GL01649

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BACA PROJECT
GEOTHERMAL DEMONSTRATION POWER PLANT

FINAL REPORT

Prepared for the
U.S.Department of Energy
San Francisco Operations Office
1333 Broadway
Oakland, California 94612

Under Cooperative Agreement ET-78-F-03-1717

December 1982

Union Oil Company of California
Union Geothermal Division

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FINAL REPORT
WELL AND STEAM PRODUCTION SYSTEM TASK WBS 1.1
BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT
REDONDO CREEK AREA, BACA LOCATION, NEW MEXICO

Report Overview

Attachments to Section 9

9A. Energy Development in Northwestern New Mexico: A Civil Rights Perspective, Section III E, January 1982.

9B. Letter from Union Oil Company regarding Attachment 9A.

Geologic Plates for Section 3

Plates 3.1-1, 3.1-2, 3.2-1, 3.2-2, 3.5-1, 3.5-2, 3.5-3
Located in pocket on inside of back cover.

REPORT OVERVIEW

The final report describes the various activities that have been conducted by Union in the Redondo Creek area while attempting to develop the resource for a 50 MW power plant. The results of the geologic work, drilling activities and reservoir studies are summarized below. In addition, the report contains sections discussing the historical costs for Union's involvement with the project, production engineering (for anticipated surface equipment), and environmental work.

Nineteen geothermal wells have been drilled in the Redondo Creek area of the Valles Caldera: a prominent geologic feature of the Jemez mountains consisting of Pliocene and Pleistocene age volcanics. The Redondo Creek area is within a complex longitudinal graben on the northwest flank of the resurgent structural dome of Redondo Peak and Redondo Border. The major graben faults, with associated fracturing, are geologically plausible candidates for permeable and productive zones in the reservoir. The distribution of such permeable zones is too erratic and the locations too imprecisely known to offer an attractive drilling target. Log analysis indicates there is a preferred mean fracture strike of N31W in the upper portion of Redondo Creek wells. This is approximately perpendicular to the major structure in the area, the northeast-striking Redondo Creek graben. Additional information must be obtained from the hot, permeable intervals of several Redondo Creek wells before any definitive correlation among preferred fracture strike, well direction, and well productivity can be drawn.

The geothermal fluid found in the Redondo Creek reservoir is relatively benign with low brine concentrations and moderate H_2S concentrations. Geothermometer calculations indicate that the reservoir temperature generally lies between 500°F and 600°F, with near wellbore flashing occurring during the majority of the wells' production.

Of the nineteen Redondo Creek wells, eight wells have been drilled since 1977. Two of these wells were successfully completed as commercial wells: Baca Nos. 20 and 24. Baca No. 20 was later recompleted during the hydraulic stimulation work conducted on it and Baca No. 23. Both stimulations were mechanically successful; however, production characteristics for the wells were subcommercial following the treatments. Three attempts were also made to obtain production from formations deeper than the Bandelier Tuff - Paleozoic Limestone and Pre-Cambrian Granite - but were unsuccessful due to low permeability or completion problems.

With the loss of Baca No. 11 (faulty casing), four commercial wells remain; Baca Nos. 4, 13, 15 and 24. These wells have an initial steam production of 268,000 lb/hr and a one year projected flow rate of between 174,000 lb/hr and 264,000 lb/hr.

From a reservoir point of view, the primary Redondo Creek reservoir is located within the "Contact Zone" consisting of the bottom of the Bandelier Tuff and the top of the Andesite. This relatively high permeability and porosity zone controls the reservoir pressure of the field and dominates all commercial wells. These commercial wells have wellbore temperatures of at least 500°F at 5500' MSL while subcommercial wells are below 480°F.

Several reservoir characteristics have been identified during recent Redondo Creek testing. Interference testing has identified three reservoir cells which communicate through relatively thin sections of the reservoir. The permeability of the wells range from 1,000 to 10,000 md-ft, with an average reservoir property of 4000 md-ft. While substantial fluid and energy exist in the Redondo Creek reservoir, there is a low frequency of drilling a well which intersects the reservoir zones controlling commercial production.

SECTION 1: INTRODUCTION

1.1 Project Definition

The Baca Geothermal Demonstration Power Plant (GDPP) Project was organized and cost shared under a cooperative agreement bringing together Union Oil Company of California (Union Geothermal Company of New Mexico), Public Service Company of New Mexico and the U.S. Department of Energy as partners in a joint undertaking. This demonstration project plays a significant role in the Geothermal Commercialization Plan of the Federal Government's Coordinated Program of Research and Development in Geothermal Energy. The goal of the federal government's geothermal energy program is to stimulate the economic, reliable, operationally safe and environmentally and socially acceptable commercial development of this energy resource.

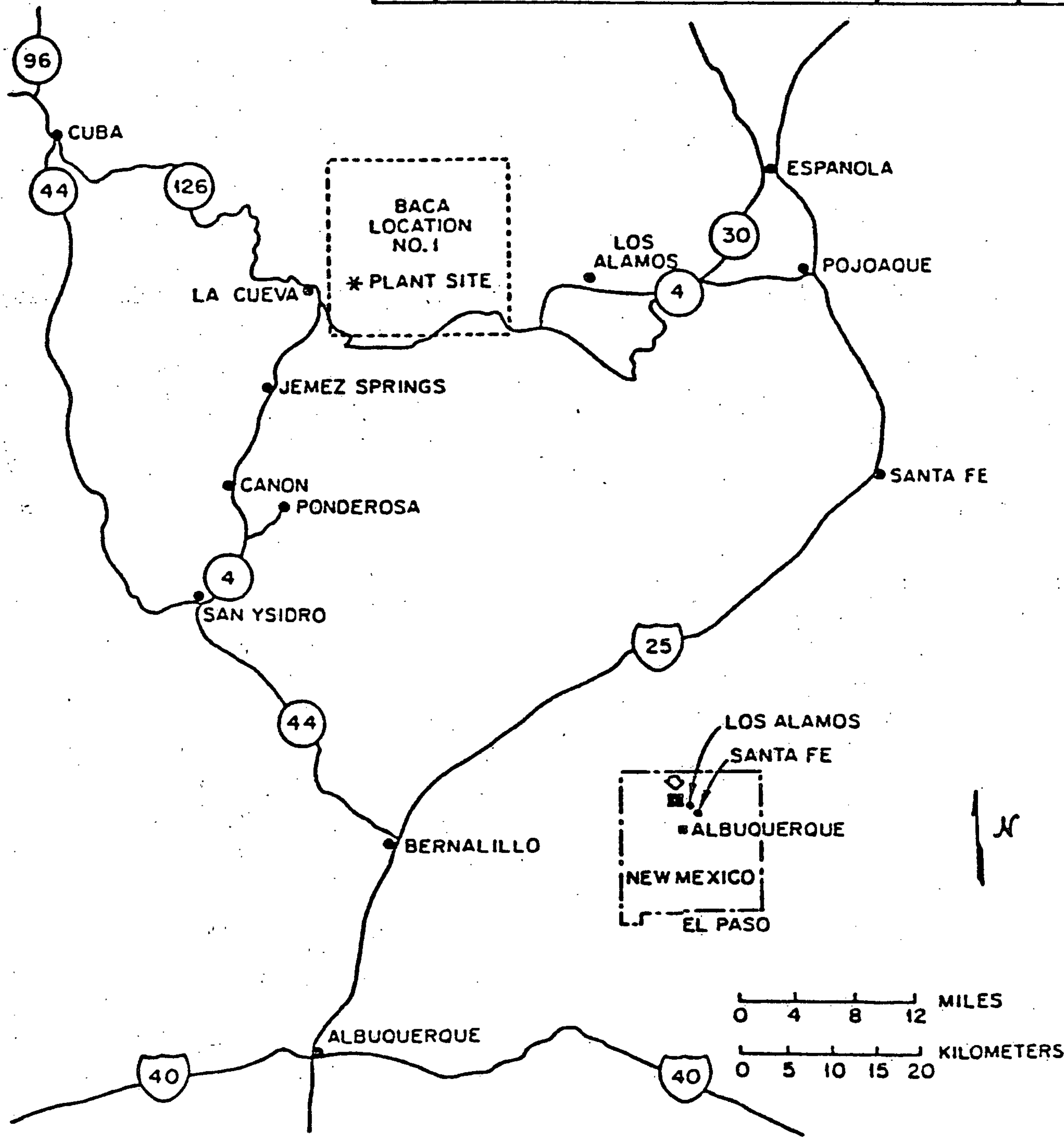
1.2 Summary

The Baca GDPP Project site is located in the Redondo Creek area of the Baca Ranch in north central New Mexico approximately 60 miles north of Albuquerque and 19 miles west of Los Alamos, as shown on Figure 1.2-1. The property is vested in the Baca Land and Cattle Company and Dunigan Enterprises, Inc. with the geothermal rights associated with the lands being leased to Union Geothermal Company of New Mexico, a wholly owned subsidiary of the Union Oil Company of California. The total bounded area is approximately 12.5 miles square and contains approximately 98,300 acres (Figure 1.2-2).

The project site is situated along Redondo Creek within the Valles Caldera, a major volcanic crater superimposed upon the western margin of the Rio Grande rift.

The geothermal potential of the Valles Caldera was recognized in the early 1960's after the drilling of four exploratory wells in the Sulphur Creek area and confirmed in 1970 with the drilling of the discovery well, Baca No. 4, in the Redondo Creek area. After leasing approximately 98,300 acres of the Baca Ranch in 1971, Union began development of the Redondo Creek area with the deepening of Baca No. 4 in 1973. The drilling program continued with the drilling of eighteen additional wells and the deepening of two wells.

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
O	APPROVAL RELEASE	3/31/80	A.V.	



UNION 76	Union Geothermal Company of New Mexico
	REDONDO CREEK UNIT NO. 1
DESIGN	REGIONAL MAP
DRAWN: ANDRE' VIGIL	BACA PROJECT — NEW MEXICO
CHECK	SIZE A — AFE NO. — DWG. NO. RC1-GN-07 — REV O
DATE	SCALE n/a — SHEET 1 of 1

FIGURE 1.2-1

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REV	DESCRIPTION	DATE	BY	APP'D
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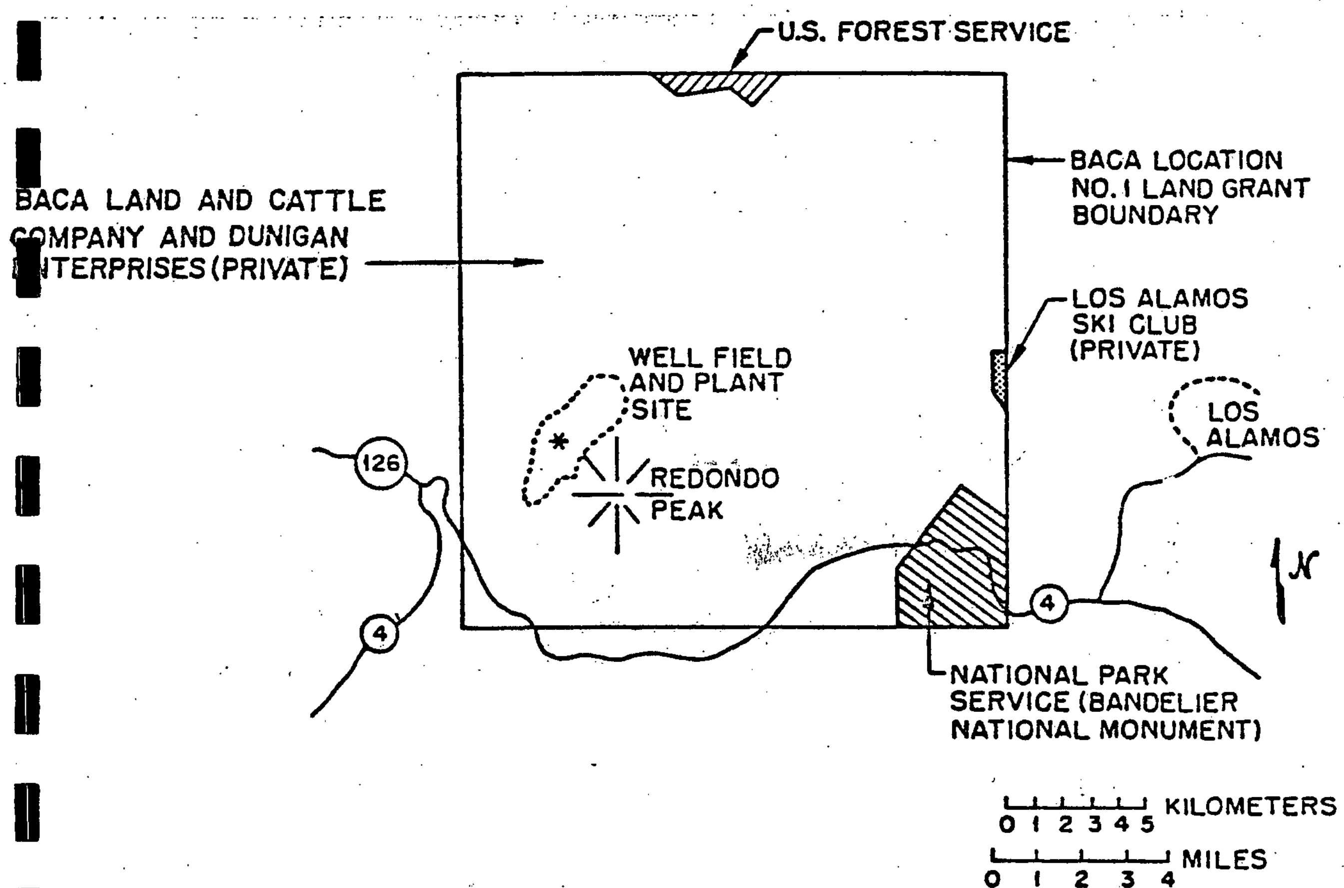


UNION 76	Union Geothermal Company of New Mexico			
	REDONDO CREEK UNIT NO. 1			
DESIGN	SURFACE OWNERSHIP			
DRAWN: Andre Vigil	BACA PROJECT — NEW MEXICO			
CHECK	SIZE A	AFE NO.	DWG. NO. RC1-GN-08	REV O
DATE	SCALE n/a		SHEET 1 of 1	

FIGURE 1.2-2

Public Service Company of New Mexico (PNM), whose service area surrounds the Jemez Mountains area containing the Baca Ranch, joined with Union in 1977 in feasibility studies for siting a 50 Mw flashed steam power plant in the Redondo Creek area. In January 1978, Union and PNM jointly proposed to the U.S. Department of Energy (DOE) for supportive funding of the plant as a hydrothermal (liquid-dominated resource) demonstration project. DOE subsequently accepted their proposal and funding was approved under a cost-sharing Cooperative Agreement between DOE and the Participant (comprised of Union and PNM). The effective date of the Cooperative Agreement was July 14, 1978.

At the time of the proposal to DOE, Union had drilled eleven wells (including deepening Baca No. 4) five of which had proven to be productive. One wellbore had collapsed, but the remaining four wells were producible at a combined rate of 320,000 lb/hr of steam, about one-third the required steam supply. It was estimated that up to ten more successful wells would be required to supply an additional 600,000 lb/hr of steam to meet the total requirement of the proposed 50 Mw plant.

From the time work began under the Cooperative Agreement to April 1981, twelve bottom hole locations had been drilled from seven wells, but only 30,000 lb/hr of additional steam had been developed.

In April 1981, a thorough technical review of drilling and testing activities was conducted. The principle conclusions derived from the review were:

1. The resource is an extensive, high temperature hydrothermal system containing fluids with benign chemical characteristics.

2. Geochemical data suggest produced fluids are originally from a common aquifer at depths below the then current completion depths in the lower Bandelier Tuff in Redondo Creek.

3. The lower Bandelier Tuff in Redondo Creek possesses insufficient distribution of natural fractures to justify the drilling and completion of future development wells solely in this zone.

4. Continued experimentation with existing wells to refine and improve hydraulically fracturing of wells appeared justified based on the qualified success of a recent first attempt in Redondo Canyon.

Based on this technical review, Union proposed a program for the remainder of 1981, the successful completion of which would dictate the viability of resumption of all phases of the project. The program consisted of drilling three deep attempts to test the productivity of the Magdalena Limestone and the upper part of the basement complex (mostly granite), and to hydraulically fracture two existing wells in the Bandelier Tuff and lower competent formations.

In the eight months following the proposed deep drilling and stimulation test program, three attempts were made to achieve a Magdalena Limestone/granite formation producer and none proved successful. One frac stimulation was performed and it, too, did not result in a commercial producer.

Further drilling to deep horizons could no longer be justified as the cost of a completed well, estimated at $3.0 million, would be economically prohibitive for the remaining wells needed to supply the 50 Mw power plant. Consequently, in January 1982, it was mutually agreed by all parties involved in the GDPP project -- Union, DOE and PNM -- that the project was no longer commercially viable and should be terminated.

This final report is provided to describe the various activities that have been conducted by Union in the Redondo Creek area since activity began in 1973 in the attempts to develop the resource for the proposed 50 Mw power plant. Included are sections on geology, drilling, reservoir engineering, production engineering and environmental work. Also included is a section presenting the historical costs for Union's involvement with the project.

Primarily only those activities for which Union was responsible under WBS Element 1.1 are included in the following descriptions of work performed for the Baca GDPP Project.

SECTION 2: BACKGROUND

2.1 Federal Geothermal Demonstration Program

Geothermal energy is one of several domestic energy sources being developed to reduce the United States' dependence on fossil fuels for power generation. The U.S. Department of Energy (DOE) has estimated that geothermal energy could provide as much as 5 percent of the United States' electric power generation capability if fully developed using today's technology. Geothermal energy has distinct advantages over other alternative sources such as solar and wind energy in that no energy storage system is required, little land area is required and conversion equipment is commercially available.

The Federal Geothermal Demonstration Program of DOE was established to aid and accelerate geothermal resource identification, development and commercialization in an environmentally and socially responsible manner. The program's main thrust is the development of hydrothermal resources; however, other areas such as geopressured (high pressure hot water with dissolved methane gas) and hot dry rock resources are also being investigated. Hydrothermal resources are the most available and most easily developed at this time.

Hydrothermal resources are generally of two types: vapor (steam)-dominated and liquid-dominated. The best known example of a vapor-dominated resource in the United States is the Geysers Known Geothermal Resource Area (KGRA) in northern California. Commercial development of the Geysers KGRA for electric power generation began as early as 1960, when a twelve megawatt generating station was completed. Large scale development did not become economically or technologically feasible until the 1970's, at which time additional units were brought on line. Current capacity is about 750 Mw and additional units are under construction. Further development is expected to bring capacity up to 2000 megawatts by the mid-1980's. While the Geysers KGRA has demonstrated the feasibility of tapping vapor-dominated resources on a large scale, this type of resource in which relatively pure, dry steam is produced is comparatively rare in the United States.

Liquid-dominated hydrothermal resources, on the other hand, are widely distributed throughout the United States; however, they have not been extensively developed. This type of resource is characterized by relatively high temperature water and steam in a wide range of salinity, depending on the particular resource. The chief difference in utilization of this type of resource (as compared to vapor-dominated) is that the energy in the geothermal fluid is not suitable for direct use in a steam turbine. The fluid must either be flashed to separate the steam fraction for direct use, or the heat of the geothermal fluid transferred to a working fluid that can be used directly to drive a turbine. While technology has been readily available to accomplish either scheme, implementation has not proceeded due to uncertainties in the costs, performance, environmental, legal and institutional impacts of large scale utilization.

Given the above setting, DOE initiated a Geothermal Demonstration Program that included the proposed utilization of a liquid-dominated hydrothermal resource for large scale electric power generation. In September 1977, a Program Opportunity Notice (PON) EG-77-N-03-1717 was issued which solicited proposals for the construction and operation of a plant as a cooperative venture with DOE. The PON required that the commercial scale demonstration plant use only geothermal energy from a liquid-dominated resource for generation and meet all applicable regulatory and environmental requirements. Included was the requirement for a program for the collection, reduction and public dissemination of all data appropriate to the project. In response to the PON, two proposals were submitted to DOE. Of these, the proposal for the Baca Geothermal Demonstration Power Plant (GDPP) development was judged to be the more complete and most likely to attain the project objectives. Also the proposed utilization of the Baca Location No. 1 KGRA was considered to represent a good example of the relatively low salinity, high temperature type of reservoir common to many KGRA's. On the basis of DOE's evaluation, the proposal for development of the Baca resource from Union Geothermal Company of New Mexico (Union) and Public Service Company of New Mexico (PNM) was accepted on July 5, 1978 for the geothermal demonstration program.

2.2 Project Cooperative Agreement

As a result of the acceptance of the Baca GDPP Project Proposal, negotiations began on a project Cooperative Agreement between the Department of Energy (DOE) and the project Participant (comprised of Union Geothermal Company of New Mexico and Public Service Company of New Mexico). The final Agreement was signed in April 1979, providing for joint participation in the Baca GDPP Project between DOE and the Participant. The effective date of the Agreement was July 14,

1978. The final Agreement called for a schedule which included a five-year operational phase commencing with firm operation of the generating plant. This operational phase was anticipated to last until approximately March 1, 1987, under the original schedule.

In January 1981 the Cooperative Agreement was modified to increase the DOE cost ceiling to offset extra costs suffered by the Participant due to delays in preparation by DOE of a Final Environmental Impact Statement. This modification reduced the operational phase from five years to two years.

The Agreement delineated the responsibilities of DOE and the Participant in the development of the resource and defined the cost and revenue sharing arrangements for the different portions of the project.

2.2.1 Project Management

Successful accomplishment of the project objectives dictated close coordination of the efforts of the three parties involved. To this end the Cooperative Agreement set forth a Project Management Plan to monitor and direct the progress of the project, and ensure that budgetary and schedule constraints were adhered to.

The Project Management Plan provided for a DOE Project Manager (DPM) and a Participant Project Manager (PPM). The role of the PPM was to provide planning, direction and control of the project within established project objectives, schedule and cost estimates. The DPM acted on behalf of and reported to DOE's San Francisco Operations Office, which had primary responsiblity for the management and administration of the project for DOE. DOE Headquarters in Washington D.C. was responsible for coordinating specific project objectives within the framework of the overall Geothermal Demonstration Program objectives. DOE Headquarters retained final authority on changes to the technical, schedule and cost parameters established in the Cooperative Agreement.

The Participant's project management team was headed by an Operating Committee composed of Union Geothermal Company of New Mexico (Union) and Public Service Company of New Mexico (PNM) technical and executive managers. Considerable authority was delegated by the Operating Committee to the Participant Project Manager (PPM), who was the primary liaison with DOE. The PPM had freedom to allocate his assigned resources as required to meet the project objectives. Work on specific areas in the project Work Breakdown Structure (described in Section 2.2.2) was assigned to functional managers that reported functionally to the PPM and administratively to their departments in Union or PNM. This resulted in a matrix-type organization well suited to a joint venture such as this. An organization chart for the GDPP Project is shown in Figure 2.2-1.

2.2.2 Work Breakdown Structure (WBS)

Specific tasks in the overall Project scope of work were assigned to Union Geothermal Company of New Mexico (Union) and Public Service Company of New Mexico (PNM) by the Project Cooperative Agreement. A Work Breakdown Structure (WBS) detailing these assignments is shown in Figure 2.2-2.

WBS 1.1 consisted of the Well and Steam Production System Task. This included well drilling, design and construction of the gathering system, associated environmental monitoring and permitting geologic exploration, surveying, production system operation during the demonstration period and other wellsite-related tasks. Union was responsible for work in this task area.

WBS 1.2 encompassed the Power Plant and Transmission System Task. This included power plant and transmission system design and construction, environmental studies and permits for the power plant and transmission corridor, construction management and power plant operation during the demonstration period. PNM was responsible for work in this task area.

WBS 1.3 comprised the Data Gathering, Evaluation and Dissemination Task, wherein project data and information were acquired, analyzed and distributed on request to information users. This task was solely funded by DOE. It was administered by the Participant Project Manager in close cooperation with the DOE Project Manager. Work on this task was performed by WESTEC Services, Inc. under a subcontract with the Participant.

As mentioned in Section 1.2, this report will address only those activities that are pertinent to WBS Element 1.1.

2.2.3 Cost and Revenue Sharing

Under the Cooperative Agreement, the total estimated cost shared obligation agreed to by Union, PNM and DOE totaled

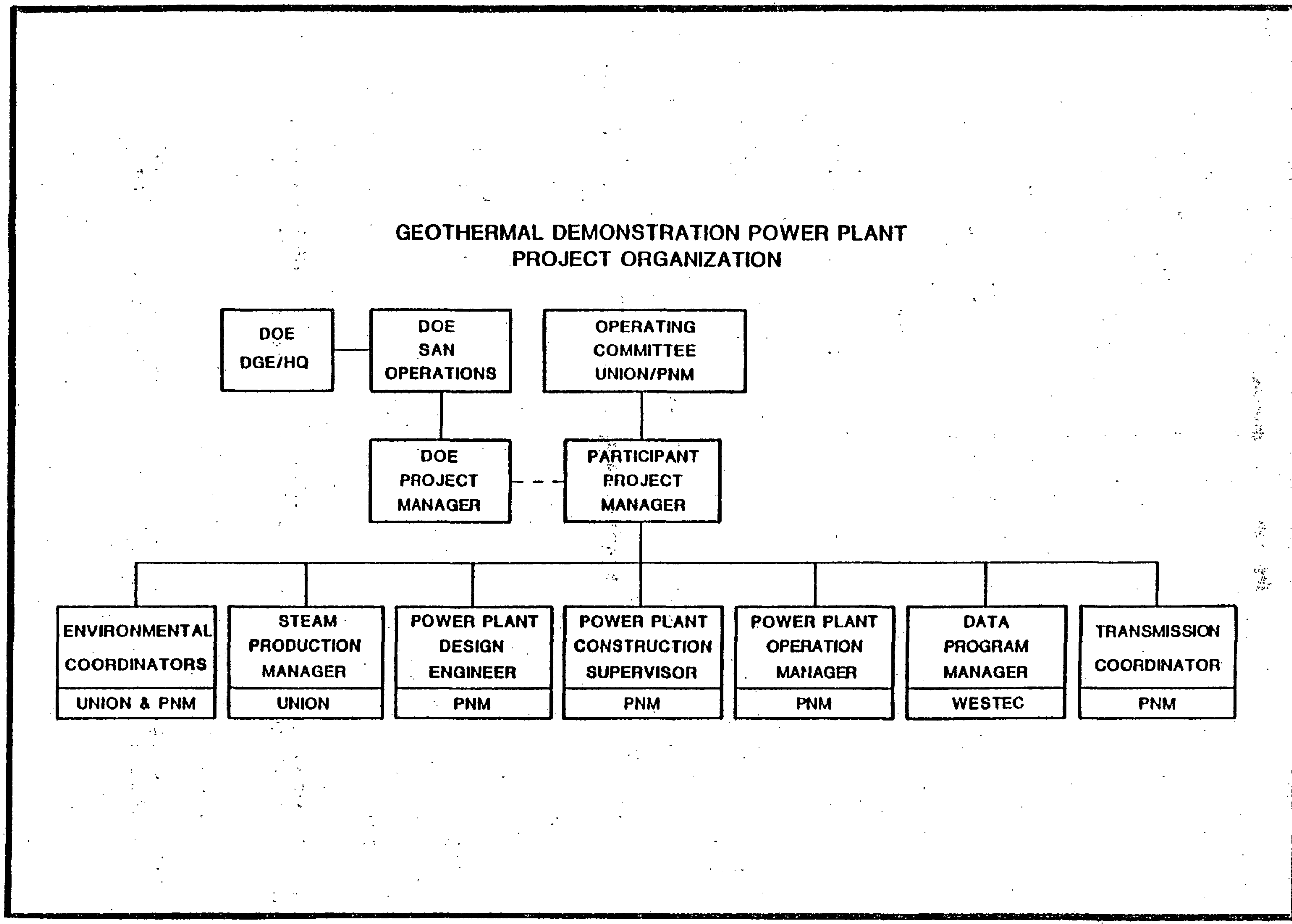


FIGURE 2.2-1 GDPP PROJECT ORGANIZATION CHART

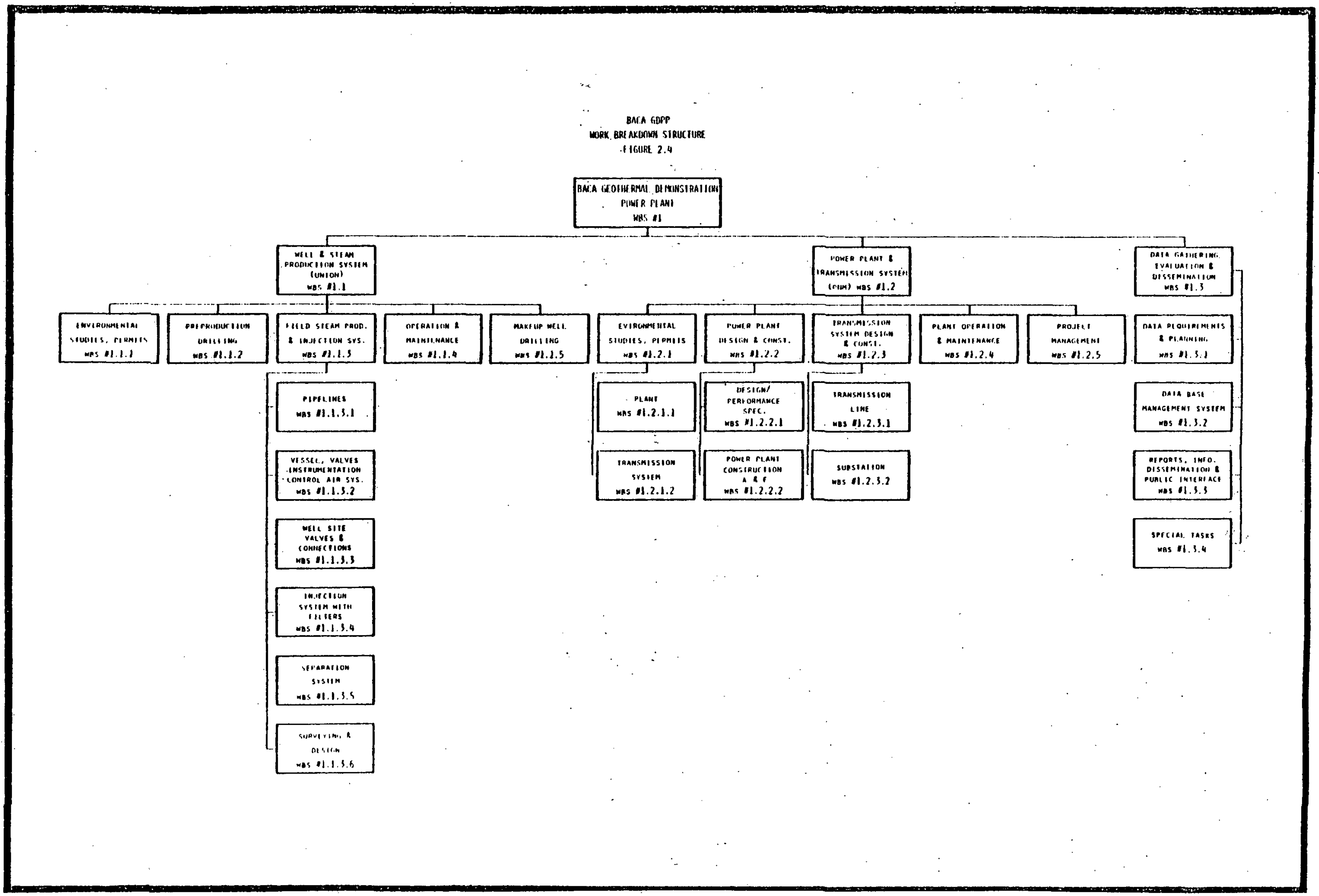


FIGURE 2.2-2 WORK BREAKDOWN STRUCTURE

$134,890,000 as revised in January 1981. This figure did not include those costs to be borne solely by DOE. The financial reimbursements DOE was to make to the Participant for specific Project work totaled approximately $55 million for the post-agreement period. This amount represented equal contributions to those phases of the project borne by Union and those borne by PNM, but did not include DOE commitments to portions of the project borne exlusively by DOE. In addition, DOE agreed to reimburse Union $7.4 million for work performed prior to the agreement in development of the resource.

The portions of the project exclusively borne by DOE included the additional documentation, data gathering and reduction, and dissemination required by the agreement that were beyond the scope of standard power plant and production system data management practice. DOE's obligation for this part of the project was estimated at approximately $9 million over the term of the agreement. These DOE contributions represented ceilings, while the Participant shares for the remainder of plant costs were open-ended commitments.

The project agreement also included a formula for revenue sharing after the five-year demonstration period was complete. Essentially, once the demonstration phase ended and the plant completed an additional year's successful commercial service, revenues generated by Union's steam sales to PNM would have been used to reimburse DOE up to one half of its aggregate project costs (excluding costs for phases funded solely by DOE), less any cost overruns incurred by the Participant as a result of DOE's involvement in the project.

Section 3: GEOLOGY

3.1 Regional Geology

The Valles Caldera is a prominent geologic feature of the Jemez Mountains, a volcanic complex of Pliocene and Pleistocene age located 60 miles north of Albuquerque. The Valles Caldera is located at the intersection of the western margin of the Rio Grande graben and the southeastern rim of the Colorado Plateau, a region of extensive Tertiary and Quaternary volcanism (Figure 3.1-1).

The Tertiary and Quaternary geologic history of the Jemez Mountains and Valles Caldera is well documented, especially by Smith and Bailey (1968), Smith, et. al. (1970) of the U.S.G.S, and Dondanville (1971, 1978). Table 3.1-1 below summarizes this history as it is currently known. Figure 3.1-2 contains the same data and is a generalized stratigraphic section of the Valles Caldera.

Table 3.1-1

Age (mybp)	Volcanic Events	Structural Events
15.0 to 10.0		Normal faulting associated with Rio Grande graben formation. Deposition of Santa Fe Gp within graben.
10.0 to 2.1	Widespread extrusion of precaldera rocks (basaltic to rhyodacitic) of older Keres Gp (Paliza Canyon Fm and related rocks) and younger Polvadera Gp (Tschicoma Fm and related rocks)	
1.4±		Emplacement of silicic magma chamber. Regional doming. Formation of ring fracture system.
1.4±	Eruption of Otowi Member Bandelier Tuff.	Simultaneous collapse of magma chamber along ring fracture system forming Toledo Caldera.

1.04 to 1.05±	Extrusion of Cerro Toledo Rhyolite and Cerro Rubio Quartz Latite.	Deposition of Caldera Fill within Toledo Caldera. Renewed silicic magmatism: regional doming and formation of new ring fracture system.
1.05±	Eruption of Tshirege Member Bandelier Tuff	Simultaneous collapse of magma chamber along younger ring fracture system forming Valles Caldera.
1.05 to 0.9±		Deposition of Caldera Fill within Valles Caldera. Formation of intra-caldera lake.
1.0 to 0.9±	Eruption of Deer Canyon Member Valles Rhyolite.	Continued intra-caldera deposition.
0.9 to 0.1±	Continued eruption of Valles Rhyolite: Redondo Creek member erupted along western margin and near center of Valles Caldera; Valle Grande and younger members along Valles Caldera ring fracture zone.	Continued intra-caldera deposition. Renewed silicic magmatism (cauldron resurgence): Uplift of Redondo Creek area beginning before and continuing after eruption of Redondo Creek Rhyolite; drainage of caldera lake forming Canon de San Diego.
0.1± present	Solfaterra and hot spring activity.	

Plate 3.1-1 is a generalized geologic map of the Valles Caldera. (Plates 3.1-1. 3.1-2, 3.2-1, 3.2-2, 3.5-1, 3.5-2 and 3.5-3 are found in the pocket on the inside of the back cover.) The map is modified from U.S.G.S Map I571 (1970). Smith, Bailey, and Ross originally mapped Paliza Canyon Formation within the caldera. Subsequent road construction and drilling have shown that these "outcrops" are really large blocks within the Caldera Fill.

The geologic Cross-section A-A' and B-B' indicated in Plate 3.1-1 are shown in Plate 3.1-2. The Bandelier Tuff is hachured for emphasis. Note that west of the caldera and Rio Grande

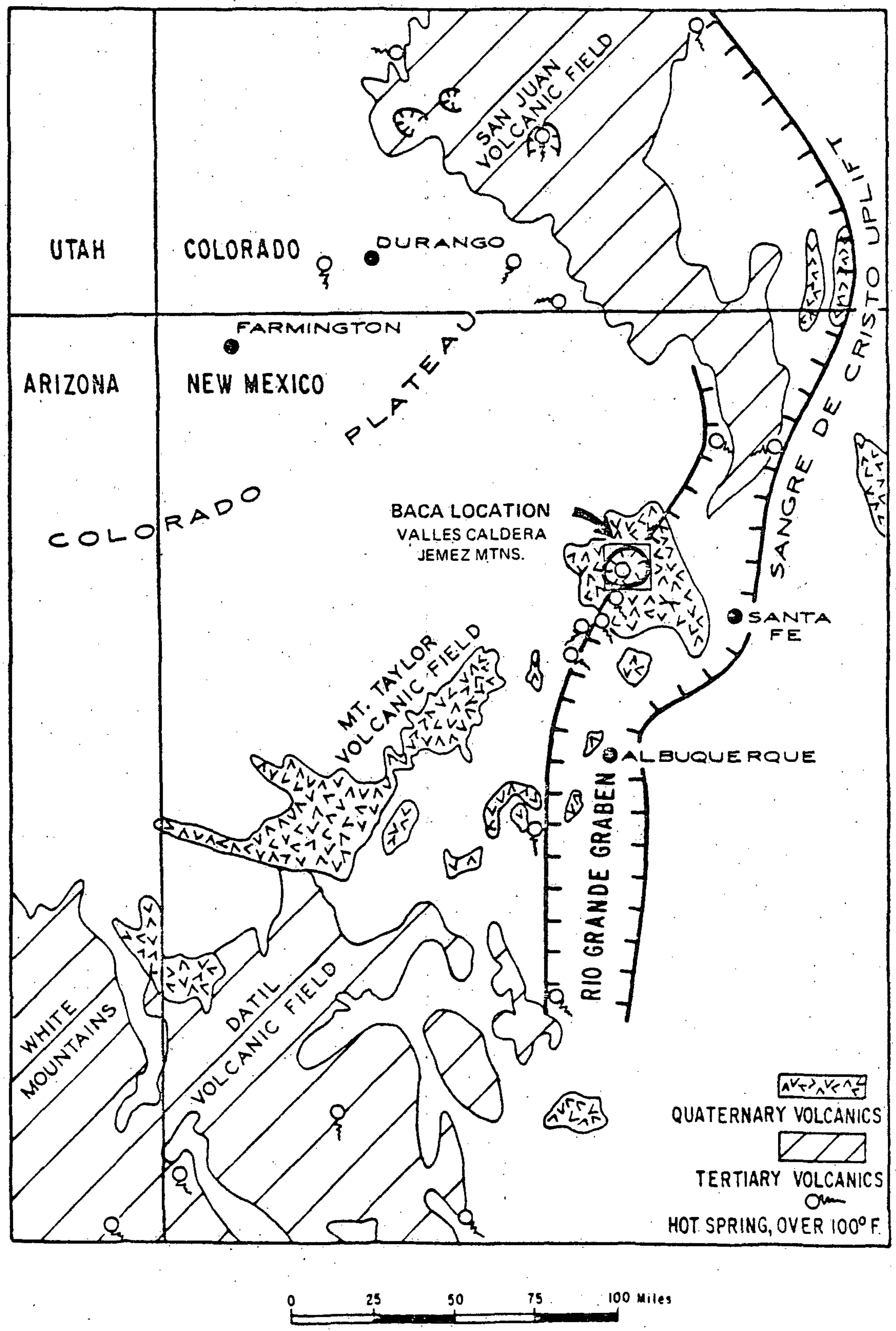


FIGURE 3.1-1

REGIONAL GEOLOGIC SETTING
OF THE
VALLES CALDERA

GENERALIZED STRATIGRAPHIC SECTION
VALLES CALDERA
after U.S.G.S. MAP I-571

	IGNEOUS ROCKS	SEDIMENTARY ROCKS	AGE
VALLES RHYOLITE	BANCO BONITO MEMBER	ALLUVIUM TERRACE DEPOSITS LANDSLIDES	QUATERNARY
	EL CAJETE "		
	BATTLESHIP ROCK "		
	VALLE GRANDE "		
	REDONDO CREEK "	CALDERA FILL FROM VALLES CALDERA / LAKE BEDS	
	DEER CANYON "		
	TSHIREGE MEMBER BANDELIER TUFF		
	CERRO TOLEDO RHYOLITE / CERRO RUBIO QUARTZ LATITE	CALDERA FILL FROM TOLEDO CALDERA	
	OTOWI MEMBER BANDELIER TUFF		
	POLVADERA GP: TSCHICOMA FM and RELATED ROCKS	INTRA-VOLCANIC DEPOSITS: SAND, GRAVEL (PUYE FM and EQUIVALENT)	TERTIARY
	KERES GP: PALIZA CANYON FM and RELATED ROCKS	SANTA FE GP (SANDSTONE)	
		ABO FM (RED BEDS)	PERM
		MAGDALENA GP (LIMESTONE, SHALE	PENN
	PRE-CAMBRIAN GRANITE, GNEISS, SCHIST		

FIGURE 3.1-2

graben Tertiary and Quaternary rocks lie unconformably on Paleozoic sediments and that eastward, Tertiary sediments thicken from a feather edge to many thousands of feet. Note also that the Bandelier Tuff is many times thicker within the ring fracture system than outside it -- compelling evidence of simultaneous Bandelier Tuff eruption and caldera collapse (Dondanville, 1978).

3.2 Redondo Creek Area Well Lithologies, Stratigraphy and Structure

3.2.1 Lithology and Stratigraphy

Figure 3.2-1 is a generalized stratigraphic column of the rock types penetrated in the Redondo Creek area. Table 3.2-1 lists the depth intervals, apparent vertical thicknesses (reliable stratigraphic dip data are sparse), and subsurface co-ordinates of the rock units penetrated by the individual wells.

Pre-Tertiary Rocks - Rocks older than Tertiary have only been penetrated in a few wells. They consist of pre-Cambrian granite, Pennsylvanian limestone, and Permian sandstone and shale. The Pennsylvania limestone is massive with shaly interbeds, some sandy horizons, and is presumed to be the Madera Limestone and associated rocks of the Magdalena Group. The overlying sandstones are probably the Abo and Yeso Formations consisting of fine grained arkosic sandstone and distinctively red shale, siltstone and clay.

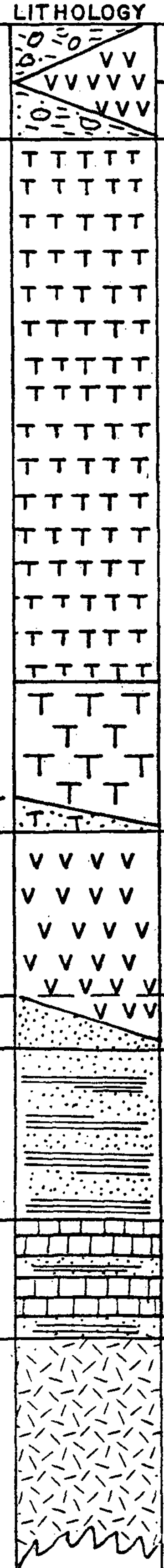
Tertiary Sedimentary Rocks - Sediments overlying the Abo and Yeso Formations are thought to be Miocene and Oligocene-age Rio Grande graben fill deposits, loosely termed the Santa Fe Group. These sediments are typically fine grained poorly consolidated sandstones with occasional siltstones and tuffs, possibly the Abiquiu Tuff mapped west of the caldera. Although attractive as a potential geothermal reservoir, wells which have penetrated this unit have had sloughing problems. Otherwise, little is known about the Santa Fe Group's potential productivity.

Tertiary Volcanic Rocks - Two groups of Tertiary volcanic rocks were erupted in the Jemez Mountains (Section 3.1). The rocks drilled have been primarily andesitic with minor amounts dacitic and basaltic rocks, presumably the Paliza Canyon Formation. No rocks resembling the Tschicoma Formation have been clearly identified.

Quaternary Rocks - Bandelier Tuff - The Bandelier Tuff exposed on the surface outside the Valles Caldera consists of two composite rhyolite ash flow units: the lower Otowi Member and the upper Tshirege Member. Each ash flow unit also has an associated basal pumice unit: the Guaje Pumice Bed underlies the Otowi Member and the Tsankawi Pumice underlies the Tshirege Member. In the absence of other field stratigraphic data the two members are distinguished by the greater abundance of clear quartz and light-colored feldspar phenocrysts in the Otowi Member (Smith, Bailey, and Ross, 1970).

FIGURE 3.2-1

COMPOSITE STRATIGRAPHIC SECTION
REDONDO CREEK WELLS



MAP SYMBOL		DESCRIPTION	APPARENT VERTICAL THICKNESS-FT.
Qcf	Qcf 2	CALDERA FILL: LANDSLIDE DEPOSITS, COARSE BRECCIA, GRAVEL, CLAY	0 - 500
	Qvrc	REDONDO CREEK RHYOLITE: RHYOLITE FLOWS. BIOTITIC, AMYGDULAR, Qtz -FREE	0 - 500
	Qcf 1		
Qb		BANDELIER TUFF: WELDED RHYOLITE ASH FLOWS	4200-6300
	Qb A	ZONE A: VERY DENSELY WELDED NO APPARENT PUMICE	3700 - 4750
	Qb B	ZONE B: MODERATELY TO DENSELY WELDED. HIGHLY VARIABLE TEXTURE. PUMICE EVIDENT	300 - 750
	Qb C	ZONE C: BASAL PUMICE. NON-WELDED.	0 - 120
Tp		PALIZA CANYON FM: ANDESITE FLOWS. MINOR AMOUNTS DACITE, TUFFS	300 - 2400
Tsf		SANTA FE GP: SANDSTONE. Poorly consolidated, very fine, occasionally tuffaceous. Includes Abiquiu Tuff ? (Tab ?)	0 - 500
Pa		ABO FM: RED BEDS. CONSOLIDATED FINE CALCAREOUS SANDSTONE AND SILTSTONE	1600 ±
IPm		MAGDALENA GP: LIMESTONE, SAND AND SHALE PARTINGS. OCCASIONALLY FOSSILIFEROUS	1000 ±
pЄ		GRANITE: MEDIUM GRAINED, SUBHEDRAL. MINOR BIOTITE	

One would expect similar Bandelier Tuff stratigraphy inside the Valles Caldera with the possible addition of a caldera fill unit between the Otowi and Tshirege Members representing the hiatus between eruption of the Toledo and Valles Calderas (Figure 3.1-2). No such a relationship is found in the Redondo Creek wells.

An attempt was made to distinguish the two Bandelier Tuff members in Redondo Creek wells by noting the depth of increased phenocryst abundance - the hypothetical top of the Otowi Member. Such a phenocryst-rich zone was identified in several wells. Cores and cuttings showed a dense welded tuff with few phenocrysts overlying a more texturally-varied welded tuff with markedly more phenocrysts. Preliminary conclusions were that the two members of the Bandelier Tuff had been successfully identified. However, subsequent drilling provided lithologic data showing that the contact between the phenocryst-poor and phenocryst-rich tuff units was highly gradational. Cuttings analysis implied the increase in phenocrysts represented only a textural change within a massive unit. The original hypothesis that the phenocryst-rich and phenocryst-poor units were separate genetic units had to be discarded.

Geophysical logs and lithologic data were used to formulate a stratigraphy consisting of three Bandelier Tuff zones in the Redondo Creek wells which appear to correlate consistently among logged wells. These zones are described below in order of increasing depth and shown schematically in Figure 3.2-1.

<u>Zone A</u> - This zone is typically very densely welded with moderately abundant phenocrysts of clear quartz and light-colored feldspar. The unit is essentially non-porous (neutron porosity = 2% or less) with the exception of occasional fracturing. Fracture permeability, characterized by increasing lost circulation problems during drilling, and phenocryst abundance appear to increase with depth. The unit can be further subdivided in a few wells into an upper altered unit (A1), a middle densely welded unit (A2), and a lower phenocryst-rich fractured unit (A3). These subdivisions are only preliminary because of insufficient data.

<u>Zone B</u> - Zone B is identifiable only from geophysical logs (Section 3.3) and is characterized by an increase in neutron porosity from 2% to 8-10% and highly variable density, porosity, electrical resistivity, and sonic velocity. The unit is welded tuff with wide variation in textures and degree of welding; phenocrysts are very abundant. The upper portion of Zone B is indistinguishable visually from the lower portion of Zone A. Textures become more pumiceous and "shardy" with depth; densely welded, phenocryst-rich tuff becomes scarce with depth.

Zone C - This is a thin basal zone consisting of highly altered tuff and may represent the Guaje Pumice Bed. The tuff appears pumiceous; phenocrysts are rarely distinguishable. The exact interval of Zone C occurrence in wells is best identified from electrical resistivity logs (Section 3.3). Alteration appears to diminish upward from Zone C into the lower portion of Zone B. The visual result is an obscure Zone B/Zone C contact not readily identified in cuttings.

Quaternary Rocks - Caldera Fill - Overlying the Bandelier Tuff is the Caldera Fill. This unit consists of landslide debris which was deposited during sloughing of over-steepened caldera walls following eruption and collapse. The upper part of the unit is highly weathered.

Quaternary Rocks - Valles Rhyolite - The Redondo Creek Member of the Valles Rhyolite overlies the Caldera Fill in a few wells. It is a rhyolite with glassy groundmass, feldspar phenocrysts, abundant biotite, and no apparent quartz. The Redondo Creek Rhyolite is contemporaneous with the Caldera Fill which locally overlies it.

TABLE 3.2-1

WELL BACA 4

PROBLEM →

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9318	200	
BANDELIER TUFF	200	200	9118	5725	1N 1E
PALIZA CANYON FM	5980	4898	3420	387	647N 360W
TD	6376	6284	3034		724N 403W

WELL BACA 5A

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9308	450	
BANDELIER TUFF	450	450	8858	6149	6N 4E
PALIZA CANYON FM	6610	6598	2710	361	252N 225W
TD	6973	6959	2349		280N 247W

WELL BACA 6

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	8726	486	
BANDELIER TUFF	500	500	8240	4221	2N 10W
PALIZA CANYON FM	4750	4705	4035	59	449N 55E
TD	4810	4764	3976		462N 55E

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET
ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

WELL BACA 10

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	8735	520	
BANDELIER TUFF	520	520	8215	4684	2S 0E
PALIZA CANYON FM	5220	[illegible] 5200	4163 3535	708	398S 53W
SANTA FE Gp	5930	5907	2828	71	458S 72W
TD	6001	5978	2757		464S 73W

WELL BACA 11

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9065	302	
BANDELIER TUFF	320	320	8763	4969	1S 0E
PALIZA CANYON FM	5300	3010 5282	3801	1239	247N 176W
SANTA FE Gp	6560	6522	2562	358	419N 321W
TD	6924	6880	2203		465N 363W

WELL BACA 12

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	8427	137	
BANDELIER TUFF	160	160	8290	6296	2N 0E
PALIZA CANYON FM	6460	6453	1997	918	69S 77W
ABIQUIU TUFF?	7380	7370	1080	195	138S 87W
ABO FM	7575	7565	885	1644	150S 88W
MAGDALENA Gp	9220	9208	- 758	966	190S 49W
PRECAMBRIAN GRANITE	10220	10171	-1721	383	8N 109E
TD	10637	10555	-2105		134N 214E

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET
ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

WELL BACA 13

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9292	560	
BANDELIER TUFF					
ZONE A	560	560	8732	4259	3S 5W
ZONE B	4850	4800	4492	755	280S 449W
ZONE C	5630	5554	3738	80	382S 620W
TOTAL BANDELIER				5094	
PALIZA CANYON FM	5712	5634	3658	2344	388S 637W
ABO FM	8090	7976	1316	136	643S 932W
TD	8228	8112	1180		659S 946W

WELL BACA 14

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	8605	280	
BANDELIER TUFF					
ZONE A	280	280	8325	4826	1S 0E
ZONE B	5240	5037	3568	530	468N 1003W
TOTAL BANDELIER				5286	
PALIZA CANYON FM	5800	5567	3038	323	534N 1172W
SANTA FE Gp	6140	5891	2714	532	562N 1273W
ABO FM	6700	6423	2182	118	604N 1441W
TD	6824	6541	2064		613N 1478W

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET
ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

WELL BACA 15

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9117	120	
BANDELIER TUFF	140	140	8997	5085	
PALIZA CANYON FM	5300	5138	3999	171	733S 361E
TD	5505	5309	3828		822S 430E

WELL BACA 16

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9622	358	
REDONDO CR. RHYOLITE	380	380	9264	500	2S 0E
BANDELIER TUFF	880	880	8764	4644	6S 0E
PALIZA CANYON FM	5560	5498	4146	1235	144S 540W
SANTA FE Gp	6880	6734	2910	113	93S 998W
TD	7002	6847	2797		87S 1043W

WELL BACA 17 ORIGINAL HOLE

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
REDONDO CR. RHYOLITE	0	0	9359	377	
CALDERA FILL	400	400	8982	580	0N 1W
BANDELIER TUFF					
ZONE A	980	980	8402	3742	3S 7W
ZONE B	4740	4712	4670	642	91S 365W
ZONE C	5400	5355	4027	98	79S 515W
TOTAL BANDELIER				4482	
PALIZA CANYON FM	5500	5452	3930	285	75S 535W
TD	5791	5737	3645		60S 594W

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET
ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

WELL BACA 17 REDRILL

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
REDONDO CR. RHYOLITE	0	0	9359	377	
CALDERA FILL	400	400	8982	580	0N 1W
BANDELIER TUFF					
ZONE A	980	980	8402	3715	3S 7W
ZONE B	4730	4695	4687	611	343S 5E
ZONE C	5380	5305	4077	132	562S 49E
TOTAL BANDELIER				4458	
PALIZA CANYON FM	5520	5436	3946		610S 59E
TD	6254	6121	3261		867S 120E

WELL BACA 18 ORIGINAL HOLE

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	8733	497	
BANDELIER TUFF	520	520	8236	4011	7S 3E
TD	4597	4520	4236		196N 671E

WELL BACA 18 REDRILL

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	8733	497	
BANDELIER TUFF					
ZONE A	520	520	8236	4088	7S 3E
ZONE B	4725	4608	4148	291	678N 380E
ZONE C	5025	4899	3857	73	734N 423E
TOTAL BANDELIER				4452	
PALIZA CANYON FM	5100	4972	3784	145	745N 438E
TD	5250	5117	3639		766N 467E

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET
ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

WELL BACA 19

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9119	200	
BANDELIER TUFF					
ZONE A	220	220	8919	4555	1S 0E
ZONE B	4835	4738	4401	413	138S 711E
ZONE C	5275	5151	3988	70	135S 862E
TOTAL BANDELIER				5038	
PALIZA CANYON FM	5350	5221	3918	243	133S 889E
TD	5610	5464	3675		123S 982E

WELL BACA 20 ORIGINAL HOLE

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9065	336	
BANDELIER TUFF					
ZONE A	360	360	8729	4200	1N 1E
ZONE B	4625	3607 4524	4565	598	347S 622E
ZONE C	5245	5121	3968	112	475S 730E
TOTAL BANDELIER				4910	
PALIZA CANYON FM	5363	5234	3855	1372	501S 752E
TD	6864	6601	2488		939S 1175E

WELL BACA 20 REDRILL

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	9065	336	
BANDELIER TUFF					
ZONE A	360	360	8729	3982	1N 1E
ZONE B	4450	3003 4342	4747	601	231N 602E
ZONE C	5100	4943	4146	92	423N 759E
TOTAL BANDELIER				4675	
PALIZA CANYON FM	5200	5035	4054	1027	456N 782E
TD	6374	6063	3026		945N 1054E

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET

ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

WELL BACA 21

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
REDONDO CR. RHYOLITE	0	0	9361	376	
CALDERA FILL	400	400	8985	555	1N 1W
BANDELIER TUFF					
ZONE A	955	955	8430	2035	1N 6W
TD	3000	2982	6403		168S 73E

WELL BACA 22 ORIGINAL HOLE

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
REDONDO CR. RHYOLITE	0	0	9270	236	
CALDERA FILL	260	260	9034	360	1N 1W
BANDELIER TUFF					
ZONE A	620	620	8674	3959	6N 0E
ZONE B	4585	4578 (4550)	4716	610	88S 187E
ZONE C	5195	5188	4106	85	94S 212E
TOTAL BANDELIER				4654	
PALIZA CANYON FM	5280	5272	4022	736	94S 216E
TD	6017	6008	3286		105S 259E

WELL BACA 22 REDRILL 1

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
REDONDO CR. RHYOLITE	0	0	9270	236	
CALDERA FILL	260	260	9034	360	1N 1W
BANDELIER TUFF					
ZONE A	620	620	8674	3891	6N 0E
ZONE B	4525	4511	4783	641	77N 103E
ZONE C	5170	5152	4142	113	131N 51E
TOTAL BANDELIER				4645	
PALIZA CANYON FM	5285	5265	4029	1136	145N 41E
SANTA FE Gp	6440	6401	2893	44	326N 60W
TD	6485	6445	2849		334N 65W

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET
ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

WELL BACA 22 REDRILL 2

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
REDONDO CR. RHYOLITE	0	0	9270	236	
CALDERA FILL	260	260	9034	360	1N 1W
BANDELIER TUFF	620	620	8674	4649	6N 0E
PALIZA CANYON FM	5280	4570 5269	4025	724	103S 226E
TD	6006	5994	3300		61S 253E

WELL BACA 22 REDRILL 3

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
REDONDO CR. RHYOLITE	0	0	9270	236	
CALDERA FILL	260	260	9034	360	1N 1W
BANDELIER TUFF					
ZONE A	620	620	8674	3908	6N 0E
ZONE B	4540	4528	4766	759	136S 93E
ZONE C	5300	5286	4008	97	186S 95E
TOTAL BANDELIER				4764	
PALIZA CANYON FM	5397	5383	3911	1362	187S 94E
ABIQUIU TUFF?	6760	6745	2549	239	158S 59E
SANTA FE Gp	7000	6984	2310	647	148S 43E
ABO FM	7650	7632	1662	965	113S 2W
MAGDALENA Gp	8620	8597	697	225	53S 73W
TD	8846	8822	472		39S 89W

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET

ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

WELL BACA 23

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	8735	456	
BANDELIER TUFF					
ZONE A	480	480	8279	4304	1S 3E
ZONE B	4800	4778	3981	463	341S 27W
ZONE C	ABSENT	---------	---------	---------	---------
TOTAL BANDELIER				4767	
PALIZA CANYON FM	5267	5241	3518	448	340S 87W
ABO FM?	5720	5689	3070	26	335S 152W
TD	5746	5715	3044		334S 155W

WELL BACA 24

MARKER NAME	DEPTH TO MARKER TOP			APPARENT VERTICAL THICKNESS	HORIZONTAL CO-ORDINATES FROM SURFACE LOCATION
	MEASURED	VERTICAL	SUBSEA		
CALDERA FILL	0	0	8740	196	
BANDELIER TUFF	220	220	8544	4793	1N 0E
PALIZA CANYON FM	5020	5011	3753	480	37N 231W
TD	5502	5491	3273		38N 273W

ALL DEPTHS, THICKNESSES AND DISTANCES IN FEET

ALL THICKNESSES CALCULATED FROM DIRECTIONAL DATA

3.2.2 Structure

Union's most recent geologic map of the Redondo Creek area is Plate 3.2-1. The lithologic units mapped are as previously described excepting the subdivision of Caldera Fill into two units presenting deposits underlying and overlying the Redondo Creek Rhyolite (Behrman and Knapp, 1979).

The Redondo Creek area is within a complex longitudinal graben on the northwest flank of the resurgent structural dome of Redondo Peak and Redondo Border (Section 3.1). The axis of the graben strikes northeast and generally coincides with Redondo Creek. Graben-bounding faults appear steeply dipping, 60-80°. Several subsidiary lower-angle faults dipping 30-40° extend to shallow depths, complicating the surface expression of the deep structure.

Major graben-bounding faults have been projected to the normally drilled depths of 5000-7000 ft. to target permeability associated with the intersection of such faults with the basal section of the Bandelier Tuff. Results have been ambiguous due to inadequate stratigraphic control from well data. The following discussion of the geologic cross-sections shown in Plate 3.2-1 and stratigraphic data illustrate the ambiguity of subsurface structure which has hindered detailed structural analysis of the Redondo Creek area.

Figure 3.2-2 shows the subsurface geology along Cross-section A-A' near Baca 16. The geologic relationships shown are interpretations of well data and surface geology projected to depth. Fault F-0 appears to intersect Baca 16 at the base of the Redondo Creek Rhyolite (Qvrc), eliminating the lower Caldera Fill (Qcf 1) from the drilled section and apparently correlating surface and subsurface data.

Subsurface data near Baca 17 and 22 are shown in Cross-section B-B' (Figure 3.2-3). Fault F-0, apparently well located in the subsurface in Baca 16, has an ambiguous subsurface location at Baca 17 and 22. Production zones at 2600-2800 ft. in Baca 17 and its twin Baca 21, which are clearly evident on geophysical logs, have been thought to be the intersection of fault F-0 with these wells. This intersection is shown on Cross-section B-B' and implies fault F-0 dips 70° southeast. Projecting fault F-0 to Baca 22 should result in the Bandelier Tuff Zone A/Zone B contact in Baca 22 being offset down relative to Baca 17; no such offset is present. One might speculate that the dip of fault F-0 shallows to 60° and intersects Baca 22 above the Bandelier Tuff Zone A/Zone B contact. Such an intersection would result in structural thinning of the Bandelier Tuff Zone A in Baca 22 relative to Baca 17; no such thinning is apparent.

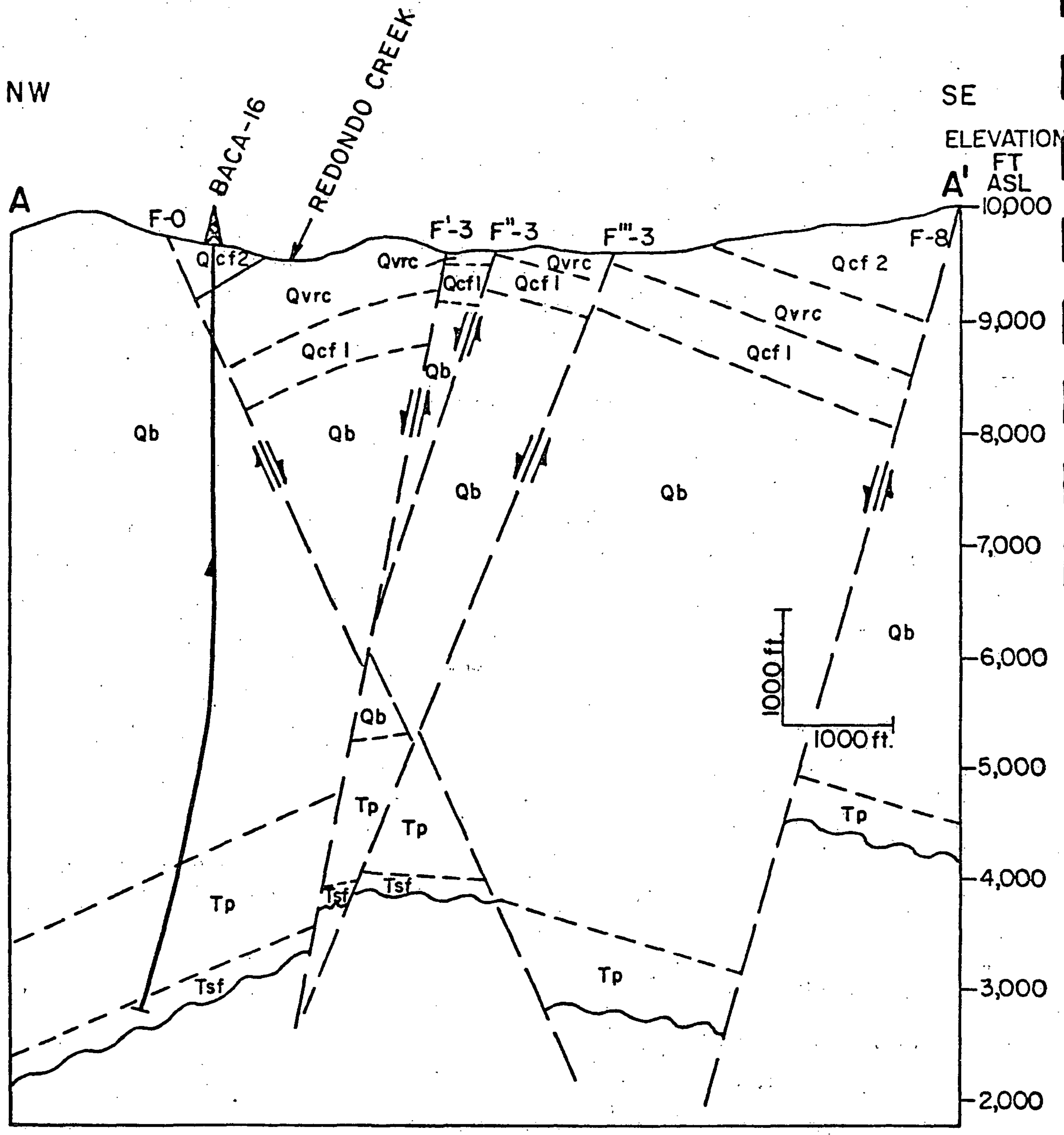


FIGURE 3.2-2

CROSS-SECTION A-A'

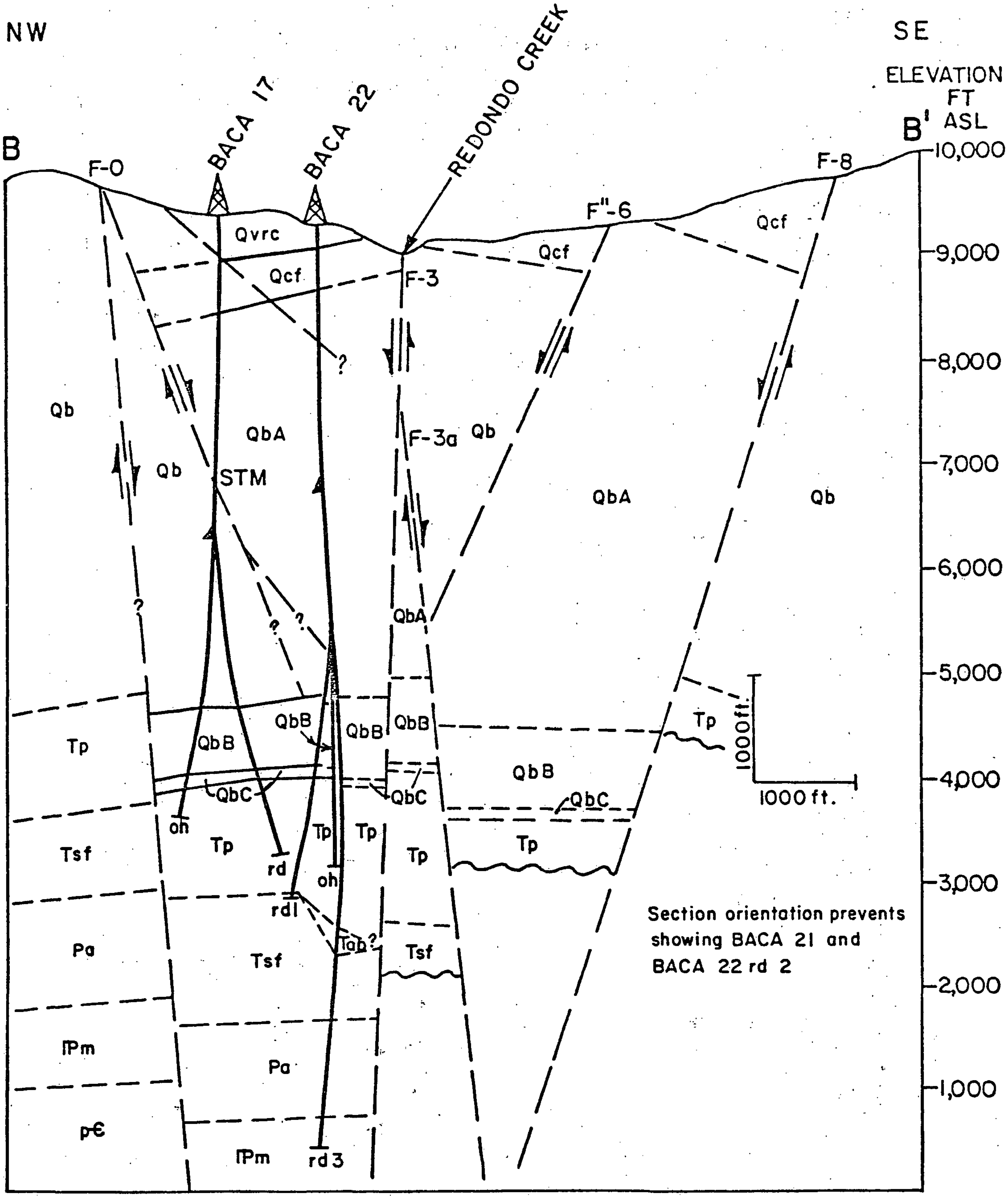


FIGURE 3.2-3

CROSS-SECTION B-B'

A third, possibly more plausible, interpretation is that fault F-0 dips more steeply than indicated by surface mapping and intersects neither Baca 17, 21, nor 22. This third interpretation implies the shallow production zones in Baca 17 and 21 may likely be due to other causes than intersection of the wells with fault F-0.

Baca Wells 4, 11, and 20 are shown in Cross-section C-C' (Figure 3.2-4). Faults F-3a and F-3b, not apparent on the surface, appear to explain Bandelier Tuff offsets between Baca 4 and Baca 20. Fault F-0 appears more steeply dipping as previously discussed: if fault F-O dips 70° southeast as mapped on the surface, one might expect Baca 11 to have penetrated rocks deeper in the stratigraphic section.

Cross-section D-D' (Figure 3.2-5) shows the interpreted subsurface geology in the vicinity of Baca 15 and 19. Fault F-3 appears to intersect both wells resulting in similar stratigraphy in both wells.

Data from the closely-spaced wells Baca 10, 18, 23, and 24 are shown in Cross-section E-E' (Figure 3.2-6). Fault F-X, not apparent on the surface, is proposed to explain stratigraphic separation between Baca 18 RD and Baca 23. Fault F-3 might be more steeply dipping in this area than in those previously discussed.

Plate 3.2-2 is a map showing the elevation in feet above sea level of the base of the Bandelier Tuff; The contours shown are computer-generated. Also shown is the apparent vertical thickness in feet of the Bandelier Tuff; insufficient stratigraphic dip data prevent calculating true thicknesses. The base of the Bandelier Tuff is significantly deeper in Baca 5A and 12, probably the result of a greater thickness of tuff in these wells. Less dramatic deepening of the base of the Bandelier Tuff as a result of apparent thickening occurs in Baca 4 and 14. The other wells in Redondo Creek exhibit less profound variations in the base and thickness of the Bandelier Tuff.

Surface mapping indicates that vertical displacements over 1000 ft. have occurred along the major graben-bounding faults. The well data shown on Plate 3.2-2 show that such large displacements are not apparent at the base of the Bandelier Tuff, the only stratigraphic horizon yet identified in all Redondo Creek wells. A combination of the following factors may explain the lack of large displacements of the base of the Bandelier Tuff:

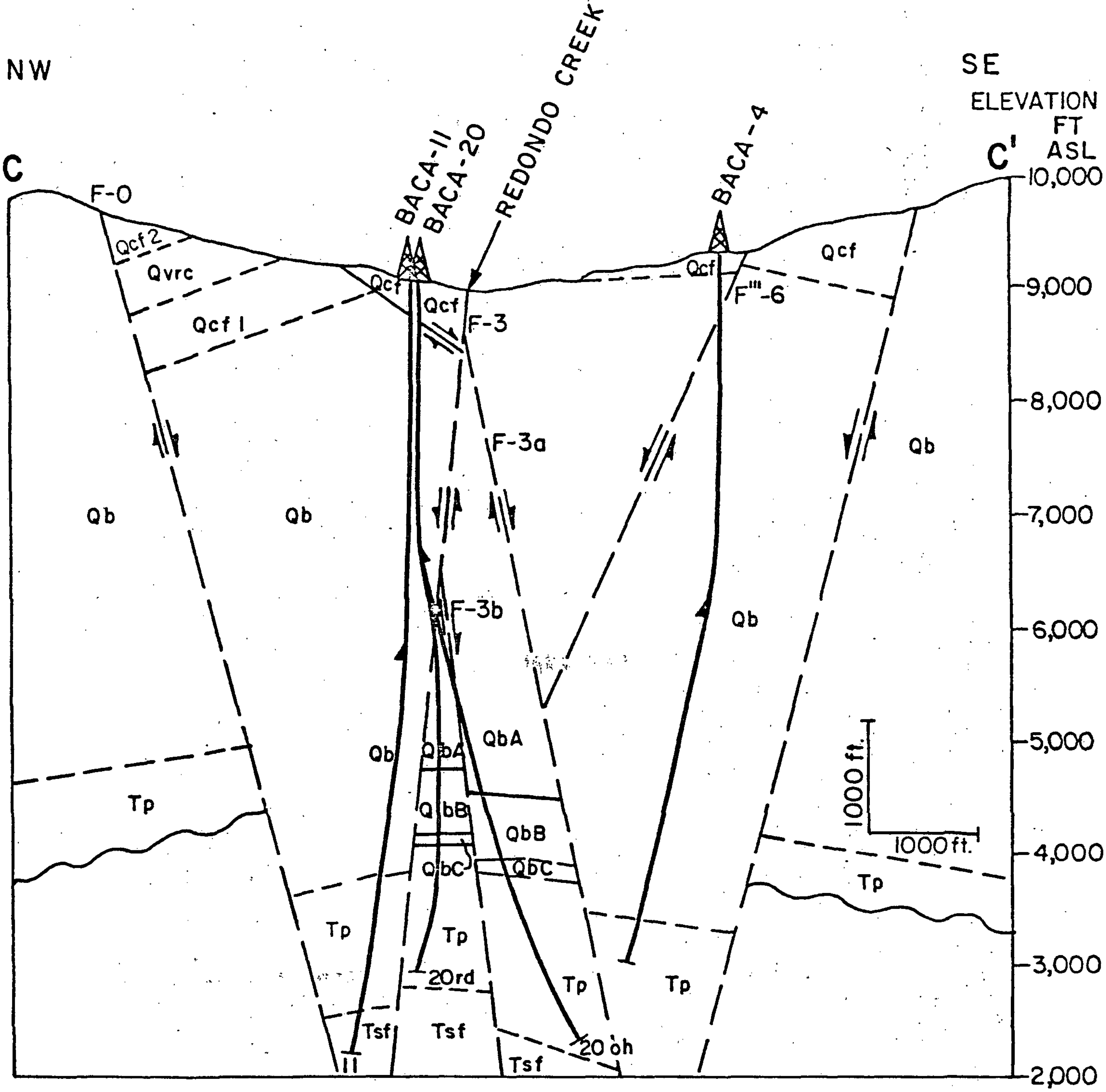


FIGURE 3.2-4

CROSS-SECTION C-C'

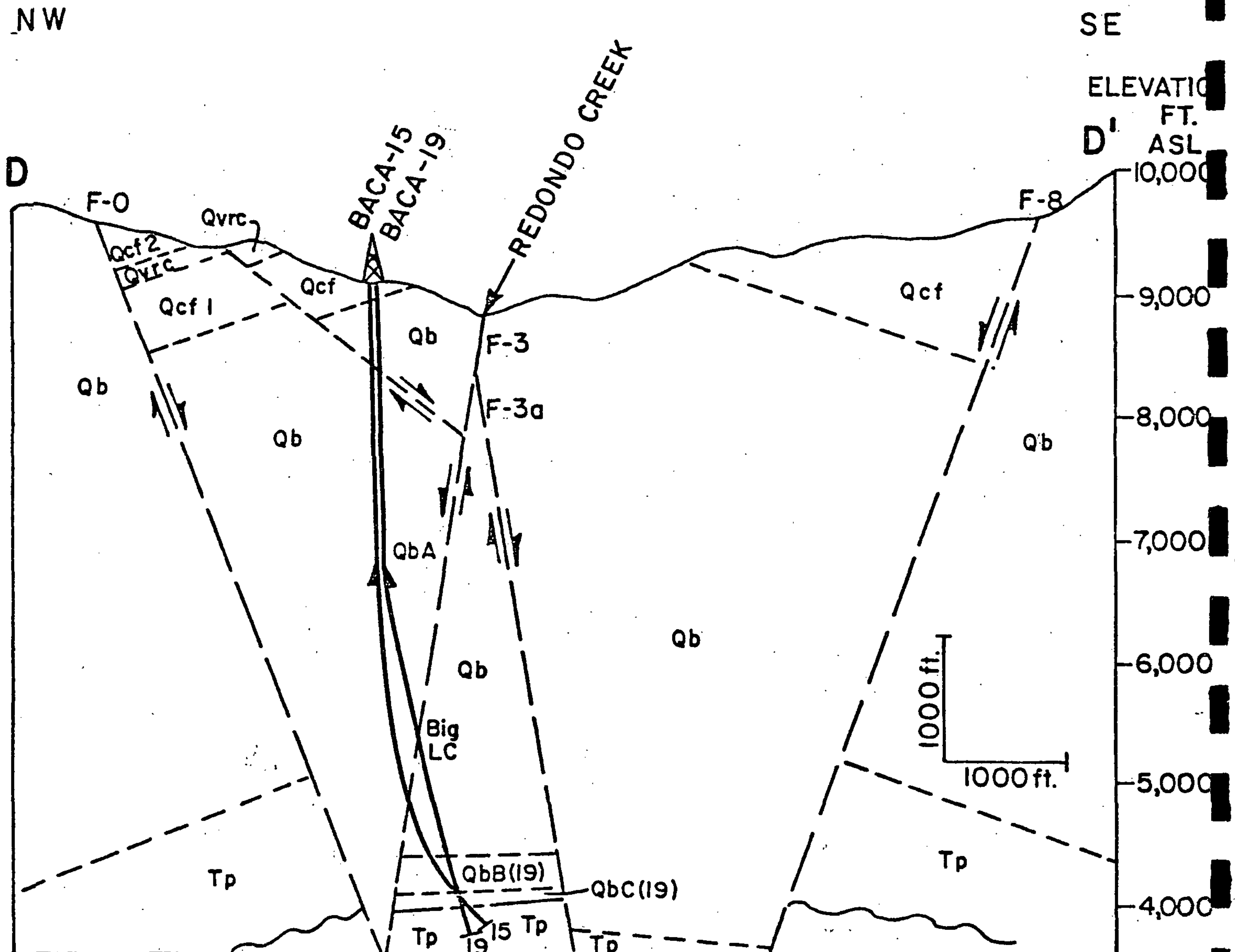


FIGURE 3.2-5

CROSS-SECTION D-D'

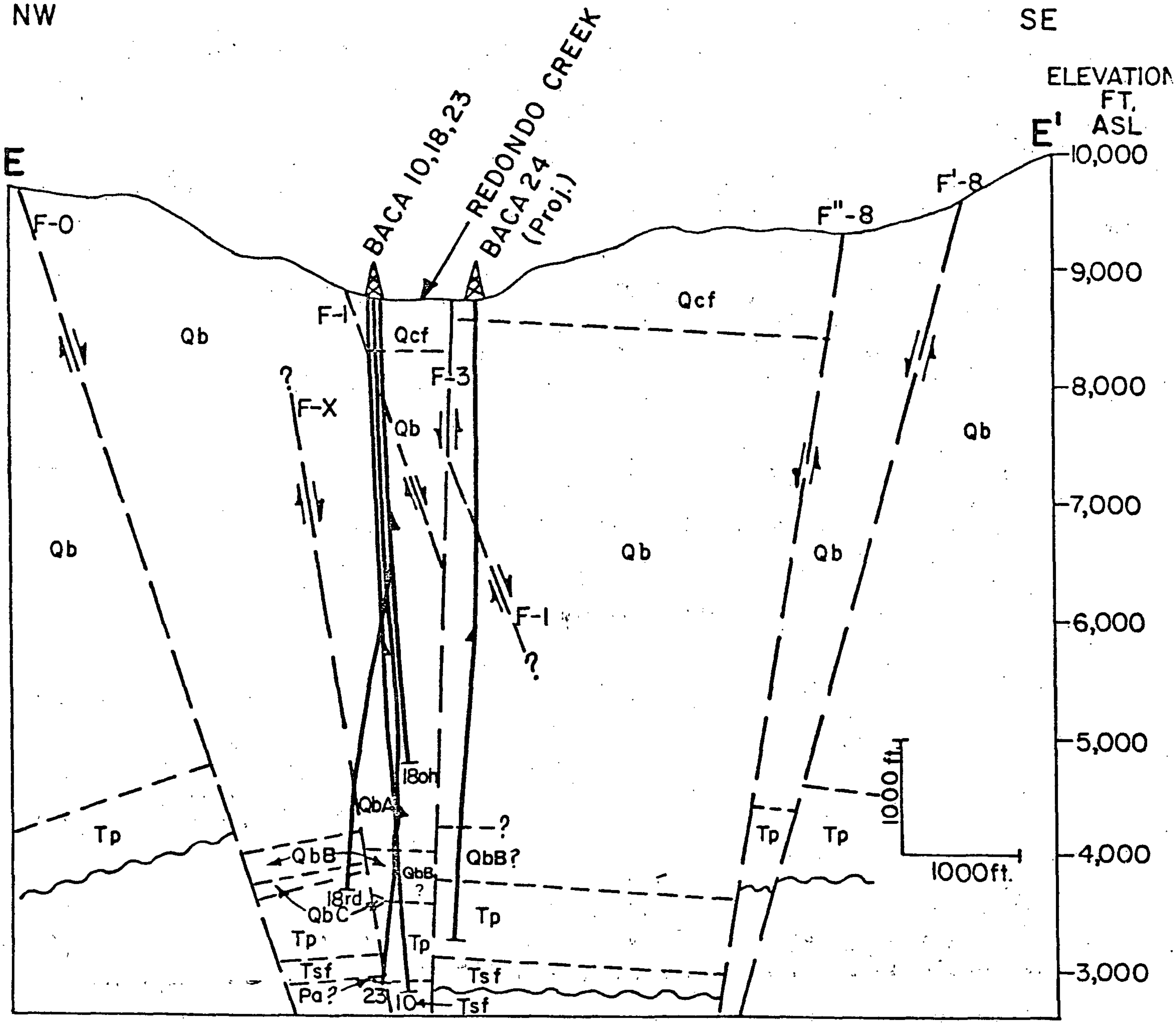


FIGURE 3.2-6

CROSS-SECTION E-E'

1. The dips of major, steeply dipping graben-bounding faults may shallow with depth and not extend to the base of the Bandelier Tuff.

