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ENVIRONMENTAL ASSESSMENT

Geothermal Direct Heat Project

Marlin, Texas

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August 1980

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Marlin, Texas

August 1980

U.S. DEPARTMENT OF ENERGY

**Assistant Secretary for Resource Applications
Washington, DC 20545**

SUMMARY

The Federal action addressed by this Environmental Assessment (EA) is joint funding the retrofitting of a heating and hot water system in a hospital at Marlin, Texas, with a geothermal preheat system. The project will be located within the existing hospital boiler room. One supply well was drilled in an existing adjacent parking lot. It was necessary to drill the well prior to completion of this environmental assessment in order to confirm the reservoir and to obtain fluids for analysis in order to assess the environmental effects of fluid disposal. Fluid from operation will be disposed of by discharging it directly into existing street drains, which will carry the fluid to Park Lake and eventually the Brazos River. Fluid disposal activities are regulated by the Texas Railroad Commission and will be conducted in accordance with the requirements of the permit issued by that agency.

The local geology is determined by past displacements in the East Texas Basin. Boundaries are marked by the Balcones and the Mexia-Talco fault systems. All important water-bearing formations are in the cretaceous sedimentary rocks and are slightly to highly saline. Geothermal fluids are produced from the Trinity Group; they range from approximately 3600 to 4000 ppm TDS. Temperatures are expected to be above 64°C (147°F). Surface water flows southeastward as a part of the Brazos River Basin. The nearest perennial stream is the Brazos River 5.6 km (3.5 miles) away, to which surface fluids will eventually discharge.

Environmental impacts of construction were small because of the existing structures and paved areas. Construction run-off and geothermal flow-test fluid passed through a small pond in the city park, lowering its water quality, at least temporarily. Construction noise was not out of character with existing noises around the hospital.

Project operation is not expected to produce significant impacts because surface discharge would not appreciably lower water quality in the Brazos River.

Alternatives are delaying or not pursuing this project.

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1. PROPOSED ACTION

The Federal action addressed by this Environmental Assessment (EA) is joint funding the retrofitting of a hospital heating and hot water system in Marlin, Texas, to use low-temperature geothermal fluid as a supplemental energy source. This EA was prepared to fulfill the Department of Energy's (DOE's) responsibilities under the National Environmental Policy Act (NEPA) as outlined in the requirement for environmental review in the Council On Environmental Quality Regulations for Implementation of the Procedural Provisions of NEPA (40 CFR 1500) and the DOE Final Guidelines for Compliance With NEPA (45 FT 20694). This EA will analyze construction and operation effects of the project.

A solicitation for direct heat applications proposals was issued during the summer of 1977, and 22 proposals were received. The Torbett-Hutchings-Smith Memorial Hospital proposal was one of eight selected for subsequent contracts, with the government share of this project amounting to about 67% of the total project cost of \$660,000. Selected on the basis of a competitive evaluation, using established criteria, this project helps to meet the objectives of the direct heat applications program to (1) provide visible evidence of the profitability of geothermal heat utilization, (2) obtain reliable, objective, definitive technical, economic, institutional, and environmental data under field operating conditions, and (3) demonstrate a variety of applications of direct utilization of geothermal energy.

1.1 SITE LOCATION

The proposed site for the geothermal well is a gravel-topped parking lot adjacent to, and owned by, the Torbett-Hutchings-Smith Memorial Hospital at 322 Coleman Street in downtown Marlin, Texas. This is approximately at 31°18'24"N latitude and 96°53'36"W longitude. Marlin is the county seat and the largest city in nonmetropolitan Falls County; it is centrally located in the county. Marlin is 50 km (31 miles) southeast of the City of Waco and 61 km (38 miles) northeast of the City of Temple. A map showing the location of Falls County relative to the major cities of Dallas, Houston, and Austin is shown in Fig. 1.1. Maps

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Fig. 1.1. Location of Falls County, Texas. Source: Radian Corporation, *An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas, Austin Tex., August 1978.*

of the downtown area of Marlin, showing the location of the project, are presented in Figs. 1.2 and 1.3.

Marlin is located in the Brazos River Basin on an upland area immediately east of the Brazos River floodplain. The river drains southeastward from eastern New Mexico across Texas and enters the Gulf of Mexico at Freeport, Texas. Marlin is situated about 5 1/2 km (3 1/2 miles) east of the river and approximately 640 river km (400 river miles) from its mouth. Local creeks and sloughs drain into the Brazos or its tributaries.

The chief land use in Falls County is agriculture, with cattle raising being the leading agricultural industry. Approximately 2000 ha (5000 acres) of land are under irrigation in the county. In the City of Marlin, however, land use in areas surrounding the project site is about 70% residential and 30% public, commercial, or industrial.¹ State highways 6 and 7 connect Marlin with neighboring towns and cities.

1.2 PROJECT DESCRIPTION

The project construction activities consist of well drilling, pipeline construction, heating system modification, and fluid disposal provision for the Torbett-Hutchings-Smith (T-H-S) Memorial Hospital to provide an environmentally acceptable, operational geothermal space heating and hot water system. The geothermal system will supplement the natural gas boiler system currently installed at the hospital and is expected to displace 85% of the hospital's annual natural gas consumption, resulting in an annual saving of about $10,500 \times 10^3 \text{ ft}^3$ of natural gas.

1.2.1 System operation

The existing system uses natural-gas-fired boilers to produce steam, which in turn passes through heat exchangers in two 3800-liter (1000-gal) hot water storage tanks. These tanks are thermostatically controlled at 60°C (140°F) for space heating application, and additional heat exchangers are used to heat the water 82°C (180°F) for laundry and dish-washing applications. The hospital is heated by circulating 54°C (130°F) water through the building from the storage tanks.

Fig. 1.2. Map of Marlin, Texas, showing the location of the T-H-S Memorial Hospital. Scale 1 in. = approximately 850 ft. Source: Radian Corporation, *An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas*, Austin, Tex., August 1978.

Fig. 1.3. Unscaled plan of the T-H-S Memorial Hospital site. Source: Radian Corporation, *An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas, Austin, Tex., August 1978.*

The new system will require a geothermal well approximately 25 m (90 ft) southeast of the boiler room, a 5700-liter (1500-gal) settling tank for the geothermal fluid, and associated pumps, piping, heat exchangers, and controls as shown in Fig. 1.4. A heating demand in the hospital will result in geothermal fluid at approximately 65°C (150°F) flowing through the new heat exchangers in the heating system prior to circulating through the existing heat exchangers of the hospital heating system. In this way the geothermal system acts as either preheat, supplemental heat, or replacement heat for the existing system, depending on the heating demand and desired mode of operation. Operation is automatically regulated by the temperature of the water going into the hospital to maintain an output temperature to the building of 54°C (130°F). The geothermal system will provide preheat only for the 82°C (180°F) domestic hot water system.

1.2.2 Effluents of operation

Spent geothermal fluid returns from the heat exchangers for disposal. (There is no mixing or contact of geothermal fluid with heating system or domestic water.) The applicant identified five alternative methods of fluid disposal: 1) discharge into the city storm sewer, 2) pretreatment of the fluid, followed by release of the treated effluent into the city's entrapment lakes where it would become part of the city's water supply, 3) untreated release of the fluid to the city's entrapment lakes where it would become part of the city's water supply, 4) discharge into the city's sanitary sewers, 5) subsurface injection. These alternatives were evaluated on the basis of economics, technical feasibility, and environmental effects. Alternative #1, discharge into the city storm sewers was preferred, and the applicant applied to the Texas Railroad Commission for a surface discharge permit. The commission determined that surface disposal was environmentally acceptable and granted the permit (see Appendix B). Accordingly, the spent geothermal fluid will be discharged into the city storm sewer which empties into City Park Lake. Park Lake empties into Bean Branch and McCullough Slough, which eventually flow into the Brazos River.

Fig. 1.4. Geothermal system conceptual design. Note: All temperatures indicate peak demand. Source: Radian Corporation, An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas, Austin, Tex., August 1978.

The Texas Railroad Commission permit requires that discharged geothermal resource waters meet appropriate Texas Water Development Board water quality standards at all times. These standards (EPA-approved, 2/11/76) include: "General Criteria" which designate qualitative parameters such as taste/odor, floating debris, settleable solids, turbidity, foaming, toxicity, nutrients and oil/grease; and "Numerical Criteria" which set limits on the annual average concentration of chlorides (9600 mg/l); total dissolved solids (TDS) (1500 mg/l); dissolved oxygen (not less than 5.0 mg/l); pH (range 6.5-8.5); temperature (95°C) and fecal coliforms (log avg not more than 200/100 ml). There is no legal requirement for pretreatment of geothermal discharge fluids to meet these standards. The Texas Water Development Board also outlines "Water Uses" deemed desirable for specific surface waters, including the Brazos River (e.g., recreation, water supply etc.).

