**GEOHERMAL EVALUATION OF
THE HOSSTON FORMATION
LACKLAND AIR FORCE BASE,
SAN ANTONIO , TEXAS**

PHASE II REPORT

Prepared for

**United States Air Force
Air Training Command
Lackland Air Force Base
San Antonio, Texas**

. And

**U.S. Department of Energy
Idaho Operations Office
Under DOE Contract No.
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May 1984

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INTRODUCTION

This report summarizes the results of a phased program to test the geothermal characteristics of the Hosston Formation at Lackland Air Force Base, San Antonio, Texas. The geothermal resource evaluation was made possible through drilling and preliminary testing of a large diameter well, Lackland AFB #1, at the south portion of the base (Figure 1). Phase I of the program (Lawford et al., 1983) had 3 major components: compilation and interpretation of surface and subsurface geologic data to site the well; design of the well; and permitting the well. Phase II consisted of well drilling and preliminary development. The goal of the program was to identify water temperature, water quality, and productivity characteristics of the Hosston aquifer, which preliminary studies (Woodruff et al., 1982b; Conover, et al., 1982; Lawford et al., 1983) suggested might be favorable for direct applications on the base. Results reported herein suggest that heat pumps or other engineering alternatives might be needed for such applications.

Results of the well drilling give data on water productivity, quality and temperature. Air-lift testing shows that, although the well does not flow to surface, good artesian pressure exists. Water quality appears acceptable, with about 2200 parts per million total dissolved solids. Equilibrated reservoir temperatures appear to be slightly less than 108°F (42°C).

This geothermal assessment program was funded by the U. S. Air Force, managed by the Idaho Operations Office of the U. S. Department of Energy, and conducted by a team of personnel from the Earth Science Laboratory/University of Utah Research Institute, and EG&G Idaho, Inc. Earth Science Laboratory efforts were conducted under DOE contract DE-AC07-80ID12079.

FIGURE 1 LACKLAND AIR FORCE BASE AND LOCATION OF LACKLAND AFB#1 GEOTHERMAL WELL

PHASE I RESULTS

Data compiled under Phase I suggested that water productivity (MacPherson, 1982) and water quality (Lawford et al., 1983) parameters of the Hosston Formation were likely to be favorable, and that temperatures of $\geq 125^{\circ}\text{F}$ (52°C) could likely be anticipated at the target depth of 4000 ft (1.22 km). Phase I studies indicated that, despite the flat topography of Lackland AFB, subsurface geologic conditions are very complex. Sedimentary rocks above a basement complex are thicker at the southern portion of the base. Shallow geologic studies indicated extensive faults that generally, but not exclusively, have down-to-the-coast displacement. A geologic target model was developed on the basis of existing data, which suggested that a well could possibly encounter thermal fluids in the Hosston Formation (largely a sandstone) near the southern edge of the base, where the Hosston would be deepest and where, it was hoped, proximity to faults might provide a conduit for upwelling thermal fluids. The well to test the Hosston was also placed such that, if successful, it could be converted to a production well and used in nearby facilities. The selected site (Figure 1) was approved by the Air Force, after which permits for the well were acquired from appropriate state agencies.

A preliminary well design was completed during Phase I, to meet requirements of regulators and to prepare for details of design of Phase II. A primary goal of this design was to insure the integrity of the Edwards Formation, which is above the Hosston. The Edwards is the source of water for the San Antonio metropolitan area (including Lackland AFB), and it was to be protected from contamination during drilling, testing, or any eventual future production from the well.

PHASE II ACTIVITIES

Following what was learned during Phase I, the functions of Phase II were planned. A geologic prognosis of Lackland AFB #1 was prepared and arrangements were finalized for the needed well site geologic facilities. A detailed study was made of the cuttings from the Pagenkopf #1 Blum, the nearest dry hole. Bids were solicited and received for all of the major subcontracts needed to drill a well and test the Hosston Formation. Services and supplies bids were processed in the order dictated by needs of the drilling sequence and a schedule of the project activities was made. The following sections cover all aspects of Phase II from the factual geology, drilling, testing and water analyses, to the more subjective thermal regime and drilling critique. At the close of the Phase II discussion, recommendations are given for possible future testing of Lackland AFB #1.

Methods of Investigation

Nearly all aspects of this project were performed with methods and equipment typical of the petroleum industry. This was made possible by the general similarity of the geologic environment to terrain and conditions familiar to south Texas drillers. Phase I well design was refined early in Phase II. The drilling and completion details, provided for in the well design, satisfied many requirements. The large diameter casings, larger than for a typical oil test, were designed for (1) a very high production rate of 500-1000 gal/min; and (2) to be able to place a large diameter pump at a moderately deep level. The underreaming and gravel-pack completion was designed to enhance the ability of the Hosston reservoir to produce large quantities of water. In addition to these project-related objectives, the well design provided securely cemented casing as protection for the Edwards Formation aquifer.

Drilling was accomplished with a Cabot Explorer III "Rocket" Model 1287-A, rated at 9000 ft capability. The extra depth capability, which is a standard procedure in geothermal wells, was specified to provide the capacity to safely handle the large, heavy casing. The drilling rig was provided by Magee-Poole Drilling Company of Alice, TX, who have extensive experience drilling within the Texas Coastal Plain. Magee-Poole provided all auxillary equipment that typically is required for drilling, including mud tanks, mud pumps, drill pipe, and miscellaneous items.

Drilling to the top of the production reservoir was on a cost-per-foot basis, during which time the drilling contractor paid for the drill bits used. Following emplacement of the intermediate casing at the top of the Hosston reservoir, the cost of drilling was on an hourly basis, during which bits were an extra charge.

Tooke Engineering performed the mud logging services. Those services included monitoring physical and chemical characteristics of the drilling fluid, providing for detection and preliminary evaluation of hydrocarbon shows, curating drill cuttings for microscopic examination, monitoring the drilling fluid temperature as it entered and exited the wellbore, and logging the drilling penetration rate.

Casing operations were performed in usual oilfield fashion. Geophysical logs were recorded in the hole just before each of three strings of casing was emplaced. Sidewall cores were obtained from selected units to help evaluate hydrocarbon shows in shallow zones and to help evaluate reservoir characteristics in the Hosston Formation. One drill stem test was run (report given as Appendix A) to obtain a measure of potential productivity of the Hosston Formation, prior to committing to the expensive well completion.

Geological methods utilized during the drilling included examination of

washed drill cuttings with a binocular microscope in normal white light for lithologic descriptions and in ultraviolet light to aid in detecting hydrocarbon shows. Under the microscope, selected fragments of the cuttings were treated with water or dilute hydrochloric acid to aid in making lithologic determinations; under ultraviolet light selected cuttings were treated with trichloroethane to aid in detection and evaluation of hydrocarbon shows.

To improve the understanding of the geologic setting in a stratigraphically and structurally complex area and to provide feedback to the drilling program, formation thicknesses and elevations relative to sea level were compared to data from nearby dry holes.

Water samples were collected during the air lift testing. The water was analyzed for selected major and trace elements; results of these analyses are presented below. Water analyses also provided raw data to allow calculations of chemical geothermometers.

Downhole temperature data were obtained during flow testing, and a high-resolution temperature log was obtained 3 months after drilling.

Results

Geology

The Lackland AFB #1 well reached a total depth of 4110 feet. The hole bottomed in a sequence of redbeds of probable Jurassic Cotton Valley Formation equivalence. Except for this unusual but anticipated redbed sequence, the well encountered a totally normal sequence of marine formations typical of the Bexar County area and adequately described in an abundance of geologic literature (Loucks et al., 1977; Sellards, 1919; Stricklin et al., 1971). Figure 2 presents a condensed lithologic log of Lackland AFB #1, with notations of the key formations.

FIGURE 2 - LITHOLOGIC LOG, LACKLAND AFB#1

The Hosston Formation aquifer in the Lackland AFB #1 well exhibited a gradationally ranging composition from a very fine-grained sandstone at the top through medium- and coarse-grain sandstone, to a chert and quartz pebble conglomerate at the base. The degree of cementation was greater in Lackland AFB #1 than was seen during Phase I studies of the cuttings of neighboring wells, where the sand and gravel were mostly disaggregated.

The Hosston Formation encountered in Lackland AFB #1 is approximately 60 ft thinner than the Hosston in the Pagenkopf #1 Blum, 1-1/2 miles away. This thinning can be attributed to the Hosston having been deposited on a pre-Cretaceous erosional surface of mild relief, developed on the Ouachita structural trend, which is subjacent to the Balcones fault zone. The Ouachita trend is characterized by thrust and reverse faults in the Paleozoic section (Figure 3). These metamorphosed Paleozoic rocks constitute the subcropping section to the Cretaceous formations throughout nearly all of the Ouachita trend. The only known exception to that is the presence of a thick section of unmetamorphosed fine-grained redbeds present in the #1 Blum, the Lackland AFB #1 and at least one other well to the southwest of Lackland AFB. It is theorized that the redbeds are present in a narrow northeast-trending graben which developed after the metamorphic event and before the pre-Hosston hiatus.

Figure 4 presents portions of the raw geophysical logs and of the computer corrected Prolog over the same interval. The primary feature shown by the Prolog is the corrected "Formation % Bulk Volume," with its visual display of porosity in the formation logged. At the right side of the Prolog, the unpatterned areas indicate pore space. Note that within the Hosston Formation (3725' - 4008' depth) there are several intervals of $\geq 20\%$ porosity (approximately 152 ft of cumulative sandstone having $\geq 5\%$ porosity). It is from these high porosity zones that the formation water is produced.

FIGURE 3 - DIAGRAMMATIC GEOLOGIC SECTION THROUGH THE LACKLAND AFB AREA

Prolog

Field Analysis

Wellsite Sandstone Analysis

LITHOLOGIC CHARACTERISTICS	DEPTH	WATER	POROSITY AND FLUIDS % BULK VOLUME	FORMATION % BULK VOLUME
SHALE % BULK VOLUME		WATER SATURATION 100 PWA	HYDROCARBON HYDROCARBON 50	CLAY CLAY CLAY
SP - 10	100		50	100
BORNEHOLE VOLUME 10 100			50	100
POROSITY FEET 1			50	100

Figure 4. Geophysical Logs of Lackland AFB #1 through the Hosston Producing Interval.

Testing

Following installation of the screen and the gravel-pack operation, air-lift tests of the producing capability of the well were conducted for two days. The testing was run jointly by Earth Science Laboratory/UURI and EG&G, Idaho personnel. The objective of the air-lift testing was to obtain data on flow and drawdown characteristics of the well and as well as samples for water chemistry. The procedure involved injecting compressed air into the cased borehole at a depth of 508 ft, to produce the fluid above that level to the surface. Having had nearly 500 ft of head removed, the artesian reservoir was free to flow. The air flow during testing was continuous; however, due to the physical problems of moving water up a large diameter pipe by air, the water was produced at the surface at a somewhat irregular rate. The depth to water level in the well was approximately 35 ft prior to testing and 20.7 ft following testing.

The water was produced through an 8-inch pipe into a pair of linked 200 barrel (8400 gal) steel tanks. The vertical filling of the tanks (139 gal/inch) was measured as a function of time during air lifting. Upon filling one tank at first, the output of two 2-inch diesel pumps was calibrated as the tank was emptied. Following all calibration, time/volume data were collected as the two tanks were filled. In order to extend the flow time during each filling of the tanks both pumps were concurrently run to displace the produced water to the reserve pit. The well was slowly developed from 350 to 400, and finally 450 gal/min.

During the first day of testing, Fesco Inc. provided downhole pressure and temperature instrumentation (Fesco Report attached as Appendix B). Calibration of the Fesco bimetal strip thermometer with an accurate mercury-in-glass thermometer showed that all Fesco temperatures are 2.1 F° low.

Preliminary calculations of specific capacity (supplied by EG&G, Idaho, Inc.) based on Fesco data indicate that the Hosston reservoir has a specific capacity of 2.32 gpm/ft of drawdown. They further calculate that the well has a transmissivity of 3800 gpd/ft, assuming a storage coefficient of 1×10^{-4} . The maximum temperature measured at the flowline during air lift testing was 105.8°F (41.0°C) on a mercury-in-glass thermometer.

