ponds using inflation rates as follows:

Electricity: 7.9% through 1988
9.1% from 1989 through 2001

Consumables, labor, and maintenance: 7%
Insurance: 2%
Sales price: 7%

Table 33-5 shows the annual costs for a 20 year life cycle as follows:

Column: 1. Geothermal Electrical
2. Consumables
3. Labor
4. Maintenance
5. Insurance
6. Total Geothermal Cost

The rate of return on invested capital, assuming 100% equity financing, is 31% for a yield of 49,000 pounds annually at a price of \$7.00 per pound.

If the assumption is made that only 35,000 pounds per year can be produced and sold at \$5.00 per pound, the rate of return drops to 9.4%.

Either a yeild of 35,000 pounds at \$7.00 per pound or 49,000 pounds at \$5.00 per pound, provides rates of return of 19.6%.

The best case is presented in Table 33-6 Column 1 and 2, followed by the worst case, Columns 3 and 4 Table 33-6, and the probable case Column 5 and 6 Table 33-6. Year of simple payback is indicated by an * appearing on the right side of the annual cash flow year that payback occurs.

Table 33-6:

Column: 1. Sales for 49,000 lbs, @ \$7/lb.
2. Net Cash Flow
3. Sales for 35,000 lbs. @ \$5/lb.
4. Net Cash Flow
5. Sales for either 35,000 lbs. @ \$7/lb. or
49,000 lbs. @ \$5/lb.
6. Net Cash Flow

Table 33-5.

Electricity Geothermal System	Consumable Materials	Labor	Maintenance	Insurance	Total Cost Geothermal System
17676	21500	46000	16491	10246	
19072	23005	49220	17645	10451	119394
20579	24615	52665	18881	10660	127400
22205	26338	56352	20202	10873	135971
23959	28182	60297	21616	11091	145145
25852	30155	64517	23129	11312	154966
27894	32266	69034	24749	11539	165481
30432	34524	73866	26481	11769	177073
33202	36941	79037	28335	12005	189519
36223	39527	84569	30318	12245	202882
39520	42294	90489	32440	12490	217232
43116	45254	96823	34711	12740	232644
47039	48422	103601	37141	12994	249198
51320	51812	110853	39741	13254	266979
55990	55438	118613	42523	13519	286083
61085	59319	126915	45499	13790	306609
66644	63472	135800	48684	14066	328665
72708	67915	145305	52092	14347	352367
79325	72669	155477	55738	14634	377843
86543	77755	166360	59640	14926	405226
94419	83198	178005	63815	15225	434663
937128	943101	2017798	723381	253930	4875338

Aquaculture Life Cycle O & M Cost
Table 33-5

Table 33-6.

	Sales For 49,000 lbs. @ \$7.00/lb	Net Cash Flow	Sales For 35,000 lbs. @ \$5.00/lb	Net Cash Flow	Sales For 35K lbs @ \$7/lb or 49K lbs @ \$5/lb	Net Cash Flow
367010		247616	187250	67856	262150	142756
392701		265300	200358	72957	280501	153100
420190		284219	214383	78412	300136	164165
449603		304458*	229389	84245	321145	176000
481075		326109	245447	90481	343625	188659
514751		349270	262628	97147	367679	202198*
550783		373710	281012	103939	393416	216343
589338		399819	300683	111164	420956	231437
630692		427769	321730	118848	450423	247540
674733		457561	344251	127019	461952	264720
721904		489320	308349	135705*	515689	283045
772502		523304	451243	165160	631741	345658
826577		559597	421723	176222	675963	369354
884437		598354	451243	165160	631741	345658
946348		639739	482831	176222	675963	369354
1012592		683928	516629	187964	723280	394616
1083474		731106	552793	100425	773910	421542
1159317		781474	591488	213646	838083	450241
1240469		635243	632892	227667	886049	480824
1327302		892639	677195	242532	948073	513410
TOTAL	15045756	10170417	7676406	2801068	10746968	5871630
SIMPLE PAYBACK		4 years		11 years		6 years
RATE OF RETURN		31%		9.42		19.6%
*Simple Payback Year						

34.0 PUBLIC AWARENESS PROGRAM*

34.1 Objectives

The success of a demonstration, or prototype, project that applies a new technology is dependant upon two functions: 1) The technical quality of design, construction and operation of the project; and 2) communication of the technical success and the feasibility of its application on a broader scale and a commercial basis. The Public Awareness Program was the principal means of performing this second function in accordance with DOE's original PON objectives.

This program had two primary objectives:

- ° To attract potential users of low temperature geothermal energy, and
- ° To inform the general public of the Navarro College project, in particular, and to the use of low temperature geothermal energy in general.

34.2 Program Elements

The formal Public Awareness Program was active over the entire project term and ended with completion of the audio/visual slide show in August of 1984. However, the public awareness function is an ongoing activity that will continue in the future. The success of the Public Awareness Program was, and is, largely due to the willingness and ability of the Colleges' administration to respond to the news media and public inquiries.

As the college conducted the program over the project period, a basic plan was followed and the following elements were created to implement the program objectives.

* This section describes an effort which is unique to the Navarro College project and which is in addition to the "standard" DOE PON outline in this report.

Navarro College to someday reap aquaculture harvest

Cafeteria patrons may dine on project fare

Navarro College students and guests may dine on the college's first aquaculture harvest.

BA — THURSDAY, JULY 15, 1982

Aquaculture project explained

Keenan Smith, aquaculture consultant for the Navarro College aquaculture project, was the guest speaker at the Wednesday morning meeting of the Navarro County Agricultural Workers Association.

Smith spoke about the difficulties of the project.

Partly and Wildlife fish hatchery were moved into the catfish pond this year as well as being moved into the catfish pond this year.

Small shrimp and catfish ponds on the Navarro College campus.

Small shrimp and catfish ponds on the Navarro College campus.

THURSDAY, JUNE 21, 1984 — BA

Navarro College hosts shrimp luncheon

Navarro College will host a shrimp luncheon on Thursday, June 21, 1984, at 11 a.m. in the cafeteria. The luncheon is a part of the Navarro College aquaculture project.

The shrimp luncheon is a part of the Navarro College aquaculture project.

Geothermal energy used to grow prawns

By Christy Groszek
Corpus Christi Daily Sun

CORPUS CHRISTI, Texas — Shrimp — freshwater prawns, technically — are being raised at Navarro College as part of a Department of Energy-funded aquaculture research project that makes use of geothermal resources.

About 18,000 nearly transparent, post-larval prawns were released recently into two one-eighth-acre grow-out ponds housed in a long, Quonset hut-type building in the northwest corner of the campus.

The quarter-inch-long prawns will grow to an edible size — when their tails are 3 to 4 inches long — in about seven months, said Keenan Smith, coordinator of the Navarro College aquaculture project.

The prawns will be harvested after seven months to a year, as the prawns grow at various rates. Nets with specially sized mesh that al-

Keenan Smith dips into the prawn pond at Navarro Col.

Shrimp make college debut

By CHRISTY GROSZEK
Sun Staff Writer

Beef may be one of the main products of Texas, but another meat animal made an appearance at Navarro College this week.

Shrimp — freshwater prawns, technically — will be raised at the college as part of a Department of Energy-funded aquaculture research project that makes use of geothermal resources.