Discharge of fluids from this project must first comply with the "General Criteria" with regard to Park Lake, Bean Branch and McCullough Slough and ultimately comply with "Numerical Criteria" upon discharging into the Brazos River. Under the Texas Railroad Commission discharge permit, the T-H-S Memorial Hospital must assure that these standards are being met. This will be accomplished through regular sampling and analysis of the geothermal discharge fluids. Samples will be collected monthly during the first year of operation, quarterly during the second year, and semi-annually thereafter. Analyses to be performed include chlorides, sulfates, total dissolved solids (TDS), pH and temperature. This sampling program, however, is subject to redefinition by EPA Region VI pending their issuance of an NPDES permit. Any violations must be reported by the hospital to the Texas Department of Water Resources. Violations may also be cited by the public or any state agency. The Texas Railroad Commission will proceed with any necessary investigation with regard to reported violations.

The water quality standards which must be met do not include any effluent limitations; however, as mentioned earlier, the discharge of geothermal fluid from this project must not degrade the quality of the surface waters into which it flows. It is anticipated that because of

1) the utilitarian nature of the City Park Lake, Bean Branch and McCullough Slough, 2) the long-term public use and acceptance of Marlin geothermal waters for bathing and drinking purposes (since 1893), and 3) the fact that these bodies of water are not used for irrigation, the geothermal discharge from this project will not require pretreatment. Additionally, the city of Marlin has agreed to construct a stair-step waterfall at the mouth of Park Lake. This will serve to further aerate the water brought in via the storm sewers, oxidizing iron present to the precipitable ferric hydroxide state, and aid in improving the water quality as it enters Park Lake. It is not likely that the Numerical Criteria set by the Texas Water Development Board for the Brazos River will be violated by the geothermal water from this project since the maximum discharge of geothermal flow of 13 l/s (0.5 cfs or 200 gpm) is infinitesimal compared to the flow of the Brazos River 19,824 l/s (700 cfs or 330,400 gpm). Future facility expansion is anticipated which would result in a maximum discharge of 25 l/s (400 gpm). In addition to the required Texas Railroad Commission surface discharge permit the applicant has completed an NPDES application with EPA Region IV. This was necessary because EPA has not delegated NPDES authority for surface disposal of saline waters produced in Texas to the Texas Railroad Commission. As a precedent, a similar DOE geothermal project in Pierre, South Dakota (St. Mary's Hospital) was ruled by EPA Region VIII not to be a new source and was put on a once-a-month sampling program.

Table 1.1 lists the results of analyses performed on samples of the hydrothermal fluids from this well. Concentrations did not exceed EPA primary or secondary drinking water standards. The spent fluids will be released at approximately 50°C (125°F) and at a maximum 13 l/s (200 gpm). No noise except that from the existing system is expected during operation.

1.2.3 Construction activities

Construction activities consist of well drilling, pipe installation, and modification of the existing boiler system at the hospital.

Table 1.1 Hydrothermal Fluid Analysis at Marlin

Parameter	Mean Concentration (mg/l)	Number of Samples Analyzed
Carbon dioxide	15.5-176	2
Hydrogen sulfide	<1.0	1
Conductivity	3930-4580 ¹	5
pH	6.2-7.2 ²	2
Total dissolved solids	3605-4037	4
Aluminum	<0.1	3
Arsenic	<0.01	3
Barium	0.08-1.4	3
Beryllium	<0.02-0.03	3
Bicarbonate	164-222	4
Boron	1.4-1.72	2
Cadmium	<0.01	3
Calcium	268-334	5
Carbonate	0	3
Chloride	84-114	5
Chromium	<0.05	3
Cobalt	<0.05	3
Copper	<0.05	3
Fluoride (total)	0.8-3.7	5
Iron (total)	1.8-5.5	5
Lead	<0.10-0.10	3
Lithium	0.45-0.60	3
Magnesium	34-46	5
Manganese (total)	<0.05-0.55	5
Mercury	<0.001	2
Molybdenum	<1.0	3
Nickel	<0.05	3
Nitrate	<0.5	4
Selenium	<0.01	3
Silica	31-40	5
Silver	<0.02	3
Sodium	765-1042	5
Sulfate	2054-2600	5
Sulfide	0.05-0.20	2
Zinc	0.04-0.06	3

¹ μ mhos/cm² Standard units

1.2.3.1 Well drilling and flow-testing

A well was drilled to a depth of approximately 1040 m (3400 ft) using conventional mud rotary drilling methods. It was necessary to drill the well prior to completion of this environmental assessment in order to confirm the reservoir and to obtain fluids for analysis to assess the environmental effects of fluid disposal. The drill pad arrangement is shown in Fig. 1.5; it required an area approximately 30 x 50 m (100 x 150 ft). The drill pad is an existing level, graveled parking lot. Mud pits and a reserve pit were excavated within this graveled area. The parking lot was restored to its original condition after drilling.

Drilling activities required about twelve persons and lasted two to three months. Noise levels of about 75 dBA at the wall of the hospital occurred during that period; levels inside the hospital depended on many factors, including the frequency of the noise, the absorptive capacity of the walls, and the number of intervening walls between critical receptors and the source. Noise levels inside the hospital were not measured during drilling activities. However, noise levels were not sufficient to require any special mitigating measures. Noise levels did not differ greatly from that of any heavy equipment that might be used near the hospital for other types of construction. Drill cuttings and mud were hauled to an approved disposal site. Solid waste was disposed of in the city's landfill. Surface runoff discharged into the city storm drain.

After drilling, the well was production-tested for 48 hr, during which time a total flow of approximately 2.3×10^6 liters (6.0×10^5 gal) of geothermal fluid was produced. The estimated temperature of the fluid was about 65°C (150°F), and the TDS content was about 4,000 ppm. The Texas Railroad Commission granted the hospital a special temporary permit to discharge the produced geothermal fluid directly into the city storm sewer. The city storm drain discharges to a small pond in the city park in southwest Marlin.

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Fig. 1.5. Generalized layout of drilling activities (not to scale).
Source: Radian Corporation, *An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas, Austin, Tex., August 1978.*

1.2.3.2 System installation

Almost all construction will occur on previously constructed areas. Geothermal lines will cross the parking lot, the settling tank will be adjacent to the existing hospital structures, heat exchangers will go inside the hospital mechanical room, and the disposal system will use existing surface drains.

1.3 KNOWN ENVIRONMENTAL ISSUES

Geothermal exploration and development in many areas of the United States to date has established that there are several environmental issues for concern. These include water use, surface and groundwater contamination, subsidence, air contamination, and noise. These and other potential environmental impacts will be treated in Sect. 3.

REFERENCE FOR SECTION 1

1. Radian Corporation, *An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas*, Austin, Tex., August 1978.

2. DESCRIPTION OF THE EXISTING ENVIRONMENT

2.1 GEOLOGY AND SOILS

2.1.1 Geology

2.1.1.1 Stratigraphy

The regional subsurface geology has been fairly well characterized by oil and gas exploration and by investigations conducted by the Texas Bureau of Economic Geology and the Texas Department of Water Resources. In general, the area is underlain by intensely deformed metamorphic and metasedimentary rocks of the Ouachita fold belt. These rocks are the source of heat in the study area. Above these Paleozoic formations are sedimentary rock, primarily shale and limestone, of Cretaceous age. The youngest deposits in the Marlin, Texas, area are the Quaternary alluvial and terrace sediments associated with the Brazos River system. A generalized geologic section is shown in Table 2.1.

Regional variations in the geologic section are illustrated in Fig. 2.1.

2.1.1.2 Structural setting

Falls County is located in a region separating two major provinces. To the west lies the Texas Craton, a relatively stable structural platform of Paleozoic rock. To the east is the East Texas Basin. In general, the structural geology is determined by the subsidence that has occurred in the past in the East Texas Basin. As a result, the Cretaceous strata thicken markedly to the east and south. Boundaries are marked by the Balcones and Mexia-Talco fault systems, which dip down to the coastal plain and are roughly parallel to it. Several hundred feet of displacement exist along these faults in the Marlin area, but none of these faults are considered active. The area is located in Seismic Risk Zone 0, as shown in Fig. 2.2. On the basis of regional tectonics, this zone is considered to have little seismic risk. However, local instabilities

Table 2.1. Geologic units in the Marlin, Texas, area

Era	System	Series	Group	Formation	Approximate thickness [m (ft)]	Lithology
Cenozoic	Quaternary	Recent and Pleistocene, undifferentiated		Alluvium	0-18 (0-60)	Gravel, sand, silt, and clay
Cenozoic	Quaternary	Gulf	Navarro		0	Shale, marl, and sand
			Taylor		350 (1150)	Marl and limy shale
			Austin		60 (200)	Chalky limestone
			Eagle Ford		30 (100)	Shale
			Woodbine			Ferruginous sand, sandstone, shale, sandy shale, and clay
Mesozoic	Cretaceous	Comanche	Washita	Buda	38 (125)	Limestone
				Del Rio	23 (77)	Shale
				Georgetown	103 (338)	Limestone
			Fredericksburg	Edwards		Bard, fossiliferous limestone (often honeycombed), shale, chert, and dolomite
			Trinity	Comanche Peak	60 (200)	Limestone and limy shale
				Walnut		Shale and calcareous clay
				Glen Rose	300 (1000)	Limestone, siltstone, and shale
				Hensel	3 (10)	Sandstone, shale, and limestone
				Cow Creek	30 (100)	Limestone
				Hammett		Shale
				Sligo		Limestone
				Hosston	210 (700)	Sandstone (locally silty), shale, and conglomerate
Paleozoic	Quachita fold belt					Shale, limestone, dolomite, and metamorphic rock

Sources:

W. D. Hall, *Hydrogeologic Significance of Depositional Systems and Facies in Lower Cretaceous Sandstones*, North-Central Texas, University of Texas, Bureau of Economic Geology, Austin, Tex., 1976.