2. Graben-bounding faults with opposite dip directions may intersect at depth yielding net displacements at the base of the Bandelier Tuff less than observed on the surface.

3. The base of the Bandelier Tuff may not have been originally horizontal due to differential rates of caldera collapse or mantling of pre-existing topography. The top of the Bandelier Tuff and the tops of its subsidiary ash-flow units such as Zones B and C are more likely to have been originally horizontal. The top of the Bandelier Tuff is near the surface and disturbed by erosion and low-angle faulting, limiting its use as a subsurface stratigraphic marker. Bandelier Tuff Zones B and C have only been recently identified in a few wells, limiting the use of these zones as stratigraphic markers throughout the Redondo Creek area; furthermore, it is uncertain whether Bandelier Tuff Zones A, B, and C represent discreet ash-flow units.

Thickness variations are sometimes useful to detect faulting in the subsurface. The Bandelier Tuff is not currently amenable to this type of analysis because of the following uncertainties:

1. The apparent vertical thickness of the Bandelier Tuff measured in the wells may vary greatly from the true vertical thickness. Better stratigraphic dip data are needed to resolve this problem.

2. The original variations in thickness of the Bandelier Tuff as a result of differential rates of caldera collapse or mantling of pre-existing topography are currently unknown.

Relationship Between Mapped Structure and Well Productivity

The major graben faults in the Redondo Creek area have been considered as potential permeable fluid conduits in the geothermal reservoir. Well productivity might be increased if wells were directionally drilled to intersect the major graben faults in the productive interval. The validity of these hypotheses is difficult to substantiate with well data for the following reasons:

1. The precise depths and magnitudes of fluid entry points in Redondo Creek wells are very difficult to determine. Various log and test data provide clues where some productive zones may be in a few wells, but no reliable method exists of determining fluid entry points in Baca wells.

2. The locations of faults in the subsurface and their correlation with surface features cannot be determined with the required precision as previously discussed.

3. Well data are inconsistent regarding the permeable and productive nature of the major graben faults. Baca 17 and 21 encountered fluid production at a depth of 2600-2800 ft. (Figure 3.2-3). This productive zone has been suspected as being the intersection of these wells with fault F-0 and appears clearly on geophysical logs. However, no such zone has been identified in Baca 22, a noncommercial well, and the previous discussion has noted that there is ambiguity whether fault F-0 intersects Baca 17 or 22 at all. Data from Baca 15 and 19 are also inconsistent (Figure 3.2-5). Fault F-3 appears to intersect both wells, apparently in a zone causing lost circulation in Baca 19. Baca 15 is a commercial producer, while Baca 19 is not.

4. The commercial wells Baca 4 and 11 (Figure 3.2-4) and 24 (Figure 3.2-6) may not intersect any major graben faults in their productive intervals.

The major graben faults with associated fracturing are plausible candidates as permeable and productive zones in the reservoir. Drilling results have indicated that if faulting has generated permeable zones in the reservoir, the distribution of such zones is too erratic and the location of such zones too imprecisely known to offer an attractive drilling target.

3.2.3 Fracture Orientations

Fracture Identification Logs (modified dipmeters) were run in Baca wells 18, 20, 21, 22, and 23. The logs were obtained over cooler intervals shallower than the producing horizon, and all the logged wells are noncommercial. The purpose of running the logs was to determine preferred fracture strike directions in the Redondo Creek area and any relationship between preferred fracture strike and well productivity.

Log analysis indicates there is a preferred mean fracture strike of N31W in the logged portion of Redondo Creek wells. This mean fracture strike is very generally perpendicular to the major structure in the area, the northeast-striking Redondo Creek graben. Of the commercial producing wells, Baca 4, 11, and 15 are parallel to the northwesterly fracture trend; Baca 13, 20 RD, and 24 are parallel to the trend; and Baca 6 is neither parallel nor perpendicular to the trend. The noncommercial wells exhibit no particular relationship among well direction, mean fracture strike, and lack of productivity.

Fracture Identification Logs have promise in helping determine the relationship between geologic structure and well productivity. The existing log data have limitations which must be resolved by future work to improve geologic interpretation of such logs:

1. The low number of logged wells and low number of calculated fracture strikes prevent definite correlation among fracture direction, well direction, and well productivity.

2. Log analysis is hampered by the lack of a computer program analogous to conventional dipmeter programs to calculate fracture strike and dip. Present analysis is limited to visual inspection of the log data.

3. Dipmeter tools with the conventional 350°F temperature rating will not operate in the hot, permeable sections of Redondo Creek wells. (Water injection during logging does not cool the hole enough to allow operation of such tools.) The result is log data which must be extrapolated from shallow depths to the producing horizon. Logging tools rated to 500°F are currently available on an experimental basis; routine availability will result in obtaining data from the producing horizon, increasing the utility of the Fracture Identification Log.

4. Only noncommercial wells have been logged at depths shallower than the productive interval.

9-2-87

Boca wells

Boca 16	no production	
(13)	moderate productivity	
(17) R/D	good prod.	
(11)	excellent prod.	no dir. survey
(4)	Good prod.	
(15)	good prod.	
(6)	good prod.	
(10)	good test but no prod. reperf → Fair to poor prod	
18	lack of prod.	
(9.) ?	no prod	(cased below fault intersection
(14)	good test	plugged off fault intersect → no prod
5a	no prod	
12	nonprod.	
18	producer	

Producers

4
6
10
11
13 mod
~~(14)~~
15
(17)

[illegible]

Fracture Identification Log data was obtained from Baca 18 OH, 20 OH, 21, and 23, and numerous fracture orientations were calculated. Baca 22 OH was logged but detected insufficient fractures to allow analysis. Baca 20 RD was logged with a 500°F-rated tool to total depth at the time of stimulation and resulted in a log which exhibited abundant fracturing. Computer and visual analyses were attempted but no successful interpretation has yet resulted. Figure 3.2-2 is a reference map of the Redondo Creek well locations and wellcourses.

Figures 3.2-3 and 3.2-4 show results from Baca 18 OH and Baca 23, wells with the same surface location. Baca 18 was logged in the interval 663-1800 ft., and Baca 23 was logged from 1406-3070 ft. Neither well is productive. The mean fracture strike in Baca 18 OH is N8W; that measured in Baca 23 is N19W. Both wells exhibit a preferred north-northwesterly striking fracture orientation.

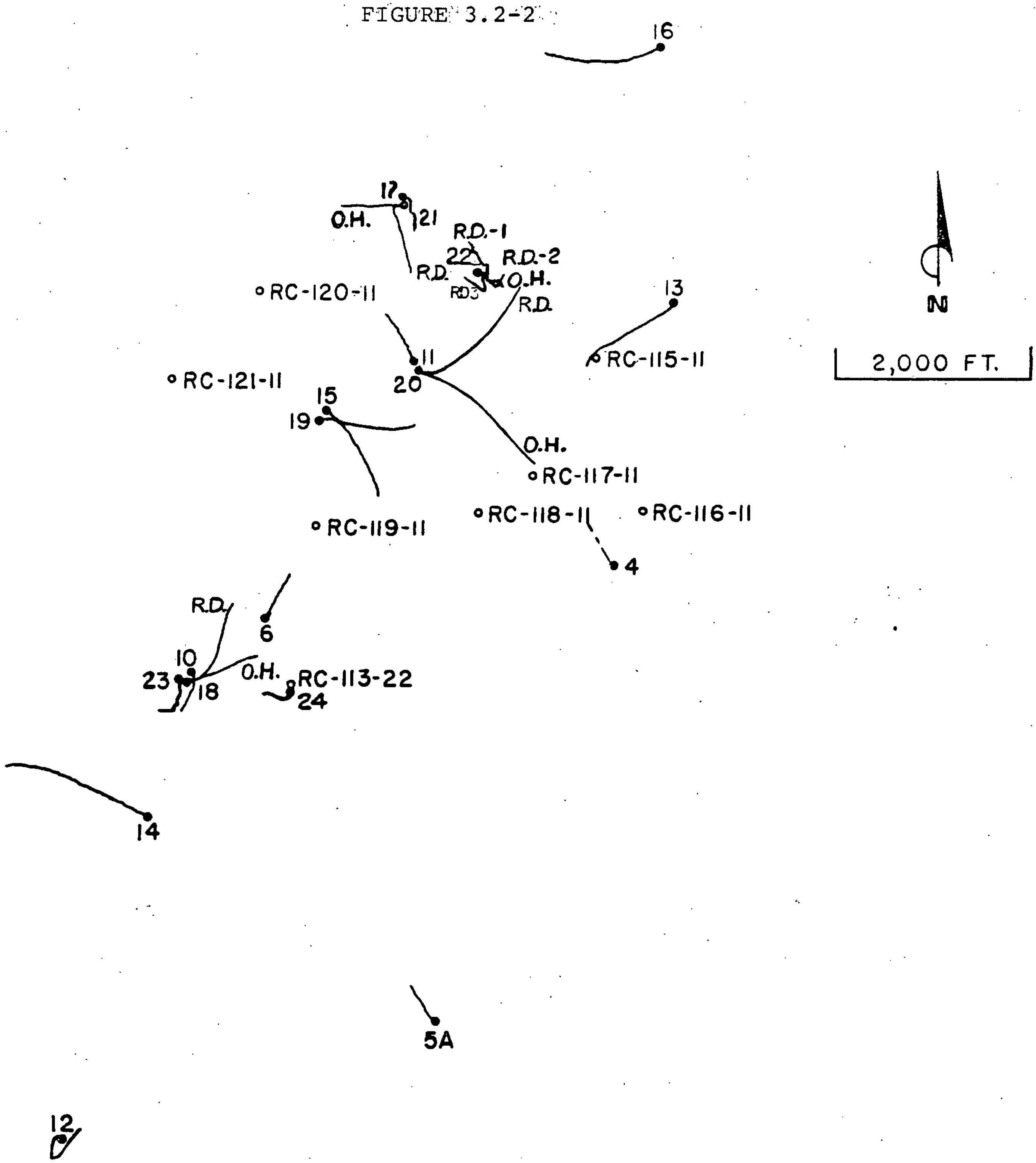
Figure 3.2-5 shows the Baca 20 OH results. The logged intervals summarized in the figure were 1414-2509 ft. prior to setting 9-5/8" casing and 2505-3500 ft. prior to redrilling. This well provided the most calculated fracture orientations, and the mean fracture strike is N40W. Partly based upon log results the unproductive original hole of Baca 20 was redrilled to be northeast, perpendicular to the northwesterly mean fracture strike and resulted in a marginal commercial producer.

Figure 3.2-6 shows results from Baca 21. Few fracture directions in the logged interval of 1504-2606 ft. were able to be calculated. The mean fracture strike of N30W is consistent with the other logged wells. Baca 21 is not a commercial producer because it apparently did not penetrate the main reservoir.

The results of all logged wells are summarized in Figure 3.2-7. The results are biased by the large number of fracture directions measured in Baca 20. The preferred northwesterly to north-northwesterly direction of fracture strikes appears consistent in all logged wells.

Preliminary conclusions are that a preferred northwesterly-trending fracture strike exists in the logged intervals of Baca 18 OH, 20 OH, 21, and 23. Additional data must be obtained from the hot permeable intervals of several wells in the Redondo Creek area before any definite correlation among preferred fracture strike, well direction, and well productivity can be drawn. Use of Fracture Identification Logs appears promising enough to continue when future wells are drilled.

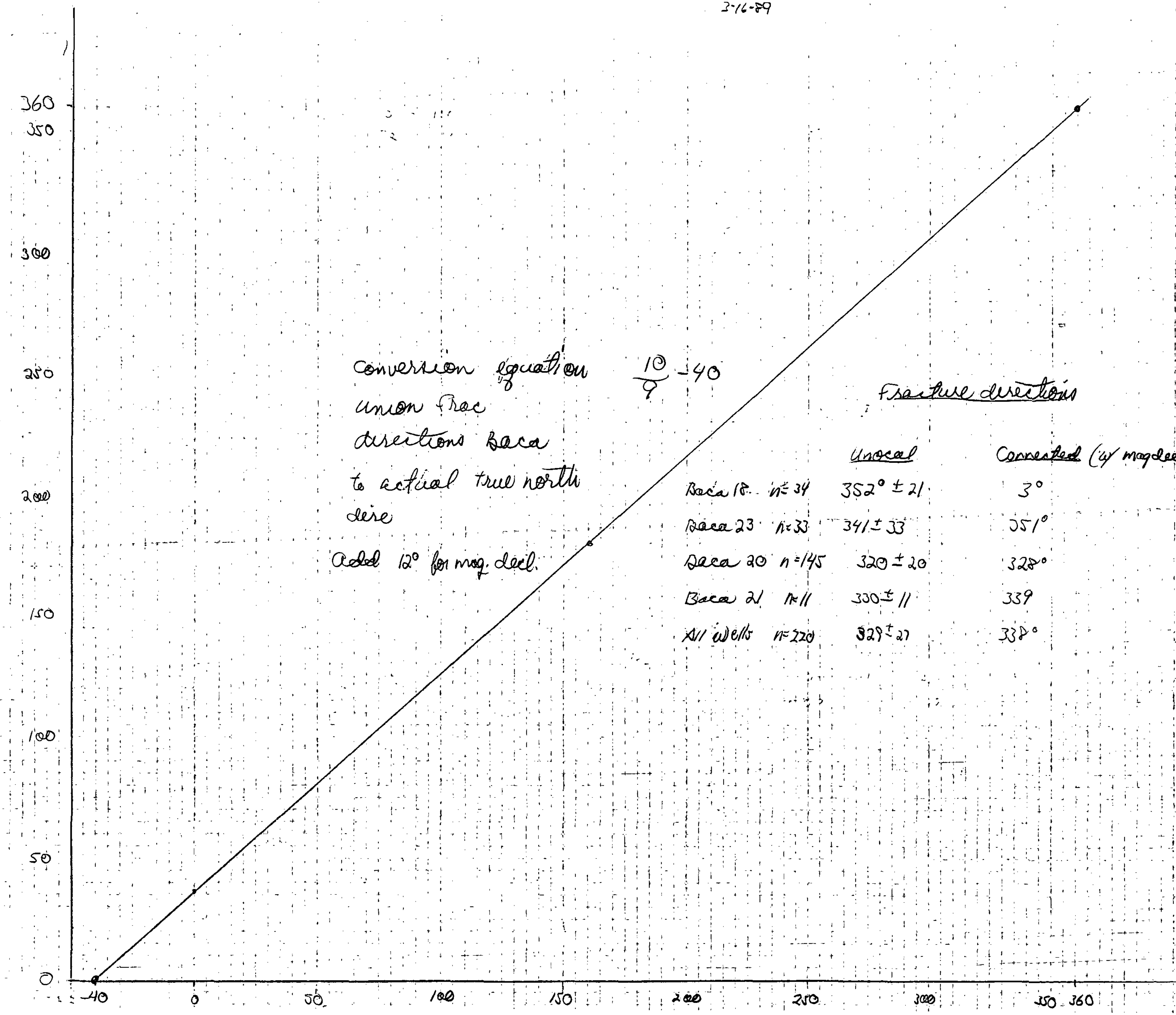
FIGURE 3.2-2



REDONDO CREEK WELL LOCATIONS

24: Existing Well with Wellcourse
RC-113-22: Future Well Location
OH: Original Hole
RD: Redrilled Hole
Preferred Mean Fracture Strike: N31W

3-16-89



conversion equation $\frac{10}{9} - 40$

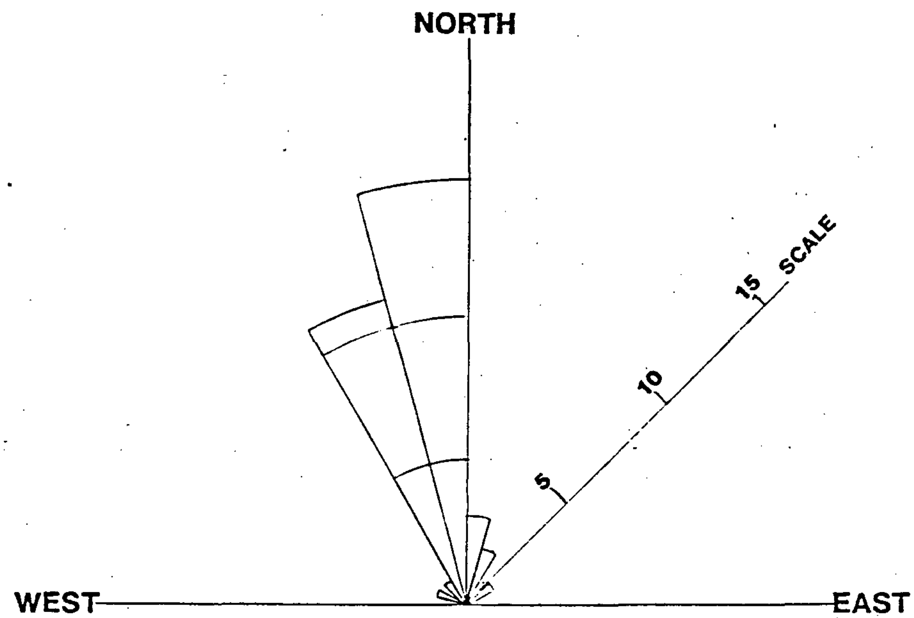
union frac directions Baca to actual true north dire

Add 12° for mag. decl.

Fracture directions

	Unocal	Corrected (w/ mag decl.)
Baca 18 n=34	352° ± 21	3°
Baca 23 n=33	341 ± 33	351°
Baca 20 n=145	320 ± 20	328°
Baca 21 n=11	330 ± 11	339
All wells n=220	329 ± 27	338°

FIGURE 3.2-3

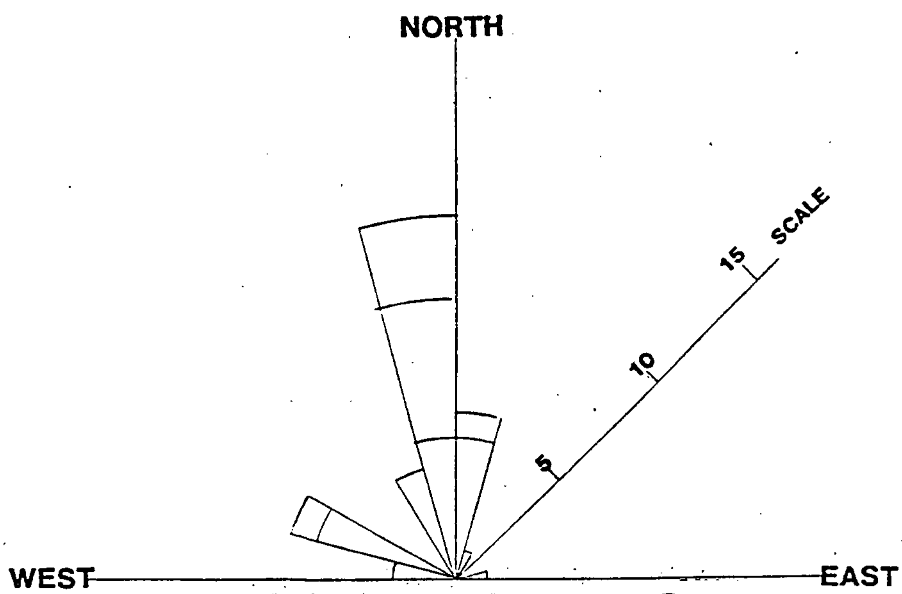


FRACTURE STRIKES
BACA 18

ORIGINAL HOLE - NONCOMMERCIAL

Number of Fractures	34
Mean Direction	N8W
Std Dev.	21 deg
Logged Interval	663'-1800'

FIGURE 3.2-4

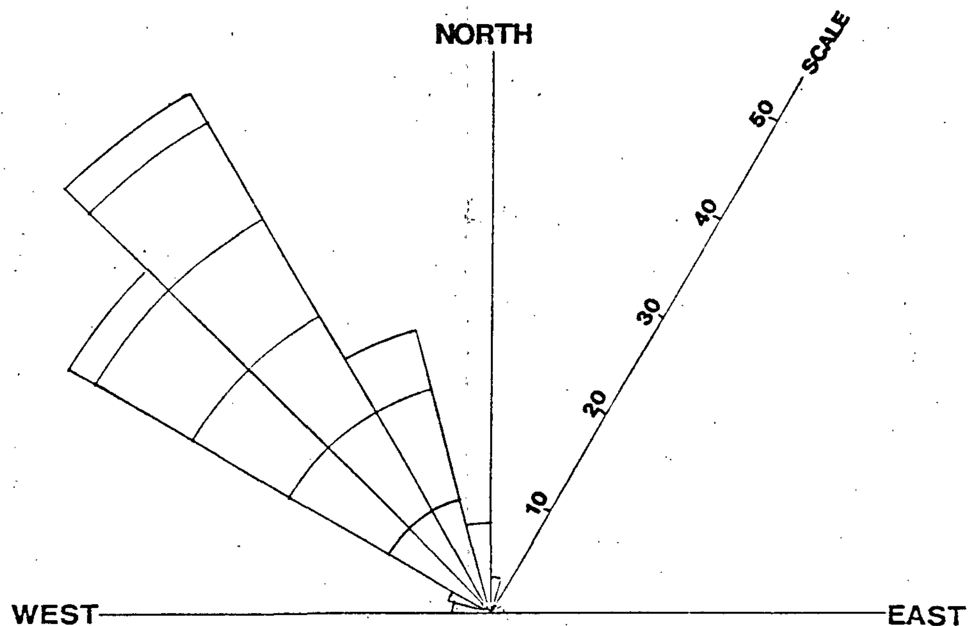


FRACTURE STRIKES
BACA 23

NONCOMMERCIAL WELL

Number of Fractures	33
Mean Direction	N19W
Std Dev.	33 deg
Logged Interval	1406'-3070'

FIGURE 3.2-5



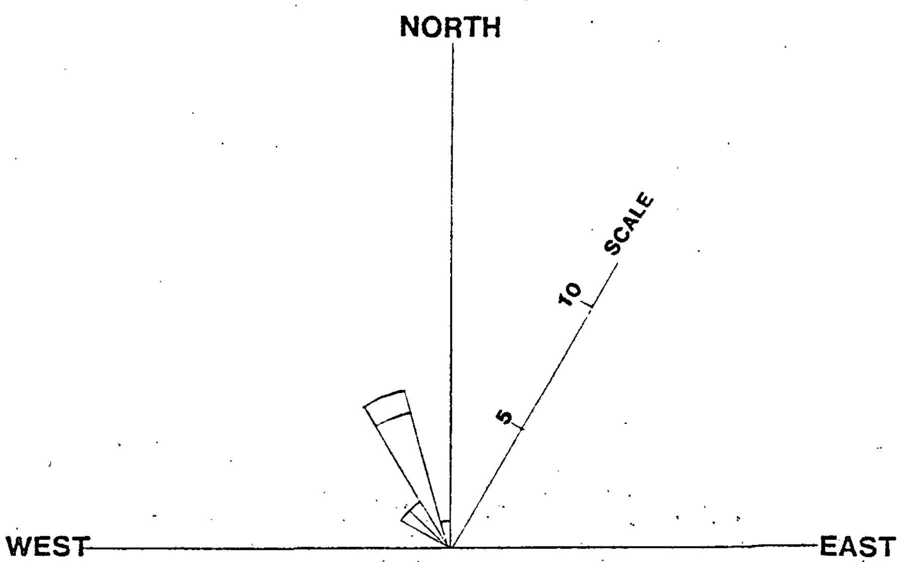
FRACTURE STRIKES

BACA 20

ORIGINAL HOLE - NONCOMMERCIAL

Number of Fractures	145
Mean Direction	N40W
Std Dev.	20 deg
Logged Intervals	1414'-2509' — 20 OH
	2481'-5842' — 20R/D

FIGURE 3.2-6



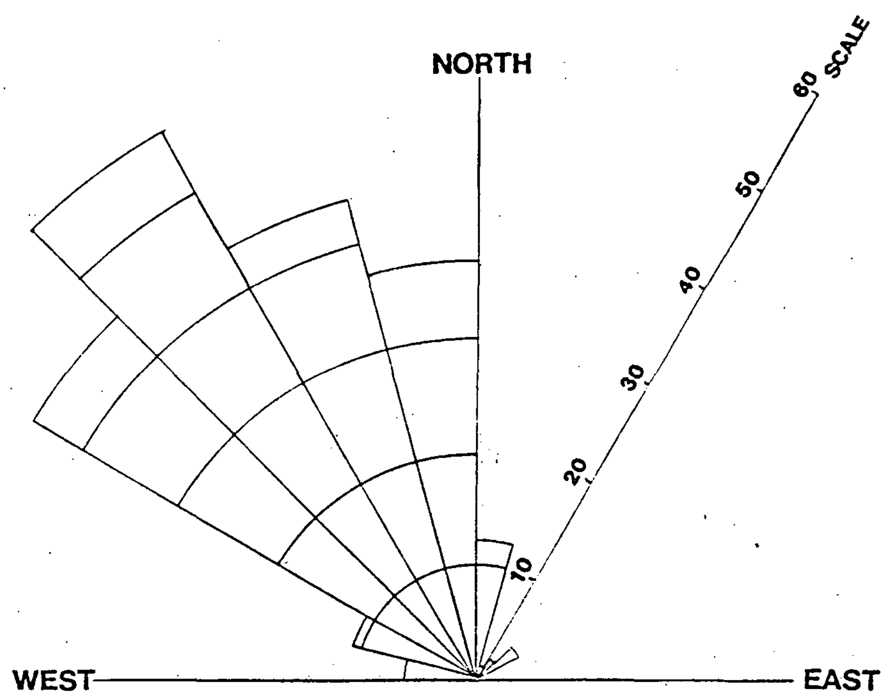
FRACTURE STRIKES

BACA 21

NON-COMMERCIAL WELL

Number of Fractures	11
Mean Direction	N30W
Std Dev.	11 deg
Logged Interval	1504'-2606'

FIGURE 3.2-7



FRACTURE STRIKES
ALL WELLS

Number of Fractures	220
Mean Direction	N31W
Std Dev.	27 deg

3.3 Geophysical Log Results

3.3.1 Tool Type and Operation

Geophysical logs have been run in several Valles Caldera wells. The logs have been very useful in determining stratigraphic correlation among wells and presence of porous and possibly productive zones. Operating problems are wellbore sloughing, wellbore temperatures exceeding tool rating, and random equipment failure.

Logs are normally obtained in open hole at three depths: 13-3/8" casing point depth (1000-2000 ft.), 9-5/8" casing point depth (2000-3500 ft.), and at total depth prior to completion. Table 3.3-1 lists the logs normally attempted at these three depths; the specific tool types listed are those marketed by Schlumberger. Normally a log suite consisting of resistivity, neutron-density, temperature, and dipmeter is considered adequate; sonic logs are occasionally run to obtain velocity and additional porosity information. Logs which have been run in Redondo Creek wells are listed in Table 3.3-2.

Operating suitably-rated logging equipment in high temperatures has not been a serious problem. Neutron-density, resistivity, and sonic logs with temperature ratings of 500°F are readily available. Logging cable with a temperature rating of 525°F is also routinely used. Temperature tools with temperature ratings above 350°F are not available in the Valles Caldera area. A high-temperature dipmeter is occasionally available, but it is still experimental and is not currently considered commercial. To minimize high temperature effects when logging at total depth, cold water is pumped into the hole while logging. This is effective if the injected water exits near total depth. If the injected water exits too shallow, the bottom portion of the hole cannot be cooled enough to log - a particular problem in deep, tight, mud drilled holes. Logs are run going into the hole rather than coming out to mitigate temperature effects and insure at least part of the hole being logged prior to tool failure.

3.3.2 Examples of Log Response

Successful logging of geothermal wells in their hot and permeable intervals is a relatively recent accomplishment. Accordingly only the most recent wells have good log data. The following discussion describes the response of various logging tools and the usefulness of such data.

TABLE 3.3-1

LOG TYPES AND DEPTHS
Listed in Order Run

DEPTH	TOOL TYPE	REMARKS
13-3/8" Csg. Pt. (1000-2000 ft.)	Resistivity - Gamma Ray (Dual Laterolog preferred)	Provides depth control with deeper logs. Detects fresh water zones which must be cased off. Detects lithologic contacts used in shallow stratigraphic correlation.
9-5/8" Csg. Pt. (2000-3500 ft.)	Temperature	Determines if high temperature tools are required and safe logging depth for dipmeter.
	Dipmeter (Fracture Identification Log)	Determines strike of fractures near top of production interval.
	Neutron - Density - Gamma Ray	Determines density and porosity of rocks near top of production interval. Detects lithologic contacts.
	Resistivity (Induction, Dual Induction or Dual Laterolog) - Gamma Ray	Provides depth control with shallower and deeper logs. Complements results of neutron density.
	Sonic (optional)	Provides velocity information. Complements porosity data from density log.
Total Depth	Temperature	Determines safe logging depth if dipmeter is to be used. Limited to temperatures less than 350°F.
	Dipmeter (Fracture Identification Log)	Determines fracture strikes as deep as hole temperature allows logging.

TABLE 3.3-1 (cont'd)
LOG TYPES AND DEPTHS
Listed in Order Run

DEPTH	TOOL TYPE	REMARKS
Total Depth	Neutron - Density - Gamma Ray (Compensated) (CNL-FDC)	High-temperature tool. Detects contact of Bandelier Tuff Zones A and B, large fracture zones, porous zones, and base of Bandelier Tuff.
	Resistivity (Induction preferred Dual Laterolog acceptable) - Gamma Ray	High temperature tool. Detects contacts between all Bandelier Tuff zones - especially contact between Zones B and C, contact between Bandelier Tuff and Paliza Canyon Formation, very large fracture zones, and complements neutron-density results.
	Sonic (optional)	High-temperature tool. Provides velocity information, additional porosity data, and helps confirm results of neutron-density and resistivity logs.

TABLE 3.3-2

GEOPHYSICAL LOGS RUN

WELL	INTERVAL FT KB	LOG TYPE*	MAX REC TEMP °F	REMARKS
13	1470-3485	Dual Induction - SP	268	
13	3494-6813	Dual Induction - SP	471	Pumped H_2O while logging
13	1150-3499	Temp	243	
13	2640-8228	Temp	471	
13	3494-7240	Sonic - GR	372	Tool quit at 7240
13	3494-6809	Neutron-Density-GR	300	Pumped H_2O while logging
14	470-5300	Temp	190	Tool quit at 5300
14	3068-5830	Neutron-Density-GR	450	Tool quit at 6200 - Density log invalid
17OH	238-1168	Dual Induction - GR	124	
17OH	250-2755	Temp	256	
17OH	1171-2763	Induction - GR	NA	Pumped H_2O while logging
17OH	1181-2755	Borehole Geometry	200	" " " "
17OH	100-4615	Temp	300	" " " "
17OH	3000-3500	Caliper	216	" " " "
17OH	3000-5801	Induction - GR	440	" " " "
17RD	3000-6270	Induction - GR	NA	" " " " Thermometers lost in hole
18OH	54-661	Dual Induction - GR	124	
18OH	100-2023	Temp	247	
18OH	663-1800	Fracture Identification	224	
18OH	659-2007	Induction - GR	270	
18OH	100-2023	Temp	305	
18RD	170-5250	Temp	343	
18RD	2018-5250	Induction - GR	338	
19	247-1506	Induction - GR	154	
19	922-2495	Temp	179	
19	1431-2466	Gamma Ray	174	Induction tool failed
19	2480-5400	Induction - GR	400	Tool would not go below 5400 - Pumped H_2O while logging. Sonic log would not operate.

* ALL LOGS BY SCHLUMBERGER

TABLE 3.3-2 (Con't)
GEOPHYSICAL LOGS RUN

WELL	INTERVAL FT KB	LOG TYPE*	MAX REC TEMP °F	REMARKS
20OH	1414-2509	Fracture Identification	236	
20OH	1414-2504	Sonic - GR	255	
20OH	1414-2500	Dual Laterolog - GR	255	
20OH	1414-2504	Neutron Density - GR	NA	Thermometers broke
20OH	2504-4000	Temp	340	
20OH	2505-3500	Fracture Identification	268	
20OH	2505-6853	Dual Laterolog - GR	428	
20OH	2505-6850	Neutron-Density - GR	454	
20RD	2646-5494	Neutron-Density - GR	500	Pumped H_2O while logging. Dual Laterolog failed.
20RD	2563-5836	Induction - GR	214	Prior to frac. Pumped H_2O while logging.
20RD	2481-5842	Dipmeter/Fracture Identification	214	" " " " " " "
20RD	2426-5836	Sonic - GR	215	" " " " " " "
20RD	4882-5129	Neutron-Density - GR	360	Post-frac. Kept hole full of H_2O.
20RD	4882-5138	Fracture Identification/ Dipmeter	360	" " " " " "
20RD	4882-5133	Sonic - GR	NA	" " " " " " Temp <200°F
20RD	4881-5128	Dual Laterolog - GR	190	Post-frac. Kept hole full of H_2O. Induction tool failed. Borehole televiewer (Sandia Lab tool) failed.
21	616-1517	Dual Induction - GR	NA	
21	0 - 2601	Temp	325	Temperature increased from 275 to 325 after sitting on bottom 10 min.
21	1504-2606	Fracture Identification	210	Logging truck winch failed after temp log. Circulated while waiting for relief truck to run subsequent logs.
21	1504-2606	Neutron-Density - GR	238	
21	1504-2592	Dual Induction - GR	250	
21	2595-2930	Neutron-Density - GR	389	Pumped 150 gpm H_2O while logging

*ALL LOGS BY SCHLUMBERGER

TABLE 3.3-2 (Cont'd)
GEOPHYSICAL LOGS RUN

WELL	INTERVAL FT KB	LOG TYPE*	MAX REC TEMP °F	REMARKS
22OH	435-1535	Dual Laterolog - GR	126	
22OH	1492-2530	Temp	325	
22OH	1531-2530	Fracture Identification	262	Induction, neutron-density tools, and logging truck computer failed at this depth
22OH	2512-5946	Neutron-Density - GR	484	Pumped H_2O while logging
22OH	2512-5864	Induction - GR	402	" " " "
22RD-1	2512-6253	Neutron-Density - GR	315	" " " "
22RD-3	2512-6525	Dual Laterolog - GR	NA	Stuck tool at 6535. Suspended all operation.
23	596-1411	Dual Induction - GR	182	
23	1200-3070	Temp	238	Temp after sitting on bottom 10 min.
23	1406-3070	Fracture Identification	254	Induction and neutron density tools failed at this depth
23	3056-5690	Induction - GR	488	Pumped H_2O while logging
23	3058-4690	Neutron-Density - GR	NA	" " " " . Thermometers lost in hole.
24	0-2944	Temp	180	
24	782-2946	Dual Laterolog - GR	236	Lost hole prior to reaching TD

*ALL LOGS BY SCHLUMBERGER

Lithology Contact Detection. Figure 3.3-1 shows sonic and porosity log responses to Bandelier Tuff Zones A and B in Baca 20 Redrill. Zone A is characterized by low neutron porosity (less than 2%) and low interval transit times (60 micro-seconds/foot). Zone B has significantly higher neutron porosity (6-8%) and longer interval transit times (65-70 microseconds/foot). Zone B is much more variable than Zone A in both interval transit time and neutron porosity - the criteria for identifying Zone B of the Bandelier Tuff.

Figure 3.3-2 shows the resistivity log responses to Bandelier Tuff Zones B and C and the Paliza Canyon Formation in Baca 20 Redrill. Zone C is characterized by a broad conductivity high. The contact between the Bandelier Tuff and the Paliza Canyon Formation is indicated by lower conductivity and gamma ray count in the Paliza Canyon Formation.

Fracture Detection. Figure 3.3-3 shows porosity and resistivity log responses to a fracture zone in Baca 20 Redrill. Fracture zone responses are characterized by abrupt increase in neutron porosity, wide fluctuations in resistivity over short intervals, hole enlargement, and lower gamma ray count.

breakouts?

The neutron tool appears more effective than the density tool in identifying porous, water-filled zones. The neutron tool detects hydrogen atoms in the formation; the source of most of the hydrogen is formation water or drilling fluid which has invaded the formation. The density tool responds to electrons in the formation which may be due to saline water present as formation or infiltrated fluid or due to electrons bound in clays. As a result, the density tool may record false porosities. Furthermore, the density tool is affected by hole rugosity, a problem not suffered by the neutron tool. The density tool's chief use is in recording formation density and providing a simultaneous check on the reliability of the neutron tool.

Figure 3.3-4 shows a Fracture Identification Log response in Baca 20 Original Hole. Pads 2 and 4 record low electrical conductivity; pads 1 and 3 record high conductivity. The azimuth and relative bearing curves allow the azimuth of Pad 1 to be determined, yielding a fracture strike of N45W. Note that the caliper curves show the hole to be only slightly out of gauge. This is an example of how hole ellipticity is not necessarily an indicator of presence or orientation of fractures.

scale misread

FIGURE 3.3-1

SONIC AND POROSITY LOG RESPONSES
TO BANDELIER TUFF ZONES A AND B
BACA 20 REDRILL

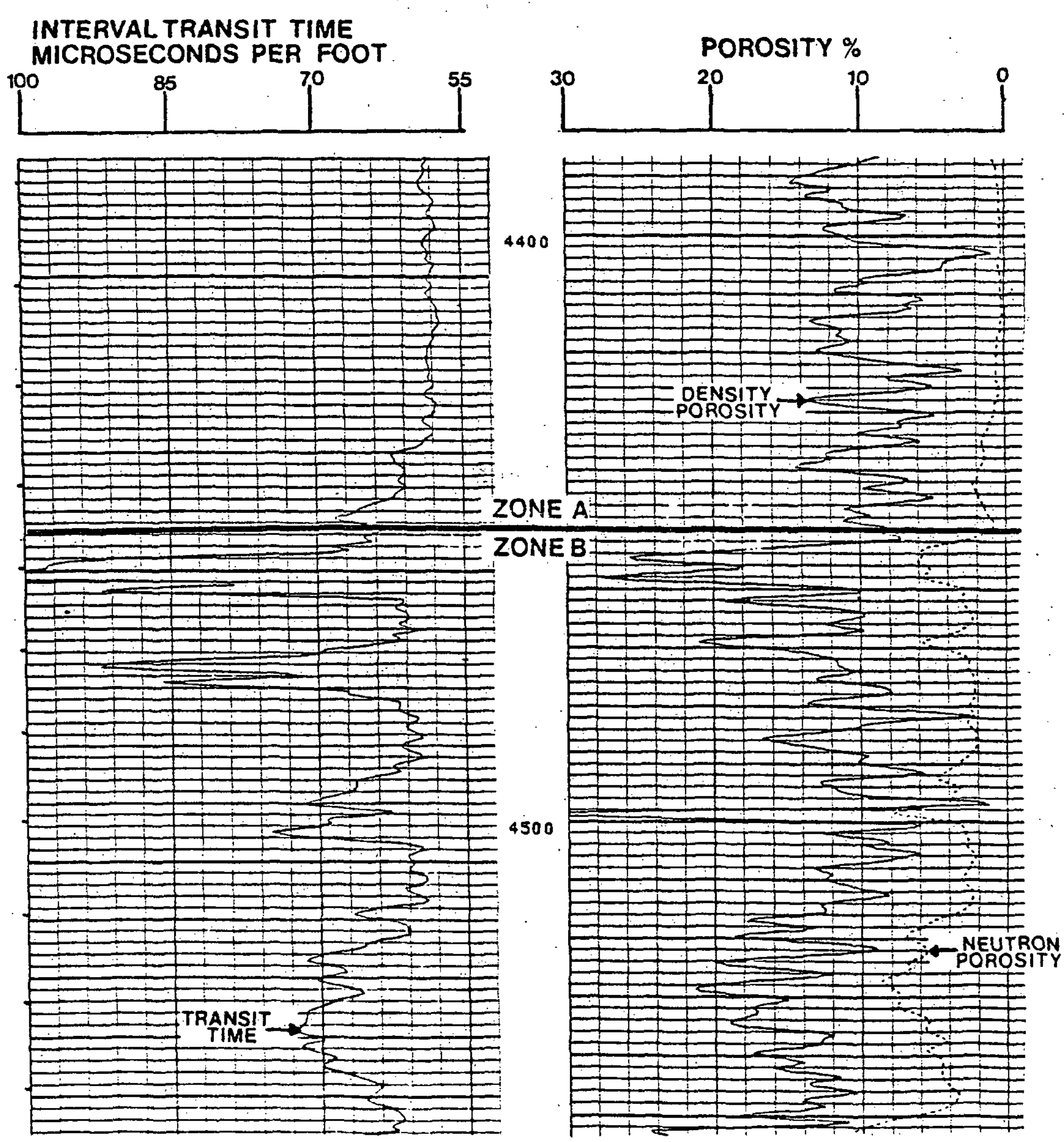


FIGURE 3.3-2

RESISTIVITY LOG RESPONSE TO
BANDELIER TUFF ZONES B AND C AND PALIZA CANYON FM
BACA 20 REDRILL

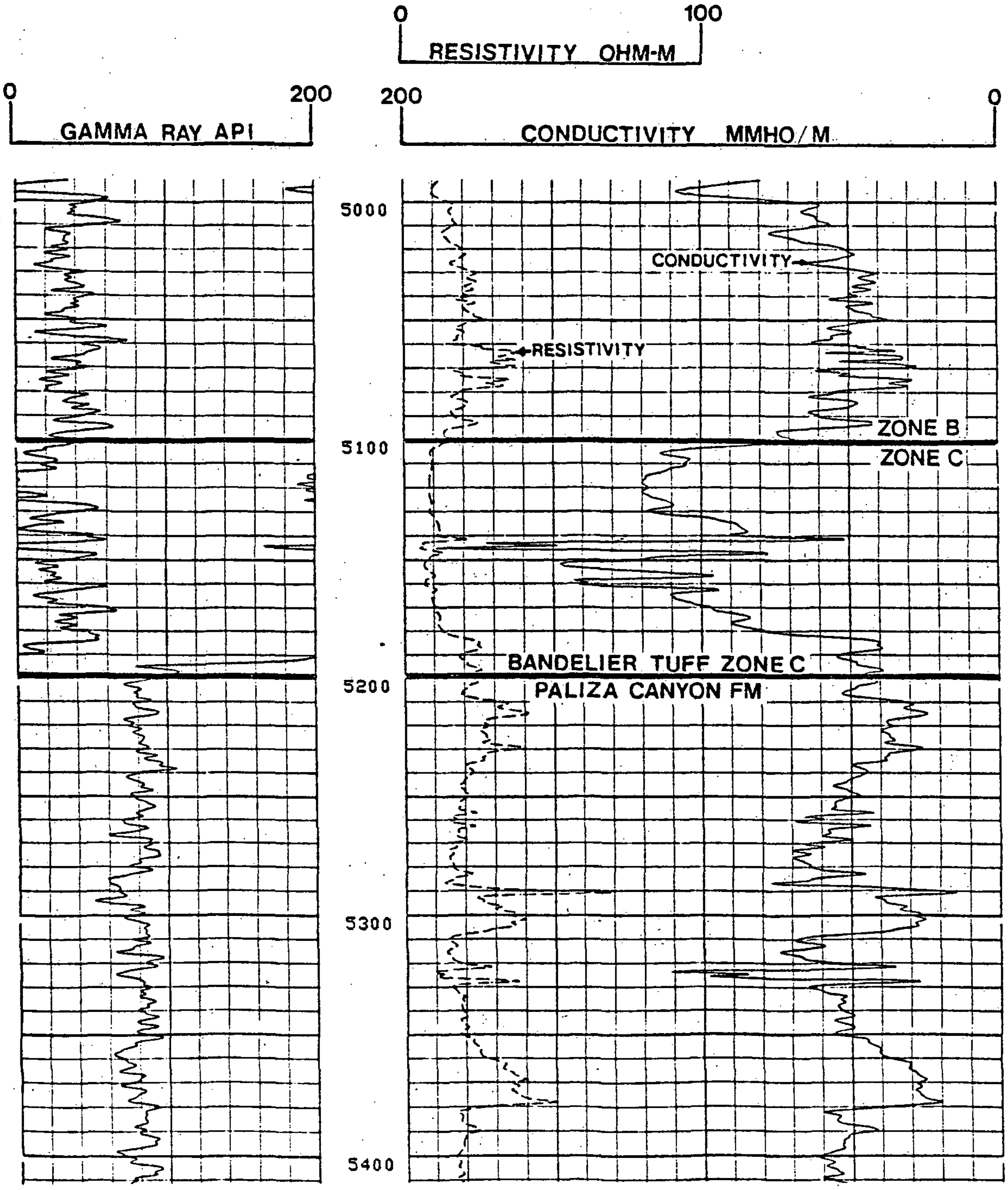


FIGURE 3.3-3

LOG RESPONSES TO FRACTURE ZONE
BACA 20 REDRILL

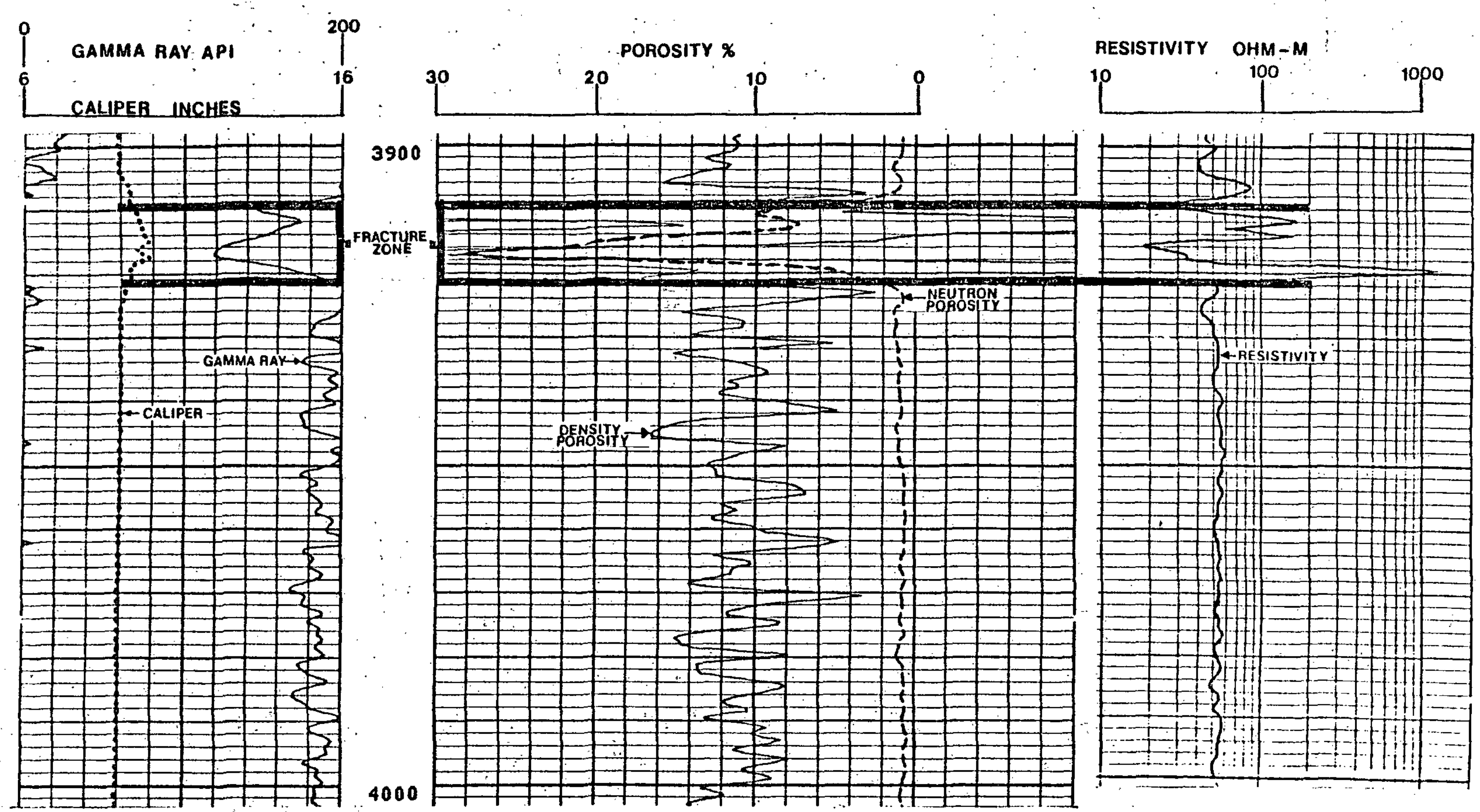
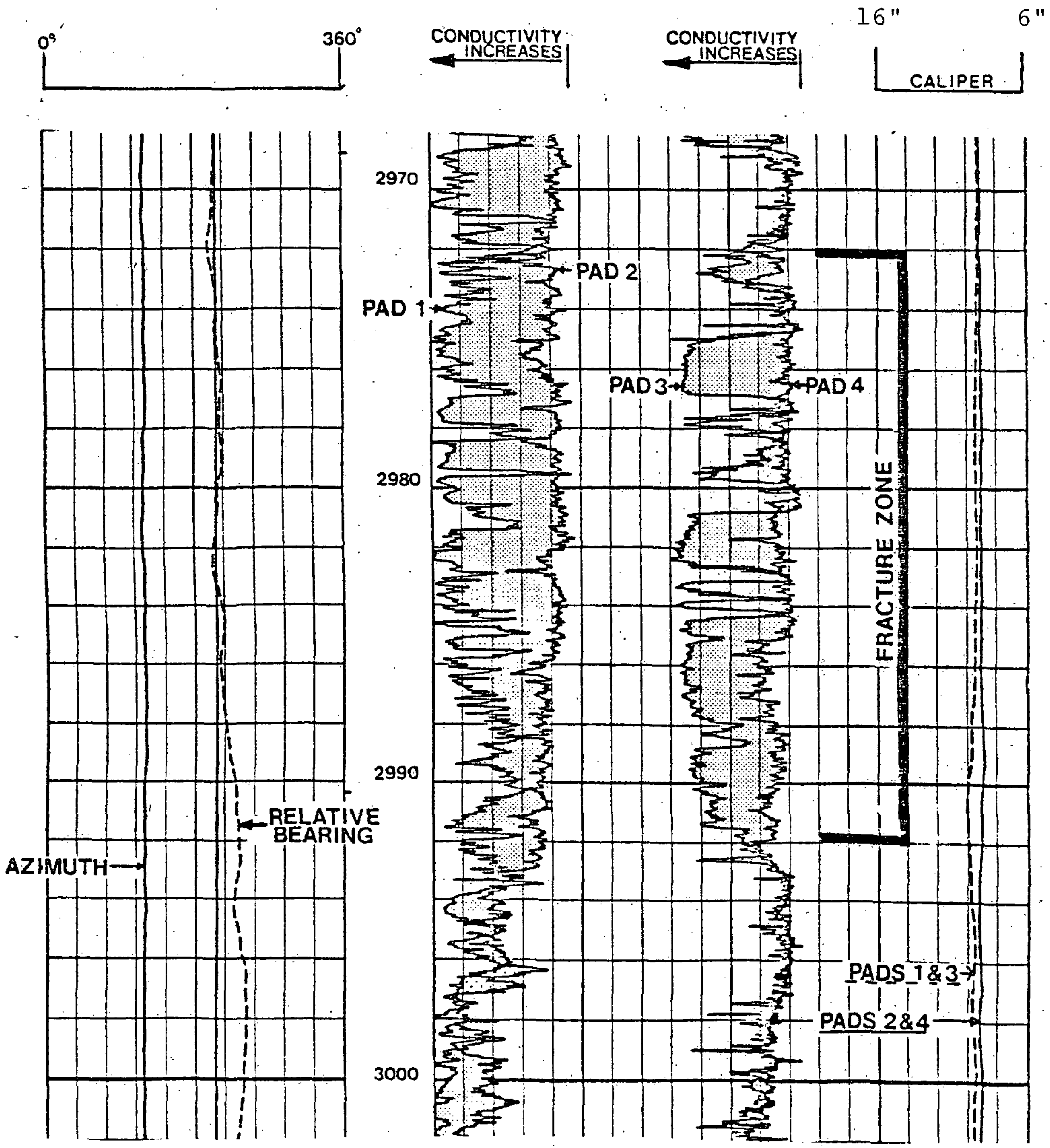


FIGURE 3.3-4

FRACTURE IDENTIFICATION LOG RESPONSE

BACA 20 ORIGINAL HOLE PRIOR TO REDRILLING



PADS 1 AND 3 ARE RECORDING CONDUCTIVE ANOMALY STRIKING N45W

3.4 Well Chemistry

3.4.1 Fluid Chemistry - Major Constituents

Samples of fluid produced from wells capable of flowing through a test separator have been obtained from the Redondo Creek wells Baca 4, 6, 11, 13, 15, 20, 22 and 24. Baca No. 23 was also sampled when flowing through a "mini" separator. The samples obtained from the two-phase line, the steam outlet of the separator and the liquid outlet of the separator (flashed brine) have been analyzed for various chemical constituents found in the well effluent. Table 3.4-1 presents the average chemical concentrations, and Table 3.4-2 gives a detailed account of the major ions Na, K, Ca, Mg, Cl, SO_4, CO_3 and HCO_3 and the trace elements As, B, Br, F and Li found in the Redondo Creek fluids. Sampling was conducted during the 1982 testing on Baca 4, 13, 15, 19, 20 and 24 but was not analyzed for this report.

Table 3.4-1 shows that the brine concentrations of the Redondo Creek fluids are extremely low (5200 to 7300 ppm) with the exception of Baca 22. The abnormally high concentration observed in the Baca 22 sample is probably due to the well being sampled prior to completely cleaning itself of drilling fluid (Section 5.2.2). The non-condensable gases are fairly consistent throughout the field but the H_2S concentration was unusually high in Baca 11. The corrosive nature of the Baca 11 fluid which eventually led to its plugging and abandonment (poor casing) is a further reflection of the anamolous fluid composition of Baca 11.

Major Ions

Table 3.4-2 shows that the produced fluid is primarily sodium chloride in nature and has a fairly uniform composition. Calcium concentration is low as would be expected from the high subsurface temperatures and rhyolitic composition of the Bandelier Tuff - the principal producing horizon. Carbonate and bicarbonate concentrations are probably controlled by the partial pressure of CO_2 at the time of sampling. The rhyolitic composition of the Bandelier Tuff suggests that the potassium concentration is more a function of temperature than lithology. (Geothermometric calculations supporting this conclusion are included in Section 3.5.2.)

The significance of differences in ionic concentrations within a single well's history and among all the wells is unclear. Systematic study of such variations is best done when several wells are flowed simultaneously for a long time, and no such

TABLE 3.4-1 AVERAGE CONCENTRATIONS OF VARIOUS CHEMICAL CONSTITUENTS IN WELL EFFLUENT

WELL	FLOW RATE (LB/HR)	FLASH %	TOTAL DISSOLVED SOLIDS		NON-CONDENSABLE GAS		H_2S
			BRINE (PPM)	CONDENSATE (PPM)	STEAM (WT%)	TOTAL MASS (WT%)	TOTAL STEAM (PPM)
BACA 4	160,000	28	5200	28	3.3	1.0	150
BACA 6	164,000	25	6018	23	1.33	.37	99
BACA 11	230,000	40	6895	59	3.76	1.5	477
BACA 13	270,000	28	6477	13	3.09	.87	149
BACA 15	150,000	61	5970	22	1.35	.82	170
BACA 20[1]	64,000	62	7272	21	2.55	1.47	75
BACA 22[2]	21,000	75	14300	37	3.48	1.47	167
BACA 23[3]	72,000	52	6600	23	.60	.25	46
BACA 24	168,000	20	5825	15	.93	.55	22

[1] Before stimulation.

[2] Sampled prior to cleanout of drilling fluids.

[3] After stimulation.

TABLE 3.4-2

SUMMARY OF FLUID CHEMISTRY BACA WELLS
All Samples Corrected for Flash

WELL	SAMPLE DATE	% FLASH	SiO2 mg/l	CATIONS mg/l Na	K	Ca	Mg	ANIONS mg/l Cl	SO_4	CO_3	HCO_3	TRACE ELEMENTS As	B	Br	F	Li
BACA 4	9/18/73	24.4	201	1194	227	5	0.1	1890	23	0	142	9	16			
	11/05/73	27.5	165	1015	225	4.7	0.4	1958	24	46	78	1.4	15			
	11/09/73	27.5	-	965	212	4.1	0.5	1798	-	0	141					
	5/06/81	33	506	986	213	3.6	0.3	1675	29		119	1.9	14		0.5	15
BACA 6	10/11/72	25.8		1218	275	0.5	0.1	2132	27	-	-					
	10/11/72	25.8		1209	263	2.2	0.1	2044	24	-	51	2.7	8.3	3.4	6.1	
	10/27/72	25.0		1328	239	8	0	2235	23	70	-	3.2	16.5			20
	11/09/75	24		1293	228	9	0.6	2585	22	0	75	3.8	13		5.1	
BACA 11	1/23/74	49.3	189	1003	189	17	0.2	1853	-	24	12					
	1/23/74	49.3	175	991	175	16	0.2	1825	-	21	18					
	9/16/74	49	246	969	246	12	0.1	1805	43	0	77					
	9/20/74	49	246	969	246	13	0.1	1438	39	0	72					
	11/08/74	51	273	1091	273	23	0.2	2179	25	0	34					
	2/24/76	40	259	1092	259	10	0.02	1564	40	0	17	2.0	15		4.3	
	4/08/76	42	314	899	172	3	.02	1520	60	0	129	1.7	12		6.2	14
BACA 13	12/07/74	30	264	1323	264	8	0.6	2310	214	33	114		16		6	
	10/15/74	30	223	1103	223	3.9	0.6	1778	47	11	130	1.6	14		7.7	
	11/07/75	34	368	990	201	3.5	0.1	1777	48	0	162					
	2/26/76	28	311	1167	236	4	.02	1674	42	0	156	2.4	18		5.1	
	4/07/76	27	395	1132	216	4	.03	1913	76	0	163	2.1	15		7.8	18
BACA 15	11/04/76	59.5	243	770	177	9	.04	1426	-	0	23		11		2.8	
	11/17/76	52.7	314	818	193	9	0.2	1533	10	0	48		11		2.9	
	11/22/76	62.7	271	701	153	7	.03	1263	5	0	25		10		2.5	
	11/24/76	67.7	255	636	156	7	0.1	1164	6	0	26		8		2.6	
	1/05/77	56.0	348	761	180	12	0.5	1558	-	0	44	0.9	12		2.9	14
BACA 20	9/30/80	64.4	267	716	127	22	1.0	1212	24	0	11		12		1.6	9
(RD-1)	10/07/80	58.5	240	851	112	35	0.5	1513	127	0	6		14		3.2	12
	10/23/80	62.4	274	1325	264	26	0.3	2207	52	0	30	2.3	19		4.1	1.8

TABLE 3.4-2 (Cont'd)
SUMMARY OF FLUID CHEMISTRY BACA WELLS
All Samples Corrected for Flash

WELL	SAMPLE DATE	% FLASH	SiO_2 mg/l	CATIONS mg/l				ANIONS mg/l				TRACE ELEMENTS				
				Na	K	Ca	Mg	Cl	SO_4	CO_3	HCO_3	As	B	Br	F	Li
BACA 22 (RD-2)	2/09/81		672	4810	720	29	.4	7880	170	77	418	4.5	68		22	50
BACA 23	5/05/81	52	360	924	130	13	0.2	1574	20	0	53	1.9	16		3.5	13
BACA 24	8/05/81	18.6	505	1490	192	11	0.07	2182	50	-	88	3.1	19	6	4.9	20
	8/19/81	21.5	454	1452	192	9	0.8	2292	48	-	92	3.0	20	6	5.3	19
	9/02/81	21.2	522	1411	210	12	0	2325	39	-	61	2.5	19	7	5.4	20

long-term production yet exists in the Valles Caldera. Low reservoir permeability may cause chemical inhomogeneities as a result of local boiling or impaired convection. Lithologic variation in rocks underlying the Bandelier Tuff (especially the Paliza Canyon Formation) may cause chemical variation among wells. Variations in ionic concentrations observed in a single well may be due to changing flashing conditions in the formation with time.

Trace elements

Table 3.4-2 lists As, B, Br, F, and Li analyses from several wells. The concentrations of these elements in the produced fluid are controlled by temperature and the igneous and sedimentary lithologies through which the fluid has circulated. Variations may be due to lithology, local boiling, or imperfect reservoir mixing due to low permeability. The concentrations of arsenic, fluorine, and bromine are environmentally important in considering how fluids will be treated during production. Boron concentration may also affect production equipment scaling. Changes in the concentrations of these trace elements might provide valuable information of fluid movement in the reservoir during production.

3.4.2 Trace Elements in Well Cuttings

Cuttings from several wells were analyzed for abundance of mercury, arsenic, and antimony and lithium in a few wells. The purpose of the study was to determine if any systematic variations in the concentrations of these trace elements occur. Any detected variations might indicate zones of fluid movement in the productive interval or chemical sealing in portions of the reservoir.

Results show that arsenic concentrations rarely exceed 10 ppm; antimony is not detectable, lithium appears to correlate with lithology, and mercury concentrations are variable - as high as 750 ppb near the surface but diminishing to generally less than 50 ppb at depth. No systematic variations appear at depth, but mercury enrichment may occur in the vicinity of suspected permeable zones.

Baca 18 Redrill 1 (Figure 3.4-1) - Arsenic concentration is uniformly low; the highest concentration recorded is 6 ppm. These low concentrations are consistent with the low arsenic concentrations measured in produced fluids (Table 3.4-2). Mercury concentration is variable.

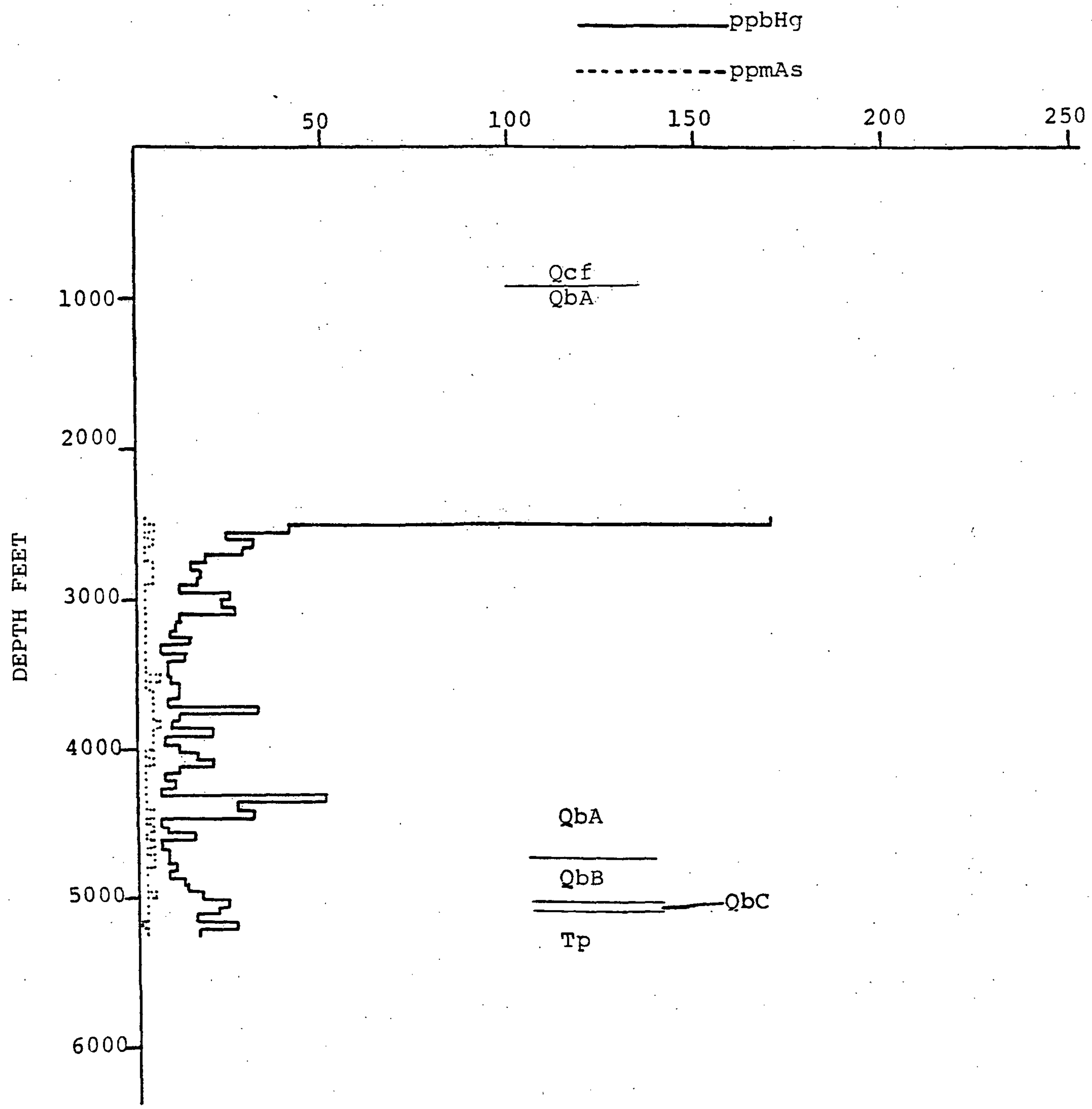


FIGURE 3.4-1

WELL CUTTINGS ANALYSIS - TRACE ELEMENTS

BACA 18 RD - NONCOMMERCIAL WELL

The mercury anomaly between 4200 and 4500 ft. may be due to presence of a permeable zone. Several hundred barrels of drilling fluid were lost while drilling this interval. Since the well is noncommercial, the significance of this suspected permeable zone and coincident mercury anomaly is probably minor. The significance of the mercury anomaly at 2500 ft. is unknown.

Baca 19 (Figure 3.4-2) - Enrichments in both mercury and arsenic occur at shallow depths. The arsenic concentration is quite low below 1500 ft. The mercury concentration is also low below 1500 ft. excepting anomalously high concentrations between 4000 and 4600 ft. Severe lost circulation was encountered (200 bbl/hr) between 3600 and 4000 ft.; aerated water drilling was commenced as a result. The mercury anomaly at 4000-4600 ft. may be a permeable and productive zone just below the lost circulation zone, whose significance is unclear because the well is noncommercial. Analysis detected no antimony.

Baca 20 (Figure 3.4-3) - Data from both the original, noncommercial and redrilled, marginally commercial holes are presented. Arsenic concentration is low and similar to the concentrations measured in the produced fluids from the redrilled hole (Table 3.4-2). Antimony was not detected. Mercury concentration is quite low.

The significance of the mercury enrichment just below 2500 ft. in the original hole is unclear. No lost circulation zones or porous zone log responses are present in this interval. The mercury anomaly at 3900 ft. in the redrilled hole corresponds to a narrow highly porous zone, possibly a fracture, apparent on the neutron porosity log.

Baca 21 (Figure 3.4-4) - The high mercury and arsenic concentrations at shallow depths are similar to those detected elsewhere. Production in the well comes from 2700-2800 ft. Note that there is no apparent mercury enrichment in the zone. There is possibly a small arsenic enrichment from 2800-2900 ft., but its small magnitude makes correlation with the productive interval speculative. Antimony was not detected.

Baca 22 (Figure 3.4-5) - Data from the original hole and first two redrills, all noncommercial, are present. Like the other wells a shallow mercury and arsenic anomaly exists. The original hole exhibits no dramatic anomalies below 3000 ft. Redrill-1 exhibits an arsenic anomaly within the basal 100 ft. of Bandelier Tuff Zone A/Zone B contact and a mercury anomaly near the top of the Paliza Canyon Formation, possibly a productive zone.