About 18,000 nearly transparent, post-larval prawns were released Thursday into the two one-eighth-acre grow-out ponds housed in a long, Quonset-type building in the northwest corner of the campus. The quarter-inch long prawns will grow to an edible size — when their tails are 3-4 inches long — in about seven months, said Keenan Smith, coordinator of the Navarro College aquaculture project.

Harvesting of the prawns will be done from seven months to a year from now as the prawns grow at various rates. Nets with specially sized mesh that allows the undersized prawns to slip through, but retains those of an edible size, are used to seine the prawns out of the ponds.

Since the shrimp-growing project is mainly for research purposes, the harvested animals will not be marketed but will be used by the college cafeteria system for faculty and students.

The freshwater prawns differ from saltwater shrimp in that they general-

ly are bigger and have a much sweeter, less fishy flavor and firmer textured meat. "It has more of a nutty, buttery taste," said Smith.

The 30- to 45-day-old prawns were shipped by air freight from a breeder in Hawaii. Since the prawns require salt-water to breed and the college does not have the funds to set up a breeding operation at this time, the project will consist of a harvest and re-stock operation at present.

Research results of the project will be reported to the Department of Energy.

The role of geothermal energy in the project is heating fresh water to a temperature conducive to growth for the shrimp. Heated waters — 125 degrees Fahrenheit — tapped from 2,600 feet under the earth's surface are pumped from a geothermal well located on the college campus.

Passing through a heat exchanger that keeps the two types of water separate, the geothermally heated water, which is saturated with heavy metals and salts that are detrimental to animal and plant life, heats fresh water to a temperature of about 84 degrees. The heated fresh water will flow into the two grow-out ponds to maintain a temperature between 80-84 degrees.

The multi-level aquaculture project also includes a catfish farming operation, a greenhouse for growing ornamental plants and fresh produce, and an experimental irrigation pro-

Project builds NC reputation

Research results of the project will be reported to the Department of Energy, which will stimulate interest in geothermal energy for aquaculture.

This all has been discussed at various stages in the story and last across Texas.

So now you are aware of the natural resources of the Navarro College aquaculture project.

College raises shrimp in energy study

Harvesting of the prawns will be done after seven months to a year, as the prawns grow at various rates. Nets with specially sized mesh that allows the undersized prawns to slip through, but retains those of an edible size, are used to seine the prawns out of the ponds.

Since the prawns require salt-water to breed and the college does not have the funds to set up a breeding operation at this time, the project will consist of a harvest and re-stock operation at present.

College's revolutionary project puts shrimp, catfish in hot water

By KAREN SVENDSEN
Corpus Christi Daily Sun

CORPUS CHRISTI — For the past six years, people in Corpus Christi have been saying Navarro College is in hot water.

Last week about 180 trustees, administrators and city officials gathered at the college to study the situation. What they found was a geothermal energy project that has the potential to revolutionize the inland fishing industry.

The project included shrimp and catfish kept in geothermal waters and greenhouse tomato plants kept warm by the same waters.

Today marks an historic occasion for Navarro College and the citizens of Navarro County, said Dr. Kenneth Walker, college president. "An experimental project which began six years ago and was backed by vision, belief, determination, positive thinking and money is today a success."

The project is not completed, however. Although officials have proven using geothermal energy is technically feasible, they now must examine the

economic feasibility of the project. The project is not completed, however. Although officials have proven using geothermal energy is technically feasible, they now must examine the

economic feasibility of the project. The project is not completed, however. Although officials have proven using geothermal energy is technically feasible, they now must examine the

Research results of the project will be reported to the Department of Energy, which will stimulate interest in geothermal energy for aquaculture.

This all has been discussed at various stages in the story and last across Texas.

So now you are aware of the natural resources of the Navarro College aquaculture project.

NATURAL HEAT

Tomatoes, catfish, and shrimp all get geothermal boost...

Through a pilot program, that the earth's natural energy can be used in some mighty creative ways when people put their mind to the task.

The college in this Texas community — surrounded by Navarro County Electric Cooperative — has a reputation for implementing a solar demonstration project. And now, using natural geothermal water, a shrimp, vegetable, and catfish production demonstration project plans new scientific ground and provides a truly innovative course of study for students.

Everybody knows (or at least ought to, according to Smith and Burkhalter) that plant and animal varieties grow best when the "just-right" temperature is provided.

A geothermal well on campus brings hot water to the surface. "How hot is it?" you ask. Well, it's hot enough — in excess of 120 degrees F.

The water is piped from the well to a heat exchanger which warms surface water piped from a public source. The geothermal water is then returned to the earth through an injection well, complying with environmental regulations. The

Aquaculture, hydroponics new watchwords at college

Research results of the project will be reported to the Department of Energy, which will use them to stimulate the interest of the private sector in using geothermal energy for aquaculture, Smith said.

Geothermal energy in the project heats fresh water to a temperature conducive to growth for the shrimp. Heated water (125 degrees Fahrenheit) tapped from 2,600 feet under the Earth's surface are pumped from a geothermal well on the college campus.

Passing through a heat exchanger that keeps the two types of heated water, which is saturated with heavy metals and salts that are detrimental to animal and plant life, heats fresh water to a temperature of about 84 degrees.

The multi-level aquaculture project also includes a catfish farming operation, a greenhouse for growing ornamental plants and fresh produce, and an experimental irrigation pro-

The project is not completed, however. Although officials have proven using geothermal energy is technically feasible, they now must examine the

- Press Releases Immediately before or after important project milestones.
- Fact Sheets Summarized important features of the project.
- Site Signs Site identification and public data on project purposes, scope, participants, and sponsors.
- Information Dissemination Mailing of information on aquaculture or geothermal uses to written or requested inquiries.
- Tours Conducted site tours to potential developers of geothermal systems.
- Audio/Visual Show An automated presentation for release to media, visitors, and other speaking engagements.

34.2.1 Press Releases

News releases were distributed at important milestones during the course of the project and included: 1) at the conclusion of the contract-signing agreement with DOE; 2) after successful completion of the geothermal well; 3) at construction and dedication ceremonies; and 4) at harvest ceremonies marking the successful completion of the operational phase of the project. A collage of these releases is in this report (Figure 34-1). All news releases were carried by local and regional papers and were also distributed outside the state through the Associated Wire Service.

In addition to coverage through newspapers, the dedication and harvest ceremonies were attended, and covered, by the representatives from WFAA channel 8 of Dallas, Texas and KXAS Channel 5 of Fort Worth, Texas. These broadcasts were then released to nation wide affiliate stations for

rebroadcasts. Also during the harvest ceremonies, a photographer and representative from National Geographic Magazine was present to record information, gather data, and take photographs for inclusion in a future publication by National Geographic.

34.2.2 Fact Sheets

During the course of the project a fact sheet was developed to explain the use of geothermal fluids for the Navarro College project. This fact sheet was distributed at speaking engagements and during the dedication and harvest ceremonies.

34.2.3 Site Sign

A four-by-eight foot sign was designed by the project director, Dr. Lary Reed, to be used during the operational phase of the project. The sign was painted by a local firm and erected by college personnel at the site on October 25, 1983. A listing of the project purpose, scope, participants, and sponsors is identified on this sign.

34.2.4 Information Dissemination

A majority of inquiries to the college requested information in the form of publications or plans to use geothermal fluids for aquaculture or space heating application. All potential developers were informed that the final report on the project at Navarro College would be available from the U.S. DOE Information Center after September, 1984. These people were also sent copies of the project fact sheet and publications on previous research from the Geo-Heat Center at Oregon Institute of Technology. Approximately 100 packets of information were distributed in this manner.