Water Analyses

Analytic data from fluids recovered during the air-lift test of the well are presented in Table 1; elements analyzed for but not detected are listed in Table 2. Sample 1 was collected at the beginning of the test, sample 2 about the middle, and sample 3 at the end. Approximately 100,000 gallons (5 well-bore volumes) of water were produced during the air-lift testing. All chemical analyses were performed at the Earth Science Laboratory/UURI. Analytic techniques are listed on Table 1. An ARL Inductively Coupled Plasma Quantometer was used for most elements. Other more traditional techniques are listed on the table. Sampling procedures followed the techniques of Kroneman (1980).

The samples analyzed are felt to be representative of reservoir fluids. Although some organic-based drilling contaminant may have been in the waters during the sample collection (based on an amber color in the water, from the breakdown of biodegradable polymers), such contamination was probably minimal.

The waters are dominantly sodium sulfate, with lesser amounts of potassium, calcium, magnesium, bicarbonate and chloride. Fluids similar to those from Lackland AFB #1 have been suggested (MacPherson, 1982) to be transitional between updip fresher water of Hosston Formation recharge zones and downdip brines in the Gulf Coast Basin. The sodium sulfate character of the water, and the total dissolved solids content (2200 ppm) are typical of the transi-

TABLE 1
LACKLAND AFB #1
WATER ANALYSES
Concentrations in ppm

<u>Element</u>	<u>Sample Number</u>			<u>Analytic Technique^a</u>	<u>lqd^b</u>
	1	2	3		
Na	565	563	561	1	0.61
K	52	46	43	1	1.22
Ca	132	127	109	1	0.24
Mg	36	35	35	1	0.49
Fe	1.4	0.7	<0.02	1	0.02
SiO ₂	21	20	20	1	0.52
B	1.1	1.0	1.0	1	0.12
Li	0.46	0.45	0.45	1	0.05
Sr	5.22	5.23	5.20	1	0.01
Zn	1.	<0.12	<0.12	1	0.12
Alkalinity as HCO ₃	359	326	338	2	10
SO ₄	649	648	646	3	2
Cl	580	559	524	2	2
F	1.9	2.5	2.3	4	0.1
TDS (measured)	2127	2210	2218	3	
TDS (calculated)	2223	2168	2113	5	

a) Analytic techniques

1. Inductively Coupled Plasma Spectrometer
2. Laboratory titration
3. Gravimetric
4. Specific Ion electrode
5. Hem (1970)

b) lqd = limit of quantitative detection, i.e. instrumental signal at least twice the background level.

TABLE 2

LACKLAND AFB #1

Elements analyzed for in water samples but not detected

<u>Element</u>	<u>Limit of Quantitative Detection^{a,b}</u>
Al	0.61
Ag	0.05
As	0.61
Au	0.10
Ba	0.61
Be	0.05
Bi	2.44
Cd	0.06
Ce	0.24
Co	0.02
Cr	0.05
Cu	0.06
La	0.12
Mn	0.24
Mo	1.22
Ni	0.12
Pb	0.24
Sn	0.12
Sb	0.73
Te	1.22
Th	2.44
Ti	0.12
U	6.10
V	1.22
W	0.12
Zr	0.12

a) Analysis by Inductively Coupled Plasma Spectrometer, concentrations in ppm

b) Concentration of element when instrumental signal is at least twice the background level.

tion zone. The overlying Edwards Formation in Bexar County shows a similar transition in chemical character from fresh to more saline. Figure 5 is a trilinear diagram of the water analyses, which illustrates the sodium-sulfate nature of the water.

Chemical geothermometers are calculations to estimate the temperature of water-rock equilibration in geothermal fluids, and are a commonly applied technique in geothermal exploration. These calculations are based on either the solubility of an element (e.g., Si, Li) or the relative concentrations of several elements (e.g. cation ratios). In order for the temperature calculated from the fluids to be interpreted as the temperature of equilibration, and therefore the temperature of the reservoir, the assumptions of no fluid mixing, adequate chemical constituents, and others listed by Fournier et al. (1974) must be satisfied. It is possible that not all of the assumptions required for reliable interpretation of geothermometry results are met by the fluids sampled from Lackland AFB #1.

The results of selected geothermometers are given on Table 3. Quartz without steam loss is the only silica geothermometer listed, as there is no evidence of boiling anywhere in the system (eliminating the need for steam loss corrections), and all other phases of silica yield results that are less than the measured temperature. The Na-K-Ca geothermometers without Mg correction are not listed, as adjustments for the Mg content must be made (Fournier and Potter, 1979). The Na/Li geothermometer gives results that agree closely with the quartz and the Mg-corrected Na-K-Ca geothermometers, but results that are less than the Li geothermometer.

These results can be interpreted to suggest that waters present in the Hosston Formation may have at some point in their chemical evolution equilibrated with rocks at a temperature of approximately 60°C. Woodruff et al.

PERCENT OF TOTAL
 MILLIEQUIVALENTS PER LITER

FIGURE 5 - TRILINEAR DIAGRAM OF LACKLAND AFB # 1 WATER ANALYSES

(1982a) note the presence of water with temperatures up to 72°C in wells of approximately similar depth to Lackland AFB #1 but in a more basinward geologic environment. Their data suggest that results such as those obtained from geothermometry calculations reported on Table 3 may be reasonable. It should be noted, however, that calculation of geothermometers with analytic data from low-temperature fluids is an inexact science, and these results may not be meaningful. It should also be noted that no data exist in this study to suggest the proximity of fluid equilibration at 60°C, if it has occurred, to Lackland AFB #1. Temperatures significantly above those measured in the well may not be encountered during long-term well production.

Thermal Regime

On 16 February 1984, a high resolution temperature log was run, after the well should have reached thermal equilibrium. The log indicated that the Hosston in Lackland AFB #1 is unusually cool, on a regional basis. The bottom hole temperature was just under 108°F (42°C). Figure 6 is a graph of the high resolution temperature/depth data, which are presented in tabular form as Appendix F.

The overall gradient of Lackland AFB #1 is slightly less than 0.9°F/100' (17°C/km). According to C. M. Woodruff, Jr. (personal communication, 1984) thermal gradients in this area should range from 1.5°F/100' (27°C/km) to 2.0°F/100 ft (36°C/km). Nathenson et al. (1983) indicate gradients from 1.4°F/100 ft (25°C/km) to 2.2°F/100 ft (40°C/km) occur in the Bexar County area. MacPherson (1982) reported thermal gradients of 0.8°F/100 ft (14.0°C/km) from a shallow well to 2.4°F/100 ft (43.9°C/km), with an average gradient of 1.6°F/100 ft (29.8°C/km), based on temperatures of produced water from the Hosston Formation in central Texas. Data of these other studies suggest that the thermal regime at Lackland AFB #1 is unusually cool.

TABLE 3
CHEMICAL GEOTHERMOMETERS
LACKLAND AFB #1 WATERS

<u>Geothermometer</u>	<u>T(°C)</u>			<u>Reference</u> ¹
	Sample 1	Sample 2	Sample 3	
Quartz (no steam loss)	65	63	63	Fournier (1981)
Na-K-Ca-Mg	63	61	53	Fournier & Potter (1979)
Na/Li	66	65	65	Fouillac & Michard (1981)
Li	129	128	128	Fouillac & Michard (1981)

¹ References cited at end of text.

FIGURE 6 - THERMAL LOG, LACKLAND AFB #1

Although the specific reasons for this phenomenon are not yet known, a local hydrologic disturbance of the regional thermal regime is indicated. The overall low nature of the gradient suggests a zone of disturbance, as would be typical of a zone of recharge, rather than of a zone of discharge. Cool recharge waters might be circulating down along the many faults beneath the base and depressing the thermal gradient. If this interpretation is correct, it is possible that the thermal regime beneath all of Lackland AFB is relatively depressed.

Drilling Summary

This is a brief account of the drilling; supporting details are presented in appendices as noted. The well site location was prepared on 4 October 1983 (all drilling activity dates are 1983). The conductor hole was drilled and the conductor pipe set and cemented to 50' depth on 15 October (see Figure 7 for well profile). A spud meeting was held at Lackland AFB on 15 October to acquaint representatives of all primary service companies with the well location, the approved route through the base, and all procedures to be followed in the course of the project. That meeting contributed significantly to the project's smooth operation.

Magee-Poole Drilling Company moved in and rigged up on 20 October. Appendix C is a detailed drilling history from the daily 7 AM morning reports with data from the preceeding 24 hours. All necessary rental equipment also was moved-in and rigged-up on 20 October. Some of these included the portable steel water tank (frac tank), the mud cleaning equipment (to remove solids from the drilling fluid), and the mud logging trailer. The well was spudded at 0800 on 21 October. The first 24 hours resulted in 1034 ft of hole drilled through soft, near-surface formations.

The 17-1/2 in. surface hole reached the first casing point at 2025 ft on

FIGURE 7 - FINAL WELL PROFILE OF LACKLAND AFB#1

day 5 of the project. The estimated time to drill this interval was 3 days. The additional 2 days are due to several factors including:

1. The carbonate formations were much harder and denser than anticipated, which resulted in lower penetration rates and frequent bit trips;
2. The drilling contractor was using reconditioned bits instead of new ones, which resulted in shorter bit life, with more frequent trips to change the bits.

The surface hole was logged by Dresser Atlas as planned. The 13-3/8 in. surface casing was run and cemented in place by Halliburton. Cement was circulated to surface with no complications. The 13-3/8 in. casing head was welded in place and blow-out preventers were installed and tested. On October 28, which was day 8 of the project, the casing and the casing shoe were tested to 1500 psi. The test was satisfactory, thus assuring isolation of the Edwards Aquifer.

The 12-1/4 in. intermediate interval was initiated on day 8 of the project. This interval reached the second casing point at 3738 ft on day 13 of the project. The estimated time to drill this interval was 3 days. The additional 3 days were the result of the same reasons mentioned above for slow drilling. The well was logged and a 9-5/8 in. liner was run and cemented in place.

At this time, when the well bore was stable, the drilling fluid, which was a lignosulfonate system, was displaced, and a biodegradable polymer mud system was introduced to reduce potential damage to the Hosston Formation.

On day 16 of the project, the target sand of the Hosston Formation was penetrated and drilling the 8-3/4 in. hole begun. It took 1-1/2 days to drill the 364 ft of sand. It was estimated to take only 10 to 15 hours; however, hard formation was encountered and penetration rates were very low. The total

depth of 4110 ft was reached on 6 November, day 17 of the project.

After the well was logged, and the logs were evaluated, the decision was made to run a Halliburton drill stem test (DST) to evaluate the flow properties of the potential reservoir. This was particularly important, since the hard drilling might have indicated little permeability in the formation, and if no permeability existed, expensive underreaming and completion would not have been warranted. The (Appendix A) test indicated pressures and a high fluid productivity enabling the Hosston to flow to near the surface elevation. Based on DST data, it was decided to underream and complete the hole to maximize fluid recovery.

The underreaming was estimated to take one day when the project was designed, however, the actual underreaming took 4 days due to hard lithologies drilled. This resulted in doubling the mud cost due to the polymer mud system being in the hole much longer than anticipated.

After the well bore was underreamed, the formation was washed with a 7-1/2% HCl solution to clean the face. After the acid wash, a stainless steel wire-wrapped screened 7 in. liner was installed. Dowell rigged-up and pumped a gravel-pack slurry. The initial slurry was insufficient to completely fill the underreamed annulus. A second slurry was prepared, and the interval was successfully packed off on 14 November, which was day 25 of the project. The Christmas tree wellhead assembly was installed, and the rig was released at 7:00 AM on 15 November.

On 16 November, Magee-Poole rigged down and moved out, and all rental equipment was released. On 17 November, the location was cleaned up and prepared for a smaller, less expensive completion rig to be brought in for use in the air lift testing. Rental pumps, tanks, and other equipment for testing were also moved in on 17 November. The completion rig arrived early on 18

November, after which Gearhart Logging Company ran a cement bond log, to record the integrity of the well casing.