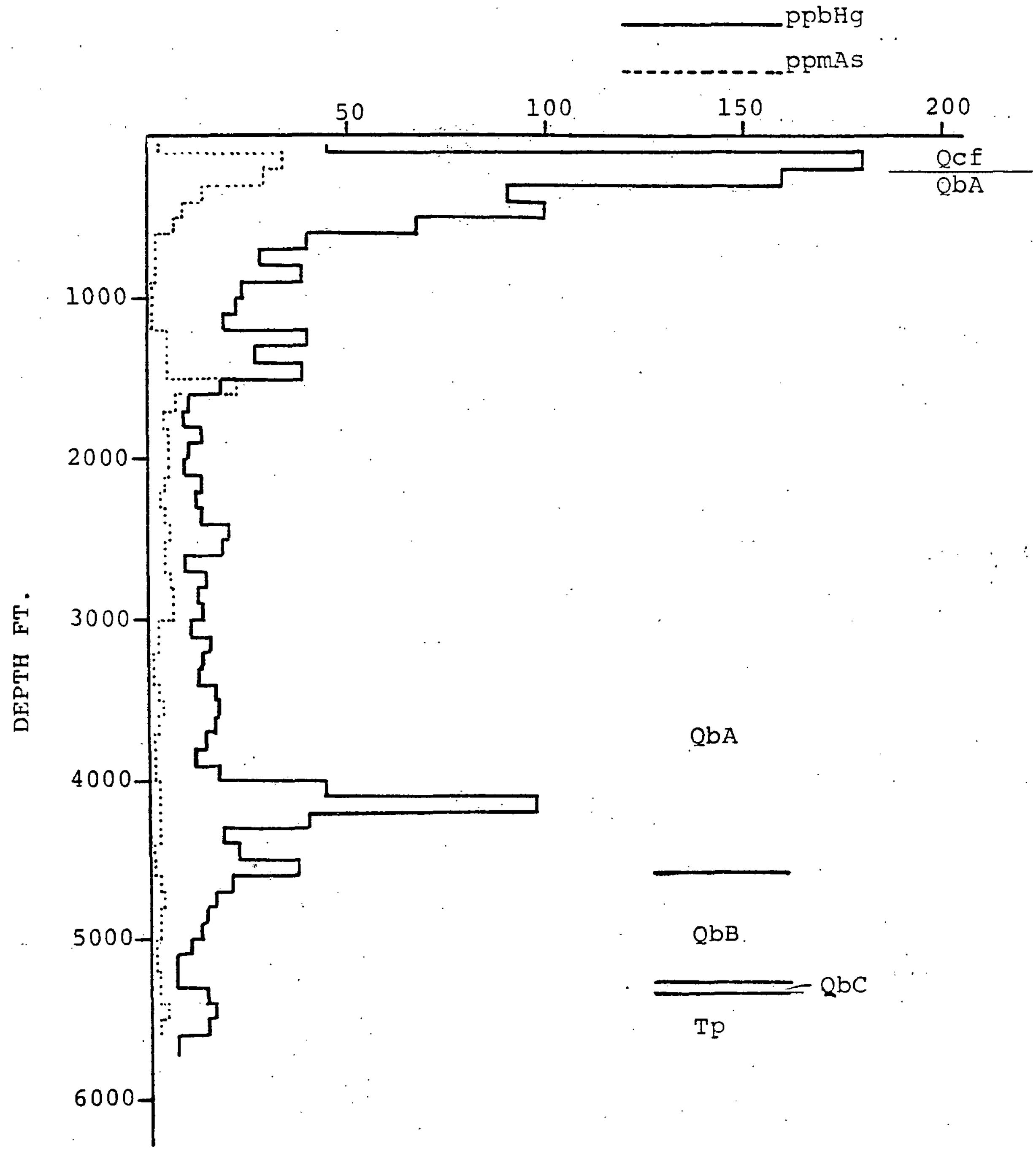


FIGURE 3.4-2

WELL CUTTINGS ANALYSIS - TRACE ELEMENTS

BACA 19 - NONCOMMERCIAL WELL

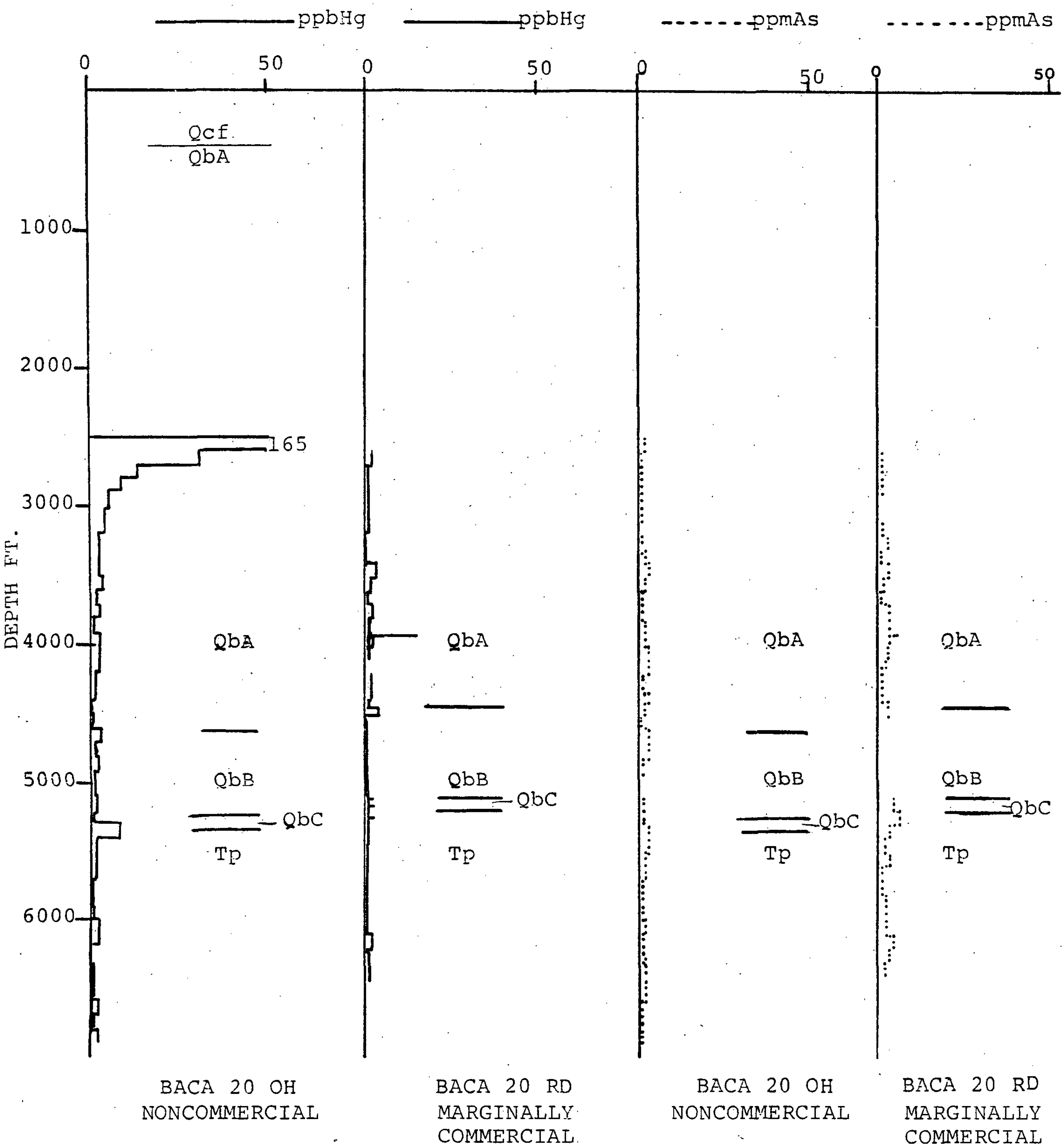


FIGURE 3.4-3

WELL CUTTINGS ANALYSIS - TRACE ELEMENTS

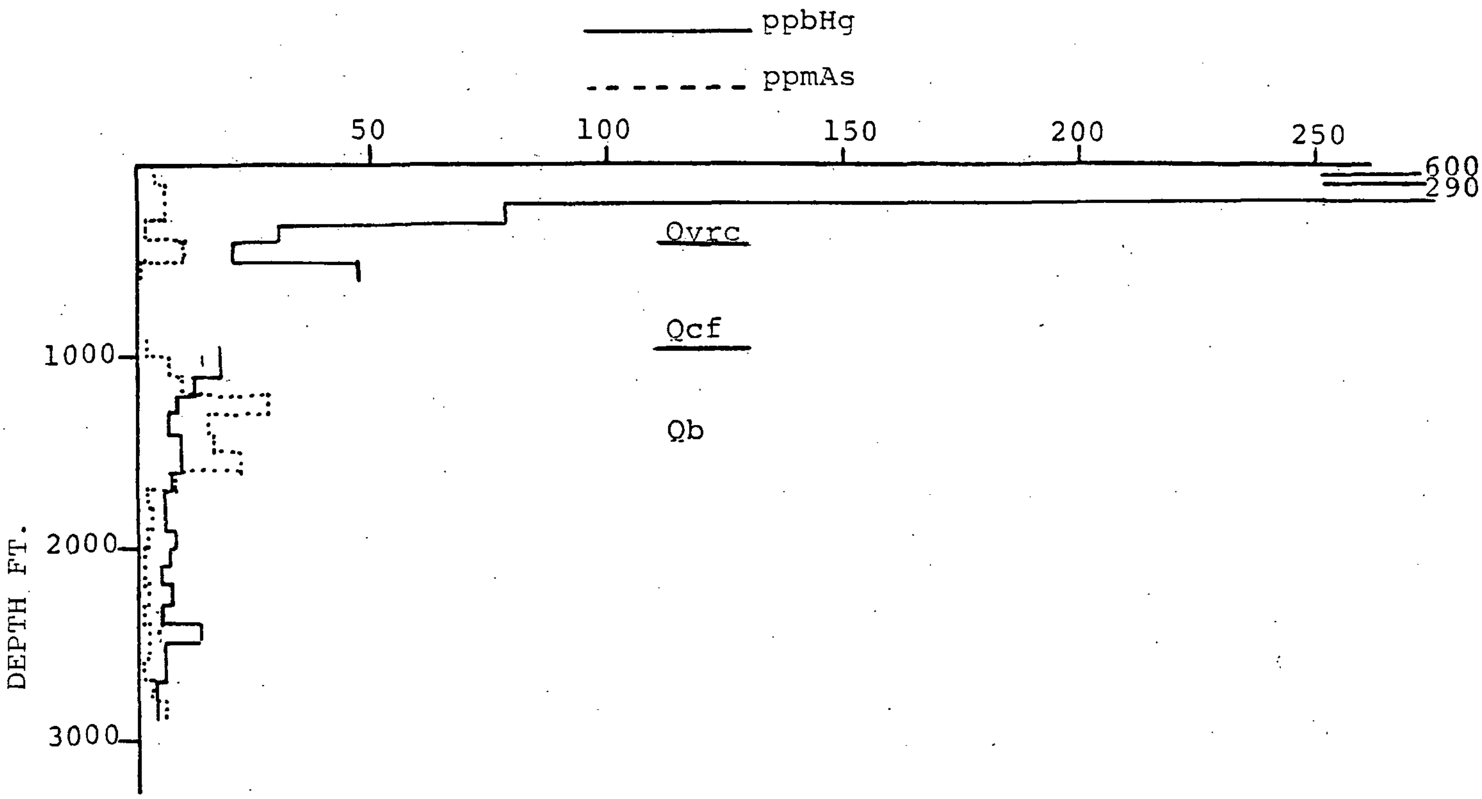


FIGURE 3.4-4

WELL CUTTINGS ANALYSIS - TRACE ELEMENTS

BACA 21 - NONCOMMERCIAL

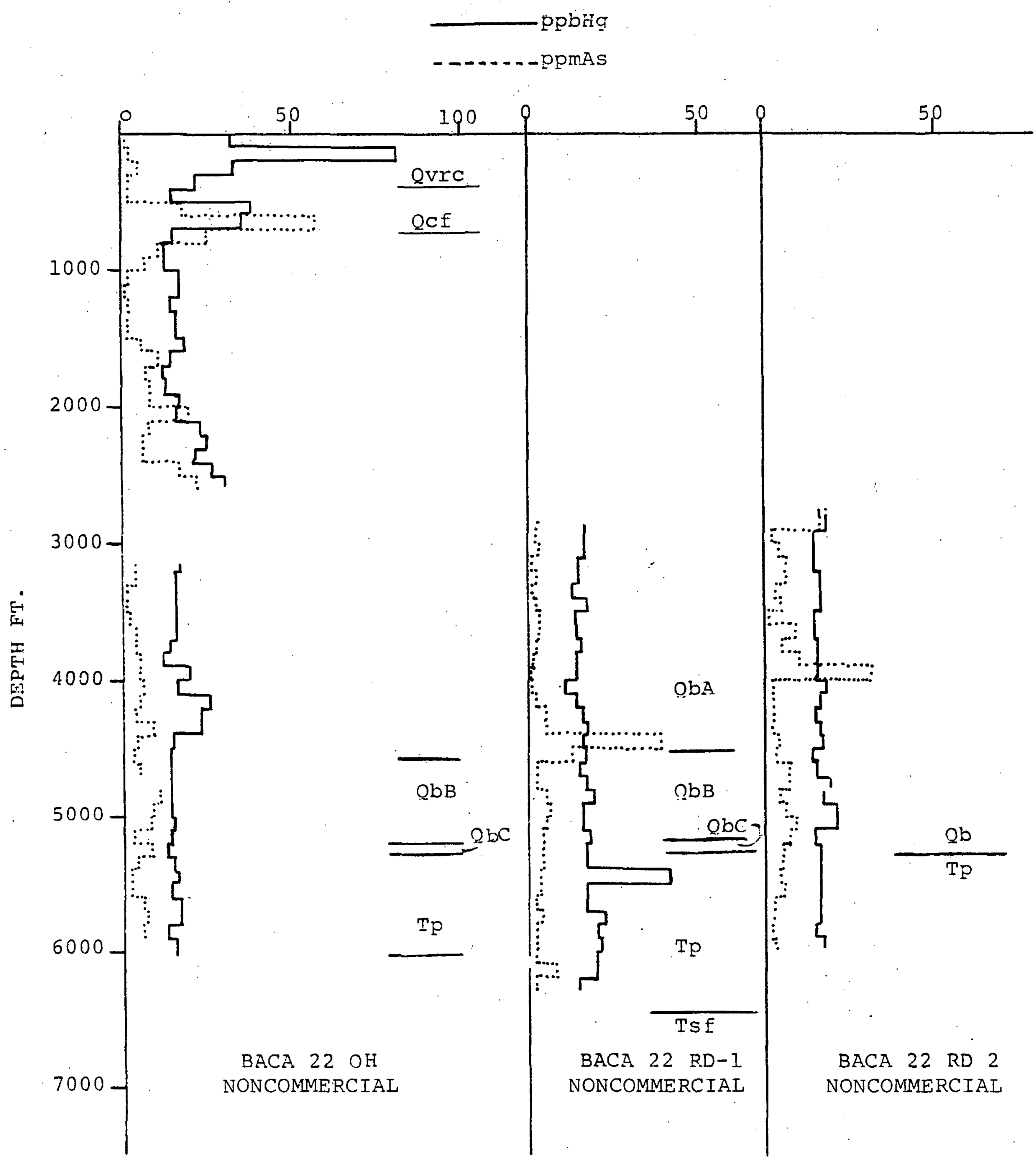


FIGURE 3.4-5

WELL CUTTINGS ANALYSIS - TRACE ELEMENTS

Redrill-2 exhibits an arsenic anomaly at 4000 ft. but not co-incident with any lithologic marker. Although the Bandelier Tuff Zone A/Zone B contact is not known in Redrill-2 it is unlikely to be as shallow as 4000 ft. No antimony was detected.

Baca 24 (Figure 3.4-6) - Because no systematic arsenic variations other than near-surface alteration were apparent from previous analyses, lithium instead of arsenic analysis was performed in Baca 24. The most obvious lithium anomaly in Baca 24 is that associated with the contact between the Bandelier Tuff and Paliza Canyon Fm. Mercury concentrations appear variable. The mercury anomaly at 3300-3500 ft. roughly corresponds to the interval where production was first encountered. Elevated mercury levels also occur in the Paliza Canyon Fm., a suspected productive zone.

The trace element analyses indicate mercury and arsenic anomalies are common at shallow depths. Deeper anomalies may be associated with permeable zones or lithologic changes. The exact depths and magnitudes of fluid entry points are unknown in most of the wells. The exact depths of individual cuttings samples are also unknown. Although these facts hamper systematic analysis, cuttings should continue to be analyzed for mercury and arsenic abundance as well as other trace elements such as fluorine, boron, and lithium in hope of resolving present ambiguities.

3.4.3 Isotope Analyses

Geothermal water from Redondo Creek area wells and surface waters in the Jemez River system have been sampled to determine the isotopic ratios $\delta^{18}O$ (SMOW) and δD (SMOW). Figure 3.4-7 shows the sampling locations. Tables 3.4-2 and 3.4-3 describe the sample locations and list the analytical results. The results are also plotted in Figure 3.4-8.

The produced geothermal waters exhibit a positive oxygen shift along a constant δD line from the composition of surface water in the area (Redondo Creek), as would be expected.

The low-temperature thermal waters discharging at Soda Dam (116°F) and Jemez Springs (120°F) have $\delta^{18}O$ values indicating less exchange than the deep, high-temperature waters in the Valles Caldera. Thermal water at Spence Springs (104°F) shows no oxygen shift, indicating no isotopic exchange which in turn indicates probable shallow circulation.

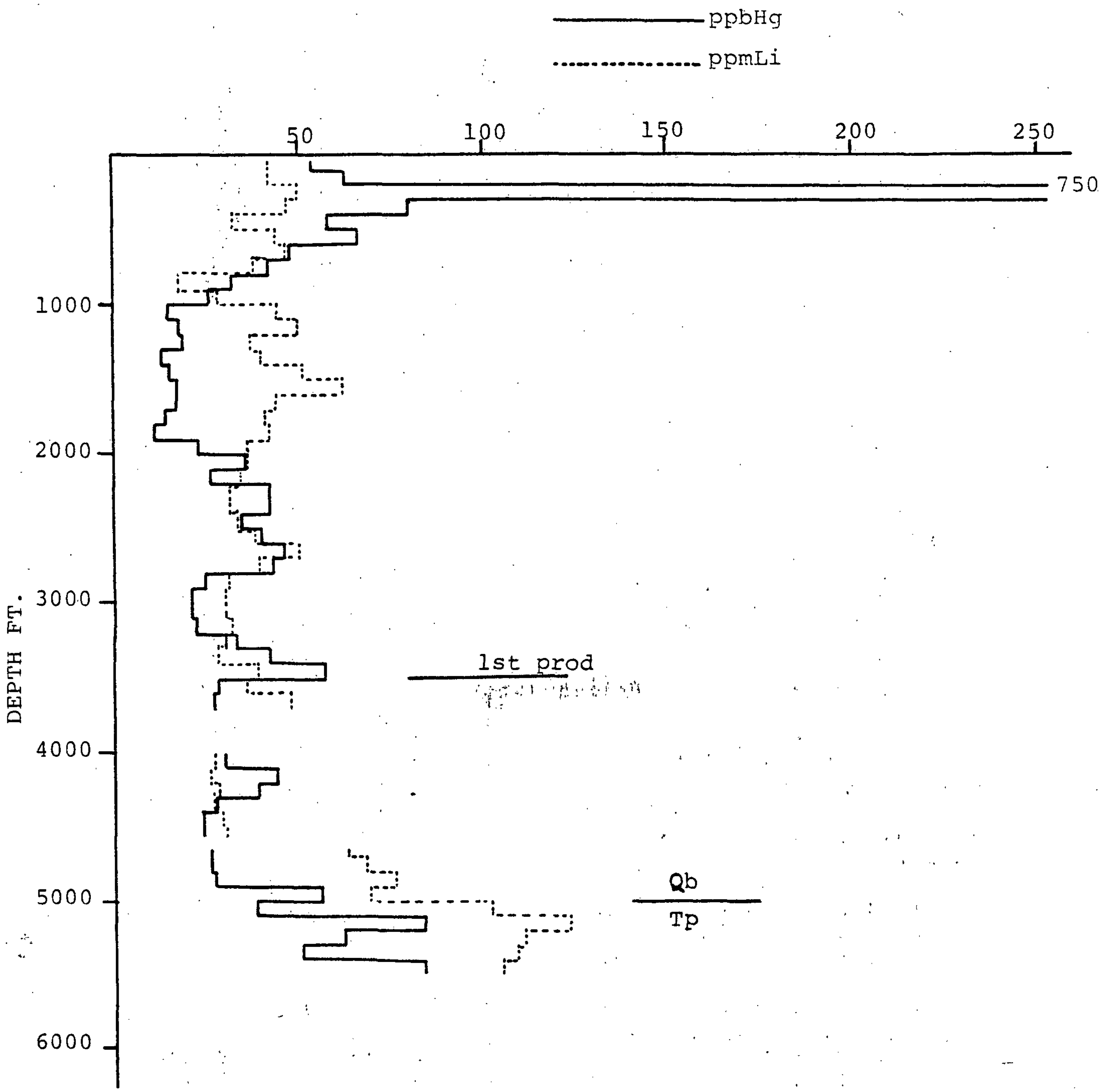


FIGURE 3.4-6

WELL CUTTINGS ANALYSIS - TRACE ELEMENTS

BACA 24 - COMMERCIAL PRODUCER

TABLE 3.4-2

GEOTHERMAL WATERS FROM REDONDO CREEK FIELD

SAMPLE NAME	SAMPLE NO.	COLLECTION DATE	$\delta^{18}O$ (SMOW)	δD (SMOW)	% FLASH	RECONSTITUTED δO^{18}	δ D
Baca 20 Separated Brine	PB1	10/23/80	- 6.98	-89	60.89		
Baca 20 Separated Brine	PB2	"	- 7.03±0.04	-89	"		
Baca 20 Stm Condensate	PS1	"	-10.64	-85.5±0.5	"		
Baca 20 Stm Condensate	PS2	"	- 9.40	-82	"		
	PR1					- 9.21	-87
	PR2					- 8.47	-86
Baca 13 Separated Brine	PB3	3/30/81	- 9.51	-89±0.05	27		
Baca 13 Stm Condensate	PS3	"	-12.03	-94	"		
	PR3					-10.19	-90
Baca 4 Separated Brine	PB4	7/9/81	- 9.39	-83±1	29.77		
Baca 4 Stm Condensate	PS4	"	-12.16	-94	"		
Baca 4 Separated Brine	PB5	"	- 9.34±0.09	-84	"		
Baca 4 Stm Condensate	PS5	"	-12.33	-93	"		
	PR4					-10.21	-86
	PR5					-10.23	-87
Baca 13 Separated Brine	PB6	8/13/81	- 9.60	-85	21.5		
Baca 13 Stm Condensate	PS6	"	-12.54	-94	"		
Baca 13 Separated Brine	PB7	"	- 9.61&-9.48	-87	"		
Baca 13 Stm Condensate	PS7	"	-13.00	-94	"		
	PR6					-10.23	-87
	PR7					-10.34&-10.24	-89
Baca 24 Separated Brine	PB8	8/13/81	- 8.99±0.08	-84	19.9		
Baca 24 Stm Condensate	PS8	"	-11.43	-89±1	"		
Baca 24 Separated Brine	PB9	"	- 8.90±0.05	-84	"		
Baca 24 Stm Condensate	PS9	"	-11.82	-88	"		
	PR8					- 9.48	-85
	PR9					- 9.48	-85

PB: PRODUCED FLUID - SEPARATED BRINE

PS: PRODUCED FLUID - STEAM CONDENSATE

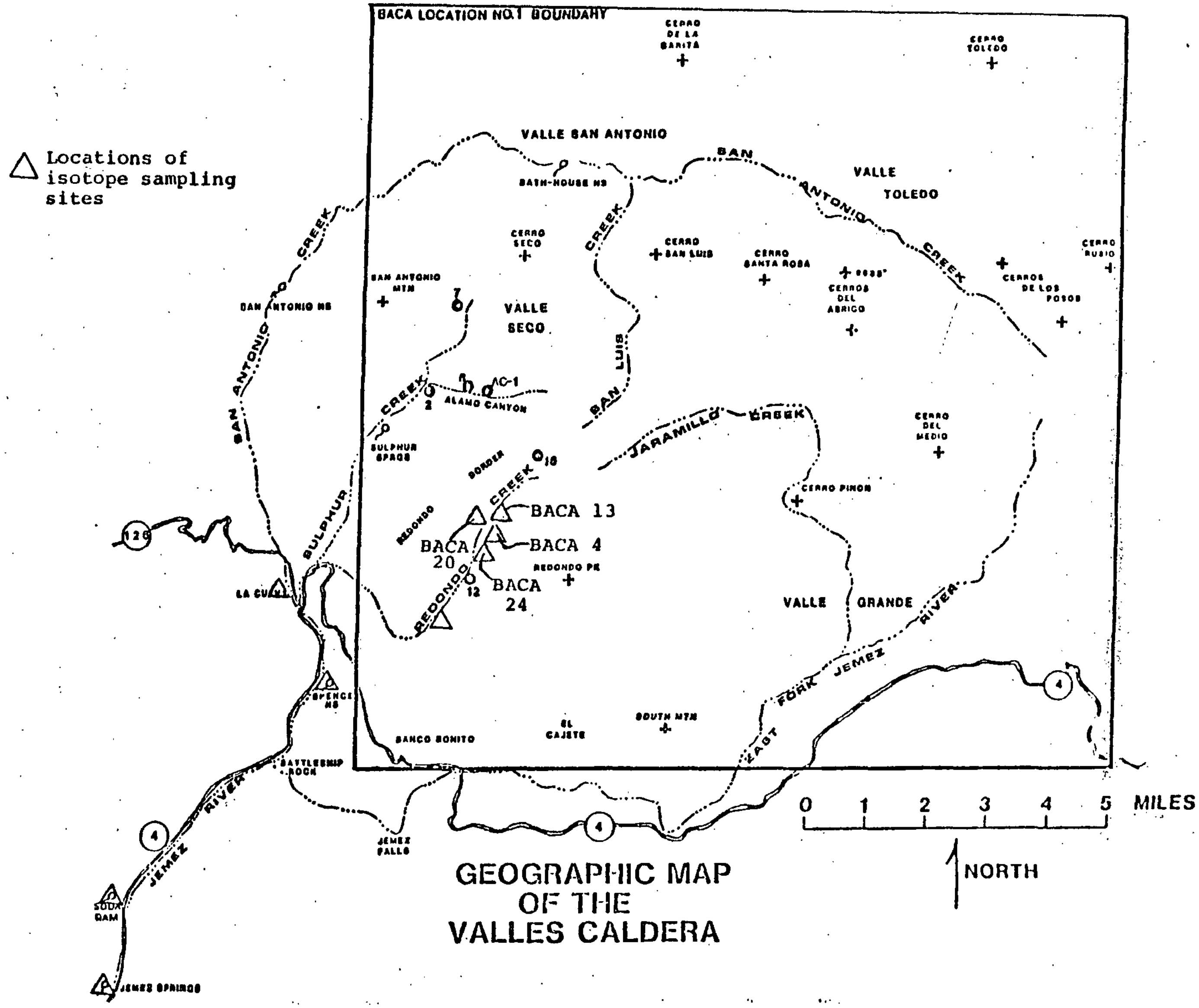
PR: PRODUCED FLUID - RECONSTITUTED FROM BRINE AND CONDENSATE SAMPLES

TABLE 3.4-3

SURFACE WATERS

SAMPLE NAME	SAMPLE NO.	COLLECTION DATE	$\delta^{18}O$(SMOW)	δD(SMOW)
San Antonio Cr. nr La Cueva	GN 1	1/22/80	-12.63	-92.9
	GN 2	"	-12.52	-91.5
Spence Spring	GT 1	1/22/80	-12.08	-88.0
	GT 2	"	-12.04	-85.5
Soda Dam Area	GT 3	1/22/80	-10.57	-87.5
	GT 4	"	-10.57	-85.6
	GT 5	"	-10.49	-84.2
	GT 6	"	-10.45	-85.2
	GT 7	"	-10.38	-86.5
	GT 8	"	-10.40	-87.2±0.2
Jemez Springs	GT 9	1/22/80	-10.54±0.04	-83.7
	GT10	"	-10.55	-84.4
Redondo Creek	GN 3	10/23/80	-12.17	-91
	GN 4	"	-12.14	-87
Redondo Creek	GN 5	7/9/81	-12.01	-89
	GN 6	"	-12.10	-88
Jemez Springs	GT11	7/9/81	-10.99	-84
	GT12	"	-11.20	-87
Redondo Creek	GN7	7/9/81	-12.23	-87
	GN8	8/13/81	-11.79	-86
	GN9	"	-11.76	-85

GN: NON-THERMAL GROUNDWATER
GT: THERMAL GROUNDWATER



Locations of isotope sampling sites
BACA LOCATION NO.1 BOUNDARY
VALLE SAN ANTONIO
VALLE TOLEDO
VALLE SECO
SAN ANTONIO CREEK
SAN LUIS CREEK
JARAMILLO CREEK
REDONDO CREEK
SULPHUR CREEK
ALAMO CANYON
BACA 13
BACA 4
BACA 20
BACA 24
REDONDO PK
VALLE GRANDE
EAST FORK JEMEZ RIVER
JEMEZ RIVER
LA CUEVA
BANCO BONITO
BATTLESHIP ROCK
JEMEZ FALLS
SODA DAM
JEMEZ SPRINGS
0 1 2 3 4 5 MILES
NORTH
GEOGRAPHIC MAP OF THE VALLES CALDERA

FIGURE 3.4-7

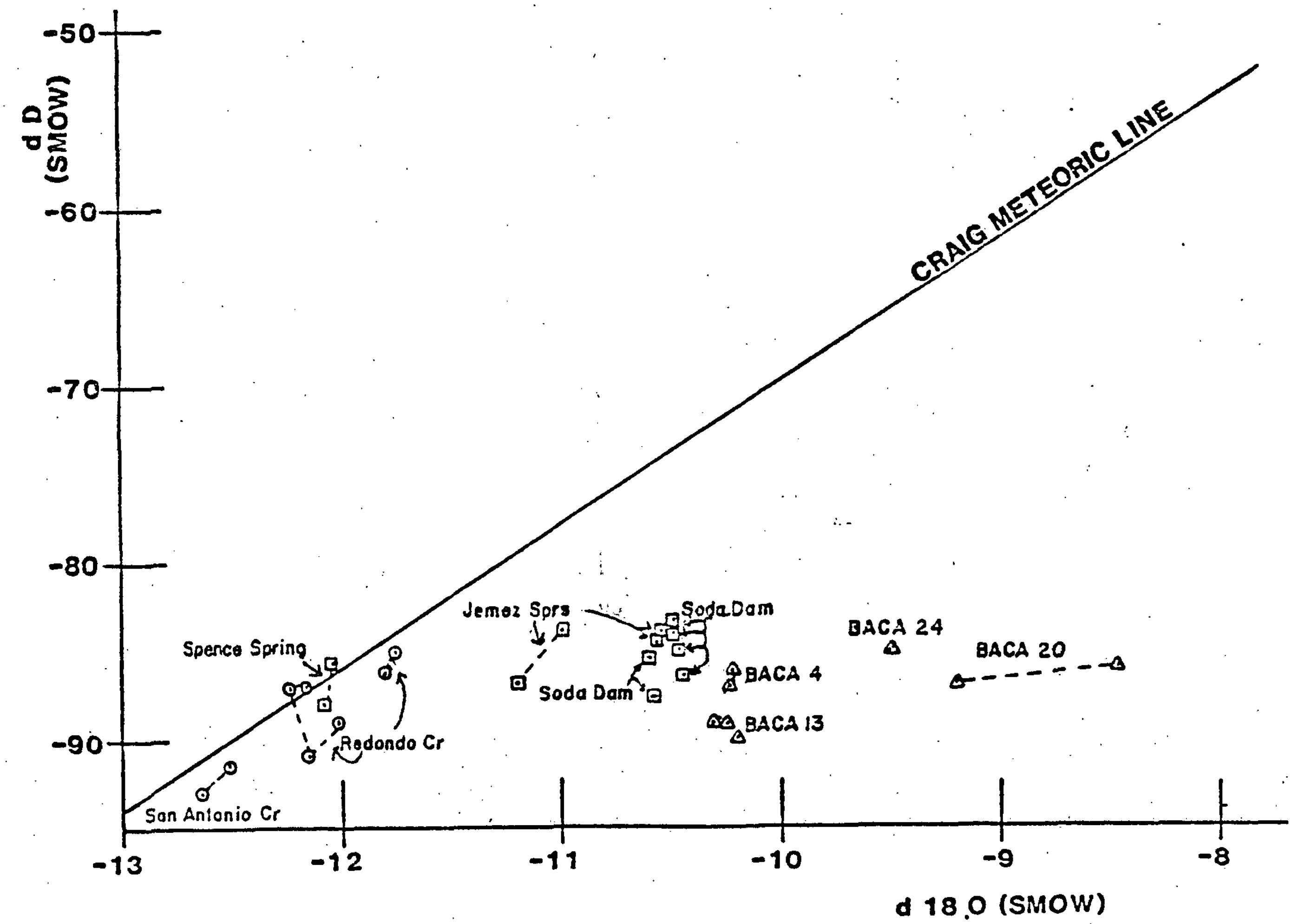


FIGURE 3.4-8
ISOTOPE RESULTS

○ NONTHERMAL SURFACE WATERS

□ THERMAL SURFACE WATERS

△ BACA WELLS PRODUCED FLUIDS (RECONSTITUTED)

Dotted lines connect replicate samples

3.5 Subsurface Temperature Distribution

3.5.1 Observed Wellbore Temperatures

Deep drilling in the Redondo Creek area has identified a large, high-temperature thermal anomaly. Plate 3.5-1 is a map showing the maximum observed temperatures and their respective elevations in Redondo Creek wells for which data exist. Table 3.5-1 summarizes the same data. Plate 3.5-1 and Table 3.5-1 show that of Redondo Creek wells drilled to the normal total depth of 4000-7000 ft., only Baca 5A has a maximum temperature less than the 500°F apparently required for commercial production (Section 5). (Baca 21 and 23 were intentionally completed at shallow depths; Baca 24 was completed shallow because of a lost fish in the hole.) Baca 12 and Baca 14 have temperatures exceeding 500°F, but these temperatures appear to occur deeper than the normal productive horizon of the lower Bandelier Tuff and Paliza Canyon Formation.

The significance of temperature differences among the wells within the high-temperature thermal anomaly is difficult to assess. Baca 19 appears cooler at a similar depth than neighboring Baca 15. The other wells exhibit less profound temperature differences. Such differences can be evaluated qualitatively and may be due to a combination of the following factors:

1. Intra-wellbore flow under shut-in conditions among fluid entry points of different temperatures and pressures - a common occurrence in Redondo Creek wells, resulting in distorted temperature profiles.

2. Convective heat transfer within the wellbore resulting in lower temperature gradients than the true static temperature profile.

3. Two-phase conditions in the wellbore or formation under shut-in conditions masking the true formation temperature profile.

The following figures and discussion help illustrate how these factors may affect interpretations of subsurface temperature distribution.

Baca 4 (Figure 3.5-1)

Three static temperature profiles from different times in the well's history are shown. The shallow, vertical gradient in the 9-11-80 survey is due to wellhead bleeding. Variations in temperature-depth relationships due to the factors listed above

TABLE 3.5-1

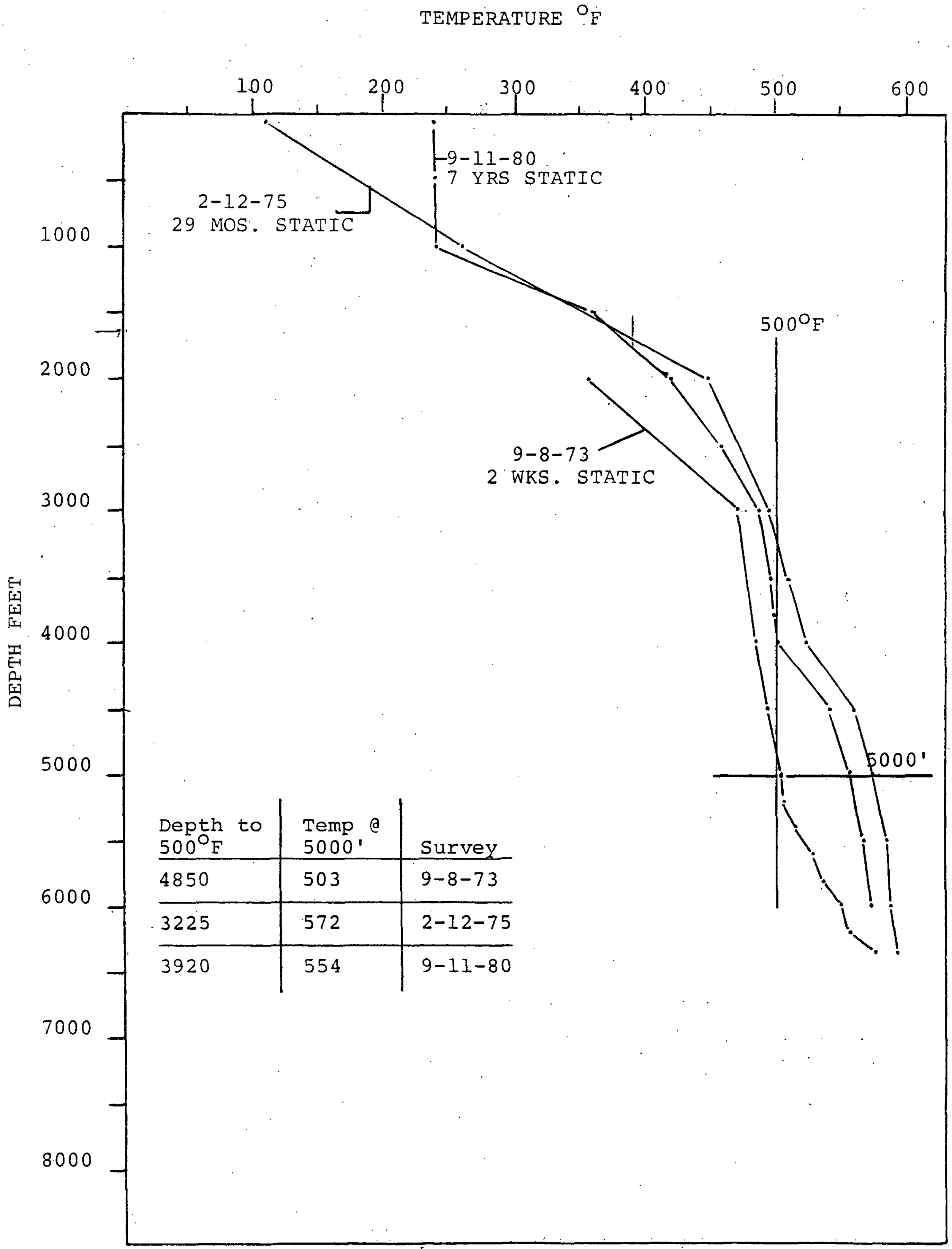
OBSERVED WELLBORE TEMPERATURES

WELL	MAXIMUM OBSERVED TEMPERATURE °F (PLATE 3.5-1)	DEPTH MD/FT ASL	TEMPERATURE °F AT 4000 FT ASL (PLATE 3.5-2)	DEPTH TO 500°F MD/FT ASL (PLATE 3.5-3)	
*BACA 4 ORIGINAL HOLE DEEPENING	590	6345/3057	513±23	4037/5315	±812
BACA 5A	485	6900/2420	368	+	
*BACA 6 ORIGINAL HOLE	528	3690/5067			
DEEPENING	536	4681/4100	536	3350/5400	±350
BACA 10	547	5500/3216	535	3500/5247	±500
*BACA 11	627	6650/2482	550±25	3075/6009	±275
BACA 12 ORIGINAL HOLE	592	9177/-725			
DEEPENING	646	10190/-1702	480±10	6150/2306	±150
*BACA 13	588	7700/1714	490±10	4600/4732	±600
BACA 14	540	6837/2065	478± 8	6325/2538	± 75
*BACA 15	544	5472/3838	532± 2	3000/6140	± 50
BACA 16	582	6746/3022	519± 2	4600/5047	±100
BACA 18 REDRILL	525	5150/3720	515± 1	4250/4608	±250
BACA 19	510	5550/3724	499± 5	5200/4055	±200
*BACA 20 REDRILL	549	5750/3476	525±10	4700/4524	±100
BACA 21	438	2720/6624	o	+	
BACA 22 REDRILL 2	522	5900/3382	510	4800/4505	
BACA 23	456	3100/5650	o	+	
*BACA 24	502	3550/5195	o	3400/5369	±150

+ TEMPERATURE NOT REACHED IN WELL

o DEPTH NOT PENETRATED BY WELL

*COMMERCIAL PRODUCERS.
BACA 6 AND 20RD NOT CURRENTLY CAPABLE OF PRODUCTION



Depth to 500°F	Temp @ 5000'	Survey
4850	503	9-8-73
3225	572	2-12-75
3920	554	9-11-80

FIGURE 3.5-1 BACA 4

are evident in the 70°F variation in temperature at 5000 ft. and the 1600 ft. variation in depth of the 500°F isotherm among the three surveys.

Baca 6 (Figure 3.5-2)

The profiles shown represent static conditions in the well at its original and deepened depths. The reason why the 2-14-75 survey records dramatically lower temperatures than the 10-5-72 survey is unclear. Like Baca 4 there is variation between temperatures at a particular depth or depth to a particular temperature at different times in the well's history.

Baca 11 (Figure 3.5-3)

Several surveys are shown to further illustrate variations in temperature-depth relationships. Of particular interest is the tandem survey of 1-24-75; temperatures vary 15-20°F between the two tools run. This difference may be due to tool accuracy or wellbore thermal effects from tool motion in the well.

Baca 12 (Figure 3.5-4)

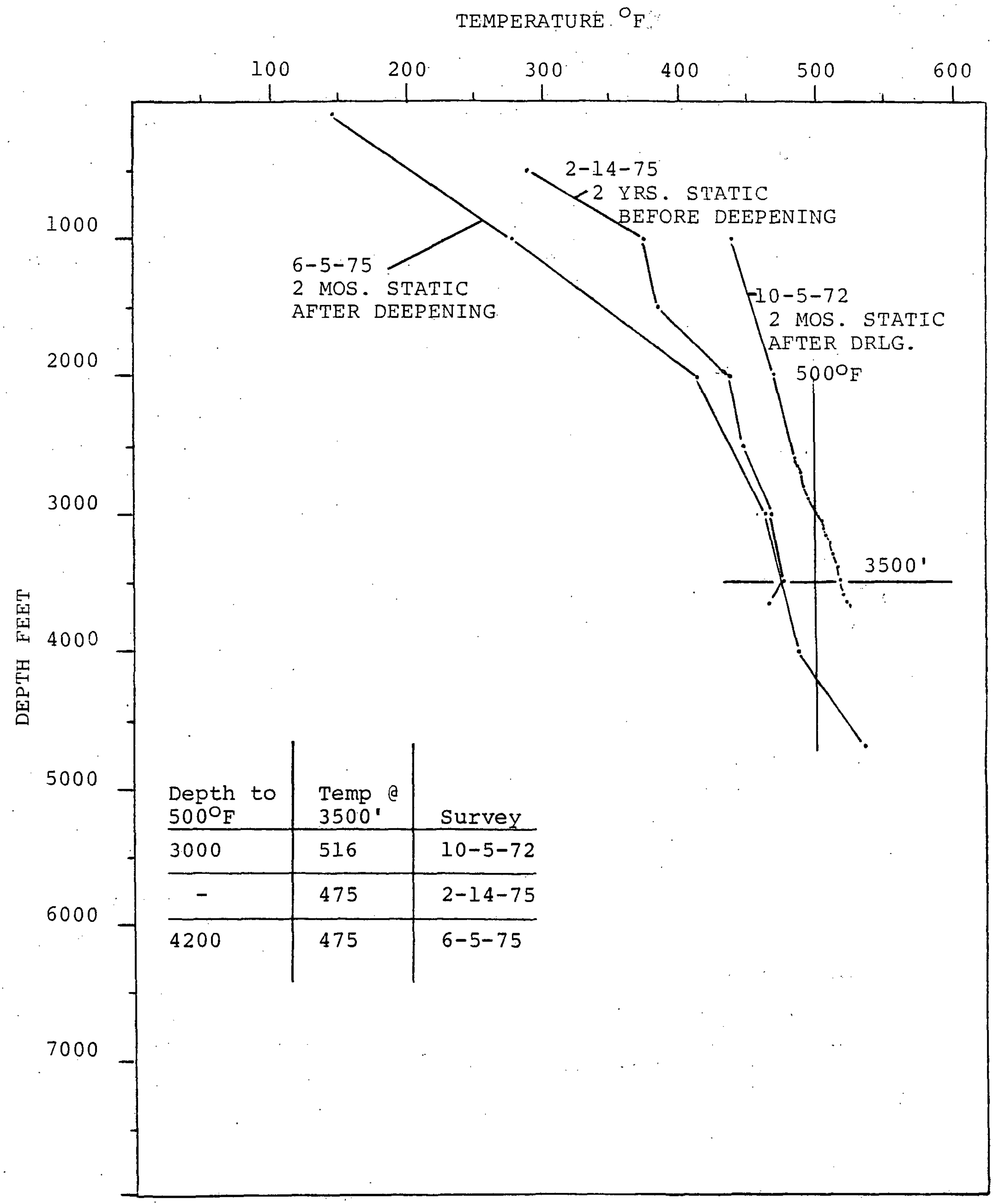
Static surveys of the well after original drilling and deepening are shown. The severe temperature reversals in the 1-8-82 survey are probably caused by cooling from long term injection. These effects are evident in the deeper 550°F isotherm in the 1-8-82 survey. The effect of heating from deeper, hotter zones is illustrated by comparing the recorded temperatures at 9000 ft. The 1-4-82 survey records temperatures 20°F higher at this depth than the 10-4-74 survey. The true original formation temperature at 9000 ft. is probably closer to that recorded in the 10-4-74 survey.

Baca 13 (Figure 3.5-5)

The reversals shown between 4000 and 6000 ft. are due to incomplete thermal recovery following testing. The variation in temperature-depth relationships at various times in a well's history are further illustrated.

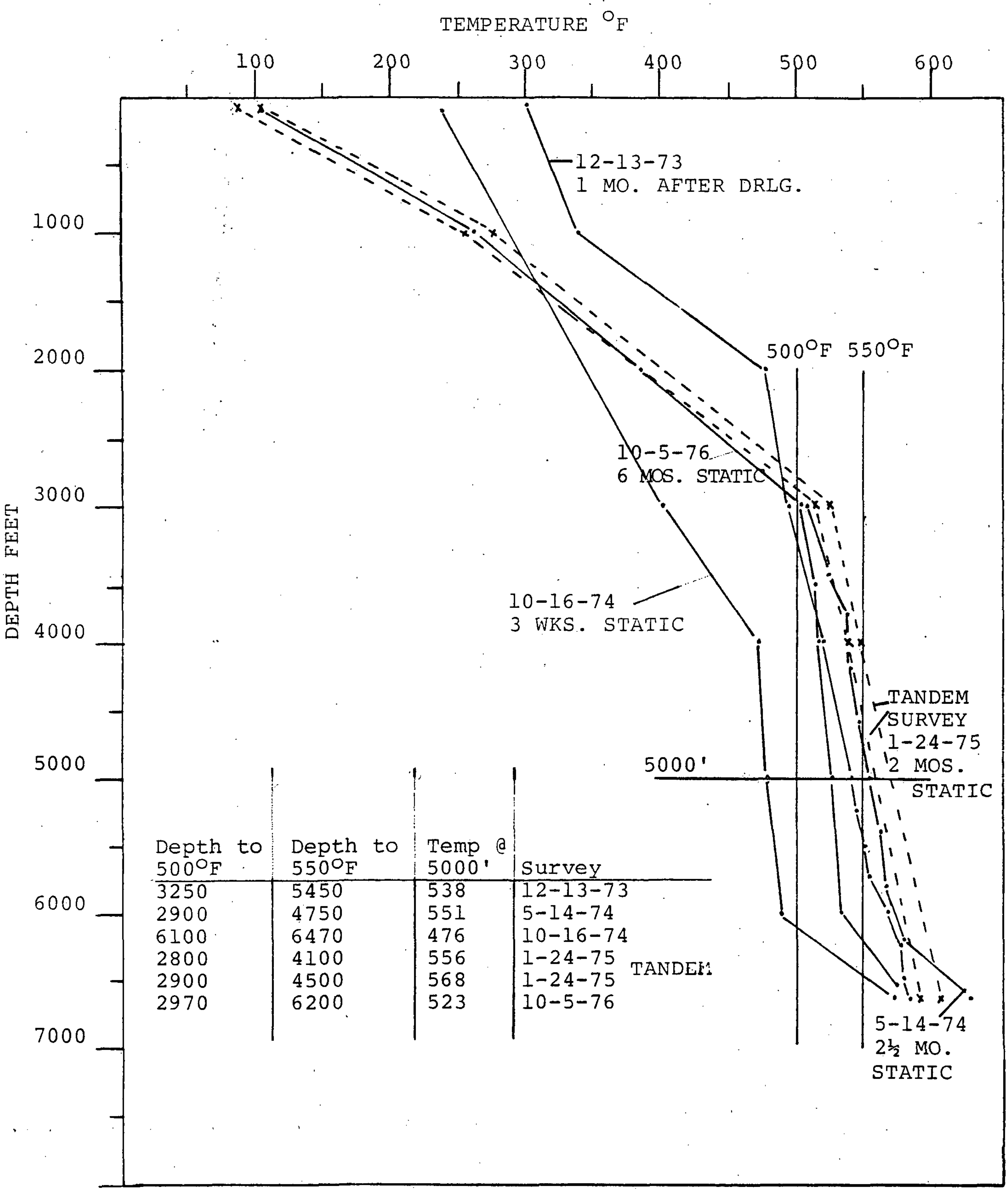
Baca 15 (Figure 3.5-6)

This figure illustrates one section of the wellbore can exhibit temperature variations while other sections of the wellbore exhibit consistent temperatures. In this case deep temperatures are similar, and shallow temperatures vary, likely due to boiling and noncondensible gas accumulation near the static fluid level. Baca 15 data would be of limited use in determining the precise depth to the 400°F isotherm in the area.



Depth to 500°F	Temp @ 3500'	Survey
3000	516	10-5-72
-	475	2-14-75
4200	475	6-5-75

FIGURE 3.5-2 BACA 6



Depth to 500°F	Depth to 550°F	Temp @ 5000'	Survey	
3250	5450	538	12-13-73	
2900	4750	551	5-14-74	
6100	6470	476	10-16-74	
2800	4100	556	1-24-75	TANDEM
2900	4500	568	1-24-75	
2970	6200	523	10-5-76	

FIGURE 3.5-3 BACA 11

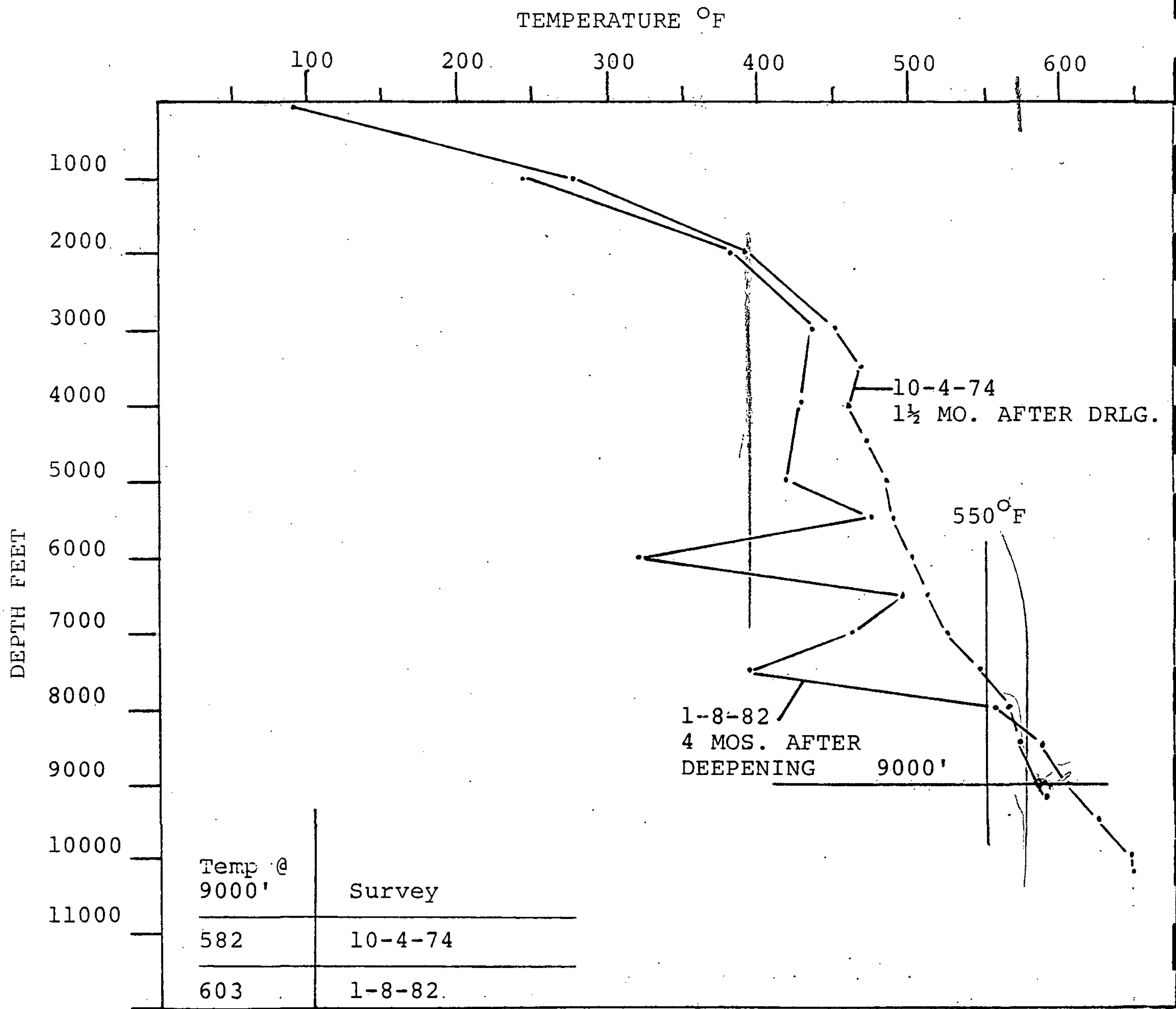
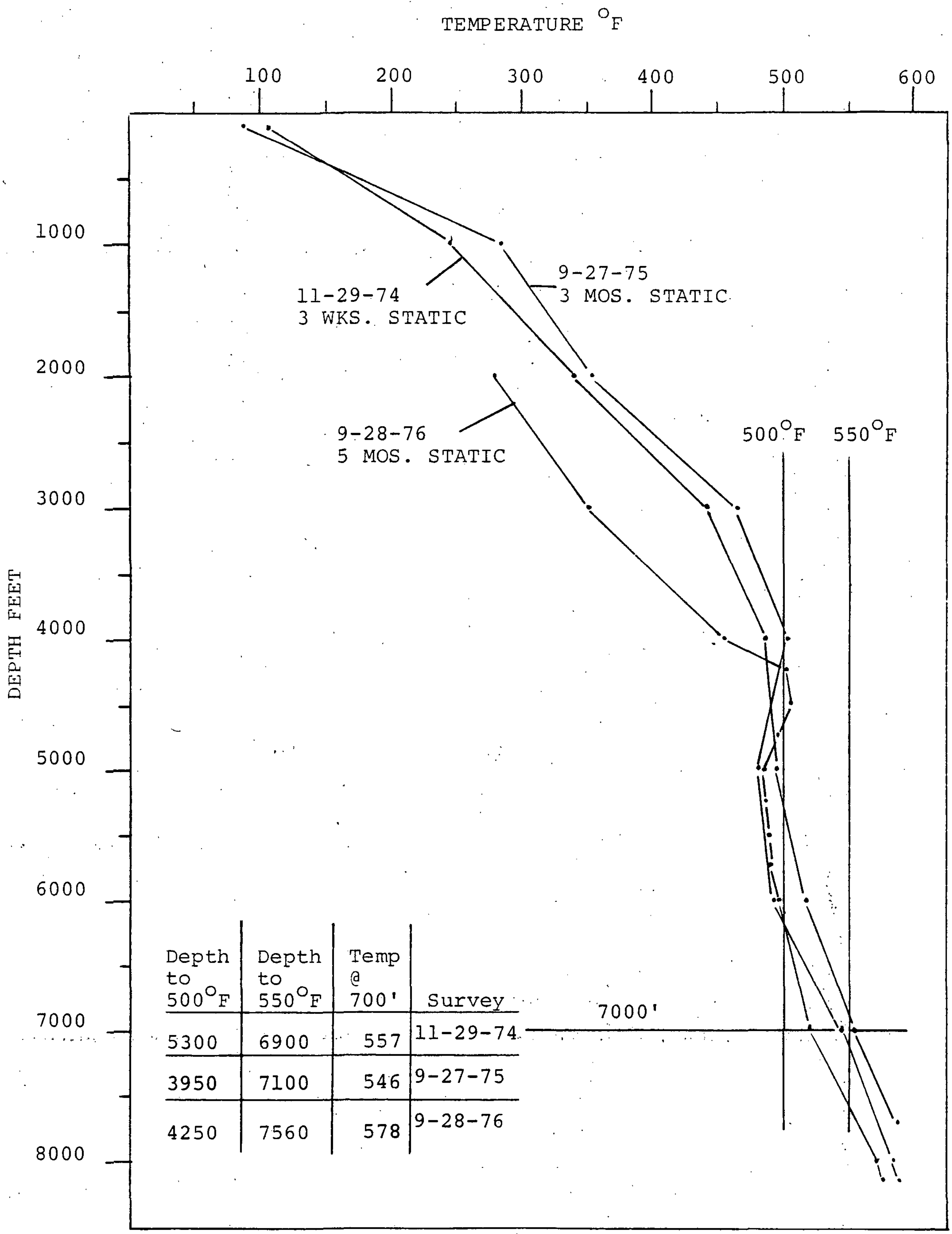
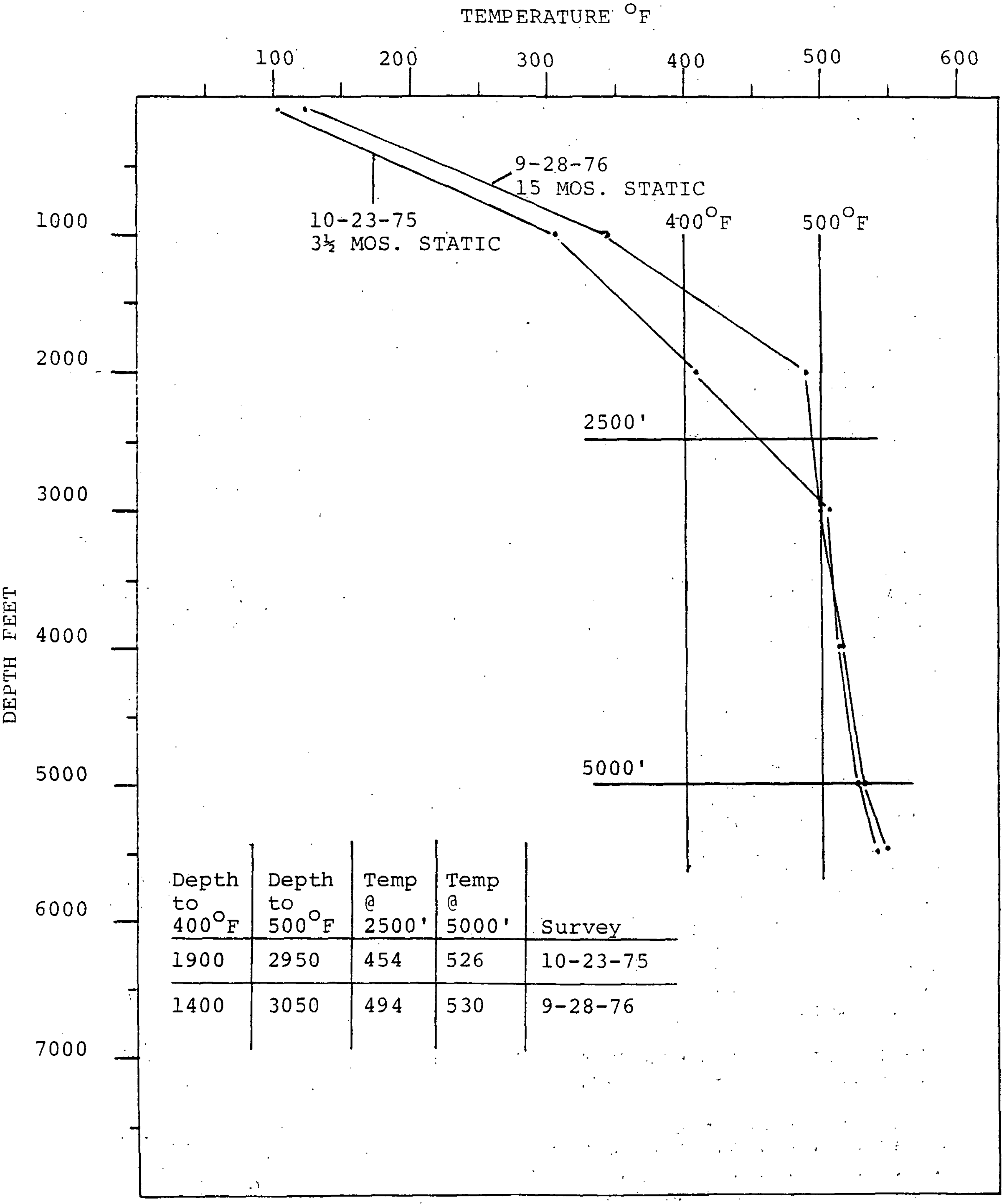


FIGURE 3.5-4 BACA 12



Depth to 500°F	Depth to 550°F	Temp @ 700'	Survey
5300	6900	557	11-29-74
3950	7100	546	9-27-75
4250	7560	578	9-28-76

FIGURE 3.5-5 BACA 13



Depth to 400°F	Depth to 500°F	Temp @ 2500'	Temp @ 5000'	Survey
1900	2950	454	526	10-23-75
1400	3050	494	530	9-28-76

FIGURE 3.5-6 BACA 15

Variations in temperature-depth relationships during a well's history as discussed above represent data precision limits. Generally only a few commercial wells in the Redondo Creek area have had sufficient testing to provide such limits. Frequently wells, particularly noncommercial ones, have only a few surveys under static temperature conditions. One must recognize that variations in temperature-depth relationships are present in all Redondo Creek wells regardless of the number of static surveys available.

Plate 3.5-2 is a map showing the temperature (°F) at 4000 ft. above sea level; the data with variations are also listed in Table 3.5-1. The data are contoured by computer on the midpoints of the temperature variation in each well; wells for which no variations noted have only one static survey. Baca 5A, 12, and 14 appear to be cooler than the other wells. Baca 19 appears significantly cooler than nearby Baca 15 and 11. The hottest wells at 4000 ft. above sea level apparently are Baca 10, 11, and 15.

Plate 3.5-3 is a map showing the depth (ft. above sea level) of the 500°F isotherm. Like Plate 3.5-2 the data with variations are listed in Table 3.5-1, contoured by computer on midpoint of variation, and exhibit no variation if only one static survey is available. Baca 5A does not encounter 500°F, and Baca 12 and 14 encounter 500°F much deeper than the other wells; these three wells appear to be off the high-temperature anomaly. Baca 19 is cooler than its neighbors. Baca 11 and 15 encounter 500°F at depths significantly shallower than the other wells.

3.5.2 Geothermometry

There are sufficient chemical analyses from the producing wells to calculate theoretical rock-water equilibrium temperatures - geothermometers. Two types were calculated: Na-K-Ca and quartz-silica (Fournier, Truesdell, 1974). The Na-K-Ca geothermometry is based on a greater number of analyses. The quartz-silica geothermometry results may suffer from lack of data and possible analytical problems associated with sample collection.

The results of the geothermometer calculations are lised in Table 3.5-2. The wells are discussed individually below.

Baca 4 - The Na-K-Ca geothermometry is quite consistent and in general agreement with observed temperatures in the well. The average equilibrium temperature of 560°F - markedly lower than the 590°F recorded maximum - indicates water-rock

TABLE 3.5-2 GEOTHERMOMETRY

WELL	SAMPLE DATE	SiO2 mg/l	Na	K	Ca	Na-K-Ca GEOTHERMOMETER °F	QUARTZ-SILICA GEOTHERMOMETER °F	MAXIMUM OBSERVED WELLBORE TEMPERATURE °F
BACA 4	9/18/73	201	1194	227	5	539	357	
	11/05/73	165	1015	225	4.7	555	333	
	11/09/73	-	965	212	4.1	555	-	
	5/06/81	506	986	213	3.6	557	488	590
BACA 6	10/11/72		1218	275	0.5	628		
	10/11/72		1209	263	2.2	581		
	10/27/72		1328	239	8	525		
	11/09/75		1293	228	9	518		536
BACA 11	1/23/74	189	1003	89	17	501	349	
	1/23/74	175	991	175	16	493	340	
	9/16/74	246	969	246	12	550	382	
	9/20/74	246	969	246	13	548	382	
	11/08/74	273	1091	273	23	537	396	
	2/24/76	259	1092	259	10	550	389	
	4/08/76	314	899	172	3	538	415	627
BACA 13	12/07/74	264	1323	264	8	540	391	
	10/15/74	223	1103	223	3.9	550	369	
	11/07/75	368	990	201	3.5	548	438	
	2/26/76	311	1167	236	4	552	414	
	4/07/76	395	1132	216	4	542	449	588
BACA 15	11/04/76	243	770	177	9	531	381	
	11/17/76	314	818	193	9	538	415	
	11/22/76	271	701	153	7	525	395	
	11/24/76	255	636	156	7	537	387	
	1/05/77	348	761	180	12	528	430	544
BACA 20 (RD-1)	9/30/80	267	716	127	22	473	393	
	10/07/80	240	851	112	35	434	379	
	10/23/80	274	1325	264	26	512	396	549

TABLE 3.5-2 GEOTHERMOMETRY (CONT'D)

WELL	SAMPLE DATE	SiO_2 mg/l	Na	K	Ca	Na-K-Ca GEOTHERMOMETER °F	QUARTZ-SILICA GEOTHERMOMETER °F	MAXIMUM OBSERVED WELLBORE TEMPERATURE °F
BACA 22 (RD-2) 2-Phase Line	2/09/81	672	4810	720	29	529	538	522
BACA 23	5/05/81	360	924	130	13	465	435	456
BACA 24	8/05/81	505	1490	192	11	478	488	
	8/19/81	454	1452	192	9	484	471	
	9/02/81	522	1411	210	12	492	493	502

equilibrium occurring shallower than 6345 ft., the depth of maximum recorded temperature. These results may indicate lateral fluid flow into the well rather than vertical flow into the well from greater depth, re-equilibration within the well during flow, vertically moving water re-equilibrating at shallow depths due to low permeability (low fluid velocity), or thermal drawdown resulting in formation temperatures closer to the calculated equilibrium temperatures. The much lower quartz-silica equilibrium temperatures (333-488°F) are likely due to near-wellbore flashing and may represent fluid temperatures under flowing conditions.

Baca 6 - The Ca analyses of 10-11-72 are probably too low, resulting in unrealistically high equilibrium temperatures. However, the Na-K-Ca equilibrium temperatures derived from the 10-27-72 and 11-9-75 analyses (525°F and 518°F, respectively) are consistent with the maximum observed wellbore temperature 536°F. This indicates that water-rock equilibrium in Baca 6 is also occurring at depths similar to the drilled depth at the well.

Baca 11 - The Na-K-Ca equilibrium temperatures are consistent excepting the 1-23-74 analyses. The average Na-K-Ca equilibrium temperature of 531°F is substantially lower than the maximum observed temperature of 627°F, indicating little or no flow from the hot bottomhole region. The low (340-415°F) quartz-silica equilibrium temperatures indicate near-wellbore flashing during flow.

Baca 13 - Geothermometry results are consistent with Baca 11. The calculated Na-K-Ca equilibrium temperatures (546°F avg.) are lower than the maximum observed temperature of 588°F). The quartz-silica temperatures (412°F avg.) indicate near-wellbore flashing.

Baca 15 - The calculated Na-K-Ca equilibrium temperatures averaging 532°F are fairly consistent (525-538°F range) and coincide closely with the maximum observed temperature of 544°F. Quartz-silica temperatures (402°F avg.) are much lower as in the other wells.

Baca 20 - The analyses from 9-30-80 and 10-7-80 may indicate formation cooling as a result of drilling. The Na-K-Ca equilibrium temperature of 10-23-80 (512°F) is lower than the maximum observed temperature (549°F). The quartz-silica equilibrium temperatures are fairly consistent (389°F avg.) with the other wells.

Baca 22 - Although the concentrations of Na, K, and Ca are suspiciously high, the geothermometer equilibrium temperature of 529°F is consistent with other wells. It is slightly higher than the maximum observed temperature of 522°F, possibly indicating the well had not completely recovered from drilling. The quartz-silica equilibrium temperature of 538°F indicates no near-wellbore flashing.

Baca 23 - The Na-K-Ca equilibrium temperature (465°F) is slightly higher than the maximum observed temperature of 456°F but consistent with the shallow (3500 ft.) completion depth. The quartz-silica equilibrium temperature (435°F) indicates little or no boiling near the well.

Baca 24 - The Na-K-Ca equilibrium temperatures are consistent (485°F) and slightly lower than the maximum observed temperature of 502°F. Little or no formation flashing is apparent due to the general agreement among quartz-silica equilibrium temperatures averaging 484°F and the maximum 502°F wellbore temperature.

The precision limits of these geothermometry calculations are not known because of low numbers of samples and limited experience in defining geochemical relationships in geothermal wells. However, there appears to be general agreement among the Na-K-Ca geothermometer and actual observed wellbore temperatures. Calculated quartz-silica equilibrium temperatures are consistent among the wells and are lower than the Na-K-Ca and measured temperatures, indicating that near-wellbore flashing occurs when flowing Redondo Creek wells.

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SECTION 4: DRILLING

4.1 Results of Drilling

From 1972 to 1977 eleven wells were drilled in Redondo Canyon. Five wells were successfully completed in the Bandelier Tuff formation yielding a total wellhead production capacity of 353,000 lbs. per hour at line pressure (125 psig). The casing in one well, Baca No. 6, subsequently collapsed reducing the steam count to 320,000 lbs. per hour.

Between 1977 and 1982 the Bandelier Tuff was penetrated thirteen times, counting original holes and redrills. Only two wells, Baca No. 20 and Baca No. 24, were successfully completed for a total of 63,000 lbs. per hour of additional steam. Baca No. 20 was later recompleted and during the recompletion the well's 30,000 lbs. per hour steam rate was plugged off. With the loss of Baca No. 11 to bad casing, the current overall steam count for the Redondo Creek Field is 268,000 lbs. per hour.

The drilling history in Redondo Canyon is summarized in Tables 4.1-1 and 4.1-2 and in Figures 4.1-1 and 4.1-2. Table 4.1-1 and Figure 4.1-1 indicate results up to the time when the Cooperative Agreement was formed and the GDPP Project began. Table 4.2-2 and Figure 4.2-2 indicate results during the time of GDPP Project activities.

The overall production success ratio in the Redondo Creek field is seven completions out of twenty-four penetrations of the Bandelier Tuff formation.

In addition, three wells were used in an attempt to achieve production from formations deeper than the Bandelier Tuff; particularly the Paleozoic limestone and Pre-Cambrian granite. Baca No. 12 was deepened from 9,212' to 10,637'; bottoming in granite. Although hot (646°F temperature) the deeper zones were impermeable. Baca No. 22 was redrilled to 8,846' (top of the limestone). The hole was lost during logging operations. Baca No. 24 was drilled from the surface as a deep test; mechanical problems led to a shallower completion in the Bandelier Tuff.

Attempts were also made on two wells, Baca No. 20 and Baca No. 23, to increase production rates by performing hydraulic fracture treatments. Both of these stimulations were mechanically successful; however, production rates for the wells were still subcommercial following the treatments.

Most wells have casing set into the top of the thermal anomaly in the Bandelier Tuff and produce from the Bandelier Tuff or a combination of Bandelier Tuff and Paliza Canyon Andesite. Production is from natural fractures in the Tuff and/or the Andesite.

Downhole pressure and temperature measurements have determined that the reservoir is underpressured by 600 to 900 psi compared to hydrostatic pressure. Reservoir pressure is 1,206 psi at 4,500' above sea level. The underpressured, but water dominated condition of the reservoir results in severe lost circulation which has necessitated the use of air assisted drilling fluids.

Produced water, which is relatively benign chemically, is the primary source of water for the drilling rigs, and the only source of water for the drilling muds.

Drilling operations are segregated into two phases: I) surface through the last cemented casing, and II) from last cemented casing to total depth. Distinct differences exist in drilling practices due to approaches to lost circulation problems associated with the two phases. In Phase I the primary effort is toward eliminating lost circulation while in Phase II (through the productive interval) the major concern is damage to the lost circulation zones.

Phase I - Surface Through Last Cemented Casing

Wells are usually spudded in rhyolite or caldera fill. A 17-1/2" hole is drilled to 200 to 500 feet with mud, and then opened to 26". After 20" casing is cemented, 17-1/2" hole is drilled to about 1,500', where 13-3/8" casing is cemented. A 12-1/4" hole is then drilled to the top of the reservoir (2,500' to 4,000'). A number of problems, however, are associated with the basic Phase I drilling program. These involve the following:

Mud Program

The mud program is a gel-lime or gel-Ben-X system mixed with produced water. An example of the properties is shown in Table 4.1-3. Drill pipe corrosion is controlled with oxygen scavengers in this part of the hole. The mud properties are adjusted to provide adequate hole cleaning and sufficient fluid loss control to avoid problems in some of the upper permeable zones. Since few hole problems encountered in this part of the hole are mud related (no swelling clays, etc.), hole cleaning and some fluid loss control, at minimum cost, are all that is required of the mud. Because of lost circulation, a low cost mud is desirable.

Lost Circulation

Lost circulation is the major time consuming and costly problem encountered at Baca. As in all geothermal areas, competent cementing of the casing is a prerequisite to having a useable well upon completing the hole. Past experience has demonstrated that poorly cemented casing cannot survive the thermal stress cycles that a geothermal well must go through, and very poorly cemented casing cannot survive even one thermal shock. It is imperative that all lost circulation be cured before attempting to cement casing in the well.

The usual lost circulation materials are used in the first attempts (mica, walnut hulls, sawdust, etc.). If the loss is occurring to larger fractures (desirable in the production zone, but not here), the common lost circulation materials usually are unsuccessful or only partially successful. Under these circumstances, only cementing off the lost circulation intervals has been found to be a reliable cure.

Cementing lost circulation zones is costly, partly because of the cost of the cement, but mostly because of the time consumed in tripping out and back in with open ended drill pipe, waiting for the cement to harden, and tripping again to pick up a bit to drill out the cement. Frequently, more than one cement plug is required. Usually this is due to the size and severity of the lost circulation zone, but occasionally one of the following problems contributes to the lack of success.

1. Fluid level was not accounted for and cement plug was overdisplaced.

2. Hole was filled too soon and cement was pushed away by pressure of hydrostatic head (this frequently can happen when cementing off zones of severe lost circulation).

3. No cement was displaced into the formation. The only cement was in the wellbore so circulation was again lost as soon as the plug was drilled out. (This can usually occur when cementing off seepage zones.)

4. Insufficient time was allowed for the cement to harden. The cement is usually retarded for protection from formation temperature which is hot. However, during the loss of circulation the hole has been cooled enough so that the cement may take longer than anticipated to set up.

The cement used for these plugs is usually a 1:1 Perlite-"G" or "H" cement with appropriate retarders. Enough rat hole is usually drilled without returns to assure being able to get back to the lost circulation zone with the cement.

Directional Drilling

Due to the steep topography and for environmental considerations, more than one well is drilled from a single location, and the wells are directionally drilled to the targets selected by the geologist. In addition, the productive fractures at Baca have proved to be elusive and this has required that the hole be plugged back and redrilled toward a secondary target more likely to obtain a productive well.

Directional work is done with either mud motors or turbines. Both good success and dismal failure have occurred with each type, which may indicate that reliability is more a function of the organization handling the tools than the equipment iself. However, the majority of work with good success has been with turbines when the temperatures increased. Most directional work is done in the 12-1/4" hole, but occasionally some is done in the 8-3/4" hole, either to sidetrack or to make a last minute correction to the direction. This has occasionally resulted in doing directional work with aerated water or without returns, but it has been successfully accomplished.

In general, the turbines and mud motors are not as reliable as desirable, and the high rpm of these tools results in a very short bit life. However, these tools have permitted successful completion of the directional work.

Phase II - From the Last Cemented Casing to T.D.

Various methods have been tried at Baca to drill the productive interval.

Air drilling was tried, but hole stability and large water influxes usually prevented successfully reaching the target, and the combination of air and produced water resulted in rapid drill string and casing corrosion.

Straight mud drilling resulted in serious lost circulation problems and frequently the well had to be drilled without returns. The problems encountered in drilling without returns often prevented the well from reaching the desired target, but more importantly, all the mud and cuttings were lost into the productive fractures where it is believed they seriously impaired the well's productivity.

The current practice at Baca is to drill out of the shoe of the 9-5/8" casing with air until sufficient water influx occurs to require switching to an aerated water system. The well is then drilled to total depth using an aerated water system.

The major problems with an aerated water system are balancing the air/water ratio and inhibiting the corrosion on drill pipe and casing.

Corrosion Inhibition

Corrosion rates with initial aerated water drilling tests were found to be unacceptably high, approaching 24#/ft^2/yr. It was then determined that most of the corrosion problems could be controlled by combining pH control of the fluid with a proprietary inhibitor, Unisteam, in the system. By keeping the pH above 10.5 to 11.0 in combination with the Unisteam, corrosion could be controlled to an acceptable 2#/ft^2/yr or less. These rates are based on corrosion coupons placed in the drill string.

The chemical requirements are a function of the chemistry of the produced water. (When drilling with an aerated system, conditions are underbalanced and formation fluids are entering the circulating system, consequently the chemistry of the circulating fluid rapidly becomes the same as the produced water.)

Produced fluids at Baca are relatively benign (see Table 4.1-4), and inhibition can be obtained with a combination of pH control and addition of Unisteam under most circumstances. However, attempts to extend this method to other areas with different water chemistries have not always been successful.

Even at Baca, the water chemistry will vary slightly from well to well, and occasionally high corrosion rates (4-6#/ft^2/yr) have occurred for short periods of time because these changes were not anticipated. The number of times that unanticipated high corrosion rates have been encountered has been reduced by continuously monitoring pH, bulk mixing caustic and using chemical pumps to continuously treat the drilling fluid with caustic to maintain the desired pH as indicated by the monitoring system.

While the caustic is added (at levels up to 4,000 lbs. per day) to the circulating fluid, the Unisteam is added to the air stream. The normal Unisteam treatment is to dissolve 30 gallons of Unisteam in 10 bbls of water and inject it into the air stream at a rate of 2 gallons/minute. It has been beneficial to add 30 gallons of ammonium hydroxide to this mixture as well.

Adding ammonium hydroxide was started after finding that the top 400' to 1,000' of the drill pipe appeared corroded on the outside, even though the ring coupons on the inside showed no excessive corrosion. This phenomenon can be explained in the following manner. Frequently, in aerated water drilling, there is a period of time involved in establishing continuous circulation during which there are no returns, except part of the air. This period of non-circulation can be anywhere from 15 minutes to many hours. During this time, water vapor is carried up the annulus from the surface of the fluid level by the air that is channeling through the water. This warm water vapor condenses on the outside of the pipe which is cooled by the fluids traveling down the inside of the drill pipe. Since this is condensed water vapor, it has a neutral pH and no inhibitive chemicals. Consequently, the air passing by diffuses oxygen into this water layer causing rapid corrosion. With the addition of ammonium hydroxide, some of the ammonia is carried along with the water vapor and air, and when the water vapor condenses on the pipe the ammonia dissolves in the water providing the necessary corrosion inhibition. The addition of ammonia at Baca has prevented excessive exterior corrosion at the top of the drill pipe.

Normal practice is to use the entire capacity of either one or two compressors, and then adjust the air/water ratio by increasing or decreasing the fluid pump rate. This is the easiest method of operation for the driller, because he has the pump controls at his station, while the air controls are out by the compressors. The compressors used at Baca deliver 1,100 to 1,200 SCFM at those elevations. Air/water ratios vary dramatically, but 60:1 is a good starting point. The driller must then adjust this ratio up or down based on how the well performs. If he is having trouble keeping the well circulating, he will increase the air/water ratio (decrease the pump rate) and if circulation becomes too violent, he will decrease the air/water ratio (increase the pump rate).

Since drilling is virtually under controlled blowout conditions, the air/water ratio is a continuously changing quantity. When circulation is initiated, the water is relatively cool, and no production has been encountered. Therefore, a high air/water ratio is required to overcome the underbalanced reservoir condition. As drilling encounters productive fractures, hot produced fluid enters the wellbore and part of this fluid flashes to steam, which usually increases the gas/liquid ratio in the annulus. The inlet gas/liquid ratio must then be decreased to counteract the increase that occurs in the annulus due to the produced fluid. Since these changes are neither predictable or readily measurable, trained personnel experience must be relied upon to handle the necessary changes in air/water ratios.

Usually only one compressor is used (1,100 to 1,200 SCFM), but occasionally two compressors are required (or something between 1,100 and 2,400 SCFM). The extra gas capacity is required to clean the hole or a higher gas/liquid ratio is required. It is preferred to maintain at least 150 gpm of liquid for carrying capacity, so if gas/liquid ratios need to exceed 60:1 then two compressors are required. Occasionally an incompetent zone is encountered which requires more carrying capacity to keep the hole clean until the zone stabilizes. The extra carrying capacity can be obtained by increasing both the air and liquid injection rates, usually doubling both of them.

Initially it would not appear that air/liquid ratios as high as 60:1 would be required based on the bottom hole pressures. However, since this is an air/water system rather than the more conventional air/mud systems, it is not as efficient. The low viscosity produced water allows the air to channel through it, so the system is not nearly as efficient at removing the liquid as a viscous mud system. An air/mud system was considered, but decided against for the following reasons:

1. A viscosifier would be required to circulate out the large volumes of water produced while drilling. This viscosifier would cause formation damage to the injection wells used to dispose of the produced water.

2. The viscosifier (clay) could also damage the well being drilled during periods when circulation could not be maintained.

3. The cost would be prohibitive in that the viscosifier could not be recirculated and would need to be continuously replenished to handle produced water.

Cementing and Completion Practices

The wells are completed by hanging a 7" pre-perforated liner through the completion interval from the 9-5/8" casing (see Figure 4.1-3). A packer is then set in the 9-5/8" casing, and a 9-5/8" tie-back is stabbed into the 9-5/8" liner hanger and cemented back to the surface. It is necessary to run this tie-back to provide a string of pipe at the surface that is known to be competent (one that has not been worn by the tool joints or experienced corrosion problems). This competent string of pipe at the surface provides added safety against the shallow casing failures which can cause blowouts.

The surface completion consists of an expansion spool, two full opening valves, a flow tee, a surveying valve and two wing valves as shown in Figure 4.1-3.

Cementing procedures are relatively simple. As discussed previously, it is necessary to fully cement all strings of pipe. The actual cementing is done with a spacer followed by a filler cement of 1 Perlite:1 "H" cement with 40% silica flour and the appropriate retarders, friction reducers and gel. The filler cement is followed by a tail-in slurry of "H" cement with 40% silica flour. When cementing the tie-back, no filler cement is used. It is imperative when cementing the tie-back that the cement have no free water. Any free water trapped between casing strings will cause the inner casing string to buckle, and while this is a serious problem to watch for when cementing the tie-back, it must also be kept in mind where the 9-5/8" casing laps over the 13-3/8" and where the 13-3/8" laps over the 20" casing.

Logging

Downhole electric logs have been generally obtained at three different stages in the drilling of a Baca well: 1) prior to running 13-3/8" casing; 2) prior to running the 9-5/8" liner; and 3) prior to installing the 7" perforated production liner. The various logs run at each stage are as follows:

<u>Prior to 13-3/8" Casing</u> - Electric Resistivity Log
<u>Prior to 9-5/8" Liner</u> - Fracture Identification Log, Compensated Density Neutron-Gamma Ray Log, Electric Resistivity Log, and Temperature Log
<u>Prior to 7" Liner</u> - Electric Resistivity Log, and Compensated Density Neutron-Gamma Ray Log

Sometimes it has been difficult to obtain a good log in the 17-1/2" hole due to centralizing problems with the tool in this large a diameter. Few problems have been encountered in logging the 12-1/4" hole. The temperature log, however, is run first to ensure no adverse effect will result from the subsequent use of low temperature tools. All logs run in the 8-3/4" hole must be high temperature tools. A Fracture Identification Log would be desirable for the 8-3/4" hole, but no commercial high temperature version of this tool exists to date.