34.2.5 Tours

All interest developers have been encouraged to visit the campus and receive a tour of the geothermal facilities. To date over 1000 individuals have taken this tour and have come from as far away as California and New York to see this system in operation. As a result of one tour, given to personnel from Texas A & M University, the college participated in the 1984 Annual Fish Farmers of Texas Convention which was held to discuss current research in fish farming and aquaculture.

34.2.6 Automated Slide Show

An automated audio/visual slide show was identified as a particularly effective means to inform the public about the Navarro College project, and about the feasibility of using geothermal energy in Central Texas. The slide show has fulfilled two needs:

- 1) To serve as an automated audio/visual presentation for visitors; and
- 2) To accompany lectures and presentations by college personnel, DOE staff, and others.

The slide show program was produced by the Navarro College Telecommunications Department and is composed of 66 slides which were selected from over 500 slides taken during the course of the project. This presentation is approximately 10 minutes in length.

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APPENDIX A

PERMITS

* Reconstructed by
Navarro College

TEXAS WATER DEVELOPMENT
STATE OF TEXAS
P.O. Box 13087 Capitol Station
Austin, Texas 78711
Area Code 512/475-3187

TEXAS WATER DEVELOPMENT BOARD

A.L. Black, Chairman
W.O. Bankston
Milton T. Potts
John H. Garrett
George W. McCluskey
Glen E. Roney

Harvey Davis
Executive Director

December 29, 1978

Navarro College Energy Development
P.O. Box 1170
Corsicana, Texas 75110

TEXAS WATER COMMISSION

Felix McDonald, Chairman
Dorsey B. Hardeman
Joe R. Carroll

SC-693

Gentlemen:

RE: Navarro College, Well #1
A. Hicks Survey, A-335
Navarro County, Texas

Reference is made to your inquiry of December 21, 1978 regarding the protection of useable-quality water strata in your above named well.

Water-bearing strata must be protected down to a depth of 100 feet.

Please send an electrical log of this when it is available.

NOTE: The depth to which we recommend that useable-quality water strata should be protected is intended to apply only to the subject well. Approval of the well-completion methods for protection of this ground water falls under the jurisdiction of the Railroad Commission of Texas. This recommendation is intended for normal drilling and production operations only and does not apply to salt water disposal operations. It should not be used as a recommendation for fieldwide useable-quality water protection rules.

Very truly yours,

J.N. Russell,
Geologist
Surface Casing Section

cc: RRC, Austin
RRC, District Office #5

* Form Reconstructed by
Navarro College

RAILROAD COMMISSION OF TEXAS
OIL & GAS DIVISION
PERMIT TO DRILL, DEEPEN OR PLUG BACK
ON REGULAR LOCATION

PERMIT NUMBER 028397	DATE OF PERMIT 7/13/78	DISTRICT 05
NUMBER (API) 42 349 30775	FORM W-1 (dated) 7/07/78	COUNTY Navarro
TYPE OF OPERATION Drill		ACRES 127
OPERATOR 601085 Navarro College Energy Dev. Highway 31 West P.O. Box 1170 Corsicana, Texas 75110		NOTICE NO ALLOWABLE WILL BE ASSIGNED unless well protects all fresh water sands with sufficient surface casing. Where Commission rules do not specify surface casing requirements, contact the Texas Department of Water Resources for depth to which fresh water sands must be protected. <u>PERMIT SUBJECT TO CONDITIONS ON BACK OF FORM</u> District Office Telephone No.: AC 214 984-3026
LEASE NUMBER Navarro College		WELL NUMBER 1
LOCATION 2 Miles W From Corsicana		TOTAL DEPTH 3,000
SECTION, BLOCK and/or SURVEY A. Hicks Sur., A-335		
DISTANCE--LEASE LINES 75 FWL & 887 FEL	--SURVEY LINES 600 FEL & 1430 FSL	--NEAREST WELL ON LEASE None
FIELD (S) WILDCAT <p style="text-align: center;">**LIMITATIONS**</p> <p>WILDCAT ABOVE 3000. REGULAR FOR GEO-THERMAL AND OIL.</p> <p>Based upon the representations made on the above FORM W-1 and those made on any plat or plats filed therewith, it is believed that the operation indicated, when carried out at that point which you have represented to be the location of the above designated Well, complies as of the date thereof, with the provisions of the applicable spacing rule SUBJECT TO THE LIMITATIONS, IF ANY, SET OUT ABOVE. Compliance with the applicable Commission spacing rule renders it unnecessary that you secure a special Commission permit to cover this indicated operation at the location shown, the same being classed as regular.</p> <p>If there are outstanding permits covering operations which have not actually been started as of the date of filing FORM W-1 above described and which, if started, would impair the regularity of this operation, then the permit covering that location on which the actual operation is the first begun shall prevail, and all other such outstanding permits shall be nullified.</p>

THE UNIVERSITY OF TEXAS AT AUSTIN
Texas Archeological Research Laboratory
BALCONES RESEARCH CENTER
10,100 BURNET ROAD, AUSTIN, TEXAS 78758

March 9, 1979

Ms. K. T. Sherrill
Staff Economist
Radian Corporation
P. O. Box 9948
Austin, Texas 78766

Dear Ms. Sherrill:

I have checked our files and find that we have no presently recorded archeological sites on the grounds or in the vicinity of either Navarro College or Navarro County Memorial Hospital in Corsicana. This does not negate the possibility of sites, but merely indicates none have been officially reported to us.

We hope this information will be of value in your environmental assessment. If we can be of further assistance, please let us know.

Sincerely yours,

Carolyn Spock
Research Associate

Invoice enclosed

United States
Department of
Agriculture

Soil
Conservation
Service

P. O. Box 648
Temple, TX
76501

March 29, 1979

Ms. Ann E. St. Clair
Staff Geologist
Radian Corporation
8500 Shoal Creek Blvd.
Austin, TX 78766

Dear Ms. St. Clair:

We have reviewed your notice of intent to prepare an environmental assessment on the drilling of a geothermal well at Navarro County Memorial Hospital and find that this proposed project will not involve any prime farmland.

The soils involved in this project are Crockett fine sandy loams, 1 to 3 percent slopes, which are not classified as prime farmland.

Sincerely,

For

George C. Marks
State Conservationist

Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, NV 89114

JUN 12 1979

Mr. C. Paul Green, Project Manager
Navarro College
Box 1170
Corsicana, TX 75110

Dear Mr. Green:

COOPERATIVE AGREEMENT DE-FC08-79ET 27058 - NAVARRO COLLEGE,
CORSIKANA, TEXAS

Please reference Cooperative Agreement Article I., D., Compliance with the National Environmental Policy Act, and the Environmental Report dated May 1, 1979, prepared by the Radian Corporation, Austin, Texas.

The DOE/Nevada Operations Office has assessed the environmental impact of the work tasks for this project, and the findings conclude that this project does not constitute a major Federal action having significant impact upon the quality of the human environment. An environmental assessment is not warranted.

Therefore, you are requested and authorized to proceed with the tasks defined in Appendix A, including the drilling of the reinjection well into the known geothermal resource area, and perform logging and production testing for a final reservoir confirmation, all according to the requirement of the Cooperative Agreement.