W. B. Klemmt, R. D. Perkins, and H. J. Alvarex, *Ground-Water Resources of Part of Central Texas With Emphasis on the Antlers and Travis Peak Formations*, vol. 2, Report 195, Texas Water Development Board, Austin, Tex., January 1976.

W. B. Klemmt, R. D. Perkins, and H. J. Alvarex, *Ground-Water Resources of Part of Central Texas With Emphasis on the Antlers and Travis Peak Formations*, vol. 1, Report 195, Texas Water Development Board, Austin, Tex., November 1975.

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Fig. 2.1. Stratigraphic dip section from McLennan County to Comanche County, north-central Texas. Source: W. D. Hall, *Hydrogeologic Significance of Depositional Systems and Facies in Lower Cretaceous Sandstones, North-Central Texas*, Bureau of Economic Geology, University of Texas, Austin, 1976.

Fig. 2.2. General seismic risk map of the United States. Source: Modified from S. T. Algermissen, *United States Earthquakes*, U. S. Government Printing Office, Washington, D.C., 1968.

may still exist, as discussed in Sect. 2.1.2. The presence of these fault systems in the area has significant implications for the region's geothermal value (Sect. 2.2.2).

2.1.2 Soils

The soils in the Marlin area generally consist of dark calcareous clays, sandy loams, and clay loams. The Brazos River floodplain occurs just west of the city and contains dark gray to reddish-brown calcareous clay loams and clays. Stream erosion is the primary cause of the alteration of the gently dipping surface formations to the rolling prairie and flat floodplain sediments. Although the drainage pattern is well developed in the uplands, the Brazos channel area is more typical of a mature stream valley (including swamps, abandoned stream channels, and oxbow lakes).

Immediately below the proposed site, the soil is composed of altered rock of the Taylor Formation. Gray, tan, and red clays that are slightly silty and sandy occur at the surface, to a depth of 4.3 to 5.2 m (14 to 17 ft). Below the clay is a layer of tan sand about 1 m (3 ft) thick; this layer is underlain by a tan and gray clayey siltstone to a depth of at least 10 m (30 ft). In general, the clays present are moderately to highly active with respect to volume changes on adsorption of water.

2.2 HYDROLOGY AND WATER QUALITY

2.2.1 Surface water

The project area lies within the Brazos River Basin above the local floodplain. The Brazos is the third largest of all rivers flowing partly or wholly in Texas. It flows southeastward from eastern New Mexico across Texas and enters the Gulf of Mexico at Freeport, Texas. The Brazos is the nearest perennial stream to Marlin, located about 5.6 km (3.5 miles) southwest of the project site at the river's nearest point. The drainage area above Marlin is about 75,000 km² (29,000 sq miles). A map showing the Brazos River and local creeks is presented in Fig. 2.3.

Fig. 2.3. Map of Marlin area showing local drainage system.
 Source: Radian Corporation, *An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas*, Austin, Tex., August 1978.

The City of Marlin's drainage is largely southward to the river via McCullough Slough, an intermittent former channel of the Brazos lying within its floodplain. A small area in the city's eastern edge is in the Big Creek watershed, which also drains southward to the Brazos at a point about 32 km (20 miles) downstream of Marlin. Some flow in this area may also reach the Little Brazos River, which parallels the Brazos until their confluence near Bryan, Texas, approximately 160 km (100 miles) downstream of Marlin. Significant surface-water impoundments in the Marlin vicinity are Marlin City Lake and New City Lake, 4.0 km (2.5 miles) northeast of the T-H-S Memorial Hospital. These lakes are both on Big Sandy Creek, a tributary of Big Creek, and constitute the major municipal water supply. During rare periods of very low rainfall, Marlin also supplements this supply via a pipeline from the Brazos River that passes close to the site of the new well.

The only available surface-water-quality records for the vicinity are for the Brazos River. The United States Geological Survey (USGS) maintains two stream gaging stations, one each about 48 km (30 miles) upstream (Waco) and downstream (Highbank) of Marlin. Data from the Highbank station for 1974 to 1975 are summarized in Table 2.3. Water from the Brazos River is currently classified as "effluent limited," meets existing State water quality standards, and is expected to continue to meet them in the future.

There are also three small man-made ponds within a 3-km (2-mile) radius of the site. One of these is in the city park in southwest Marlin. This pond is roughly 2 ha (5 acres) in area and contains about $3.1 \times 10^4 \text{ m}^3$ (25 acre-feet) of water, or about 3×10^7 liters (8×10^6 gal). It serves as a storm-water catchment basin and drains into McCullough Slough and hence into the Brazos River. Table 2.2 lists a comparison of pH and TDS values for the lake and streams within the project area.

2.2.2 Groundwater and geothermal resources

The geothermal waters in the Marlin area occur in the Trinity Group at the base of the Cretaceous formations. The existing geothermal

**Table 2.2 Water Quality Data for Park Lake, Bean Branch,
McCullough Slough and Brazos River in
Marlin, Texas, August 1979**

Sample Collection Site	pH (units)	TDS (mg/l)
Park Lake Inlet	8.02	3960
Park Lake Outlet (Bean Branch Inlet)	7.65	1110
McCullough Slough Outlet	7.57	1460
Brazos River Cty Park	7.69	840

Source: Radian Corporation, 1979. Letter, M. Conover to W. Staub (ORNL).

Table 2.3 Water quality data for the Brazos River near Highbank, Texas, USGS Station No. 08098290, October 1974-September 1975

Parameter	Mean value ^a	Range	State water quality standard
Flow, cfs	4,853	331-52,700	
Sulfate, mg/liter	123	89-170	225
Chloride, mg/liter	207	96-310	600
Total nitrogen, mg/liter	1.5	0.7-3.3	
Total phosphorous, mg/liter	0.22	0.08-0.83	
Total dissolved solids, mg/liter	691	391-927	1,500
pH range	7.8	6.8-8.5	6.5-8.5
Temperature, °F	69	45-91	95
Total suspended solids, mg/liter	360	12-1,210	
Dissolved oxygen, mg/liter	10.0	7.8-12.2	5.0
Fecal coliform, number/100 ml	1,270 ^b	12-5,800	200

^a12 analyses.

^bThe water quality standard for fecal coliform bacteria is based on a 30-day logarithmic (geometric) mean. Thus, when a violation is suspected on the basis of a single sample (or of several collected more than 30 days apart), a 30-day sampling program must be undertaken before the stream segment can be declared in violation. Therefore, this value represents a suspected, but unverified, violation.

Sources:

U.S. Geological Survey, Water Resources Division, *Water Resources Data for Texas, 1975*, 3 vols., 1976.

Bureau of National Affairs, Inc., *Texas Water Quality Standards, Environment Report*, 1976.

wells at Marlin produce water at a temperature of about 64°C (147°F) from the entire Glen Rose Formation and part of the Hosston Formation. The chemistry resulting from a mixture of water from these two aquifers is reported in Table 2.4. On the basis of the total dissolved solids (TDS) levels in the Hosston Formation in the surrounding areas, it appears that most of the dissolved solids in the well water are derived from the Glen Rose Formation.

Recharge to the Hosston (anticipated as the major source of geothermal water for this project) occurs in an outcrop area about 160 km (100 miles) to the west. The thermal regime is believed to be related to the faulting in the area. In particular, the Mexia-Talco fault system east of Marlin is believed to provide a pathway for the conduction of hot water from the deeper rocks of the Ouachita fold belt into the shallower aquifers of the Trinity Group.

All of the important water-bearing formations in the area of the Marlin well site are in the Cretaceous sedimentary rocks. Most of the aquifers capable of producing useful amounts of water contain slightly (greater than 1000 ppm TDS) to very saline water.

The Trinity Group, from which geothermal water is produced, contains three important water-bearing units. The deepest formation is the Hosston [1030-1232 m (3345-4045 ft)], from which production will occur. Above this are the Hensel Formation [at a depth of 98-989 m (3235-3245 ft)] and the Glen Rose Formation [at a depth of 681-986 m (2235-3235 ft)]. No other formations in the group are important water-bearing units.