Water is injected to cool the hole while logging. Consequently excess temperatures have not been a problem, unless the water was not going out the bottom of the hole. If the water is exiting high in the hole (zones of high permeability) the tools have usually continued to function, but the logging cable burned up. To circumvent this, the wells have been logged going into the hole so a log can be obtained if the cable burns up at some point in the logging operation.

Using the Data Developed at Baca in Other Geothermal Areas

The methods used to drill and complete wells in Baca have direct application to almost every geothermal area under development. The basic methods of drilling down to the top of the reservoir and installing a competent completion in that hole are the same for every geothermal area Union is developing and, therefore, have wide application. The aerated water method of drilling the producing formation may not have as wide an application, but it does describe one of a number of alternative methods for drilling wells into underpressured geothermal reservoirs.

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TABLE 4.1-1

1972 - 1977 WELLS

WELL	T.D.	COST ($000)	STATUS	STEAM (At Line Pressure)
Baca 4	6378'		Commercial	45,000 lbs/hr
Baca 5A	6973'		Water Injector	Off High Temp. Reservoir
Baca 6	4810' (3455' Bridge)		Initially Commercial Collapsed	(33,000) Now Bridged
Baca 9	5303'	333	P&A	
Baca 10	6001'	635	Mechanical Problems	
Baca 11	6931'	425	Commercial	116,000 lbs/hr
Baca 12	9212'	542	Water Injector	(Off High Temp. Reservoir)
Baca 13	8228'	718	Commercial	54,000 lbs/hr
Baca 14	6824' (5780' cmt.)	908	Water Injector	
Baca 15	5505'	610	Commercial	105,000 lbs/hr
Baca 16	7002'	557	Non-Productive	
			TOTAL:	

TABLE 4.1-2

1977 - 1982 WELLS

WELL	T.D.	COST ($000)	STATUS	STEAM
Baca 17	*OH 5791'	914	Non-Productive	
	**RD 6254'	733	Initially Productive, Mechanical Problems	
		$1,647		
Baca 18	OH 4597'	996	Pot. Productive	
	RD 5250'	477	Lost Hole Non-Productive	
		$1,473		
Baca 19	5610'	$ 999	Sub-Commercial	(32,000 @ 10 psi)
Baca 20	OH 6863'	905	Non-Productive	
	RD 6374'	791	Commercial	30,000 lbs/hr @ 125 psi
		$1,696		
Baca 21	3000'	$ 875	Sub-Commercial	(34,000 @ 75 psi)
Baca 22	OD 6017'	1,263	Pot. Productive, Lost Hole	
	RD1 6485'	400	Sub-Commercial	(41,000 @ 45 psi)
	RD2 6006'	531	Sub-Commercial	(20,000 @ 8 psi)
		$2,194		
Baca 23	TD 5746'	1,261	Non-Productive	
	Recpl.3515'	602	Possible Commercial	(48,000 @ 51 psi)
		$1,863		
Baca 24	TD 5502' Eff. TD 3591'	$1,895	Commercial	33,000 @ 131 psi
Baca 12 (deepening to granite)	TD10637'	$1,654	Non-Productive	
Baca 22 (deep re-drill)	TD 8846'	$1,993	Non-Productive	
			TOTAL:	

* OH - Original Hole
** RD - Redrilled Hole

TABLE 4.1-3

MUD PROPERTIES

(Surface Casing Through Last Cemented Casing)

Weight	-	8.5 to 9.0 #/gallon
Funnel Viscosity	-	30 to 38 seconds
Plastic Viscosity	-	2 to 8 cp
Yield Point	-	1 to 10 #100ft^2
Gel Strength	-	10 seconds: 0 to 10 #/100ft^2 10 minutes: 4 to 25 #/100ft^2
Fluid Loss Control	-	10 cc API to no control

TABLE 4.1-4

AVERAGE PRODUCED FLUID CHEMISTRY

	BRINE UNCORRECTED FOR FLASH		CONDENSATE	
	AVG.	(NO. OF SAMPLES)	AVG.	(NO. OF SAMPLES)
pH	7.2	(26)	4.5	(20)
SUSPENDED SOLIDS, mg/l	319	(13)	4.9	(16)
TOTAL DISSOLVED SOLIDS, mg/l	6093	(24)	29	(21)
SiO_2, mg/l	599	(40)	29	(21)
$CO_3^=$	19	(27)	0	(20)
HCO_3^-	127	(26)	6.6	(19)
S^-	2	(15)	8.6	(1)
$SO_4^=$	64	(23)	1.8	(17)
Cl^-	3061	(43)	17	(25)
Na	1749	(43)	6	(23)
K	370	(43)	1.4	(23)
Ca	15	(42)	0.4	(19)
Mg	0.3	(21)	0.2	(21)
Ba	0.05	(6)	0.04	(7)
B	23	(26)	0.8	(21)
F	6	(21)	<0.2	(8)

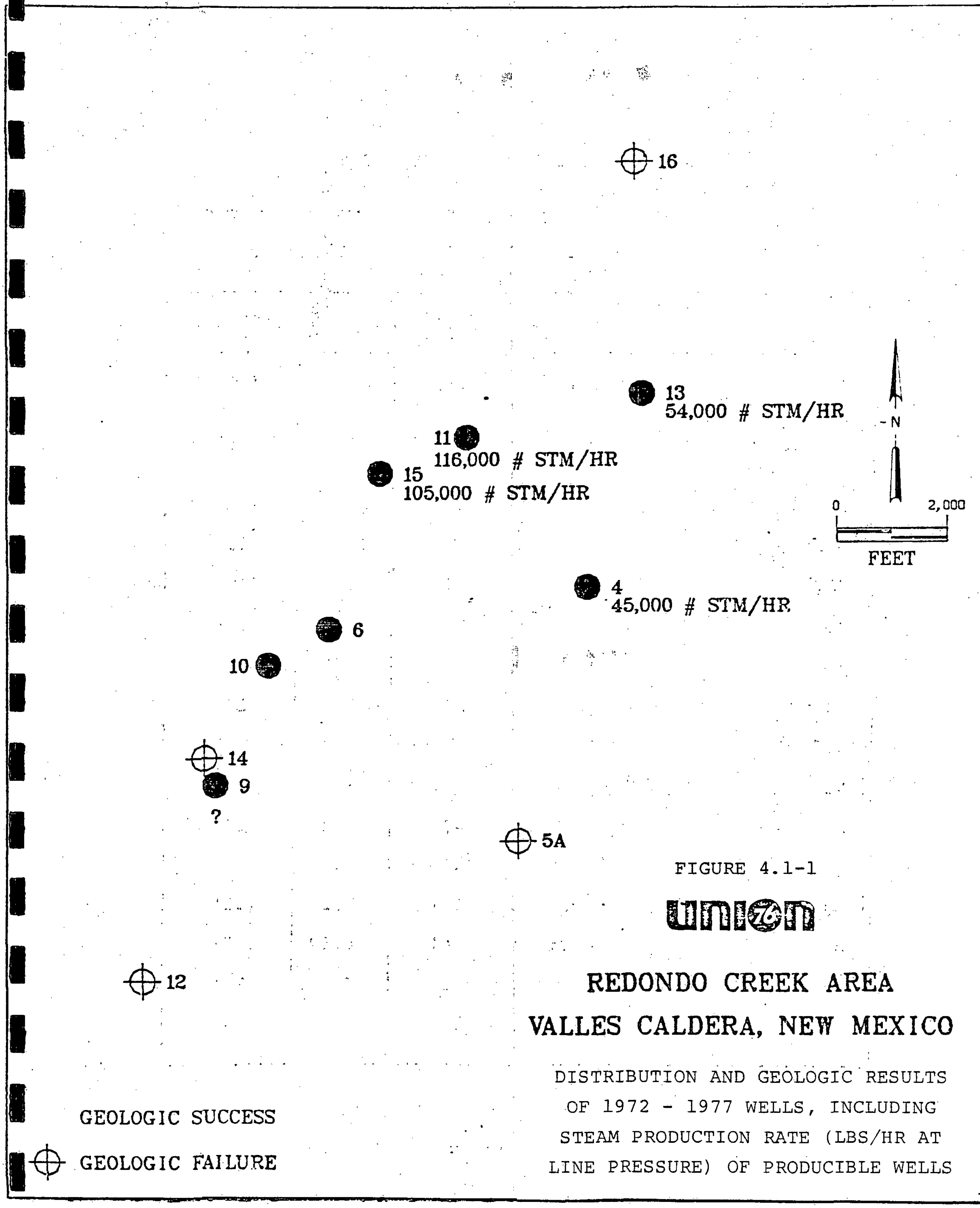


FIGURE 4.1-1

UNION 76

REDONDO CREEK AREA
VALLES CALDERA, NEW MEXICO

DISTRIBUTION AND GEOLOGIC RESULTS OF 1972 - 1977 WELLS, INCLUDING STEAM PRODUCTION RATE (LBS/HR AT LINE PRESSURE) OF PRODUCIBLE WELLS

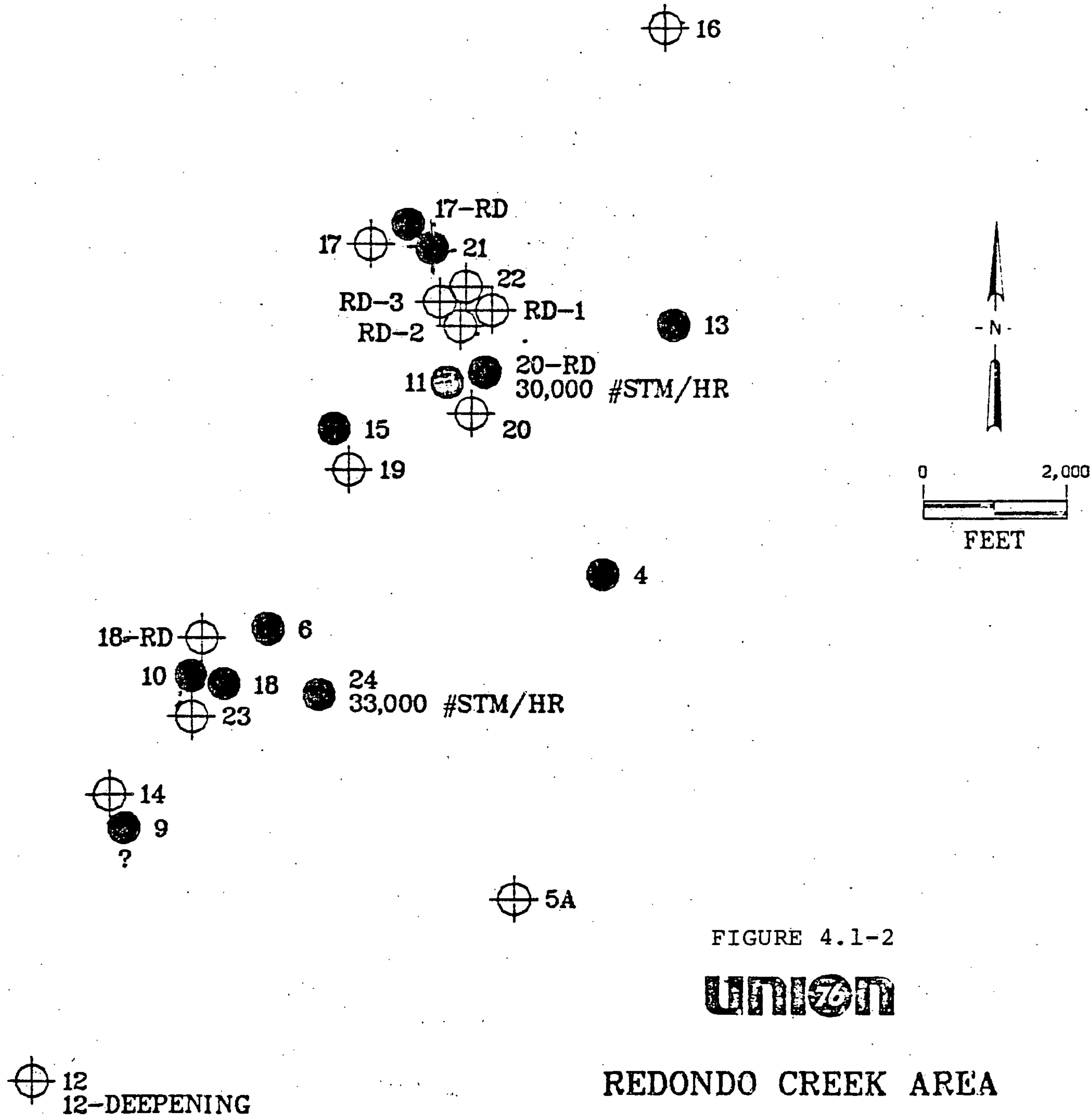


FIGURE 4.1-2

UNION

REDONDO CREEK AREA
VALLES CALDERA, NEW MEXICO

DISTRIBUTION AND GEOLOGIC RESULTS OF ALL WELLS-DEC. 31, 1981 INCLUDING INCREMENTAL STEAM PRODUCTION OF DOE-WELLS (#/HR AT LINE PRESSURE)

GEOLOGIC SUCCESS

GEOLOGIC FAILURE

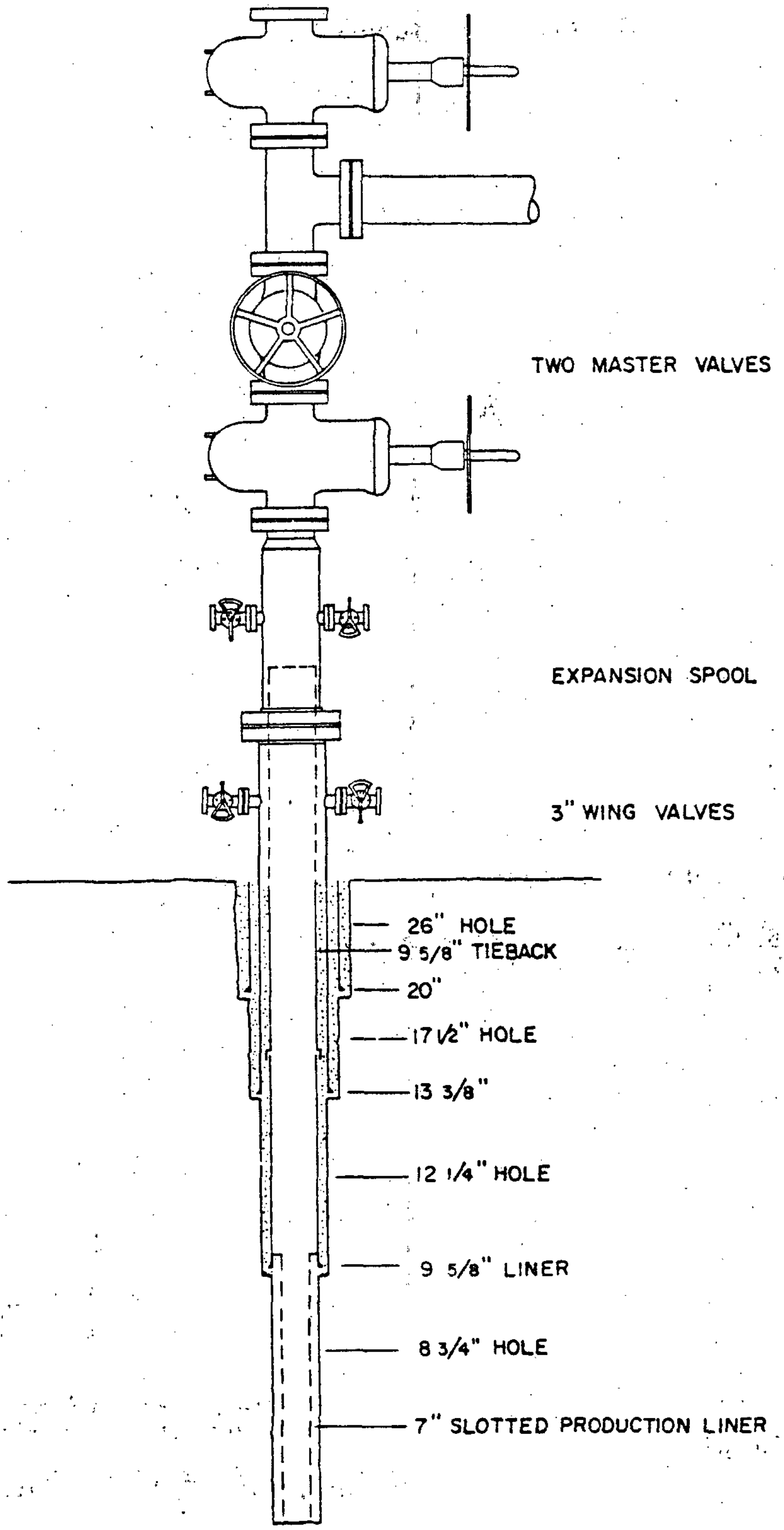


FIGURE 4.1-3

SCHEMATIC DIAGRAM OF BACA COMPLETION

4.2 Cementing and Casing Condition

Following are details for the drilling and completion of the wells drilled in the Redondo Creek area. Schematic diagrams of each well's current completion are shown on Figure Nos. 4.2-1 through 4.2-18:

4.2.1 BACA NO. 4

Drilled 17-1/2" hole using mud to 1,442'. Cemented 13-3/8" 48# J-55 casing at 1,442' with 1,800 CF of cement. Drilled 12-1/4" hole using air to 3,182'. Cemented 9-5/8" 36# J-55 casing at 3,182' with 1,700 CF of cement. Drilled 8-3/4" hole to 5,048' using air.

See 4.3.1 for recompletion details.

4.2.2 BACA NO. 5

Drilled 26" hole to 390' using mud. Cemented 20" 94# H-40 casing at 390' with 850 sacks of cement with 2% $CaCl_2$. Drilled 17-1/2" hole to 2,878' using air. Drill pipe parted; left top of fish at 432'. Fishing attempts failed. Filled casing with cement plug and abandoned well.

4.2.3 BACA NO. 5A

Skidded rig over from Baca 5 on same location. Drilled 26" hole to 676' using mud. Cemented 20" 94# H-40 casing at 676' with 1,660 sacks of cement with 2% $CaCl_2$. Drilled 17-1/2" hole to 3,090' using air mist. Cemented 13-3/8" 54.5# and 61# K-55 casing at 2,828' with 1,435 sacks of cement with 1:1 Perlite followed by 565 sacks of cement. Drilled 12-1/4" hole to 4,400' using air mist. Cemented 9-5/8" 40# K-55 blank casing liner at 4,400' (liner top at 2,692') with 470 sacks of cement with 1:1 Diamix M, 0.8% R-6. Drilled 8-3/4" hole to 6,973' using air mist.

4.2.4 BACA NO. 6

Drilled 17-1/2" hole to 36'. Cemented 13-3/8" 54.5# K-55 casing at 36' with 10 sacks of cement with 1:1 gravel. Drilled 12-1/4" hole to 795' using mud. Cemented 9-5/8" 40# K-55 casing at 795' with 200 sacks of cement with 1:1 Pozmix.

Drilled 8-3/4" hole to 3,715' using air mist. Hung 7" 23# and 26# K-55 perforated and blank casing liner at 3,700'. Liner top at 692' with various slots from 2,633' to 3,699'.

See 4.3.2 for recompletion details.

4.2.5 BACA NO. 9

Drilled 17-1/2" hole to 805' using mud. Cemented 13-3/8" 48# H-40 casing at 805' with 406 sacks of cement with 1:1 Pozmix. Drilled 12-1/4" hole to 3,519' using air. Stuck drill pipe and backed off at 3,005'. Sidetracked hole at 2,433'. Drilled 12-1/4" sidetrack hole to 3,340' with air and to 3,600' with mud. Cemented 9-5/8" 36# K-55 blank casing liner at 3,599' (liner top at 385') with 765 sacks of cement with 1:1 Pozmix, 0.8% R-11. Drilled 8-3/4" hole to 4,619' using air. Found 9-5/8" casing collapsed at 2,911'. Milled casing from 2,911'-2,913' and 2,943'-2,957'. Drilled 8-3/4" hole to 5,303' using air. Stuck drill pipe and backed off at 4,503'. Found leak in 13-3/8" casing twenty feet from surface. Set bridge plug at 2,795'. Filled casing with cement plug and abandoned well.

4.2.6 BACA NO. 10

Drilled 26" hole to 656' using mud. Cemented 20" 94# H-40 casing at 653' with 1,500 CF of cement with 3% $CaCl_2$. Drilled 17-1/2" hole to 2,804' using air. Cemented 13-3/8" 61# and 54.5# K-55 casing at 2,794' with 2,441 CF of cement with 1:1 Pozmix, 36% silica flour, 0.5% CFR-2, 0.4% HR-7. Drilled 12-1/4" hole to 4,418' using air. Cemented 9-5/8" 40# and 36# K-55 blank casing liner at 4,418' (liner top at 2,480') with 100 CF of cement with 1:1 Perlite, 35% silica flour, 2% gel, 0.75% CFR-2, 0.3% HR-12. Drilled 8-3/4" hole to 6,001' using air. Hung 7" 23# and 26# K-55 perforated and blank casing liner at 6,000'. Liner top at 4,278' with slots at 4,406' to 5,595' and 5,761' to 5,986'. Cemented 9-5/8" 36# K-55 blank tie-back casing at 2,480' with 915 CF of cement with 1:1 Pozmix, 2% gel, 35% silica flour, 0.5% CFR-2, 0.4% HR-7. Perforated 9-5/8" casing at 2,439', 2,440', 2,418'-2,421', 2,362'-2,364', 2,062'-2,064', 1,582'-1,584' and 1,336'-1,341'. Recemented 9-5/8" x 13-3/8" annulus with 1,236 CF of cement with 1:1 Pozmix, 2% gel, 0.5% CFR-2, 1/4 lb/sack Flocel and 35% silica flour. Cleaned out to 5,988'.

See 4.3.3 for recompletion details.

4.2.7 BACA NO. 11

Drilled 26" hole to 208' using mud. Cemented 20" 94# H-40 casing at 207' with 600 CF of cement with 3% $CaCl_2$. Drilled 17-1/2" hole to 1,345' using mud. Cemented 13-3/8" 54.5# K-55 casing at 1,336' with 1,600 CF of cement with 1:1 Pozmix, 35% silica flour, 0.5% CFR-2, 1/4 lb/sack Flocel. Drilled 12-1/4" hole to 3,381' using water. Cemented 9-5/8" 36# K-55 blank casing liner at 3,380' (liner top at 1,219') with 1,400 CF of cement with 1:1 Pozmix, 2% gel, 35% silica flour, 0.5% CFR-2, 0.2% HR-7. Drilled 8-3/4" hole to 6,814' using aerated water. Hung 7" 26# K-55 slotted and blank casing liner at 6,926'. Liner top at 3,320', with various slots from 3,489' to 6,892'. Cemented 9-5/8" 36# K-55 blank tie-back casing at 1,219' with 565 CF of cement with 1:1 Pozmix, 36% silica flour, 0.5% CFR-2. Drilled out cement and bridge plug.

See 4.3.4 for rework details.

4.2.8 BACA NO. 12

Drilled 26" hole to 250' using mud. Cemented 20" 94# H-40 casing at 247' with 816 CF of cement with 3% $CaCl_2$. Drilled 17-1/2" hole to 1,457' using water. Cemented 13-3/8" 68# K-55 casing at 1,453' with 626 CF of cement with 1:1 Pozmix, 36% silica flour, 0.5% CFR-2, 0.1% HR-7, 1/4 lb/sack Flocel followed by 808 CF of cement with 1:1 Pozmix, 35% silica flour, 0.5% CFR-2. Drilled 12-1/4" hole to 3,540' using water. Cemented 9-5/8" 36# K-55 blank casing liner at 3,540' (liner top at 1,269') with 400 CF of cement with 1:1 Perlite, 40% silica flour, 0.5% CFR-2, 0.4% HR-7, 2% gel followed by 1,000 CF of cement with 1:1 Pozmix, 35% silica flour, 0.5% CFR-2, 0.3% HR-7. Drilled 8-3/4" hole to 9,212' using aerated water. Hung 7" 26# K-55 slotted and blank casing liner at 9,211'. Liner top at 3,343'. Cemented 9-5/8" 40# K-55 blank tie-back casing at 1,270' with 562 CF of cement with 35% silica flour. Drilled out cement and bridge plug.

See 4.3.5 for recompletion details.

4.2.9 BACA NO. 13

Drilled 26" hole to 215' using mud. Cemented 20" 94# H-40 casing at 211' with 694 CF of cement with 3% $CaCl_2$. Drilled 17-1/2" hole to 1,474' using mud. Cemented 13-3/8" 68# K-55 casing at 1,469' with 684 CF of cement with 1:1 Perlite, 40% silica flour, 0.5% CFR-2, 0.2% HR-7, followed by 1,460 CF of cement with 1:1 Pozmix, 35% silica flour, 0.5% CFR-2, 1/4 lb/sack Flocel. Drilled 12-1/4" hole to 2,607' using mud and to 3,500' using aerated water. Cemented 9-5/8" 36# K-55 blank casing liner at 3,499' (liner top at 1,270') with 400 CF of cement with 1:1 Perlite, 40% silica flour, 0.5% CFR-2, 0.2% HR-7 followed by 900 CF of cement with 1:1 Pozmix, 35% silica flour, 0.5% CFR-2. Drilled 8-3/4" hole to 5,084' using aerated water. Cored from 5,084' to 5,095'. Drilled 8-3/4" hole to 5,286' using aerated water. Cored from 5,286' to 5,300'. Drilled 8-3/4" hole to 6,292' using aerated water. Cored from 6,292' to 6,308'. Drilled 8-3/4" hole to 8,228' using aerated water. Hung 7" 26# N-80 blank and K-55 slotted liner at 8,200'. Liner top at 3,340'. Cemented 9-5/8" 36# K-55 blank tie-back casing at 1,270' with 750 CF of cement with 35% silica flour. Cleaned out cement and bridge plug.

4.2.10 BACA NO. 14

Drilled 26" hole to 196' using mud. Cemented 20" 94# H-40 casing at 193' with 643 CF of cement with 3% $CaCl_2$. Drilled 17-1/2" hole to 1,457' using mud. Cemented 13-3/8" 54.5# and 61# K-55 casing at 1,452' with 450 CF of cement with 1:1 Perlite, 40% silica flour, 2% gel, 0.5% CFR-2, 0.2% HR-7 followed by 1,460 CF of cement with 1:1 Pozmix, 2% gel, 35% silica flour, 0.5% CFR-2. Drilled 12-1/4" hole to 3,075' using mud. Cemented 9-5/8" 36# K-55 casing at 3,074' (liner top at 1,371') with 225 CF of cement with 1:1 Perlite, 40% silica flour, 0.5% CFR-2, 0.4% HR-7, 2% gel followed by 1,168 CF of cement with 1:1 Pozmix, 35% silica flour, 0.5% CFR-2, 0.4% HR-7, 2% gel. Drilled 8-3/4" hole to 6,824' using aerated water. Set cement plug from 5,780' to 6,040'.

4.2.11 BACA NO. 15

Drilled 26" hole to 211' using mud. Cemented 20" 94# K-55 casing at 210' with 500 sacks of cement with 3% $CaCl_2$. Drilled 17-1/2" hole to 1,283' using mud. Cemented 13-3/8" 54.5# K-55 casing at 1,273' with 345 sacks of cement with 1:1 Perlite, 2% gel, 40% silica flour followed by 575 sacks of cement with 1:1 Pozmix, 2% gel, 35% silica flour. Drilled 12-1/4" hole to 2,415' using mud and to 2,515' with water. Cemented 9-5/8" 40# K-55 blank casing liner at 2,509' (liner top at 1,173') with 267 sacks of cement with 1:1 Perlite, 40% silica flour, 0.2% HR-12, 0.5% CFR-2, 0.5% HR-7. Drilled

8-3/4" hole to 5,505' using aerated water. Cemented 9-5/8" 36# K-55 blank tie-back casing at 1,173' with 405 sacks of cement with 40% silica flour, 2% gel, 0.75% CFR-2. Cleaned out cement and bridge plug.

See 4.3.6 for recompletion details.

4.2.12 BACA NO. 16

Drilled 26" hole to 208' using mud. Cemented 20" 94# K-55 casing at 193' with 590 CF of cement with 3% $CaCl_2$. Drilled 17-1/2" hole to 1,216' using mud. Cemented 13-3/8" 54.5# K-55 casing at 1,215' with 900 sacks of cement with 1:1 Perlite, 2% gel, 40% silica flour. Drilled 12-1/4" hole to 2,980' using water. Cemented 9-5/8" 36# K-55 blank casing liner at 2,905' (liner top at 1,100') with 500 sacks of cement with 1:1 Perlite, 40% silica flour, 2% gel, 0.5% CFR-2, 0.5% HR-7. Drilled 8-3/4" hole to 7,002' using aerated water.

4.2.13 BACA NO. 17

Drilled 26" hole to 252' using mud. Cemented 20" 94# K-55 casing at 247' with 700 CF of cement with 2% $CaCl_2$. Drilled 17-1/2" hole to 1,200' with severe lost circulation. (A total of 15 cement plugs were required to cement off lost circulation zones). Cemented 13-3/8" 54.5# K-55 buttress casing at 1,171' with 1,350 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2 and 40% silica flour followed by 324 CF of cement with 0.5% CFR-2 and 40% silica flour. Performed "top job" in 13-3/8" x 20" annulus through 1" pipe at 270' using 410 CF of cement with 40% silica flour. Drilled 12-1/4" hole to 3,303'. Cemented 9-5/8" 36# K-55 casing liner through shoe at 3,000' (liner top at 980') with 620 CF of cement with 2:1 Perlite, 3% gel and 40% silica flour followed by 118 CF of cement with 0.3% HR-7 and 40% silica flour. Cemented through DV tool at 2,581' using 201 CF of Thix-Set cement with 1:1 Perlite and 1/2 lb/sack Flo-Seal followed by 1,125 CF of cement with 1:1 Perlite, 0.5% CFR-2 and 40% silica flour. Ran cement bond log then squeeze cemented 9-5/8" casing through perforations at 2,450' using 1,197' CF of cement with 1:1 Perlite, 3% gel and 40% silica flour. Squeezed 9-5/8" liner lap using 750 CF of cement with 1:1 Perlite, 3% gel and 40% silica flour. Drilled 8-3/4" hole with aerated water to 5,147'. Cored from 5,147' to 5,173'. Drilled 8-3/4" hole to 4,791' using aerated water. Tested well and determined it would not flow. Set cement plugs at various intervals from 5,791' to 3,056' to perform sidetrack.

Kicked off at 3,056' and directionally redrilled 8-3/4" hole to 6,254' with aerated water. Hung combination blank and perforated 7" 26# K-55 lines from 2,886' to 6,250'. Following a short flow test the 13-3/8" casing was found to be damaged at 407'. Subsequently a combination 7" 26# K-55 and 9-5/8" 36# K-55 tie-back casing string was installed to 1,285' and cemented with 280 CF of cement with 2:1 Perlite, 3% gel and 40% silica flour followed by 412 CF of cement with 1:1 Perlite, 3% gel and 40% silica flour followed by 881 CF of cement with 0.05% CFR-2 and 40% silica flour. Following an unsuccessful attempt to flow the well the tie-back casing string was found collapsed at 408'. Installed cement plugs at various intervals from 1,485' to surface.

4.2.14 BACA NO. 18

Drilled 17-1/2" hole to 662' using mud. Cemented 13-3/8" 54.5# and 61# K-55 buttress casing at 660' with 944 CF of cement with 2% $CaCl_2$. Drilled 12-1/4" hole to 2,020' using mud. Cemented 9-5/8" 36# K-55 buttress casing at 2,018' with 1,400 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2, 0.2% HR-7 and 40% silica flour followed by 300 CF of cement with 0.5% CFR-2 and 40% silica flour. Drilled 8-3/4" hole to 2,865' with mud. Drilled 8-3/4" hole using aerated water to 4,597' where pipe stuck. Fishing and washover attempts were unsuccessful in recovering drilling tools below 3,845'.

Plugged back with cement to 2,720'. Kicked off and directionally drilled 8-3/4" hole using mud to 2,736' when the bit broke off bottom of dynadrill. Fishing operations for the bit were unsuccessful.

Plugged back to 2,410' with cement. Kicked off and directionally drilled 8-3/4" hole to 5,250' using mud. Hung 7" 26# K-55 combination blank and slotted casing from 1,863' to 5,240'.

4.2.15 BACA NO. 19

Drilled 26" hole using mud to 253'. Cemented 20" 94# H-40 casing at 248' with 475 CF of cement with 2% $CaCl_2$. Drilled 17-1/2" hole using mud to 1,512'. Cemented 13-3/8" 54.5# K-55 casing at 1,504' using 1,750 CF of cement with 1:1 Perlite, 2% gel, 0.5% CFR-2 and 40% silica flour followed by 338 CF of cement with 0.75% CFR-2 and 40% silica flour. Recemented 13-3/8" x 20" annulus through 1" pipe at 214' using 312 CF of cement with 1:1 Perlite, 2% gel and 40% silica flour. Drilled 12-1/4" hole using mud to 2,495'. Cemented 9-5/8" 40# K-55 blank casing liner at 2,480' (liner top at 1,255') using 687 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2, 0.3% HR-7 and 40% silica flour followed by 238 CF of cement with 0.5% CFR-2 and 40% silica flour. Directionally drilled 8-3/4" hole using mud to 4,000'. Drilled 8-3/4" hole using aerated water to 5,610'. Cemented 9-5/8" 40# K-55 buttress tie-back casing at 1,258' using 556 CF of cement with 2% gel, 0.75% CFR-2 and 40% silica flour. Hung combination blank and slotted 7" 26# K-55 casing from 2,328' to 5,585'.

4.2.16 BACA NO. 20

Drilled 26" hole using mud to 290'. Cemented 20" 94# K-55 casing at 280' with 890 CF of cement with 2% $CaCl_2$. Drilled 17-1/2" hole using mud to 1,430'. Cemented 13-3/8" 54.5# K-55 buttress casing at 1,415' using 2,040 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2 and 40% silica flour followed by 334 CF of cement with 0.5% CFR-2 and 40% silica flour. Directionally drilled 12-1/4" hole using mud to 2,511'. Cemented 9-5/8" 40# K-55 blank casing liner at 2,505' (liner top at 1,233') using 360 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2, 0.4% HR-7 and 40% silica flour followed by 360 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2 and 40% silica flour. Recemented liner lap with 80 CF of cement with 40% silica flour. Drilled 8-3/4" hole using mud to 2,600'. Cored from 2,600' to 2,605'. Drilled 8-3/4" hole using mud to 6,864'. The well would not flow when tested at 6,864' depth.

Plugged back to 2,591' with cement. Kicked off and directionally drilled 8-3/4" hole with mud to 3,778'. Drilled 8-3/4" hole using aerated water to 5,500'. Cemented 9-5/8" 40# K-55 tie-back casing using 750 CF of cement with 40% silica flour and 0.5% CFR-2. Drilled 8-3/4" hole using aerated water to 6,374'. Drill pipe stuck and twisted off at 1,278'. Fished out drilling tools down to 5,827'. Hung combination blank and slotted 7" 26# K-55 liner from 2,390' to 5,812'.

See 4.3.7 for recompletion details.

4.2.17 BACA NO. 21

Drilled 26" hole to 635' using mud. Cemented 20" 94# K-55 casing at 618' with 1,176 CF of cement with 2% $CaCl_2$. Drilled 17-1/2" hole to 1,521' using mud. Cemented 13-3/8"

54.5# K-55 casing at 1,503' with 2,200 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2 and 40% silica flour followed by 228 CF of cement with 0.5% CFR-2 and 40% silica flour. Directionally drilled 12-1/4" hole to 2,605' using mud. Cemented 9-5/8" 40# K-55 blank casing liner at 2,593' (liner top at 1,361') with 738 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2 and 40% silica flour followed by 80 CF of cement with 0.5% CFR-2 and 40% silica flour. Drilled 8-3/4" hole to 2,842' with air. Tested well open-hole at indicated commercial rate and pressure. Cemented 9-5/8" 40# K-55 tie-back casing at 1,361' with 632 CF of cement with 40% silica flour, 0.5% CFR-2 and 0.2% HR-7. Hung combination blank and perforated 7" 26# K-55 liner from 2,479' to 2,900'.

4.2.18 BACA NO. 22

Drilled 26" hole to 480' using mud. Cemented 20" 94# H-40 casing at 467' with 1,652 CF of cement with 2% $CaCl_2$. Drilled 17-1/2" hole to 1,545' using mud. Cemented 13-3/8" 54.5# K-55 buttress casing at 1,535' with 1,291 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2 and 40% silica flour followed by 196 CF of cement with 0.5% CFR-2 and 40% silica flour. Drilled 12-1/4" hole to 2,528' using mud. (Six cement plugs were required to combat lost circulation at various intervals while drilling the 12-1/4" hole). Cemented 9-5/8" 40# K-55 blank casing liner at 2,512' (liner top at 1,352') using 720 CF of cement with 40% silica flour and 0.5% CFR-2. Drilled 8-3/4" hole to 4,470' using air. Cored from 4,470' to 4,481'. Drilled 8-3/4" hole to 4,487'. Cored from 4,487' to 4,500'. Drilled 8-3/4" hole to 6,011' using aerated water. Cored from 6,011' to 6,017'. Cemented 9-5/8" 40# K-55 tie-back casing at 1,352' with 633 CF of cement with 40% silica flour, 0.5% CFR-2 and 0.2% HR-7. Stuck drilling assembly at 5,168' while cleaning out the 8-3/4" hole in preparation for intalling the production liner. Failed to recover drilling tools from 3,396' to 5,168'.

Plugged back to 2,735' with cement. Kicked off and directionally drilled 8-3/4" hole to 4,046' using mud. Continued drilling 8-3/4" hole to 6,351' using aerated water. Open-hole flow test indicated sub-commercial rate and pressure.

Plugged back to 2,650' with cement. Kicked off and directionally drilled 8-3/4" hole to 6,006' using aerated water. Hung combination blank and slotted 7" 26# K-55 liner from 2,361' to 5,980'.

See 4.3.8 for recompletion details.

4.2.19 BACA NO. 23

Drilled 26" hole to 622' using mud. Cemented 20" 94# H-40 casing at 612' with 1,500 CF of cement with 2% $CaCl_2$. Drilled 17-1/2" hole to 1,419' using mud. (Eight cement plugs were required to combat lost circulation zones). Cemented 13-3/8" 54.5# K-55 buttress casing at 1,409' using 1,920 CF of cement with 1:1 Perlite, 3% gel, 0.5% CFR-2 and 40% silica flour followed by 203 CF of cement with 0.5% CFR-2 and 40% silica flour.

Drilled 12-1/4" hole to 3,072' using mud. (Three cement plugs were used to shut off lost circulation zones). Cemented 9-5/8" 40# K-55 blank casing liner at 3,057' (liner top at 1,239') using 76 CF of cement with 0.5% CFR-2 and 40% silica flour followed by 1,440 CF cement with 1:1 Perlite, 3% gel, 0.5% CFR-2 and 40% silica flour followed by 298 CF of cement with 0.5% CFR-2 and 40% silica flour. Drilled 8-3/4" hole to 5,746' using aerated water.

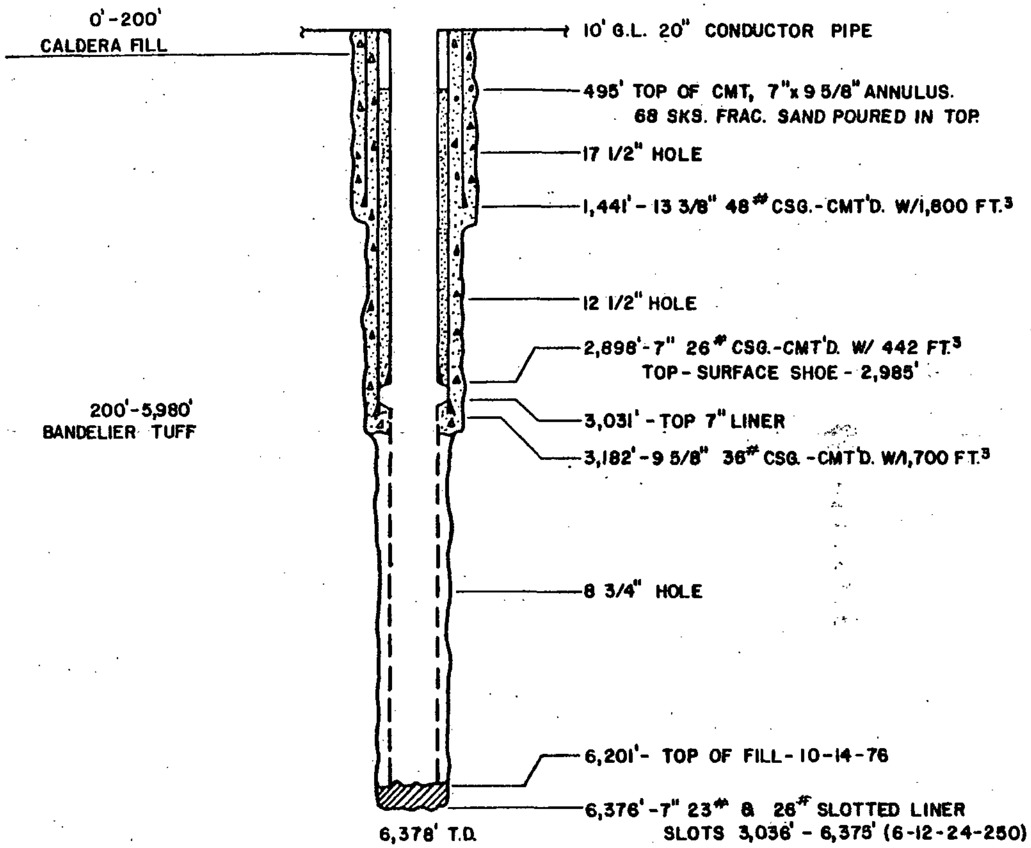
See 4.3.9 for recompletion details.

4.2.20 BACA NO. 24

Drilled 26" hole to 788' using mud. Cemented 20" 94# H-40 casing at 782' with 2,733 CF of cement with 1:1 Perlite, 3% gel and 40% silica flour. Drilled 17-1/2" hole to 2,946' using mud. Cemented 13-3/8" 54.5# and 61# K-55 buttress casing at 2,938' with 2,720 CF of cement mixed with 50 lb/sack Spherelite, 4% gel, 5% lime, 1% CFR-2, 0.3% HR-7 and 40% silica flour followed by 301 CF of cement with 0.5% CFR-2, 0.3% HR-7 and 40% silica flour. Performed "top job" through 1" pipe at 147' in 13-3/8" x 20" annulus using 610 CF of cement with 40% silica flour. Drilled 12-1/4" hole to 5,502' using aerated water. Stuck drill pipe and tools. Failed to recover all of drilling tools; however, operations were successful in retrieving tools down to 3,616'. Hung combination blank and perforated 7" 26# K-55 liner from 2,838' to 3,589'.

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	6-30-80	REG	
2	REDRAWN	3-28-80	[illegible]	

KELLY BUSHING 17'
GROUND ELEVATION 9,318'



DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
STEAM 1,887' 1,988' 2,000' 2,115' 2,200' 2,490' 2,591' 2,625' 3,120' 3,150' - 3,177' 3,468' H_2O 3,710' 4,300' - 4,400' 4,610' - 4,618' 4,975' 4,991' - 5,000' 5,291' 5,866'	1,286' - 1,294' 1,988' - 2,000' 2,220'	1,400'	5,814' - 5,823'	

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
9-12-70	10-12-70	6-28-73	

UNION 76

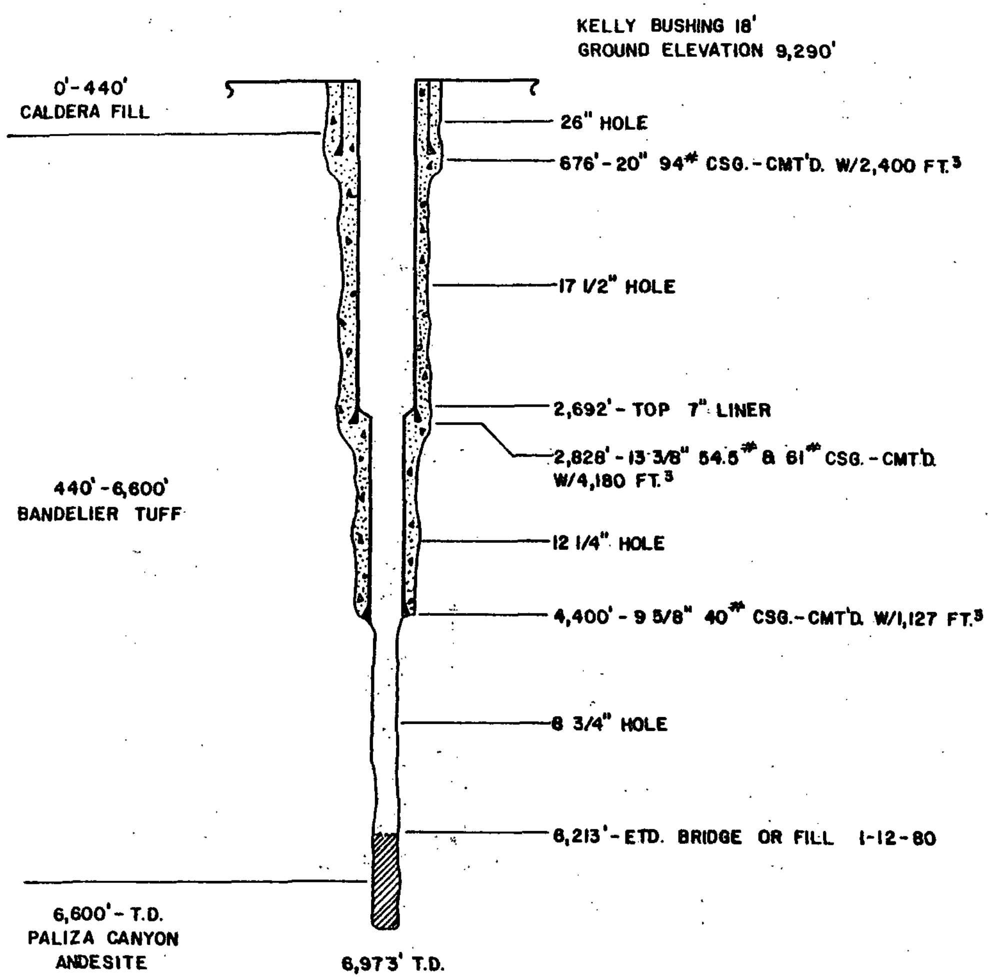
Union Geothermal Company of New Mexico

WELL SCHEMATIC
BACA NO. 4

DESIGN		SIZE B	AFE NO. 303005
DRAWN	E. K.	DWG NO.	RC 1-DR-01
CHECK		REV	2
DATE	3-28-80	SCALE 1"=1,000'	SHEET 1 OF 1

BRUNING 40-522 44574

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	3-28-80	R.E.G.	
2	REDRAWN	6-30-80	B.	



DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
STEAM 1,226' 2,360' 2,375'-2,705' 3,860' 4,270'-4,280' H_2O 1,229' 3,375' 2,375'-2,705' 2,795'-2,800' 3,860' 5,010'-5,016' 5,290'-5,296' 5,295'-5,310' 5,655'	1,780'-1,820' 5,295'-5,310' 5,655' 6,070'-6,075'		5,010'-5,016'	

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
8-13-71	9-20-71		

UNION 76

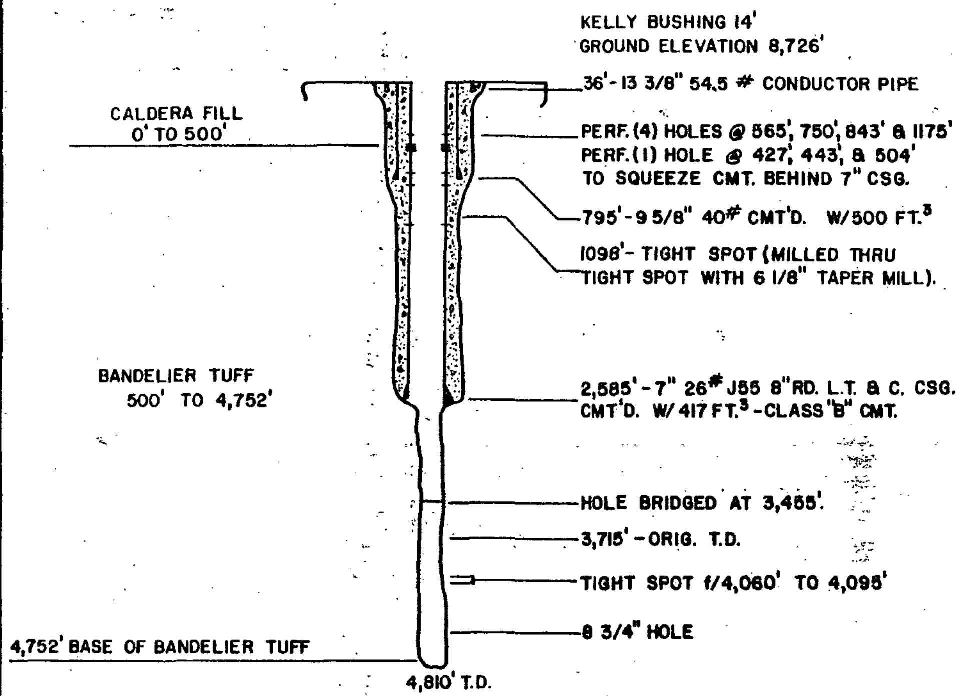
Union Geothermal Company of New Mexico

WELL SCHEMATIC
BACA NO. 5A

DESIGN	
DRAWN	E. K.
CHECK	
DATE	3-28-80

SIZE	AFE NO.	DWG NO.	REV
B	303005	RC 1-DR-02	
SCALE: 1"=1,000'		SHEET 1 OF 1	

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	2-12-80	G.K.	
2	REDRAWN	7-1-80	[illegible]	



DRILLING DETAIL

H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	

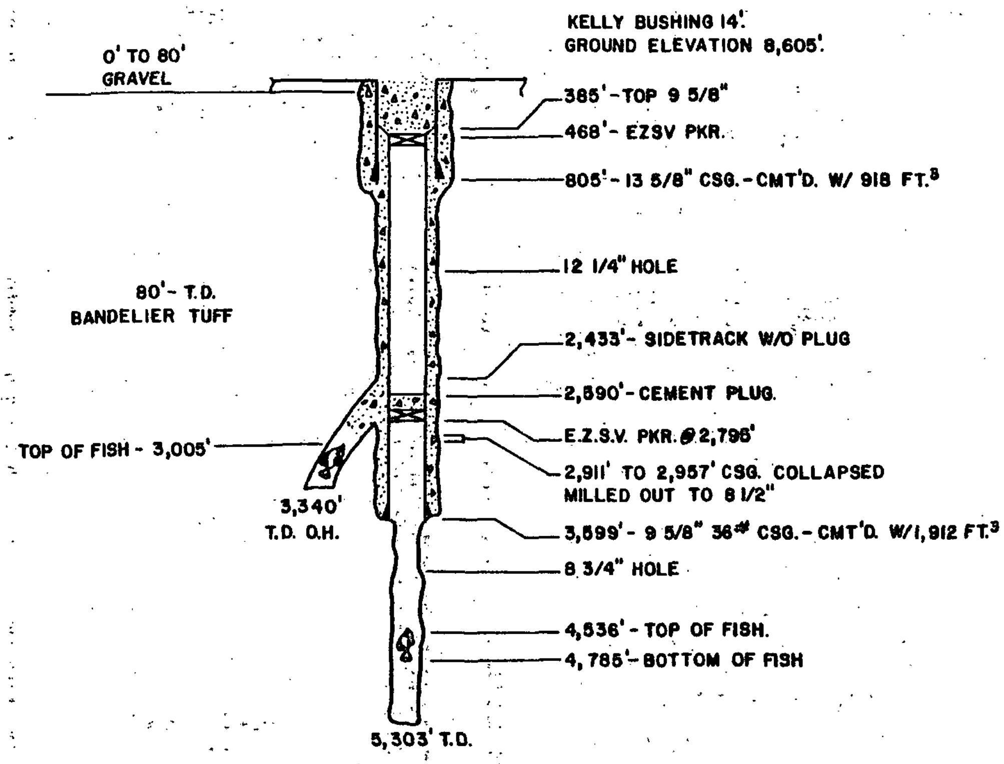
DATE SPUDDED	DATE COMPLETED	REMEDIALS DATE STARTED	REMEDIALS DATE COMPLETED
7-7-72	7-22-72	3-1-75	4-14-75
		9-15-75	9-25-75
		12-8-75	1-15-76

Union Geothermal Company of New Mexico

WELL SCHEMATIC
BACA NO. 6

DESIGN		SIZE B	AFE NO. 303005
DRAWN	E.K.	DWG NO. RC 1-DR-03	REV
CHECK		SCALE: 1"=1,000'	SHEET 1 OF 1
DATE	2-12-80		

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	3-28-80	R.E.G.	
2	REDRAWN	7-2-80	B.	



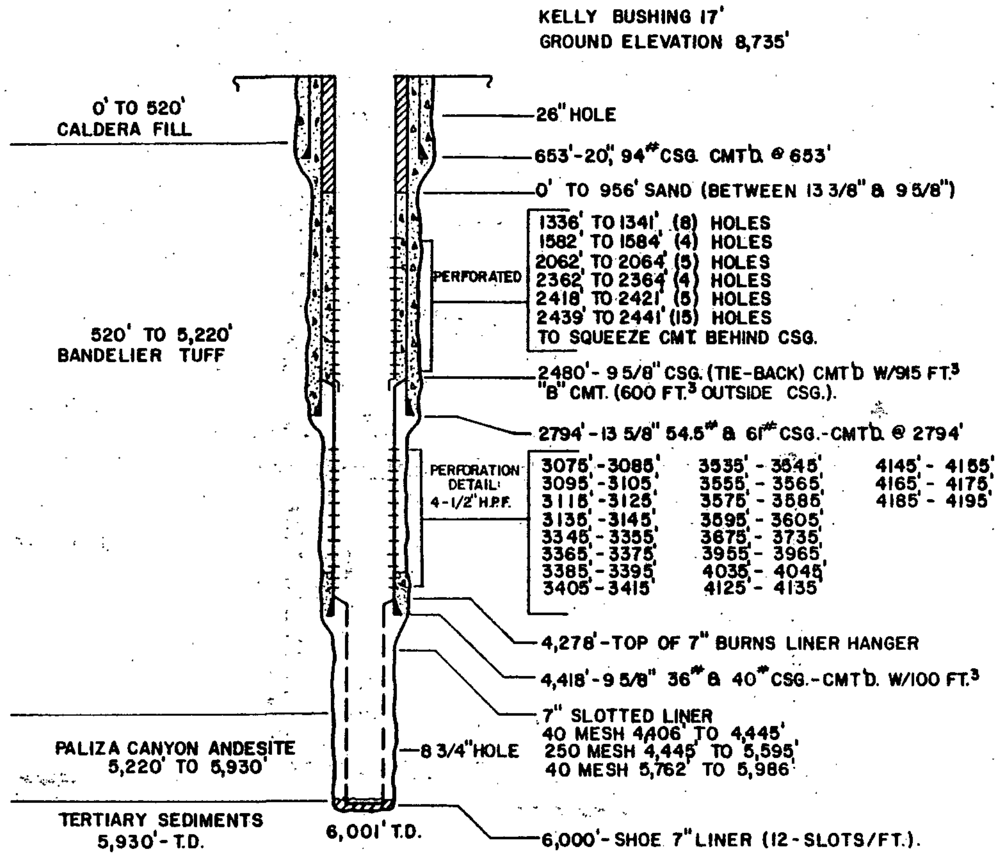
DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
H_2O 1,370' 2,474' 2,482' 2,732' STEAM 2,482' 2,732' 3,702' 4,077' 5,000'		3,340'		

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
9-15-72	11-22-73		PLUGGED & ABANDONED 11-22-74

UNION 76	Union Geothermal Company of New Mexico			
DESIGN		WELL SCHEMATIC BACA NO. 9		
DRAWN	E.K.			
CHECK		SIZE B	AFE NO. 303005	DWG NO. RC I-DR-04 — REV 2
DATE	3-28-80	SCALE: 1"=1,000'		SHEET 1 OF 1

-30-

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	2-13-80	G.K.	
2	REDRAWN	7-2-80		



DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
STREAM 2622' 3030' 3103' 3200' 3370' 3560' 3713' 4150' 4500' 4595' 4760' 4886' 5310' 5480' 5936'				

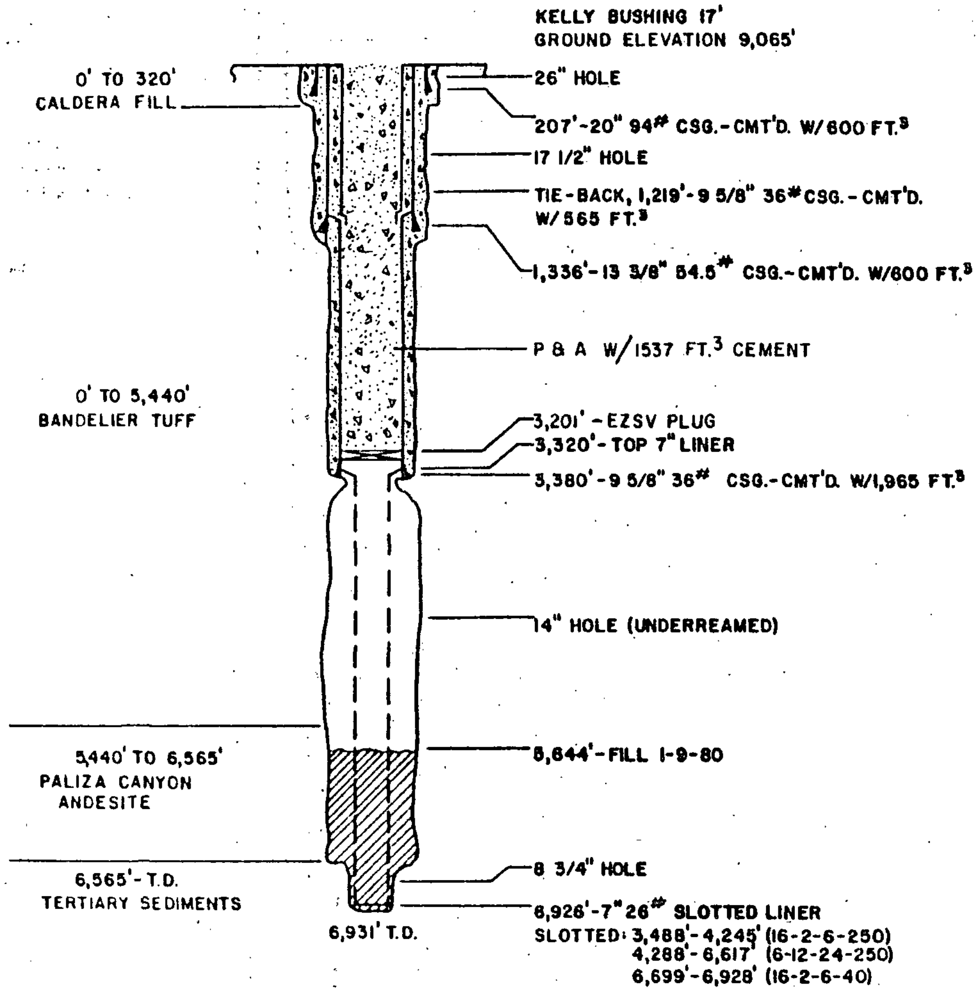
DATE SPUDDED	DATE COMPLETED	REMEDIALS: DATE STARTED	REMEDIALS: DATE COMPLETED
7-6-73	9-18-73		PERFORATED CSG. 7-22-75

UNION 76	Union Geothermal Company of New Mexico
DESIGN	
DRAWN	E.K.
CHECK	
DATE	2-29-80

WELL SCHEMATIC
BACA NO. 10

SIZE	AFE NO.	DWG NO.	REV
B	303005	RC1-DR-05	2
SCALE: 1"=1,000'		SHEET 1 OF 1	

PLUGGED & ABANDONED 8-12-82



REVISIONS

REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	3-31-80	REG	
2	REDRAWN	7-3-80	[illegible]	
3	P & A	11-9-82	L.D.C.	

DRILLING DETAIL

H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
		1,825' 1,973' 2,038' 2,226' 2,559' 3,507' 3,959' (WELL BLEW IN) 3,984'-4,085'	3,950'-3,960' 4,005'-4,010' 4,032'-4,039' 5,431'-5,935'	

DATE SPUDDED	DATE COMPLETED	REMEDIALS DATE STARTED	REMEDIALS DATE COMPLETED
9-26-73	11-13-73	9-11-76	
			8-12-82 P & A

UNION 76

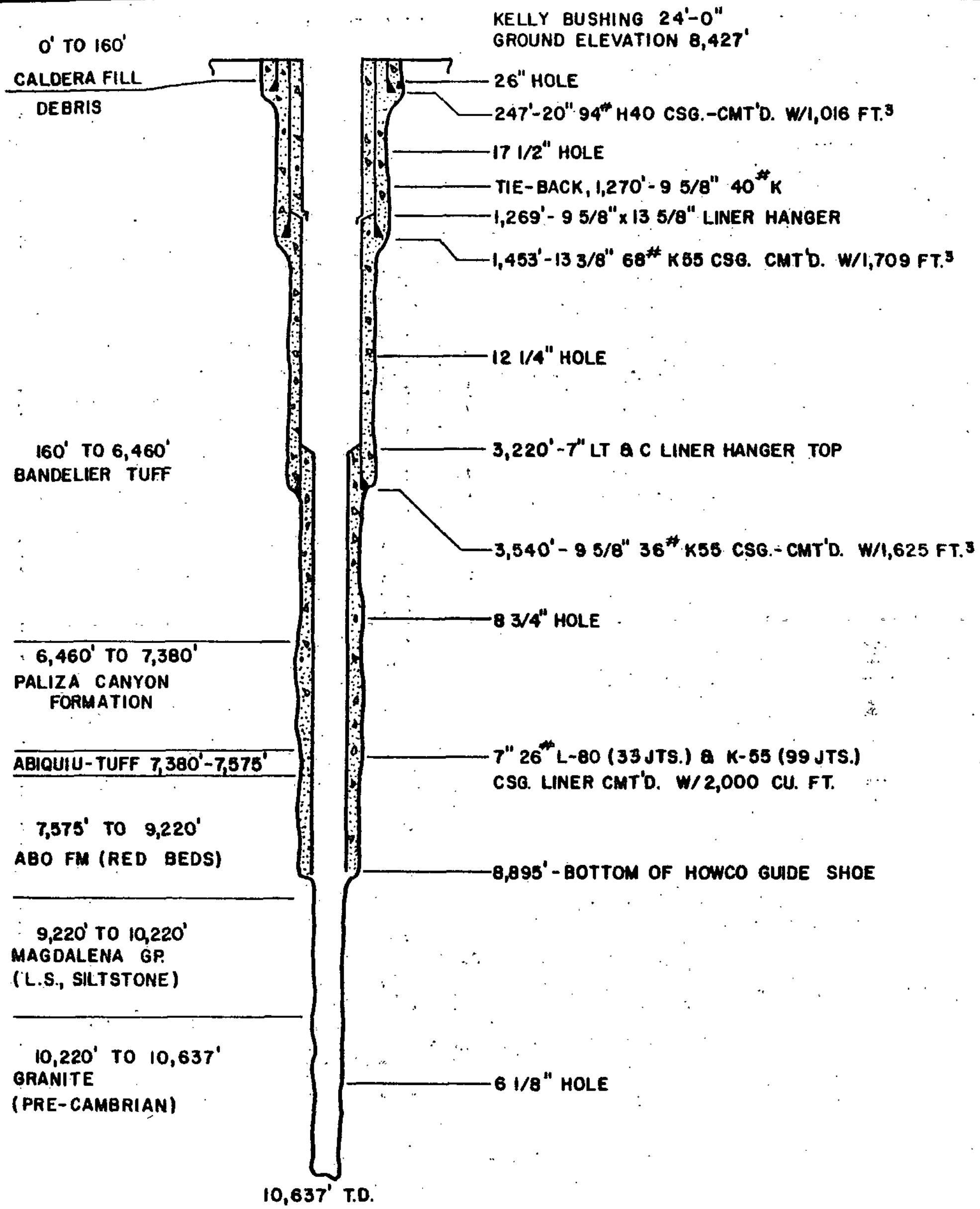
Union Geothermal Company of New Mexico

WELL SCHEMATIC
BACA NO. 11

DESIGN	
DRAWN	E.K.
CHECK	
DATE	3-31-80

SIZE B | AFE NO. 303005 | DWG NO. RCI-DR-06 | REV 3
SCALE N.T.S. | SHEET 1 OF 1

BRUNING 40-522 44574



REVISIONS

REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	3-31-80	REG.	
2	REDRAWN	11-13-81	8	

DRILLING DETAIL

H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	LOGS
		3,540'-9,212' (SET 45 CMT. PLUGS)		NONE

DATE SPUDDED	DATE COMPLETED	DEEPENING DATE STARTED	DEEPENING DATE COMPLETED
6-19-74	8-19-74	6-27-81	9-16-81

UNION 76

Union Geothermal Company of New Mexico

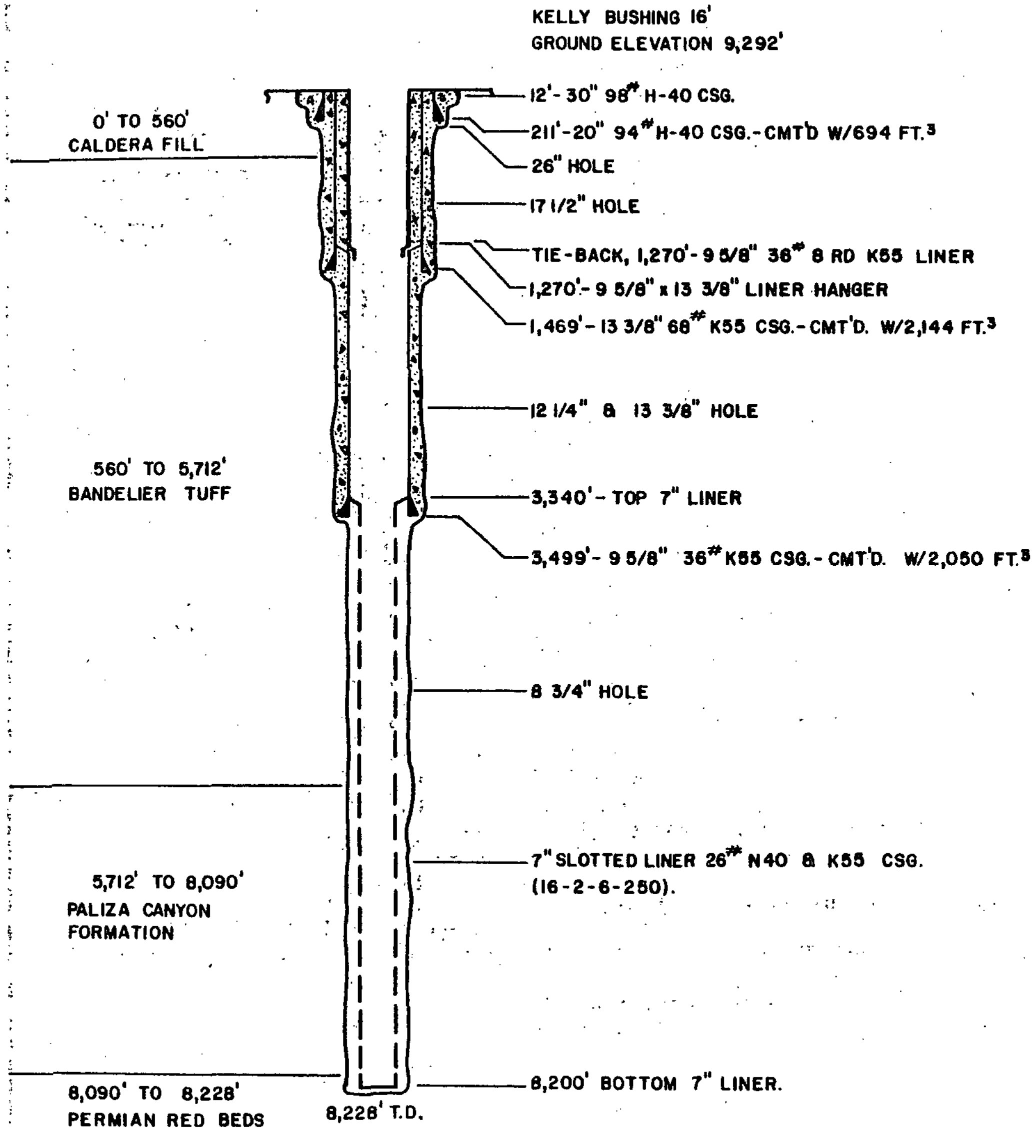
WELL SCHEMATIC BACA NO. 12

DESIGN	
DRAWN	S. PENZAK JR.
CHECK	(signature)
DATE	3-31-80

SIZE B | AFE NO. 303005 | DWG NO. RC 1-DR-07 | REV 2

SCALE: N.T.S. | SHEET 1 OF 1

BRUNING 40-522 44574



REVISIONS

REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	3-31-80	REG	
2	REDRAWN	7-7-80	[illegible]	

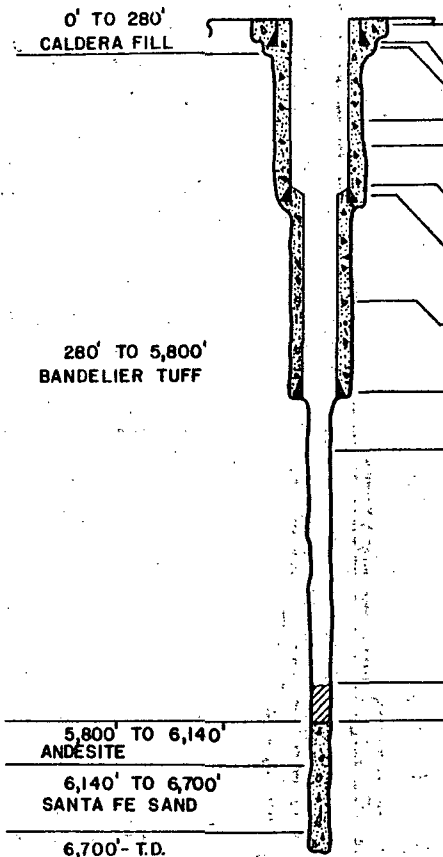
DRILLING DETAIL

H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
8-23-74	11-5-74		

UNION 76	Union Geothermal Company of New Mexico		
DESIGN		WELL SCHEMATIC BACA NO. 13	
DRAWN	E.K.		
CHECK		SIZE B · AFE NO. 303005 · DWG NO. RC 1-DR-08	REV 2
DATE	3-31-80	SCALE: 1"=1,000'	SHEET 1 OF 1

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	3-31-80	REG	
2	REDRAWN	7-7-80	[illegible]	



DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
H_2O 4,108'				

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
11-16-74	2-24-75	8-22-76	

UNION 76

Union Geothermal Company of New Mexico

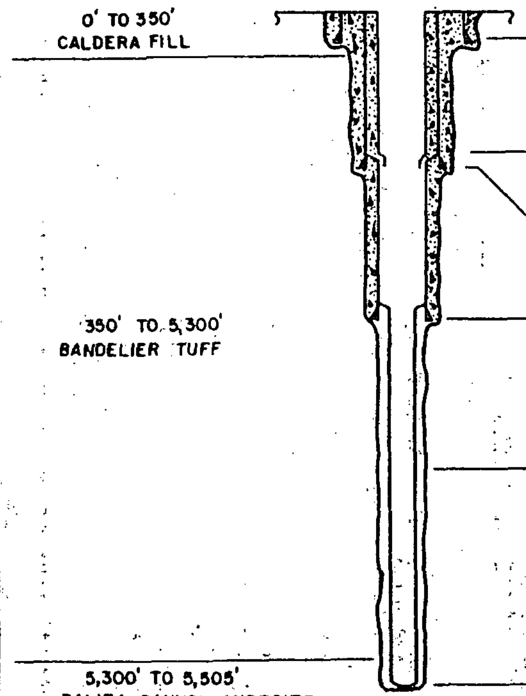
WELL SCHEMATIC
BACA NO. 14

DESIGN	
DRAWN	E.K.
CHECK	
DATE	3-31-80

SIZE	AFE NO.	DWG NO.	REV
B	303005	RC I-DR-09	
SCALE: 1"=1,000'		SHEET 1 OF 1	

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	2-11-80	GK	
2	REDRAWN	7-8-80	[illegible]	

KELLY BUSHING 15'
GROUND ELEVATION 9,117'



DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
		1,211'		

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
4-29-75	6-13-75	9-13-76	

UNION 76

Union Geothermal Company of New Mexico

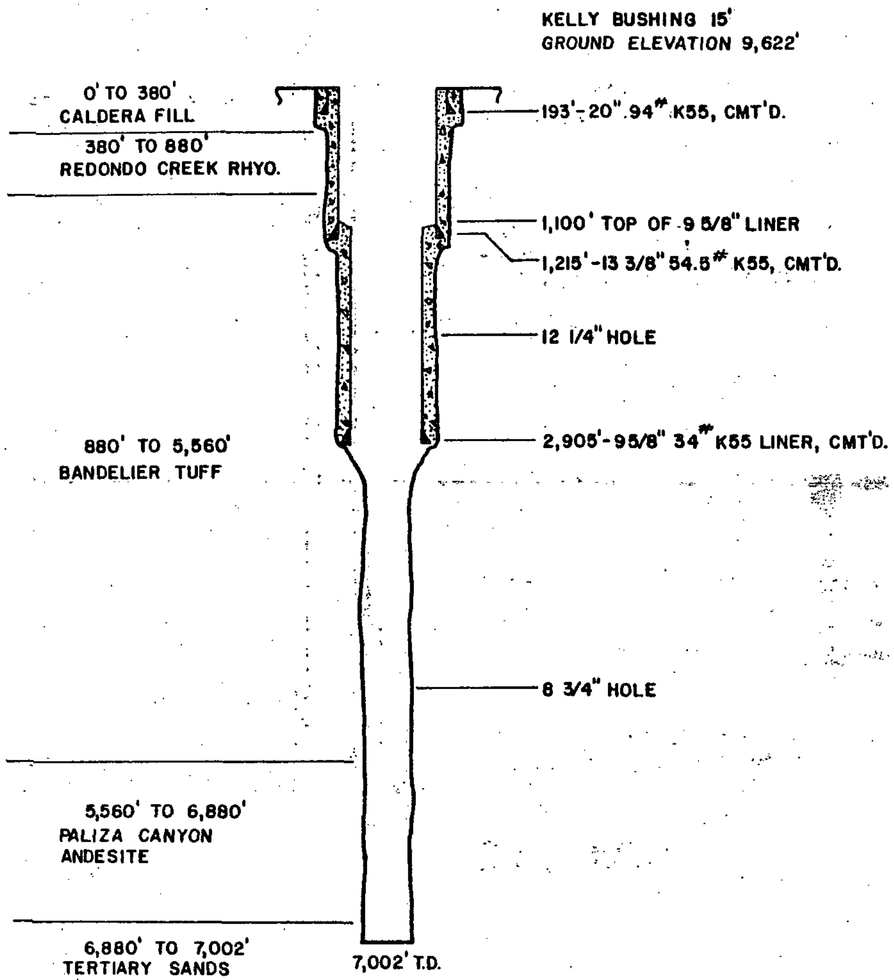
WELL SCHEMATIC
BACA NO. 15

DESIGN	
DRAWN	E.K.
CHECK	
DATE	2-12-80

SIZE	AFE NO.	DWG NO.	REV
B	303005	RC1-DR-10	2
SCALE: 1"=1,000'		SHEET 1 OF 1	

BRUNING 40-522 44574

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	2-7-80	GK	
2	REDRAWN	7-8-80	[illegible]	



DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
		2,169'		

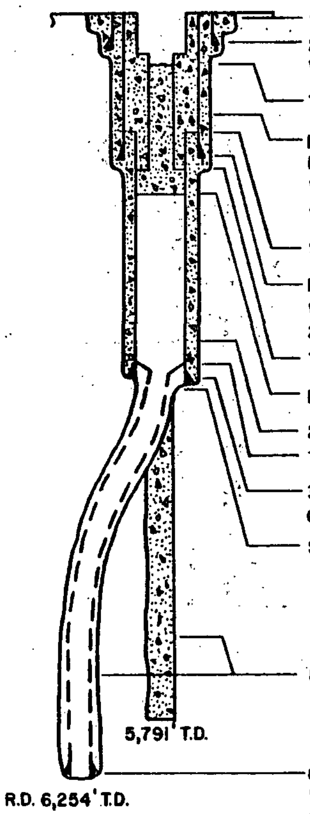
DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
6-19-75	8-21-75		

UNION 76 — Union Geothermal Company of New Mexico

WELL SCHEMATIC
BACA NO. 16

DESIGN		SIZE B	AFE NO. 303005	DWG NO. RC 1-DR-11		REV 2
DRAWN	J. C.					
CHECK						
DATE	8-29-75	SCALE: 1"=1,000'			SHEET 1 OF 1	

KELLY BUSHING 20'
GROUND ELEVATION 9,361'



NOTE:
13 3/8" & 7" CSG. COLLAPSED @ 408'
PLUGGED WELL FROM 420' TO 1,485'
W/ 316 FT.³ "B" CMT.