Sincerely,

Robert W. Taft, Assistant Manager
for Plans, Engineering & Budgets

E&EAD:RLM-1256

cc: M. Conover, Radian Corp.,
Austin, TX
B. Allen, CC
D. Morse, C&P
D. Parker, FIN

* Form Reconstructed by
Navarro College

RAILROAD COMMISSION OF TEXAS
OIL & GAS DIVISION
PERMIT TO DRILL, DEEPEN OR PLUG BACK
ON REGULAR LOCATION

PERMIT NUMBER 057126	DATE OF PERMIT 9/04/79	DISTRICT 05
API NUMBER 42 349 30937	FORM W-1 (dated) 8/21/79	COUNTY Navarro
TYPE OF OPERATION Drill		ACRES 127
OPERATOR 601085 Navarro College Energy Dev. Highway 31 West P.O. Box 1170 Corsicana, Texas 75110		NOTICE NO ALLOWABLE WILLBE ASSIGNED unless well protects all fresh water sands with sufficient surface casing. Where Commission rules do not specify surface casing requirements, contact the Texas Department of Water Resources for depth to which fresh water sands must be protected. <u>PERMIT SUBJECT TO CONDITIONS ON BACK OF FORM</u> District Office Telephone No.: AC 214 984-3026
LEASE NUMBER Navarro College		WELL NUMBER 2
LOCATION 2 Miles W From Corsicana		TOTAL DEPTH 5,000
SECTION, BLOCK and/or SURVEY A. Hicks Sur., A-335		
DISTANCE--LEASE LINES 800 FNL & 1470 FEL	--SURVEY LINES-- 2000 FNL & 880 FEL	--NEAREST WELL ON LEASE 900 E
FIELD (S) WILDCAT <p style="text-align: center;">**LIMITATIONS**</p> WILDCAT ABOVE 5000. <u>REGULAR PROVIDED THIS WELL NEVER COMPLETED IN THE SAME RESERVOIR AS ANY OTHER WELL CLOSER THAN 1200 FEET ON THIS SAME LEASE.</u> <p>Based upon the representations made on the above FORM W-1 and those on any plat or plats filed therewith, it is believed that the operation indicated, when carried out at that point which you have represented to be the location of the above designated Well, complies as of the date thereof, with the provisions of the applicable spacing rule SUBJECT TO THE LIMITATIONS, IF ANY, SET OUT ABOVE. Compliance with the applicable Commission spacing rule renders it unnecessary that you secure a special Commission permit to cover this indicated operation at the location shown, the same as being classed as regular.</p> <p>If there are outstanding permits covering operations which have not actually been started as of the date of filing FORM W-1 above described and which, if started, would impair the regularity of this operation, then the permit covering that location on which the actual operation is the first begun shall prevail, and all other such outstanding permits shall be nullified.</p>		

RETURN TO:
Railroad Commission of Texas
Oil and Gas Division
Production and Proration Section
Capitol Station - P. O. Drawer 12967
Austin, Texas 78711

RAILROAD COMMISSION OF TEXAS
OIL AND GAS DIVISION

ORGANIZATION REPORT
TYPE OR PRINT--INSTRUCTIONS ON REVERSE SIDE

Form P-5
REV 1/81

This is the initial and principal instrument that identifies an organization to the Commission. It is imperative that it be fully and correctly executed and filed before an organization initiates operations.

1. Organization Name and Mailing Address

Navarro College Energy Dev.
Highway 31 West
P.O. Box 1170
Corsicana, Texas 75110

If mailing address has changed, indicate new address here.

N/A

2. RRC Operator No. (if assigned)

NEW VENTURE

3. Purpose of Filing

- ☒ New Filing
☐ Address Correction
☐ Change of Officers
☐ Annual Refiling

4. Street Address if different from above mailing address.

Street

N/A

City

State

Zip Code

If street address has changed, indicate new address here.

N/A

5. Current Plan of Organization:

If this application is new or organization has changed, select one.

☐ A. Corporation

☐ C. Sole Proprietorship

☐ E. Trust

☐ F. Joint Venture

☐ B. Limited Partnership

☐ D. Partnership

☒ G. Other PUBLIC JR. COLLEGE

6. Principal Officers, Partners, Joint Venturers, and Trustees (required on all organizations)

Name Dr. Kenneth P. Walker
Title President
Address P.O. Box 1170
Corsicana, Texas 75110

Name James R. Ruth
Title Plant Specialist
Address P.O. Box 1170
Corsicana, Texas 75110

Name Darrell R. Raines
Title Fiscal Officer
Address P.O. Box 1170
Corsicana, Texas 75110

Name N. H. Hardgrave
Title Agent
Address P.O. Box 92
Corsicana, Texas 75110

Name C. Paul Green
Title Director of Development
Address P.O. Box 1170
Corsicana, Texas 75110

Name _____
Title _____
Address _____

7. If a reorganization, give name and address of previous organization.

N/A

8. If Item No. 1 listed above is a subsidiary or an assumed name (dba), give name and address of associated company.

N/A

FOR RRC USE ONLY

Approved by:

Date:

Remarks:

*Reconstructed by Navarro College

Signature *Darrell R. Raines*
Name Darrell R. Raines

Title Fiscal Officer

Date 2/05/80

Telephone 214 874-6501

Area Code Number

CERTIFICATE: I declare under penalties prescribed in Sec. 91.143, Texas Natural Resources Code, that I am authorized to make this report, that this report was prepared by me or under my supervision and direction, and that data and facts stated therein are true, correct, and complete, to the best of my knowledge.

RAILROAD COMMISSION OF TEXAS
OIL AND GAS DIVISION

JAMES E. (JIM) NUGENT, Chairman
MACK WALLACE, Commissioner
BUDDY TEMPLE, Commissioner

BOB R. HARRIS, P.E.
Director
JERRY W. MULICAN
Director of Underground
Injection Control

1124 S. IH 35

CAPITOL STATION - P. O. DRAWER 12967

AUSTIN, TEXAS 78711

October 13, 1981

Navarro College Energy Development
P.O. Box 1170
Corsicana, Texas 75110
ATTENTION: Dr. Larry L. Reed

Re: Permit to Inject Fluid Into a
Reservoir Productive of Geothermal Resources
Wildcat Field,
Navarro County, Texas.

Gentlemen:

This will acknowledge receipt of Commission Form GT-5 and supporting evidence submitted in connection with your "Application to inject into a Geothermal Reservoir" on the subject lease in compliance with Commission Statewide Rule 46.

The Commission hereby grants you permission to use only the following well to inject Geothermal Water into the Woodbine Formation at an average depth of 2234 feet underlying the subject lease;

Navarro College (02112) Lease, Well No. 2

Fluid Injection must be through tubing set on a mechanical packer, and the injection pressure may not exceed 550 psi. The Commission's district director must be notified prior to any workover or remedial operation, including running tubing and setting a packer.

A new Form W-2 must be filed to show the current completion status of the injection well. The injection permit date should be indicated on the new Form W-2. Also, the date that injection operations commenced (or the anticipated date that such operations will commence) should be included in the Remarks Section of Form W-2.

Provided further that, should it be determined by the Commission that such injected fluid is not confined to the approved strata, then the permission given herein shall be suspended and the fluid injection stopped until the fluid migration from such strata is eliminated.

Sincerely yours,

Jerry W. Mullican
Director of Underground
Injection Control

cc: RRC, Kilgore
Proration - 05
Radian Corp.