The Hosston Formation is an aquifer capable of producing moderate to large quantities of water. Recharge rates have not been determined, but the Texas Department of Water Resources has indicated that Marlin is in an area where the Hosston is capable of considerable further development. Estimates in 1966 indicated that an additional 23 m³/min (6000 gpm) could be produced from a band 16 to 32 km (10 to 20 miles) wide at Marlin. The transmissivity of the formation (i.e., the ability of the aquifer to transmit water) at Marlin was measured to be about 200 m³/day/meter (16,000 gpd/ft). The water quality varies in the area from 1060 mg/liter to 4950 mg/liter TDS, as indicated in Table 2.5. TDS values range from 3605 to 4037 ppm. The results of the hydrothermal fluid analysis are presented in Table 1.1.

Table 2.4 Chemical analyses of water from the two existing geothermal wells in Marlin, Texas

Parameter	Well number			
	602	604		
	1967 ^a	1938 ^a	1944 ^a	1960 ^a
Ca ⁺⁺	248	182	193	217
Mg ⁺⁺	64	69	69	66
Na ⁺ and K ⁺	3,127	2,993	2,940	2,548
HCO ₃ ⁻	481	504	503	488
SO ₄ ⁻	4,906	4,375	4,330	3,437
Cl ⁻	1,546	1,615	1,580	1,598
SiO ₂	24			41
Fe	0.32			
TDS	10,512	9,482	9,360	9,625
Hardness, as CaCO ₃	885	738	765	1,067
pH, units	7.16			
Temperature, °F	125		147	

^aYear in which analysis was performed.

Source: W. B. Klemt, R. D. Perkins, and H. J. Alvarex, *Ground-Water Resources of Part of Central Texas With Emphasis on the Antlers and Travis Peak Formations*, vol. 1, Report 195, Texas Water Development Board, Austin, Tex., November 1975.

Table 2.5 Chemical analyses of water from the Hosston Formation
for three areas surrounding Marlin, Texas

Parameter	Area		
	16-32 km (10-20 miles) west ^a	13 km (8 miles) north ^b	32 km (20 miles) south ^c
Ca ⁺⁺	39	21	265
Mg ⁺⁺	10	4	47
Na ⁺ and K ⁺	427	278	1384
HCO ₃ ⁻	426	455	205
SO ₄ ⁻	541	212	3262
Cl ⁻	79	61	210
SiO ₂	32	27 ^d	105
Fe	0.88	0.57	0.48
TDS	1449	1062	5445
Hardness, as CaCO ₃	137	71	885
pH, units	8.1	7.6	7.3

^aEleven analyses from seven wells.

^bTwo analyses from two wells.

^cFive analyses from one well.

^dSingle analysis.

Source: W. B. Klemt, R. D. Perkins, and H. J. Alvarex,
*Ground-Water Resources of Part of Central Texas With Emphasis on
the Antlers and Travis Peak Formations*, vol. 1, Report 195, Texas
Water Development Board, Austin, Tex., November 1975.

The Hansel Formation is a productive aquifer in the area west of Marlin and yields small to moderate amounts of fresh to slightly saline water. This formation, however, becomes progressively more shaley to the east toward the Marlin area, where the net sand thickness is only about 3 m (10 ft). At this point, the Hensel is essentially non-water bearing.

The Glen Rose Formation, at the top of the Trinity Group, can produce small to moderate supplies of mineralized water. Concentrations of TDS as high as 10,500 mg/liter have been measured in wells penetrating the Glen Rose near Marlin.

Above the Trinity Group are several aquifers that the Marlin geothermal well would have to penetrate. In the Gulf Series, the Taylor Marl may locally yield small quantities of fresh to slightly saline water in shallow wells. Underlying the Taylor Marl, but still in the Gulf Series, is the Woodbine Sand, which is an important aquifer north of Falls County and which supplies small to moderate amounts of water to public, industrial, and domestic wells. Below the Woodbine are the Georgetown Formation (part of the Washita Group) and the Edwards Limestone (part of the Fredericksburg Group). Hydraulically connected, these two units are capable of supplying small to large quantities of water. Generally, TDS levels in the Falls County area are greater than 3000 ppm. The other units in the Gulf and Comanche series are not important water-bearing formations, either in Marlin or the surrounding areas.

2.3 ATMOSPHERIC CHARACTERISTICS

2.3.1 Climate

Eastern and central Texas can generally be characterized as having a humid, subtropical climate. Southerly and southeasterly flows of warm maritime air bring moisture from the Gulf of Mexico. The easternmost third of the state has hot summers and cool winters, and rainfall is fairly evenly distributed throughout the year. Further west, winters are drier and summers hotter because polar or continental air masses from the north and west intrude more frequently, cutting off the moist southerly air. Marlin is located roughly on the border between the eastern and central zones.

2.3.1.1 Temperature and humidity

Climatological records are available for Waco, Texas, which is 50 km (31 miles) northwest of Marlin.¹ The annual temperature for Waco for 1931 to 1960 was 19.6°C (67.2°F), with a range of 9°C (48°F) in January to 29.7°C (85.5°F) in August. Both July and August have average afternoon maximum temperatures of about 36°C (96°F) for Marlin.² The lowest average minimum temperature for Marlin is 2.9°C (37.3°F) for January. The mean length of the warm season, defined as the number of days between mean dates of last freeze in spring and first freeze in fall, is 245 to 260 days for Waco.¹

The region experiences moderate to high relative humidity. The mean annual relative humidity for 6 A.M. and 6 P.M. CST is 80 to 85% and 50 to 55% respectively.¹

2.3.1.2 Precipitation and severe weather occurrences

Mean annual precipitation in the Marlin area totals about 89 cm (35 in.).² Mean monthly rainfall for Waco ranges from 11.61 cm (4.57 in.) in May to 4.27 cm (1.68 in.) in August.¹ Thunderstorms occur about 45 days per year in the Marlin area. Heavy rains of up to 18 cm (7 in.) can be expected about once every ten years.

Periods of sustained high winds of up to 30 km/hr (50 mph) occur about once every two years.² Marlin is sufficiently far inland, however, so that the frequent hurricanes [winds about 110 km/hr (70 mph) or greater] that affect the Texas coast occur only about once every 100 years at Marlin. Usually, one tornado a year will be reported within a 32-km (20-mile) radius of Marlin. Similarly, one hailstorm can be expected every 20 years. Drought, during which annual rainfall is less than 75% of normal, occurs approximately once every seven years; two-year droughts occur only about once every 40 years.

2.3.2 Air quality and dispersion conditions

Falls County is in Environmental Protection Agency (EPA) Air Quality Control Region (AQCR) No. 212. The agency's air quality monitoring data for concentrations of nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and

total suspended particulates for AQCR No. 212 for 1973 through 1975 are presented in Table 2.6. Comparison of data in this table with those in Table 2.7, which gives Federal ambient air quality standards, shows that SO_2 and NO_2 concentrations are typically low and well below the national standards.

Dispersion conditions in Marlin are normally very good during the afternoon because of strong vertical mixing of air and high wind speeds. Table 2.8 shows the average afternoon mixing heights and transport wind speeds (wind speeds within the mixed layer). Air stagnation episodes are rare in the Marlin area. Episodes lasting at least two days, with dispersion conditions limited by maximum mixing heights of no more than 1500 m (5000 ft) and corresponding transport winds of no more than 14 km/hr (9 mph), occur only about once every two years. Figure 2.4 shows the number of forecast days of high meteorological potential for air pollution for the United States. Falls County is in the zero isopleth region.

2.4 NOISE

2.4.1 Noise characteristics of the site

Because of its urban setting, the project site is not particularly quiet. Ambient noise levels were measured at and around the site by the Radian Corporation on July 17, 1978, between 10 A.M. and 4 P.M. Measured levels are representative of daytime sound levels in the area. Sound levels on nearby streets forming the boundaries of the hospital complex approximated 55 dBA. Because of the presence of an air conditioning cooling tower, ambient noise increases toward the center of the hospital complex, where levels of 68 dBA were measured. In addition, the tracks of the Missouri-Pacific Railroad form the western boundary of the hospital complex. Trains pass 8 to 12 times daily and must sound a 3-sec warning horn before crossing street intersections adjacent to the hospital. Sound level measurements during train passage were made at the well site and in the hospital complex center. Levels registered for the two locations were 76 and 80 dBA respectively, increasing to 92 and 95 dBA during sounding of the warning horn.

Fig. 2.4. Isopleths of total number of forecast days of high meteorological potential for air pollution in a five-year period. Data are based on forecasts issued since the program began (Aug. 1, 1960, and Oct. 1, 1963, for eastern and western parts of the United States respectively) through Apr. 3, 1970. Source: G. C. Holzworth, *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*, Environmental Protection Agency, U.S. Government Printing Office, Washington, D.C., 1972.

Table 2.6 Concentrations of total suspended particulates, sulfur dioxide, and nitrogen dioxide recorded for 1973-1975 at air quality monitoring stations in AQCR No. 212

Year	Concentration ($\mu\text{g}/\text{m}^3$)		
	Annual mean	Minimum ^a	Maximum ^a
Total suspended particulates			
1973	68.1	0	386
1974	69.4	5	421
1975	85.8	12	1235
Sulfur dioxide			
1973	0.6	0	9
1974	0.3	0	39
1975	1.21	0	266
Nitrogen dioxide			
1973	32.2	7	60
1974	48.1	8	112
1975	25.9	0	161

^a24-hr value.