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	2-7-80		
2	REDRAWN	7-10-80		

DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	
STEAM 4,796'-4,805'	4,796'-5,510'	1,087'	4,796'-5,510	
H_2O 2,660'		2,660'		

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
8-13-78	12-5-78 P & A		

UNION 76

Union Geothermal Company of New Mexico

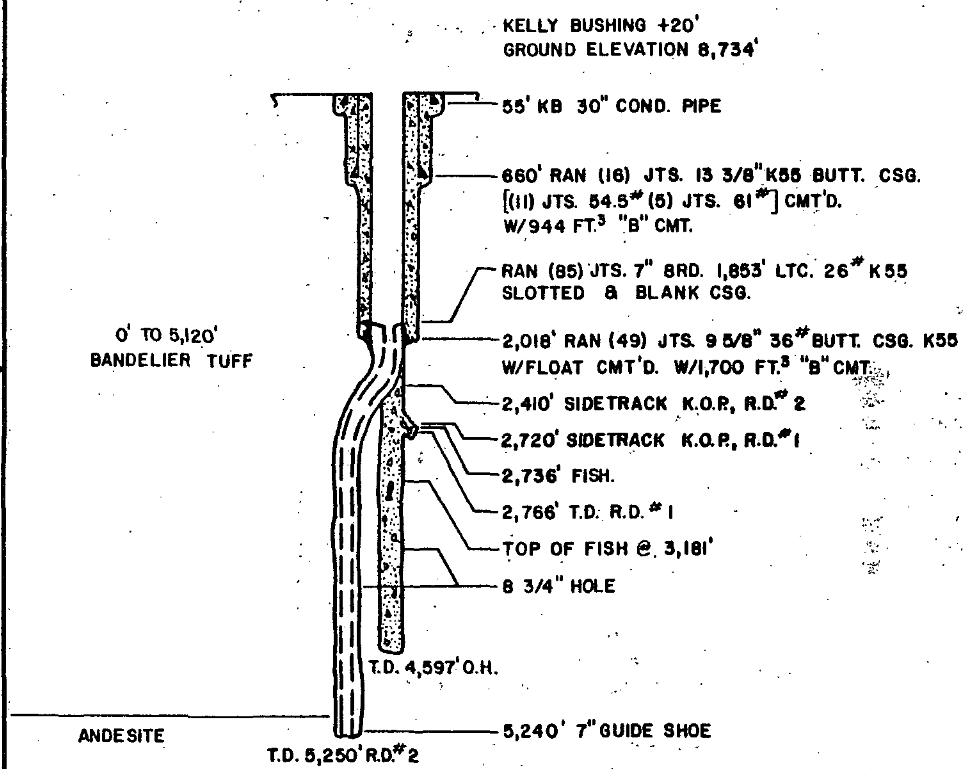
WELL SCHEMATIC BACA NO. 17

DESIGN		SIZE B	AFE NO. 303005	DWG NO. RC 1-DR-12	REV 2
DRAWN	S. PENZAK JR.				
CHECK					
DATE	12-14-78	SCALE: 1"=1,000'		SHEET 1 OF 1	

-38-

BRUNING 40-522 44574

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	2-7-80	D.A.	
2	REDRAWN	7-10-80	B.	



DRILLING DETAIL			
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	CASING DETAIL 7" LINER
			EVERY OTHER JT. SLTD. F/1,978' TO 3,618' 60M: 3618' - 3656', 3697' - 3737', 3776' - 3815', 3853' - 3892', 3931' - 3971', 4010' - 4090', 4127' - 4206', 4247' - 4326' 20-2-6-125 — 4367' - 4446' 1/4" x 4": 4486' - 4574', 4612' - 4699', 4736' - 4822', 4863' - 4951', 4990' - 5075', 5114' - 5201'

DATE SPUDDED	DATE COMPLETED	REMEDIALS DATE STARTED	REMEDIALS DATE COMPLETED
12-16-78	3-16-79		

Union Geothermal Company of New Mexico

WELL SCHEMATIC BACA NO. 18

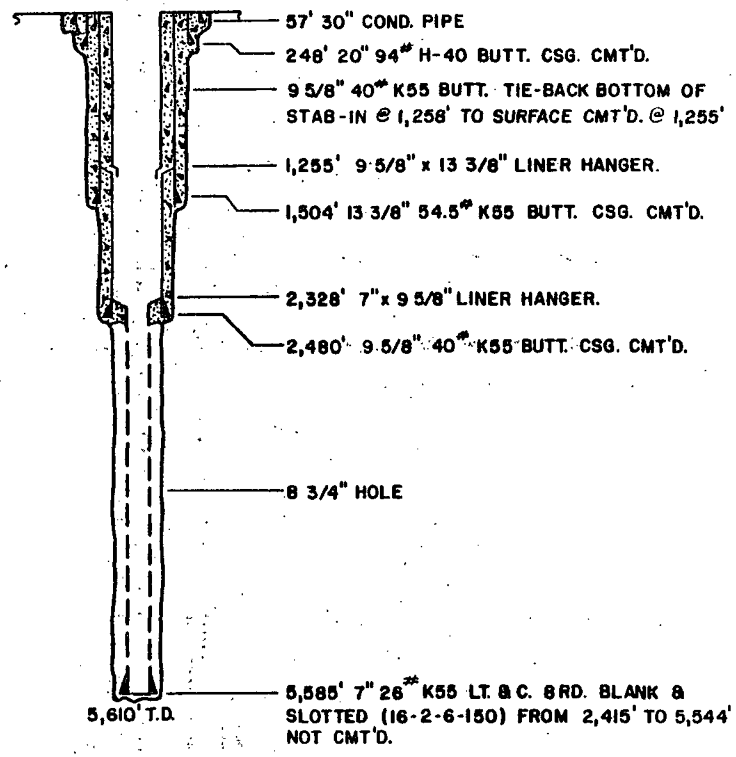
DESIGN	
DRAWN	L. D. C.
CHECK	
DATE	4-30-79

SIZE B | AFE NO. 303005 | DWG NO. RC 1-DR-13 | REV 2

SCALE 1"=1,000' | SHEET 1 OF 1

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
1	CHECK FOR ACCURACY	2-12-80	G.K.	
2	REDRAWN	7-11-80	[illegible]	

KELLY BUSHING 20'
GROUND ELEVATION 9,117'



DRILLING DETAIL

H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	

DATE SPUDDED	DATE COMPLETED	REMEDIALS DATE STARTED	REMEDIALS DATE COMPLETED
9-24-79	11-3-79		

UNION 76 — Union Geothermal Company of New Mexico

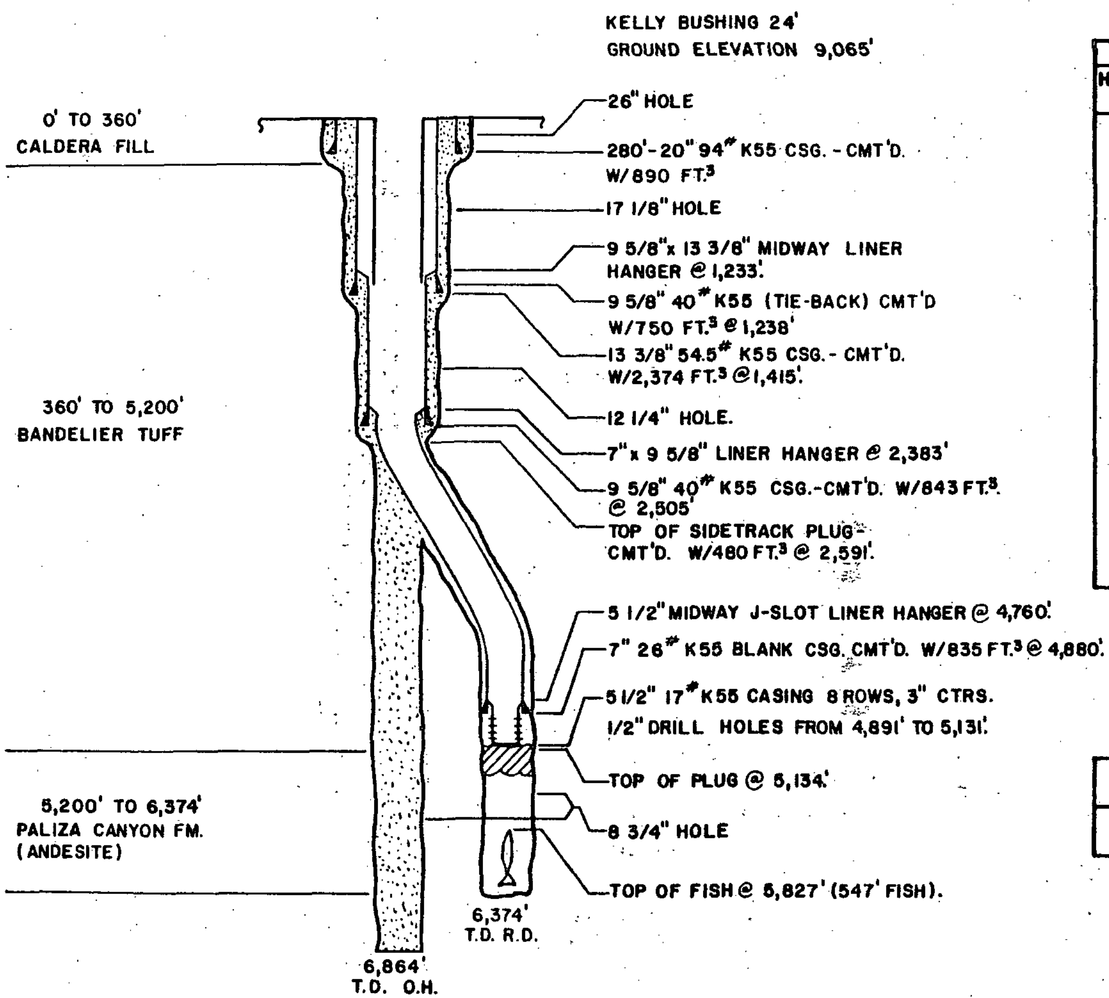
WELL SCHEMATIC BACA NO. 19

DESIGN	
DRAWN	L.D.C.
CHECK	
DATE	11-28-79

SIZE: B | AFE NO.: 303005 | DWG NO.: RC 1-DR-14 | REV: 2

SCALE: 1"=1,000' | SHEET 1 OF 1

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
0	RELEASED	11-25-80	[illegible]	MLB
1	REMEDIAL WORK CHANGES	1-15-82	[illegible]	



DRILLING DETAIL				
H_2O & STREAM ENTRIES	BRIDGES	LITHOLOGY	DRLG. BREAK	LOGS
	4943'-5827'	CALDERA FILL 0'-360' BANDELIER TUFF RHYOLITE TUFF 360'-5200' ANDESITE 5200'-T.D.	3910'-3975'	TEMP. LOG 0'-4100' FRAC. I.D. LOG 2505'-3500' DUAL LATEROLOG 2505'-6853' CNF-DGR 2505'-6850' REDRILL CNL.-FDC. 2600'-5500'

DATE SPUDDED	DATE COMPLETED	REMEDIALS DATE STARTED	REMEDIALS DATE COMPLETED
6-27-80	8-30-80	9-12-81	10-13-81

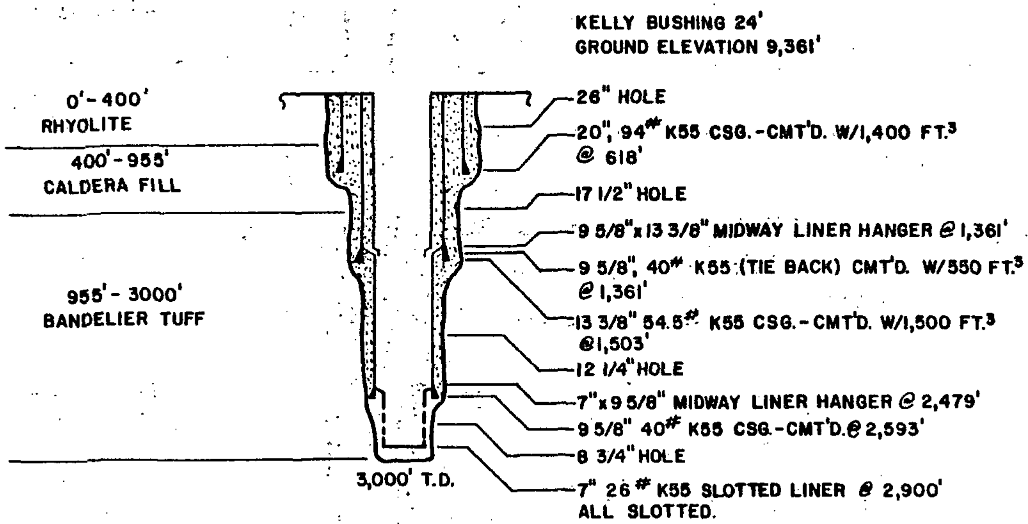
UNION 76

Union Geothermal Company of New Mexico

WELL SCHEMATIC BACA NO. 20

DESIGN	S. PENZAK JR.	SIZE B	AFE NO. 303705
DRAWN	S. PENZAK JR.	DWG NO.	RC 1-DR-16
CHECK	MLB	REV	1
DATE	11-20-80	SCALE: 1"=1,000'	SHEET 1 OF 1

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
0	RELEASED			



DRILLING DETAIL				
H_2O & STREAM ENTRIES	BRIDGES	LITHOLOGY	DRLG. BREAK	LOGS
		RHYOLITE 0'-400' CALDERA FILL 400'-955' BANDELIER TUFF 955'-T.D.		DIL-GR 616'-1,517' HRT 0'-2,601' FIL 1,504-2,606' CNL-FDC-GR 1,504'-2,606' DLL-GR 1,504'-2,592' CNL-FDC-GR 2,595'-2,930'

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
9-9-80	10-5-80		

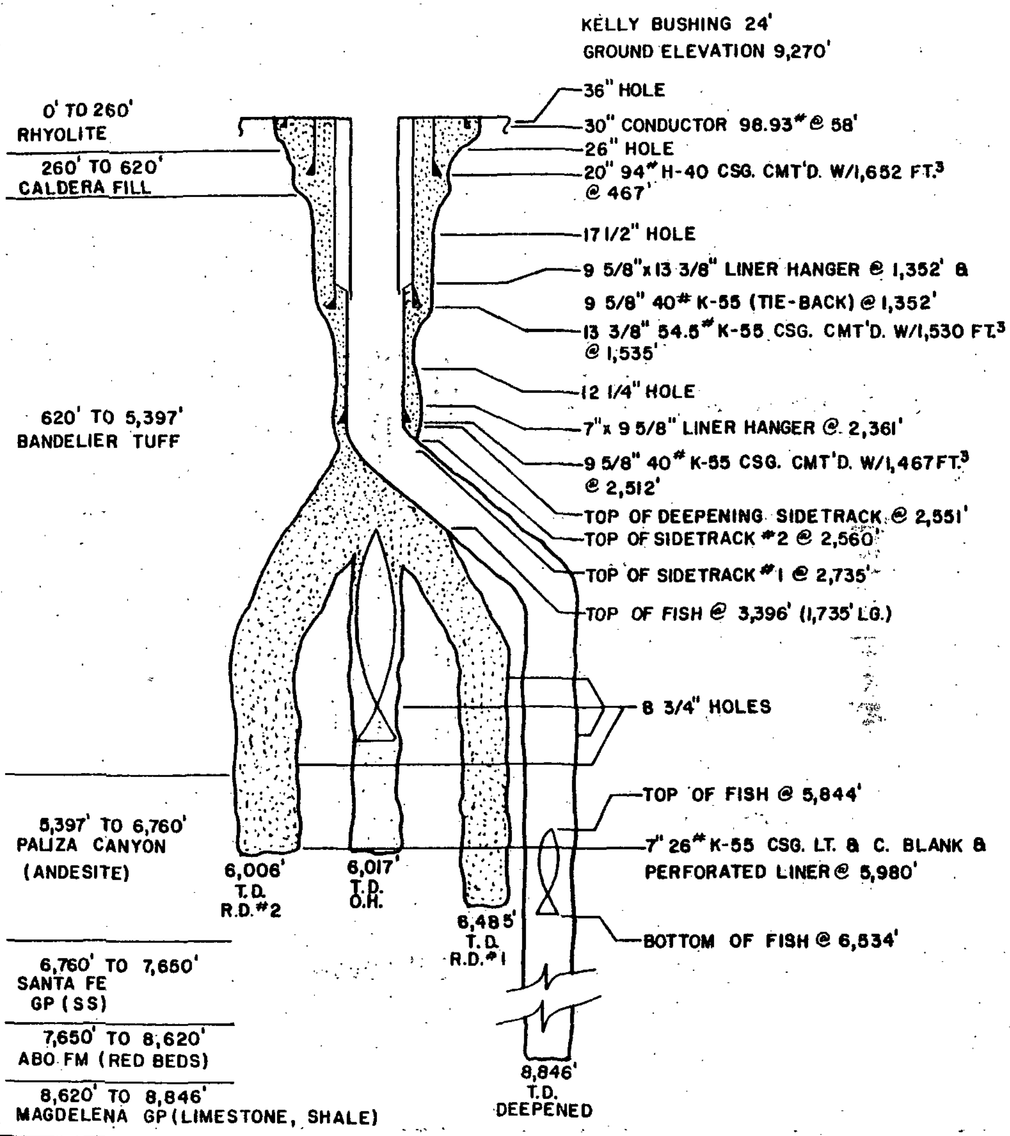
UNION 76 — Union Geothermal Company of New Mexico

WELL SCHEMATIC
BACA NO. 21

DESIGN	S.PENZAK JR.
DRAWN	S.PENZAK JR.
CHECK	
DATE	11-20-80

SIZE	AFE NO.	DWG NO.	REV
B	303706	RC1-DR-17	0
SCALE: 1"=1,000'		SHEET 1 OF 1	

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
0	RELEASED	7-16-81	[illegible]	MLB
1	DEEPENING CHANGES	1-15-82	[illegible]	



DRILLING DETAIL				
H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	LOGS
		652' 685' 2046' 2049'-2120' 2122'-2144' 2144'-2255' DEEPENING 4240'-4250' 4764'-4955' 5668'-5900' 6017'-6071' 6748'-6765' 8190'-8237'	5000'-5060' CORED: 6011'-6017' 4470'-4481'	O.H.: DLL - GR 435'-1,538' HTR (TEMP.) 1,492'-2,530' FIL-1,531'-2,530' CNL-FDC-GR 2,512'-5,946' I-G-2,512'-5,864' R.D. #1 2,512'-6,253' DEEPENING DLL-GR. 2,512'-6,535' (LOST TOOL)

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
10-12-80	1-3-81	10-18-81	12-18-81

UNION 76

Union Geothermal Company of New Mexico

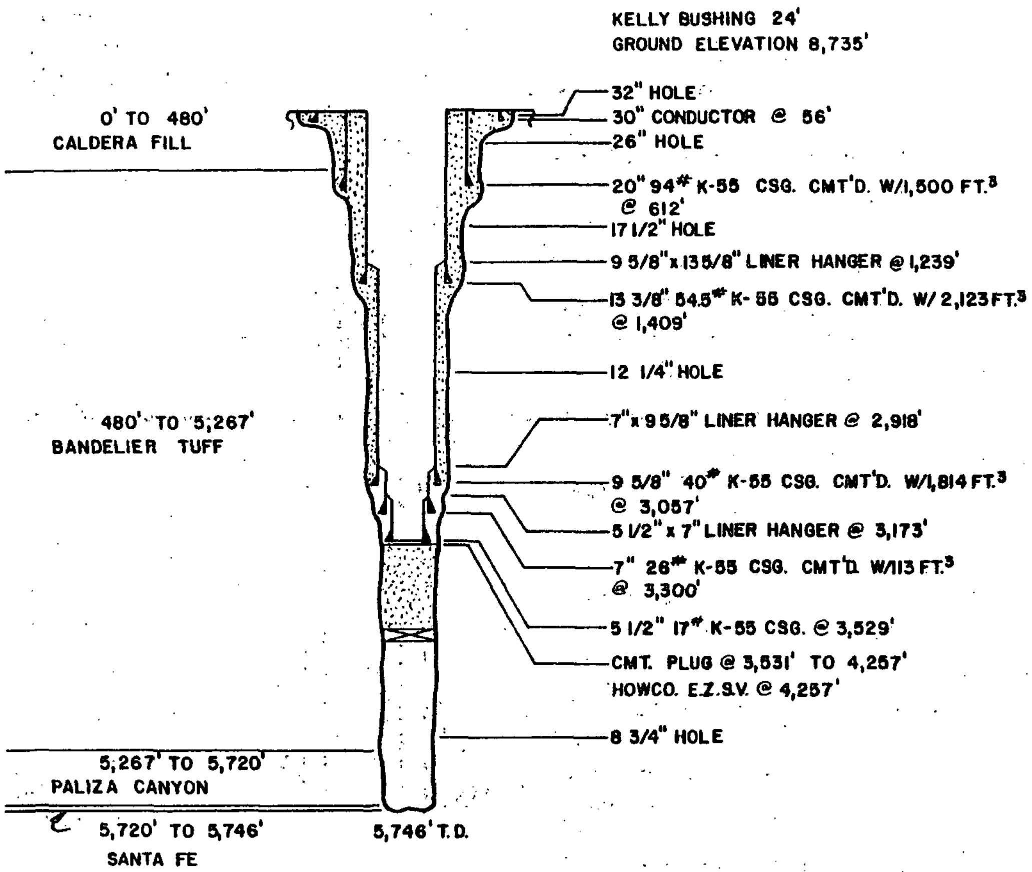
WELL SCHEMATIC BACA NO. 22

DESIGN	
DRAWN	S.PENZAK JR.
CHECK	MLB
DATE	

SIZE	AFE NO.	DWG NO.	REV
B		RC 1-DR-18	1
SCALE 1"=1,000'		SHEET 1 OF 1	

BRUNING 40-522 44574

REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
0	RELEASED	7-17-81		



DRILLING DETAIL

H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	LOGS
	FRAC. JOB: 320, 930 GAL. WATER INCLUDING 124,740 GAL. 50% SUPERSAND & 50% BAUXITE, PUMPED @ 43-75 GPM. 3110 - 4450 PSI	1,419' 2254' - 2460' 2835' - 3063'	4209' - 4226' 4260' - 4270' 4880' - 4895' 5000' - 5010'	DI.-SFL 596' - 1411' HRT. (TEMP.) 1200' - 3070' FIL 3070' - 1406' I-GR 3056' - 5690' CNL-FDC-GR 3058' - 5690'

DATE SPUDDED	DATE COMPLETED	REMEDIALS (STIMULATION) DATE STARTED	DATE COMPLETED
1-12-81	2-23-81	2-24-81	3-31-81

UNION 76 — Union Geothermal Company of New Mexico

WELL SCHEMATIC
BACA NO. 23

DESIGN		SIZE B	AFE NO.
DRAWN	S. PENZAK. JR.	DWG NO.	RC 1-DR-19
CHECK		REV	0
DATE	7-17-81	SCALE: 1"=1,000'	SHEET 1 OF 1

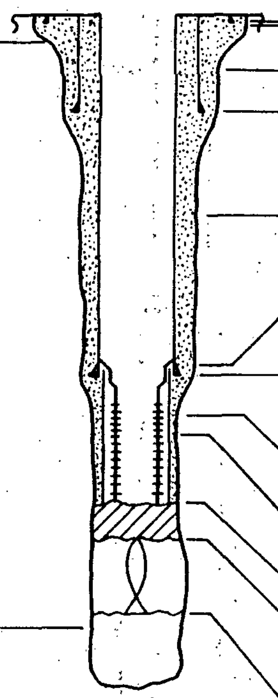
REVISIONS				
REV	DESCRIPTION	DATE	BY	APP'D
0	RELEASED	7-21-81	[signature]	

KELLY BUSHING 24'-0"
GROUND ELEVATION 8,740'

0' TO 220'
CALDERA FILL

220' TO 5,020'
BANDELIER TUFF

5,020' TO 5,502' (T.D.)
PALIZA CANYON FM
(ANDESITE)



DRILLING DETAIL

H_2O & STREAM ENTRIES	FRACTURES	LOST CIR.	DRLG. BREAK	LOGS
3,636'		923'	3,658' (REPLACED ROTATING HEAD RUBBER)	HTR. (TEMP.) @ 160°F 0'-2,944'
			3,662' (TWISTED OFF REC'D. FISH)	DIL-GR. 782'-2,944' @ 236°F
			3,730' (REPLACED ROTATING HEAD RUBBER)	
			4,647' (UNSCREWED DRILL PIPE)	
			5,490' (STUCK PIPE @ 5,502')	

DATE SPUDDED	DATE COMPLETED	REMEDIALS	
		DATE STARTED	DATE COMPLETED
4-23-81	6-3-81		

UNION 76

Union Geothermal Company of New Mexico

WELL SCHEMATIC
BACA NO. 24

DESIGN	
DRAWN	S. PENZAK JR.
CHECK	[signature]
DATE	7-21-81

SIZE	AFE NO.	DWG NO.	REV
B		RC1-DR-20	0
SCALE: 1"=1,000'		SHEET 1 OF 1	

BRUNING 40-522 44574

4.3 Workovers and Recompletions

4.3.1 BACA NO. 4

Deepened 8-3/4" hole from 5,048' to 6,378' using aerated water. Hung 7" 23# and 26# K-55 perforated and blank casing liner at 6,376'. Liner top at 3,031', with slots from 3,036' to 6,375'. Cemented 7" 26# K-55 blank tie-back casing at 2,899' with 275 sacks of cement with 1:1 Perlite, 2% gel, 40% silica flour, 0.2% HR-5, 0.5% CFR-2 followed by 50 sacks of cement with 40% silica flour, 2% gel, 0.2% HR-5, 0.5% CFR-2.

Ran casing caliper tool in the 9-5/8" casing from surface to 2,965'. Severe drill pipe wear on the casing indicated at various intervals from 1,050' to 2,697'. Performed ten cement squeeze jobs at various intervals in the 9-5/8" casing in preparation for running a tie-back casing string. Cemented 7" 26# K-55 tie-back casing at 2,899' using 325 sacks of cement with 1:1 Perlite, 2% gel and 40% silica flour. Cleaned out wellbore to 6,201' total depth.

See Figure 4.2-1 for well schematic.

4.3.2 BACA NO. 6

Pulled and retrieved combination blank and slotted 7" 23# and 26# liner originally installed from 692' to 3,700'. Drilled 8-3/4" hole to 4,810' using air. Cemented blank 7" 26# K-55 casing through shoe at 2,585' with 125 CF of cement with 1:1 Perlite, 0.5% CFR-2, 0.3% HR-7 followed by 200 sacks of cement with 1:1 Pozmix, 2% gel, 0.5% CFR-2, 0.4% HR-7 and 35% silica flour. Cemented through DV collar at 1,096' using 230 sacks of cement with 1:1 Pozmix, 2% gel, 0.5% CFR-2, 0.3% HR-7 and 35% silica flour. Cleaned out to 4,805'.

Hole bridged off at 3,800' while well was being produced. Cleanout attempts were made so a production liner could be installed, but continued sloughing hole problems precluded the completion of the work and the well was left shut-in. The 7" casing currently has an indicated collapsed area (6-1/16" ID) at 1,075'.

See Figure 4.2-3 for well schematic.

4.3.3 BACA NO. 10

Attempted to stimulate production by perforating at intervals from 3,075' to 4,195'. No production increase resulted.

See Figure 4.2-4 for perforation details.

4.3.4 BACA NO. 11

Rigged up service unit and killed well with water. Ran 8-3/4" bit and 9-5/8" casing scraper to top of bridge at 3,068'. Drilled out scale in wellbore from 3,068' to 3,194'. Changed out 8-3/4" bit with 6-1/8" bit. Drilled out scale from 3,211' to 3,937'. No scale encountered below 3,937'. Cleaned well out to 6,575'.

Moved in service unit, rigged up and killed well with water. Ran 8-3/4" bit on 5-1/4" Eastman turbodrill. Located top of scale in wellbore at 1,565'. Turbodrilled using aerated water from 1,565' to 2,658' with well flowing to reserve pit. Eastman turbodrill failed. Ran 8-3/4" bit on 5" Grant turbodrill. Turbodrilled scale using aerated water from 2,658' to 3,186'. Changed out 8-3/4" bit with 6-1/8" bit on turbodrill. Turbodrilled scale using aerated water from 3,186' to 4,179'. No scale encountered below 4,179'. Cleaned well out to 6,609'.

Moved in service unit, rigged up and killed well with water. Ran Dia-Log 3.75 ring gauge to 1820'. Ran Dia-Log minimum I.D. caliper to 3400'. The log showed a reduced I.D. in some sections and in other sections showed an enlarged I.D. The enlarged I.D. indicates casing wall loss and holes or parted casing. Set EZSV plug at top of 7" liner at 3200'. Filled well with cement to the surface. Completed plug and abandonment.

See Figure 4.2-5 for well schematic.

4.3.5 BACA NO. 12

Pulled 7" production liner originally installed from 3,343' to 9,211'. Cemented off lost circulation zones and plugged back to 6,068' using a total of 45 cement plugs. Cleaned out to 8,900'. Cemented blank 7" 26# N-80 and K-55 casing liner at 8,895' (liner top at 3,220') using 417 CF of cement with 0.5% HR-7 followed by 1,287 CF of cement with 0.4% HR-7, 50# per sack Spherelite, 40% silica flour, 4% gel, 5% lime and 0.4% CFR-2 followed by 306 CF of cement with 0.5% CFR-2, 0.4% HR-7 and 40% silica flour. Drilled 6-1/8" hole to 10,632' using mud. Cored from 10,632' to 10,637' and recovered 38" granite core. Unsuccessfully attempted to flow well.

See Figure 4.2-6 for well schematic.

4.3.6 BACA NO. 15

Made cleanout run to 5,505' with 8-3/4" bit. Hung combination blank and slotted 7" 26# K-55 liner from 2,371' to 3,503'. Ran 2-3/8" 4.7# A-95 Hydril tubing to 5,472' with 1/4" diameter ports in tubing string at 100', 1,000', 2,000', 3,000', 4,000' and 5,000'.

Pulled 2-3/8" tubing from 5,472'. Scraped 9-5/8" casing and ran 9-5/8" casing caliper to 2,371'. Casing found in good condition. Changed out wellhead assembly. Scraped 7" liner to 5,503' then made cleanout run to 5,503'.

See Figure 4.2-9 for well schematic.

4.3.7 BACA NO. 20

Pulled 7" production liner originally installed from 2,390' to 5,812'. Plugged back with sand from 5,827' to 5,400'; with cement from 5,400' to 5,079'; and with sand from 5,079' to 4,873'. Cemented off lost circulation zones plugging back to 3,520' using a total of 15 cement plugs. Cleaned out to 4,890'. Cemented blank 7" 26# K-55 liner at 4,880' (liner top at 2,383') using 835 CF of cement with 50 lb/sack Spherelite, 1% CFR-2, 0.4% HR-7, 4% gel, 5% lime and 40% silica flour followed by 230 CF of cement with 0.5% CFR-2, 0.3% HR-7 and 40% silica flour. Recemented liner lap with 213 CF of cement with 0.5% CFR-2, 0.2% HR-7 and 40% silica flour. Cleaned out cement and sand to 5,120'. Performed hydraulic fracture stimulation down 4-1/2" tubing, with packer set at 2,412', using 119,700 lbs. of 16/20-mesh sintered bauxite and 119,700 lbs. of 12/20-mesh sintered bauxite mixed 2-12 lbs. per gallon in gelled water and injected at 40-80 BPM at surface pressures from 3,800 psig down to 1,800 psig. Preceded frac proppant with 4,200 lbs. of 200-mesh and 42,000 lbs. of 100-mesh calcium carbonate as fluid loss additive. Hung blank and perforated 5-1/2" 17# K-55 Flush Joint casing liner from 4,760' to 5,131'.

Moved in service unit, rigged up and killed well with water. Ran 2-7/8" tubing to 4836'. Performed acid cleanout of calcium carbonate fluid loss additive used in hydraulic stimulation. Pumped through tubing, 200 bbl of water as pre-flush, 711 bbl of 15% hydrochloric acid inhibited for 6 hours to 250°F. Overdisplaced acid by 632 bbl of water. Located top of fill at 5112'.

See Figure 4.2-14 for well schematic.

4.3.8 BACA NO. 22

Pulled 7" production liner originally installed from 2,361' to 5,980'. Cemented well back to 2,525'. Kicked off plug at 2,551' and directionally drilled to 8,846'. (Severe lost circulation problems, encountered below 4,232', required a total of 26 cement plugs). Stuck Dual Induction Laterolog tool at 6,535' while logging up from 8,846'. Stuck fishing tools while attempting to recover logging tools. Failed to recover fishing string below 5,844' depth. Discontinued drilling operations.

See Figure 4.2-16 for well schematic.

4.3.9 BACA NO. 23

Plugged back with sand from 4,257' to 3,841'; with cement from 3,800' to 3,525'; and with sand from 3,525' to 3,331'. Cemented off lost circulation zones plugging back to 3,088'. Cleaned out cement to 3,305'. Cemented blank 7" 26# K-55 liner at 3,300' (liner top at 2,917') using 113 CF of cement with 0.5% CFR-2, 0.2% HR-7 and 40% silica flour. Cleaned out cement and sand to 3,531'. Performed hydraulic fracture stimulation down 4-1/2" tubing, with packer set at 2,964', using 97,200 lbs. of 20/40-mesh sintered bauxite and 82,800 lbs. of 20/40-mesh resin coated sand in gelled water and injected at 60-75 BPM at maximum surface pressure of 3,500 psig. Preceded frac proppant with 5,400 lbs. of finely ground calcium carbonate and 42,000 lbs. of 100-mesh sand as fluid loss additives. Hung blank and perforated 5-1/2" 17# K-55 Flush Joint liner from 3,173' to 3,529'.

See Figure 4.2-17 for well schematic.

4.4 Special Drilling Field Tests

4.4.1 Drillpipe Corrosion Control Using an Inert Drilling Fluid

A major contribution to the high cost (4-5 times higher than a comparable oil or gas well) of geothermal wells is extensive corrosion of drill pipe -- principally caused by oxygen present in the drilling fluid. A low density fluid must be used when drilling in the typically underpressured geothermal reservoirs. Air drilling techniques are commonly used to provide the low density circulating medium. Water is usually injected into the air stream to aid cuttings removal, introduce chemicals into the circulating system and maintain well control while drilling through liquid dominated geothermal reservoirs. The combination of aerated water, high downhole temperatures and high circulating fluid velocities results in rapid drill pipe corrosion leading to pipe downgrading and/or premature failure.

Existing corrosion control techniques include adding caustic soda (NaOH) to raise the pH of the water to about 10 or 11. Another technique for hot geothermal wells is to inject Unisteam, an amine resin that polymerizes at about 250°F, to form a viscous, water-insoluable, oily coating. For protection of lower temperature sections of the drill string, ammonium hydroxide (NH_4OH) is injected and condenses on the pipe to form a protective coating.

Removal of oxygen from the circulating system has been proposed as another technique to control corrosion. However, oxygen scavengers, which have successfully been used with mud drilling, are not practical due to large volumes of air needed when drilling with an aerated water system. Therefore, a test was conceived that would substitute an anerobic gas for air to evaluate the corresponding change in corrosion rates. Since unmeasurable amounts of air would be introduced into the system each time a joint of drill pipe was added while drilling, and during each drill pipe trip, an actual field test was the only method available to establish overall representative corrosion rates.

In November, 1980 Union Geothermal and Sandia National Laboratories jointly conducted a field test on Baca No. 22 evaluating the effectiveness of using an inert gas circulating system.

A diagrammatic drill site layout is provided as Figure 4.4.1-1. It also defines the location of monitoring and sampling points installed for the test.

Figure 4.4.1-2 shows all the activities associated with the drill rig. It also defines the test phases and shows well depth versus time. Some significant features of each test phase are:

- Phase 1 - Treated aerated water drilling fluid for:
  - Six short reaming operations
  - Two drilling bit runs
  - Two coring bit runs
  - 1,315 feet drilled
  - 131.5 hours duration

- Phase 2 - Nitrogen and water drilling fluid for:
  - Two short reaming operations
  - Three drilling bit runs
  - 1,500 feet drilled
  - 74.8 hours duration

- Phase 3 - Treated aerated drilling fluid for:
  - One short coring bit run
  - 10 feet drilled
  - 19.5 hours duration

Practically all drilling was through the Bandelier Tuff formation. The test was concluded at a depth of 6,011 feet, near the top of the Paliza Canyon Andesite formation. The well showed evidence of producing geothermal energy during the first bit run of Phase 2 at about 4,900 feet.

A total of 24 corrosion rings was installed inside the drill pipe at tool joints and six corrosion coupons were installed in recesses on the outside of the pipe. Two coupons were damaged during removal and one was inadvertently left on the rig floor so that only three provided weight loss data. Figure 4.4.1-3 displays the remaining 27 data points. Also plotted on Figure 4.4.1-3 is a line representing a uniform corrosion of 23 microinches. Data points below this line were arbitrarily ruled to have too little corrosion to be reliable.

The surviving data are provided in Table 4.4.1-1 and Figure 4.4.1-4. These data show that corrosion is more severe near the bottom of the drill string and that Phase 2 rates (with inert gas) were at least an order of magnitude (one cycle on the log plot) lower than Phase 1 (with air). Phase 3 included less than six hours of circulating time while the remaining time was spent tripping or waiting. These data should be considered less reliable than those from the other phases.

Additional evidence of the effectiveness of an anerobic drilling fluid is provided by examining the corrosion rings. Figure 4.4.1-5 shows a direct comparison of two rings exposed for comparable times to each of the drilling fluids at the bottom of the drill string. The measured corrosion rates differ by a factor of 36 and the Phase 1 ring shows numerous shallow pits.

Corrosometer probes were installed in the standpipe and the blooie line. These probes operate on the principle that the electrical resistance of a conductor increases as its cross sectional area decreases. Probes are built with an element for which resistance increases as it is exposed to corrosion. Since the probes have a finite life, a new probe was installed in the standpipe for test Phases 2 and 3. All the probes used an element that was mounted flush with the inside surface of the flowlines.

The standpipe corrosometer data are presented in Figure 4.4.1-6. Since the probes measure average rates over the time between readings, a bar is plotted which represents the average rate for each test phase. All the intermediate readings are also plotted as lines. Phase 1 data indicate a fairly uniform rate dropping to about 98 mpy, a rate consistent with the upper corrosion ring measurement.

Phase 2 data show a high initial rate with the final value about 3 mpy, again in agreement with the ring data. Although only two readings were taken during Phase 3, the corrosometer and upper ring data are comparable.

The blooie line corrosometer data are shown in Figure 4.4.1-7. Although a similar pattern is observed, as for the standpipe corrosometer, the readings are lower by about a factor of ten. It is estimated that intermittently only about 10 percent of the return line flow came out of the blooie line, which could explain the low readings. These data do, however, provide additional evidence as to the effectiveness of nitrogen as a drilling fluid.

Samples were taken periodically and the oxygen content and pH levels were measured on the liquid samples after appropriate cooling. Figures 4.4.1-8 and 4.4.1-9 show the alkalinity of the water line liquid and the blooie line liquid respectively. Both plots show the pH was lower as planned during Phase 2 and that pH tends to drop as each bit run progresses.

The primary reason for reduced corrosion during Phase 2 is presented in Figure 4.4.1-10. During Phase 2 bit runs, the oxygen content in the blooie line liquid dropped to a few tenths of a part per million. Since the equilibrium concentration of dissolved oxygen in water with nitrogen at typical downhole conditions is about 40 ppb, the effect of tripping and adding joints appears to raise oxygen levels to those measured.

The flow rates of air (Phases 1 and 3) and nitrogen (Phase 2) are shown on Figure 4.4.1-11. During the first bit run of Phase 1 two air compressors were used which provided about 2200 SCFM flow rate. Subsequent bit runs of Phase 1 and Phase 3 saw only one compressor used which provided about 1100 SCFM of air. Data on Figure 4.4.1-11 are not considered completely accurate until late November 9, when calibration problems were resolved.

Nitrogen was provided during Phase 2 by a pump vaporizer truck supplied with liquid nitrogen from an air separation plant. The rate at which nitrogen was supplied was comparable to one air compressor's capacity.

Water flow, supplied by the rig mud pumps, as a function of time is plotted on Figure 4.4.1-12. Between 240 to 400 gpm of water were pumped most of the time.

Chemicals were injected into the suction water line during Phases 1 and 2. Since the fluid rate was fairly constant at about 2 gpm and the chemical concentrations were changed between Phase 1 bit runs, the plot on Figure 4.4.1-13 shows only the amount of chemicals used. Included are Unisteam, ammonium hydroxide and H35 Surflo scale inhibitor.

This test demonstrated that severe drill pipe corrosion problems can be reduced by use of an anerobic drilling fluid. The cost of corrosion control during Phases 1 and 3 of this test were estimated at $3,000 per day. When the estimated cost of drill pipe loss is added, the total corrosion cost is about $4,000 per day. Although nitrogen for this test cost about $17,000 per day, on-site generation of an anerobic gas is expected to be possible for about $2,000 per day. Two approaches are currently being persued by Sandia Laboratories for the development of an on-site generator: 1) cleaned up gas from diesel exhaust, and 2) a portable cryogenic air separation unit. Successful future field testing of either of these approaches could lead to significant savings in the cost of drilling geothermal wells.

References

Pyle and Fischer, U.S. Patent No. 3,749,554

Caskey, Billy C. and Copass, K. S., Drill Pipe Corrosion Control Using an Inert Drilling Fluid, Proceedings of the International Conference on Geothermal Drilling and Completion Technology, 21-23 January, 1981, Albuquerque, New Mexico.

Table 4.4.1-1

Corrosion Ring Data

NUMBER	PHASE	LOCATION[1]	CORROSION RATE (mm/y)	CORROSION RATE (mpy)	EXPOSURE TIME (HOURS)	REMARKS
15519	1	Bottom	8.3	330.	39.2	Badly pitted, heavy scale
6299	1	Bottom	4.1	160.	66.8	Numerous pits, magnetite scale
6247	1	Bottom	6.0	240.	32.8	Shallow pitting, magnetite scale
6272	1	Bottom	11.4	450.	13.5	Pitting over outside edges
6287	1	Top	1.9	76.	105.0	Numerous shallow pits, magnetite scale
6284	2	Bottom	0.75	30.	46.7	Slight pitting, $CaCo_3$ ad magnetite scale
6275	2	Bottom	0.33	13.	46.7	Slight pitting, $CaCO_3$ and magnetite scale
7874	2	Bottom	0.13	4.9	74.8	Light pitting, some $CaCO_3$ and magnetite scale
7868	2	Bottom	0.11	4.4	74.8	Light etching, some scale
6281	2	Top	0.09	3.4	67.5	No pitting, slight $CaCO_3$ scale
7841	2	Top	0.11	4.3	73.0	Minute pitting, slight magnetite scale
18154	3	Bottom	2.7	108.	19.5	Pitting, magnetite scale
18155	3	Bottom	3.3	131.	19.5	Moderate pitting beneath magnetite scale
18159	3	Bottom	2.7	108.	19.5	Moderate pitting and heavy magnetite scale
18162	3	Bottom	1.9	73.	19.5	Pitting, heavy magnetite scale
18147	3	Top	0.39	15.	14.2	Etching, magnetite scale

Note 1: "Bottom" is defined as about 150 m (500 feet) above the drill bit; "Top" is defined as not more than 180 m (600 feet) below the Kelly at the top of the drill string. All rings were installed between a tool joint pin and box inside the pipe.

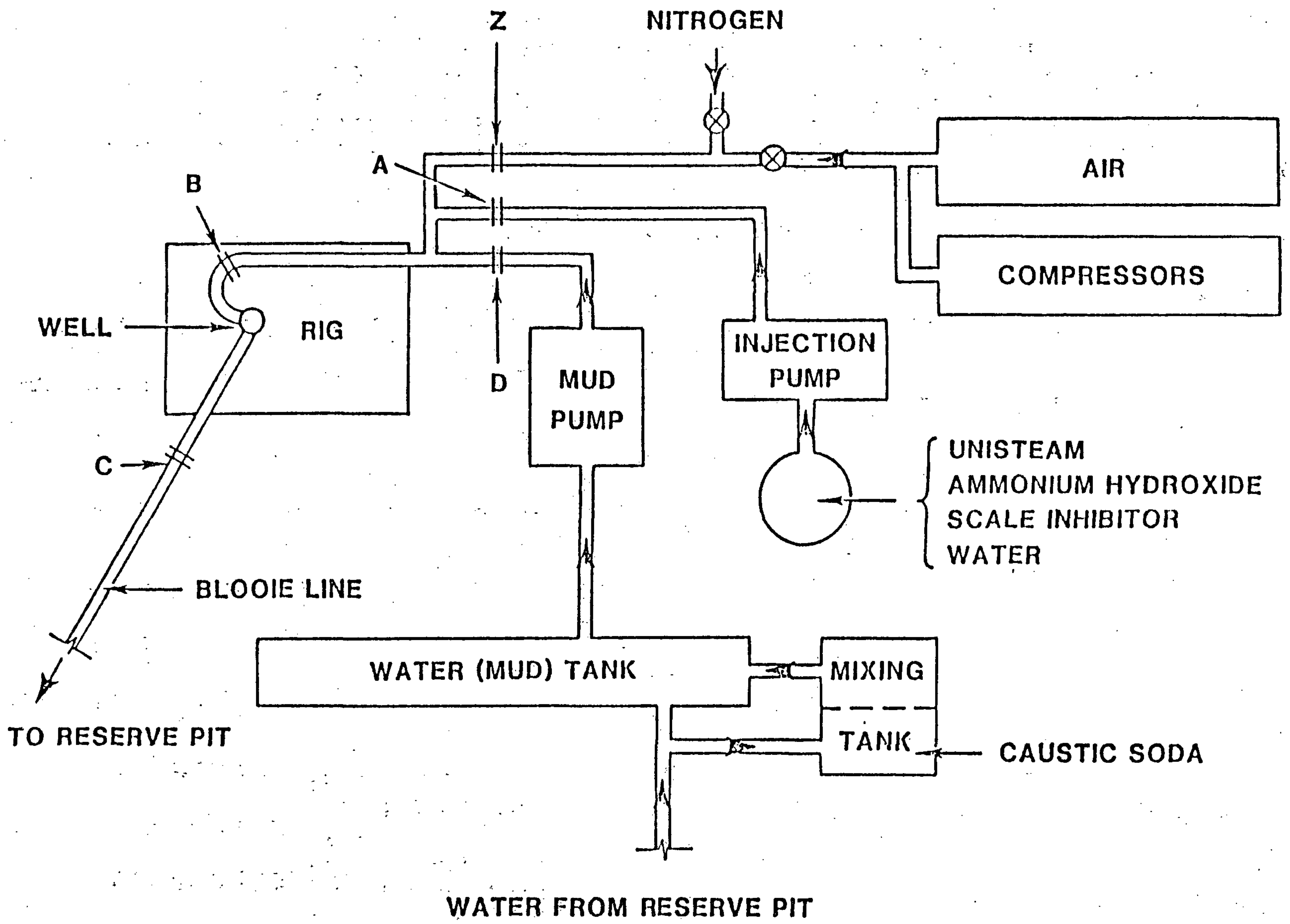


Figure 4.4.1-1 Diagrammatic Drill Site Layout and Monitoring Point Locations.

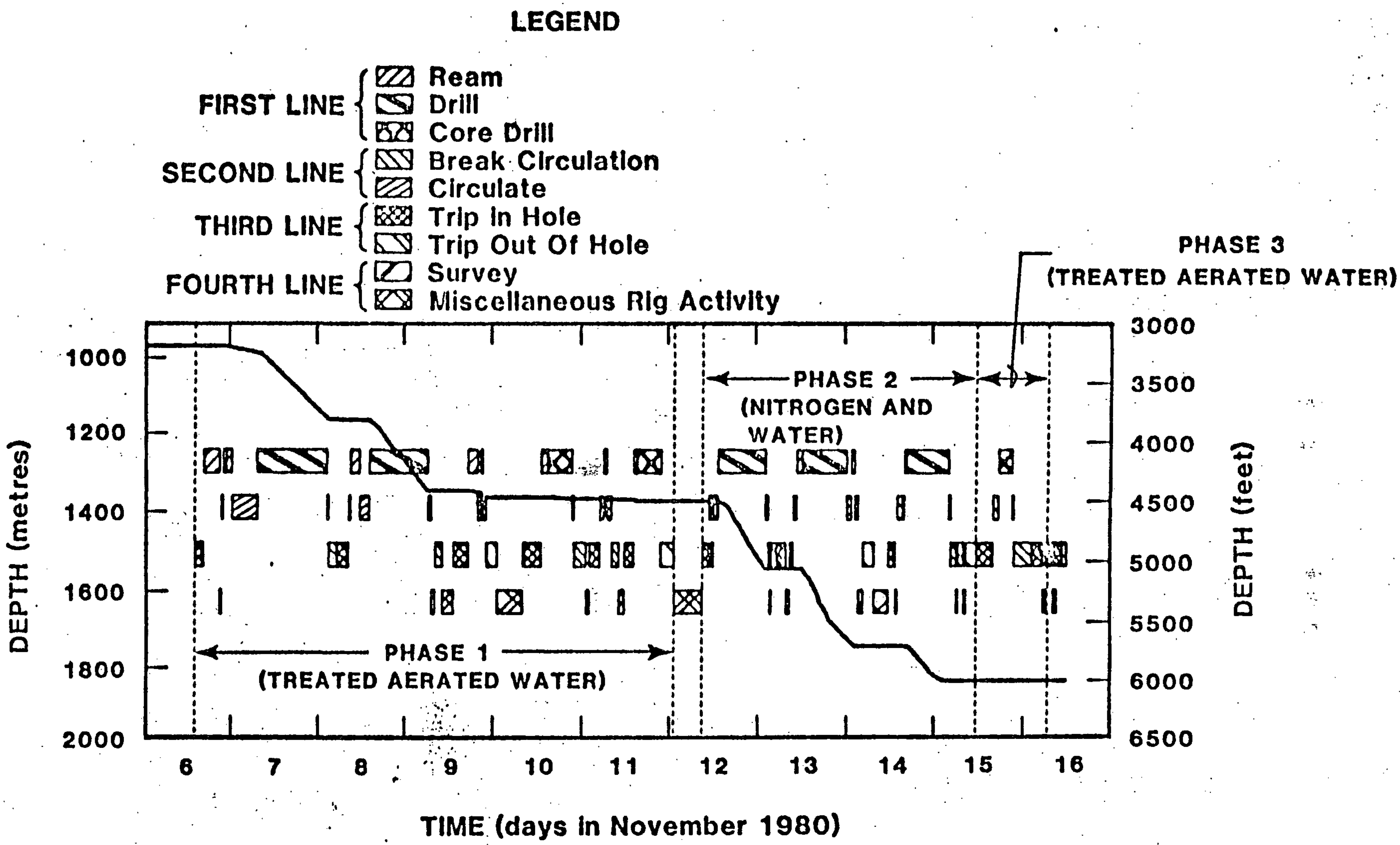


Figure 4.4.1-2 Rig Activities Versus Time and Well Depth. The activities related to drilling are broken out on the first line in the plot. The second and third lines are related to circulation and tripping respectively. The bottom line is related to other activities. The three test phases are also defined on the figure.

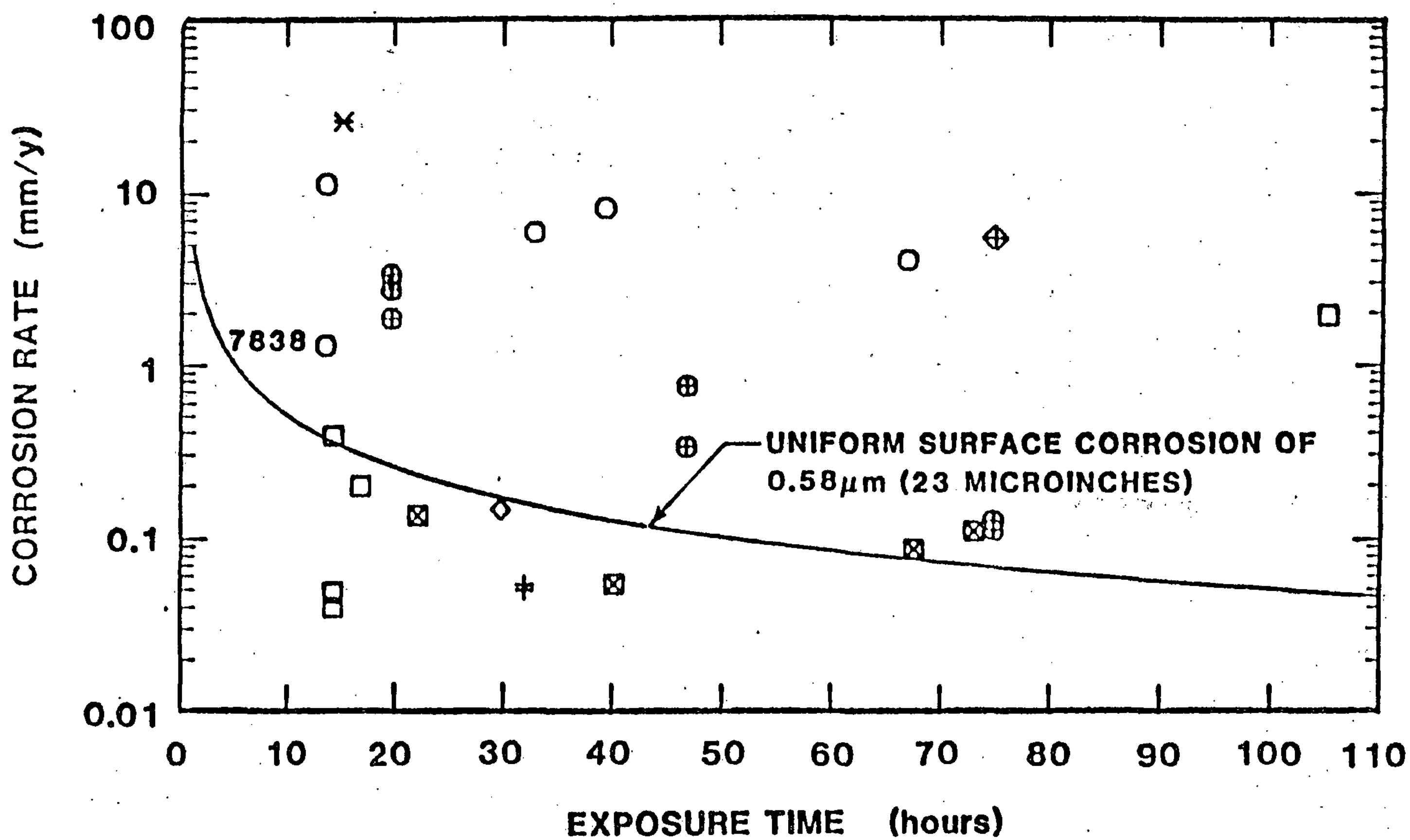


Figure 4.4.1-3 Corrosion Ring and Coupon Data. All the rings and coupons used during the test are plotted. The square and round symbols were rings near the top and bottom of the drill string, respectively. The symbols with internal markings represent those used during phase 2 (nitrogen). The diamonds and X's were external coupons and the +'s were rings that were inadvertently left in the derrick.

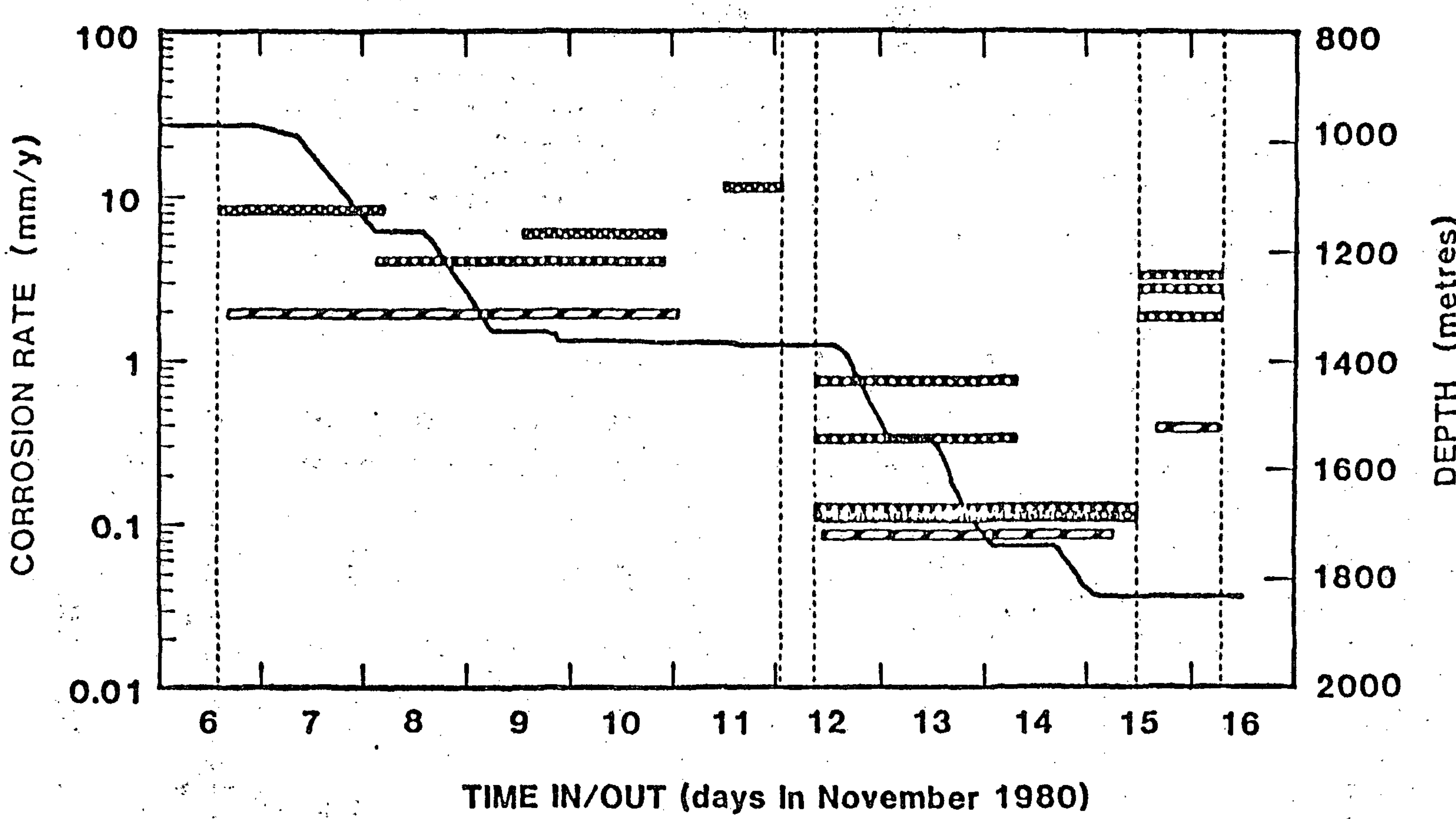
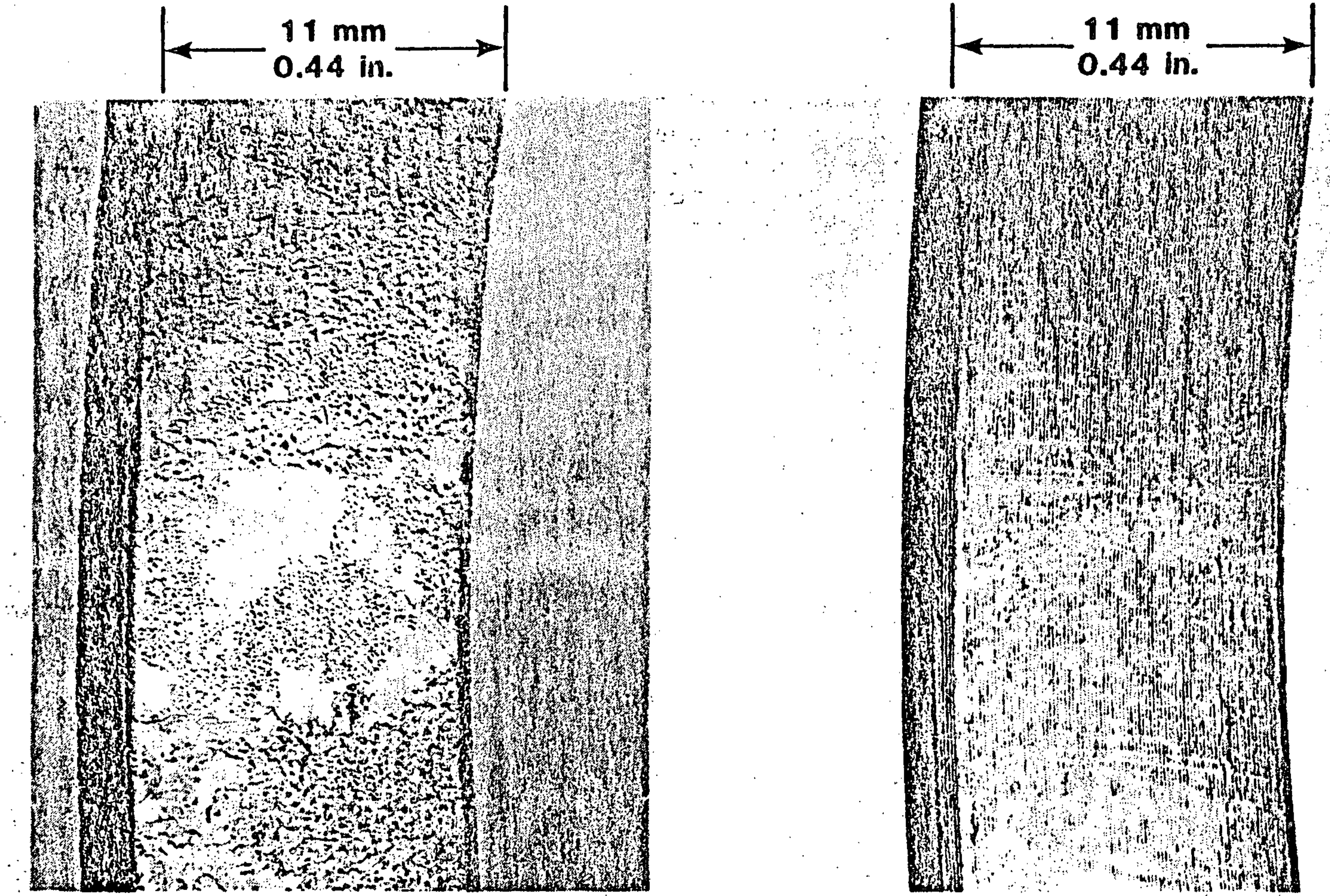


Figure 4.4.1-4 **Corrosion Ring Data. Only rings that exhibited a weight loss corresponding to a uniform surface corrosion of more than 0.58 m (23 microinches) are plotted. These data are also shown in Table 3. The cross hatched bars represent rings installed near the bottom of the drill string; the barberpole bars represent those near the top of the drill string.**



RING NO. 6299

RING NO. 7868

Figure 4.4.1-5 Corrosion Ring Comparison. The ring on the left was exposed during phase 1 to treated aerated water for 66.8 hours; its measured corrosion rate is 4.1 mm/y (160 mpy). The ring on the right was used during phase 2 (nitrogen and water) for 74.8 hours; its corrosion rate is 0.11 mm/y (4.4 mpy). Both rings were installed just above the drill collars about 150 m (500 feet) above the drill bit.

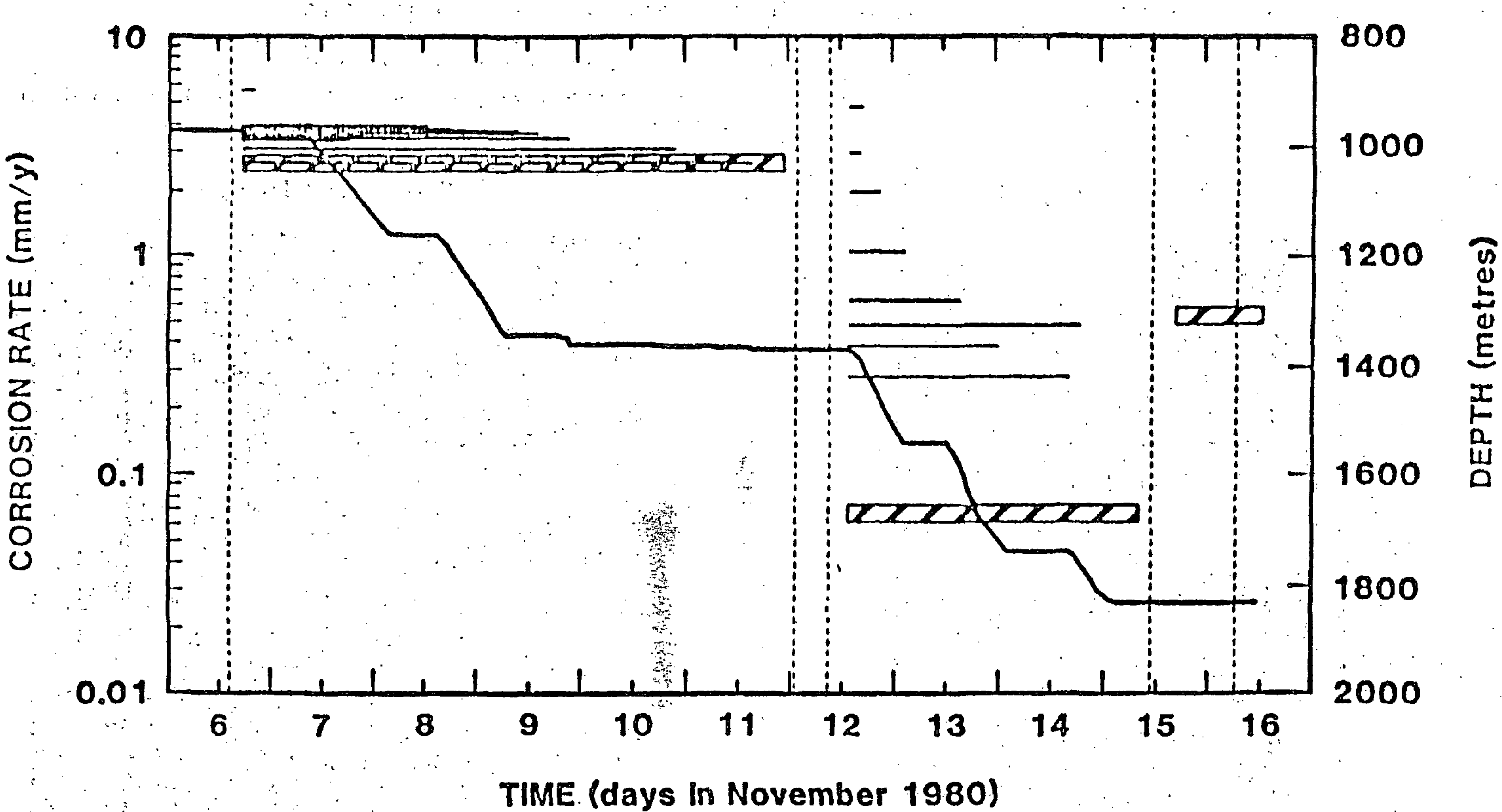


Figure 4.4.1-6 **Corrosometer Probe Data from the Standpipe. Since these probes measure corrosion rate by a resistance change of a corroding element, the average rate for each phase is shown by the bar. Intermediate values are plotted to show rate changes as the test progressed.**

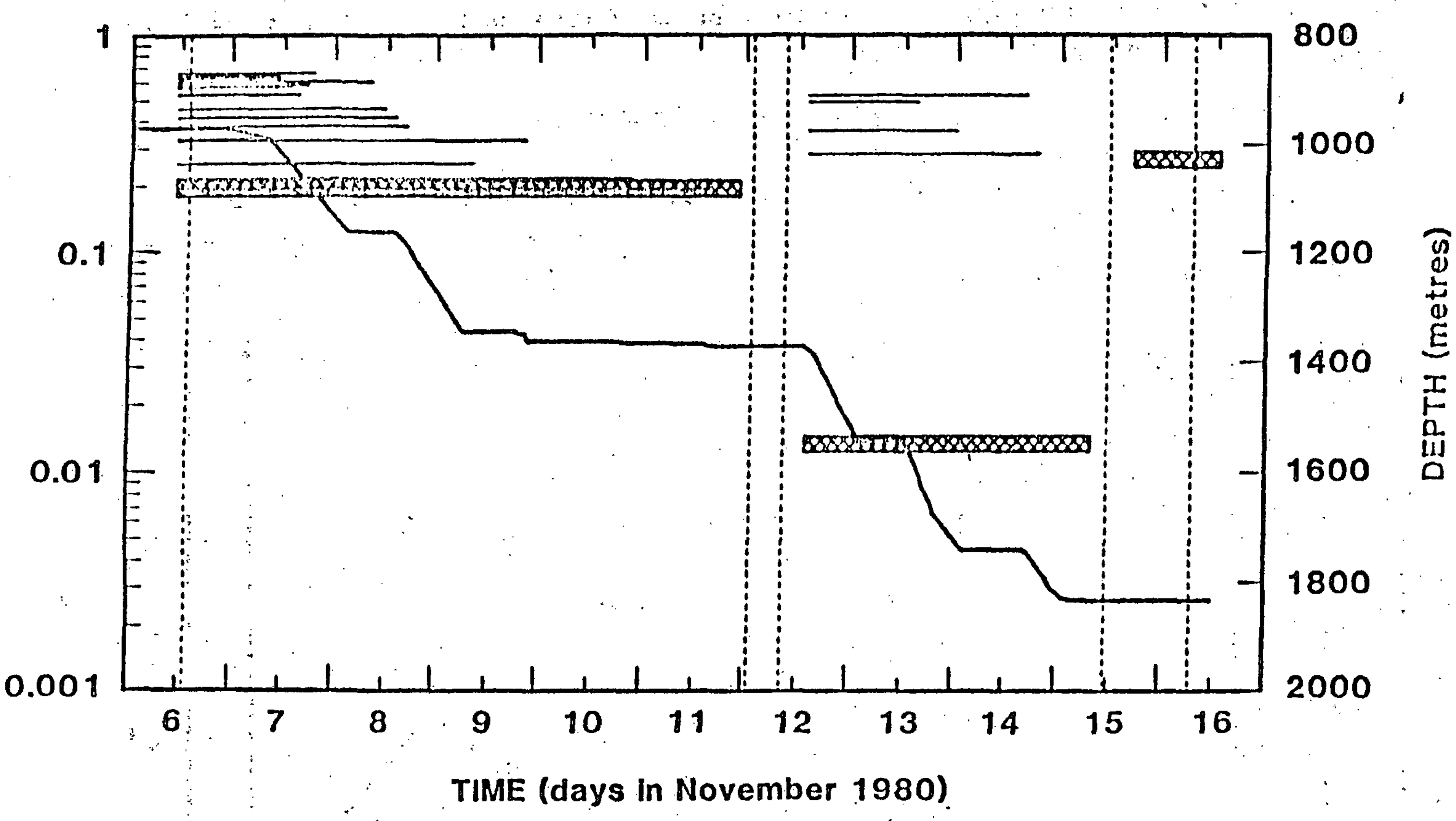


Figure 4.4.1-7 Corrosometer Probe Data from the Blooie Line. These data do not represent the average rates for the top of the drill string since approximately 90% of all returns did not flow through the blooie line.

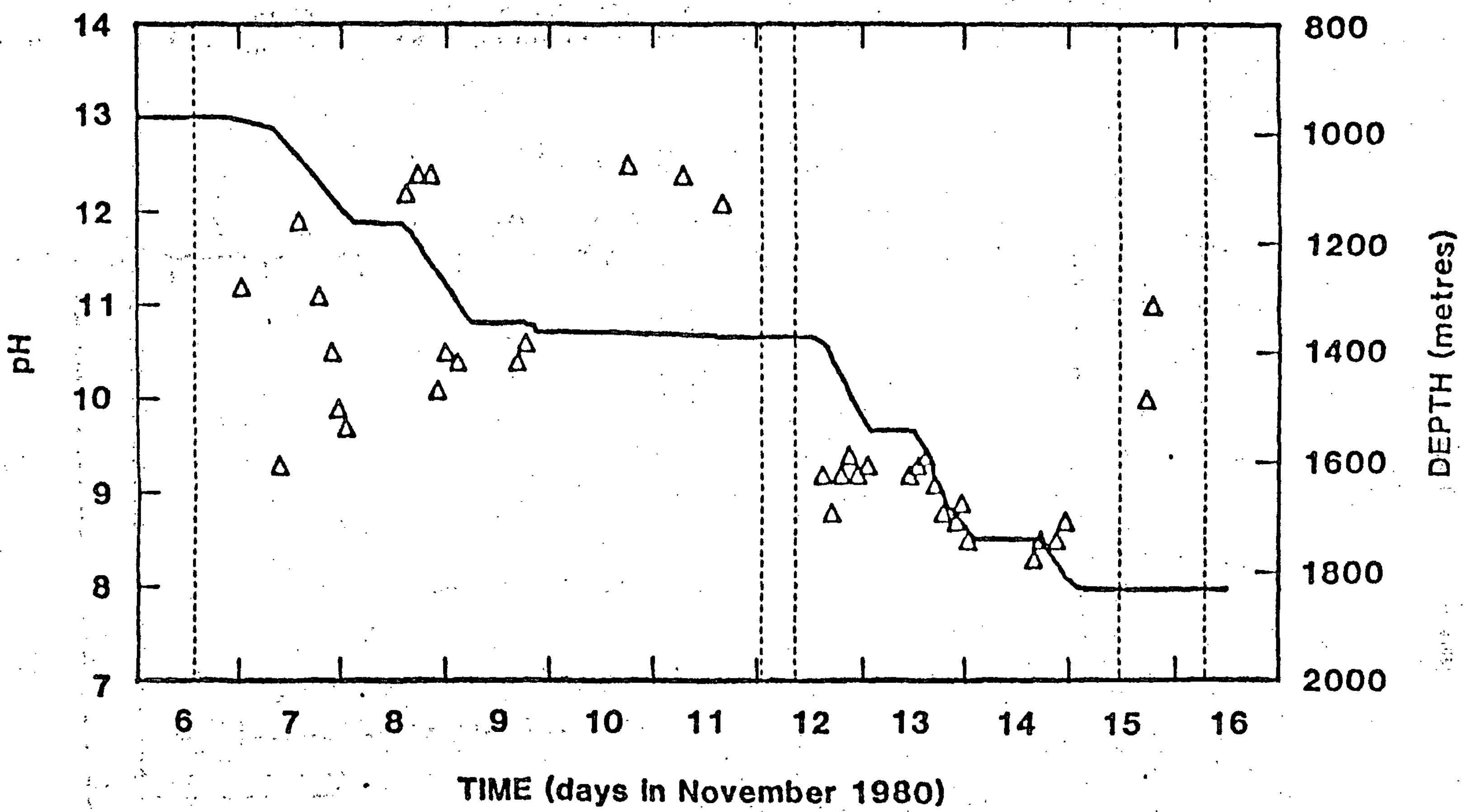


Figure 4.4.1-8 **Alkalinity of the Liquid in the Water Line. During phase 2, the pH was specified to be kept between 8 and 9; for the other phases it was to be maintained between 10 and 12.**

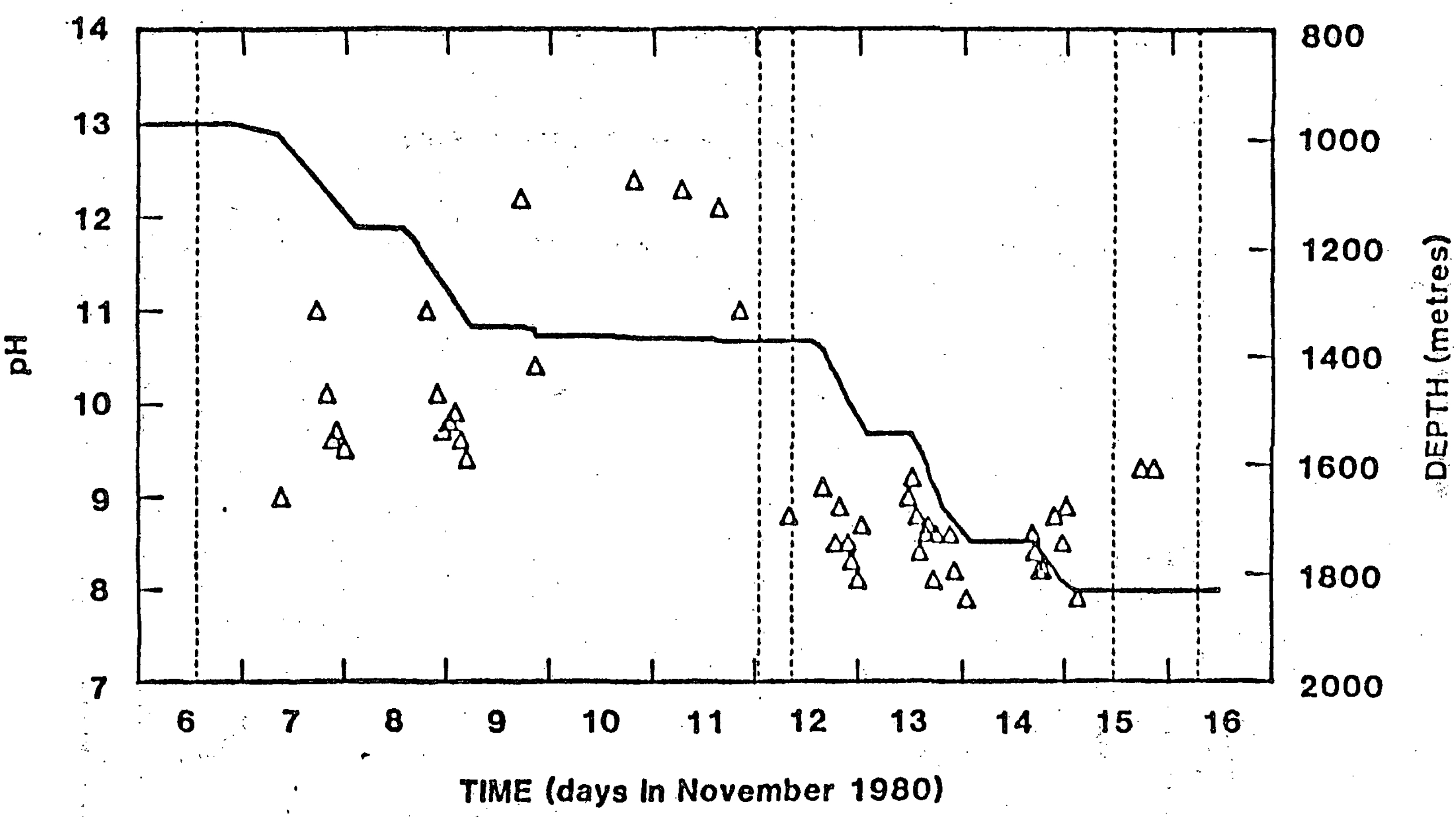


Figure 4.4.1-9 **Alkalinity of the Liquid Through the Blooie Line.**

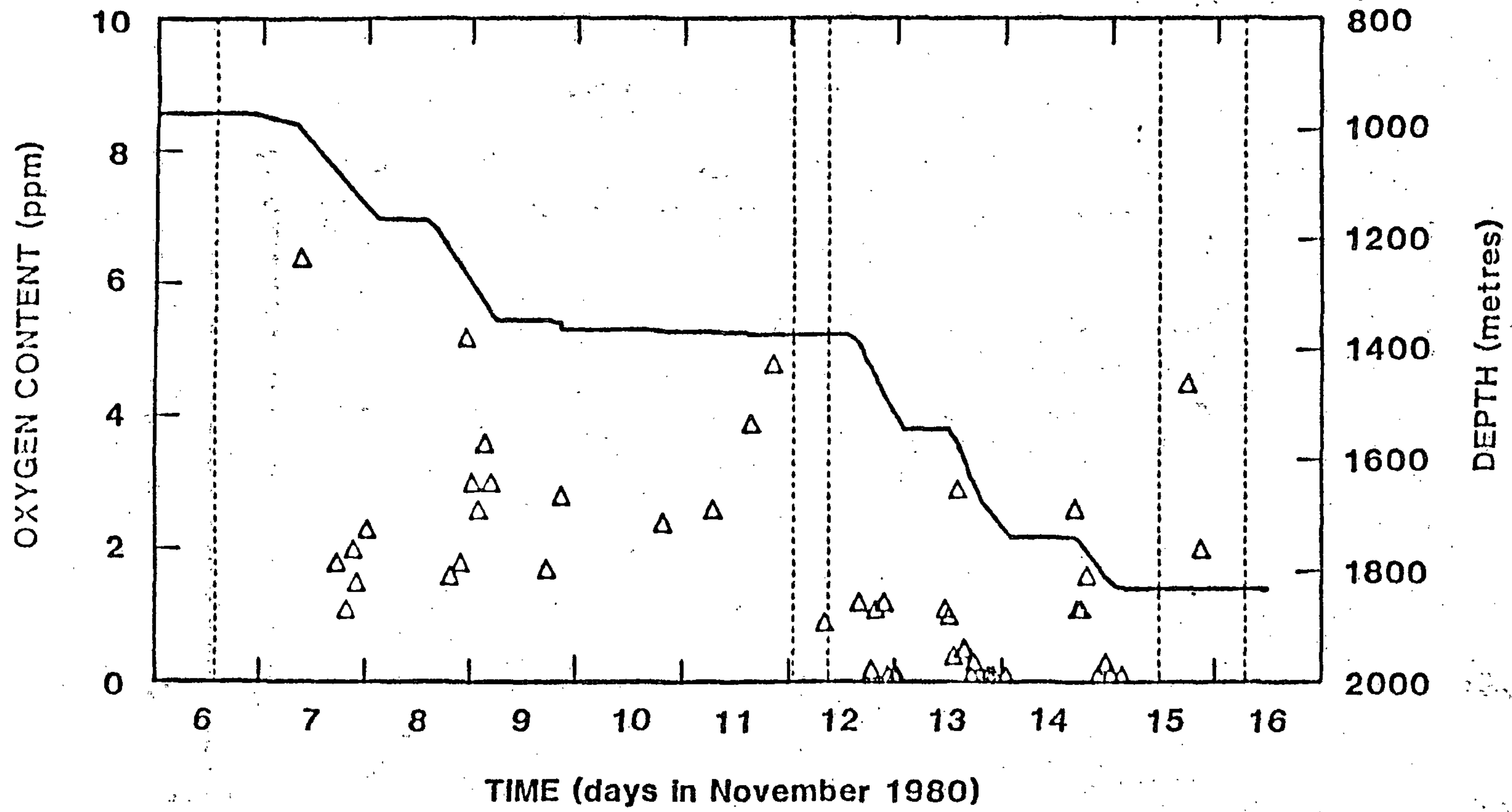


Figure 4.4.1-10 Oxygen Content of the Liquid Returns Through the Blooie Line.