NAVARRO COLLEGE

POST OFFICE BOX 1170 • CORSICANA, TEXAS 75110 • 214/874-6501

May 19, 1982

Ms. Jane Watson
Environmental Protection Agency
1201 Elm St.
First International Bldg.
Dallas, Texas 75270

Dear Ms. Watson:

Thank you for the information you provided in our telephone conversation on May 19, 1982. As you are aware, we at Navarro College will be involved in an aquaculture project which will consist of less than one acre of research ponds with the effluent being collected in an irrigation reservoir. The total annual yield from these ponds will be considerably less than the guideline limit of 20,000 pounds. The majority of the effluents will be used for irrigation purposes with only limited discharge being eliminated by way of a natural drainage system during periods of excessive run off.

It is our understanding that the project as designed will meet Environmental Protection Agency rules and regulations; therefore, we request a letter from you confirming that Environmental Protection Agency permits are not required for our proposed aquaculture research project. Based on our telephone conversation, it is my understanding that this confirmation creates no problem for you; however, if additional information is needed and if forms need to be completed, please inform us.

Thank you once again for your help; if you are in the Corsicana area during the near future, I invite you to the campus for a visit.

Sincerely,

Larry L. Reed, Ed. D
Executive Dean

Kenan C. Smith
Aquaculture Research Consultant

LLR:mw
KCS:ss

APPENDIX B
WATER QUALITY TESTS

TABLE 2-6. CONCENTRATIONS OF CHEMICAL CONSTITUENTS IN
WATER FROM THE WOODBINE FORMATION NEAR
CORSICANA (all units except pH are mg/l)

	Woodbine ¹ at Corsicana	Woodbine ² East of Corsicana	Woodbine ² Navarro College Test Well
Ca	13	96	13
Mg	5.4	420	5.6
Na	1,810 (Na + K)	6,100	2,020
HCO ₃	1,580	1,250	1,140
SO ₄	153	<5	38
Cl	1,790	8,700	2,560
F	2.5	1.05	--
TDS	4,550	15,000	5,300
Hardness, CaCO ₃	.55	--	--
pH	--	8.0	--

¹From Thompson, Gerald L., Ground-Water Resources of Navarro County, Texas.
Report 160, Texas Water Development Board. November 1972.

²Analyses performed by Radian Corporation.

TABLE 2-7. CONCENTRATIONS OF CHEMICAL CONSTITUENTS
IN WATER FROM THE NACATTOCH SAND AND NAVARRO
GROUP NEAR CORSICANA (all units except pH
are mg/l).

	Nacatoch 33-61-401	Nacatoch 33-61-402	Navarro 33-61-701
Depth, meters (ft.)	39 (127)	55 (181)	15 (48)
SiO ₂	28	22	27
Ca	11	7	99
Mg	4	1	11
Na	290	317	146
K	2.1	12.0	31.0
HCO ₃	448	428	426
SO ₄	129	118	187
Cl	132	150	53
F	0.7	0.8	0.7
TDS	817	838	765
Hardness as CaCO ₃	43	24	292
pH	7.4	8.5	7.2

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

**ANALYTICAL CHEMISTS
AND TESTING ENGINEERS**

Dallas, Texas 10-22-82 File No. New

Report of: Analysis of Water

Reported to: Navarro College, Attn: Dr. Larry Reed
P.O. Box 1170
Corsicana, TX 75110

Date received: 8-30-82

Identification: Water from Geothermal Well #1

pH 8.8 (**7.0) Specific Gravity _____
Conductivity, micromhos/cm 11400 Resistivity _____ @ _____ °F

	<u>Mg/l</u>	
Silica	<u>23.2</u>	
Iron	<u>*0.05</u>	(0.3)
Aluminum	<u>*0.10</u>	
Manganese	<u>*0.05</u>	(0.5)
Calcium	<u>28</u>	
Magnesium	<u>9</u>	
Sodium	<u>2500</u>	
Potassium	<u>9.56</u>	
Carbonate, CO ₃	<u>168</u>	
Bicarbonate, HCO ₃	<u>695</u>	
Sulfate, SO ₄	<u>6</u>	(300)
Chloride, Cl	<u>3530</u>	(300)
Fluoride, F	<u>2.5</u>	(1.8)
Nitrate, NO ₃	<u>0.95</u>	
Phosphate, PO ₄	<u>0.7</u>	
Hydroxide, OH	<u>0</u>	
P-Alkalinity (as CaCO ₃)	<u>140</u>	
Total Alkalinity (as CaCO ₃)	<u>850</u>	
Total Hardness (as CaCO ₃)	<u>110</u>	
Total Dissolved Solids		
(by evaporation @ 180°C)	<u>7110</u>	(1000)
Total Suspended Solids	<u>7</u>	

*Less than **Greater than (...) Maximum Specifications on drinking water standards.

Distribution of report:

3c-Navarro College
3c-Navarro College, 10-25-82
Corrected copy

Respectfully submitted,

SOUTHWESTERN LABORATORIES, INC.

Per: *Ronald G. Yarbrough*

Lab. No. D-18078 /bc

143

Ronald G. Yarbrough

Samples are discarded 30 days after reports are mailed unless prior arrangements are made in writing. A storage fee will apply on samples held over 30 days. Our letters and reports are for the exclusive use of the client to whom they are addressed. The use of our name must receive our prior written approval. Our letters and reports apply to the sample tested and/or inspected, and are not necessarily indicative of the qualities of apparently identical or similar products.

	<u>mg/l</u>	
Uranium, U	<u>0.005</u>	
Arsenic, As	<u>*0.01</u>	(0.05)
Barium, Ba	<u>0.89</u>	(1)
Cadmium, Cd	<u>*0.01</u>	(0.01)
Chromium, Cr	<u>*0.05</u>	(0.05)
Lead, Pb	<u>*0.05</u>	(0.05)
Mercury, Hg	<u>*0.002</u>	(0.002)
Selenium, Se	<u>*0.01</u>	(0.01)
Silver, Ag	<u>*0.01</u>	(0.05)
Zinc, Zn	<u>*0.01</u>	(5.0)
Boron, B	<u>17.3</u>	

	<u>pci/L</u>	
Radium - 226	<u>2.18 ± 0.46</u>	(5)
Gross Alpha	<u>24 ± 60</u>	(15)
Gross Beta	<u>15 ± 50</u>	

APPENDIX C

WELL LOGS

Electric Log

COMPANY <u>NAVARRO COLLEGE ENERGY DEVELOPMENT</u>				
WELL <u>WELL NO. - 1 (THERMAL SUPPLY)</u>				
FIELD <u>WATER WELL</u>				
COUNTY <u>NAVARRO</u>	STATE <u>TEXAS</u>			
Location <u>ON WEST EDGE OF NAVARRO COLLEGE CAMPUS</u> Sec. _____ Twp. _____ Rge. _____				
Type Log <u>E. S.</u>				
Permanent Datum <u>G. L.</u> Elev. _____				
Log Measured From <u>G. L.</u> Ft. Above Perm. Datum _____				
Drilling Measured From <u>G. L.</u> _____				
Elev. K.B. _____				
D.F. _____				
G.L. _____				
Date	<u>09-21-78</u>	<u>09-28-78</u>		
Run No.	<u>ONE</u>	<u>TWO</u>		
Depth - Driller	<u>2523'</u>	<u>2665'</u>		
Depth - Logger	<u>2523'</u>	<u>2664'</u>		
Btm. Log Inter.	<u>2520'</u>	<u>2664'</u>		
Top Log Inter.	<u>238'</u>	<u>2200'</u>		
Casing - Driller	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Casing - Logger	<u>10-3/4" @ 238'</u>			
Bit Size	<u>9-5/8"</u>			
Type Fluid in Hole	<u>CHEMICAL</u>			
Dens.	Visc.			
pH	Fluid Loss	ml	ml	ml
Source of Sample				
Rm. a Meas Temp.	<u>0</u> °F	<u>0</u> °F	<u>0</u> °F	<u>0</u> °F
Rmf. a Meas Temp.	<u>0</u> °F	<u>0</u> °F	<u>0</u> °F	<u>0</u> °F
Rmc. a Meas. Temp.	<u>0</u> °F	<u>0</u> °F	<u>0</u> °F	<u>0</u> °F
Source Rmf. Rmc				
Rm. a BHT	<u>0</u> °F	<u>0</u> °F	<u>0</u> °F	<u>0</u> °F
Time Since Circ.				
Max. Rec. Temp.	°F	°F	°F	
Equip.	Location			
Recorded By	<u>T. C. LARGENT</u>			
Witnessed By	<u>H. N. HARDGRAVE</u>			