On 19 November, 2-3/8 in. tubing was run to 508.7 ft for use as a jetting pipe during air lifting. Fesco downhole pressure and temperature instruments were positioned at 3400 ft depth. The well was air lifted for 9 hours.

On 20 November, after 4 additional hours of air lift testing was completed, the rig was released at 1430 hours. Fesco downhole services and all rental equipment were also released at that time. Final site restoration was done on 28 November.

Records of the drilling bits used and daily drilling mud properties are given in Appendices D and E, respectively. A time/depth drilling progress plot is given as Figure 8. A listing of the logging is presented on Table 4. Figure 4 illustrates the reservoir through reduced scale copies of the detailed geophysical logs.

Drilling Critique

Technically the drilling operation at Lackland AFB #1 went smoothly, due to good well design, and adequate planning by and interfacing between the geological and engineering portions of the project direction. Additionally, the operation was facilitated by adequate planning far enough in advance so there were no delays, and by a good drilling contractor who provided well maintained equipment and experienced personnel. There were no rig breakdowns, no fishing operations for drilling equipment lost or twisted-off in the hole, and through an efficient mud program plus the operation of adequate mud cleaning equipment there were no lost circulation problems. Faulty or inappropriate equipment brought by service company subcontractors caused the only slight delays experienced, and appropriate adjustments in pricing were made in each case to compensate for rig time expense caused by the delays.

TABLE 4
GEOPHYSICAL LOGGING SUMMARY
LACKLAND AFB #1

Logging Data - Dresser Atlas

<u>Date</u>	<u>Type of Log Run</u>	<u>Logged Interval</u>	<u>Total Depth</u>
10-25-83	Dual-Induction Focused Log with Gamma Ray, SP, Compensated Density Porosity, Compensated Neutron Porosity, Caliper and Prolog.	65'-2038'*	2040'*
11-2-83	Dual-Induction Focused Log with Gamma Ray, SP, Compensated Density Porosity, Compensated Neutron Porosity, Caliper and Prolog, plus temperature.	2044-3757*	3759*
11-7-83	Dual-Induction Focused Log with Gamma Ray, SP, Compensated Density Porosity, Compensated Neutron Porosity, Caliper and Prolog, plus temperature.	3758-4126*	4128*

Logging Data - Gearhart

11-18-83	Gamma Ray - Cement Bond Log	30-3430*	3438*
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Logging Data - Southern Methodist University

2-16-84	High Resolution Temperature Log	492-3960	3960
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* As is standard practice with the petroleum industry geophysical logging companies, these logs were measured from the Kelly Bushing, which was 18 feet above permanent ground elevation.

Drilling bits were felt to be of proper design for the various intervals drilled. However, we feel it was poor economy for the drilling company to have used re-built bits in the upper (approximately) 65% of the hole. The rebuilt bits cost less, but they each had shorter usable life than new bits would have had, thus necessitating more frequent stopping of progress to change bits. The bit changes often each took more than four hours. It must be reiterated here that, above the target formation, the drilling contractor by contract had the right to choose what bits were run. If additional warm water or injection wells are to be drilled on Lackland AFB we recommend that new bits be used and that the drilling contract includes that stipulation.

The drilling fluid (mud) program was well planned and served its purposes well. Through proper choice of mud additives, and with proper mud cleaning equipment to remove solids from the system, the mud weight was minimized, which contributed to preventing lost circulation in the very porous Edwards Formation. The potential reservoir zone was drilled and underreamed with a biodegradable polymer mud system to minimize formation damage. Although the polymer mud was expensive, the reduced formation damage it provided enhanced reservoir productivity.

The completion of the hole by screen and gravelpack treatment was highly successful. The .012 in. gauge screen and the pack material, actually well rounded sand repeatedly resieved between 20 and 40 mesh sieves, were planned upon sieving the Hosston Formation sand brought to the surface as drill cuttings. This type of hole completion added significantly to the productivity of Lackland AFB #1 and will contribute to its longevity.

RECOMMENDATIONS

Our recommendations fall into the areas of additional study of Lackland AFB #1, and future drilling at Lackland AFB. We recommend that, subject to a positive Air Force decision to use the fluids from Lackland AFB #1, additional environmental, testing, and economic studies be undertaken. The present Environmental Assessment was applicable through the well drilling phase only; it will need to be modified and appropriate fluid disposal permits will need to be obtained for further testing the well.

Additional well testing will allow the gathering of data necessary to forecast the long term performance of the reservoir from the standpoints of water quantity, quality and temperature. Insufficient data exist from the air lift well-cleaning test to forecast longer term aquifer productivity. Initial results are encouraging, and ESL professionals feel they warrant the longer test. Initial water quality data suggest that Hosston Formation fluids are from the transition zone between fresh water and basin brines. Water samples collected during a longer test would allow further evaluation of the fluid regime, and would allow engineering analysis of potential adverse impacts on materials that might be selected for future construction.

Economic studies of options for applications of the fluids would allow evaluation of potential energy and monetary savings of various utilization methods. Alternative direct applications to the planned dormitory heating, or heat pump boosting of the fluid temperature, might be possible options for use of the well fluid. An economic analysis of various alternatives would be based on data gathered during the longer term well test, and would be a more reliable indicator of project economics than can be calculated presently.

If there is to be any future drilling at Lackland AFB for additional production wells or an injection well we recommend that the technical drilling

procedures of the Lackland AFB #1 well be used with few exceptions. Based on having found a much less porous and permeable Hosston Formation beneath Lackland AFB than was observed elsewhere, we would modify the mud program to use the polymer system only during the underreaming operations. The Hosston could be drilled with a lignosulfonate mud if it were to be underreamed shortly after drilling. This is the only change we would advise for the mud system.

Drilling could be made more efficient by avoiding the refurbished bits, such as were used in much of Lackland AFB #1. Those bits, although less expensive, cost the project more through extending the time of personnel and rental equipment. The long, mostly carbonate, section below the casing point at the base of Edwards Formation should be drilled with a carbide insert type bit rather than the milled-tooth bits as were used on Lackland AFB #1.

To reduce the high costs of hauling away the used drilling fluid we recommend the use of a much larger reserve pit even if that will entail greater site restoration costs later.

These recommendations will serve as areas of cost savings for future drilling activities at Lackland AFB.

If similar geothermal resource evaluation projects are considered for other USAF bases we recommend the consideration of a less than all-out drilling commitment. Although it would not be usable for geothermal production, we feel that a slim-hole (4-6 in. diameter at total depth) would give an initial understanding of an otherwise untested geothermal resource at substantially less expense than a production-size well. If the temperature productivity or water quality were not sufficient for the intended application, the investment in the project would be less.

ACKNOWLEDGEMENTS

We would like to thank the many U.S. Air Force personnel who contributed to smooth operations of this project. Colonel D. J. Baumgartner, Lackland base commander, supported this project from its inception. Lt. Colonel S. P. Menzies showed continuing support of the base's upper echelon by frequent, interested visits during drilling operations. Mr. John Nepute, civilian engineer on the base, provided a very high level of cooperation in numerous ways throughout the project.

Instrumental in promoting the project were Mr. R. Steede and Col. H. D. Paul of Air Training Command Headquarters at Randolph AFB. At many times during the planning and drilling, Mr. Roberto Trevino, also from Randolph AFB, provided assistance with administrative matters.

The project benefited by the sound planning and execution of the drilling operations by R. W. Dirks, J. R. Fischer, and Gene Terrell of the R. W. Dirks Petroleum Engineer, Inc., consulting firm. These consultants also contributed to cost savings in the equipment planning of the air lift testing operations.

We are especially indebted to Dr. C. M. Woodruff, Jr., formerly of the Texas Bureau of Economic Geology (TBEG), for providing a significant amount of data and insight into the geology of Lackland AFB and particularly the Hosston Formation. His contacts saved much time in arranging for us to use the drill cuttings at the TBEG sample library.

Thanks to P. M. Wright, D. L. Nielson and J. N. Moore for technically reviewing the manuscript and offering comments of improvement.

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APPENDIX A

Drill Stem Test Report by Halliburton Services

FORMATION TESTING SERVICE REPORT

Duncan, Oklahoma 73536

A Halliburton Company

NOMENCLATURE

B	= Formation Volume Factor (Res Vol / Std Vol)	—
C_t	= System Total Compressibility	(Vol / Vol) psi
DR	= Damage Ratio	—
h	= Estimated Net Pay Thickness	Ft
k	= Permeability	md
m	{ = (Liquid) Slope Extrapolated Pressure Plot (Gas) Slope Extrapolated m(P) Plot	psi cycle
		MM psi ² cp cycle
m(P*)	= Real Gas Potential at P*	MM psi ² cp
m(P _f)	= Real Gas Potential at P _f	MM psi ² cp
AOF ₁	= Maximum Indicated Absolute Open Flow at Test Conditions	MCFD
AOF ₂	= Minimum Indicated Absolute Open Flow at Test Conditions	MCFD
P*	= Extrapolated Static Pressure	Psig
P _f	= Final Flow Pressure	Psig
Q	= Liquid Production Rate During Test	BPD
Q ₁	= Theoretical Liquid Production w Damage Removed	BPD
Q _g	= Measured Gas Production Rate	MCFD
r _i	= Approximate Radius of Investigation	Ft
r _w	= Radius of Well Bore	Ft
S	= Skin Factor	
t	= Total Flow Time Previous to Closed-in	Minutes
Δt	= Closed-in Time at Data Point	Minutes
T	= Temperature Rankine	R
φ	= Porosity	—
μ	= Viscosity of Gas or Liquid	cp
Log	= Common Log

TICKET NO. 64058800

14-NOV-83

CORPUS CHRISTI

FORMATION TESTING SERVICE REPORT

LACKLAND A.F.B.		1		1		3707.1 - 4128.1		UNIVERSITY OF UTAH RESEARCH INSTITUTE	
LEASE NAME		WELL NO.		TEST NO.		TESTED INTERVAL		LEASE OWNER/COMPANY NAME	
LEGAL LOCATION SEC. - TYP. - RNC.		FIELD AREA		SAN ANTONIO		COUNTY		BEXAR	
						STATE		TEXAS SM

GAUGE NO: 499 DEPTH: 3696.9 BLANKED OFF: NO HOUR OF CLOCK: 24

ID	DESCRIPTION	PRESSURE		TIME		TYPE
		REPORTED	CALCULATED	REPORTED	CALCULATED	
A	INITIAL HYDROSTATIC	1695	1763.8			
B	INITIAL FIRST FLOW	1294	1319.1			
C	FINAL FIRST FLOW	1461	1552.3	11.0	10.5	F
C	INITIAL FIRST CLOSED-IN	1461	1552.3			
D	FINAL FIRST CLOSED-IN	1582	1588.1	115.0	117.3	C
E	INITIAL SECOND FLOW	1582	1574.2			
F	FINAL SECOND FLOW	1582	1587.5	58.0	56.3	F
F	INITIAL SECOND CLOSED-IN	1582	1587.5			
G	FINAL SECOND CLOSED-IN	1582	1591.6	62.0	62.0	C
H	FINAL HYDROSTATIC	1692	1751.4

GAUGE NO: 378 DEPTH: 3722.8 BLANKED OFF: YES HOUR OF CLOCK: 24

ID	DESCRIPTION	PRESSURE		TIME		TYPE
		REPORTED	CALCULATED	REPORTED	CALCULATED	
A	INITIAL HYDROSTATIC	1768	1773.1			
B	INITIAL FIRST FLOW	1555	1537.4	11.0	10.5	F
C	FINAL FIRST FLOW	1616	1592.1			
C	INITIAL FIRST CLOSED-IN	1616	1592.1	115.0	117.3	C
D	FINAL FIRST CLOSED-IN	1616	1599.7			
E	INITIAL SECOND FLOW	1616	1595.1	58.0	56.3	F
F	FINAL SECOND FLOW	1616	1602.0			
F	INITIAL SECOND CLOSED-IN	1616	1602.0	62.0	62.0	C
G	FINAL SECOND CLOSED-IN	1616	1602.0			
H	FINAL HYDROSTATIC	1737	1761.4			