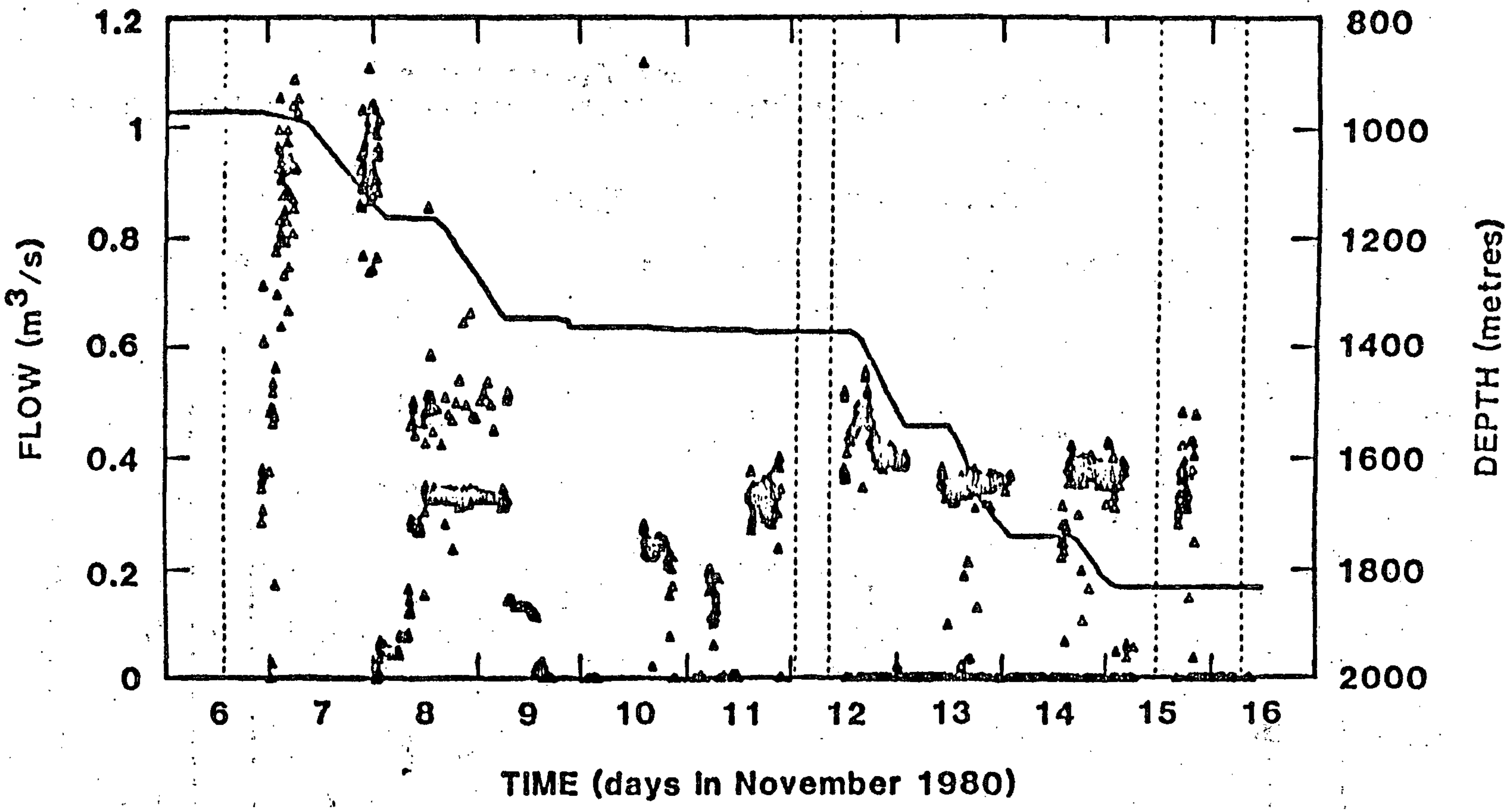


Figure 4.4.1-11 Air or Nitrogen Flow Rate. Data plotted have been adjusted for standard conditions of 15.6°C (60°F) and 101 kPa (14.7 psia).

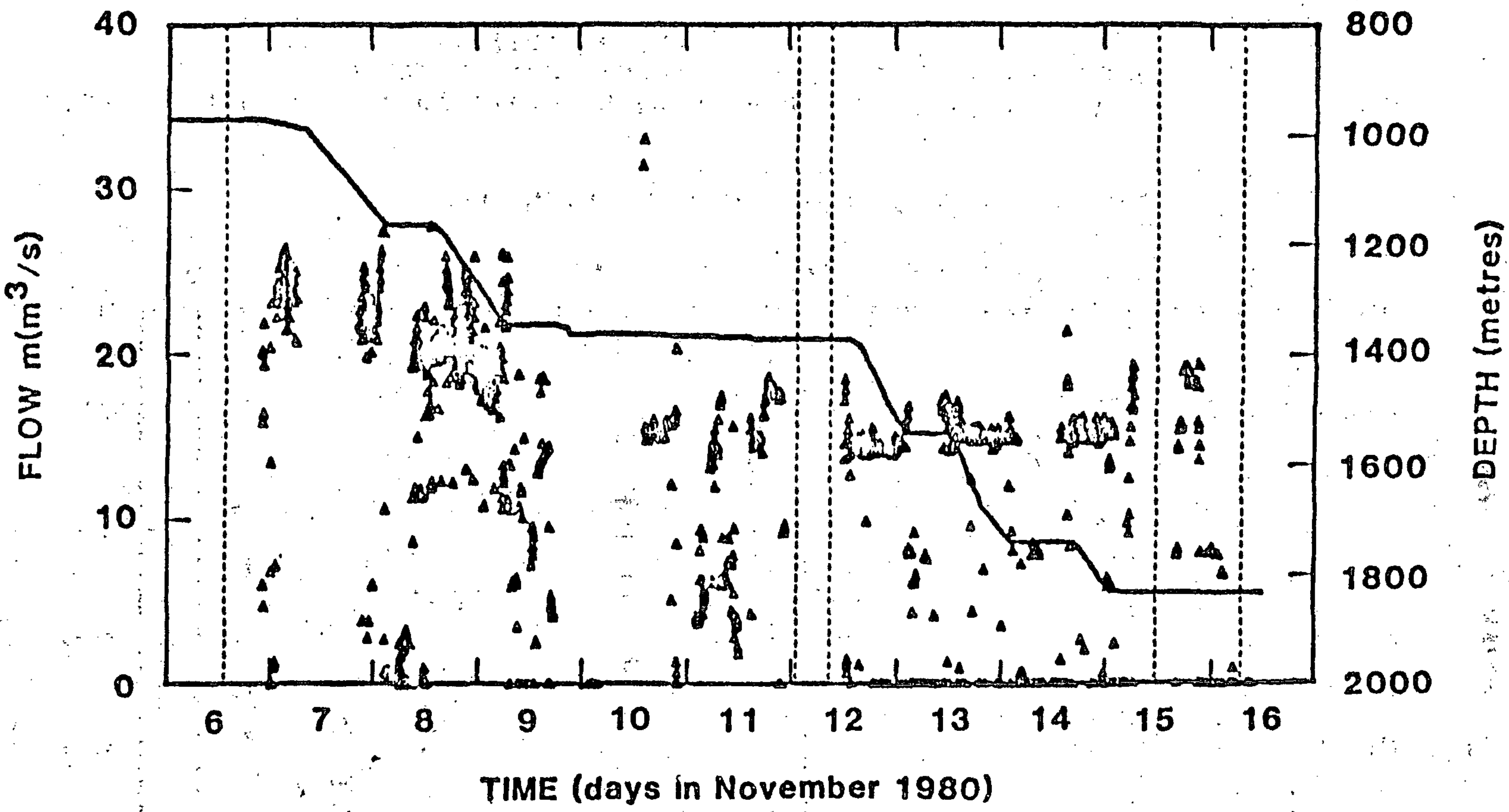


Figure 4.4.1-12 Water Flow Rate. During drilling operations the flow rate was relatively constant.

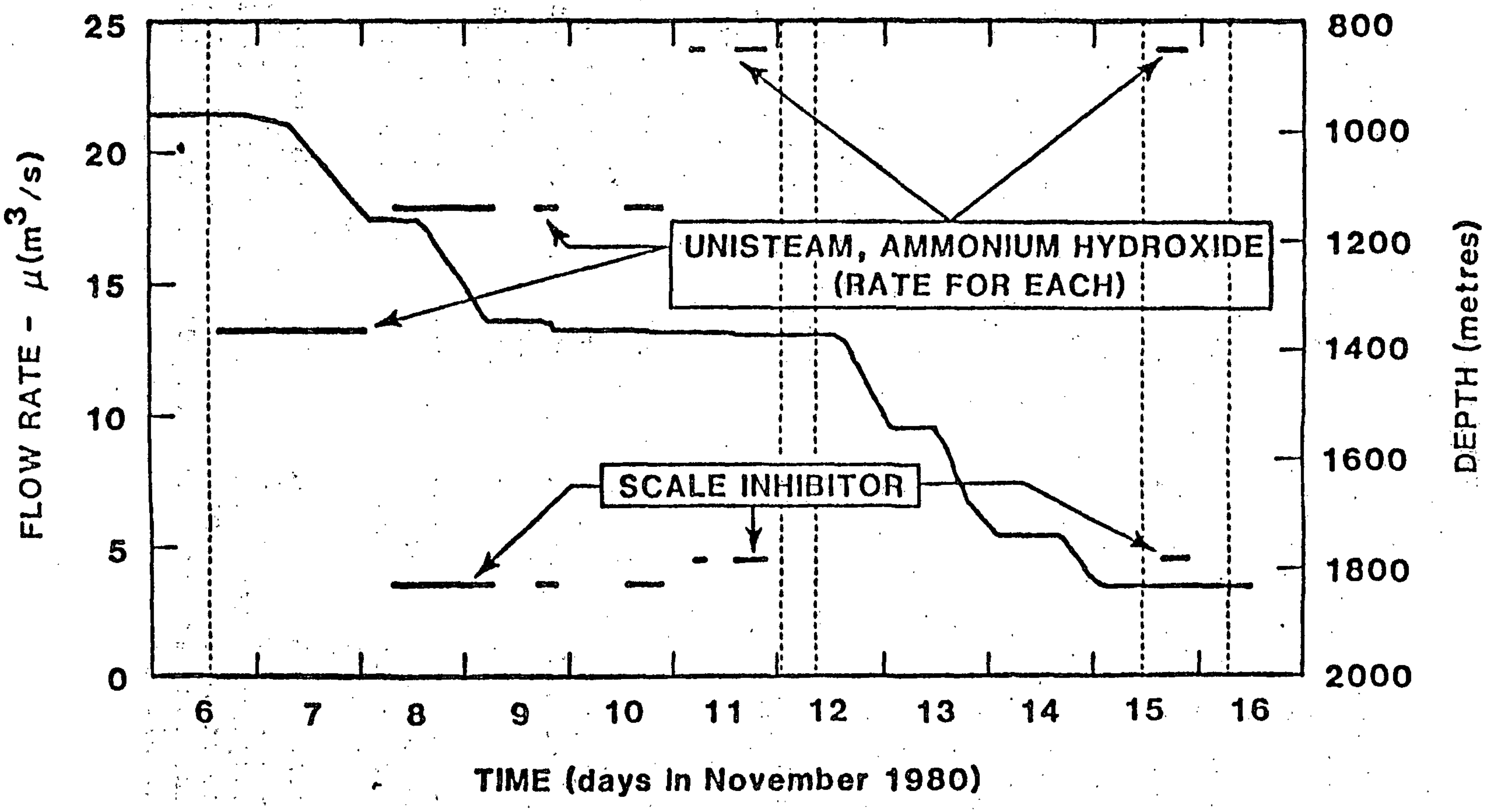


Figure 4.4.1-13 Chemical Injection Flow Rate. Unisteam and ammonium hydroxide were each used at the same rate; H35 Surflo Scale inhibitor was used at a lower rate. No chemicals were injected during phase 2.

4.4.2 Fracture Stimulation Experiments

The U.S. Department of Energy-sponsored Geothermal Reservoir Well Stimulation Program (GRWSP) was initiated in February 1979 to pursue industry interest in geothermal well stimulation work and to develop technical expertise in areas directly related to geothermal well stimulation activities. Republic Geothermal, Inc. (RGI), prime contractor for the GRWSP, has completed seven field experiments, two of which were conducted in the high temperature reservoir of the Baca GDPP Project.

The main reservoir, 4,000 to 6,000 feet in thickness, is composed of volcanic tuffs with low permeability and a primary flow system of open fracture channels. Although they encounter a high temperature liquid dominated reservoir, several wells have not been of commercial capacity, primarily because of the absence of productive natural fractures at the wellbore.

It is believed that hydraulic fracture treatments can create the fractures required to make these wells commercial and that such a well stimulation may be an attractive alternative to redrilling. The relatively large amount of reservoir data available and the high reservoir temperature made this field a good candidate for field experiments in the evaluation of geothermal stimulation techniques, fracture fluids, proppants and mechanical equipment.

After considering several candidate wells, Union and RGI agreed that Baca No. 23 and subsequently Baca No. 20 were the best sites for the fracture treatments. These wells, shown in Figures 4.4.2-1 and 4.4.2-5 were selected because: 1) they were noncommercial or a poor producer; 2) the fracture system is present in the area as proven by the surrounding wells; 3) the wells could be recompleted to isolate the stimulation interval; 4) observation wells were available within 1,500 feet; 5) the wellsites were large enough for the frac equipment; and 6) in the case of Baca No. 23 the rig was already on location.

The experiments were cost-shared by Union and the GRWSP. Union paid the cost of rig mobilization and demobilization plus the cost of recompleting the wells for the treatments. The GRWSP paid for the stimulation treatment and other directly related costs. Total cost amounted to about $1.1 million for Baca No. 23 and about $1.4 million for Baca No. 20.

4.4.2.1 Baca No. 23

Well Recompletion

Baca No. 23 was originally completed as shown in Figure 4.4.2-1(A) with a 9-5/8" liner cemented at 3,057 feet and 8-3/4" open hole to 5,700 feet. The well was flow tested and at that time would not sustain flow. An interval from 3,300 feet to 3,500 feet in the well was selected for fracture stimulation. Good production had previously been encountered near this depth approximately 200 feet away in Baca No. 10. The interval is now cemented off behind casing in Baca No. 10. Fracturing a more shallow interval, immediately below the shoe of the 9-5/8" casing, was considered to have a substantial risk of communication with lower temperature formations above. The temperature in the zone selected was approximately 450°F.

Since the top of the selected interval was deeper than the existing 9-5/8" liner, a 7" liner was cemented to a depth of 3,300 feet to exclude the interval above. The lower portion of the hole was sanded back to 3,800 feet and plugged with cement to 3,531 feet to contain the treatment in the desired interval. This recompletion is shown in Figure 4.4.2-1(A). The treatment interval was totally nonproductive after being isolated for the stimulation treatment.

Treatment Summary

A hydraulic fracture treatment was performed on the well consisting of 7,641 bbl. of fluid and 180,000 lb. of 20/40-mesh proppant pumped in eight stages. The stages are detailed in Table 4.4.2-1 and the pressure/rate history is shown in Figure 4.4.2-2.

The treatment was pumped through a 4-1/2" tubing frac string with a packer set near the top of the 7" liner as shown in Figure 4.4.2-1(A). The frac string was necessary to isolate liner laps in the well from the treating pressure.

Although the job was basically a conventional hydraulic fracture treatment, the high formation temperature (450°F) dictated special design and materials selection requirements. Therefore, 50 percent of the frac fluid was dedicated to wellbore and fracture pre-cooling with the final 50 percent of the fluid used to place the proppant. While frac fluid properties are known to degrade rapidly at high temperature, these effects were minimized by pre-cooling, by pumping at high rates (up to 75 BPM), and by limiting the frac interval to 231 feet. Proppants were selected for their insensitivity to the high temperature (Sinclair, et al., 1980). Both resin-coated sand and sintered bauxite were used. Chemical work included compatibility studies of the frac materials with the formation fluids and the use of chemical tracers to monitor fluid returns.

The job was separated into eight stages. In Table 4.4.2-1 the eight stages are shown with the planned and actual stage sizes. The fluid used for pre-cooling the formation (Stage 1) was produced geothermal water stored in a pit near the location. The job ran short by 418 bbl. of pre-pad water because the usable volume of the pit was underestimated. No harmful effects resulted from this short fall, however. Otherwise, the schedule was followed closely. The fluid for Stages 2-7 was a 60 lb/1,000 gal. hydroxypropyl guar polymer gel pre-mixed using fresh water. The gel was crosslinked as it was pumped.

Finely ground calcium carbonate was selected as a fluid-loss additive (FLA) for Stages 1-4. About 5,700 lb. of fine fluid-loss additive were used during the job. A larger fluid-loss additive consisting of 42,000 lb. of 100-mesh sand was pumped in Stage 3 to slow leaks into the natural fractures of the formation.

Total proppant placed in the formation during the job was 180,000 lb. The original plan was to use a 50/50 mixture of sintered bauxite and resin-coated sand, both 20/40-mesh. The actual proportion of the proppants was 54 percent sintered bauxite and 46 percent resin-coated sand by weight.

Actual horsepower required for the job was 6,400 hhp versus the 5,880 hhp estimated by assuming an 80 BPM pump rate and 3,000 psi wellhead pressure. Higher than expected frac gradients were responsible for the increase. Frac gradients measured at the beginning, middle and end of the job were 0.83, 0.92 and 1.175 psi/ft respectively. The buildup in frac gradient is difficult to interpret here, but nonetheless should be noted for consideration in planning and evaluating future fracture treatment.

Test Results and Analyses

During the fracture treatment, Los Alamos National Laboratory performed a fracture mapping experiment using Baca No. 6 as an observation well. A triaxial geophone system was placed in the well; and using techniques developed for the Hot Dry Rock Project, microseismic activity caused by the fracture job was mapped. The 14 discrete seismic events indicate northeast trending activity in a zone roughly 2,300 feet long, 650 feet wide and 1,300 feet high. The rock failure, therefore, occurred in a broad zone and suggests the stimulation did not result in the creation of a singular monolithic fracture. These microseismic events would be expected to proceed in advance of any significantly widened, artificially created fracture and would not necessarily define a final propped flow path to the wellbore at Baca No. 23. Calculations of the theoretical fracture length were made assuming a 300-foot high fracture. The results suggest a fracture wing of 430 to 580 feet in length may have been created, depending on the assumptions utilized for the frac fluid, fluid efficiency and fracture width.

As discussed above, the 231-foot interval isolated for stimulation was nonproductive prior to the treatment. This indicated that no significant natural fractures intersected the wellbore. Twelve hours after the frac job, a static temperature survey (shown in Figure 4.4.2-3 with a pre-frac survey) was obtained by Denver Research Institute. This survey showed a zone cooled by the frac fluids estimated to be more than 300 feet in height at the wellbore.

After the post-frac temperature survey was obtained, the frac string was pulled and the well was circulated with aerated water and allowed to flow to be sure that production of proppant into the wellbore would not interfere with subsequent testing. No significant amount of proppant was produced into the wellbore after the frac job. At this time it was determined that the well was worthy of final completion and further testing. A 5-1/2" pre-perforated liner was installed in the treatment interval as shown in Figure 4.4.2-1(C).

On March 26, 1981, a six-hour production test through drillpipe was performed in which transient, downhole pressure and temperature measurements were obtained. A unique testing method was utilized to overcome the data gathering problems usually associated with flow testing a geothermal well. The procedure was a combination of conventional drillstem test (DST) methods (to eliminate large wellbore storage effects) and gas lift to maintain steady, single-phase flow to the wellbore. The gas lift was provided by injecting nitrogen gas at depth through coil tubing inside the drillpipe. As a result of this procedure, the well flowed at a low, steady rate (about 21,000 lb/hr) and the transient pressure data obtained downhole provided an indication of wellbore storage effects, fracture flow effects and reservoir transmissivity.

A Horner analysis of the drillstem pressure buildup data gave an apparent kh of 2040 md-ft with a skin of -3.8. This compares closely with results from other non-commercial wells in the area and with the 6,000 md-ft average reservoir value obtained by Union from interference well tests (Hartz, 1976). The maximum recorded temperature was 342°F which indicated that the near wellbore area had not recovered from the injection of cold fluids.

Following the modified DST, a 49-hour flow test was performed to determine the well's productive capacity. The results showed that the well could produce approximately 99,000 lb/hr total mass flow at a wellhead pressure of 51 psig, although the rate was continuing to decline. The chemical tracer data showed that the frac fluid stages were thoroughly mixed together in the return fluids and the frac polymer had thermally degraded by the end of this test.

Union performed a long-term flow test on the well during April-May 1981. A static temperature profile of the well prior to this test showed that the bottom-hole temperature still remained low (401°F). Temperature and pressure surveys run on April 21 (Figure 4.4.2-3) recorded a maximum temperature of 344°F and a maximum pressure of 120 psig at 3,500 feet. Therefore, two-phase flow was occurring in the formation, with the steam fraction estimated at more than 50 percent. This two-phase flow condition has been observed in other wells in the field.

The formation cooling seen in the April 13 temperature survey is apparently a result of the temperature drop associated with flashing in the formation.

The long-term flow test revealed a total mass flow after 10 days (assuming a 50% flash) of 68,000 lb/hr against a wellhead pressure of 35 psig. Attempts to flow the well against a higher wellhead pressure were unsuccessful. The relatively high steam quality and the quick productivity recovery following each shut-in period suggests that much of the poor productivity is caused by relative permeability effects. The relatively low formation temperature in the completion interval also contributes to the well's poor productivity. The pressure buildup analysis following the flow test showed indications of a fracture-flow pressure response which eliminated the radial flow regime of the buildup data.

4.4.2.2 Baca No. 20

Well Recompletion

Baca No. 20 was originally completed as shown in Figure 4.4.2-5(A) with a 9-5/8" liner cemented at 2,505 feet and a 7" slotted liner hung at 2,390 feet with the shoe at 5,812 feet. The 7" slotted liner was pulled, lost circulation zones cured using cement plugs, and then a 7" blank liner was cemented in place at 4,880 feet in order to isolate the desired treatment interval. Since the frac interval was to be from 4,880 feet to 5,120 feet, a sand plug was placed from 5,827 feet total depth to 5,400 feet and then capped with cement to 5,120 feet. The recompletion is shown in Figure 4.4.2-5(B). This particular 240-foot interval was chosen primarily because the best production in the area has been found near the bottom of the Bandelier Tuff and because of its high reservoir temperature (540°F).

Treatment Summary

The hydraulic fracture treatment was accomplished in the eleven stages defined in Table 4.4.2-2. The high formation temperature (540°F) once again dictated special design and materials selection.

The treatment was pumped through a 4-1/2" tubing string with a packer set at 2,412 feet, just below the 7" liner hanger. A 3,000 bbl. fresh water pre-pad was used to cool the wellbore and fracture. The proppant selected was 119,700 lb. of 16/20-mesh sintered bauxite followed by 119,700 lb of 12/20-mesh sintered bauxite. The proppant was carried by a 60 lb/1,000 gal. hydroxypropyl guar polymer gel mixed in fresh water. This fluid was a new high-pH crosslinked HP guar system having better stability at high temperature. The gel was crosslinked as it was being pumped. Chemical tracers were added to the injected fluid to monitor fluid returns.

Approximately 4,200 lb. of 200-mesh calcium carbonate were added in Stages 1-6 to act as a fluid-loss additive. In an effort to stop leakage into the small natural fractures, 42,000 lb. of 100-mesh calcium carbonate were pumped in Stages 2 and 5 in concentrations of 0.39 ppg and 1.33 ppg respectively. The 100-mesh material was injected in "slugs" to enhance its chances of bridging on the fractures.

The majority of the treatment fluid was pumped at approximately 80 BPM. The rate was slowed to 40 BPM in Stage 10 when the proppant concentration was increased to 4.2 lb/gal. In anticipation of frac gradients of 0.9 psi/ft and higher, as seen in Baca No. 23, a total capacity of 11,000 hhp was made available and connected in the system. However, the actual peak hydraulic horsepower used was only 7,450 hhp because of lower frac gradients. An instantaneous shut-in pressure was measured soon after the treatment was initiated (1,000 psig) and again near the end of the job (1,300 psig), giving frac gradients of 0.63 psi/ft and 0.69 psi/ft respectively. The pressure/rate history is shown in Figure 4.4.2-6.

Minor variations in the planned pumping schedule occurred during the treatment (Table 4.4.2-2), but all fluids and proppants were injected into the formation and the desired goal of ending the treatment at a relatively high proppant concentration was achieved. The variations occurred: (1) in Stage 7 when only 1/2 lb/gal of proppant was inadvertently added instead of the planned 1 lb/gal; (2) in Stage 8 when a higher proppant concentration was used to make up for the smaller amount used in Stage 7; and (3) in Stage 9 where the proppant concentration was increased to 3 lb/gal of the larger proppant instead of the planned 2 lb/gal. In Stage 10 the rate was slowed and the proppant concentration increased to 4.2 lb/gl to achieve a more widely propped fracture. The wellhead pressure and frac gradient were lower than expected, offering reasonable assurance that the proppant would not screen out at the lower rate and higher concentration.

Test Results and Analyses

During the fracture treatment Los Alamos National Laboratory again performed a fracture mapping experiment using Baca No. 22 as an observation well. A triaxial geophone system was placed in the well at a depth of approximately 3,000 feet and the microseismic activity caused by the fracturing job was mapped. A large number of discrete events (45) was recorded during the job, however, the orientation measurement of the tool was lost. Again the activity occurred in a broad zone which was roughly 2,000 feet long, 1,600 feet wide and 1,700 feet high. Theoretical calculations of the artificially created fracture length would be 340-800 feet in a homogeneous matrix material, depending on the assumptions utilized for the frac fluid, fluid efficiency and fracture height. These calculations were based primarily on the injected fluid and proppant volumes in a single, vertical fracture.

As discussed above, the 240-foot interval was nonproductive prior to the treatment, although there was a small rate of fluid loss during the well completion operations. This indicated that at least one lost circulation zone existed at the wellbore. Approximately 12 hours after the frac job the first of several temperature surveys, as shown in Figure 4.4.2-7, was obtained in the well. These temperature surveys showed a zone cooled by the frac fluids, estimated to be less than 100 feet in height, near the bottom of the open interval. In addition, the zone located behind the 7" liner casing at approximately 4,720 feet also indicated some cooling. This zone was apparently cooled by the workover fluids and possibly by the fracturing fluids; however, the communication between this zone and the open interval (if it exists) appears to be at some distance away from the wellbore. Electric log surveys were run in the open interval following the frac job. No significant new fracture zones (or high porosity) were observed, although several zones did show increased neutron porosity values.

At this time it was determined that the well was worthy of final completion and further testing. A 5-1/2" pre-perforated liner was installed in the treatment interval as shown in Figure 4.4.2-5(C). On October 10-11, 1981, a 6-hour production test through drillpipe was performed in the same manner as the drillstem test at Baca No. 23. A steady rate of about 21,000 lb/hr single-phase flow was maintained to the wellbore. Transient pressure and temperature data were obtained downhole during the DST.

The transient pressure response during drawdown and buildup was dominated by linear flow. Application of type curve matching to the drawdown data resulted in an apparent kh of 540 md-ft. This value was confirmed by the application of a Horner buildup analysis which resulted in an apparent kh of 600 md-ft with a skin factor of -3.8.

Evaluation of the type curve match also indicated a fracture half-length of 40 feet. This compares with an apparent half-length of less than 100 feet calculated from the pressure versus square root of time graphs for both drawdown and buildup.

The maximum recorded temperature during the test was 320°F and indicated that the near wellbore area had not recovered from the injection of cold fluids. Additional temperature surveys were run in the well following the DST, as shown in Figure 4.4.2-7, which again indicated the fluid was entering (leaving) the wellbore in the lower part of the open interval.

Following the modified DST, a 14-day flow test was performed to determine the well's productive capacity. The well produced approximately 120,000 lb/hr total mass flow initially, but declined rapidly to a final stabilized rate of approximately 50,000 lb/hr (wellhead pressure of 25 psig) under two-phase flow conditions in the formation.

Acid Job

During the post-fracture testing, production of the calcium carbonate fluid-loss additive was not observed and it was believed that most of it still resided in the formation. Analysis of pressure data from the drillstem test suggested that a permeable fracture exists, but that it did not communicate with highly conductive natural fractures in the formation. It was believed that this was a possible result of the fluid-loss additive plugging flow channels in the formation. There is no diagnostic technique, however, that can establish this with any degree of certainty other than an acid treatment that would remove the material from the formation and possibly change the productivity of the well. Therefore, it was deemed important, both for the purpose of reaching a conclusive result in Baca 20 and for the purpose of guiding the design of future stimulation work, to do an acid treatment in Baca 20.

A pre-acidize flow test was conducted August 3 through 5, 1982 and showed that Baca No. 20 had essentially the same productivity as it had immediately following the hydraulic stimulation (Section 5.2.1).

The acid treatment was done in Baca 20 on August 11, 1982. The treatment consisted of injecting 29,860 gal. of 15 percent hydrochloric acid into the formation in the interval originally isolated for the fracture treatment. As discussed above, the treatment was designed to dissolve 57,800 lbs. of finely ground calcium carbonate fluid-loss additive which was injected into the same interval (4880'-5120') during the fracture treatment.

The high static temperature in the treatment interval (520°F) required that several precautions be taken to prevent acid corrosion damage to the well tubulars. In preparation for the treatment an oil well-type servicing rig was moved in and well control equipment was installed on the well. A bailer was used to check for fill in the producing interval and then a 2-7/8" tubing string was run to a depth of 4,836' for use as a temporary acid injection string. The acid was mixed on-site in the tanks with a corrosion inhibitor chemical added to provide protection for the well tubulars up to 250°F for a minimum of four hours. In order to cool the well within the range of effectiveness of the corrosion inhibitor, 200 bbls of fresh water was pumped down the tubing-casing annulus immediately prior to injecting the acid. Immediately following the injection of cooling water, acid injection commenced at an average rate of 10.8 bbls. per minute down the tubing while fresh water was injected simultaneously down the annulus at an average rate of 5.1 bbls. per minute. The annular water injection served to cool the tubulars and mixed with the acid above the treatment interval to yield an acid concentration of approximately 10.2 percent. Upon completion of the acid injection, the acid was displaced with fresh water and then the tubing was lowered to a depth near the bottom and an additional 632 bbls. of water was pumped (half down the tubing and half down the annulus) to displace any acid from the bottom of the hole and to overdisplace the acid into the formation. The tubing was then pulled and the well was prepared for testing.

A four day flow test was conducted two weeks after the acidization of Baca No. 20. Comparison of pre-acidize and post-acidize flow rates indicates that the productivity of Baca No. 20 did not increase (Section 5.2.1).

The buildup analysis of the pressure response following shut-in of the flow test was again dominated by linear flow. The Horner analysis resulted in an apparent kh of 540 md-ft and a skin of -6.7 (Section 5.3.1). The pressure versus the square root of time graphs for the buildup data resulted in an apparent fracture half-length of 100 feet.

The acid cleanout may be called a success if the change in skin from the drillstem test to pressure buildup 7 is considered. While the different type of tests may be accountable for some of the skin variance, it may be partly due to fracture cleanout during the cleanout. The skin improvement had no observable affect on production rates: probably a reflection of the poor matrix permeability surrounding Baca No. 20.

Conclusions

1. Large hydraulic fracture treatments were successfully performed on both Baca No. 23 and Baca No. 20. Production tests indicated that high conductivity fractures were propped near the wellbore and communication with the reservoir system was established.

2. The productivities of Baca No. 23 and Baca No. 20 have declined to noncommercial levels since the fracture treatments. A contributing factor is relative permeability reduction associated with two-phase flow effects in the formation.

3. The ability of Baca No. 23 to produce substantial quantities of fluid at a high wellhead pressure is limited because of the low formation temperature in the shallow treatment interval. The productivity of Baca No. 20 is severely restricted because of the low permeability formation surrounding the artificially created fracture.

4. Although the stimulation treatments did not result in commercial wells at Baca, the hydraulic fracturing techniques show promise for future stimulation operations and for being a valid alternative to redrilling in other reservoirs.

References

Hartz, J. D., Geothermal Reservoir Evaluation of the Redondo Creek Area, Sandoval County, N.M., A Union Oil Company Report, September, 1976.

Morris, C. W. and Bunyak, M. J., Fracture Stimulation Experiments at the Baca Project Area, A Republic Geothermal Report, January, 1982.

BACA 23 COMPLETION DETAILS

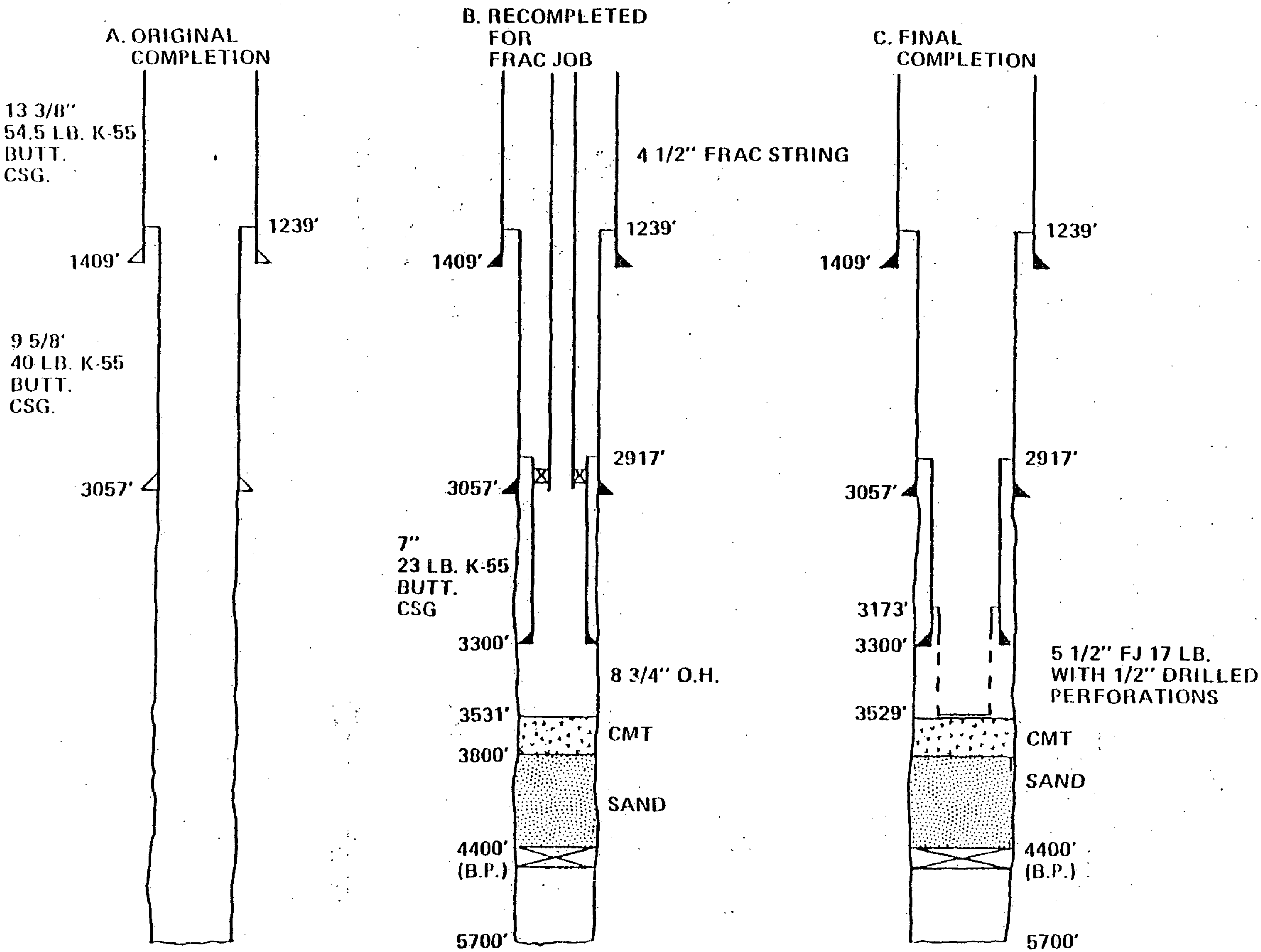


FIGURE 4.4.2-1

TABLE 4.4.2-1

BACA 23 WELL TREATING SCHEDULE

Stage No.	Planned Size (bbl)	Actual Size (bbl)	Proppant (lb/gal)	Proppant (Size)	Fluid
1	4,000	3,582	0	-	Produced water with Fluid Loss Additive (FLA) 40 BPM rate
2	500	502	0	-	Crosslinked HP Guar 60 lb/1000 gal with FLA; 60 to 70 BPM rate
3	500	502	2	100-mesh	Crosslinked HP Guar 60 lb/1000 gal with FLA; 60 to 70 BPM
4	500	526	0	-	Crosslinked HP Guar 60 lb/1000 gal with FLA; 60 to 70 BPM rate
5	900	905	1	20/40-mesh	Crosslinked HP Guar 60 lb/1000 gal with no FLA; 65 to 75 BPM rate
6	1,000	1,000	2	20/40-mesh	Crosslinked HP Guar 60 lb/1000 gal with no FLA; 65 to 75 BPM rate
7	600	562	3	20/40-mesh	Crosslinked HP Guar 60 lb/1000 gal with no FLA; 65 to 75 BPM rate
8	58	62	0	-	Flush with produced pit water
	8,058	7,641			

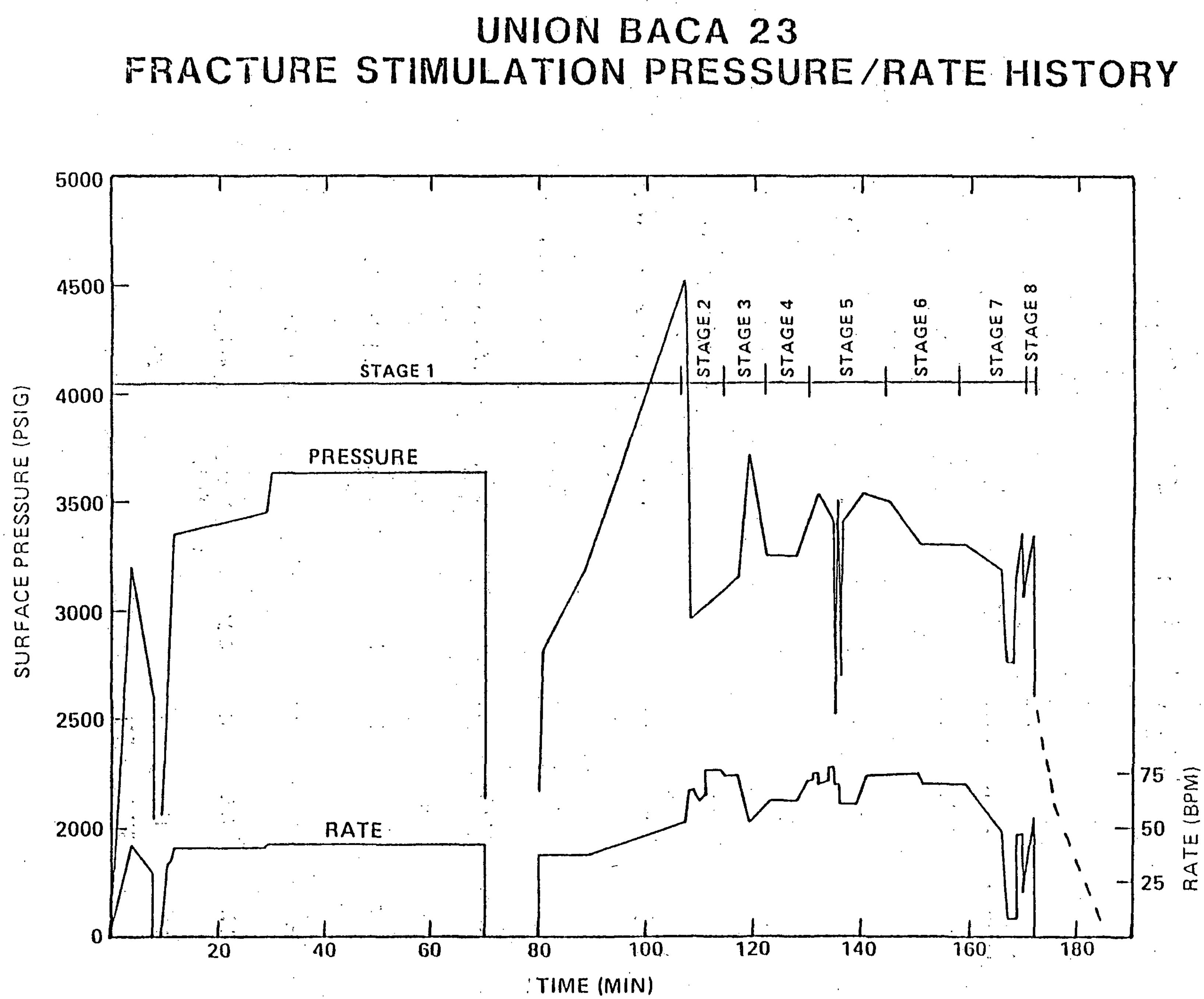

UNION BACA 23
FRACTURE STIMULATION PRESSURE/RATE HISTORY
5000
4500
4000
3500
3000
2500
2000
0
SURFACE PRESSURE (PSIG)
STAGE 1
STAGE 2
STAGE 3
STAGE 4
STAGE 5
STAGE 6
STAGE 7
STAGE 8
PRESSURE
RATE
75
50
25
RATE (BPM)
20
40
60
80
100
120
140
160
180
TIME (MIN)

FIGURE 4.4.2-2

TABLE 4.4.2-2

BACA 20 TREATING SCHEDULE

Stage No.	Planned Size (bbl)	Actual Size (bbl)	Proppant (lb/gal)	Proppant Size	Fluid
1.	2000	2000			FRESH WATER WITH FLUID LOSS ADDITIVE (FLA)
2.	500	639	0.39	100-MESH $CaCO_3$ (10,500 LB)	FRESH WATER WITH FLA
3.	500	350			FRESH WATER WITH FLA
4.	1500	1400			POLYMER GEL WITH FLA
5.	500	566	1.33	100-MESH $CaCO_3$ (31,500 LB)	POLYMER GEL WITH FLA
6.	500	500			POLYMER GEL WITH FLA
7.	1150	1168	0.46	16/20-MESH BAUXITE	POLYMER GEL
8. a	850	682	1.85	16/20-MESH BAUXITE	POLYMER GEL
b		378	2.77	16/20-MESH BAUXITE	POLYMER GEL
9.	300	450	2.11	12/20-MESH BAUXITE	POLYMER GEL
10.	750	451	4.21	12/20-MESH BAUXITE	POLYMER GEL
11.	150	151			FRESH WATER
	8700	8735			

BACA 23 TEMPERATURE SURVEYS

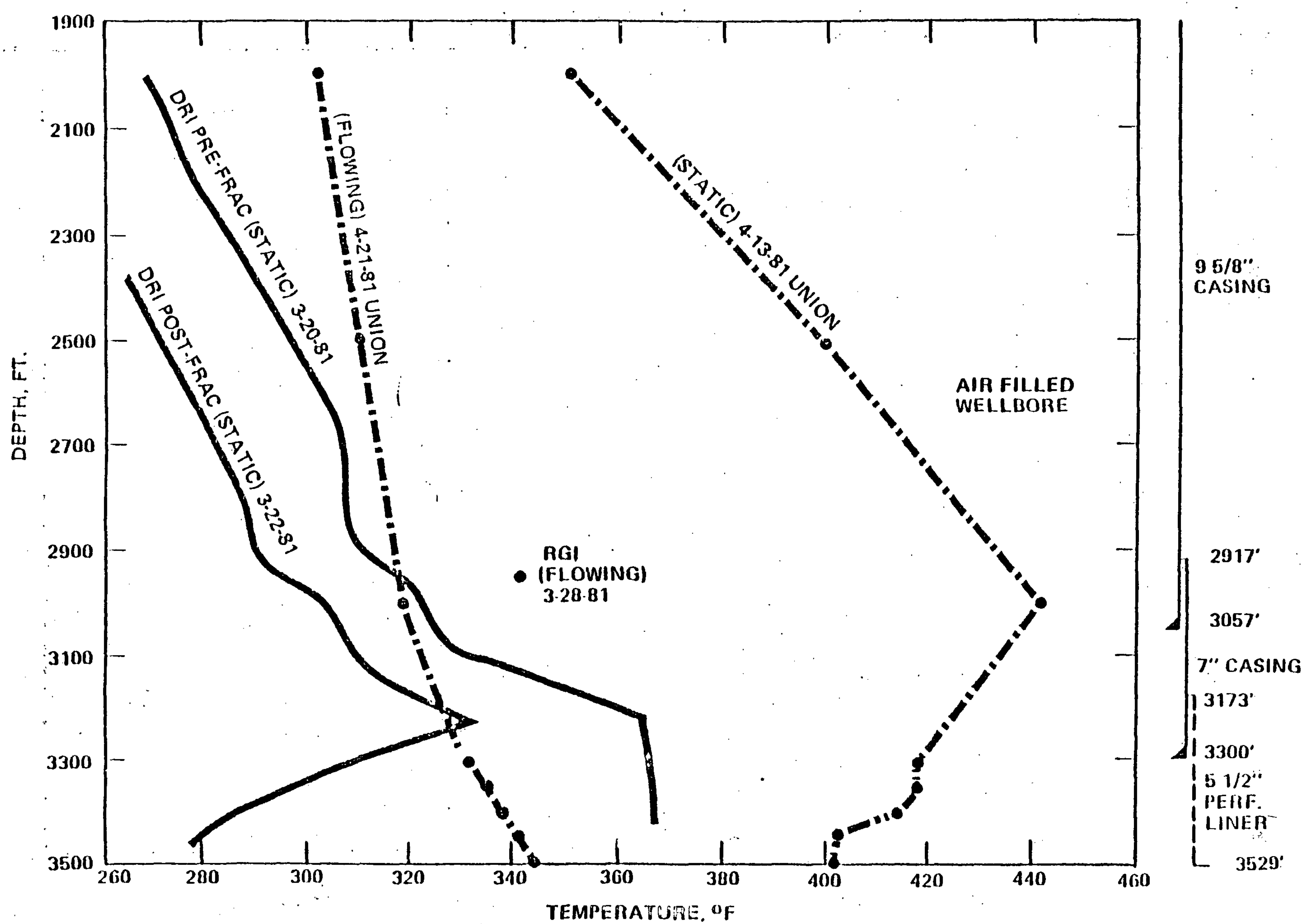
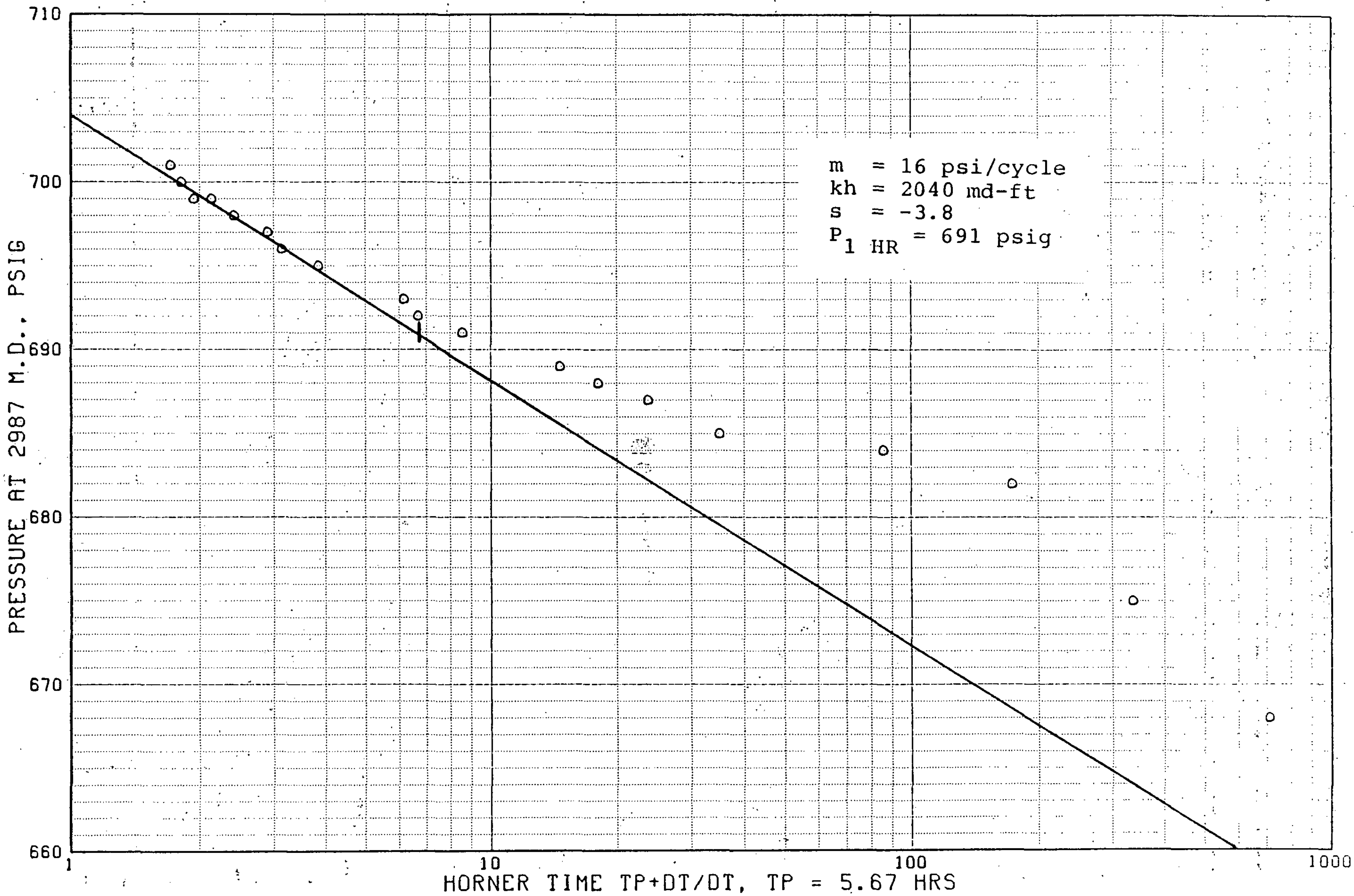


FIGURE 4.4.2-3

FIGURE 4.4.2-4

BACA NO. 23 DRILLSTEM TEST PRESSURE BUILDUP, HORNER PLOT
SHUT-IN ON 3/26/81 0801 HRS, PWF = 665 PSIG



BACA 20
COMPLETION DETAILS

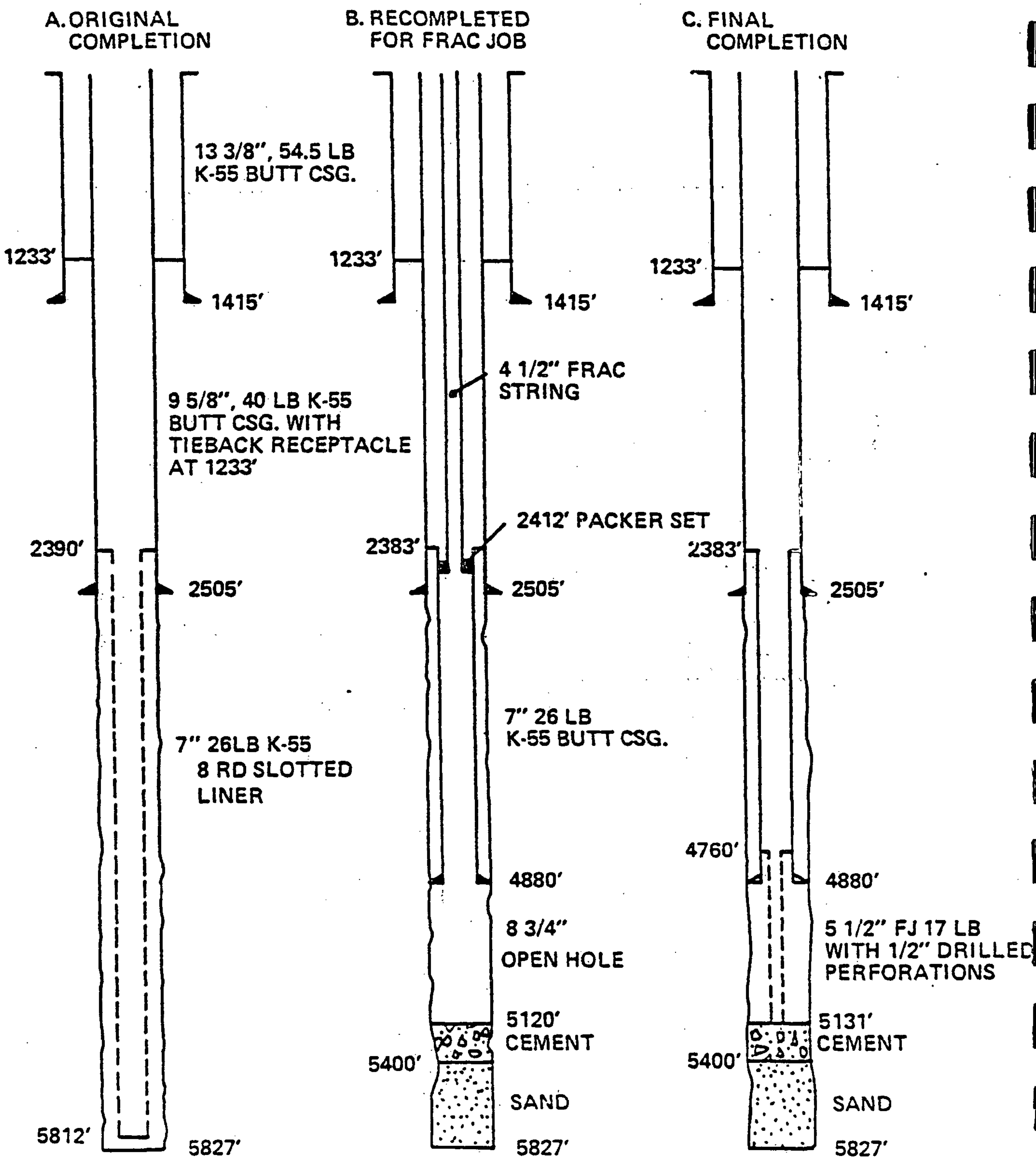
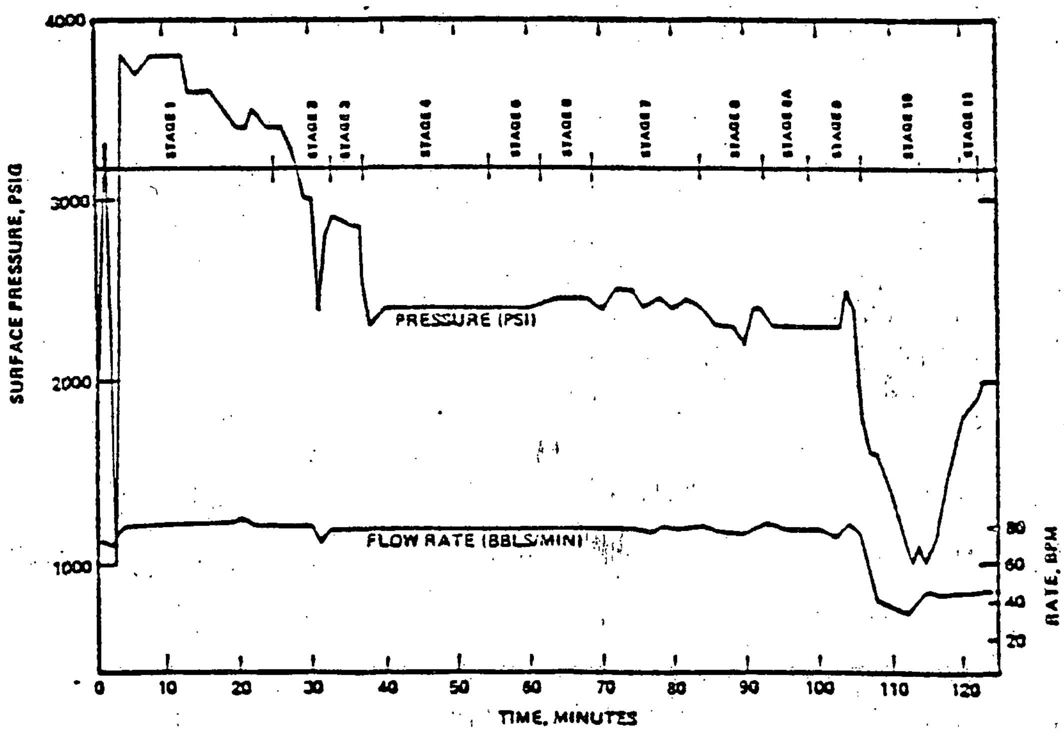


FIGURE 4.4.2-5



BACA 20 FRACTURE STIMULATION PRESSURE/RATE HISTORY.

FIGURE 4.4.2-6

BACA 20 TEMPERATURE PROFILES
October 1981

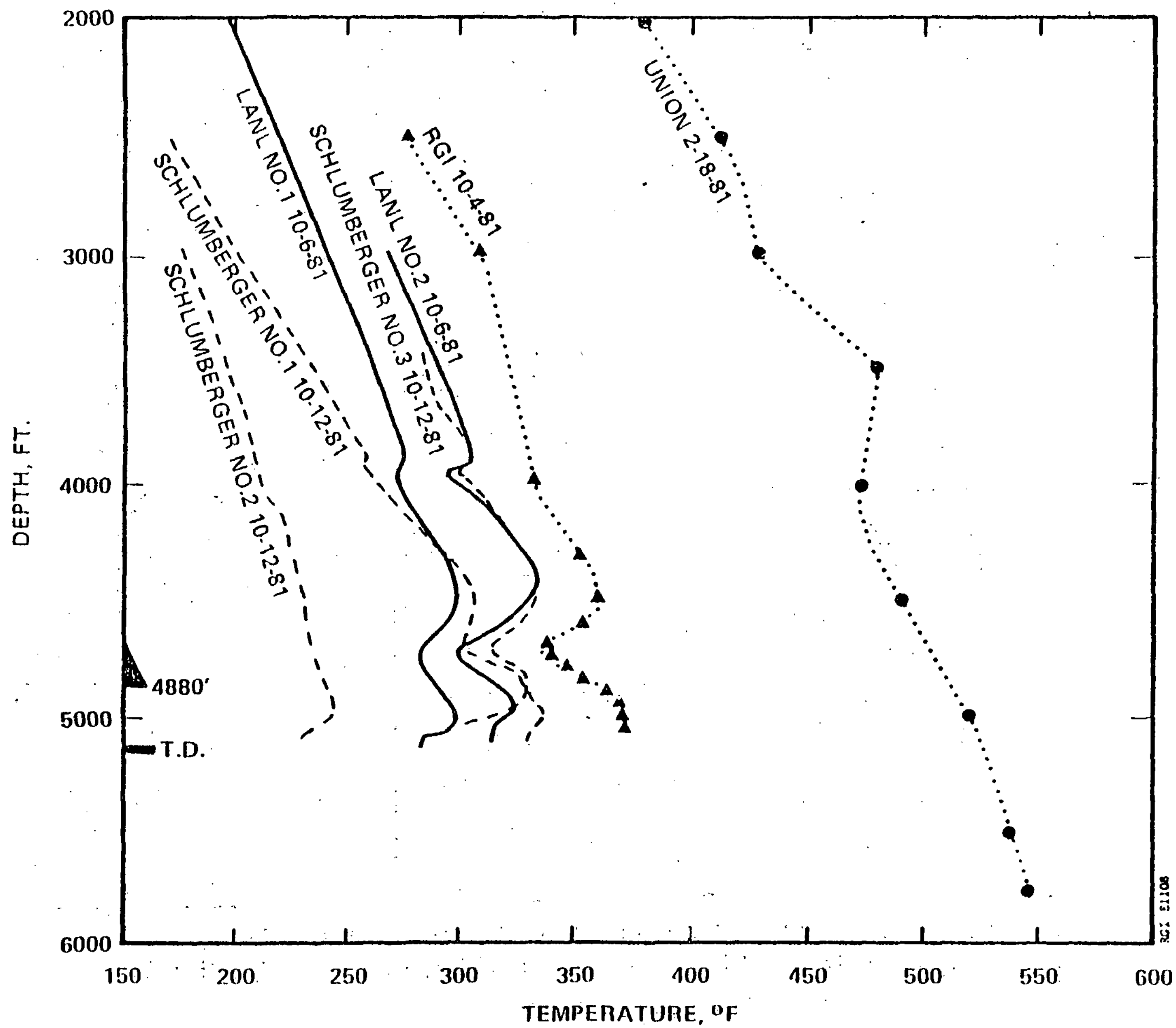
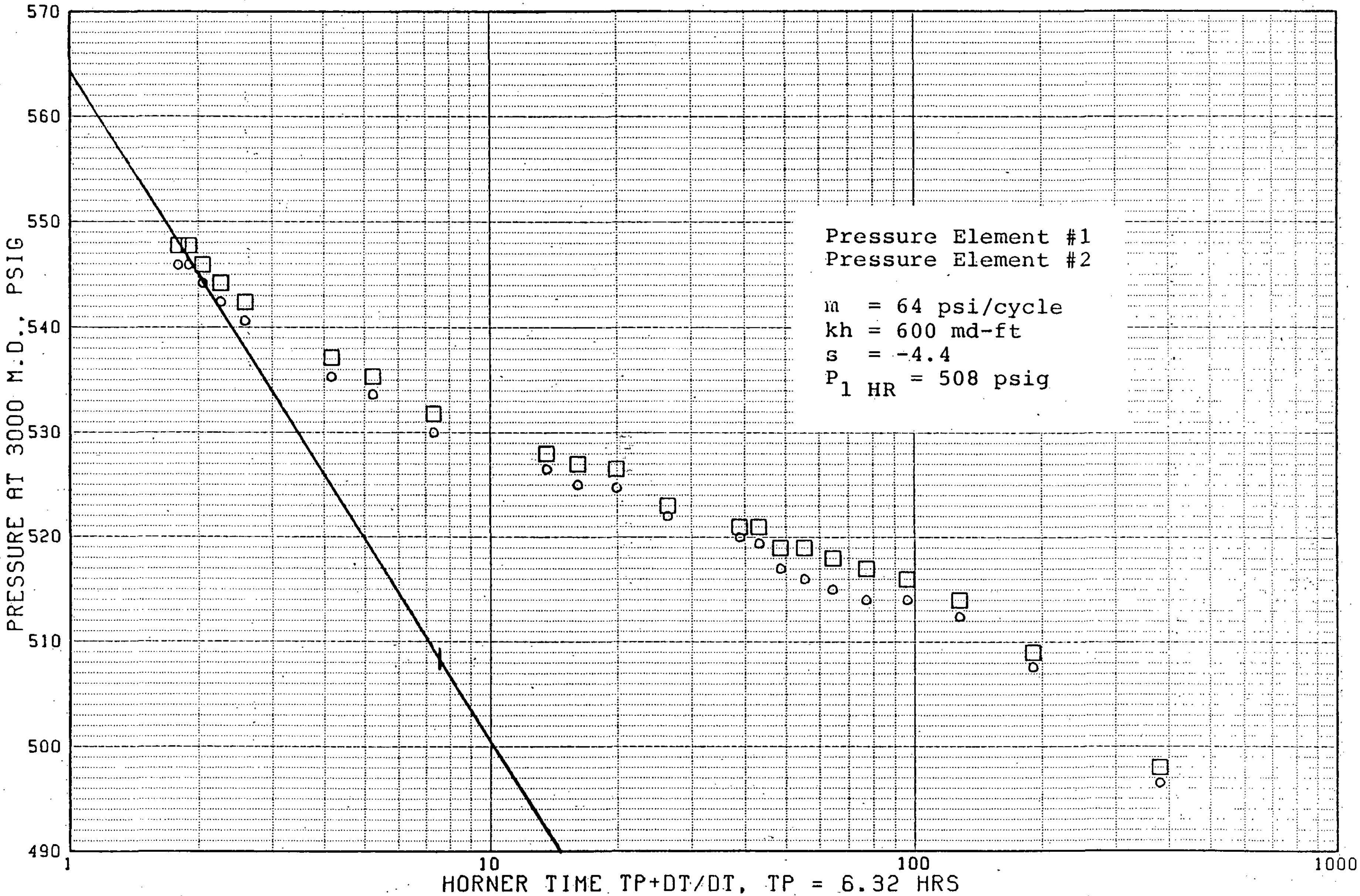


FIGURE 4.4.2-7

FIGURE 4.4.2-8

BACA NO. 20 DRILLSTEM TEST PRESSURE BUILDUP, HORNER PLOT
SHUT-IN ON 10/11/81 0234 HRS, PWF = 487.5 PSIG



SECTION 5: RESERVOIR

5.1 STATIC CONDITIONS

Identification of a commercial geothermal resource is dependent upon the temperature of the resource and the reservoir pressure. Regardless of the productivity of the reservoir-to-wellbore flow, if the reservoir's fluid temperature and pressure are not sufficient, the resource cannot flow to the surface in commercial quantities. The determination of the static reservoir conditions is therefore an important step in any reservoir evaluation. These static conditions are also used as reference points in all further reservoir testing.

A wellbore found in a completely static condition would by definition be in complete equilibrium with the exposed formation and with itself for its entire depth. As a motionless column of fluid the well should accurately reflect the pressures and temperatures of the reservoir at any chosen depth. Unfortunately a completely static well is rarely, if ever, found. The closing of a wellhead valve does not ensure the cessation of flow into, out of, or within the wellbore. The well may flow from one zone to another or may circulate due to convective forces. The use of the word "static" in this report does not refer to a true static case, but is the "most static" situation i.e. a well which has been shut-in at the surface for an extended period of time.

The Redondo Creek field contains the nineteen wells shown on Figure 5.1-1. All of the temperature measurements and most of the pressure measurements discussed in this report were acquired using mechanical downhole recording instruments manufactured by Kuster company. These Amerada-type instruments are lowered into the well on a wireline and the pressure and/or temperature is recorded mechanically with a stylus on a time-drive chart, driven by a spring-wound clock. These instruments do not supply a continuous survey. A 10-20 minute stop is required at each survey point in order for the pressure and/or temperature element to reach equilibrium and provide an identifiable mark on the chart. The number of survey points is limited by the duration of the clock, usually 12 hours.

5.1.1 Static Temperature

All measurements of static temperatures in the Redondo Creek wells have been made with wireline temperature tools. The temperature measured is the wellbore temperature which is highly sensitive to internal wellbore flow. In extreme cases, there is only one true static temperature obtained - the maximum recorded temperature - which could correspond to any reservoir depth in the exposed interval. The temperature profile, in connection with the pressure profile, does give a good indication of the fluid phase.

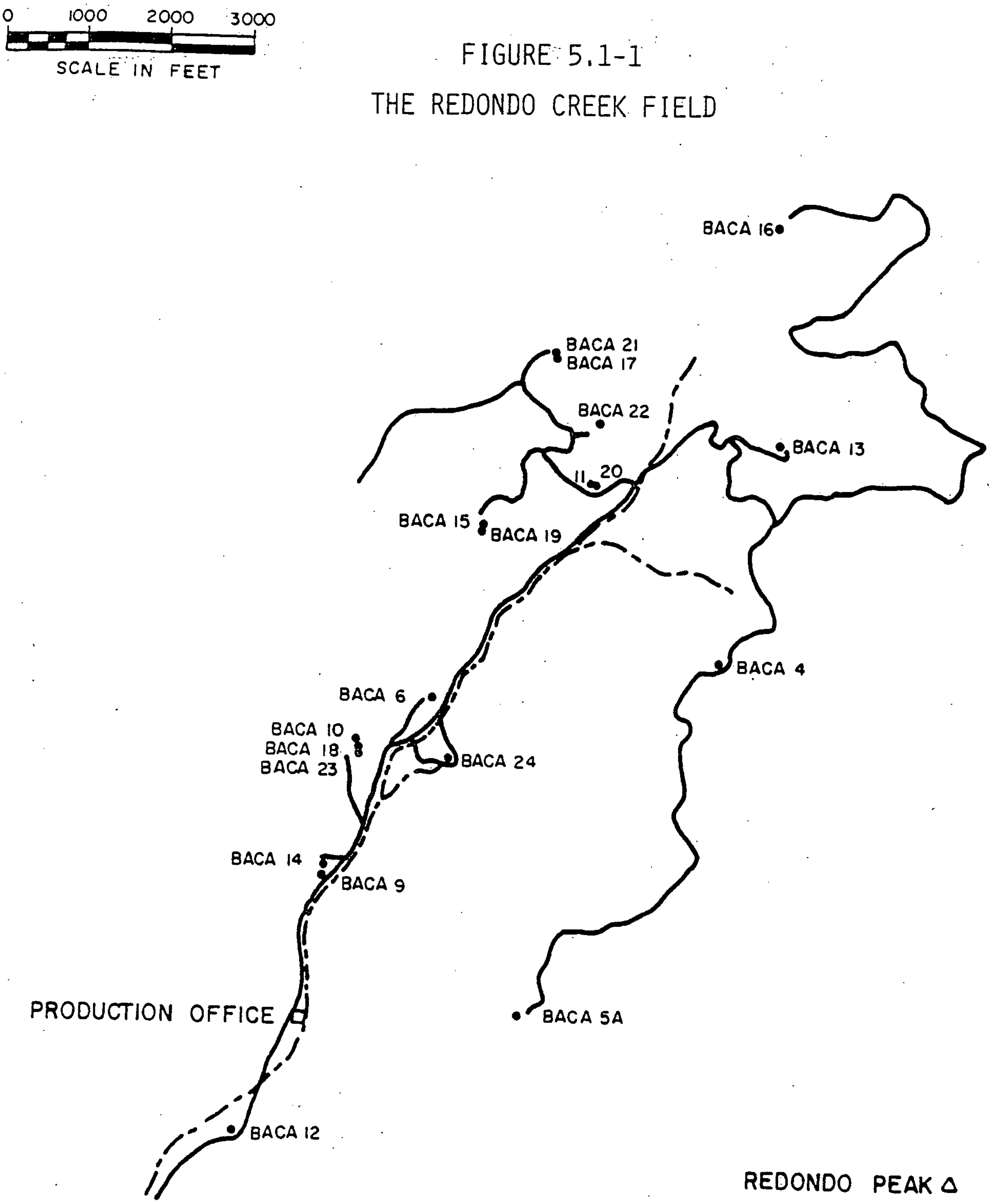


FIGURE 5.1-1
THE REDONDO CREEK FIELD

Figure 5.1.1-1 shows static temperature gradients for all of the Redondo Creek wells except Baca No. 9, revealing the scatter of the profiles. To eliminate possible differences between instruments, all of the profiles shown were obtained with a single temperature element. With few exceptions the Redondo Creek wells exhibit a wellbore temperature gradient falling within a fairly narrow temperature bandwidth. Two groups of wells are found within this bandwidth: commercial wells and subcommercial wells.

Figure 5.1.1-2 shows the static temperature gradients of the four commercial wells plus gradients of Baca Nos. 10 and 11 which previously were commercial wells. All of these wells encounter a temperature of ± 500°F at an elevation of + 5500' MSL and a suspected boiling point curve at 6000' MSL.

Figure 5.1.1-3 shows the static temperature gradients of five subcommercial wells. All of these wells have the same basic profile as those shown in Figure 5.1.1-2 but are 20-40°F below 500°F at the 5500' datum. Most of the subcommercial wells shown have a flatter profile which is an indication of less internal flow, but Baca No. 19 has the same steep temperature gradient as the commercial wells, only 30°F cooler. Considering the close proximany of Baca No. 15 and the 30°F difference between these two wells, one commercial and one not, it is speculated that a well in the Redondo Creek field must have a static wellbore temperature of 500°F at 5500' MSL to produce commercial quantities of fluid.

Of the eight Redondo Creek wells remaining, four - Baca Nos. 9, 17, 21 and 23 - do not have representative static temperature gradients. Temperature profiles of Baca Nos. 5, 6, 12 and 14 are shown individually in Figures 5.1.1-4 through 5.1.1-7.

Baca No. 5A is a relatively cold well down to the Bandelier Tuff and the Paliza Canyon Andesite at 2710' MSL. Cold fluid entering the wellbore from a high zone flows down the wellbore until it exits just above the bottom of the Bandelier Tuff.

Baca No. 6 was a commercial well but was not surveyed deep enough to be included in Figure 5.1.1-2. The temperature profile indicates that the temperature should exceed 500°F at 5500' MSL, a further proof of its commercial characteristics.

Baca No.12 was recompleted in 1981 with, among other changes, casing cemented from 4912' MSL to 433' MSL. (see Section 4.3) The two surveys shown on Figure 5.1.1-6 are before and after profiles, revealing a significant change. Without the cemented casing, warm water was flowing up the wellbore, masking the cold water zones. After being cased, there apparently is little wellbore flow and the true formation temperature of the cold zones is recorded (Section 5.6).