REMARKS

COMPANY: NAVARRO CO. JR. COLLEGE
WELL: GEOTHERMAL #2
FIELD:
COUNTY: NAVARRO STATE: TEXAS
NATION: U. S. LONGITUDE:
LATITUDE:
LOCATION: NAVARRO JR. COLLEGE

SEC: TWP: RGE:

PERMANENT DATUM: GL
ELEVATION OF PERMANENT DATUM: 467.5 FEET
LOG MEASURED FROM: KB
DRILLING MEASURED FROM: KB
ELEVATION-
K.B.: 480.5 FEET D.F.: 479.5 FEET G.L.: 467.5 FEET

OTHER SERVICES-
REPEAT FORMATION TESTER

Date 12/21/79

APPENDIX D
TESTING AND BALANCING OF SYSTEM

 

Δ_t

DELTA-T

AIR CONDITIONING SYSTEMS ANALYSIS — TESTING AND BALANCING

February 20, 1984

McKinney & Moore, Inc.
P.O. Box 787
Jacksonville, TX 75766

Attn: Mr. George McKinney

Re: Testing & Balancing
Aquaculture Facility With
Cascade Greenhouse
Navarro College
Corsicana, Texas

Gentlemen:

We have completed the testing and balancing on the above referenced project. Listed below are the results of our tests.

WATER FLOWS

The water flows were adjusted and read out with a differential flow meter supplied to the college by the mechanical contractor as per the mechanical specifications.

The GPM on the primary side of the plate heat exchanger was determined by reading the Venturi installed by the mechanical contractor. The GPM on the secondary side of the plate heat exchanger was determined by the water meter measuring city water.

The GPM being pumped to the effluent pond by pumps HWP-1 and HWP-2 was determined by using manufacturers curves and test gauge readings. We would like to point out that the pump is not a meter and the accuracy of the GPM is less than that of a meter.

The GPM can only be approximated by using the manufacturers test curves, test gauge readings and estimating the velocity pressure head. The velocity pressure head cannot be measured in the field.

TEMPERATURE READINGS

The temperature readings were taken with a Keithley 871 Digital Thermometer which was checked with a laboratory thermometer before the temperature tests were performed. The calibration points of the temperature recorders were also established by using a Keithley digital type thermometer.

CONTROLS

The controllers were checked by simulating temperature conditions by turning the installed thermostats. All controls function as they should as specified at the time of the test with the exception of the three way valve controlling the geothermal water, the valve control head was being repaired.

EXHAUST FANS

The exhaust fans were tested by using a Jaquet Tachometer and a Digital Ammeter manufactured by Amprobe. Static pressure and CFM could not be determined on these fans because they are a propeller type and do not have any duct work attached. The results of our readings are recorded on the exhaust fan data sheets.

HEATING AIR UNITS (CASCADE GREENHOUSE)

...
The CFM of FAHU-1 and FAHU-2 was determined by traversing the entering side of the heating coil with an Airflow Development Electronic Vane Anemometer. The results of all our tests are recorded on the air handling unit coil test data sheets.

PIPING CHANGES

The following piping changes have been made from the original contract drawings.

The boiler has been piped in series with the plate heat exchanger. This piping change was made during the extremely cold weather during December of 1983. For more explanation, see Boiler tab.

The pond effluent water has been piped to the mechanical equipment room. A new pump has been added and the piping changed to use the pond effluent water instead of city water. This change was made because of the operating cost of using city water. When observing the new piping from the effluent pond we discovered that the pressure relief valve on the boiler had been changed from 30 pounds to 45 pounds. The boiler maximum operating pressure is 30 pounds. The boiler does not meet code requirements and the pressure relief valve should be changed back to the original 30 pound valve. If the 30 pound boiler pressure relief valve relieves when the pond effluent water is being pumped to the aquaculture ponds the piping and valving arrangement should be changed so this condition cannot exist.

AMPERAGE (IMBALANCED)

When taking the amperage readings on the electric motors serving the fans and pumps we noticed an imbalance of amperage on each of the three phases. These readings are recorded on their respective data sheets. The electrician should check this problem.

SUGGESTIONS

1. We suggest that some type of water meter device be installed in each of the branch lines serving the two aquaculture ponds. This should be done so that the run off of each pond can be accurately set within a minimum amount of time. The only way to measure GPM entering the ponds at the present time is to measure the run off in each effluent sump. This method is time consuming.
2. There should be a Venturi installed on the common discharge for pumps HEWP-1 and HEWP-2 so that the GPM can accurately be measured.
3. There should be a thermometer well (pete's plug) installed in the new piping that goes from the plate heat exchanger to the boiler.
4. Also, pressure taps should be installed on the primary and secondary sides of the plate heat exchanger. These taps would be used to take pressure readings across the heat exchanger to determine if they are becoming dirty, corroded or plugged.

...

If there are any questions concerning this report, please contact me.

DELTA-T, INC.

JAMES M. NIX
President

JMN/ee

FANS

VF-1 THRU VF-10

DELTA-T

FAN TEST REPORT

PROJECT Aquaculture FacilityADDRESS Navarro College

DATE _____

FAN NUMBER	VF-1			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	365	.667
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 1.6 / 2.6 / 3.3		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x			
MOTOR DRIVE	2 5/80.D.5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8			
REMARKS: *Not field obtainable, no duct work, set by RPM.				

FAN NUMBER	VF-2			
SERVICE	Exhaust			
LOCATION	Aquaculture Inc.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	365	.667
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 1.6 / 2.6 / 3.3		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x1"			
MOTOR DRIVE	2 5/80.D.x5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8 + 1 - 1/4			
REMARKS: *Not field obtainable, no duct work, set by RPM.

DELTA-T

FAN TEST REPORT

PROJECT Aquaculture Facility ADDRESS Navarro College

DATE _____

FAN NUMBER	VF-3			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	360	.667
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 1.5 / 2.5 / 3.5		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x			
MOTOR DRIVE	2 5/80.D.5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8			
REMARKS: *Not field obtainable, no duct work, set by RPM.				

FAN NUMBER	VF-4			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	365	.667
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 1.5 / 2.5 / 3.5		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x1"			
MOTOR DRIVE	2 5/80.D.x5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8 + 1 - 1/4			
REMARKS: *Not field obtainable, no duct work, set by RPM.