EQUIPMENT & HOLE DATA			TICKET NUMBER: <u>64058800</u>	
FORMATION TESTED: <u>HOSSTON</u>			DATE: <u>11-8-83</u> TEST NO: <u>1</u>	
NET PAY (ft): <u>120.0</u>			TYPE DST: <u>CASED HOLE</u>	
GROSS TESTED FOOTAGE: <u>421.0</u>			HALLIBURTON CAMP: <u>CORPUS CHRISTI</u>	
ALL DEPTHS MEASURED FROM: <u>KELLY BUSHING</u>			TESTER: <u>S.D. BLASKIEWICZ</u> <u>TOM SMITH</u>	
CASING PERFS. (ft): _____			WITNESS: <u>DAVE ALLMAN</u>	
HOLE OR CASING SIZE (in): <u>9.625</u>			DRILLING CONTRACTOR: <u>MAGEE POOLE #14</u>	
ELEVATION (ft): <u>0</u>				
TOTAL DEPTH (ft): <u>4128.0</u>				
PACKER DEPTH(S) (ft): <u>3707</u>				
FINAL SURFACE CHOKE (in): _____				
BOTTOM HOLE CHOKE (in): _____				
MUD WEIGHT (lb/gal): <u>8.70</u>				
MUD VISCOSITY (sec): _____				
ESTIMATED HOLE TEMP. (°F): <u>118</u>				
ACTUAL HOLE TEMP. (°F): <u>0</u> _____ ft				
FLUID PROPERTIES FOR RECOVERED MUD & WATER			SAMPLER DATA	
SOURCE	RESISTIVITY	CHLORIDES	Pslg AT SURFACE: _____	
_____	_____ °F	_____ ppm	cu.ft. OF GAS: _____	
_____	_____ °F	_____ ppm	cc OF OIL: _____	
_____	_____ °F	_____ ppm	cc OF WATER: _____	
_____	_____ °F	_____ ppm	cc OF MUD: _____	
_____	_____ °F	_____ ppm	TOTAL LIQUID cc: _____	
_____	_____ °F	_____ ppm		
HYDROCARBON PROPERTIES			CUSHION DATA	
OIL GRAVITY (°API): _____ °F			TYPE AMOUNT WEIGHT	
GAS/OIL RATIO (cu.ft. per bbl): _____			_____	
GAS GRAVITY: _____			_____	
<div style="display: flex; justify-content: space-between;"> <div style="width: 85%;"> <p style="margin: 0;">RECOVERED:</p> <p style="margin: 5px 0 0 40px;">2091 FEET OF DRILLING MUD</p> <p style="margin: 0 0 0 40px;">1352.9 FEET OF MUDDY FRESH WATER</p> </div> <div style="width: 10%; text-align: center; border-left: 1px solid black; padding-left: 5px;"> <p style="writing-mode: vertical-rl; transform: rotate(180deg); margin: 0;">MEASURED FROM TESTER VALVE</p> </div> </div>				
<p>REMARKS:</p> <p>TESTING OPEN HOLE BELOW CASING FROM 3757' TO 4138'.</p> <p>NET PAY IS FROM 3890' TO 4010'</p> <p>CASING WEIGHT IS 36#/FT.</p>				

TYPE & SIZE MEASURING DEVICE: _____	TICKET NO: <u>64058800</u>
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TYPE & SIZE MEASURING DEVICE: _____	TICKET NO: <u>64058800</u>
-------------------------------------	----------------------------

[illegible]

TICKET NO: 64058800

CLOCK NO: 18753 HOUR: 24

 HALLIBURTON
SERVICES

GAUGE NO: 499

DEPTH: 3696.9

REF	MINUTES	PRESSURE	ΔP	$\frac{t \times \Delta t}{t + \Delta t}$	$\log \frac{t + \Delta t}{\Delta t}$
FIRST FLOW					
B 1	0.0	1319.1			
2	1.0	1322.2	3.0		
3	2.0	1332.7	10.5		
4	3.0	1348.0	15.3		
5	4.0	1364.7	16.7		
6	5.0	1390.6	25.8		
7	6.0	1400.5	9.9		
8	7.0	1432.2	31.8		
9	8.0	1480.7	48.5		
10	9.0	1510.3	29.6		
11	10.0	1545.3	35.0		
C 12	10.5	1552.3	7.0		

FIRST CLOSED-IN					
C 1	0.0	1552.3			
2	1.0	1587.2	35.0	0.9	1.044
3	2.0	1587.2	35.0	1.6	0.802
4	3.0	1587.2	35.0	2.3	0.649
5	4.0	1587.2	35.0	2.9	0.555
6	5.0	1587.2	35.0	3.4	0.493
7	6.0	1587.2	35.0	3.8	0.437
8	7.0	1587.2	35.0	4.2	0.397
9	7.9	1587.2	35.0	4.5	0.365
10	9.0	1587.2	35.0	4.8	0.335
11	10.0	1587.2	35.0	5.1	0.311
12	30.0	1587.2	35.0	7.8	0.130
13	60.0	1587.2	35.0	8.9	0.070
14	90.0	1587.2	35.0	9.4	0.048
D 15	117.3	1588.1	35.9	9.6	0.037

SECOND FLOW					
E 1	0.0	1574.2			
2	1.0	1578.7	4.6		
3	2.0	1582.1	3.3		
4	3.0	1584.8	2.7		
5	4.0	1585.7	0.9		
6	5.0	1586.3	0.6		
7	10.0	1586.3	0.0		
8	20.0	1586.3	0.0		
9	30.0	1587.2	0.9		
10	40.0	1587.2	0.0		
11	50.0	1587.2	0.0		
F 12	56.3	1587.5	0.3		

SECOND CLOSED-IN					
F 1	0.0	1587.5			

REF	MINUTES	PRESSURE	ΔP	$\frac{t \times \Delta t}{t + \Delta t}$	$\log \frac{t + \Delta t}{\Delta t}$
SECOND CLOSED-IN - CONTINUED					
G 2	62.0	1591.6	4.1	32.1	0.317

REMARKS:

TICKET NO: 64058800

CLOCK NO: 2498 HOUR: 24

GAUGE NO: 378

DEPTH: 3722.8

REF	MINUTES	PRESSURE	ΔP	$\frac{t \times \Delta t}{t + \Delta t}$	$\log \frac{t + \Delta t}{\Delta t}$
FIRST FLOW					
B 1	0.0	1537.4			
2	1.0	1557.4	20.1		
3	2.0	1564.6	7.1		
4	3.0	1569.6	5.0		
5	4.0	1573.9	4.3		
6	5.0	1577.8	4.0		
7	6.0	1582.2	4.4		
8	7.0	1583.7	1.5		
9	8.0	1586.8	3.0		
10	9.0	1589.5	2.7		
11	10.0	1591.9	2.4		
C 12	10.5	1592.1	0.2		
FIRST CLOSED-IN					
C 1	0.0	1592.1			
2	1.0	1597.6	5.5	0.9	1.069
3	2.0	1597.6	5.5	1.7	0.787
4	3.0	1597.6	5.5	2.3	0.654
5	4.0	1597.6	5.5	2.9	0.561
6	5.0	1597.6	5.5	3.4	0.492
7	6.0	1597.6	5.5	3.8	0.438
8	7.0	1597.6	5.5	4.2	0.396
9	8.0	1597.6	5.5	4.5	0.364
10	9.0	1597.6	5.5	4.8	0.334
11	10.0	1597.6	5.5	5.1	0.311
12	30.0	1598.0	5.9	7.8	0.130
13	60.0	1598.0	5.9	8.9	0.070
14	90.0	1598.8	6.7	9.4	0.048
D 15	117.3	1599.7	7.6	9.6	0.037
SECOND FLOW					
E 1	0.0	1595.1			
2	1.0	1596.7	1.5		
3	2.0	1597.3	0.6		
4	3.0	1597.3	0.0		
5	4.0	1597.4	0.2		
6	5.0	1597.6	0.2		
7	10.0	1599.2	0.6		
8	20.0	1598.9	0.6		
9	30.0	1599.5	0.6		
10	40.0	1599.5	0.0		
11	50.0	1599.5	0.0		
F 12	56.3	1602.0	2.4		
SECOND CLOSED-IN					
F 1	0.0	1602.0			

REF	MINUTES	PRESSURE	ΔP	$\frac{t \times \Delta t}{t + \Delta t}$	$\log \frac{t + \Delta t}{\Delta t}$
SECOND CLOSED-IN - CONTINUED					
G 2	62.0	1602.0	0.0	32.1	0.317

REMARKS:

		O.D.	I.D.	LENGTH	DEPTH
1		DRILL PIPE.....	4.000	3.340	3616.6
5		CROSSOVER.....	5.625	2.875	0.9
51		PUMP OUT REVERSING SUB.....	5.625	2.750	1.0
5		CROSSOVER.....	5.625	2.750	1.6
1		DRILL PIPE.....	4.000	3.340	61.4
5		CROSSOVER.....	5.625	2.875	0.7
11		HANDLING SUB & CHOKE ASSEMBLY...	5.000	2.813	2.7
12		DUAL CIP VALVE.....	5.000	0.870	4.1
60		HYDROSPRING TESTER.....	5.000	0.750	5.0
80		AP RUNNING CASE.....	5.000	3.060	4.0
15		JAR.....	5.000	1.000	5.0
16		VR SAFETY JOINT.....	5.000	1.000	2.8
71		CASING PACKER.....	8.250	4.000	5.4
5		CROSSOVER.....	6.250	3.250	0.7
20		FLUSH JOINT ANCHOR.....	5.000	2.438	10.0
81		BLANKED-OFF RUNNING CASE.....	5.000		4.1
TOTAL DEPTH					4128.0

EQUIPMENT DATA

EQUATIONS FOR DST LIQUID WELL ANALYSIS

Transmissibility	$\frac{kh}{\mu} = \frac{162.6 QB}{m}$	$\frac{\text{md-ft}}{\text{cp}}$
Indicated Flow Capacity	$kh = \frac{kh}{\mu} \mu$	md-ft
Average Effective Permeability	$k = \frac{kh}{h}$	md
Damage Ratio	$DR = .183 \frac{P^* - P_f}{m}$	—
Theoretical Potential w / Damage Removed	$Q_1 = Q DR$	BPD
Approx. Radius of Investigation	$r_i = 4.63 \sqrt{kt}$	ft

EQUATIONS FOR DST GAS WELL ANALYSIS

Indicated Flow Capacity	$kh = \frac{1637 Q_g T}{m}$	md-ft
Average Effective Permeability	$k = \frac{kh}{h}$	md
Skin Factor	$S = 1.151 \left[\frac{m(P^*) - m(P_f)}{m} - \text{LOG} \frac{kt}{\phi \mu c_{frw}^2} + 3.23 \right]$	—
Damage Ratio	$DR = \frac{m(P^*) - m(P_f)}{m(P^*) - m(P_f) - 0.87 mS}$	—
Indicated Flow Rate (Maximum)	$AOF_1 = \frac{Q_g m(P^*)}{m(P^*) - m(P_f)}$	MCFD
Indicated Flow Rate (Minimum)	$AOF_2 = Q_g \sqrt{\frac{m(P^*)}{m(P^*) - m(P_f)}}$	MCFD
Approx. Radius of Investigation	$r_i = 0.032 \sqrt{\frac{kt}{\phi \mu c_i}}$	ft

APPENDIX B

Fesco Inc. Report of Downhole Pressure and
Temperature Data During Airlift Testing

FESCO Inc.
Petroleum Engineers

1408 EAST MAIN ST • 512 664-3479 • ALICE, TEXAS 78332

MCALLEN	512 686-7671	COMPOS	512 682-4124	EL CAMPO	713 543-9431
LARCOO	512 724-7501	REFUGIO	512 528-4644	BEVAN	713 775-1825
ODON	515 392-3621	VICTORIA	512 575-7533	KILGORE	214 984-4814

November 23, 1983 Page 1 of 2

FOR: University of Utah Research Institute
Research Park
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Test Date: 11-19-83