FIGURE 5.1.1-1
TEMPERATURE GRADIENTS FOR ALL
REDONDO CREEK WELLS

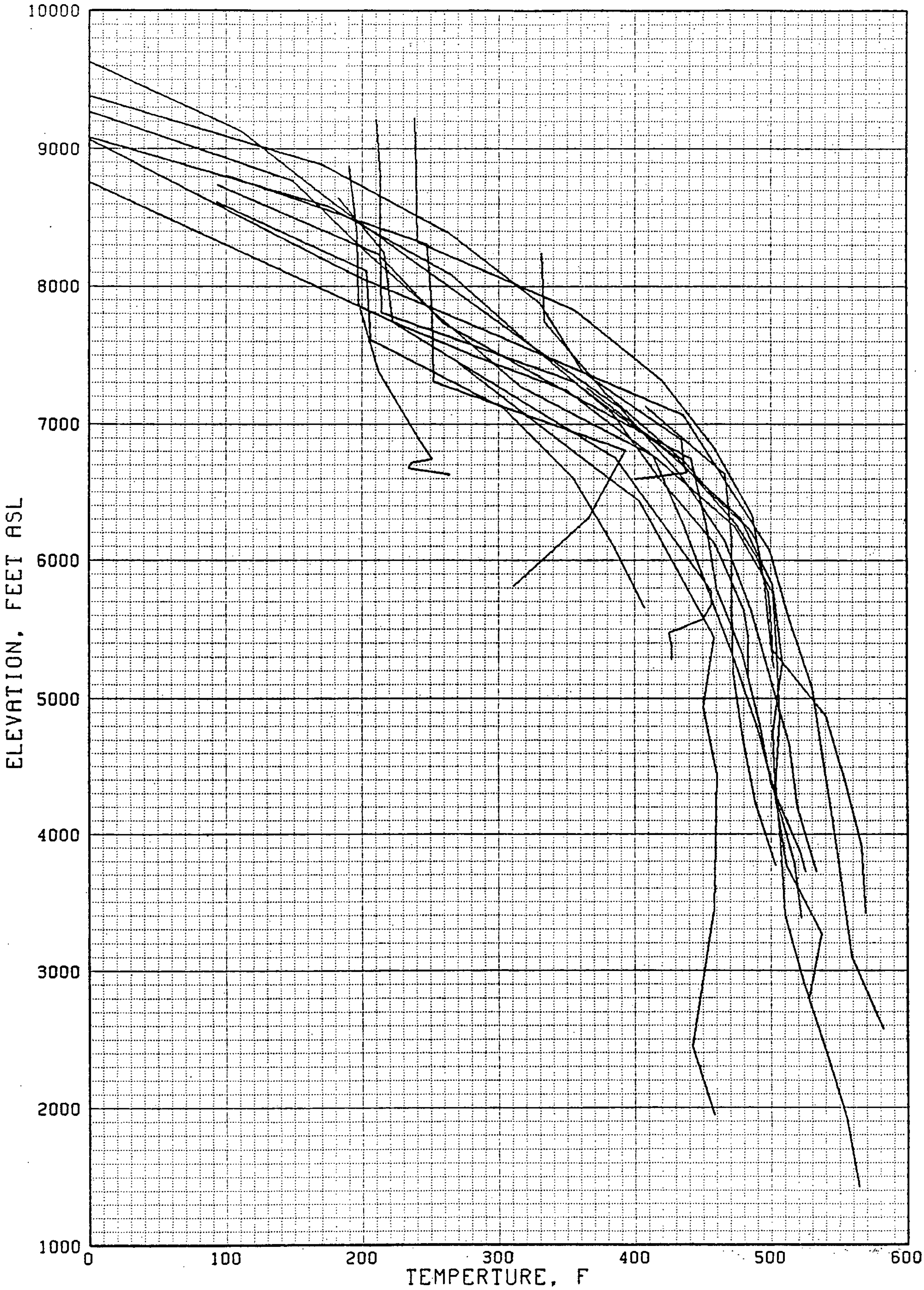


FIGURE 5.1.1-2
TEMPERATURE GRADIENTS FOR BACA NOS. 4,10,11,13,15,24
USING ELEMENT 10222

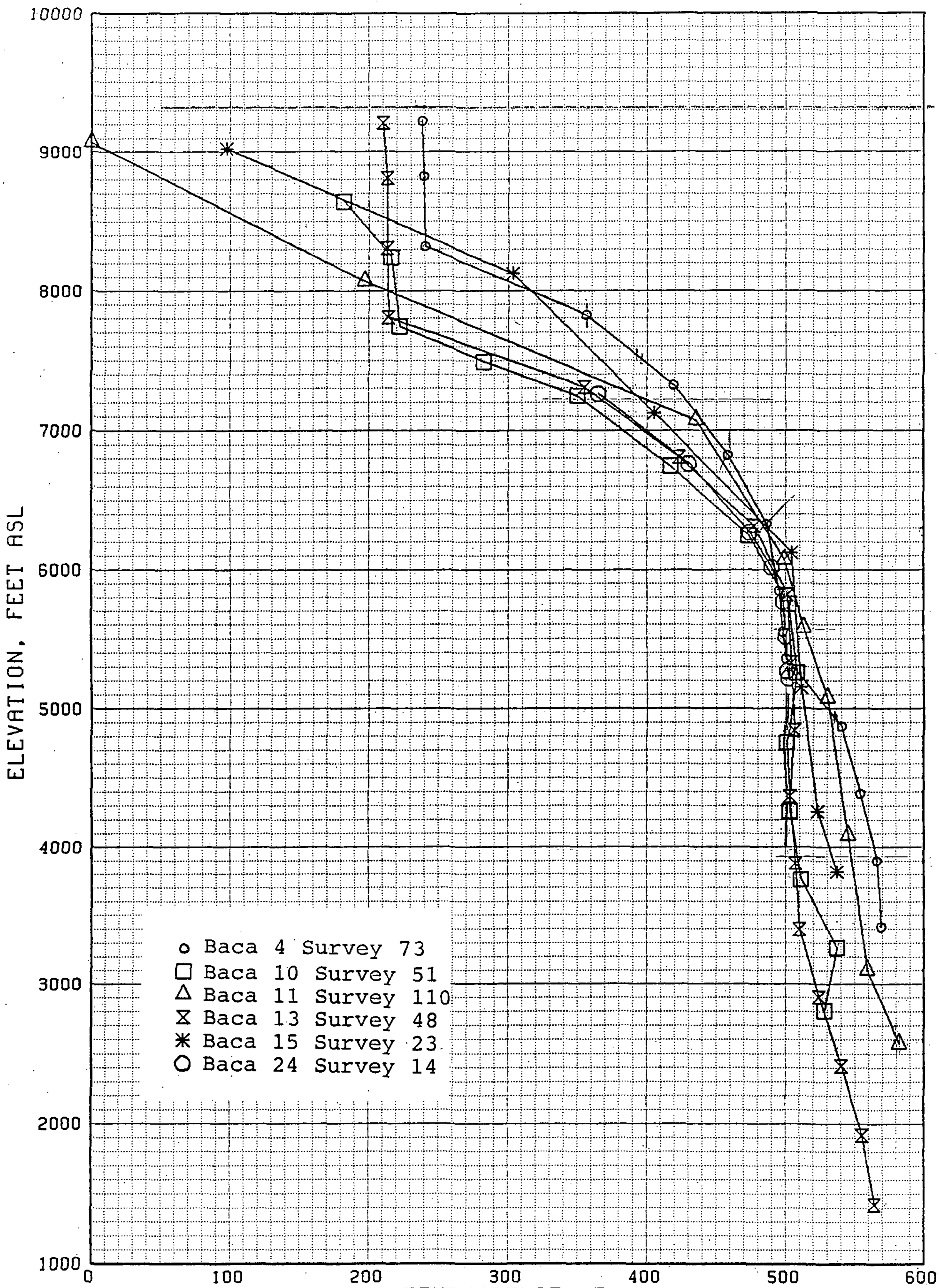


FIGURE 5.1.1-3
TEMPERATURE GRADIENTS FOR BACA NOS. 16,18,19,20,22
USING ELEMENT 10222

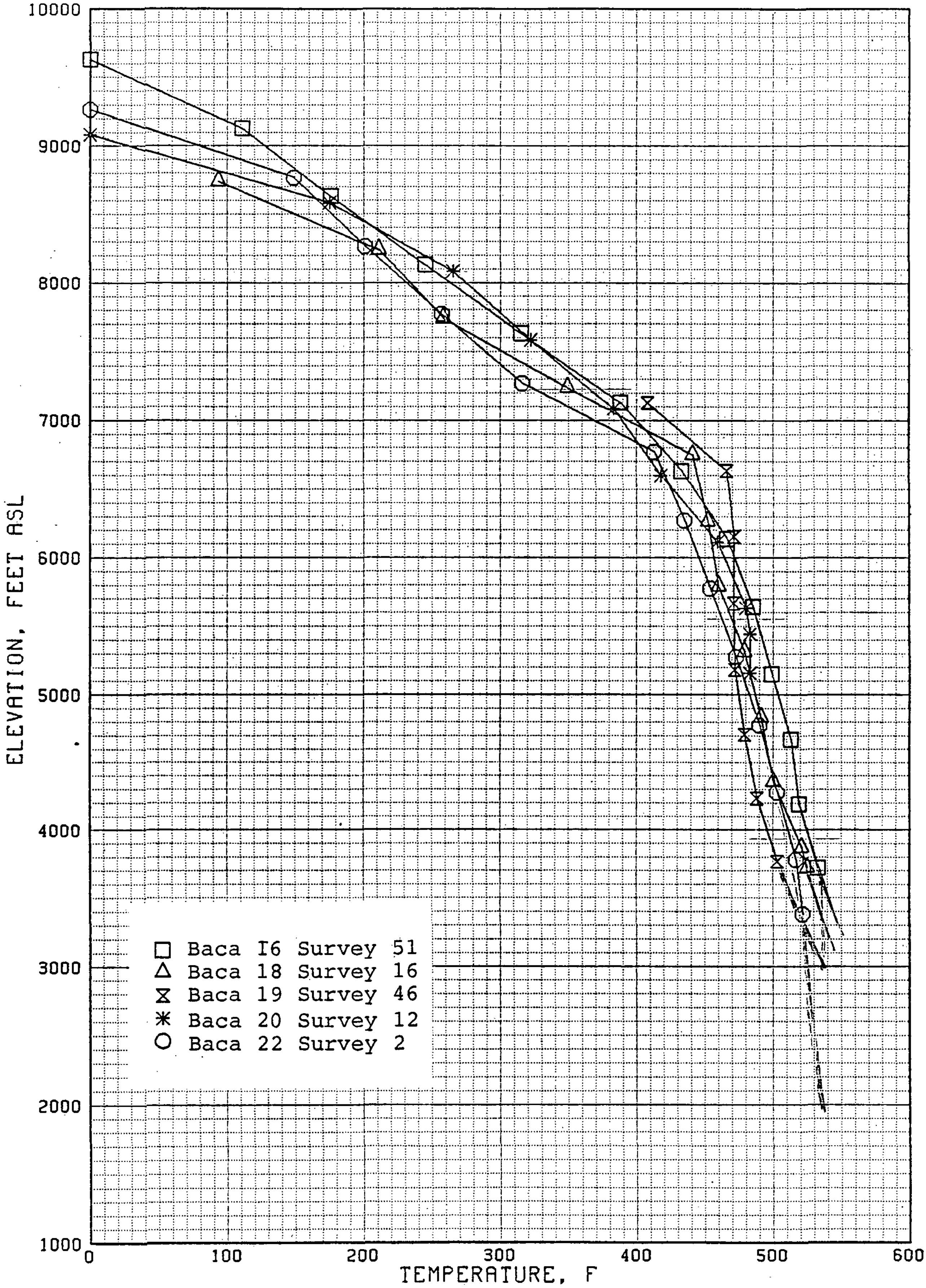


FIGURE 5.1.1-4
TEMPERATURE GRADIENTS FOR BACA NO. 5A, SURVEYS 9 AND 17

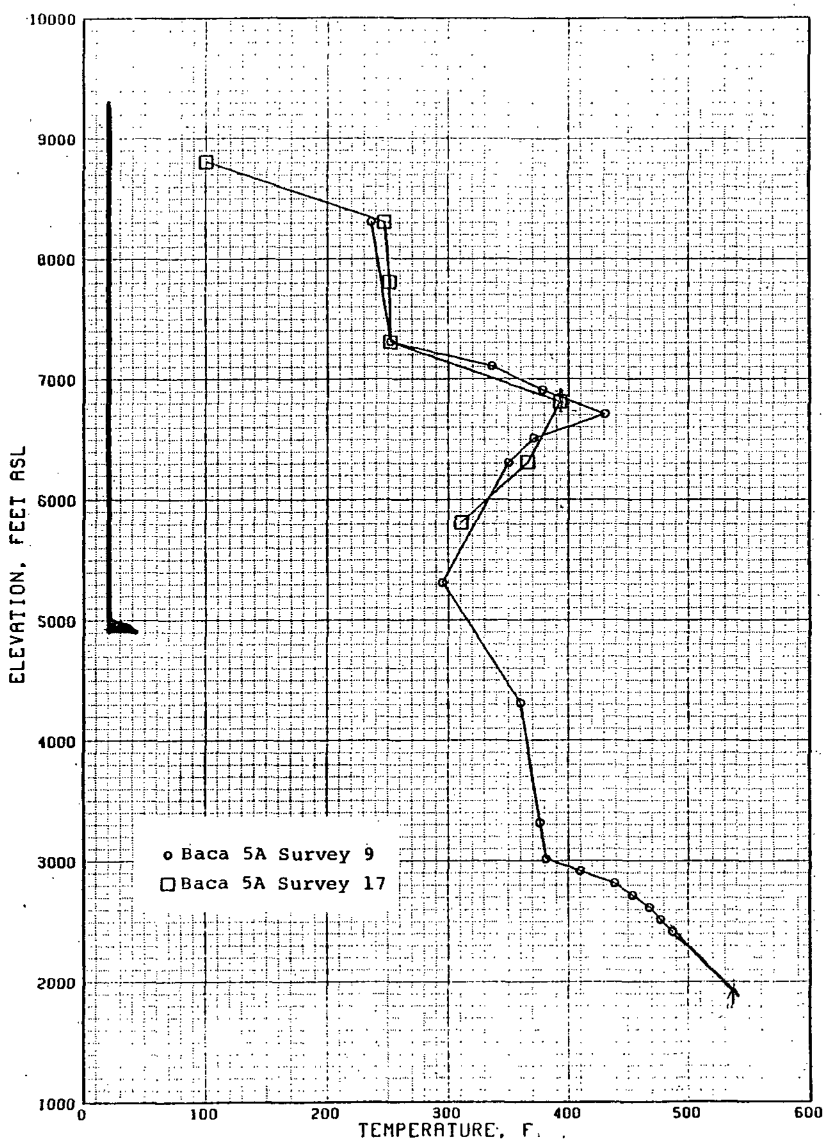


FIGURE 5.1.1-5
TEMPERATURE GRADIENT FOR BACA NO. 6, SURVEY 49

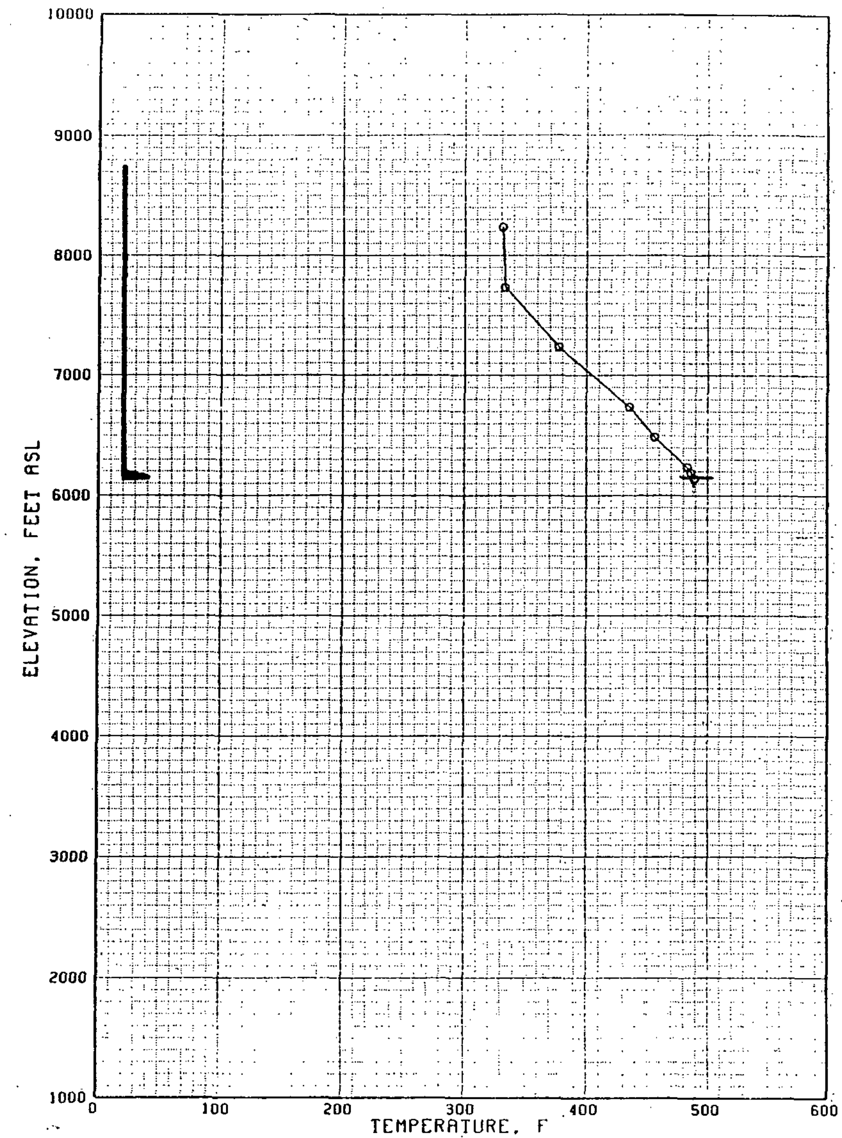


FIGURE 5.1.1-6
TEMPERATURE GRADIENTS FOR BACA NO. 12. SURVEYS 47 AND 51
BEFORE AND AFTER RECOMPLETION

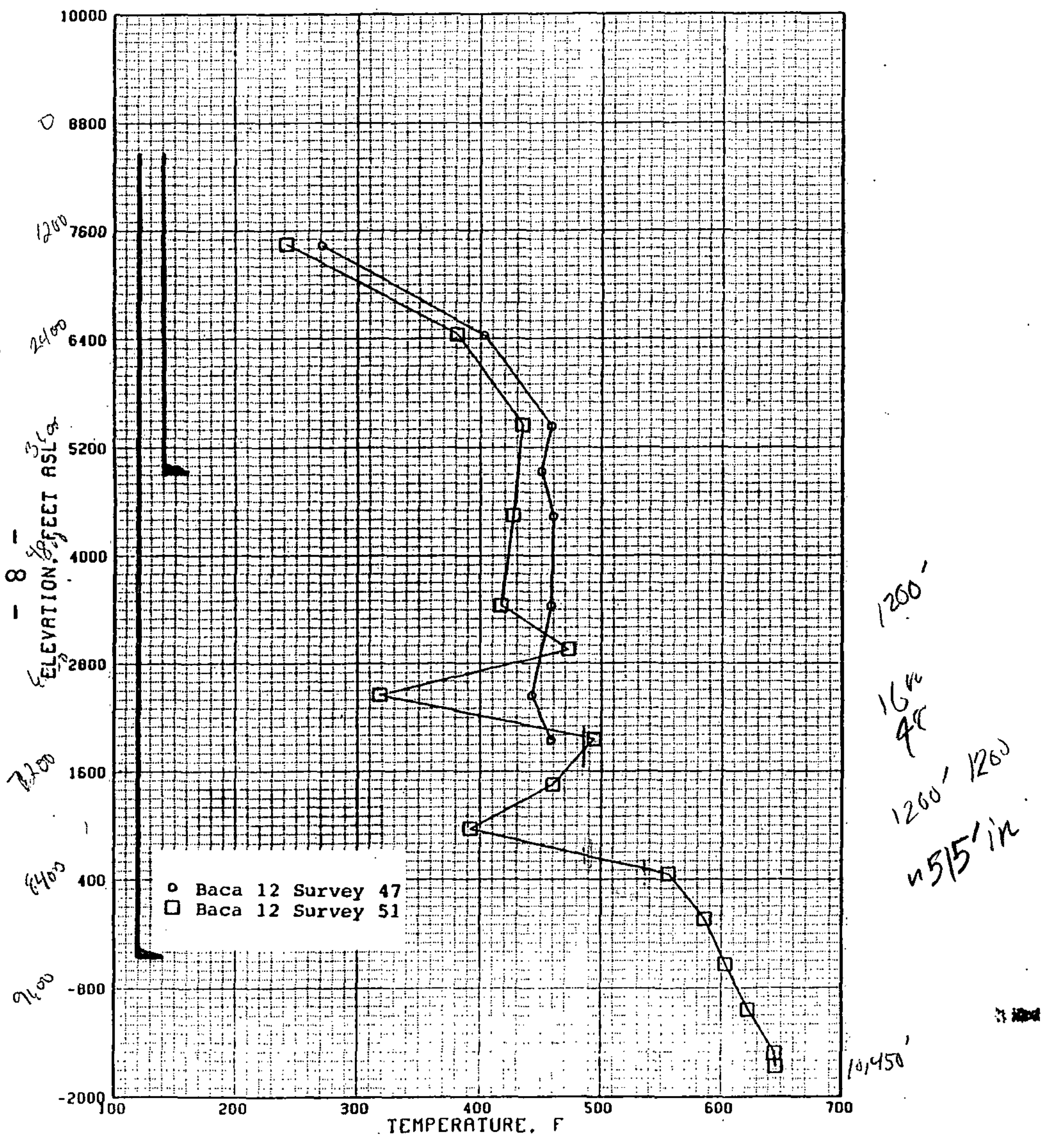
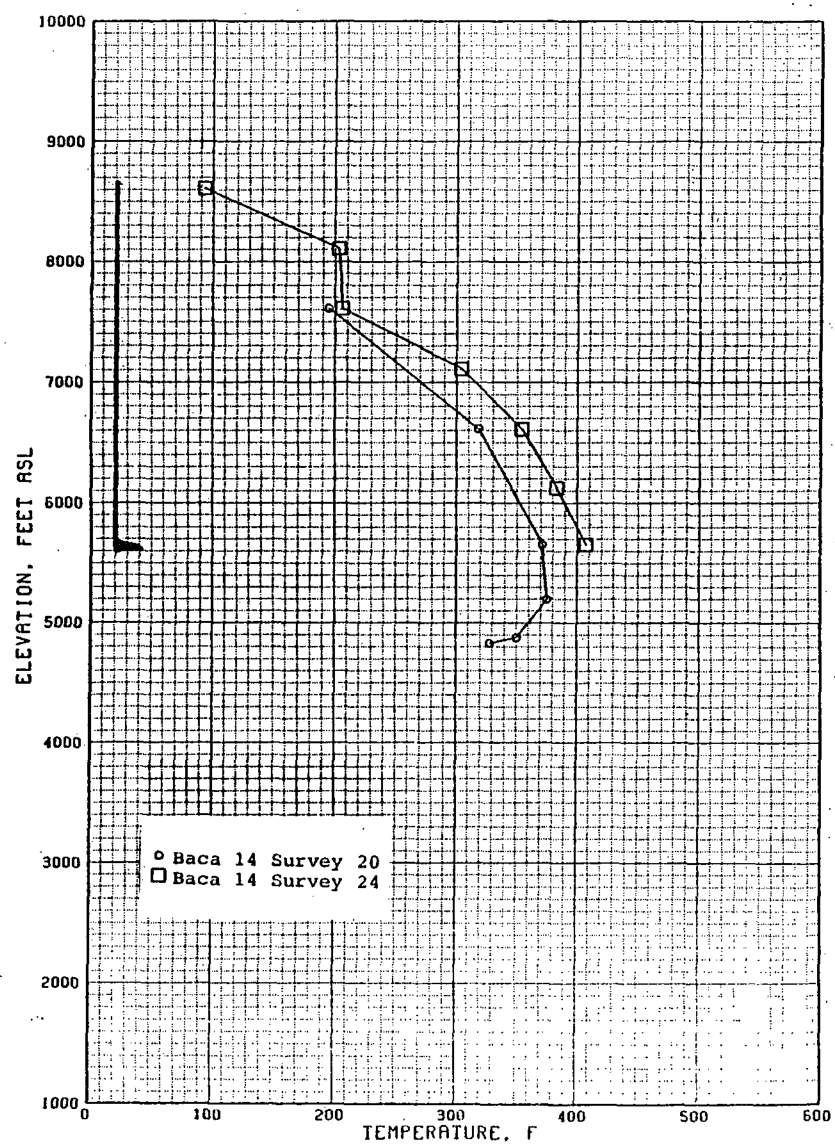


FIGURE 5.1.1-7
TEMPERATURE GRADIENTS FOR BACA NO. 14. SURVEYS 20 AND 24



Baca No. 14 is a relatively cold well with a temperature reversal below 5700' MSL. This reversal corresponds to the bottom of the cemented casing which would seem to indicate that it was the result of an extensive cold water injection. However, the consistency of the temperature logs suggests that the temperature reversal is a characteristic of the well and is not a phenomenon created by cold water injection.

In summary the Redondo Creek field contains three southern wells - Baca 5A, 12 and 14 - which are cooler than the remaining wells at comparable depths. If these wells are included in an areal temperature trend analysis, the temperature of the Redondo Creek field increases to the northern end of the field.

5.1.2 Static Pressure

The static pressures of the Redondo Creek wells have been measured using two methods: 1) the Sperry-Sun pressure observations during the four interference tests and 2) Kuster wireline surveys run into static wells. The Sperry-Sun pressure observations are more accurate than the Kuster readings. While theoretically the buildup/falloff tests should extrapolate to an accurate static pressure, various factors discussed in Section 5.3 tend to distort the results.

The Sperry-Sun instrumentation is discussed in Section 5.5. An expansion chamber hung in the wellbore is connected to the surface by a capillary tube, both of which are filled with nitrogen. The surface pressure of the nitrogen system is monitored and a temperature survey is used to calculate the nitrogen gradient and hence the pressure at the expansion chamber.

The four interference tests conducted in the Redondo Creek field have resulted in eleven out of the nineteen wells being fitted with Sperry-Sun instrumentation. Tables 5.1.2-1 and 5.1.2-2 show ten of these wells - minus Baca No. 10 - and the values used to calculate the wellbore pressures at 5500' MSL datum. Baca No. 10 was not included in the tables because the setting depth of its Sperry-Sun expansion chamber was substantially lower than 5500' MSL datum.

The Kuster pressure tools used in the Redondo Creek field are accurate to with ±10 psi and are subject to even greater inaccuracy if one pressure recording element is compared against another pressure element. Table 5.1.2-1 shows the absolute inaccuracy of the various Kuster pressure elements as compared against the Sperry-Sun tools. Figure 5.1.2-1 contains pressure gradients obtained from several pressure elements, but even considering the error introduced by the use of different pressure elements, a basic pressure gradient trend exists for all Redondo Creek wells.

TABLE 5.1.2-1
COMPARING SPERRY-SUN PRESSURES TO
KUSTER TOOL PRESSURES

WELL NAME	SPERRY-SUN CHAMBER SETTING DEPTH K.B.	T.V.D.	SPERRY-SUN PRESSURES WELLHEAD PSIA	BOTTOMHOLE PSIG	KUSTER TOOL SURVEYS SURVEY NUMBER	DATE	ELEMENT NUMBER	PRESSURE PSIG	ΔP PSI
Baca No. 4	3800	3794	790	848	73	9/11/80	14191	846	- 2
Baca No. 5A	3000	2996	386	405	17	5/08/81	9235	421	+16
Baca No. 6	2100	2098	411	420	49	5/08/81	9235	429	+ 9
Baca No. 13	3850	3800	802	867	48	3/02/81	14191	860	- 7
Baca No. 14	2500	2486	527	550	24	6/17/81	9235	567	+17
Baca No. 18	3650	3573	865	926	16	7/06/81	9235	948	+22
Baca No. 19	3500	3458	693	740	47	1/26/82	22390	718	-22
Baca No. 20	3700	3642	800	859	12	5/07/81	9235	878	+24
Baca No. 23	3200	3183	750	799	10	5/26/81	9235	813	+14
Baca No. 24	3000	2995	689	727	20	1/29/82	22390	704	-23

TABLE 5.1.2-2
CONVERSION OF SPERRY-SUN PRESSURES TO
5500' MSL DATUM

WELL NAME	ELEVATION OF K.B. MSL FT	T.V.D. OF THE 5500' MSL DATUM FT	T.V.D. OF SPERRY-SUM CHAMBER FT	WELLBORE TEMPERATURE °F	HYDROSTATIC GRADIENT PSI/FT	SPERRY-SUN PRESSURES BOTTOMHOLE PSIG	CORRECTED TO 5500' MSL PSIG
Baca No. 4	9335	3835	3794	500	.3404	848	862
Baca No. 5A	9308	3808	2996	365	.3816	405	715
Baca No. 6	8740	3240	2098	480	.3472	420	816
Baca No. 13	9308	3808	3800	500	.3404	867	870
Baca No. 14	8621	3121	2486	385	.3774	550	789
Baca No. 18	8754	3254	3573	460	.3543	926	813
Baca No. 19	9139	3639	3458	470	.3507	740	803
Baca No. 20	9089	3589	3642	475	.3490	859	840
Baca No. 23	8759	3259	3183	450	.3580	799	826
Baca No. 24	8764	3264	2995	495	.3421	727	819

TABLE 5.1.2-3
CONVERSION OF KUSTER TOOL PRESSURES
TO 5500' MSL DATUM

WELL NAME	ELEVATION OF K.B. MSL FT	T.V.D. OF THE 5500' MSL DATUM FT	SURVEY DATE	PRESSURE ELEMENT	KUSTER TOOL PRESSURE 5500' MSL PSIG	5500' MSL CORRECTED PSIG
Baca No. 10	8752	3252	6/02/77	9222	828	828
Baca No. 11	9082	3582	10/05/77	9222	866	866
Baca No. 12	8451	2951	6/09/80	14191	783	788
Baca No. 15	9132	3632	6/24/82	22315	810	810
Baca No. 16	9637	4137	10/21/80	14191	862	867
Baca No. 22	9295	3795	1/22/81	14191	838	843

FIGURE 5.1.2-1
PRESSURE GRADIENTS FOR ALL
REDONDO CREEK WELLS

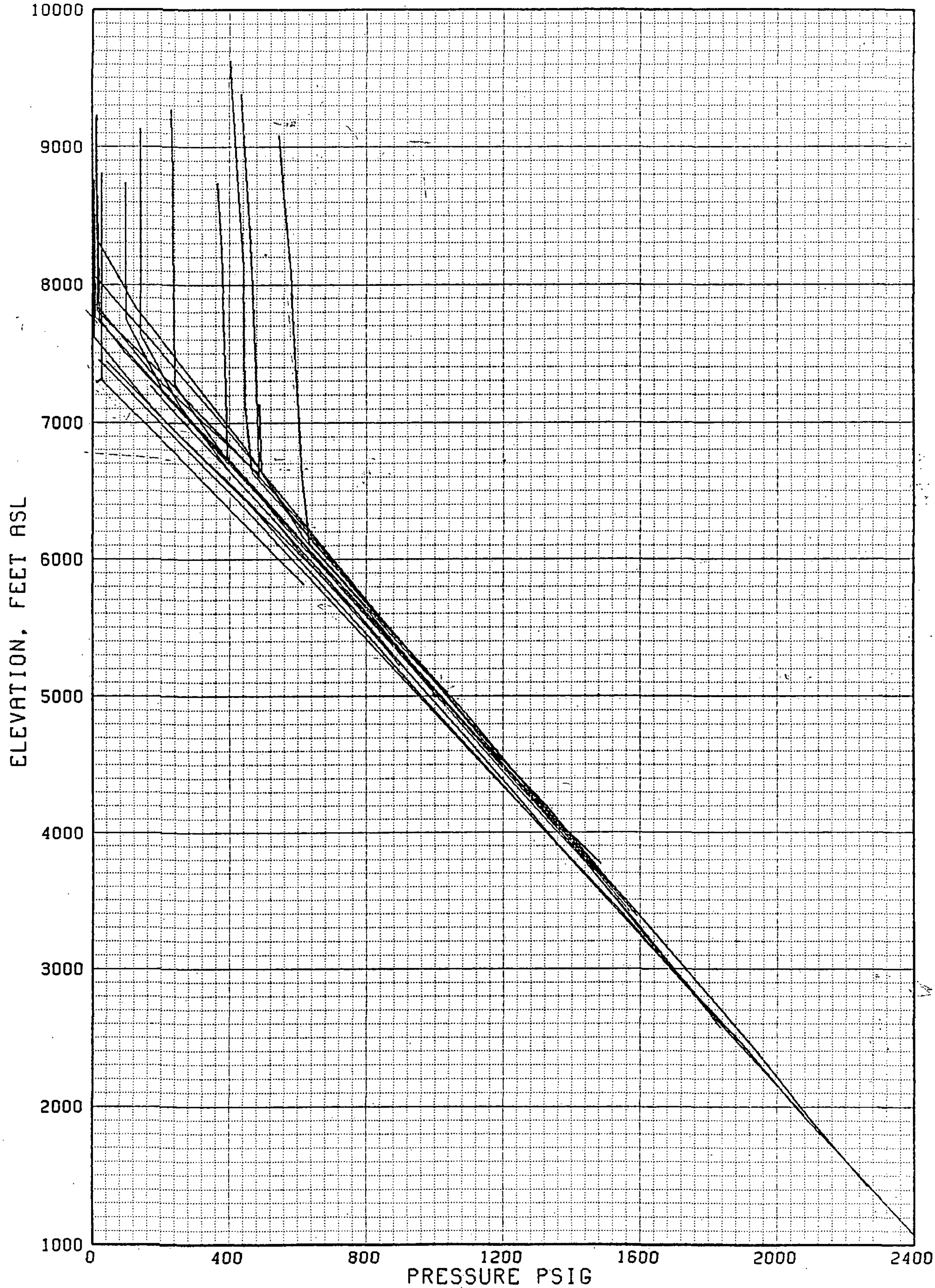


Table 5.1.2-3 contains the data used to calculate the 5500' MSL datum pressures for six of the remaining nine Redondo Creek wells. These calculations include element adjustment as determined from Table 5.1.2-1, and do not include results for Baca Nos. 9, 17, and 21.

Figure 5.1.2-2 shows the areal pressure distribution of the Redondo Creek wells at the 5500' datum. This distribution includes the results of Tables 5.1.2 and 5.1.3, revealing an increase in pressure from the south to the north. Since there is also a general increase in temperature from south to north, Figure 5.1.2-2 indicates that the Redondo Creek wellbore pressures are controlled by a deep reservoir. For example, if the Redondo Creek field were pressure controlled by a reservoir at 3000 feet MSL, the static pressure calculated at any higher datum would be lower for a cold well than a hot well due to the magnitude of their respective hydrostatic gradients.

Figures 5.1.2-3, 5.1.2-4 and 5.1.2-5 show the pressure gradients of static Redondo Creek wells surveyed with elements 14191, 9235 and 9222. An attempt to find a pivot point around which all Redondo Creek wells moved was unsuccessful, (as were attempts to identify "static" wellbore flow) due to the absence of sufficient tool accuracy which is needed for these high resolution techniques. However, considering the wellbore temperature of the various wells, and the general convergence at depth of the pressure gradients in Figures 5.1.2-3, 5.1.2-4 and 5.1.2-5, supporting evidence is obtained for the hypothesis that the wellbore pressures appear to be controlled by a reservoir pressure at depth.

FIGURE 5.1.2-2
BACA WELL INTERSECTION AT 5500' ASL
WITH STATIC PRESSURES, PSIG

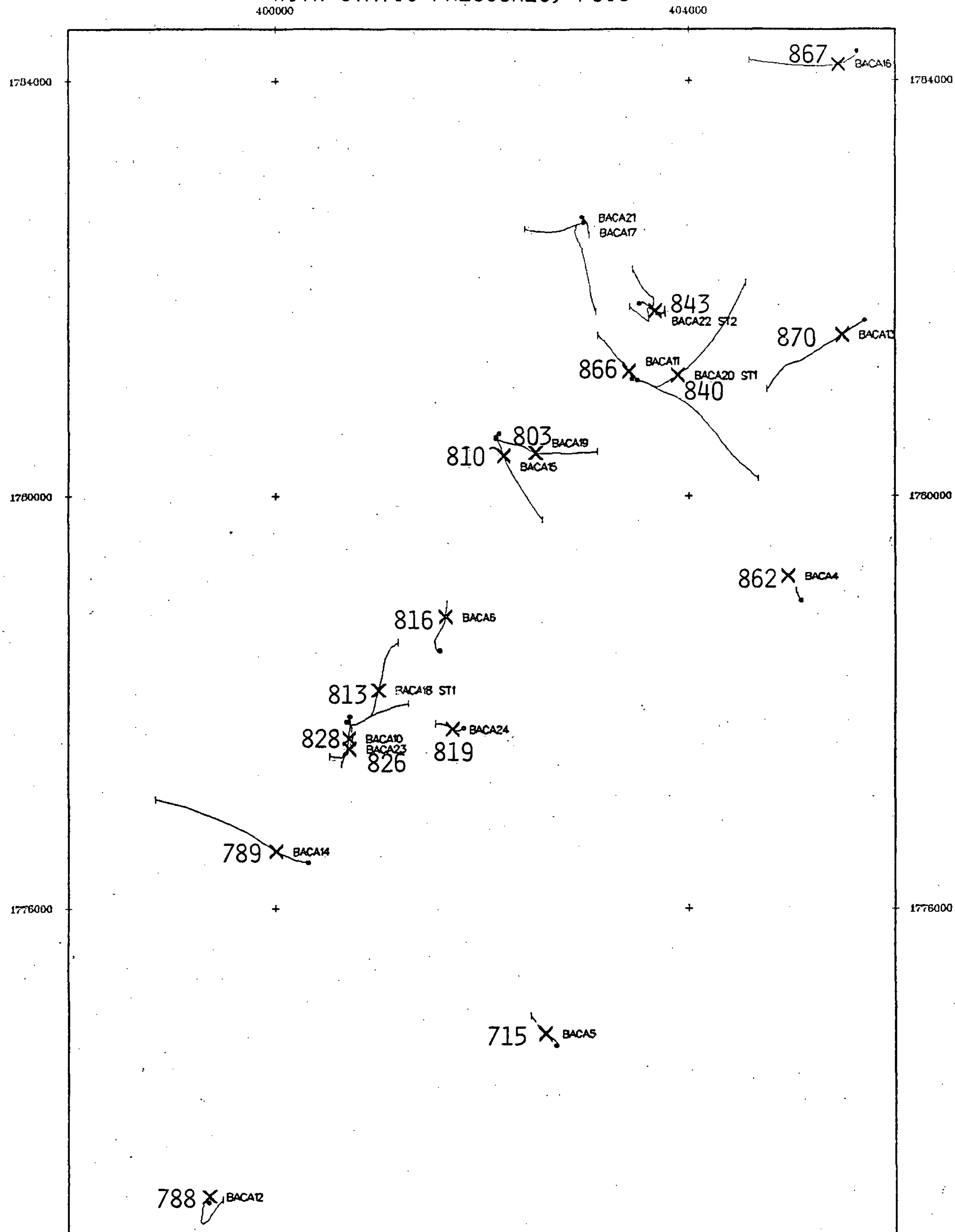
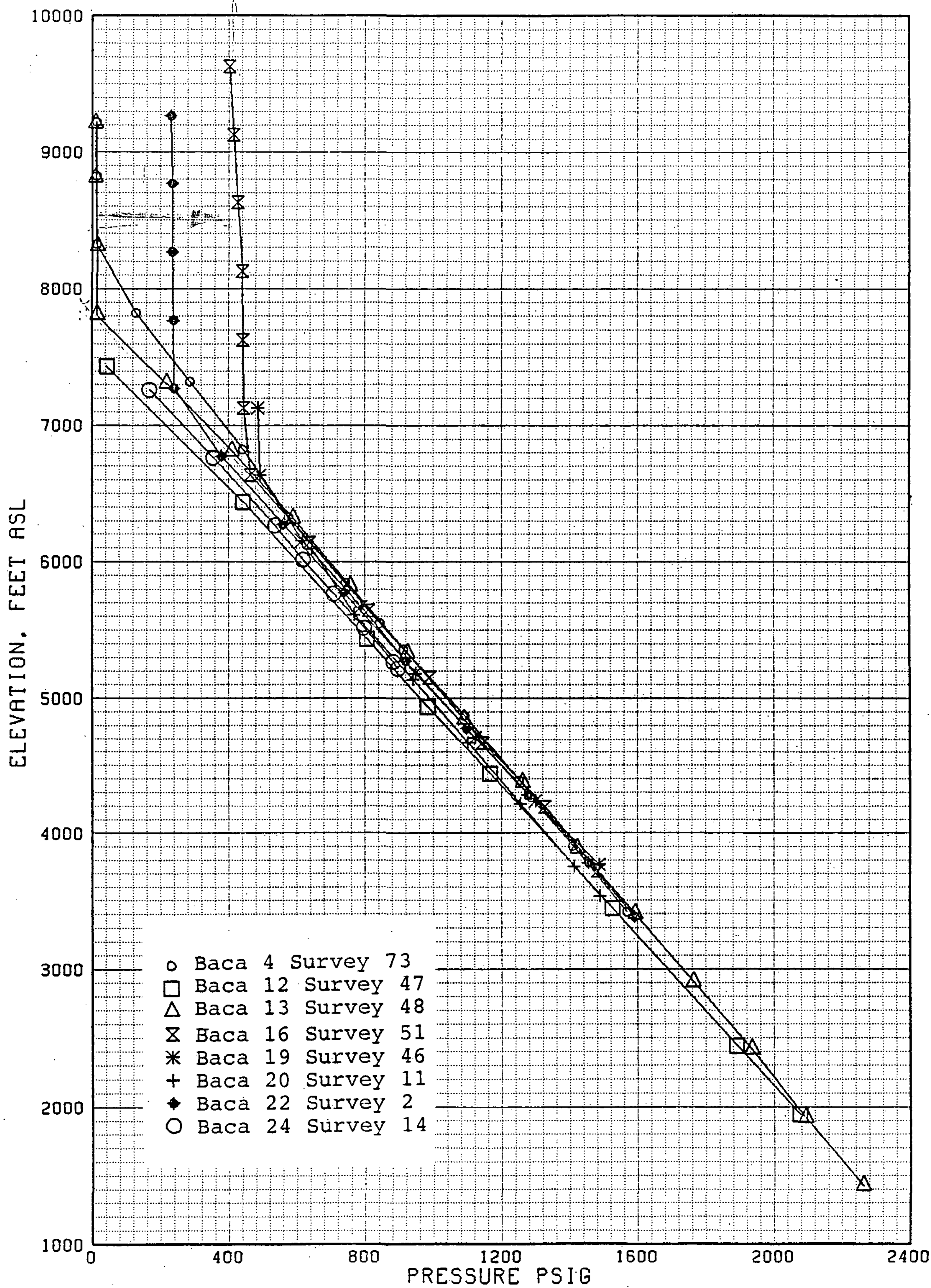


FIGURE 5.1.2-3

PRESSURE GRADIENTS FOR BACA NOS. 4,12,13,16,19,20,22,24

USING ELEMENT 14191



CASING
saturation pressure temp [250-300°C]
100°C ④
5.5 rainwater

FIGURE 5.1.2-4
PRESSURE GRADIENTS FOR BACA NOS. 5A,6,14,18,20,21,23
USING ELEMENT 9235

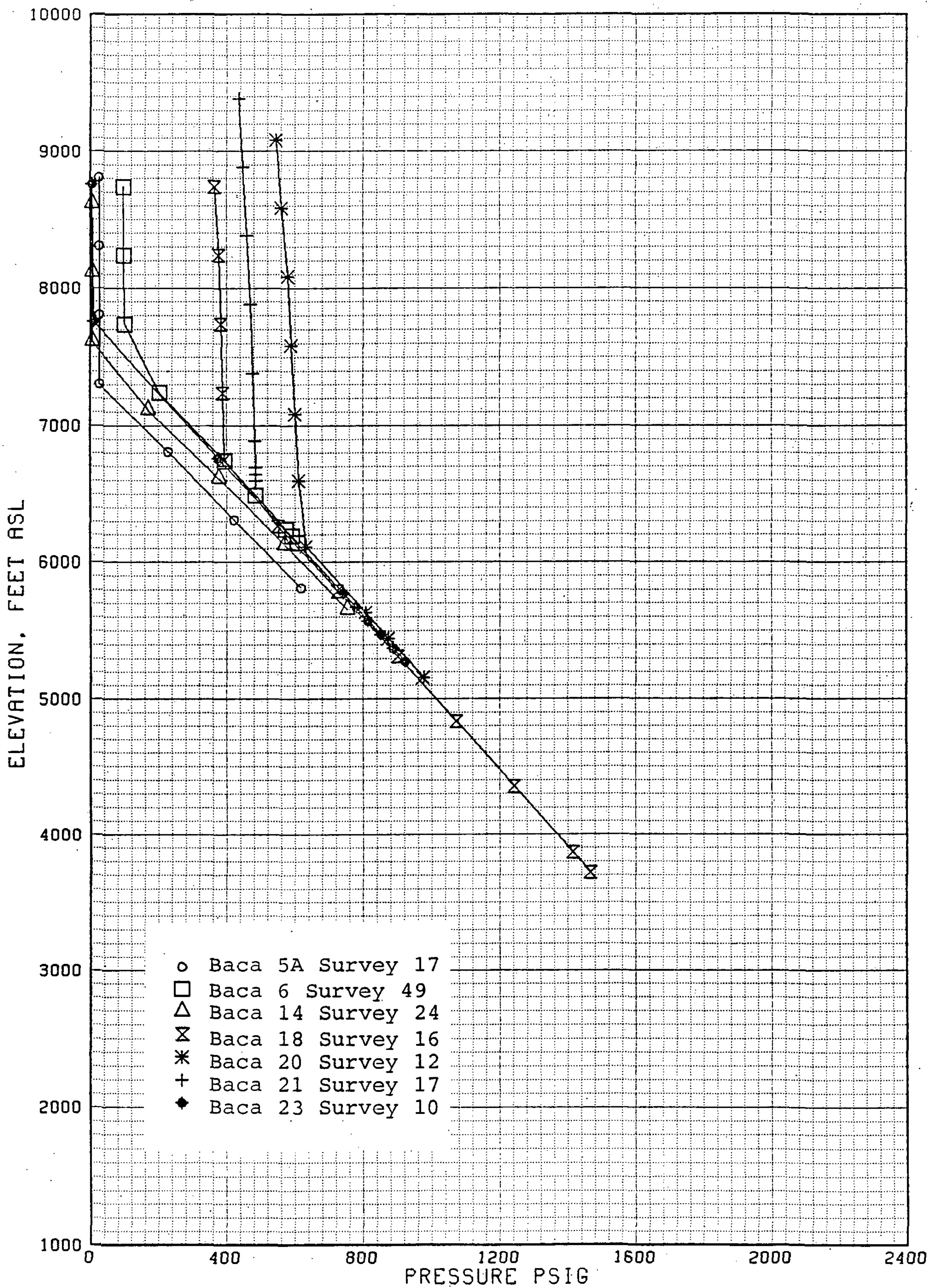
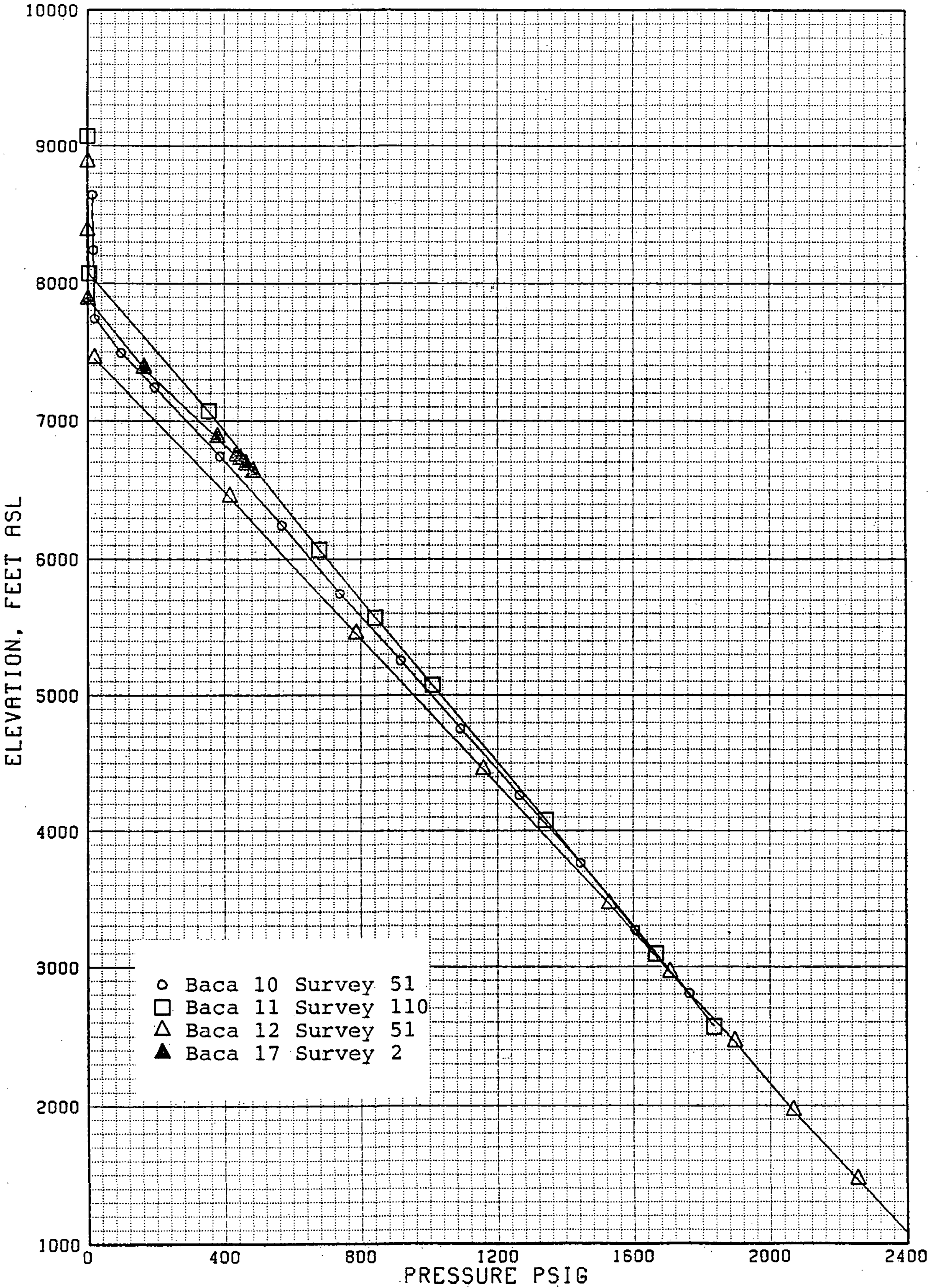


FIGURE 5.1.2-5
PRESSURE GRADIENTS FOR BACA NOS. 10, 11, 12, 17
USING ELEMENT 9222



5.2 WELL TESTING

5.2.1 Flow Tests

Flow tests in the Redondo Creek Field have consisted of two-phase tests, separator tests, rig tests and two drillstem tests. A tabulation of all production tests conducted in the Redondo Creek Field is presented in Table 5.2.1-1. The majority of the early production tests - up to and including 1977 - have been presented in earlier reports (Union, 1978) and will not be discussed here.

The purpose of a two-phase test is to establish that a well is productive and to provide a preliminary estimate of its flow rate. The test method consists of flowing a well to the reserve pit and measuring the flow rate with an orifice meter. By monitoring the pressure drop across the orifice, and assuming a percent flash, an approximate flow rate is calculated using the Murdock Equation. The steam rates calculated with this method are fairly accurate but the water rates - and hence the total mass rates - determined can only be considered approximate. Certain later flow tests gave better flow rates estimates by incorporating a mini-separator which extracted a small sample of production fluid from the flow line and used this to approximate the steam percentage of the flow stream.

Separator tests provide a means of evaluating flow characteristics of a well by determining the percent flash of the well at any point in time, at any producing pressure. Wells with low flow rates have not been subjected to separator tests due to operational problems. Wells which have been tested through a separator are Baca Nos. 4, 6, 11, 13, 15, 19, 20 pre-frac, 21, 22 and 24.

A typical separator test consisted of flowing a well into a separator vessel and measuring the separated steam and water rates individually with continuous recording orifice pressure meters. Steam enthalpy and quality were determined with a throttling calorimeter.

The first flow test performed on a well has generally been run before the drilling rig has been moved off of the hole, and is known as a rig test. A rig test is short in duration and is only used as a gross generalization of the type of well; producer or non-producer. The production is usually flowed through a two-phase orifice much like a two-phase test, but occasionally the only measurement of flow is determined by calculating the increasing pit volume or using a "bucket test".

TABLE 5.2.1-1
REDONDO CREEK FLOW TEST SUMMARY
THROUGH DECEMBER, 1982

WELL	DATE	FLOW TIME HRS.	WHP PSIG	SEP. PRESS. PSIG	PROD FLUID QUALITY %	TOTAL MASS FLOW LB/HR	EFF. ENTHALPY BTU/LB	REMARKS
B4-1	08/13/73-08/22/73	228	204	175	26.0	145,800	569.5	
B4-2	09/10/73-11/13/73	1538	120	113	27.5	172,500	556.1	
B4-3	03/31/81-07/22/81	2715	131	124	29.97	140,926	582	
B4-4	06/09/82-06/14/82	118.48	141	122	27	161,000	555	@ 117 hrs
B4-5	06/30/82-07/12/82	286.7	141	122	30	158,800	581	@ 286 hrs
B6-1	10/08/72-10/15/72	166	137	92	24.4	153,500	517	
B6-2	10/25/72-11/04/72	190	92	69.5	27.6	146,900	530.9	
B6-3	11/06/72-01/16/73	1700	515	37.75	30.7	147,700	532.2	
B6-4	06/05/75-06/24/75	428	58	--	30 (Est)	248,000 (Est)	--	Two Phase Test
B6-5	07/03/75-07/21/75	428	53	--	30.3 (Est)	240,000 (Est)	--	Two Phase Test
B6-6	07/25/75-08/19/75	584	107.5	100.5	22	175,000	500.9	
B6-7	10/03/75-12/05/75	1505.3	95	90	24.5	156,000	515	Interference Test
B10-1	08/26/75-09/03/75	215	31	--	34.1 (Est)	126,000	--	Two Phase Test
B11-1	01/08/74-01/09/74	24	--	140	33.4	480,500	619.9	
B11-2	01/11/74-01/25/74	311	121	105	49.6	205,000	746.6	
B11-3	01/29/74-01/30/74	27	143					No Data
B11-4	02/01/74-02/24/74	546	131	115	41.1	271,400	675.9	
B11-5	06/26/74-09/25/74	2182	138	126.5	35.6	267,100	633.1	@ 745 hrs
			127	114	32.9	252,000	604	@ 1440 hrs
			129	124	26.7	164,300	556.4	@ 2182 hrs

TABLE 5.2.1-1
REDONDO CREEK FLOW TEST SUMMARY
THROUGH DECEMBER, 1982
(Continued)

WELL	DATE	FLOW TIME HRS.	WHP PSIG	SEP. PRESS. PSIG	PROD FLUID QUALITY %	TOTAL MASS FLOW #/HR	EFF. ENTHALPY BTU/#	REMARKS
B11-6	11/08/74-11/17/74	293	120	101	39	305,900	651	
B11-7	10/28/75-04/19/76	4073.3	108	98	38.8	113,000	647	Interference Test
B12-1	12/06/76-12/15/76	240	14	--	16 (Est)	96,900	--	Two Phase Test
B13-1	11/30/74-01/06/75	792	62	--	29.6 (Est)	200,000	--	Two Phase Test
B13-2	01/10/75-02/25/75	1103	124	115	25.4	303,700	537.8	@ 1100 hrs
B13-3	05/14/75-06/06/75	471	110	92.5	31.6	257,200	581	
B13-4	06/13/75-06/20/75	163	110	87	27	273,200	537	@ 115 hrs
		--	190	33	20.5	161,000	432	@ 159 hrs
B13-4A	10/03/75-04/27/76	4967.5	90	74	27.5	205,000	531	Interference Test
B13-5	03/05/81-04/21/81	1174	1505	125	26.59	215,685	553	@ 960 hrs
			133	100	29.72	213,234	568	@ 1174 hrs
B13-6	07/21/81-12/18/81	3594	140	100	26.18	205,137	537	@ 881 hrs
			152	126	23.29	181,943	525	@ 3594 hrs
B13-7	02/16/82-04/13/82	1343.1	148.5	121	23.3	187,000	523	@ 1321 hrs
B13-8	06/02/82-06/07/82	119.9	138	116	24.7	205,700	533	@ 118 hrs
B13-9	06/24/82-07/06/82	288.1	138	122.5	24.7	187,200	536	@ 288 hrs
B13-10	08/11/82-08/15/82	97.75	150	--	25 (Est)	291,900	--	Two Phase Test
B13-11	09/14/82-09/20/82	145.25	150	--	25 (Est)	291,300	--	Two Phase Test
B15-1	06/27/75-07/14/75	429	63	--	70 (Est)	169,400	--	Two Phase Test
B15-2	10/07/76-01/06/77	2185	110	100	61	149,000	850	

TABLE 5.2.1-1
REDONDO CREEK FLOW TEST SUMMARY
THROUGH DECEMBER, 1982
(Continued)

WELL	DATE	FLOW TIME HRS.	WHP PSIG	SEP. PRESS. PSIG	PROD FLUID QUALITY %	TOTAL MASS FLOW #/HR	EFF. ENTHALPY BTU/#	REMARKS
B15-3	07/21/82-07/26/82	118.83	159	123	34.1	282,700	618	@ 118 hrs
B15-4	08/30/82-09/08/82	215.73	187	128	35.9	227,600	636	@ 215 hrs
B17-1	10/13/78-10/15/78	13	.5	--	--	15,000-30,000	--	Rig Test
B17-2	11/12/78-11/13/78	.33	140	--	--	175,000	--	Rig Test
B18-1R	03/12/79	3	35	--	--	28,000-56,000	--	Rig Test
B18-1	04/24/79	8.5	26	--	25 (Est)	40,000	--	Two Phase Test
B18-2	06/29/79	4	22	--	60 (Est)	50,000	--	Two Phase Test
B19-1	11/15/79-11/27/79	288	21	--	30 (Est)	109,904	--	Two Phase Test
					50 (Est)	69,435	--	Two Phase Test
B19-2	03/26/80-04/02/80	172	43	--	30 (Est)	138,388	--	
					50 (Est)	88,008	--	@ 169 hrs
B19-3	04/07/80-05/14/80	886	9	--	30 (Est)	54,102	--	2Q @ 842 hrs
					50 (Est)	33,951	--	
			40	--	30 (Est)	168,513	--	2Q @ 885 hrs
					50 (Est)	107,133	--	
B19-4	07/28/80-08/19/80	524	34	--	30 (Est)	128,618	--	Two Phase Test
					50 (Est)	81,442	--	
B19-5	02/20/81-02/27/81	169	39	--	25 (Est)	163,563	--	Two Phase Test
					35 (Est)	122,442	--	
B19-6	09/23/82-09/27/82	92.75	45	21.5	20.5	158,600	415	@ 92 hrs

TABLE 5.2.1-1
REDONDO CREEK FLOW TEST SUMMARY
THROUGH DECEMBER, 1982
(Continued)

WELL	DATE	FLOW TIME HRS.	WHP PSIG	SEP. PRESS. PSIG	PROD FLUID QUALITY %		TOTAL MASS FLOW #/HR	EFF. ENTHALPY BTU/#	REMARKS
B19-7	10/07/82-10/18/82	263.75	46	22.5	20.4		163,473	416	@ 263 hrs
B20-1	08/17/80	7.5	30	--	30	(Est)	142,866	--	Two Phase Test
					50	(Est)	90,165		
B20-2	08/28/80	2.55	85	--	30	(Est)	356,000	--	Two Phase Test
					50	(Est)	217,105	--	
B20-3	09/16/80-09/17/80	27.7	125	118	62		81,589	865	
B20-4	09/24/80-01/06/81	2496	129	100	55.6		54,751	706	@ 2068 hrs
			116	75	56.4		56,128	793	@ 2495 hrs
B20-DST	10/05/81	6.3	--	--	--		21,000	--	Drillstem Test
B20-5	10/26/81-11/09/81	335.5	24	--	86	(Est)	47,429	--	Two Phase Test
B20-6	08/03/82-08/05/82	54.1	27.5	--	80	(Est)	53,700	--	Two Phase Test
B20-7	08/26/82-08/30/82	96.17	22	--	80	(Est)	46,700	--	Two Phase Test
B21-1	10/01/80	4.5	138	--	60	(Est)	204,136	--	Two Phase Test
B21-2	10/02/80	9.25	55	--	60	(Est)	179,863	--	Two Phase Test
B21-3	11/18/80	7.17	75	--	60	(Est)	200,300	--	Two Phase Test
B21-4	11/25/80-11/29/80	94.8	23	--	80	(Est)	60,273	--	Two Phase Test
B21-5	02/03/81-03/21/81	1107.25	77	75	95		35,233	1139	@ 312 hrs
			13.75	--	90	(Est)	35,320	--	Two Phase Test
B22-1	12/11/80	4.75	47	--	40	(Est)	94,205	--	Two Phase Test
B22-2	12/13/80	9.25	43	--	40	(Est)	82,290	--	Two Phase Test

TABLE 5.2.1-1
REDONDO CREEK FLOW TEST SUMMARY
THROUGH DECEMBER, 1982
(Continued)

WELL	DATE	FLOW TIME HRS.	WHP PSIG	SEP. PRESS. PSIG	PROD FLUID QUALITY %		TOTAL MASS FLOW #/HR	EFF. ENTHALPY BTU/#	REMARKS
B22-3	01/30/81-01/31/81	32.75	8	--	40	(Est)	49,319	--	Two Phase Test
B22-4	02/01/81-02/24/81	554	15	13.75	75.7		20,255	928	@ 383 hrs
B23-1	02/22/81	10.6	27	--	60	(Est)	42,105	--	2Q @ 9 hrs
B23-DST	03/26/81	5.7	--	--	--		21,000	--	Drillstem Test
B23-2	03/28/81-03/30/81	49	51	--	50	(Est)	98,894	--	2Q @ 48.5 hrs
B23-3	04/13/81-04/23/81	243	34.5	--	70	(Est)	51,110	--	Two Phase Test
B23-4	05/01/81-05/12/81	265.42	34.5	--	50.63	(Est)	68,439	--	Two Phase Test
B24-1	06/29/81	6.1	43	--	40	(Est)	93,243	--	2Q @ 2 hrs
B24-2	07/01/81-07/07/81	147.2	124	--	26.5	(Est)	332,582	--	Two Phase Test
B24-3	07/17/81-09/15/81	1436	156	150	18.6		171,376	495	@ 430 hrs
			131	125	20.8		163,805	503	@ 1365.5 hrs
B24-4	06/16/82-06/21/82	119.83	148	125	20		281,300	492	@ 119 hrs
B24-5	07/08/82-07/19/82	263.8	142	122	19.6		259,800	491	@ 263 hrs

Drillstem tests have been run on the two hydraulically stimulated wells - Baca Nos. 20 and 23 - and are discussed in Section 4.4.2.

Following is a discussion of all flow tests which have been conducted since 1978. The flow rates, surface pressures and percent steam flash (quality) are discussed for each flow test. Figures Nos. 5.2.1-1 through 5.2.1-11 are schematics of various flow tests for Baca Nos. 4, 13, 15, 19, 20, 21, and 24. The rates discussed in the text are the total mass rates of the wells, unless specified otherwise. The surface pressures reported, psig, are dependent upon the type of test. For a separator test, two pressures are reported, the wellhead pressure and the separator pressure. 140/122 implies a wellhead pressure of 140 psig and a separator pressure of 122 psig. For two-phase tests only the wellhead pressure is relevent.

Baca No. 4 - Five (5) flow tests have been run on Baca No. 4. The first two flow tests were run prior to 1978 and are included in the earlier report.

Flow Test 3, run during the 1981 Interference Test, lasted 113 days and was ended to alleviate water disposal problems that arose in conjunction with flowing Baca Nos. 4, 13 and 24 simultaneously. The flow test was switched to the separator after 24 hours of flow, with an initial separator flow rate of 176,100 lb/hr at pressures of 132/125 and a 33% flash. A partially failed rupture disk eliminated accurate flow readings from July 1 to July 14, but assuming a constant flow rate during this interval, a total of 394×10^6 lbs total mass was produced at an average flow rate of 145,000 lb/hr total mass.

Flow Test 4 was a five day separator test run during June 1982. The initial separator flow rate was 219,200 lb/hr total mass at pressures of 156/126 and a calculated flash of 25%. The flow rate immediately before shut-in was 161,000 lb/hr at 27% flash and pressures of 141/122 psig. 20.7×10^6 lb of total mass were produced during the flow test, at production rates slightly higher than those seen during Flow Test 3.

The flow rates of Baca No. 4 during Flow Test 5 were almost identical to the flow rates of Flow Test 4. The flow rate immediately before shut-in was 158,800 lb/hr at pressures of 131/122 and a 30% flash. 46.76×10^6 lb of total mass were produced during the twelve day separator test, at an average rate of 163,100 lb/hr total mass.

Baca No. 13 - Baca No. 13 has produced more mass than any other Redondo Creek well. Of the eleven Baca No. 13 flow tests, five were conducted prior to 1978 and are included in the earlier report.

FIGURE 5.2.1-1
BACA NO. 4 FLOW TEST 3

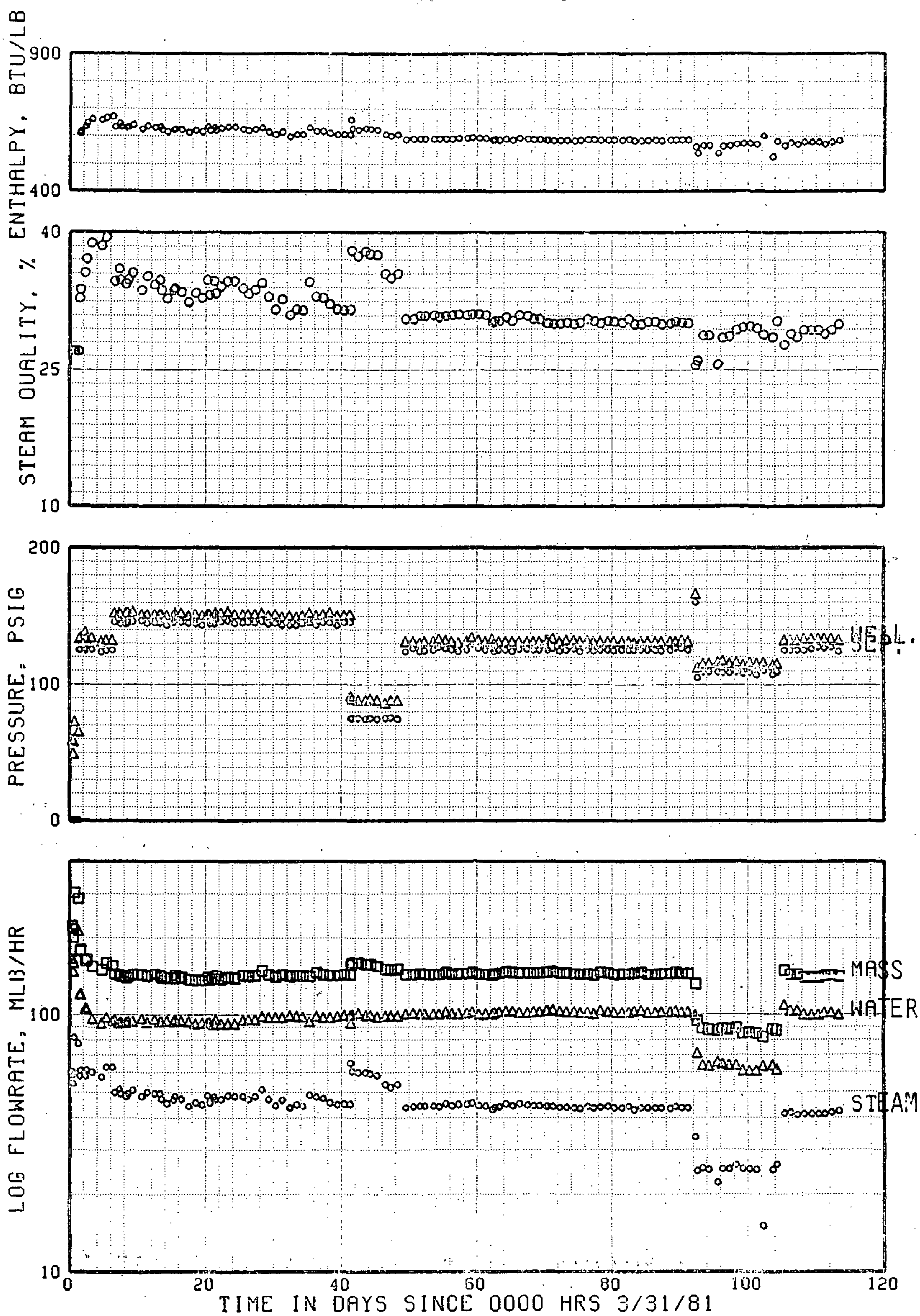
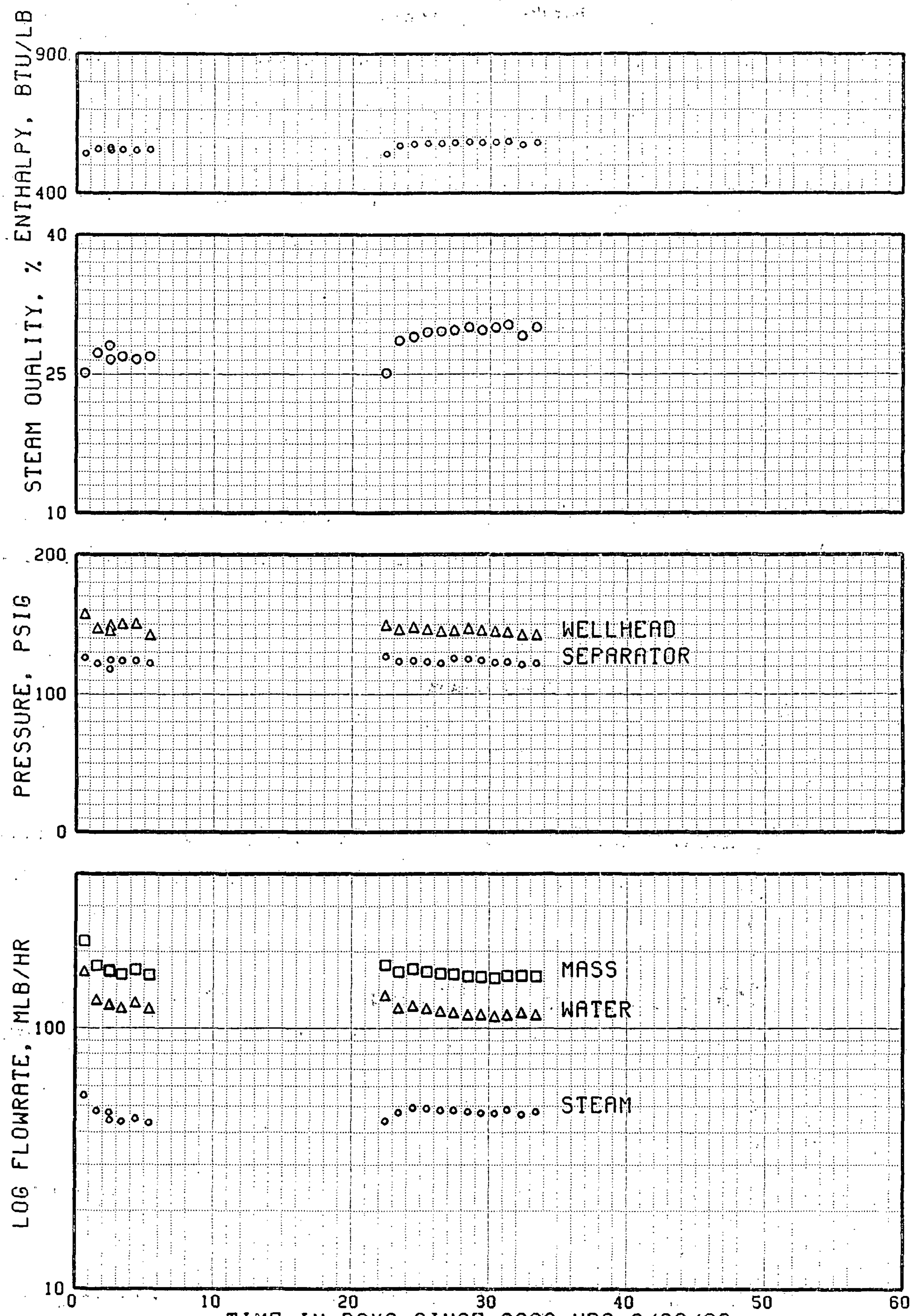


FIGURE 5.2.1-2
BACA NO. 4 FLOW TESTS 4 AND 5



Flow Test 5 was started during the end of the 1980-1981 Interference Test. This 47-day test was initially flowed through a two-phase line at a rate of 400,000 lb/hr against a wellhead pressure of 167 psig, assuming a steam fraction of 30%. The well was switched to the separator after four days but the separator was not working efficiently. The problem was resolved after 16 days of flow which included two short shut-in intervals. At the end of the test Baca No. 13 was flowing 214,000 lb/hr at pressures of 133/100 and a 29.7% flash. 273.3×10^6 lb of total mass were produced during the 47 days, for an average rate of 242,000 lb/hr.

Flow Test 6 was started during the middle and continued to the end of the 1981 Interference Test. This 150-day flow period is the longest flow test performed in the Redondo Creek Field since 1978. The flow rates are smaller than Flow Test 5 due to a wellbore bridge which formed between the two flow tests, restricting flow below 6000'. Flow Test 6 was switched to the separator after 16 hours, showing an initial rate of 250,000 lb/hr at pressures of 150/99 and 23.6% flash. At the end of the test Baca No. 13 was flowing at 182,000 lb/hr at pressures of 150/126 and 23.2% flash. 690.8×10^6 lb of mass were produced at an average rate of 192,000 lb/hr.

Baca No. 13 was produced for 56 days during the first part of the 1982 Interference Test. The initial flow rate of Flow Test 7 was 208,000 lb/hr at pressures of 167/141 and a 20% steam flash. This initial rate is significantly lower than the initial flow rate of Flow Test 6. The decrease is felt to be caused by the short time span between the end of lengthy Flow Test 6 and the start of Flow Test 7. The final flow rate of Flow Test 7 was 187,000 lb/hr at pressures of 149/121 and a steam flash of 23%. The total production during the flow test was 260×10^6 lb at an average rate of 193,600 lb/hr.

Four (4) more flow tests occurred during the second stage of the 1982 Test. Flow Tests 8 and 9 were designed to be of different flow times to facilitate identification of non-radial, non-infinite acting behavior during the build-up (Section 5.3.1).

Flow Test 8 produced 29×10^6 lbs of total mass during five days of production, for an average rate of 242,200 lb/hr. The initial separator flow rate of 277,700 lb/hr at pressures of 149/127 and 16% flash, declined to 205,700 lb/hr at pressures of 138/116 and a flash of 25% immediately before shut-in.

Flow Test 9 had an initial separator flow rate of 214,800 lb/hr at pressures of 143/122 and 26% flash. This rate declined to 187,200 lb/hr at pressures of 138/122 and 25% flash at the end of the twelve day flow period. During Flow Tests 8 and 9, 26.8×10^6 and 57.8×10^6 lb of total mass were produced at average flow rates of 223,200 lb/hr and 200,600 lb/hr respectively.