DELTA-T

FAN TEST REPORT

PROJECT Aquaculture FacilityADDRESS Navarro College

DATE _____

FAN NUMBER	VF-5			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	365	.667
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 1.5 / 2.5 / 3.5		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x			
MOTOR DRIVE	2 5/80.D.x5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8			
REMARKS: *Not field obtainable, no duct work, set by RPM.				

FAN NUMBER	VF-6			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	365	.667
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 1.5 / 2.5 / 3.5		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x1"			
MOTOR DRIVE	2 5/80.D.x5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8 + 1 - 1/4			
REMARKS: *Not field obtainable, no duct work, set by RPM.

DELTA-T

FAN TEST REPORT

PROJECT Aquaculture FacilityADDRESS Navarro College

DATE _____

FAN NUMBER	VF-7			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	365	.724
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 2.3 / 2.7 / 3.6		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x1			
MOTOR DRIVE	2 5/80.D.x5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8			
REMARKS: *Not field obtainable, no duct work, set by RPM.				

FAN NUMBER	VF-8			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	365	.650
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 2.1 / 2.6 / 3.6		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x1"			
MOTOR DRIVE	2 5/80.D.x5/8"			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8 + 1 - 1/4			
REMARKS: *Not field obtainable, no duct work, set by RPM.

DELTA-T

FAN TEST REPORT

PROJECT Aquaculture FacilityADDRESS Navarro College

DATE _____

FAN NUMBER	VF-9			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	360	.724
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 2.4 / 2.9 / 3.3		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x			
MOTOR DRIVE	2 5/80.D.x5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8			
REMARKS: *Not field obtainable, no duct work, set by RPM.				

FAN NUMBER	VF-10			
SERVICE	Exhaust			
LOCATION	Aquaculture Incl.			
FAN MFG.	Acme			
TYPE	Prop			
MODEL NO.	DC48J			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	18000	.125	385	
ACTUAL	*	*	360	.724
MOTOR MFG.	General Electric			
FRAME	56			
H.P.	1			
RPM	1725			
AMPS	3.4	ACT: 2.4 / 2.9 / 3.3		
VOLTS	230	ACT: 234 / 234 / 240		
DRIVE MFG.	Browning			
FAN DRIVE	AK121x1"			
MOTOR DRIVE	2 5/80.D.x5/8			
NO. BELTS & SIZE	1 @ A46			
CENTER'S DIST.	11 3/8+1"-1/4"			
REMARKS: *Not field obtainable, no duct work, set by RPM.				

GREENHOUSE EXHAUST

DELTA-T

FAN TEST REPORT

PROJECT GreenhouseADDRESS Navarro College

DATE _____

FAN NUMBER	West			
SERVICE	Exhaust			
LOCATION	Greenhouse			
FAN MFG.	Quiet Air			
TYPE	Prop			
MODEL NO.	CHP44100			
TEST DATA	CFM	SP	RPM	BHP
DESIGN	...			
ACTUAL	*	*	400	.98
MOTOR MFG.	Doerr			
FRAME	J56H			
H.P.	1			
RPM	1725			
AMPS	13.6	ACT: 13.1/	/	
VOLTS	115	ACT: 114 /	/	
DRIVE MFG.	Browning			
FAN DRIVE	AK144x1"			
MOTOR DRIVE	3 1/20.D.x5/8			
NO. BELTS & SIZE				
CENTER'S DIST.	16"			
REMARKS: *Not field obtainable, no duct work, set by RPM.				

FAN NUMBER	East			
SERVICE	Exhaust			
LOCATION	Greenhouse			
FAN MFG.	Quiet Air			
TYPE	Prop			
MODEL NO.	CHP44100			
TEST DATA	CFM	SP	RPM	BHP
DESIGN				
ACTUAL	*	*	405	.98
MOTOR MFG.	Doerr			
FRAME	J56H			
H.P.	1			
RPM	1725			
AMPS	13.6	ACT: 13.1/	/	
VOLTS	115	ACT: 114 /	/	
DRIVE MFG.	Browning			
FAN DRIVE	AK144x1"			
MOTOR DRIVE	3 1/20.D.x5/8			
NO. BELTS & SIZE				
CENTER'S DIST.	16"			
REMARKS: *Not field obtainable, no duct work, set by RPM.				

PUMPS

DELTA-T

PUMP TEST REPORT

PROJECT Aquaculture Facility
Cascade Greenhouse

ADDRESS Navarro College

DATE _____

PUMP NO.	HEWP-1		
MANUFACTURER	Aurora		
SIZE	3/4x1x7B		
SERVICE	Pond Effluent		
TEST DATA	GPM	FT. HD.	BHP.
DESIGN	30	34	.548
ACTUAL	23.5	38.8	1490
DISCHARGE	11.5#	26.56	
SUCTION	60"WG=5		
Δp	380	X 2.31 = 31.56 FT. HD.	
BLOCK OFF			
DISCHARGE	17.75#	41	
SUCTION	40"WG	3.3	
Δp	X 2.31 = 44.3 FT. HD.		
MOTOR MFG.	Marathon		
FRAME	56.6		
H.P.	3/4		
RPM	1725		
AMPS	3	ACT: 2.6 / 1.9 / 2.3	
VOLTS	208	ACT: 226 / 226 / 234	
REMARKS:			

PUMP NO.	HEWP-2		
MANUFACTURER	Aurora		
SIZE	3/4x1x7B		
SERVICE	Pond Effluent		
TEST DATA	GPM	FT. HD.	BHP
DESIGN	30	34	.548
ACTUAL	26	33.54	.490
DISCHARGE	9#	20.79	
SUCTION	60"WG=5		
Δp	X 2.31 = 25.79 FT. HD.		
BLOCK OFF			
DISCHARGE	16.25	37.5	
SUCTION	45"	3.75	
Δp	X 2.31 = FT. HD.		
MOTOR MFG.	Marathon		
FRAME	56.6		
H.P.	3/4		
RPM	1725		
AMPS	3	ACT: 2.6 / 2.2 / 1.9	
VOLTS	208	ACT: 226 / 226 / 234	
REMARKS:			

DATED MARCH 19

HEWP#

30 GPM @ 34 TDH

A UNIT OF GENERAL SIGNAL CORPORATION

AURORA : ILLINOIS

HEWP #2

AURORA PUMP

A UNIT OF GENERAL SIGNAL CORPORATION

AURORA - ILLINOIS

HEAT EXCHANGER

MANUFACTURER Baltimore Aircoil

MODEL ECS-033-1

PRIMARY SIDE

DESIGN		ACTUAL	
EWT	LWT	EWT	LWT
125°	71.93 @ 30 GPM	122	67.6 @ 34 GPM

SECONDARY SIDE

DESIGN		ACTUAL	
EWT	LWT	EWT	LWT
62°	115° @ 30 GPM	*40.5	110 @ 30 GPM **

* 21.5° below design temperature
** Venturi reading

...

- NOTE: (1) The above tests were run in the first week of January.
- (2) The boiler was in series with the plate heat exchanger (see explanation under boiler tab) when the above tests were being performed. The actual water temperature entering the aquaculture ponds was 128°. The boiler was operating as listed below.

BOILER

EWT	LWT	GPM
110	128.3	30

Boiler controls were operating.

BOILER FIRES

116.6°

BOILER SHUTS OFF

128.3°

HEATING AIR SPACE

DELTA-T

AIR UNIT / COIL TEST REPORT

PROJECT Aquaculture Facility With SYSTEM/UNIT FAHU-1
Cascade Greenhouse
ADDRESS Navarro College LOCATION Cascade Greenhouse

UNIT MFG.	Trane
TYPE	Draw Thru
MODEL NO.	