BHP Gage: 1"; 4000#; SN: 43903
1.25"; 40-240°F; SN: 14108

Well: Lackland Air Force Base No. 1

Field: Lackland Air Force Base

RESERVOIR PRESSURE BUILD-UP & TEMPERATURE SURVEY TESTS

Test Date	Time	Accum. Time			BHP, Psig @3400'	BHP, Temp. @3400'	Remarks
		Mins.	Hrs.	Days			
1983							
11-19	10:30 AM	0	0	0	1461	103.82	On bottom w/gages.
		5			1464	103.82	
		10			1464	103.82	Started Jetting Fluid.
		15			1465	103.82	
		20			1468	103.82	
11-19	10:40 AM	25			1394	103.82	
		30	.5		1398	104.46	
		35			1400	104.46	
		40			1430	104.46	
		45			1453	104.46	
		50			1459	104.46	
		55			1461	104.31	
		60	1		1461	104.31	
		65			1462	104.31	
		70			1463	104.15	
11-19	11:30 AM	75			1466	104.15	
		80			1382	104.15	
		85			1400	104.31	
		90	1.5		1398	104.31	
		95			1391	104.31	
11-19	12:00 N	100			1387	104.31	
		105			1396	104.46	
		110			1389	104.46	
		115			1384	104.46	
		120	2		1378	104.46	
11-19	12:30 PM	125			1392	104.62	
		130			1402	104.62	
		135			1441	104.62	
		140			1452	104.62	
		145			1457	104.46	
		150	2.5		1459	104.46	
		155			1459	104.31	
		160			1402	104.46	
		165			1382	104.46	
		170			1382	104.46	
11-19	1:00 PM	175			1378	104.46	
		180	3		1378	104.46	
		185			1376	104.46	
		190			1374	104.46	
		195			1380	104.46	
11-19	1:30 PM	200			1393	104.46	
		205			1385	104.46	
		210	3.5		1376	104.46	
		215			1382	104.46	
		220			1373	104.46	
11-19	2:00 PM	225			1373	104.46	
		230			1371	104.46	
		235			1371	104.46	
		240	4	.16	1371	104.46

FESCO Inc.
Petroleum Engineers

1408 EAST MAIN ST. • 512 664-3479 • ALICE, TEXAS 78332

MCALLEN 512 686-7671
LAREDO 512 724-7501
OZONA 915 392-3621

CORPUS 512 882-4124
REFUGIO 512 526-4644
VICTORIA 512 575-7533

EL CAMPO 713 543-9451
BRYAN 713 775-1825
KILGORE 214 984-4814

November 23, 1983 Page 2 of 2

FOR: University of Utah Research Institute
Research Park
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Test Date: 11-19-83

BHP Gage: 1"; 4000#; SN: 43903
1.25"; 40-240°F; SN: 14108

Well: Lockland Air Force Base No. 1

Field: Lackland Air Force Base

RESERVOIR PRESSURE BUILD-UP & TEMPERATURE SURVEY TESTS

Test Date	Time	Accum. Time			BHP, Psig @3400'	BHP, Temp. @3400'	Remarks
		Mins.	Hrs.	Days			
1983							
11-19	2:35 PM	245	4.08	.17	1400	104.46	
		250			1436	104.46	
		255			1445	104.46	
		260			1450	104.46	
		265			1451	104.46	
11-19	3:00 PM	270	4.5		1453	104.31	
		275			1454	104.31	
		280			1455	104.31	
		285			1456	104.31	
		290			1456	104.31	
11-19	3:30 PM	295	5		1457	104.15	
		300			1457	104.15	
		305			1458	104.15	
		310			1458	104.15	
		315			1458	104.15	
11-19	4:00 PM	320	5.5	.23	1459	104.00	
		325			1459	104.00	
		330			1459	104.00	
					1459	104.00	Off bottom w/gages.

Certified: FESCO Inc.

By: Gerald Morgan
Gerald Morgan

FESCO Inc.
Petroleum Engineers

1408 EAST MAIN ST. • 512 664-3479 • ALICE, TEXAS 78332

MCALLEN 512 686-7671
LAREDO 512 724-7501
OZONA 915 392-3773

CORPUS 512 882-4124
REFUGIO 512 526-4644
VICTORIA 512 575-7533

EL CAMPO 409 543-9451
BRYAN 409 775-1825
KILGORE 214 984-4814

November 23, 1983

FOR: University of Utah Research Institute
Research Park
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Field: Lackland Air Force Base

Gage: 1.25"; 40-240°; SN: 14108

Well: Lackland Air Force Base No. 1
Status: Shut in
Perfs.: Screen from 3790-3990'

Test Date: 11-20-83
Tbg. Size & Setting: 2 3/8" @ 508.78'
Zero Ref.: 17' above GL

TEMPERATURE SURVEY

<u>Depth, Ft.</u>	<u>Temp., °F</u>
Surface	48.67
100	86.71
500	90.32
1000	91.76
1500	94.09
2000	94.27
2100	94.27
2200	94.81
2300	94.81
2400	95.71
2500	96.26
2600	96.44
2700	96.98
2800	96.98
2900	97.16
3000	97.16
3100	98.06
3200	98.60
3300	99.86
3400	100.22

Remarks: 13 3/8" Casing to 1822' - 9 5/8" Casing to 3432' (Pkr.) - 7 " Casing to bottom of Screen @ 3990'

Certified: FESCO Inc.

By: Gerald Morgan
Gerald Morgan

APPENDIX C

Well Drilling Chronology

WELL DRILLING CHRONOLOGY

R. W. DIRKS PETROLEUM ENGINEER, INC.

Sheet D

UNIVERSITY OF UTAH RESEARCH INST. DRILLING RECORD

Page No. 1

LEASE Lackland AFB

WELL NO. 1 FIELD

Brewster County, Tx.

DATE	DETAILS OF OPERATIONS, DESCRIPTIONS & RESULTS
10-21-83	Present operation: Making up bit. Remarks: 18 hrs. rigging up Mapee-Poole; 10 hrs. nipping up Conductor pipe. Moved 13-3/8 casing to pipe rack and measured same: 1 hr. ream mouse hole and drill rat hole; 2 hrs. pick up, make up Bottom hole assembly.
10-22-83	1034 Present operation: Drilling. Remarks: 1/2 hr. rig service; 3 1/2 hrs. drilling; 1/2 hr. unplug flow line; 4 1/2 hrs. drilling; 1/2 hr. survey; 14 1/2 hrs. drilling.
10-23-83	1438 Present operation: Drilling. Remarks: 1/2 hr. rig service; 15 1/2 hrs. drilling; 1/2 hr. slug and survey; 2 1/2 hrs. TFB; 5 hrs. drilling.
10-24-83	1736 Present operation: Drilling. Remarks: 1/2 hr. rig service; 23 1/2 hrs. drilling. Background gas 12, Connection gas 0, Trip gas 0, Max. Gas 12, ROP 8.
10-25-83	1960 Present operation: Drilling. Remarks: 1/2 hr. rig service; 1/2 hrs. drilling; 1/2 hr. slug and survey; 3 hrs. TFB 3A.; 1/2 hr. ream from 1700' to 1745'; 19 hrs. drilling.
10-26-83	2046 Present operation: Circulate and condition. Remarks: 1/2 hr. rig service; 1 hr. drilling; 3 hrs. slug and TFE 4A: 4 1/2 hrs. drilling; 1/2 hr. short trip; 1 1/2 hrs. circulate and condition; 1/2 hr. slug and survey; 1 1/2 hrs. POH, laid down 2, 17 1/2" stabilizers; 1 1/2 hrs. rig up Dresser Atlas, TIH w/log tools. Tagged up @ 2043: 3 1/2 hrs. logging; 3 hrs. wireline coring; 2 1/2 hrs. rig down Dresser & TIH: 8 1/2 hrs. circulate and condition. Background gas 8 units, connection gas 0 units, trip gas 0 units: Max. Gas 8 units: ROP 7 units.
10-27-83	2046 Present operation: WOC. Remarks: 1 hr. circulating: 1 1/2 hrs. POH to run 13-3/8 casing: 1 hr. rig up casing crew: 3 1/2 hrs. wait on elevator bails: 8 hrs. ran 51 jts. 13-3/8 casing; 1/2 hr. rig up Halliburton: 1/2 hr. circulate and condition: 3 1/2 hrs. cement casing w/900 sks 85/15 Poz mix + 8% gel, 3% salt, mixed @ 12.7#/gal. Tailed in w/410 sks common cement. Mixed @ 15.6#/gal.: 4 1/2 hrs. WOC. Casing set @ 2043.
10-28-83	Present operation: Nipping up. Remarks: 2 hrs. wait on cement: 10 hrs. cut off 20' conductor + 13-3/8 surface casing. Weld on and test head to 1800 psi and held OK; 12 hrs. nipple up 13-5/8" BOP stack.
10-29-83	2379 Present operation: Drilling. Remarks: 4 hrs. finish nipping up and test BOP to 2000, Test OK: 1 hr. TIH and tag plug @ 1998: 1 hr. drill plug & 5' of new hole: 1/2 hr. test to 10 ppg, Test OK; 17 1/2 hrs. drilling. Mud Logger: Background gas 4 units, Max G 40 units. ROP 18
10-30-83	2742 Present operation: Drilling. Remarks: 1/2 hr. rig service; 5 1/2 hrs. drilling; 1 1/2 hrs. slug and survey: 4 hrs. TFB 22.1, pick up 2 stabilizers; 2 hrs. ream stabilizers back to bottom: 11 1/2 hrs. drilling. Mud Logger: Background gas 3 units, connection gas 3 units, Trip gas 6 units, Max Gas 6 units, ROP 12'/hr.
10-31-83	2983 Present operation: Drilling. Remarks: 1/2 hr. rig service; 8 1/2 hrs. drilling; 3 1/2 hrs. TFB #3B: 11 1/2 hrs. drilling. Mud Logger: Background gas 3 units, Connection gas 0 units, Trip gas 0 units, Max Gas 4 units.
11-1-83	3273 Present operation: Drilling. Remarks: 1/2 hr. rig service; 23 1/2 hrs. drilling. Mud Logger: Background gas 4 units, Connection gas 0 units, Trip Gas 0 units, Max Gas 4 units.

R. W. DIRKS PETROLEUM ENGINEER, INC.

Sheet D

UNIVERSITY OF UTAH RESEARCH INST.