Source: U.S. Environmental Protection Agency, Aerometric Data Bank, Research Triangle Park, N.C., 1976.

Table 2.7 Federal ambient air quality standards
for particulates, sulfur dioxide,
and nitrogen oxides

Pollutant	Concentrations ($\mu\text{g}/\text{m}^3$)		Averaging time
	Primary standard	Secondary standard	
Particulates	75	60	Annual
	260 ^a	150 ^a	24 hr
Sulfur dioxide	80		Annual
	365 ^a		24 hr
		1300 ^a	3 hr
Nitrogen oxides	100		Annual

^aNot to be exceeded more than once a year.

Source: Department of Energy—Environmental Protection Agency, *Energy/Environment Fact Book*, Decision Series, EPA-600/9-77-041, Washington, D.C., 1978.

**Table 2.8 Average mixing heights
and transport winds
in the Marlin, Texas, area**

Season	Afternoon mixing height [m (ft)]	Afternoon transport wind [kmph (mph)]
Spring	1400 (4500)	29 (18)
Summer	1800 (6000)	21 (13)
Fall	1500 (5000)	23 (14)
Winter	1100 (3500)	27 (17)
Annual	1400 (4500)	26 (16)

Source: G. C. Holzworth, *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*, Report AP-101, Research Triangle Park, N.C., EPA, 1972.

The B and D wings of the hospital are the building areas most apt to be affected by drilling noise. Sound level measurements were made in rooms in the interiors of these two wings with windows both closed and open. Resulting measurements were 53 and 55 dBA for rooms with open windows in B and D wings respectively, and 42 dBA for both areas with windows closed.

2.4.2 Noise regulations

There are no local, county, or State regulations concerning acceptable noise levels.

2.5 ECOLOGY

2.5.1 Terrestrial ecology

No biological community exists at the proposed site because it is a gravel parking lot in downtown Marlin. All of the area surrounding the hospital is developed for commercial, industrial, or residential use. There is virtually no vegetation on the site, and the only terrestrial animals likely to frequent the area are domestic dogs and cats or cosmopolitan species such as starlings, pigeons, and sparrows.

Outside the City of Marlin, much of the county's land is used for pasture or cultivated for crops. Marlin lies on the border of two major geographic or vegetational regions. To the east and south of the city, Post Oak Savannah-type vegetation is typical of the area. Native climax grasses such as little bluestem (*Schizachyrium scoparium* var. *frequens*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and silver bluestem (*Bothriocloa saccharoides*) are found in pastureland. Improved pastures are also seeded with Bermuda grass (*Cynodon dactylon*), Dallis-grass (*Paspalum dilatatum*), Vasey-grass (*Paspalum urvillei*), carpetgrass (*Axonopus* sp.), and clovers (*Trifolium* sp.). Dominant overstory species are post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*).³

Blackland Prairie-type vegetation is typical of the land west of Marlin. Most of this area is under cultivation. Little bluestem, big

bluestem (*Poa ampla*), Indiangrass, switchgrass, sideoats grama (*Bouteloua cortipendola*), hairy grama (*Bihirsota*), tall dropseed (*Sporobolus asper*), silver bluestem, and Texas wintergrass (*Stipa leucotricha*) are native grasses found in a few remaining hay meadows. Mesquite (*Prosopis*) has invaded hardland sites of the southern portion of the Blackland prairies. Post oak and blackjack oak are also found on certain soil types in the area.³

Falls County is not listed as an important habitat location for any endangered species.⁴ In addition, none of the endangered or threatened animals⁵ or plants⁶ of Texas are listed as occurring in Falls County or the Brazos River, nor are any such species likely to occur in the project area. Because of the urban nature of the site, no endangered or threatened species are likely to be affected by the project.

2.5.2 Aquatic ecology

No studies of the biota in the Brazos River have been conducted in the immediate vicinity of Marlin. The Texas Parks and Wildlife Department has provided an inexhaustible list of fish species that possibly occur in the area (Table 2.9). The list includes species that were taken in a sampling program conducted on the Brazos River in Hood and Somervell counties, about 160 air km (100 air miles) northwest (upstream) of Marlin from 1971 to 1973. In addition, sport fish species introduced into the river below Lake Whitney Dam [80 air km (50 air miles) upstream of Marlin] are included and may be present. The Brazos River near Marlin is characterized as a pool-and-riffle stretch with relatively slow-moving, turbid water. Hence, rough fishes and bottom-dwelling species (e.g., catfish) are probably relatively more abundant than the other sport fishes listed.

2.6 LAND USE

2.6.1 The project site

The site of the proposed geothermal well is a gravel-topped parking lot adjacent to the T-H-S Memorial Hospital in downtown Marlin. The

Table 2.9 Fish species possibly occurring
in the Brazos River
near Marlin, Texas

Sport fishes

Walleye (*Stizostedion vitreum*)^a
 Stripped bass (*Morone saxatilis*)^a
 Channel catfish (*Ictalurus punctatus*)
 Flathead catfish (*Pylodictus olivaris*)
 Green sunfish (*Chaenobryttus cyanellus*)
 Warmouth (*Chaenobryttus gulosus*)
 Bluegill (*Lepomis macrochirus*)
 Longear sunfish (*Lepomis megalotis*)
 Redear sunfish (*Lepomis microlophus*)
 Spotted bass (*Micropterus punctulatus*)
 Largemouth bass (*Micropterus salmoides*)
 White crappie (*Pomoxis annularis*)

Rough fishes

Longnose gar (*Lepisosteus osseus*)
 Gizzard shad (*Dorosoma cepedianum*)
 Threadfin shad (*Dorosoma petenense*)
 Carp (*Cyprinus carpio*)
 River carpsucker (*Carpionodes carpio*)
 Gray redhorse (*Moxostoma congestum*)
 Smallmouth buffalo (*Ictiobus bubalus*)
 Freshwater drum (*Aplodinatus grunniens*)

Minnows

Silver chub (*Hybopsis storeriana*)
 Red shiner (*Notropis lutrensis*)
 Redfin shiner (*Notropis umbratilis*)
 Blacktail shiner (*Notropis venustus*)
 Stoneroller (*Campostoma anomalum*)
 Blackstripped topminnow (*Zygonectes notatus*)
 Mosquitofish (*Gambusia affinis*)
 Brook silverside (*Labidesthes sicculus*)
 Mississippi silverside (*Menidia audens*)
 Orangethroat darter (*Etheostoma spectabile*)
 Logperch (*Percina caprodes*)

^aIntroduced species.

rest of the land in the same city block is used by commercial businesses (auto repair shop and pharmacies).

Land use in the surrounding areas of the city is about 70% residential and 30% public, commercial, or industrial. A map showing the primarily residential areas in the site vicinity [1/2-km (1/3-mile) radius] is presented in Fig. 2.5.

2.6.2 Falls County

The land surrounding Marlin is used primarily for agriculture. Cattle raising is the leading agricultural industry. Falls County is among the top five Texas counties in total number of cattle, and Falls County pastureland is regularly used for winter grazing of calves transported from North Dakota (Fran Sharples, Oak Ridge National Laboratory, personal communication to Tim Wolterink, Radian Corporation, September 1978). Cotton, sorghum, and milo are the chief cultivated crops. East of Marlin, much of the county land is native or improved pasture; west of Marlin, the land has been brought under cultivation. Approximately 2000 ha (5000 acres) of land in the county are under irrigation.

2.6.3 Prime and unique farmland

Prime farmlands are those whose value derives from their general advantage as cropland, due to soil and water conditions. Unique farmlands are those whose value derives from their particular advantages for growing specialty crops. Paragraph 101 (b) (4) of the National Environmental Policy Act (NEPA) establishes a Federal policy to preserve and maintain, wherever possible, an environment which supports diversity and variety of individual choice, including the preservation of highly productive farmlands.

The proposed well site is in an already urbanized area. The Soil Conservation Service has determined that the project as a whole will not significantly affect prime farmland (Appendix A).

Fig. 2.5. Distribution of residential areas in central Marlin. Source: Radian Corporation, *An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas*, Austin, Tex., August 1978.

2.7 WATER USE

During drilling of the new geothermal well, approximately 1.9×10^6 liters (5.0×10^5 gal) of water will be used. This water will be provided by the City of Marlin, either from the hospital water system or from a municipal fire hydrant adjacent to the site. No water will be required for the geothermal system during the operational phase.

2.8 DEMOGRAPHY AND SOCIOECONOMICS

The estimated 1977 population of Marlin was 8,400 persons; that of Falls County was 17,300. Of the total county population in 1970, 63.3% lived in rural areas. Both the City of Marlin and Falls County experienced population declines during the 1960 to 1976 period, but this trend was believed to have ended by 1977, with a slight gain. The median age in Falls County in 1970 was 40.5 years. For those people 25 years or older, the median number of years of school completed in 1970 was 10.6 years for Marlin and 9.3 for Falls County. Per capita incomes in both Marlin and Falls County were significantly below the State average during the 1969 to 1974 period (Table 2.10). In 1969, over one-half of all families in Falls County had incomes of less than \$5000, whereas only one-fourth of the families statewide were in this income category. In 1969 about one-third of all families in both Marlin and Falls County earned incomes less than poverty level, over twice the statewide average incidence of poverty.