FILTER	None
S.P. ACROSS	
CONDITION	

DESIGN COND.	CFM	SP	RPM	BHP
DESIGN	2200	1.0	1430	
ACTUAL	2149	1.0	1360	.510

STATIC PRESSURE READINGS "H ₂ O	
FAN SUCTION	.48
FAN DISCHARGE	.52

OUTSIDE AIR	RETURN	O.S.A.
DESIGN		
ACTUAL		

MOTOR MFG.	Gould
Frame	143T
H.P.	1
RPM	1745
AMPS	3.9 ACT: 2.2 / 2.6 / 3.5
VOLTS	230 ACT: 236 / 232 / 240

DRIVE MFG.	Browning
FAN DRIVE	BK60x1.0"
MOTOR DRIVE	1VF5.0x7/8"
NO. BELTS & SIZE	1 5L4L440
Center's Dist.	14 1/8 + 1 - 3/4

COILS TYPE		CFM	ΔP "H ₂ O ACROSS	E.A.T.		L.A.T.		E.W.T. °F	L.W.T. °F	ROWS	GPM	H ₂ O ΔP THRU
				D.B.	W.B.	D.B.	W.B.					
Heating	DES.	2200		50	/	67.4	/	80	74.4	4	15	.60
	ACT.			49	/	64.7	/	79	72.3	4	*	*
	DES.			/	/	/	/					
	ACT.			/	/	/	/					
	DES.			/	/	/	/					
	ACT.			/	/	/	/					

* Pressure drop was measured at 3'. Pump GPM is below design requirements; we notified the Trane Company to check to see if pressure drop is in error.

REMARKS:

Entering side of coil traversed with vane anemometer for total CFM.

17"	1	2	3	1	2	3
				FPM	FPM	FPM
				900	810	680
				840	860	680
				830	840	700
				2570	2510	2060
	23"					

Total FPM - No. Readings = Average FPM X Area = Total CFM

7140 - 9 = 793 X 2.71 = 2149

TEST DATE _____ READINGS BY _____

170

PAGE _____ OF _____

PROJECT	Aquaculture Facility With Cascade Greenhouse	SYSTEM/UNIT	FAHU-1
ADDRESS	Navarro College	LOCATION	Cascade Greenhouse

FILTER	None
S.P. ACROSS	
CONDITION	

STATIC PRESSURE READINGS "H ₂ O	
FAN SUCTION	.48
FAN DISCHARGE	.52

MOTOR MFG.	Gould
Frame	143T
H.P.	1
RPM	1745
AMPS	3.9 ACT: 2.2 / 2.6 / 3.5
VOLTS	230 ACT: 236 / 232 / 240

DRIVE MFG.	Browning
FAN DRIVE	BK60x1.0
MOTOR DRIVE	1VM5.0x7/8"
NO. BELTS & SIZE	1 56 4L440
Center's Dist.	14 1/8 + 1" - 3/4"

COILS TYPE		CFM	ΔP "H ₂ O ACROSS	E.A.T. D.B. W.B.		L.A.T. D.B. W.B.		E.W.T. °F	L.W.T. °F	ROWS	GPM	H ₂ O ΔP THRU
Heating	DES.	2200		50	/	67.4	/	80	74.4	4	15	.60
	ACT.	2114		49	/	64.7	/	79	72.3	4	*	*
	DES.			/	/	/	/					
	ACT.			/	/	/	/					
	DES.			/	/	/	/					
	ACT.			/	/	/	/					

Entering side of coil traversed with vane anemometer for total CFM.

	1	2	3
17"			
	23"		

1	2	3
FPM	FPM	FPM
800	800	740
840	840	640
<u>840</u>	<u>780</u>	<u>740</u>
2480	2420	2120

$$7020 - 9 = 780 \quad \times 2.71 = 2114$$

BOILER

JOB: Aquaculture Facility With
Cascade Greenhouse
Navarro College

BOILER

MANUFACTURER	Peerless
SERIAL NUMBER	211-8015
MAX BTU PER HR	1,260,000
MIN BTU PER HR	50,400
OUT PUT BTU PER HR	1,008,000
MAX OPERATING PRESSURE	30#

BOILER OPERATION

ACTUAL EWT	LWT	GPM
110°F	128.3	*30 (Note orig. design 15 GPM)

BOILER FIRES

116.6°F

BOILER SHUTS OFF

128.3

*The piping to the boiler has been changed from the original design. The plate heat exchanger has been piped so it can manually be put in series with the boiler. When operating in this mode the boiler will have 30 GPM passing through it instead of the original designed 15 GPM.

The above piping changes were made because the water temperature in the aquaculture ponds could not be maintained during the extremely cold weather of December 1983.

CONTROLS

AQUACULTURE FACILITY
WITH CASCADE GREENHOUSE

CONTROLS

VENTILATION

The ventilation controls were checked by adjusting the set points of the controlling thermostat to simulate the vent mode of operation. The vent louvers operate as they were designed to. The vent fans come on as they were designed to.

AQUACULTURE POND TEMPERATURE CONTROL

The motorized temperature control valves that were originally installed would not close completely off. This allowed heating water to continue to flow into the aquaculture ponds.

The above motorized valves were changed out to a Solenoid type valve. Those valves also leaked through. Balancing valves were added to the down stream piping to try to correct his problem by adding back pressure to the Solenoid valve. Mr. Kennen Smith is continually checking the Solonoid valves to see if the Solonoid valves are maintaining closed position when heating water is not required.

Aquaculture pond temperatures are controlled as required by thermostat settings with the exception of the month of December, 1983 when the ambient temperatures were below normal and remained that way for a long period of time.

When pond temperatures could not be maintained in December the piping was changed to the plate heat exchanger and boiler. The plate heat exchanger has been piped so it can manually be put in series with the boiler. When operating in this mode in December 1983 and January 1984 the heating water entering the aquaculture ponds was being maintained between 116.6°F and 128.3°F. The fluctuating temperature was caused by the differential setting of the boiler water temperature controller.

TEMPERATURE RECORDERS

The temperature recorders were calculated by using a Keithley 871 Digital Thermometer. The thermometer set points were checked several times and were maintaining their calibration points.

APPENDIX E
NTIS PRICE CODES

DOMESTIC PRICE CODES

Standard Priced Documents (Schedule A)

Effective January 1, 1983

Prices are for customers in the United States, Canada, and Mexico.

<u>Code</u>	<u>Price**</u>	<u>Page Range</u>
A01	\$ 4.50	Microfiche
A02	7.00	001 - 125
A03	8.50	026 - 050
A04	10.00	051 - 075
A05	11.50	076 - 100
A06	13.00	101 - 125
A07	14.50	126 - 150
A08	16.00	151 - 175
A09	17.50	176 - 200
A10	19.00	201 - 225
A11	20.50	226 - 250
A12	22.00	251 - 275
A13	23.50	276 - 300
A14	25.00	301 - 325
A15	26.50	326 - 350
A16	28.00	351 - 375
A17	29.50	376 - 400
A18	31.00	401 - 425
A19	32.50	426 - 450
A20	34.00	451 - 475
A21	35.50	476 - 500
A22	37.00	501 - 525
A23	38.50	526 - 550
A24	40.00	551 - 575
A25	41.50	576 - 600

For documents over 600 pages, Contact NTIS for a price quote.

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