DRILLING RECORD

Page No. 2

LEASE Lackland AFB

WELL NO. 1 FIELD

Bexar County, Texas

DATE		DETAILS OF OPERATIONS, DESCRIPTIONS & RESULTS
11-02-83	3707	Present operation: Drilling. Remarks: ½ hr. rig service; 8½ hrs. drilling; ½ hr. slug and survey; 4 hrs. TFB #4B; 10½ hrs. drilling. Mud Logger: Background gas 4 units, Connection gas 0 units, Trip Gas 0 units, Max Gas 4 units, ROP 22.
11-03-83	3764	Present operation: Running 9-5/8 liner. Remarks: 3 hrs. drilling. 1 hr. circulate bottoms up; ½ hr. 10 stands, short trip: 1½ hrs. circulate bottoms up: 1½ hrs. slug and survey: 1½ hrs. POH to log: 6½ hrs. log and temp. survey w/Dresser Atlas; 2 hrs. TIH and laid down 2 stabilizers; 1½ hrs. circulate and condition; 3 hrs. POH, laid down 2, 9" drill collars; 3 hrs. rig up to run 9-5/8 liner. Mud Logger: Background gas 4 units, Connection gas 0 units, Trip Gas 0 units, Max Gas 4 units, ROP 15.
11-04-83	3764	Present operation: WOC. Remarks: 1 hr. finish running 9-5/8 liner; 1 hr. rig down casing crew, rig up Halliburton; ½ hr. make up liner hanger; 2 hrs. TIH w/29 stands + 1 single of drill pipe and tag bottom; 1 hr. circulate bottoms up; ½ hr. set hanger @ 1837'; 2½ hrs. cement liner w/870 sks Class H w/4% gel. Liner set @ 3757. ½ hr. POH, 10 stands; ½ hr. reverse out; 1½ hrs. POH w/setting tool, laid down same; 1 hr. strap in hole w/BHA + 6 stands drill pipe: 12 hrs. WOC.
11-05-83	3766	Present operation: Cleaning mud tanks. Remarks: 2 hrs. WOC; ½ hr. TIH. Tag at 1401'; 1 hr. circulate while WOC; 2 hrs. drilling cement to 1756'; 3 hrs. circulate while WOC; 1 hr. drill cement to 1835' and tag top of liner at 1835'; 1½ hrs. circulate and condition; ½ hr. tests top to 10.1 mud - held fine; 1½ hrs. POH. Laid down 15 jts. drill pipe and pick up 8-3/4" bit; 1 hr. TIH to top liner and reamed out liner hanger; 1 hr. Finish in hole; 4 hrs. drill float equipment & 2' of new hole; 1 hr. test casing seat to 10.0 mud weight; 2 hrs. displace mud with fresh water; 1½ hrs. clean out mud tanks.
11-06-83	3973	Present operation: Drilling. Remarks: 2 hrs. wash mud tank; 4 hrs. build poly-mud; 12½ hrs. drilling; 3½ hrs. Trip bit 2-C. Laid down 4 jts. drill pipe: 1½ hrs. ream 3831-3955. ½ hr. drilling. Mud Logger: Background Gas 4 units; Max Gas 4 units. TOP 12.
11-07-83	4128	Present operation: Circulate and condition mud to log. Remarks: ½ hr. rig service; 3½ hrs. drilling; 2½ hrs. POH. Change bit, pick up 2 stabilizers and TIH w/BHA: 1 hr. cut and slip drill line; 1 hr. finish in hole; 2 hrs. ream from 3683-3998. Had under gauge hole from 3988-3998; 1 hr. drilling; ½ hr. circulating; 8 hrs. drilling; ½ hr. circulating; ½ hrs. 10 stands, short trip; 2 hrs. circulate and condition mud to log. Mud Logger: Background gas 4 units, Max Gas 4 units. ROP 15.
11-08-83	4128	Present operation; Test well w/Halliburton test tool. Remarks: 2 hrs. POH; 12½ hrs. rig up loggers, log w/Dresser Atlas Ran induction, compensated density, compensated neutron gamma ray plus temperature survey and shot 10 sidewall cores; 2½ hrs. wait on Halliburton test tools; 1½ hrs. pick and made up test tools; 2½ hrs. TIH, set packer @ 3707; 3 hrs. test well.
11-09-83	3788	Present operation: Underreaming. Remarks: 1½ hrs. test well w/Halliburton Test Tool; 3 hrs. chain out of hole; 2 hrs. TIH w/bit; 2½ hrs. circulate and condition; 2 hrs. strap out of hole; 2½ hrs. made up underreamer. TIH; 10½ hrs. underream.

R. W. DIRKS PETROLEUM ENGINEER, INC.

Sheet D

UNIVERSITY OF UTAH RESEARCH
INSTITUTE

DRILLING RECORD

Page No. 3

LEASE --- Jackson AFB ---

WELL NO. 1 FIELD

Bexar County, Texas

DATE		DETAILS OF OPERATIONS, DESCRIPTIONS & RESULTS
11-10-83	3856	Present operation: Underreaming. Remarks: 3 hrs. underreaming; 1 hr. circulate bottoms up; 2 hrs. POH, laid down underreamer; 5 1/4 hrs. pick up underreamer #2 and inspect drill collars; 1 hr. finish in hole; 11 1/2 hrs. underream.
11-11-83	3933	Present operation: Trip. Remarks: 2 hrs. underreaming; 1 hr. circulate out; 1 1/2 hrs. POH; 1/2 hr. change cutters on underreamer; 1 1/2 hrs. TIH w/reamer; 15 1/2 hrs. reaming; 1 1/2 hr. circulate bottoms up; 1/2 hr. POH.
11-12-83	3991	Present operation: Underreaming. Remarks: 2 hrs. TOH; 1 1/2 hrs. TIH w/8 1/2" bit; 2 hrs. wash and ream hole from 3933-4093; 1 1/2 hrs. circulate and condition; 2 hrs. TOH; 2 hrs. pick up underreamer #4 & TIH; 13 hrs. underreaming.
11-13-83	3991	Present operation: Rig up to Pump Acid. Remarks: 1 hr. circulate and condition; 2 hrs. TOH w/underreamer; 2 hrs. TIH w/8 1/2" bit and tag fill in rathole @ 4083; 1 1/2 hrs. circulate and condition; 2 hrs. POH, 7 stands and wait on rathole fill; 1/2 hr. TIH and tag @ 4077; 1 hr. circulate and condition; 1 1/2 hrs. POH to remove bit and bit sub; 2 hrs. TIH and tag @ 4077; 2 hrs. displace mud w/fresh water; 2 hrs. wash out mud tanks; 2 1/2 hrs. POH, 1 stand to 3983. Spotted 36 cu. ft. sand; 2 hrs. POH to 9-4/8" casing and wait on sand to settle; 1/2 hr. TIH and tag sand @ 3993; 2' below 16" hole; 1/2 hr. rig up to flush water w/7 1/2% HCl.
11-14-83	3991	Present operation: Gravel packing. Remarks: 1 hr. flushing water sand w/7 1/2% HCl acid; 1/2 hr. POH; 5 1/2 hrs. wait on elevator slips and lift nipple to pick up 7" screen. Handling tools furnished by Dowell unable to do job; 4 hrs. pick up 7" screen and 2-7/8" wash pipe; 4 hr. made up Dowell liner hanger and packer assembly; 4 1/2 hrs. TIH w/screen; 2 hrs. set packer and hanger @ 3430, test annular side of packer w/1000 psi and held okay; 3 1/2 hrs. gravel packing, unable to get gravel pack to screen out. 1 hr. made up additional 20 bbls. of gravel pack slurry.
11-15-83	3991	Present operation: Rig released @ 7:00 A.M. Remarks: 2 1/2 hrs. finish gravel packing and reverse out; 1/2 hr. rig down Dowell; 2 hrs. POH w/setting tool; 1 1/2 hrs. laid down 16 jts. tubing and set tool; 6 hrs. laid down drill collar and drill pipe; 11 1/2 hrs. nipple down BOP, nipple up tree. Clean out mud tanks.
11-16-83		Remarks: Rig down Magee-Poole and return all rentals. SDFN.
11-17-83		Remarks: Prepare well sight for completion rig.
11-18-83		Present operation: Logging w/Gearhart. Remarks: 2 1/2 hrs. wait on completion rig; 1 1/2 hrs. rig up rig; 8 hrs. rig up Gearhart and run CBL gamma Ray. Had trouble w/tool and panel.
11-19-83		Remarks: 2 hrs. jet water well; 1 hr. rig up Fesco unit in hole w/temperature survey tool and bottom hole pressure tool; 9 hrs. jetting well w/Fesco in hole recording data.
11-20-83		Present operation: Rig released @ 2:30 P.M. Remarks: 1 1/2 hrs. ran temperature survey w/Fesco; 4 hrs. jet well; 1/2 hr. POH. Laid down 15 jts. 2-3/8" tubing; 1 1/2 hrs. rig down Released rig.
11-21-83		Remarks: Load out air compressor, water pumps, water line and 2, 200 bbls. tanks.
11-28-83		Remarks: Cleaned up and restored location - FINAL REPORT

APPENDIX D

Drilling Bit Record

DRILLING RECORD

Page No. _____

DEVIATION (B.H.L.) _____
COMPANY ENGINEER R. W. Dirks Pet. Eng., Inc.

ELEVATIONS: GROUND _____
CASING HEAD 17.00 _____
TUBING HEAD _____
ROTARY DRIVE BUSHING 18.00 _____

APPROVED _____

[illegible]

APPENDIX E

Drilling Fluid Record

SHEET 8

MUD RECORD

Page No. 1

LEASE Lackland A.F.B. WELL NO. 1 FIELD Wildcat
TYPE _____ DISTRIBUTOR Milchem

[illegible]

APPENDIX F

High Resolution Temperature-Depth Data Recorded by
Southern Methodist University, February 16, 1984.

(Note that these depths are recorded from the ground surface.)

LOCATION: SAN ANTONIO, TEXAS

HOLE NAME: LACKLD#1

DATE MEASURED: 2/16/84

DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT		I	DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT	
		DEG C	DEG F	DEG C/KM	DEG F/100 FT				DEG C	DEG F	DEG C/KM	DEG F/100 FT
150.0	492.0	26.455	79.62	0.0	0.0	I	272.5	893.8	28.252	82.85	13.6	0.7
152.5	500.2	26.523	79.74	27.2	1.5	I	275.0	902.0	28.276	82.90	9.6	0.5
155.0	508.4	26.568	79.82	18.0	1.0	I	277.5	910.2	28.311	82.96	14.0	0.8
157.5	516.6	26.626	79.93	23.2	1.3	I	280.0	918.4	28.359	83.05	19.2	1.1
160.0	524.8	26.671	80.01	18.0	1.0	I	282.5	926.6	28.391	83.10	12.8	0.7
162.5	533.0	26.712	80.08	16.4	0.9	I	285.0	934.8	28.417	83.15	10.4	0.6
165.0	541.2	26.746	80.14	13.6	0.7	I	287.5	943.0	28.448	83.21	12.4	0.7
167.5	549.4	26.780	80.20	13.6	0.7	I	290.0	951.2	28.480	83.26	12.8	0.7
170.0	557.6	26.823	80.28	17.2	0.9	I	292.5	959.4	28.474	83.25	-2.4	-0.1
172.5	565.8	26.846	80.32	9.2	0.5	I	295.0	967.6	28.502	83.30	11.2	0.6
175.0	574.0	26.862	80.35	6.4	0.4	I	297.5	975.8	28.531	83.36	11.6	0.6
177.5	582.2	26.897	80.41	14.0	0.8	I	300.0	984.0	28.568	83.42	14.8	0.8
180.0	590.4	26.911	80.44	5.6	0.3	I	302.5	992.2	28.599	83.48	12.4	0.7
182.5	598.6	26.962	80.53	20.4	1.1	I	305.0	1000.4	28.628	83.53	11.6	0.6
185.0	606.8	26.998	80.60	14.4	0.8	I	307.5	1008.6	28.667	83.60	15.6	0.9
187.5	615.0	27.036	80.66	15.2	0.8	I	310.0	1016.8	28.704	83.67	14.8	0.8
190.0	623.2	27.090	80.76	21.6	1.2	I	312.5	1025.0	28.727	83.71	9.2	0.5
192.5	631.4	27.117	80.81	10.8	0.6	I	315.0	1033.2	28.751	83.75	9.6	0.5
195.0	639.6	27.160	80.89	17.2	0.9	I	317.5	1041.4	28.785	83.81	13.6	0.7
197.5	647.8	27.218	80.99	23.2	1.3	I	320.0	1049.6	28.815	83.87	12.0	0.7
200.0	656.0	27.255	81.06	18.1	1.0	I	322.5	1057.8	28.840	83.91	10.0	0.5
202.5	664.2	27.298	81.14	-14.8	-0.8	I	325.0	1066.0	28.867	83.96	10.8	0.6
205.0	672.4	27.340	81.21	21.6	1.2	I	327.5	1074.2	28.894	84.01	10.8	0.6
207.5	680.6	27.374	81.27	12.8	0.7	I	330.0	1082.4	28.926	84.07	12.8	0.7
210.0	688.8	27.408	81.33	18.4	1.0	I	332.5	1090.6	28.953	84.12	10.8	0.6
212.5	697.0	27.442	81.39	8.0	0.4	I	335.0	1098.8	28.975	84.16	8.8	0.5
215.0	705.2	27.476	81.45	11.2	0.6	I	337.5	1107.0	29.011	84.22	14.4	0.8
217.5	713.4	27.510	81.51	15.6	0.9	I	340.0	1115.2	29.034	84.26	9.2	0.5
220.0	721.6	27.544	81.57	12.8	0.7	I	342.5	1123.4	29.074	84.33	16.0	0.9
222.5	729.8	27.588	81.66	9.2	0.5	I	345.0	1131.6	29.103	84.39	11.6	0.6
225.0	738.0	27.632	81.73	15.2	0.8	I	347.5	1139.8	29.160	84.49	22.8	1.3
227.5	746.2	27.674	81.81	8.4	0.5	I	350.0	1148.0	29.189	84.54	11.6	0.6
230.0	754.4	27.720	81.90	10.4	0.6	I	352.5	1156.2	29.248	84.65	23.6	1.3
232.5	762.6	27.740	81.93	11.6	0.6	I	355.0	1164.4	29.300	84.74	20.8	1.1
235.0	770.8	27.768	81.98	16.4	0.9	I	357.5	1172.6	29.338	84.81	15.2	0.8
237.5	779.0	27.807	82.05	7.6	0.4	I	360.0	1180.8	29.401	84.92	25.2	1.4
240.0	787.2	27.839	82.11	22.0	1.2	I	362.5	1189.0	29.421	84.96	8.0	0.4
242.5	795.4	27.862	82.15	11.2	0.6	I	365.0	1197.2	29.453	85.02	12.8	0.7
245.0	803.6	27.900	82.22	12.4	0.7	I	367.5	1205.4	29.486	85.07	13.2	0.7
247.5	811.8	27.921	82.26	15.2	0.8	I	370.0	1213.6	29.511	85.12	10.0	0.5
250.0	820.0	27.947	82.30	12.0	0.7	I	372.5	1221.8	29.538	85.17	10.8	0.6