Percentage of employment in the major economic sectors is presented in Table 2.11. A substantial fraction of the Falls County labor force also commutes to work in the Waco or Killeen-Temple areas. Economic exchange between Marlin and these two metropolitan centers is facilitated by good transportation (Greyhound bus lines). The 1970 median family income was \$5256 for Marlin and \$4522 for Falls County. The unemployment rate at that time was 3 to 4% for the City of Marlin and 4 to 7% for Falls County.

Table 2.10 Income characteristics of the City of Marlin,
Falls County, and Texas, 1969-1974

	City of Marlin	Falls County	Texas
Income characteristics in 1969			
Per capita income, \$	2,206	1,823	2,810
Families (number of)	1,643	4,516	2,818,123
Median income, \$	5,256	4,522	8,940
Mean income, \$	7,095	6,003	9,955
Families by income category, %			
Under \$5,000	48.0	54.4	25.6
\$5,000-\$10,000	28.8	28.6	34.4
\$10,000-\$15,000	13.3	10.9	23.4
\$15,000 and over	9.9	6.1	16.5
Incomes less than poverty level, %			
All persons	38.8	41.2	18.8
All families	30.3	34.3	14.6
Per capita income in 1972	2,690	2,327	3,409
Per capita income (estimated) in 1974	3,364	2,870	4,188

Sources:

U.S. Department of Commerce, Bureau of the Census, *1970 Census of Population, Volume 1, Characteristics of the Population, Pt. 45 (Section 1), Texas*, U.S. Government Printing Office, Washington, D.C., May 1973.

U.S. Department of Commerce, Bureau of the Census, *Gross Migration by County: 1965 to 1970*, Current Population Report Series P-25, No. 701, U.S. Government Printing Office, Washington, D.C., 1977.

Table 2.11 Employment and labor force characteristics
of the City of Marlin, Falls County, and Texas

	City of Marlin	Falls County	Texas
Employment characteristics, 1970 (by place of residence)			
Total employed, 16 and older	2,219	5,577	4,141,529
Percentage, by industry:			
Agriculture	NA ^a	16.9	4.7
Mining	NA	1.0	2.5
Construction	6.4	7.8	7.7
Manufacturing	8.8	11.2	18.5
Transportation, communications, and utilities	5.9	6.0	6.9
Wholesale and retail trade	19.5	17.2	22.2
Financial, insurance, and real estate	34.2	2.6	5.1
Services	4.8	33.4	27.0
Public administration		3.8	5.5
Percentage, by occupation:			
Professional, technical, and managerial	24.1	16.4	23.3
Sales and clerical	24.4	18.4	25.2
Craftsmen and foremen	12.3	11.8	14.3
Operatives	11.6	14.3	15.1
Laborers, nonfarm	4.3	6.5	4.9
Farm managers and laborers	5.0	15.6	4.0
Service workers	18.3	17.1	13.3
Median employment earnings, dollars			
Males, 16 and older	NA	3,884	6,824
Professional and managerial	NA	7,367	10,106
Craftsmen and foremen	NA	4,417	7,260
Operatives	NA	4,590	5,956
Laborers, nonfarm	NA	2,240	3,636
Farmers and farm managers	NA	1,912	4,705
Farm laborers	NA	1,589	2,607
Females, 16 and older	NA	2,264	3,241
Employment characteristics, 1975 (by place of work)			
Total employed (March 12, 1975)	NA	2,338	3,534,425
Percentage, by industry:			
Construction	NA	4.3	9.0
Manufacturing	NA	15.7	22.8
Transportation and public utilities	NA	5.0	7.1
Wholesale and retail trade	NA	33.4	29.6
Financial, insurance, and real estate	NA	6.0	7.0
Services	NA	32.2	19.2
Labor force characteristics, 1970			
Male, 16 and older	2,087	5,758	3,663,340
In labor force	1,269	3,667	2,853,736
Percentage of total	60.8	63.7	77.9
Civilian labor force	1,269	3,662	2,692,016
Percentage unemployed	3.0	3.6	3.0
Females, 16 and older	2,672	6,910	3,961,142
In labor force	1,034	2,192	1,610,881
Percentage of total	38.7	31.7	40.7
Civilian labor force	1,034	2,192	1,605,770
Percentage unemployed	4.4	6.6	4.7

^aNA = not available.

Sources:

U.S. Department of Commerce, Bureau of the Census, *1970 Census of Population, Volume 1, Characteristics of the Population, Pt. 45 (Section 1), Texas*, U.S. Government Printing Office, Washington, D.C., May 1973.

U.S. Department of Commerce, Bureau of the Census, *County Business Patterns 1975, Texas*, Report CBP-75-45, U.S. Government Printing Office, Washington, D.C., May 1973.

2.9 HISTORICAL AND ARCHAEOLOGICAL SITES AND NATURAL LANDMARKS

2.9.1 Historical sites

No historical places in Marlin or Falls County are listed in the "National Register of Historic Places"⁷ or the "National Register of Historic Places in Texas."⁸

2.9.2 Archaeological sites

Neither the Texas Historical Commission nor the Texas Archaeological Research Laboratory has any records of archaeological resources in the Marlin vicinity. No archaeological survey of the drill site was performed. Because of the site's location in an urban area, previous construction activities probably have already destroyed any existing value at the site. The staff, therefore, does not believe that an archaeological survey of the well site is necessary.

2.9.3 Natural landmarks

There are no natural landmarks at or near the site.⁹

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7. "National Register of Historic Places," *Fed. Regist.* 43(26): 5161-5345 (1978) and all supplements to August 1, 1978.
8. Kit Fontaine, Ed., "The National Register of Historic Places in Texas," Texas Historical Commission, Austin, 1976.
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3. POTENTIAL ENVIRONMENTAL IMPACTS

3.1 IMPACTS ON GEOLOGY

Seismicity and subsidence are the most important concerns in the assessments of geologic impacts of geothermal projects. Faulting may be induced by alteration of the hydrostatic head in the rock surrounding the well (changing stress relationships) or by alteration of water content and clay properties of surficial deposits.

Although areas of possible faulting have been identified within 5 km (3 miles) of the site, there is no evidence of displacement or accumulation of in situ stresses. From calculations for the Hosston Formation, a drawdown of 2 m (6 ft) or less is likely in this area of faulting; this figure corresponds to a reduction in the heat of approximately 0.2%. The withdrawal rate of 13 liters/sec (200 gpm) is low and would alter the head near one well by only about 1%.

Displacements due to volume changes in the surface rock may occur if fluid leaks into the deposits during drilling or through leaks in the casing. Although the clays present are known to swell with the addition of water, there is no historical evidence of faulting or subsidence problems from previous water or geothermal wells. The use of conductor pipes and cemented casing should further reduce the possibility of disturbance of the surrounding formations and aquifers. Also, the low withdrawal rates and the depth of the producing formations (below well-consolidated rock) reduce the possibility of subsidence during operation.

Little impact on the use of surface soils is anticipated from drilling and operation. Fluid will be disposed through buried pipelines, and the site itself will be constructed in an area currently paved for a parking lot.

3.2 IMPACTS ON WATER QUALITY

3.2.1 Impacts during construction

During construction and testing, contaminated water from drill-site runoff and initial flow-testing entered the city storm-water drainage system. Runoff contaminants consisted of suspended solids, drilling mud, and mud additives. The discharge initially flowed to the city Park Lake in southwest Marlin. This pond is designed as a catchment basin, and no aquatic life is deliberately maintained in it. The pond, however, drains into McCullough Slough and then into the Brazos River. Drilling muds with nontoxic additives were chosen to prevent pollution of the lake and river. Temporary retention of fluid in the city park pond resulted in reduction of suspended solids and cooling.

During production testing, an estimated 2.18×10^6 liters (5.76×10^5 gal) of geothermal fluid were produced in a 48-hr test period. In accordance with a temporary permit granted by the Texas Railroad Commission, this fluid was discharged directly into the city storm sewer.

3.2.2 Impacts during operation

No significant effects on water quality in the project area are expected during operation. Geothermal fluid will be disposed of by discharging it into the Marlin City storm sewer. The storm sewer empties into Park Lake which in turn empties into Bean Branch and McCullough Slough. These streams eventually flow into the Brazos River.