LOCATION: SAN ANTONIO, TEXAS

PAGE 2

0 0 0
HOLE NAME: LACKLD#1
DATE MEASURED: 2/16/84

DEPTH		TEMPERATURE		GEOTHERMAL GRADIENT		DEPTH		TEMPERATURE		GEOTHERMAL GRADIENT	
METERS	FEET	DEG C	DEG F	DEG C/KM	DEG F/100 FT	METERS	FEET	DEG C	DEG F	DEG C/KM	DEG F/100 FT
375.0	1230.0	29.592	85.27	21.6	1.2	477.5	1566.2	30.877	87.58	38.0	2.1
377.5	1238.2	29.639	85.35	18.8	1.0	480.0	1574.4	30.899	87.62	8.0	0.5
380.0	1246.4	29.690	85.44	20.4	1.1	482.5	1582.6	30.948	87.71	19.6	1.1
382.5	1254.6	29.737	85.53	18.8	1.0	485.0	1590.8	30.992	87.79	17.6	1.0
385.0	1262.8	29.765	85.58	11.2	0.6	487.5	1599.0	31.007	87.81	6.0	0.3
387.5	1271.0	29.856	85.74	36.4	2.0	490.0	1607.2	31.043	87.88	14.4	0.8
390.0	1279.2	29.835	85.70	-8.4	-0.5	492.5	1615.4	31.074	87.93	12.4	0.7
392.5	1287.4	29.859	85.75	9.6	0.5	495.0	1623.6	31.120	88.02	18.4	1.0
395.0	1295.6	29.890	85.80	12.4	0.7	497.5	1631.8	31.076	87.94	-17.6	-1.0
397.5	1303.8	29.927	85.87	14.8	0.8	500.0	1640.0	31.139	88.05	25.2	1.4
400.0	1312.0	29.961	85.93	13.6	0.7	502.5	1648.2	31.189	88.14	20.0	1.1
402.5	1320.2	29.982	85.97	8.4	0.5	505.0	1656.4	31.194	88.15	2.0	0.1
405.0	1328.4	30.005	86.01	9.2	0.5	507.5	1664.6	31.212	88.18	7.2	0.4
407.5	1336.6	30.027	86.05	8.8	0.5	510.0	1672.8	31.244	88.24	12.8	0.7
410.0	1344.8	30.051	86.09	9.6	0.5	512.5	1681.0	31.289	88.32	18.0	1.0
412.5	1353.0	30.082	86.15	12.4	0.7	515.0	1689.2	31.302	88.34	5.2	0.3
415.0	1361.2	30.114	86.21	12.8	0.7	517.5	1697.4	31.341	88.41	15.6	0.9
417.5	1369.4	30.147	86.26	13.2	0.7	520.0	1705.6	31.369	88.46	11.2	0.6
420.0	1377.6	30.185	86.33	15.2	0.8	522.5	1713.8	31.419	88.55	20.0	1.1
422.5	1385.8	30.180	86.32	-2.0	-0.1	525.0	1722.0	31.446	88.60	10.8	0.6
425.0	1394.0	30.222	86.40	16.8	0.9	527.5	1730.2	31.505	88.71	23.6	1.3
427.5	1402.2	30.256	86.46	13.6	0.7	530.0	1738.4	31.502	88.70	-1.2	-0.1
430.0	1410.4	30.305	86.55	19.6	1.1	532.5	1746.6	31.584	88.85	32.8	1.8
432.5	1418.6	30.321	86.58	6.4	0.4	535.0	1754.8	31.580	88.84	-1.6	-0.1
435.0	1426.8	30.344	86.62	9.2	0.5	537.5	1763.0	31.609	88.90	11.6	0.6
437.5	1435.0	30.374	86.67	12.0	0.7	540.0	1771.2	31.642	88.96	13.2	0.7
440.0	1443.2	30.402	86.72	11.2	0.6	542.5	1779.4	31.655	88.98	5.2	0.3
442.5	1451.4	30.388	86.70	-5.6	-0.3	545.0	1787.6	31.677	89.02	8.8	0.5
445.0	1459.6	30.422	86.76	13.6	0.7	547.5	1795.8	31.714	89.09	14.8	0.8
447.5	1467.8	30.508	86.91	34.4	1.9	550.0	1804.0	31.711	89.08	-1.2	-0.1
450.0	1476.0	30.492	86.89	-6.4	-0.4	552.5	1812.2	31.728	89.11	6.8	0.4
452.5	1484.2	30.574	87.03	32.8	1.8	555.0	1820.4	31.747	89.14	7.6	0.4
455.0	1492.4	30.607	87.09	13.2	0.7	557.5	1828.6	31.806	89.25	23.6	1.3
457.5	1500.6	30.591	87.06	-6.4	-0.4	560.0	1836.8	31.806	89.25	0.0	0.0
460.0	1508.8	30.641	87.15	20.0	1.1	562.5	1845.0	31.827	89.29	8.4	0.5
462.5	1517.0	30.628	87.13	-5.2	-0.3	565.0	1853.2	31.857	89.34	12.0	0.7
465.0	1525.2	30.716	87.29	35.2	1.9	567.5	1861.4	31.891	89.40	13.6	0.7
467.5	1533.4	30.734	87.32	7.2	0.4	570.0	1869.6	31.932	89.48	16.4	0.9
470.0	1541.6	30.783	87.41	19.6	1.1	572.5	1877.8	31.982	89.57	20.0	1.1
472.5	1549.8	30.783	87.41	0.0	0.0	575.0	1886.0	32.016	89.63	13.6	0.7
475.0	1558.0	30.782	87.41	-0.4	-0.0	577.5	1894.2	32.057	89.70	16.4	0.9

LOCATION: SAN ANTONIO, TEXAS

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 0 0 0
 HOLE NAME: LACKLAND
 DATE MEASURED: 2/16/84

DEPTH ETERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT		I	DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT	
		DEG C	DEG F	DEG C/KM	DEG F/100 FT				DEG C	DEG F	DEG C/KM	DEG F/100 FT
590.0	1902.4	32.097	89.77	16.0	0.9	I	682.5	2238.6	33.472	92.25	12.8	0.7
592.5	1910.6	32.125	89.83	11.2	0.6	I	685.0	2246.8	33.499	92.30	10.8	0.6
595.0	1918.8	32.155	89.89	12.0	0.7	I	687.5	2255.0	33.558	92.40	23.6	1.3
597.5	1927.0	32.184	89.93	11.6	0.6	I	690.0	2263.2	33.586	92.45	11.2	0.6
599.0	1935.2	32.207	89.97	9.2	0.5	I	692.5	2271.4	33.617	92.51	12.4	0.7
592.5	1943.4	32.234	90.02	10.8	0.6	I	695.0	2279.6	33.671	92.61	21.6	1.2
595.0	1951.6	32.266	90.08	12.8	0.7	I	697.5	2287.8	33.686	92.63	6.0	0.3
597.5	1959.8	32.300	90.14	13.6	0.7	I	700.0	2296.0	33.725	92.71	15.6	0.9
600.0	1968.0	32.327	90.19	10.8	0.6	I	702.5	2304.2	33.766	92.78	16.4	0.9
602.5	1976.2	32.364	90.26	14.8	0.8	I	705.0	2312.4	33.808	92.85	16.8	0.9
605.0	1984.4	32.399	90.32	14.0	0.8	I	707.5	2320.6	33.838	92.91	12.0	0.7
607.5	1992.6	32.438	90.39	15.6	0.9	I	710.0	2328.8	33.865	92.96	10.8	0.6
610.0	2000.8	32.479	90.46	16.4	0.9	I	712.5	2337.0	33.894	93.01	11.6	0.6
612.5	2009.0	32.518	90.53	15.6	0.9	I	715.0	2345.2	33.928	93.07	13.6	0.7
615.0	2017.2	32.544	90.58	10.4	0.6	I	717.5	2353.4	33.968	93.14	16.0	0.9
617.5	2025.4	32.565	90.62	8.4	0.5	I	720.0	2361.6	34.002	93.20	13.6	0.7
620.0	2033.6	32.589	90.66	9.6	0.5	I	722.5	2369.8	34.045	93.28	17.2	0.9
622.5	2041.8	32.614	90.71	10.0	0.5	I	725.0	2378.0	34.090	93.36	18.0	1.0
625.0	2050.0	32.644	90.76	12.0	0.7	I	727.5	2386.2	34.131	93.44	16.4	0.9
627.5	2058.2	32.677	90.82	13.2	0.7	I	730.0	2394.4	34.168	93.50	14.8	0.8
630.0	2066.4	32.715	90.89	15.2	0.8	I	732.5	2402.6	34.234	93.62	26.4	1.4
632.5	2074.6	32.738	90.93	9.2	0.5	I	735.0	2410.8	34.255	93.66	8.4	0.5
635.0	2082.8	32.780	91.00	16.8	0.9	I	737.5	2419.0	34.298	93.74	17.2	0.9
637.5	2091.0	32.822	91.08	16.8	0.9	I	740.0	2427.2	34.344	93.82	18.4	1.0
640.0	2099.2	32.863	91.15	16.4	0.9	I	742.5	2435.4	34.378	93.88	13.6	0.7
642.5	2107.4	32.901	91.22	15.2	0.8	I	745.0	2443.6	34.400	93.92	8.8	0.5
645.0	2115.6	32.938	91.29	14.8	0.8	I	747.5	2451.8	34.440	93.99	16.0	0.9
647.5	2123.8	32.983	91.37	18.0	1.0	I	750.0	2460.0	34.485	94.07	18.0	1.0
650.0	2132.0	33.022	91.44	15.6	0.9	I	752.5	2468.2	34.526	94.15	16.4	0.9
652.5	2140.2	33.054	91.50	12.8	0.7	I	755.0	2476.4	34.573	94.23	18.8	1.0
655.0	2148.4	33.093	91.57	15.6	0.9	I	757.5	2484.6	34.607	94.29	13.6	0.7
657.5	2156.6	33.126	91.63	13.2	0.7	I	760.0	2492.8	34.649	94.37	16.8	0.9
660.0	2164.8	33.187	91.74	24.4	1.3	I	762.5	2501.0	34.684	94.43	14.0	0.8
662.5	2173.0	33.194	91.75	2.8	0.2	I	765.0	2509.2	34.725	94.51	16.4	0.9
665.0	2181.2	33.271	91.89	30.8	1.7	I	767.5	2517.4	34.758	94.56	13.2	0.7
667.5	2189.4	33.265	91.88	-2.4	-0.1	I	770.0	2525.6	34.839	94.71	32.4	1.8
670.0	2197.6	33.305	91.95	16.0	0.9	I	772.5	2533.8	34.843	94.72	1.6	0.1
672.5	2205.8	33.336	92.00	12.4	0.7	I	775.0	2542.0	34.892	94.81	19.6	1.1
675.0	2214.0	33.376	92.08	16.0	0.9	I	777.5	2550.2	34.938	94.89	18.4	1.0
677.5	2222.2	33.466	92.24	36.0	2.0	I	780.0	2558.4	34.979	94.96	16.4	0.9
680.0	2230.4	33.440	92.19	-10.4	-0.6	I	782.5	2566.6	35.009	95.02	12.0	0.7

LOCATION: SAN ANTONIO, TEXAS

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HOLE NAME: LACKLAND#1
DATE MEASURED: 2/16/84

DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT		I	DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT	
		DEG C	DEG F	DEG C/KM	DEG F/100 FT				DEG C	DEG F	DEG C/KM	DEG F/100 FT
785.0	2574.8	35.051	95.09	16.8	0.9	I	897.5	2911.0	36.638	97.95	16.8	0.9
787.5	2583.0	35.234	95.42	73.2	4.0	I	890.0	2919.2	36.787	98.22	59.6	3.3
790.0	2591.2	35.154	95.28	-32.0	-1.8	I	892.5	2927.4	36.720	98.10	-26.8	-1.5
792.5	2599.4	35.244	95.44	36.0	2.0	I	895.0	2935.6	36.763	98.17	17.2	0.9
795.0	2607.6	35.260	95.47	6.4	0.4	I	897.5	2943.8	36.802	98.24	15.6	0.9
797.5	2615.8	35.379	95.68	47.6	2.6	I	900.0	2952.0	36.865	98.36	25.2	1.4
800.0	2624.0	35.368	95.66	-4.4	-0.2	I	902.5	2960.2	36.921	98.46	22.4	1.2
802.5	2632.2	35.421	95.76	21.2	1.2	I	905.0	2968.4	36.990	98.58	27.6	1.5
805.0	2640.4	35.574	96.03	61.2	3.4	I	907.5	2976.6	37.062	98.71	28.8	1.6
807.5	2648.6	35.500	95.90	-29.6	-1.6	I	910.0	2984.8	37.147	98.86	34.0	1.9
810.0	2656.8	35.652	96.17	60.8	3.3	I	912.5	2993.0	37.202	98.96	22.0	1.2
812.5	2665.0	35.683	96.23	12.4	0.7	I	915.0	3001.2	37.362	99.25	64.0	3.5
815.0	2673.2	35.609	96.10	-29.6	-1.6	I	917.5	3009.4	37.332	99.20	-12.0	-0.7
817.5	2681.4	35.702	96.26	37.2	2.0	I	920.0	3017.6	37.483	99.47	60.4	3.3
820.0	2689.6	35.681	96.23	-8.4	-0.5	I	922.5	3025.8	37.480	99.46	-1.2	-0.1
822.5	2697.8	35.716	96.29	14.0	0.8	I	925.0	3034.0	37.450	99.41	-12.0	-0.7
825.0	2706.0	35.754	96.36	15.2	0.8	I	927.5	3042.2	37.492	99.49	16.8	0.9
827.5	2714.2	35.892	96.61	55.2	3.0	I	930.0	3050.4	37.531	99.56	15.6	0.9
830.0	2722.4	35.822	96.48	-28.0	-1.5	I	932.5	3058.6	37.703	99.87	68.8	3.8
832.5	2730.6	35.954	96.72	52.8	2.9	I	935.0	3066.8	37.619	99.71	-33.6	-1.8
835.0	2738.8	35.931	96.68	-9.2	-0.5	I	937.5	3075.0	37.667	99.80	19.2	1.1
837.5	2747.0	36.025	96.85	37.6	2.1	I	940.0	3083.2	37.737	99.93	28.0	1.5
840.0	2755.2	35.958	96.72	-26.8	-1.5	I	942.5	3091.4	37.822	100.08	34.0	1.9
842.5	2763.4	35.986	96.77	11.2	0.6	I	945.0	3099.6	38.027	100.45	82.0	4.5
845.0	2771.6	36.021	96.84	14.0	0.8	I	947.5	3107.8	37.955	100.32	-28.8	-1.6
847.5	2779.8	36.051	96.89	12.0	0.7	I	950.0	3116.0	38.027	100.45	28.8	1.6
850.0	2788.0	36.121	97.02	28.0	1.5	I	952.5	3124.2	38.217	100.79	76.0	4.2
852.5	2796.2	36.120	97.02	-0.4	-0.0	I	955.0	3132.4	38.133	100.64	-33.6	-1.8
855.0	2804.4	36.190	97.14	28.0	1.5	I	957.5	3140.6	38.316	100.97	73.2	4.0
857.5	2812.6	36.193	97.15	1.2	0.1	I	960.0	3148.8	38.358	101.04	16.8	0.9
860.0	2820.8	36.232	97.22	15.6	0.9	I	962.5	3157.0	38.256	100.86	-40.8	-2.2
862.5	2829.0	36.306	97.35	29.6	1.6	I	965.0	3165.2	38.447	101.20	76.4	4.2
865.0	2837.2	36.307	97.35	0.4	0.0	I	967.5	3173.4	38.489	101.28	16.8	0.9
867.5	2845.4	36.353	97.44	18.4	1.0	I	970.0	3181.6	38.533	101.36	17.6	1.0
870.0	2853.6	36.380	97.48	10.8	0.6	I	972.5	3189.8	38.428	101.17	-42.0	-2.3
872.5	2861.8	36.415	97.55	14.0	0.8	I	975.0	3198.0	38.469	101.24	16.4	0.9
875.0	2870.0	36.449	97.61	13.6	0.7	I	977.5	3206.2	38.650	101.57	72.4	4.0
877.5	2878.2	36.487	97.68	15.2	0.8	I	980.0	3214.4	38.551	101.39	-39.6	-2.2
880.0	2886.4	36.514	97.73	10.8	0.6	I	982.5	3222.6	38.718	101.69	66.8	3.7
882.5	2894.6	36.552	97.79	15.2	0.8	I	985.0	3230.8	38.771	101.79	21.2	1.2
885.0	2902.8	36.596	97.87	17.6	1.0	I	987.5	3239.0	38.698	101.66	-29.2	-1.6

LOCATION: SAN ANTONIO, TEXAS

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HOLE NAME: LACKLD#1
DATE MEASURED: 2/16/84

DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT		DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT	
		DEG C	DEG F	DEG C/KM	DEG F/100 FT			DEG C	DEG F	DEG C/KM	DEG F/100 FT
990.0	3247.2	38.723	101.70	10.0	0.5	1092.5	3583.4	40.572	105.03	19.2	1.1
992.5	3255.4	38.899	102.02	70.4	3.9	1095.0	3591.6	40.622	105.12	20.0	1.1
995.0	3263.6	38.941	102.09	16.8	0.9	1097.5	3599.8	40.669	105.20	18.8	1.0
997.5	3271.8	38.848	101.93	-37.2	-2.0	1100.0	3608.0	40.707	105.27	15.2	0.8
000.0	3280.0	39.005	102.21	62.8	3.4	1102.5	3616.2	40.750	105.35	17.2	0.9
002.5	3288.2	39.039	102.27	13.6	0.7	1105.0	3624.4	40.803	105.45	21.2	1.2
005.0	3296.4	38.985	102.17	-21.6	-1.2	1107.5	3632.6	40.843	105.52	16.0	0.9
007.5	3304.6	39.029	102.25	17.6	1.0	1110.0	3640.8	40.885	105.59	16.8	0.9
010.0	3312.8	39.216	102.59	74.8	4.1	1112.5	3649.0	40.927	105.67	16.8	0.9
012.5	3321.0	39.115	102.41	-40.4	-2.2	1115.0	3657.2	40.971	105.75	17.6	1.0
015.0	3329.2	39.313	102.76	79.2	4.3	1117.5	3665.4	41.016	105.83	18.0	1.0
017.5	3337.4	39.217	102.59	-38.4	-2.1	1120.0	3673.6	41.056	105.90	16.0	0.9
020.0	3345.6	39.265	102.68	19.2	1.1	1122.5	3681.8	41.093	105.97	14.8	0.8
022.5	3353.8	39.456	103.02	76.4	4.2	1125.0	3690.0	41.133	106.04	16.0	0.9
025.0	3362.0	39.360	102.85	-38.4	-2.1	1127.5	3698.2	41.174	106.11	16.4	0.9
027.5	3370.2	39.551	103.19	76.4	4.2	1130.0	3706.4	41.215	106.19	16.4	0.9
030.0	3378.4	39.438	102.99	-45.2	-2.5	1132.5	3714.6	41.259	106.27	17.6	1.0
032.5	3386.6	39.464	103.04	10.4	0.6	1135.0	3722.8	41.410	106.54	60.4	3.3
035.0	3394.8	39.514	103.13	20.0	1.1	1137.5	3731.0	41.338	106.41	-28.8	-1.6
037.5	3403.0	39.691	103.44	70.8	3.9	1140.0	3739.2	41.362	106.45	9.6	0.5
040.0	3411.2	39.723	103.50	12.8	0.7	1142.5	3747.4	41.383	106.49	8.4	0.5
042.5	3419.4	39.607	103.29	-46.4	-2.5	1145.0	3755.6	41.407	106.53	9.6	0.5
045.0	3427.6	39.610	103.30	1.2	0.1	1147.5	3763.8	41.431	106.58	9.6	0.5
047.5	3435.8	39.615	103.31	2.0	0.1	1150.0	3772.0	41.493	106.69	24.8	1.4
050.0	3444.0	39.764	103.58	59.6	3.3	1152.5	3780.2	41.493	106.69	0.0	0.0
052.5	3452.2	39.811	103.66	18.8	1.0	1155.0	3788.4	41.537	106.77	17.6	1.0
055.0	3460.4	39.862	103.75	20.4	1.1	1157.5	3796.6	41.556	106.80	7.6	0.4
057.5	3468.6	39.918	103.85	22.4	1.2	1160.0	3804.8	41.595	106.87	15.6	0.9
060.0	3476.8	39.964	103.94	18.4	1.0	1162.5	3813.0	41.626	106.93	12.4	0.7
062.5	3485.0	39.995	103.99	12.4	0.7	1165.0	3821.2	41.819	107.27	77.2	4.2
065.0	3493.2	40.029	104.05	13.6	0.7	1167.5	3829.4	41.687	107.04	-52.8	-2.9
067.5	3501.4	40.089	104.16	24.0	1.3	1170.0	3837.6	41.728	107.11	16.4	0.9
070.0	3509.6	40.136	104.24	18.8	1.0	1172.5	3845.8	41.757	107.16	11.6	0.6
072.5	3517.8	40.182	104.33	18.4	1.0	1175.0	3854.0	41.785	107.21	11.2	0.6
075.0	3526.0	40.222	104.40	16.0	0.9	1177.5	3862.2	41.816	107.27	12.4	0.7
077.5	3534.2	40.266	104.48	17.6	1.0	1180.0	3870.4	41.866	107.36	20.0	1.1
080.0	3542.4	40.314	104.57	19.2	1.1	1182.5	3878.6	41.885	107.39	7.6	0.4
082.5	3550.6	40.363	104.65	19.6	1.1	1185.0	3886.8	41.900	107.42	6.0	0.3
085.0	3558.8	40.412	104.74	19.6	1.1	1187.5	3895.0	41.919	107.45	7.6	0.4
087.5	3567.0	40.467	104.84	22.0	1.2	1190.0	3903.2	41.942	107.50	9.2	0.5
090.0	3575.2	40.524	104.94	22.8	1.3	1192.5	3911.4	41.966	107.54	9.6	0.5

LOCATION: SAN ANTONIO, TEXAS

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HOLE NAME: LACKLD#1
DATE MEASURED: 2/16/84

DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT		DEPTH METERS	DEPTH FEET	TEMPERATURE		GEOTHERMAL GRADIENT	
		DEG C	DEG F	DEG C/KM	DEG F/100 FT			DEG C	DEG F	DEG C/KM	DEG F/100 FT
95.0	3919.6	41.999	107.60	12.8	0.7	1202.5	3944.2	42.091	107.76	17.2	0.9
97.5	3927.8	42.020	107.64	8.8	0.5	1205.0	3952.4	42.125	107.83	13.6	0.7
100.0	3936.0	42.048	107.69	11.2	0.6	1207.5	3960.6	42.159	107.89	13.6	0.7