Surface disposal activities will be conducted in accordance with the Texas Railroad Commission discharge permit. The permit requires that discharged geothermal resource waters meet appropriate Texas Water Development Board water quality standards at all times. These standards (EPA-approved, 2/11/76) include: "General Criteria" which designate qualitative parameters such as taste/odor, floating debris, settleable solids, turbidity, foaming, toxicity, nutrients and oil/grease; and "Numerical Criteria" which set limits on the annual average concentration of chlorides (9600 mg/l); total dissolved solids

(TDS) (1500 mg/l); dissolved oxygen (not less than 5.0 mg/l); pH (range 6.5-8.5); temperature (95°C) and fecal coliforms (log avg not more than 200/100 ml). There is no legal requirement for pretreatment of geothermal discharge fluids to meet these standards. The Texas Water Development Board also outlines "Water Uses" deemed desirable for specific surface waters, including the Brazos River (e.g., recreation, water supply etc.).

Discharge of fluids from this project must first comply with the "General Criteria" with regard to Park Lake, Bean Branch and McCullough Slough and ultimately comply with "Numerical Criteria" upon discharging into the Brazos River. Under the Texas Railroad Commission discharge permit, the T-H-S Memorial Hospital must assure that these standards are being met. This will be accomplished through regular sampling and analysis of the geothermal discharge fluids. Samples will be collected monthly during the first year of operation, quarterly during the second year, and semi-annually thereafter. Analyses to be performed include chlorides, sulfates, total dissolved solids (TDS), pH and temperature. This sampling program, however, is subject to redefinition by EPA Region VI pending their issuance of an NPDES permit. Any violations must be reported by the hospital to the Texas Department of Water Resources. Violations may also be cited by the public or any state agency. The Texas Railroad Commission will proceed with any necessary investigation with regard to reported violations.

The water quality standards which must be met do not include any effluent limitations; however, as mentioned earlier, the discharge of geothermal fluid from this project must not degrade the quality of the surface waters into which it flows. It is anticipated that because of 1) the utilitarian nature of the City Park Lake, Bean Branch and McCullough Slough, 2) the long-term public use and acceptance of Marlin geothermal waters for bathing and drinking purposes (since 1893), and 3) the fact that these bodies of water are not used for irrigation, the geothermal discharge from this project will not require pretreatment. Additionally, the city of Marlin has agreed to construct a stair-step waterfall at the mouth of Park Lake. This will serve to further aerate the water brought

in via the storm sewers, oxidizing iron present to the precipitable ferric hydroxide state, and aid in improving the water quality as it enters Park Lake. It is not likely that the Numerical Criteria set by the Texas Water Development Board for the Brazos River will be violated by the geothermal water from this project since the maximum discharge of geothermal flow of 0.5 cfs anticipated for the current facility is infinitesimal compared to the flow of the Brazos River (700 cfs). The following analyses were conducted based on the discharge from the expanded facility, i.e. 25 l/s or 400 gpm, in order to determine the maximum impact. At minimum flow rate for the Brazos River maximum discharge of geothermal water (25 l/s or 400 gpm) will increase the river's flow by only 0.26%. During low flow of the Brazos River (worst case) geothermal discharge would increase the TDS and sulfate concentrations in the river by 8 mg/l and 6 mg/l, respectively. Except at the point of discharge (McCullough Slough) and short distance downstream the environmental impact on the Brazos River will be undiscernible.

Thermal pollution of Park Lake by surface discharge is unlikely. Mixing with storm sewer water and heat loss will reduce the temperature from 36°C where geothermal water enters the storm sewer to near ambient (between 10°C and 30°C) at the Park Lake Inlet located 1.6 km from the hospital. Heat loss and dilution in the storm sewer negates the need for a cooling pond or holding tank. If heat losses from both the lake and storm sewer are neglected, the lake's summer equilibrium temperature would rise 1 to 2°C (Table 3.1). This small increase in temperature is expected to have no discernible effect on the environment of Park Lake.

Park Lake will be chemically degraded by surface discharge of geothermal water. Although some dilution will take place by mixing with surface runoff the lake's TDS will increase 2 to 3 fold from a baseline of 1100 mg/l after a few months of discharge at the design rate (Figure 3.1). Table 3.2 lists the predicted yearly average concentrations of the principle chemical pollutants in Park Lake. These figures take into account the effect of mixing with surface runoff.

Table 3.1 Summary of Park Lake Thermal Analysis Results

Geothermal Fluid Temperature at Hospital Discharge Point (°V)*	Lake's Summer Equilibrium Temperature (°C)		
	0	Discharge Rate 5 l/s (80 gpm)	10 l/s (160 gpm)
57	29.5	30.5	31.1
52	29.5	30.5	31.1
41	29.5	30.0	30.5

* Assumption: 1) No temperature loss between hospital discharge point and lake, 2) thorough mixing, and 3) no vertical temperature gradient.

Figure 3.1 Estimated TDS Levels in Park Lake

The environmental effect of chemical degradation of Park Lake is difficult to assess because no survey of the aquatic life of the lake has been conducted. However, Park Lake is designed as a catchment basin and no aquatic life is deliberately maintained in it.

If there is significant aquatic life in the lake there is potential for adverse effects. Geothermal water is low in dissolved oxygen which will create obvious problems for aquatic life. Iron in the reduced state (Fe^{2+}) is probably present in oxygen deficient water. Aeration will oxidize this iron (Fe^{3+}), causing it to precipitate out as ferric hydroxide. Precipitation in the lake can coat the gills of fish, and smother eggs and benthic invertebrates. While precipitation may take place in the storm sewer rather than the lake, this chemical reaction will consume at least some of the dissolved oxygen which would otherwise be replenished by aeration. Finally, without knowing what aquatic species are present there is no way to predict how they would react to increased TDS and concentration of sulfate, boron and other chemical species.

Plants growing along the banks of the lake will probably be adversely effected. The sodium adsorption ratio (SAR, or ratio of sodium to calcium plus magnesium) will be high (Table 3.2). Therefore, only salt tolerant plant species will be likely to thrive in the altered environment. Food supply and habitat for aquatic organisms might be adversely effected as the character of vegetation changes around the shoreline. In addition to the required Texas Railroad Commission surface discharge permit the applicant has completed an NPDES application with EPA Region VI. Additional monitoring requirements may be imposed on T-H-S Hospital as part of the NPDES permit.

3.2.3 Groundwater

The primary groundwater concern in the Marlin geothermal project is the protection of any area aquifers from contamination. Such contamination may arise from saline water intrusion because of faulty well construction, infiltration of wastewater from surface impoundments, or unanticipated hydraulic behavior of the aquifers in the production zone.

The possibility of contamination of aquifers above the Hosston and Glen Rose formations will be minimized through careful design and

**Table 3.2 Estimated Concentrations In Park Lake Effluent
(Yearly Average)**

Constituent	Concentration (mg/l)	
	Current Design	Expanded Facility
Total Dissolved Solids	2339	2837
Sodium	548	665
Sulfate	1426	1729
Magnesium	24	30
Calcium	182	221
Iron	2.1	2.5
Boron	0.9	1.1

construction of the well. Cemented-in casing will be used over the entire interval from the surface to the production zone and, when properly installed, will eliminate contact with freshwater aquifers. Because the geothermal fluid is relatively noncorrosive and the formation pressures relatively low, no unusual problems in maintaining the well are anticipated.

Contamination of groundwater due to infiltration of wastewater or leachates from solid wastes could occur either accidentally or through improper waste disposal practices. In this project, solid wastes (e.g., well cuttings, trash, construction debris) were disposed of in the city sanitary landfill. This facility is constructed in a manner designed to prevent surface-water and groundwater contamination; it has been used as an example in courses offered by Texas A&M University on solid waste management and environmental geology. Accidental release and infiltration of saline water would be most likely to affect the shallow alluvium aquifer in the Brazos River floodplain. Volumes, however, will be small compared to the aquifer's capacity.

If the geothermal well uses water from both the Glen Rose and Hosston formations, contamination of the Hensel aquifer (immediately below the Glen Rose) could occur. This formation is productive elsewhere but consists of only 3 m (10 ft) of sand near the well site. The actual amount of leakage into the Hensel would depend on pressure relationships, transmissivity, and structural characteristics of the aquifer.

The production rate for the new well [13 liters/sec (200 gpm)] is low compared to the ability of the aquifer to transmit water to the well. Depletion or subsidence problems, therefore, are not likely to occur.

3.3 IMPACTS ON AIR QUALITY

Air quality impacts will result from equipment operation and surface disposal of geothermal fluids.

During the construction phase, exhausts from vehicle and drilling rig operation were emitted. However, the effect of increased vehicle use in Marlin small because only a small number of vehicles were added

to the existing traffic and the streets surrounding the project are main traffic thoroughfares for the downtown area.

Construction equipment requirements were modest. A backhoe and dozer were used in site preparation. The drilling rig consumed about 30,300 liters (8000 gal) of diesel fuel over the two-to three-month drilling period. Exhaust emissions did not provide a detectable increase in the urban setting of the site. In short, impacts of construction-phase equipment operation were slight and brief.

Emissions of hydrogen sulfide (H_2S) and other noncondensable gases are possible during drilling, well testing, and system operation. The odor of H_2S may be detectable in the vicinity of the rig and mud pits, especially if water from the Glen Rose Formation is used for production. Water from the Rosebud well, 32 km (20 miles) south of Marlin, contains about 50 mg/liter of sulfide. At a maximum discharge rate of 13 liters/sec (200 gpm), 2.27 kg of H_2S per hour would be released during well testing. If water from the Hosston Formation is used, which appears to be the case, water from the well will contain even less sulfide. The dissolved hydrogen sulfide concentration in the fluid from the new well was measured to be less than 1 mg/l. At a maximum discharge rate of 13 liters/sec (200 gpm), less than 0.05 kg of H_2S per hour will be emitted during well testing. For comparison, well testing at the Geysers releases 15kg of H_2S per hour during an average well test.¹ Hence, relative to other geothermal sites, sulfide emissions should be a minor concern at the Marlin site. The generally good atmospheric conditions at Marlin will help minimize odor impact. Drilling and well testing lasted less than three months, and no noticeable H_2S emissions should occur during operation since there will be no flashing or venting of gases.

Little or no dust was raised by equipment during site preparation because the site is already gravel topped and surrounded by paved city streets.

3.4 NOISE IMPACTS

Noise-producing aspects of the project include: two to three months of drilling activity to drill one well in a parking lot adjacent

to the hospital [about 25 m (90 ft) southeast of the boiler room]; excavation of mud pits and a reserve pit; production testing for 48 hr; and construction of geothermal lines across the parking lot, a settling tank, and heat exchangers inside the hospital mechanical room. Although noise levels were not measured, it is estimated that noise levels of about 75 dBA occurred at the wall of the hospital; interior noise levels in hospital rooms were probably 53 to 58 dBA in B wing and 58 to 63 dBA in D wing. These noise levels are considered "quiet" - corresponding to light auto traffic at 15 m (50 ft) or an air conditioning unit at 6 m (20 ft).² These noise levels did not create any significant impacts on the hospital patients or surrounding community nor were they sufficient to require any special mitigation measures. Pre-existing ambient noise levels in hospital rooms with the window open, however, were measured at 53 and 55 dBA, so that in some areas of the hospital there was little change in noise.

Community sound levels during drilling was about 60 to 65 dBA along the first row of houses of each street; this is about 5 to 10 dBA higher than the representative ambient level. The noise levels were lower than this inside houses. Although a few individuals may have been adversely affected, the noise levels from drilling and construction activities were not significantly different from those produced by any heavy equipment, and there was no major adverse reaction or impact.

There are no impacts expected during operation.

3.5 ECOLOGICAL PROJECTS

3.5.1 Terrestrial ecology

This proposed drill site is in a developed urban area. Thus, no disturbance of natural vegetation or wildlife habitat will occur. Atmospheric emissions during drilling and flow-testing should not affect offsite biota.

3.5.2 Aquatic ecology

The Marlin geothermal project is not expected to impact aquatic biological communities. Surface disposal of geothermal fluids during

operation will only occur if the water quality of the fluids is high enough not to degrade Brazos River water below State water quality standards. Proper site preparation, drilling, and flow-testing practices will protect aquatic biota in the Brazos River and its tributaries.

3.6 IMPACTS ON LAND USE

The location of the geothermal well in urban land will not significantly change current land use practices. Noise and other emissions will not affect offsite agricultural land use or use of natural areas. Noise disturbance to nearby residential areas is unavoidable but should be brief.

3.7 IMPACTS ON WATER USE

There will be no negative impact on water use. The municipal water supply is adequate to meet needs during the construction phase, and no water will be required for the geothermal system during the operational phase.

3.8 SOCIOECONOMIC IMPACTS

Because of the small scale of the proposed project, neither drilling nor operation of the geothermal well will have a significant impact on the existing socioeconomic environment.

During the operational phase, it is anticipated that one technician at most will be needed, unless the existing maintenance staff of the T-H-S Memorial Hospital can handle the well operation.

3.9 IMPACTS ON HISTORICAL AND ARCHAEOLOGICAL RESOURCES AND NATURAL LANDMARKS

There are no historical sites or natural landmarks close enough to the project area to be potentially affected by it. No archaeological survey was deemed necessary because the site has been previously developed for the T-H-S Memorial Hospital complex.

REFERENCES FOR SECTION 3

1. U.S. Environmental Protection Agency, *Western Energy Resources and the Environment: Geothermal Energy*, Energy Environment R & D Series, May 1977.
2. Radian Corporation, *An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas*, Austin, Tex., August 1978.

4. COORDINATION WITH STATE, LOCAL, AND REGIONAL PLANS

This project is being planned in conjunction with the T-H-S Memorial Hospital in the City of Marlin; it will adhere to all applicable requirements for additions to the hospital, as determined by the city. In addition, permission to use existing city drains, if feasible, for spent geothermal fluid must be obtained from the city. The nature of the project is such that no additional significant effect on planning bodies is anticipated. The disposal of saline waters is regulated by the Texas Railroad Commission which also regulates all gas, oil, geothermal, and other mineral production in the state. Since saline waters are commonly produced from gas, oil, and geothermal, it follows that the Texas Railroad Commission should control their disposal. Regulation of chemical wastes and surface disposal is done by the Department of Water Resources.

In order to obtain permission for disposal of geothermal fluid from the proposed system, a request was made by letter for a Texas Railroad Commission staff hearing to present the hospital's case. An environmental impact exhibit was prepared in support of the hospital's request for exception to Statewide Rule 8 (Off-Lease Discharge) of the Commission's Oil and Gas Division Rules. This exhibit was also provided to DOE/DGE and ORNL/UCC. The hearing examiner heard the case and submitted the case to the Commission staff for determination of a proposed action. The staff's proposed action to grant the surface disposal request was presented to the Commissioners at one of their regular meetings. The Commissioners requested further information and the staff performed a field environmental investigation of the proposed disposal scheme. Following this investigation, the staff again presented its proposed action to the Commissioners with the additional information requested. The Commissioners then approved the application for disposal of geothermal fluid into the Brazos River on 17 March 1980.

5. ALTERNATIVES TO THE PROPOSED ACTION

The reasonably available alternatives to the proposed action are to abandon the project or to delay it and demonstrate direct heat application of geothermal energy at another location.

The mandate of the Geothermal Research, Development and Demonstration Act of 1974 to explore all reasonable avenues to increased use of geothermal energy encourages the pursuit of economically attractive, petroleum-conservative demonstrations such as this one. This project will examine the technical and economic feasibility of direct use of geothermal fluids at a low temperature in an application that currently uses natural gas. To abandon or delay this project precludes the determination of the technical and economic feasibility of direct application of lower temperature geothermal resources and continues the hospital's dependence on natural gas.

Other locations for this demonstration are reasonable alternatives because low-temperature geothermal resources are abundant in the United States. This project is but one of six projects awarded on a competitive basis over the entire United States. Thus this location is but one of many experiencing similar feasibility examinations for geothermal development.

APPENDIX A**Correspondence With the Soil Conservation Service
Regarding the Effects of the Project on Prime and
Unique Farmland**

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

P. O. Box 648
Temple, Texas 76501

September 8, 1978

Ms. Fran Sharples
Environmental Sciences Division
Oak Ridge National Lab
Oak Ridge, Tennessee 37830

Dear Ms. Sharples:

We have reviewed your request concerning the effect on prime farmland of the geothermal well located within the City of Marlin, Falls County, Texas. We have determined that there are no adverse effects on prime farmland in this instance. If we can be of further help, please let us know.

Sincerely,

George C. Marks
State Conservationist

APPENDIX B**Final Order Approving the Application for a Permit
for Surface Disposal of Geothermal Fluids**

FINAL ORDER
APPROVING THE APPLICATION OF TORBETT-HUTCHINGS-SMITH MEMORIAL
HOSPITAL FOR SURFACE DISPOSAL OF GEOTHERMAL
DISCHARGE WATER
IN FALLS COUNTY, TEXAS

The Commission finds that, after statutory notice in the above-numbered docket, heard on November 13, 1979, the presiding examiners have made and filed a report and proposal for decision containing findings of fact and conclusions of law, for which service was waived by parties of record; that the proposed application is in compliance with all statutory requirements; and that this proceeding was duly submitted to the Railroad Commission of Texas at conference held in its offices in Austin, Texas.

The Commission, after review and due consideration of the proposal for decision, the findings of fact and conclusions of law contained therein, hereby adopts as its own the findings of fact and conclusions of law contained therein, and incorporates said findings of fact and conclusions of law as if fully set out and separately stated herein.

Therefore, it is ordered by the Railroad Commission of Texas that effective March 17, 19 80, the application of Torbett-Hutchings-Smith Memorial Hospital, City of Marlin, Falls County, Texas for an exception to Statewide Rule 8 (c) (1) (C) be and is hereby approved. This exception will permit the discharge of geothermal resource waters into the Brazos River and is subject to the condition that at all times discharged geothermal resource waters will comply with the water quality standards established by the Texas Water Development Board or its successor.

Done this 17th day of March, 1980.

RAILROAD COMMISSION OF TEXAS

CHAIRMAN

COMMISSIONER

COMMISSIONER

ATTEST:

Secretary

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