FIGURE 5.2.1-3
BACA NO. 13 FLOW TEST 5

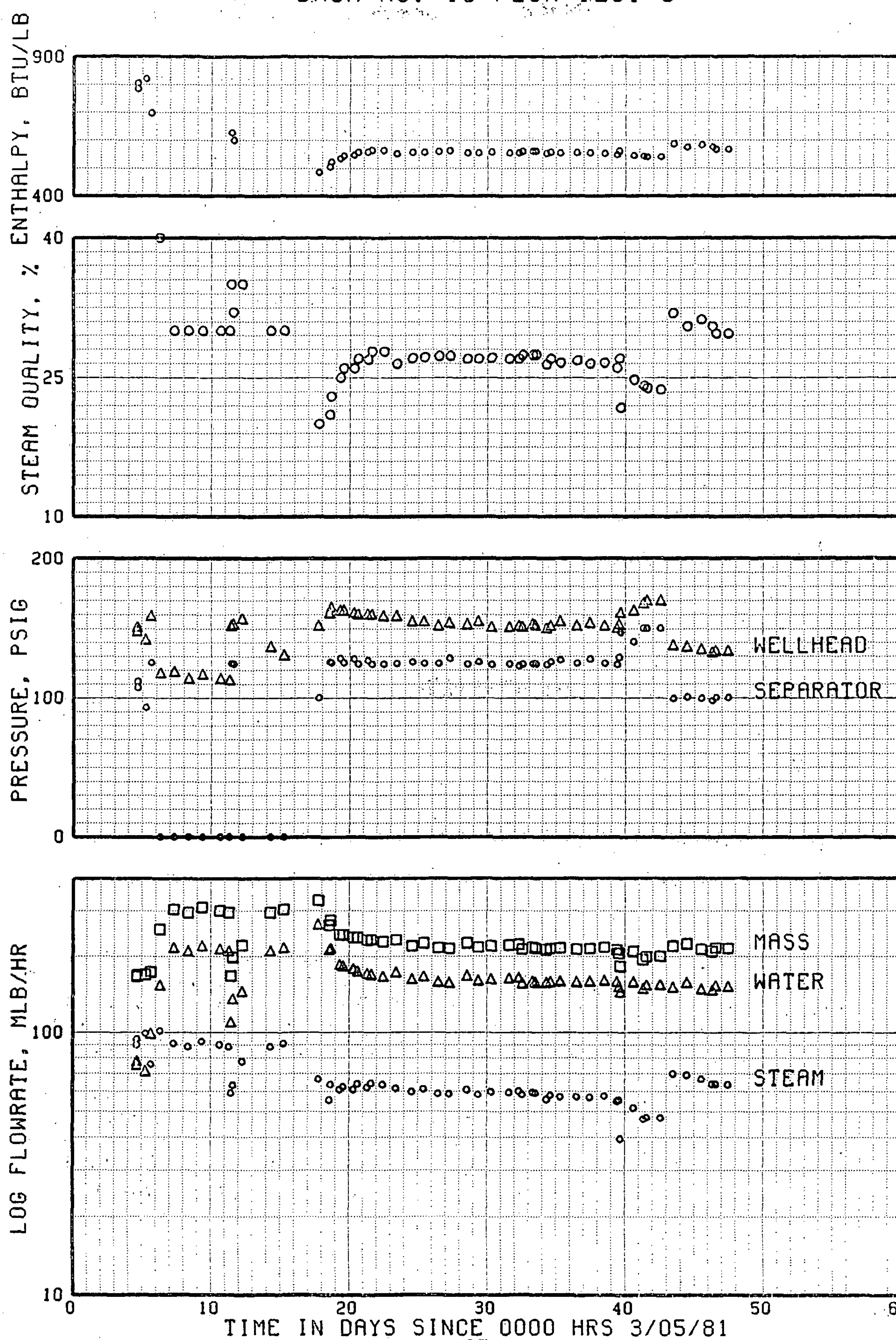


FIGURE 5.2.1-4
BACA NO. 13 FLOW TEST 6

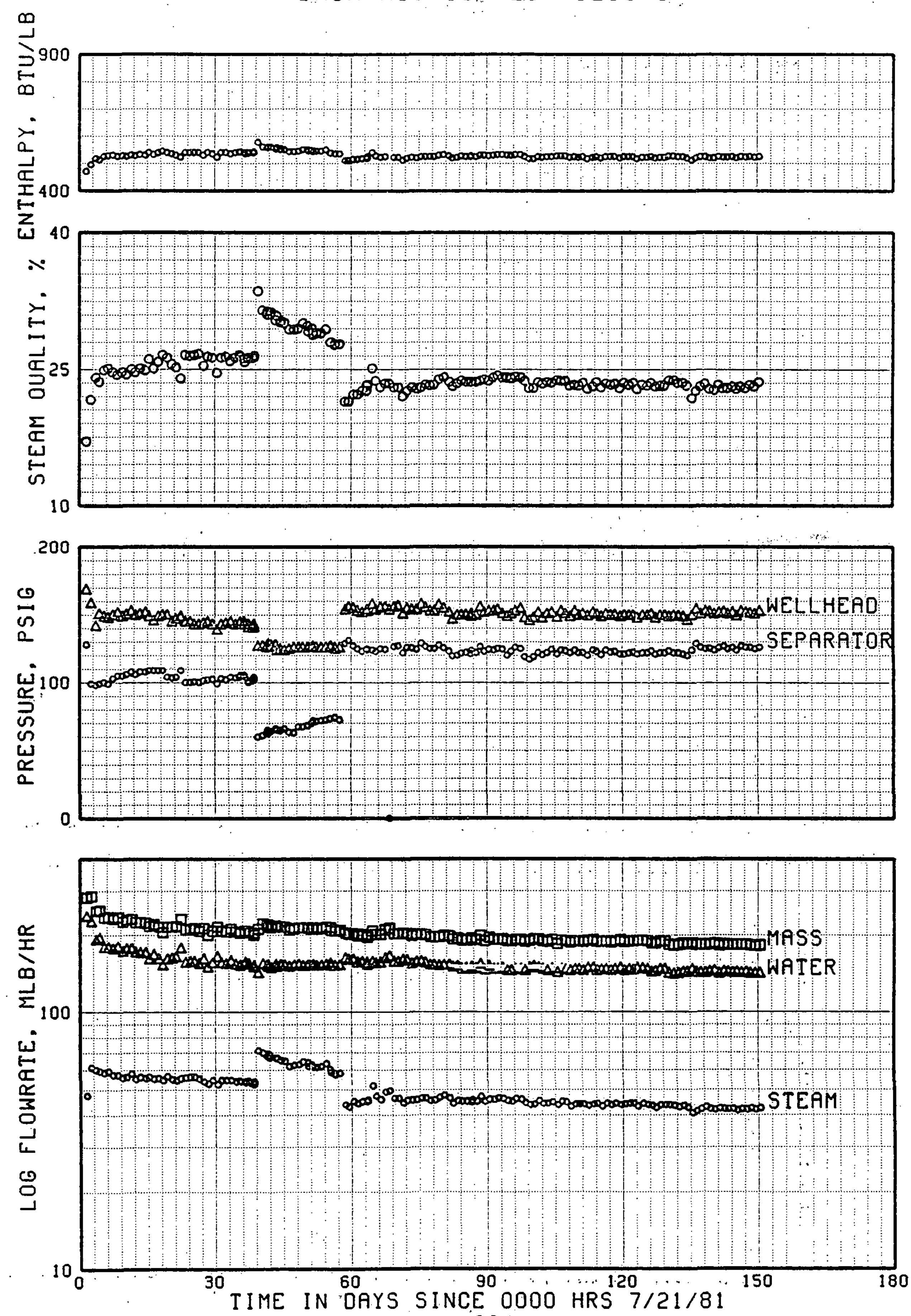
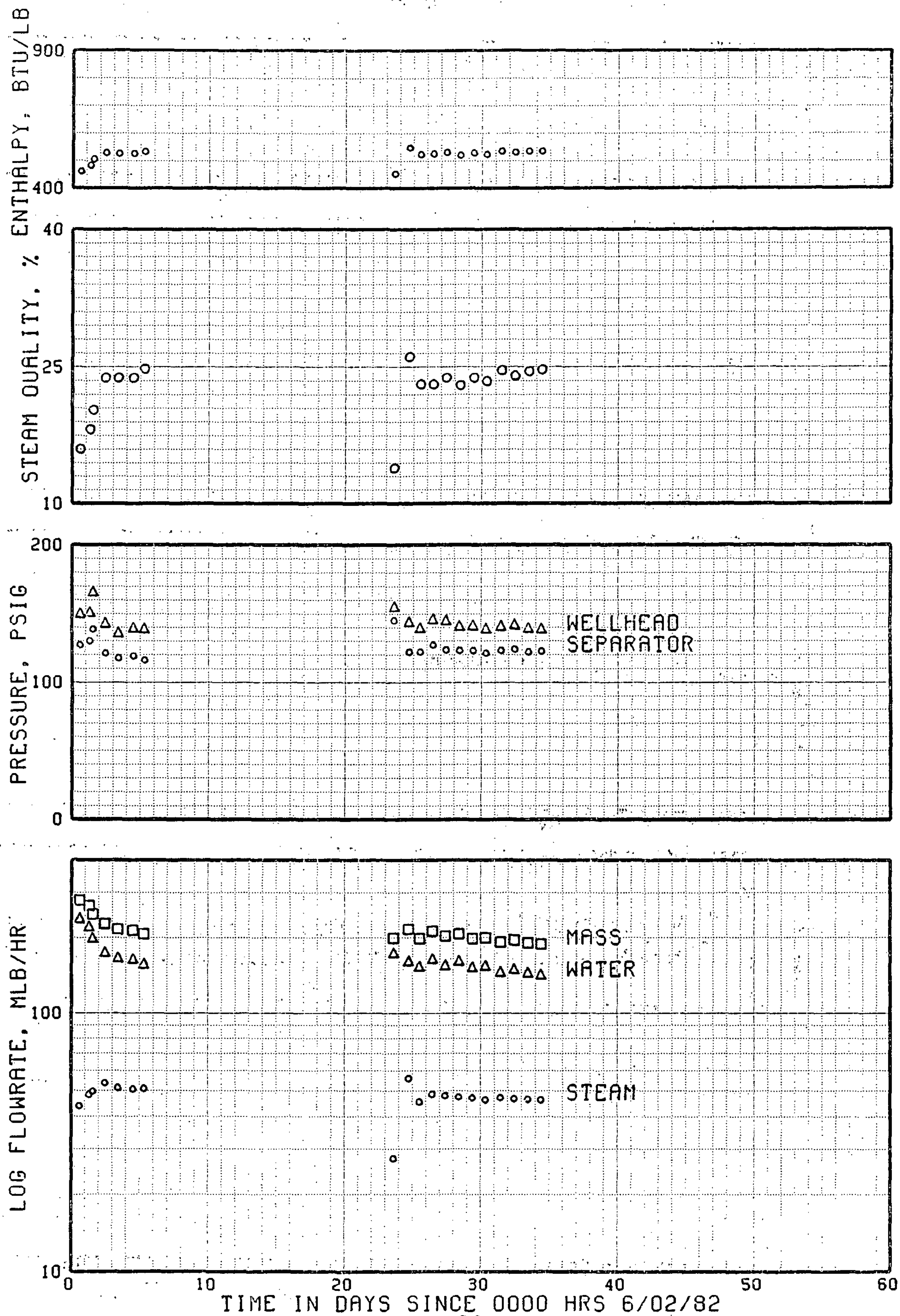


FIGURE 5.2.1-5
BACA NO. 13 FLOW TESTS 8 AND 9



Flow Test 10 was conducted to provide a water source to assist in the proposed wellbore acid cleanout of Baca No. 11. The test was conducted through a two-phase line for four days before it was terminated following plugging and abandonment of Baca No. 11. An average flow rate of 289,900 lb/hr resulted in 28.3 x 10^6 lb of production during the 4-day test.

Flow Test 11 was performed for six days through a two-phase line to provide water for Baca No. 24 Injection Test 2. An average flow rate of 298,700 lb/hr resulted in 43.4 x 10^6 lb of production.

Baca No. 15 - Baca No. 15 has been produced for four (4) flow tests, the two longest which were conducted prior to 1977 and are included in the earlier report.

Flow Tests 3 and 4 were conducted during the second stage of the 1982 Test and were designed to facilitate identification of non-radial, non-infinite acting behavior during the buildup (Section 5.2.1).

Flow Test 3 produced 39.6 x 10^6 lb of total mass during five days of production for an average rate of 333,000 lb/hr. The total mass rate was significantly higher than previously observed, with little change in the calculated steam flow rate. This increase is the direct result of producing the water injected during Baca No. 15 Injection Test 1 and Baca No. 19 Injection Test 3. The water production rate declined almost 40% during the test with a final flow rate of 282,700 lb/hr total mass and 96,400 lb/hr steam at pressures of 159/123.

Flow Test 4 produced 61.6 x 10^6 lb of total mass during nine days of production for an average rate of 285,525 lb/hr. The total mass rate and steam rate were slightly lower than those observed during Flow Test 3, due to a higher wellhead pressure caused by the testing of the multiple orifice meter test (MOMTEST). The water production rate declined over 50% during the flow test while the steam rate was constant. The initial rate of 371,400 lb/hr total mass at pressures of 180/116 and 17% steam fraction declined to a final rate of 227,600 lb/hr at pressures of 187.5/128 and 36% steam fraction.

Baca No. 17 - Baca No. 17 was flow tested during the original hole completion and later following the completion of the redrilled hole. These rig tests were characterized by poor, unsustained flow periods.

FIGURE 5.2.1-6
BACA NO. 15 FLOW TEST 2

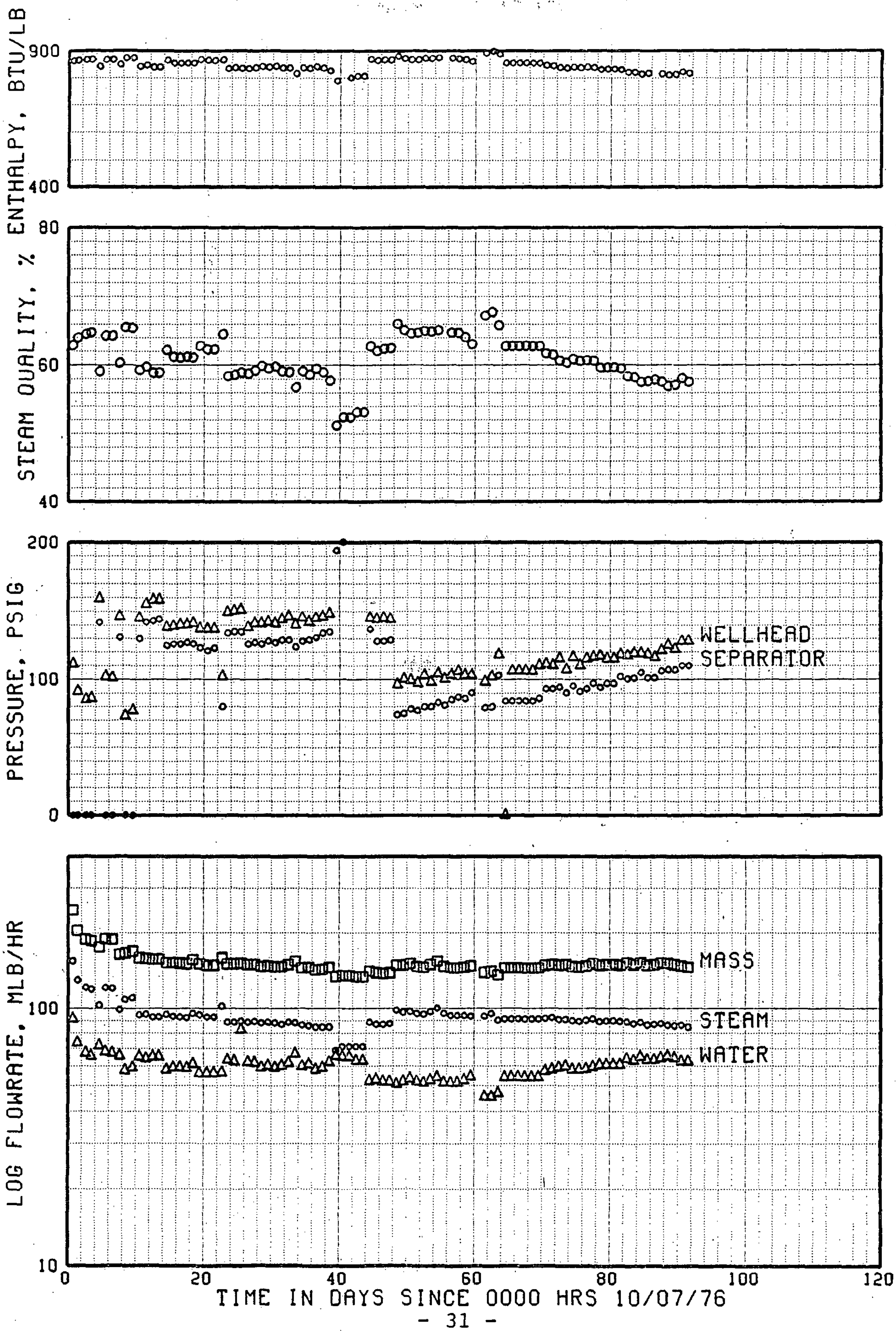
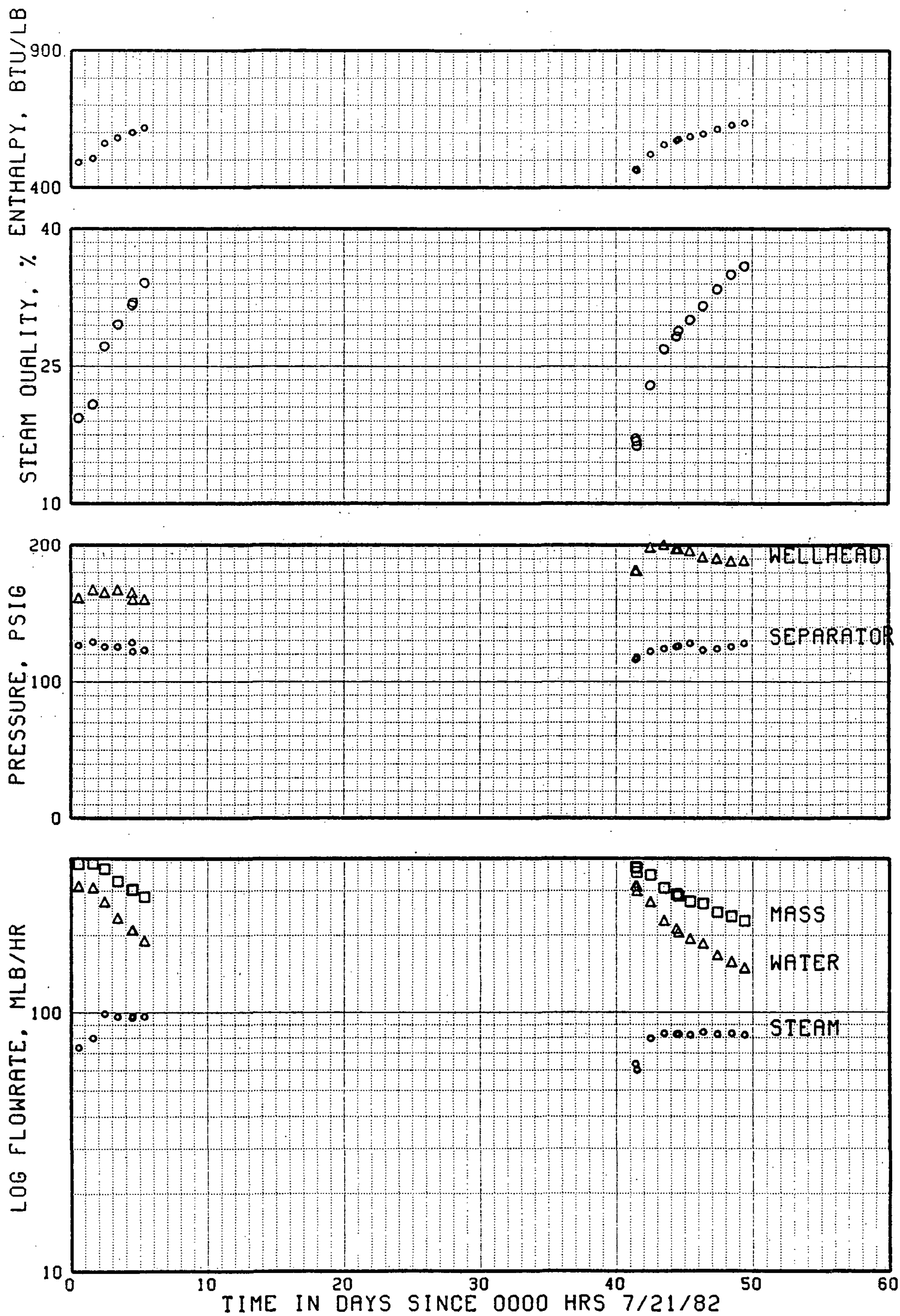


FIGURE 5.2.1-7
BACA NO. 15 FLOW TESTS 3 AND 4



Flow Test 1 includes the tests run on the original hole. The original rig test would not flow after being pressured to 400 psig for eight hours. The well was then kicked off (assisted) by injecting air down the drill pipe to act as a gas lift. Following termination of air injection, the well continued to flow at an estimated rate of 15,000-30,000 lb/hr against a low wellhead pressure and a 200°F flow line temperature. The well was shut-in after nine hours of production determined that the well was not a commercial producer.

Flow Test 2 includes all the tests run on the redrilled hole. The rig test flowed small quantities of fluid at a wellhead pressure of 1 psig after pressurization to 400 psig for eight hours prior to flow. The well was shut-in and again pressured up with air to 800 psig for two hours with no difference in the subsequent flow rate. The well was finally pressurized to 800 psig for twelve hours. When opened, the well flowed at an estimated 175,000 lb/hr water (no estimate of steam fraction) against an initial wellhead pressure of 90 psig. This rate was maintained - with the wellhead pressure increasing to 140 psig - for 20 minutes before the well was shut-in to repair damaged surface equipment. Baca No. 17 was subsequently plugged off when casing problems developed.

Baca No. 18 - Three (3) flow tests have been run on Baca No. 18, previously labeled as a rig test, Flow Test 1 and Flow Test 2. In this report the flow tests will be referred to as Flow Test 1R, 1 and 2 respectively.

Flow Test 1R was a two-phase flow test performed while the rig was still on the hole. Various attempts were made to clean out the well and assist it in flowing. The well was pressurized to 800 psig for seven hours prior to opening, producing 63,000 lb of water in three hours with a final wellhead pressure of 3.5 psig. The well was again pressurized to 650 psig and produced with similar results. Attempts were made to flow the well with drillpipe in the hole. Using air and aerated water as a gas lift did not give any significant improvement in the productivity of the well.

Flow Test 1 was an 8.5-hour two-phase test conducted approximately one month after the end of Injection Test 1. Baca No. 18 flowed at an initial rate of in excess of 400,000 lb/hr against a wellhead pressure of 88 psig and an assumed 25% flash. The well quickly declined to a zero production rate, ending the test.

Flow Test 2 was a four hour two-phase test. The flow rate peaked about 20 minutes after blowdown at a flow rate of 340,000 lb/hr with a wellhead pressure of 68 psig and an assuming flash of 30%. The well stabilized after three hours of flow, at a rate of 50,000 lb/hr against a wellhead pressure of 22 psig and an estimated 60% flash.

Baca No. 19 - Five (5) two-phase flow tests have been run on Baca No. 19, each of which have indicated that Baca No. 19 cycles and is not a commercial producer. The cause of this cycling has been attributed to geysering in the wellbore. Two later separator tests did not observe the cycling behavior.

Flow Test 1 was a twelve day two-phase test. At an assumed flash of 30%, the flow rate and wellhead pressure steadily declined from an initial rate of 286,000 lb/hr at 96 psig to about 57,000 lb/hr and 10 psig after 1-1/2 hours of production. For the remainder of the flow test, the well cycled at approximately 4-6 hour intervals from a low rate of 38,200 lb/hr at 5 psig to 214,500 lb/hr at 47 psig. Occasionally the well would quit cycling and maintain a steady flow rate of about 120,000 lb/hr at 22 psig for about twelve hours before reverting to its cyclic nature. 36.4×10^6 lb were produced during this test, for an average rate of 126,000 lb/hr.

Flow Test 2 lasted for seven days before the well died after being throttled at the surface. The flow rates were similar to those experienced during Flow Test 1. At the same 30% assumed flash for the two-phase test, Baca No. 19 cycled from 56,000 lb/hr at 10 psig to 213,000 lb/hr at 65 psig. The total mass produced during Flow Test 2 was 23.1×10^6 lb for an average rate of 134,500 lb/hr.

Flow Test 3 was carried out over a 37-day period starting five days after the end of Flow Test 2. The flow rate and wellhead pressure during the two-phase test steadily declined - as in Flow Tests 1 and 2 - from about 215,000 lb/hr at 105 psig to about 54,000 lb/hr at 10 psig after two hours of production. The high and low cycle rates were 165,000 lb/hr at 55 psig and 31,000 lb/hr at 10 psig respectively. This cycling continued at 4-7 hour intervals for the duration of the test. This test differed from earlier tests in that the well did not maintain a stablized flow rate for more than seven hours and the cycling did tend to increase with time from approximately four hours at the start of the test to just under seven hours near the end of the test. An estimated 86.8×10^6 lb of total mass were produced at an average rate of 98,000 lb/hr.

Flow Test 4 was a 22-day two-phase test which was run to provide water to assist in the drilling of Baca No. 20. The initial flow rate of 371,600 lb/hr at a wellhead pressure of 100 psig and an assumed flash of 25% dropped rapidly and began cycling. The final flow rate was calculated to be 150,200 lb/hr at 34 psig and the asssumed flash of 25%. 81.8×10^6 lb of total mass were produced at an average flow rate of 154,600 lb/hr.

Flow Test 5 was a seven day test during the 1980-1981 Interference Test. The initial rate of 268,000 lb/hr total mass at a wellhead pressure of 55 psig and 25% assumed flash dropped quickly and exhibited cycling as in previous flow tests. The final rate was calculated to be about 160,000 lb/hr total mass at 39 psig wellhead pressure and 25% assumed flash. The total mass produced was estimated to be 31.6×10^6 lb for an average rate at 25% flash of 188,000 lb/hr total mass.

Baca No. 19 was sucessfully flow tested through a separator during Flow Test 6. The cyclic behavior exhibited during the previous two-phase tests was eliminated. The well declined from an initial separator rate of 165,500 lb/hr at pressures of 48.5/21.5 and a 22.4% steam fraction to a final rate of 158,600 lb/hr at pressures of 45/21.5 and a 20.5% steam. Baca No. 19 produced 14.9×10^6 lb of total mass during the four day test, for an average rate of 160,500 lb/hr.

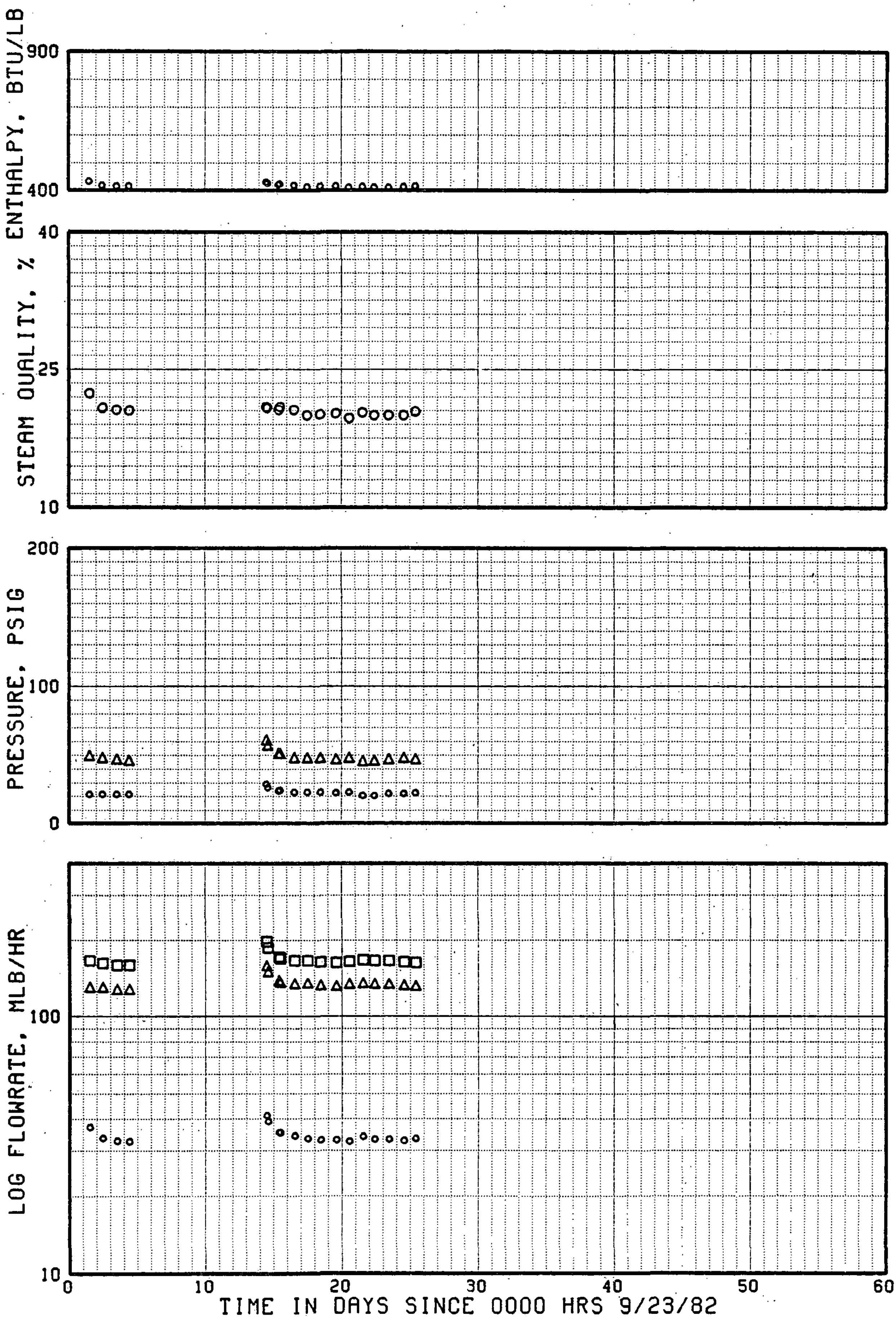
The well was separator tested again during the eleven-day Flow Test 7. An attempt to flow the well at a higher wellhead pressure was not successful. Baca No. 19 declined in two days from an initial separator flow rate of 196,900 lb/hr at pressures of 60/29 and a 20.9% steam flash to 166,200 lb/hr at pressures of 47/23 and 20.6% steam. The flow rate basically stabilized for the remainder of the test with a final flow rate of 163,500 lb/hr at pressures of 46/22.5 and a 20.6% steam fraction. 43.8×10^6 lb of total mass were produced at an average rate of 165,900 lb/hr.

<u>Baca No. 20</u> - Seven (7) flow tests and one (1) drillstem test have been conducted on Baca No. 20. The first two tests were two-phase tests run while the rig was still on the hole. Flow Test 1 was run on the original hole and characterized by no flow. Flow Test 2 was conducted prior to running the 7" liner in the redrilled hole. Consequently, golfball-sized chunks of formation rock unloaded and plugged the surface equipment.

Flow Test 3 was started through a two-phase line and switched to a separator, but was stopped after 27.5 hours due to the limited capacity of the sump. The initial two-phase line flowed 390,000 lb/hr at 150 psig and an assumed 30% flash. At the end of the separator test, Baca No. 20 was flowing 82,000 lb/hr at pressures of 125/118 and a 62% flash. Only 6×10^6 lb of mass were produced during the test, for an average rate of 220,000 lb/hr.

FIGURE 5.2.1-7A

BACA NO. 19 FLOW TESTS 6 AND 7



Flow Test 4 was the longest flow test of the 1980-1981 Interference Test, lasting 105 days. Baca No. 20 initially flowed at 56,700 lb/hr at pressures of 145/142 and a flash of 56%. The final flow rate was almost identical - 56,100 lb/hr - but occurred at the lower pressures of 116/75 and a steam flash of 56%. $149x10^6$ lb were produced during the separator test, at an average rate of 59,300 lb/hr.

Baca No. 20 was recompleted and hydraulically stimulated in the fall of 1981. After the stimulation a modified drillstem test was run and is described in the discussion of the stimulation (Section 4.4.2).

Flow Test 5 was a two-phase test started approximately two weeks after the completion of the modified drillstem test. The steam fraction was estimated with the mini-separator and varied from an initial value of 32% to a final value of 86%. The total mass flow rate decreased from 140,000 lb/hr at 51 psig to 47,400 lb/hr at 24 psig. The decreased productivity is attributed to the recompletion. $26x10^6$ lb of fluid were produced at an average flow rate of 79,000 lb/hr.

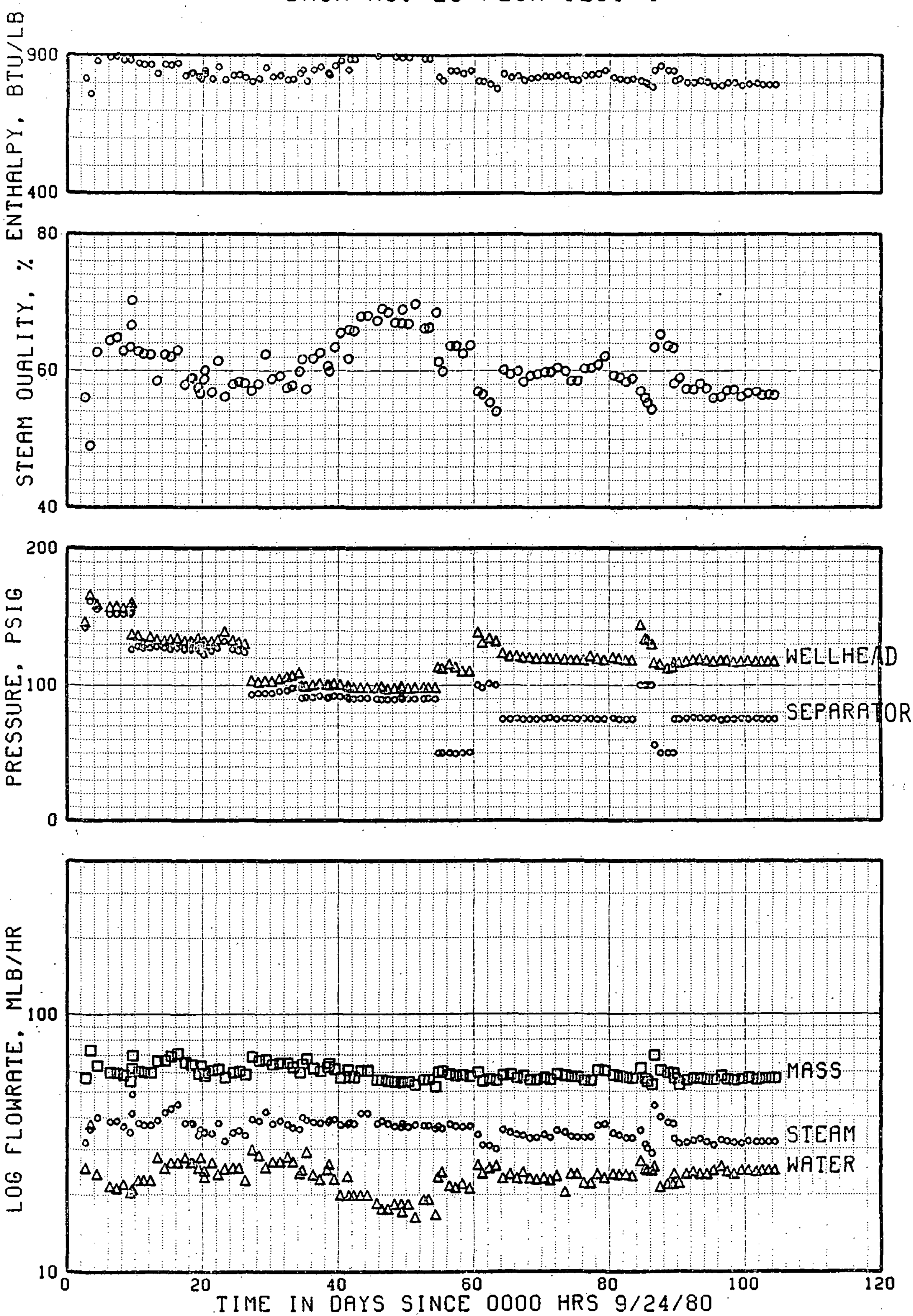
One explanation of the poor productivity observed in Baca No. 20 following the stimulation was that the calcium carbonate used as a fluid-loss additive during the hydraulic fracture treatment (Section 4.4.2.2) had plugged the reservoir flow paths. The acid cleanout of Baca No. 20 during August of 1982 was designed to remedy the problem. Flow Test 6 was conducted prior to the acid job and Flow Test 7 was run after the job.

Flow Test 6 was a 2.5-day two-phase test run to collect pre-acidize characteristics of Baca No. 20. The well rapidly decreased from an initial flow rate of 107,100 lb/hr at 74 psig at 74 psig and an assumed 80% flash to 53,700 lb/hr at 28 psig and the same 80% flash prior to shut-in. 3.5×10^6 lb of total mass were produced at an average rate of 64,000 lb/hr.

Flow Test 7 was a four day two-phase test conducted after the acidization of Baca No. 20. Comparison of the pre-acid and the post-acid flow rates indicate that the productivity of Baca No. 20 did not increase. Flow Test 7 rapidly decreased from an initial flow rate of 109,000 lb/hr at 82 psig and an assumed 80% flash to 46,700 lb/hr at 22 psig and the same 80% flash prior to shut-in. 5.0×10^6 lb of total mass were produced at an average rate of 51,900 lb/hr.

<u>Baca No. 21</u> - Five (5) flow tests have been conducted on Baca No. 21. The first two flow tests were two-phase tests run while the rig was still on the hole: the third and fourth were two-phase tests and the fifth was a partial separator test, partial two-phase test.

FIGURE 5.2.1-8
BACA NO. 20 FLOW TEST 4



Flow Test 1 was a short 4.5-hour test run after encountering a producing zone at a measured depth of 2842'. Baca No. 21 flowed at a rate of 204,000 lb/hr and a pressure of 138 psig, assuming 60% flash. Flow Test 2, lasting 9.5 hours, was run after deepening Baca No. 21 to 3000', but prior to running the 7" liner. Assuming 60% steam flash, the well flowed at 180,000 lb/hr against a wellhead pressure of 55 psig.

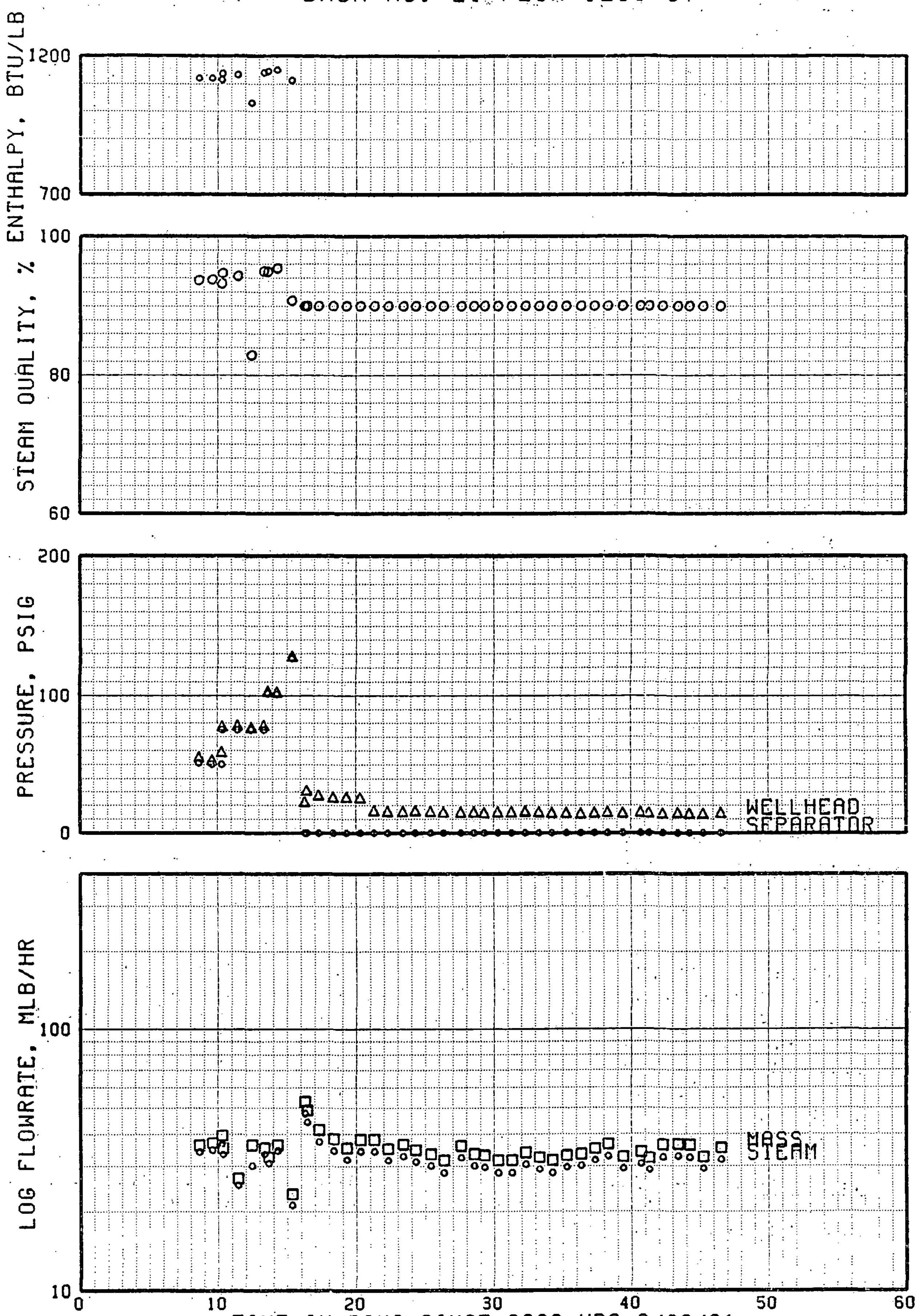
Flow Test 3 lasted seven hours with a final flow rate of 200,000 lb/hr at a pressure of 75 psig and 60% flash. Baca No. 21 was shut-in when a piece of surface equipment needed to be repaired. After repairs, Flow Test 4 began and lasted four days before the same problem reoccurred. During Flow Test 4, the flow rate decreased at a constant assumed 60% flash from 220,000 lb/hr at 133 psig to 60,000 lb/hr at 23 psig. The total mass produced was 8×10^6 lb at an average rate of 84,000 lb/hr.

Flow Test 5 lasted 46 days through a two-phase line and separator. Baca No. 21 initially flowed 220,000 lb/hr at a wellhead pressure of 150 psig and a 60% assumed flash. After eight days of production the flow was switched to the separator for seven days before it was again switched back to the two-phase line for the remainder of the test. During the separator testing, the well flowed at 35,000 lb/hr with pressures of 77/75 and a 95% flash. A NOWSCO coil tubing unit was used to attempt to clean out suspected fill while the flow test was underway. A bridge was cleaned out from 2819 to 2821 with no apparent increase in production. Prior to shut-in Baca No. 21 was producing 32,000 lb/hr at 13 psig wellhead pressure and an assumed flash of 90%. Overall, Flow Test 5 produced 45×10^6 lb of total mass for an average flow rate of 40,700 lb/hr.

<u>Baca No. 22</u> - Four (4) flow tests have been conducted on Baca No. 22. The original hole appeared to have commercial well characteristics but was not successfully completed. Flow Test 1 and Flow Test 2 were run in the first sidetrack as two-phase tests. Flow Test 1 lasted 4-3/4 hours and was characterized by little flow and the production of formation rocks. The maximum rate attained was approximately 95,000 lb/hr total mass at 50 psig wellhead pressure and an assumed flash of 40%. Flow Test 2 lasted 9-1/4 hours with a final flow rate of 82,000 lb/hr against a wellhead pressure of 43 psig and 40% assumed flash.

Flow Test 3 was a two-phase test run after the completion of the second sidetrack. The well was pressured to 800 psig prior to opening; earlier attempts to flow the well after 240 psig pressurization had been unsuccessful. The 32-3/4 hour flow test produced at a final flow rate of 49,000 lb/hr at a wellhead pressure of 8 psig and an assumed 20% steam flash. 2×10^6 lb of total mass were produced at an average rate of 60,600 lb/hr.

FIGURE 5.2.1-9
BACA NO. 21 FLOW TEST 5



Flow Test 4 lasted 23 days before being terminated to allow the separator to be moved to Baca No. 13. The well initially flowed through a two-phase line at a rate of 59,000 lb/hr with wellhead pressure of 11 psig and an assumed flash of 40%. The flow was switched to the separator after three days of production, remaining there for ten of thirteen days before it was again shifted back to the two-phase line for the remainder of the test. During the separator test interval, Baca No. 22 flowed at 20,000 lb/hr at pressure of 15/14 and a steam fraction of 75%. Prior to shutting in the well, the two-phase flow rate was 17,400 lb/hr at a wellhead pressure of 3 psig and an assumed steam flash of 75%. The total mass produced during the test was $13x10^6$ lb for an average total mass flow rate of 23,500 lb/hr.

Baca No. 23 - Four (4) flow tests and one (1) modified drillstem test have been conducted on Baca No. 23. Flow Test 1 was a two-phase test run on the original hole completion. The flow test ended when the well quit flowing after ten hours of flow. The test was characterized by little flow at low wellhead pressures, with a maximum flow rate of 61,300 lb/hr at 49 psig and 60% flash attained after the wellbore unloaded.

After recompletion, the well was hydraulically stimulated as part of the D.O.E. stimulation program. The modified drillstem test was run immediately after the stimulation and is included in the discussion of the stimulation (see Section 4.4.2).

Flow Test 2 was a 49-hour rig test carried out through a two-phase line two days after the completion of the drillstem test. Baca No. 23 flowed against an essentially stabilized wellhead pressure of 51 psig, declining from 110,000 lb/hr at 50% to 99,000 lb/hr at 50%. An attempt to flow the well at a higher wellhead pressure killed the well.

Flow Test 3 was a ten day two-phase test performed after the rig was moved. The flow rate declined from an initial rate of 100,000 lb/hr at 56 psig and 50% assumed flash to a final rate of 51,000 lb/hr at 34.5 psig and 70% assumed flash. The well again died when the wellhead pressure was raised while adjusting the flow into the mini-separator.

Flow Test 4 started eight days after the end of Flow Test 3. During the eleven day two-phase test, five mini-separator calculations were performed which showed the steam fraction to be 50%. Using this value the Baca No. 23 flow rate declined from an initial rate of 120,000 lb/hr at 73 psig to a final rate of 68,000 lb/hr at 34.5 psig. During Flow Tests 3 and 4, Baca No. 23 produced $17x10^6$ and $20x10^6$ lb of total mass respectively, for an average production rate of 73,500 lb/hr.

Baca No. 24 - Five (5) flow tests have been conducted on Baca No. 24. The first two flow tests were two-phase tests, the last three separator tests.

Flow Test 1 was a 6.1-hour production period during which the well flowed at a very small production rate, decreasing to about 10,000 lb/hr at a wellhead pressure of 3 psig near the end of the test.

Flow Test 2 was a six day (147-hour) test which exhibited commercial well characteristics. Baca No. 24 initially flowed at 350,000 lb/hr against a wellhead pressure of 147 psig and with an assumed 30% flash. The final rate was calculated based upon the mini-separator steam fraction of 27%. Flow rate was 326,000 lb/hr at a wellhead pressure of 125 psig. 48×10^6 lb of total mass were produced during Flow Test 2, at an average rate of 329,000 lb/hr.

Flow Test 3 was a lengthy test run to establish the deliverability of Baca No. 24, and as such was run at three different wellhead pressures. The initial flow rate was 211,000 lb/hr at pressures of 134/122 and a steam fraction of 18%. The final rate was determined to be 163,800 lb/hr at pressures of 131/125 and 20% steam fraction. During Flow Test 3, 247×10^6 lb of fluid were produced at an average flow rate of 172,300 lb/hr.

Flow Tests 4 and 5 occurred during the second stage of the 1982 Test, exhibiting much higher flow rates than were observed during Flow Test 3. These flow tests were conducted to create a reservoir pressure disturbance for the subsequent pressure buildups (Section 5.3.1). Flow Test 5 was roughly twice as long as Flow Test 4.

The flow rates of both tests were almost identical for any given producing time. The first separator flow rate for the tests were at times of 25 hours and 29 hours and exhibited rates of 306,500 at pressures of 152/126 and 19.0% steam and 309,500 at pressures of 155/124 and 20.0% steam. The respective rates associated with the shut-in time of Flow Test 4 - at t_p = 5 days - were 281,300 at pressures of 148/125 and 19.6% steam and 281,700 at pressures of 148/126 and 19.0% steam. Flow Test 5 continued for six more days until it was shut-in at a final rate of 259,800 lb/hr at pressures of 142/122 and 19.6% steam. The cummulative and average production during the two tests were 34.8×10^6 lb and 74.1×10^6 lb at 290,700 and 280,800 lb/hr respectively.

FIGURE 5.2.1-10
BACA NO. 24 FLOW TEST 3

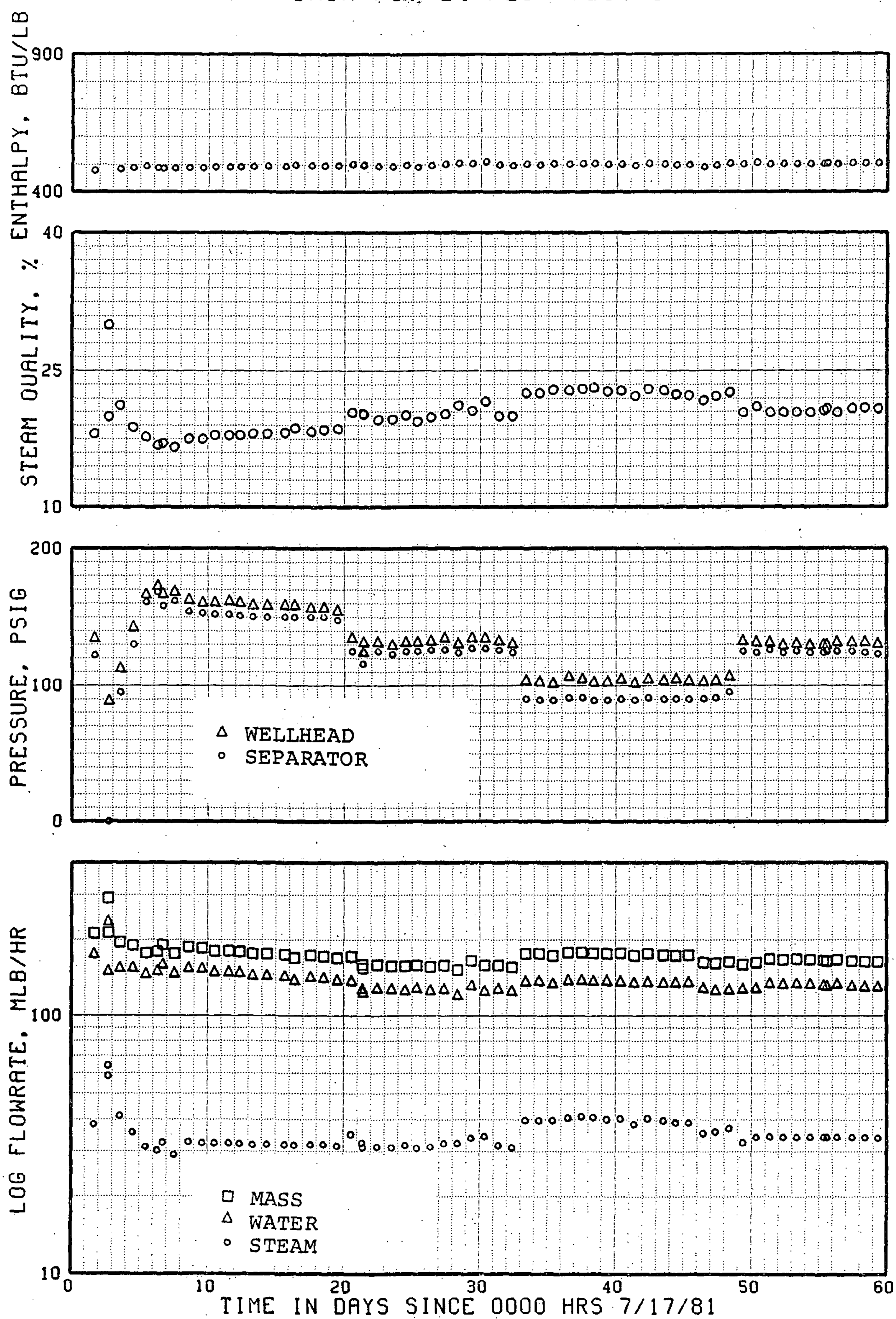
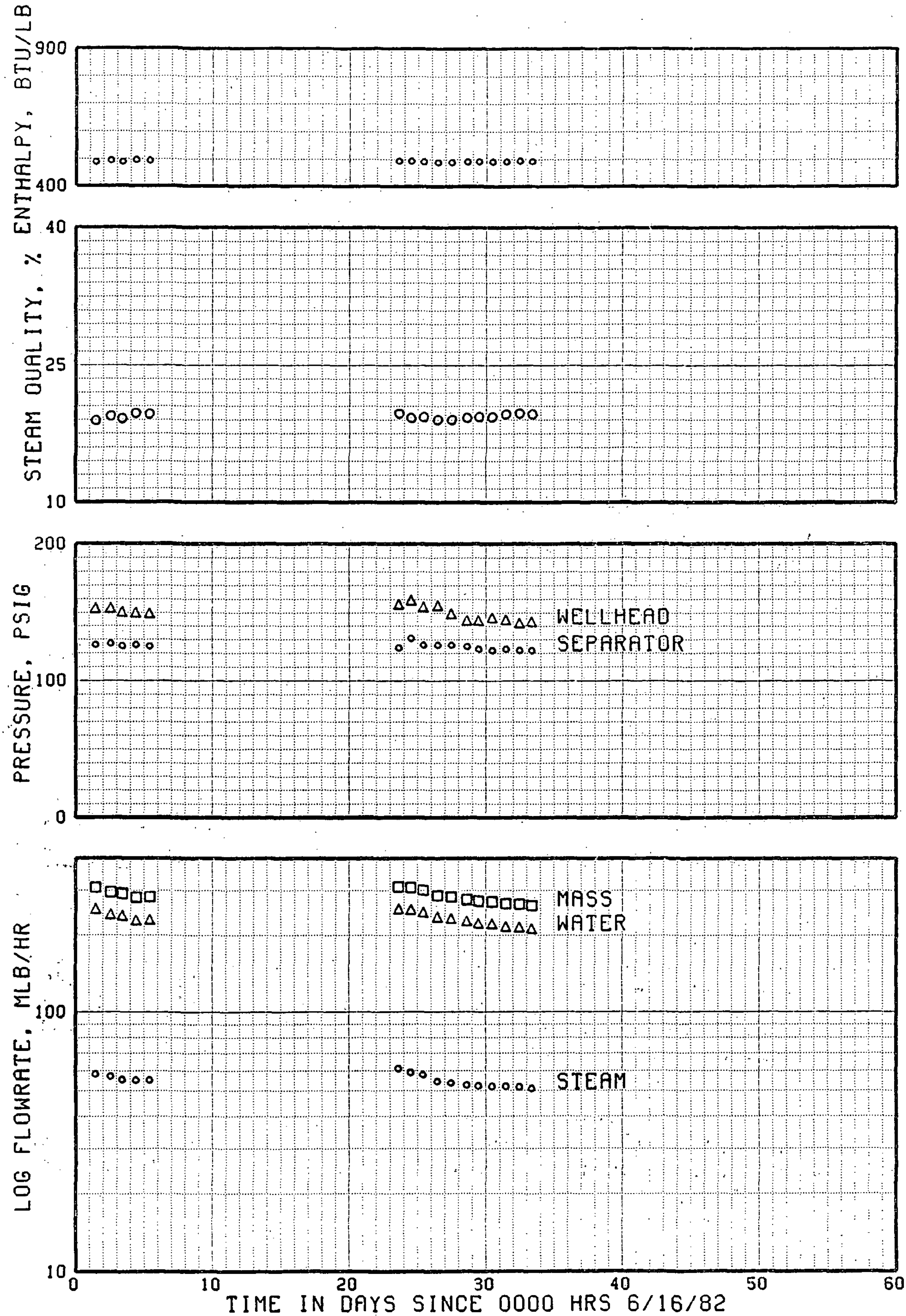


FIGURE 5.2.1-11
BACA NO. 24 FLOW TESTS 4 AND 5



5.2.2 Water Injection

Large volumes of water have been injected into the Redondo Creek field during the last 10 years for the purpose of injection tests and water disposal. The majority of this water was injected as a means of disposing unmanageable amounts of surface waters accumulated during production tests or surface runoff. The purpose of an injection test is two-fold: 1) to evaluate the reservoir, while 2) disposing of water. The injection tests performed in the Redondo Creek Field were normally designed for a short time interval - one to six days - at a constant, controlled injection rate. During the injection period, wellbore pressure/temperature monitoring and spinner surveys were run with wireline units. Combined with the pressure monitoring following the termination of injection (pressure falloff), the injection test evaluation of the reservoir results in determination of fluid-loss zones, injectivity, reservoir permeability-thickness, and skin (Sections 5.3.2 and 5.3.3).

Table 5.2.2-1 lists the injection periods for all of the Redondo Creek wells; both injection tests and water disposal. Injection tests run on 11 of the 19 Redondo Creek wells - 4, 5A, 12, 13, 14, 15, 18, 19, 20, 23 and 24 - are presented following discussion of water disposal. The designation of a water disposal period in Table 5.2.2-1 does not necessarily imply one continuous water injection interval. The nature of disposal injection is such that some injection rate peaks, valleys and discontinuities occur. In general, two rules applied to the labeling designation: 1) all water disposal prior to 1978 was labeled as one injection period for Baca Nos. 5A, 12 and 14; and 2) injection which did not stop for a significant time interval and originated from one flow test was labeled as one injection period.

Prior to 1978 water disposal in the Redondo Creek Field was limited to three wells: Baca Nos. 5A, 12 and 14; with Baca No. 12 accepting over 43% of the water disposal fluid. Since 1978, Baca No. 12 has been used sparingly as a water disposal well and Baca No. 5A has not been used at all. The majority of the recent water disposal has been into Baca No. 14, with Baca Nos. 18 and 19 also used during selected time intervals. The various water disposal periods and the injection tests for each well are described in brief below. While the actual mechanics of the successful injection tests - injection rates, volumes and fluid loss zones - are presented, the discussion of the falloff analysis and the injectivities are contained in Sections 5.3.2 and 5.3.3.

When a well contains a slotted liner, the interpretation of the fluid loss zones is severely hindered by the lack of a known effective flow area. All analyses have been performed using the best engineering judgment of the flow area and relying on

TABLE 5.2.2-1

REDONDO CREEK INJECTION SUMMARY
THROUGH DECEMBER 1982

WELL	DATE	INJECTION RATE gpm	CUMMULATIVE INJECTION GALLONS	$lb \times 10^6$	WATER SOURCE	TYPE OF INJECTION
Baca 4-1	10/21/82-10/22/82	153	240,482	2.0	Reserve Pit	Test
Baca 5A-A	09/20/71-12/31/77	-	71,992,060	604.7	---	Water Disposal
Baca 5A-1	09/04/74	163	156,480	1.3	Reserve Pit	Test
Baca 5A-2	02/12/76	277	132,960	1.1	Reserve Pit	Test
Baca 5A-3	12/21/76	416	570,900	4.9	Reserve Pit	Test
Baca 12-A	08/19/74-12/31/77	-	125,445,000	1041.2	---	Water Disposal
Baca 12-1	10/14/74-10/15/74	157	263,760	2.2	Reserve Pit	Test
Baca 12-2	11/09/74	380	57,000	.5	Reserve Pit	Test
Baca 12-3	05/05/80-05/06/80	400	811,200	6.6	Baca 19	Test
Baca 12-4	06/23/82-07/21/82	70	1,308,300	10.7	Baca 24	Water Disposal
Baca 13-1	05/13/81-05/18/81	130	844,121	6.9	Baca 4	Test
Baca 14-A	02/24/75-12/31/77	-	90,000,000	735.2	---	Water Disposal
Baca 14-1	02/11/75	450	648,000	5.3	Reserve Pit	Test
Baca 14-2	02/21/75	500	267,792	2.2	Reserve Pit	Test
Baca 14-3	06/02/80-06/05/80	200	814,885	6.7	Reserve Pit	Test
Baca 14-4	11/18/80-01/06/81	40	1,323,875	10.8	Baca 20	Water Disposal
Baca 14-5	03/05/81-04/03/81	248	5,074,228	41.5	Baca 13	Water Disposal
		400	5,044,620	41.2	Baca 13, 4	Water Disposal
Baca 14-6	07/01/81-07/07/81	350	2,938,436	24.0	Baca 24	Water Disposal
Baca 14-7	07/17/81-09/15/81	220	18,811,587	153.7	Baca 24	Water Disposal

TABLE 5.2.2-1
REDONDO CREEK INJECTION SUMMARY
THROUGH DECEMBER 1982
(Continued)

WELL	DATE	INJECTION RATE gpm	CUMMULATIVE INJECTION GALLONS	CUMMULATIVE INJECTION lb X 10^6	WATER SOURCE	TYPE OF INJECTION
Baca 14-8	10/09/81-10/14/81	226	1,626,515	13.3	Reserve Pit	Water Disposal
Baca 14-9	10/26/81-12/18/81	220	15,241,692	124.5	Baca 13	Water Disposal
Baca 14-10	01/11/82-02/03/82	238	918,382	7.5	GRI	Water Disposal
Baca 14-11	06/02/82-06/07/82	260	1,652,707	13.5	Baca 13	Water Disposal
Baca 14-12	06/09/82-06/13/82	179	1,056,679	8.6	Baca 4	Water Disposal
Baca 14-13	06/16/82-06/21/82	261	1,876,675	15.3	Baca 24	Water Disposal
Baca 14-14	06/24/82-07/06/82	360	3,076,009	25.1	Baca 13	Water Disposal
	07/06/82-07/19/82	290	5,082,861	41.5	Baca 4, 24	Water Disposal
Baca 14-15	07/21/82-07/27/82	300	2,684,153	21.9	Baca 15	Water Disposal
Baca 14-16	08/11/82-08/15/82	300	1,479,150	12.1	Baca 13	Water Disposal
Baca 14-17	08/26/82-08/30/82	67	385,147	3.1	Baca 20	Water Disposal
	08/30/82-09/09/82	230	839,290	6.9	Baca 15	Water Disposal
Baca 14-18	09/14/82-09/15/82	345	487,215	4.0	Baca 13	Water Disposal
Baca 14-19	09/23/82-09/27/82	220	1,247,411	10.2	Baca 19	Water Disposal
Baca 14-20	10/07/82-10/18/82	200	2,965,436	24.2	Baca 19	Water Disposal
Baca 15-1	06/24/82-06/30/82	273	2,599,204	21.2	Baca 13	Test
Baca 18-1R	03/15/79	Slugged	300,000	2.5	Reserve Pit	Test
Baca 18-1	05/09/79-05/10/79	281	526,697	4.3	Reserve Pit	Test
Baca 18-2	02/16/82-04/13/82	230	20,128,608	164.4	Baca 13	Test
Baca 18-3	06/02/82-06/03/82	364	572,390	4.7	Baca 13	Water Disposal

TABLE 5.2.2-1
REDONDO CREEK INJECTION SUMMARY
THROUGH DECEMBER 1982
(Continued)

WELL	DATE	INJECTION RATE gpm	CUMMULATIVE INJECTION GALLONS	CUMMULATIVE INJECTION lb X 10^6	WATER SOURCE	TYPE OF INJECTION
Baca 18-4	06/13/82-06/14/82	339	417,468	3.4	Baca 4	Water Disposal
Baca 18-5	06/30/82-07/12/82	186	1,758,005	14.4	Baca 4	Water Disposal
Baca 18-6	09/01/82-09/07/82	250	2,773,902	22.7	Baca 15	Test
Baca 19-1	12/03/79-12/05/79	50	39,000	.3	Reserve Pit	Test
		150	198,000	1.6	Reserve Pit	Test
Baca 19-2	12/08/79-12/09/79	380	286,800	2.3	Reserve Pit	Test
		680	61,200	.5	Reserve Pit	Test
Baca 19-3	06/21/81-10/19/81	154	6,888,200	56.2	Baca 4	Water Disposal
		230	29,752,625	243.1	Baca 13	Water Disposal
Baca 20-1	07/24/81-07/29/81	230	1,793,000	14.6	Baca 13	Test
Baca 23-1	05/28/81-06/03/81	149	1,392,079	11.4	Baca 4	Test
Baca 24-1	10/19/81-10/24/81	241	1,773,830	14.5	Baca 13	Test
Baca 24-2	09/15/82-09/20/82	260	1,905,791	15.6	Baca 13	Test

assistance from the injection-temperature profiles. Only the largest fluid loss zones can be identified with accuracy; minor fluid loss zones mentioned actually represent possible zones.

The majority of the spinner surveys have utilized the Crelad spinner tool; a mechanical device which records the fluid velocity as marks on a Kuster tool chart. The Crelad spinner is positive displacement spinner rotor and recorder run either individually or in trandem with a Kuster temperature element. Typically for every 100 revolutions of the rotor, one mark is made on the clock recorder. A spinner survey consists of a limited number of timed stops.

Two of the injection tests, Baca Nos. 13-1 and 19-2, were conducted with a fullbore flowmeter; Schlumberger's continuous surface readout log. These logs gave a complete flow profile, including the difference in flow velocity between a perforated pipe interval and a blank pipe interval. This difference was observed to be on the order of 10% of the total velocity, well within the accuracy of the Crelad Spinners Instruments.

Baca No. 4 During the one injection test conducted on Baca No. 4, 2.0 x 10^6 lb of water were injected at an average rate of 153 gpm. An injectivity value of 1.8 gpm/psi was calculated from the gradient survey run just prior to shut-in of the 27-hour test. Two Crelad Spinner surveys run during the injection indicated that there were at least four permeable zones. About 150 gpm of fluid was entering the wellbore through the 7" liner hanger located at 3031' M.D. A small amount of fluid was also entering the wellbore between 4500' and 4700 M.D. A major fluid loss zone where approximately 70% of the fluid was leaving the wellbore was identified between 5250' and 5375' M.D. The remaining 30% of the fluid was lost between 5875' and 6000' M.D.

Baca No. 5A is a low temperature well which has been used solely for water injection. Prior to the drilling of Baca No. 12 in August of 1974, Baca No. 5A was the main water disposal well in the Redondo Creek Field. Of the 604.7 x 10^6 lb of water injected into Baca No. 5A, 17 x 10^6 lb were injected during the 1975-1976 Interference Test with most of the remainder injected before the start of the 1975-1976 Interference Test and during Baca No. 15 Flow Test 2. Due to the cost of pumping water to Baca No. 5A, it was slowly phased out as an injector following completion of the lower elevation wells: Baca Nos. 12 and 14.

Three (3) injection tests were run on Baca No. 5A, none of which lasted longer than 24 hours. Although the injection rates varied widely during these three tests from 163 to 416 gpm, the calculated injectivies remained fairly constant; ranging from 2.46 to 3.55 gpm/psi (see Section 5.3.3). An injection profile run in the well on 2/12/76 indicated about 50% of the water was leaving the wellbore in the interval

5550'-5880'. The tools stopped at 5886' but it is assumed that the rest of the water was being injected into the bottom of the Bandelier Tuff between 5880'-6600'. The wellbore restriction at 5886' indicated possible scale deposition, but due to an open-hole completion bridging in the hole could not be ruled out.

Baca No. 12 was used extensively as a water disposal well during a two-year time interval following its completion date in 1974 to the middle of 1976. During this period over 1000 x 10^6 lb of water were injected into Baca No. 12, greater than half of which (575 x 10^6 lb) was injected during the 1975-1976 Interference Test. After several years of little usage, Baca No. 12 was recompleted and will currently accept about 70 GPM. It was used during Baca No. 12 Injection Period 4 to dispose of small amounts of excess water which Baca No. 14 could not handle from Baca No. 24 Flow Tests 4 and 5.

Three (3) short-term injection tests were run on the original completion of Baca No. 12. The first two tests were felt to be unreliable and will not be discussed. Injection Test 3 determined that Baca No. 12 has a calculated injectivity of .9 gpm/psi at an injection rate of 400 gpm (see Section 5.3.3). While the spinner readings above 4500' are questionable, Injection Test 3 indicated that there was regular wellbore fluid loss between 4500' and 6500' and substantial fluid movement (approximately 30%) below the last survey stop at 6500'. A wellbore restriction was observed from 3343' to 3715' during Injection Tests 2 and 3.

Baca No. 13 During May, 1981 the five day Injection Test 1 was conducted on Baca No. 13 resulting in injection of 6.9 x 10^6 lb of water at an average rate of 130 gpm. The injectivity index seemed to stabilize during the test near 1.06 gpm/psi (Section 5.3.3). A fullbore flowmeter survey (Schlumberger) indicated that the fluid was leaving the wellbore between 4800' and 5850', with 60% of the fluid leaving the bottom 220' of this interval. There was good correlation between the results of this flowmeter survey and the interpretation of the compensated neutron-formation density survey conducted on 10/28/74. (Section 3.3)

Baca No. 14 has been used as an injection well throughout its history and is currently the main water disposal well in the Redondo Creek Field. A total of 1352.3 x 10^6 lb of water have been injected into Baca No. 14 during the 21 recorded injection periods, including 499 x 10^6 lb of water during the 1975-1976 Interference Test. Baca No. 14 has also been used during the three other interference tests.

Baca No. 14 Injection Period 4 disposed of water which was produced from Baca No. 20 Flow Test 4 when that water was not being used to drill Baca Nos. 21 and 22. Baca 14-5 included the water produced from Baca No. 13 Flow Test 5 and Baca No. 4 Flow Test 3 before that water was diverted to be used during the remedial workover of Baca No. 15.

Injection Periods 6 and 7 disposed of 177.7 x 10^6 lb of water produced from Baca No. 24 during Flow Test Nos. 2 and 3. Injection Period 8 was used to dispose of water which had collected in the various reserve pits. Injection Period 9 disposed of the last 53 days of production from Baca No. 13 Flow Test 6, when that water was not used for the redrilling of Baca No. 22. Injection Periods 6 through 9 occurred during the 1981 Interference Test and were an integral part of the analysis (see Section 5.5.2).

Water produced from the Geothermal Resource Inc. well (Water Canyon 4-23) was disposed during Injection Period 10. This water, hauled by truck, was injected very sporadically over a 23 day period. The pressure disturbance created by this activity delayed the beginning of the 1982 Interference Test.

During the second stage of the 1982 testing program (begun 6/82), Baca No. 14 was used extensively as a water disposal well (Section 5.5.3). The second stage activity included 14 individual flow tests, eleven of which were either partially or fully disposed of in Baca No. 14. The only production not disposed of in Baca No. 14 was associated with the four injection tests run on Baca Nos. 4, 15, 18 and 24 and with the high production rates which required using Baca Nos. 12 and 18. Baca No. 14 will currently accept more than 400 GPM without exhibiting a positive wellhead pressure.

Three (3) Injection Tests were conducted on Baca No. 14. The apparent injectivity of the well varys from a value of less than 1 gpm/psi at 450 gpm calculated during Injection Test 1, to values of 2.05 and 2.51 gpm/psi calculated at injection rates of 500 gpm and 200 gpm during Injection Tests 2 and 3 respectively (Section 5.3.3). The injection fluid loss profile is not known in detail. Injection Tests 2 and 3 did not have successful spinner tool runs and Injection Test 1 had its tools stopped at 3984' M.D. due to wellbore scale and/or bridging. Injection Test 1 did indicate that essentially all of the fluid was leaving the wellbore between 3800' and 3984'.

Baca No. 15 Injection Test 1 lasted 141.6 hours at essentially two constant rates - 320 gpm and 275 gpm - resulting in injection of 21.2 x 10^6 lb of water. The injectivity of Baca No. 15 remained a constant 2.0 gpm/psi throughout the injection test (Section 5.3.3). The fluid loss zones were identified from three spinner surveys. While the injection rate was 320 gpm the majority of the injection was leaving the wellbore between 5000' and 5350', with a less major fluid loss zone at 4600-4700'. When the injection rate dropped to 275 gpm, the fluid was still leaving the wellbore in the same zones, but a fluid (steam) entry point was identified at 2500', immediately below the 9-5/8" casing shoe.

Baca No. 18 was used to dispose of small amounts of water during the 1982 testing. Baca No. 18 Injection Period 2, while certainly not one to six days long, was treated as an injection test. Injection Periods 3 and 4 were short-term solutions to problems associated with the injection capabilities of Baca No. 14. The fifth injection period disposed of water produced during Baca No. 4 Flow Test 5.

Four (4) injection tests have been conducted on Baca No. 18, including one rig injection test and one 56-day injection test. The rig injection test consisted of 14 slugs of water being injected at rates of up to 856 gpm (maximum capacity of rig pumps) for periods of approximately 30 minutes. During the 56-day injection test, 164.4×10^6 lb of water produced during Baca No. 13 Flow Test 7 were injected in Baca No. 18 as part of the 1982 Interference Test (Section 5.5.3). The two other injection tests - Nos. 1 and 6 - were normal tests of 31.2 hours and 120 hours respectively, although Test 1 was conducted with 3 injection rates of 225, 450 and 225 GPM.

The injectivity values of Baca No. 18 are consistent at 1.6 - 2.2 gpm/psi (Section 5.3.3). The injection profile, based upon the results of Injection Tests 2 and 6, indicates that 100% of the fluid is leaving the wellbore between 3500' and 4500'.

Baca No. 19 was used as a water disposal well during the 1981 Interference Test (Section 5.5.3). After the drilling of Baca No. 24, Baca No. 19 Injection Period 3 disposed of the water produced from Baca No. 4 Flow Test 3. Upon opening Baca No. 13 for Flow Test 6, the sum of the production from Baca Nos. 4 and 13 was too much to be injected into Baca No. 19, Baca No. 4 was shut-in and the remainder of Injection Period 3 water originated at Baca No. 13.

Two (2) injection tests have been run on Baca No. 19, both during December, 1979. Injection Test 1 was a low rate test with 13 hours of 50 gpm injection and 22 hours of 150 gpm injection. Injection Test 2 was a high rate test with 11 hours of 380 gpm and 1.5 hours of 680 gpm injection which was stopped when a high pressure hose on the supply pump failed. The injectivity of Baca No. 19 varied during the test from 1.4 to 1.5 gpm/psi (Section 5.3.3).

A Schlumberger continuous spinner and temperature log was run during Injection Test 2 at an injection rate of 380 GPM. The spinner survey indicated fluid leaving the wellbore as follows: 1/5 total flow over 3500-3700'; 1/5 over 5000'-5170'; and 3/5 over 5170-5180'. The temperature analysis agreed except it indicated a small amount of injection fluid (approx. 5%) continuing below 5180'; a quantity which lies below the detection limit of the spinner tool.

Baca No. 20 The 5-day Baca No. 20 injection test was conducted prior to recompletion and stimulation of the well. The injection test concluded on July 29, 1981 after 132.5 hours of injection and 14.6 x 10^6 lb of injected fluid. The injectivity index observed during injection into Baca No. 20 was between 0.6 and 1.00 gpm/psi at a relatively constant injection rate of 230 gpm. (Section 5.3.3) Two spinner surveys run during the injection indicated that there were no major points of fluid loss above the deepest point of the spinner survey at 5780'. There were possible minor fluid loss zones between 4000' and 5000'.

Baca No. 23 The 5-day Baca No. 23 injection test began on May 28, 1981 following recompletion and stimulation. The injection test averaged 160 gpm with 11.4 x 10^6 lb of water injected in 155.6 hours. The calculated injectivity ranged from a low of 0.76 gpm/psi to a high of 0.92 gpm/psi (Section 5.3.3). Three Crelad spinner surveys run during the test indicated that the injection water was leaving between 3300' and 3450'. The surveys did not indicate any single major fluid loss zone in the wellbore.

Baca No. 24 Two five day injection tests have been conducted on Baca No. 24. Injection Test 1 lasted 122.7 hours during which 14.5 x 10^6 lb of water were injected at an average rate of 240 gpm. Injection Test 2 lasted 122.1 hours at an average injection rate of 260 gpm, for a slightly higher cummulative injection of 15.6 x 10^6 lb. The spinner and temperature surveys run during the two injection tests indicate that there were no fluid loss zones above 3550'. It is felt that the fluid loss zone is near the bottom of the drilled hole. The large vertical distance between the pressure observation depth and the assumed fluid loss zone makes the calculation of injectivity invalid. The values calculated - 4.3 and 6.8 gpm/psi - are substantially higher than injectivities for other Redondo Creek wells and may not be physically significant.

5.3 Single Well Pressure Transient Tests

Pressure transient testing techniques are defined as the measurement of reservoir pressure variations with time. In a well which has recently been or is currently active with either production or injection, pressure buildup, falloff, drawdown, and injectivity tests are all applicable pressure transient tests. Interference tests, discussed in Section 5.5, are another type of pressure transient test which utilizes two or more wells. Ideally the information obtainable from transient testing includes wellbore volume, damage, and improvement; reservoir pressure; permeability thickness; reserves; reservoir and fluid discontinuities; and other related data. All of this information can be used to help analyze and characterize a reservoir and to forecast reservoir performance.

Pressure buildup tests - probably the most familiar pressure transient testing technique - have been widely used in the geothermal industry. The 1978 Redondo Creek Report (Union, 1978) utilized this type of testing in describing the reservoir rock-fluid flow relationship and the mechanical condition of six Redondo Creek wells. While in theory much quantitative data can be obtained, in practice the majority of the useful data is more qualitative. Section 5.3.1 presents the pressure buildup testing results of the Redondo Creek wells since the 1978 report. Section 5.3.2 describes the pressure falloff testing conducted in the Redondo Creek field. The results of these two sections have been combined and presented in a alternate manner in Section 5.3.3. The injectivity and productivity calculations discussed in Section 5.3.3 are not pressure transient tests but are by-products of pressure buildup and falloff tests.

Two drillstem tests have been successfully conducted in the Redondo Creek field on the two wells which were hydraulically stimulated (Section 4.4.2). The cost of these tests make extensive application impractical.

Alternate pressure transient tests have not been conducted due to their dependence upon obtaining accurate flowing bottomhole pressures. This is a difficult objective when dealing with the flow velocities and temperatures of a geothermal well. For falloff tests and small flow tests the final bottomhole flowing pressures can be measured, but for substantial flow tests they must be calculated. Even the least productive Redondo Creek wells flow at high initial flow rates, eliminating consideration of drawdown tests.

Injectivity Tests - the time monitoring of the pressure increase associated with injection (not to be confused with injectivity calculations) - can be physically run but invariably are distorted by an unsteady injection rate or an incorrect monitoring depth.

The analyses of a pressure buildup or falloff tests are completely analagous: the pressure increase following shut-in of a flow test should be equal and opposite of the pressure decrease following shut-in of an injection tests of the same volumetric rate conducted at the reservoir temperature. When the pressure falloff or buildup data is graphed on a log-log plot showing the change in pressure versus the shut-in time, wellbore storage regime (unit slope), linear flow regimes (one-half slope) and the true pseudo-steady state regime (semilog straight line) are identified (Earlougher, 1977).

The focal point of the buildup and falloff analysis is the Horner Analysis. The pressure data is plotted versus the Horner Time Ratio $[tp + \Delta t]/\Delta t$ on a semilog graph, with tp and Δt defined below. The slope of the correct semilog straight line, as identified from the log-log plot, is used to calculate the apparent permeability-thickness product, kh, and the wellbore skin, s from:

$$kh = \frac{695\ W\mu v}{m}$$

$$s = 1.151\left(\frac{P_{1\ HR} - P_{wf}}{m} - \log \frac{kh}{\phi h \mu c_t r_w^2} + 3.23\right)$$

tp	=	length of activity, hrs
Δt	=	shut-in time, hrs
W	=	mass flow rate, lb/hr
μ	=	fluid viscosity, cp.
v	=	fluid specific volume, ft^3/lb
m	=	slope of semilog straight line, psi/cycle
P_{1HR}	=	straight-line pressure associated with Δt = 1 HR, psig
Pwf	=	flowing pressure immediately prior to shut-in, psig
ϕh	=	reservoir storage, ft
c_t	=	total reservoir compressibility, psi^{-1}
r_w	=	radius of well, ft

The Horner Analysis assumes that the well has been active for tp hours at a constant flow rate W. If the rate has not been constant a correction is necessary. For small rate fluctuations this correction is made by defining tp as the cummulative mass removed or injected divided by the mass rate observed immediately before shut-in.

Various conditions during the buildups and falloffs often affect the pressure response such that the validity of the identified semilog straight line may be suspect. For this reason the parameters derived from the Horner Analysis have been checked against the log-log plot in type-curve match method. The wellbore storage coefficient(s) calculated from the log-log plot and the skin parameters obtained from the Horner Analysis have been used to generate a type-curve for each buildup and falloff test. If the shape of this type-curve is a reasonable reflection of the log-log plot, the correct semilog straight line has been analyzed.

The various pressure buildup and falloff tests have been labeled to be consistent with the flow test or injection test which they follow. It adds continuity to the report and avoids confusion within this report.

5.3.1 Pressure Buildup Tests

Geothermal pressure buildup tests are adversely affected by the geothermal fluid flashing in the reservoir and wellbore. The degree of this flashing must be considered in the buildup analysis. Redondo Creek wells with less than 30% wellhead mass steam fraction have been considered to be dominated by a single-phase reservoir response. Wells with between 30% and 70% mass steam fraction have been analyzed as if the reservoir was two-phase, in a manner proposed by Garg and Pritchett (1981). Wells with higher than 70% mass steam have utilized the same two-phase analysis, but have combined it with the ΔP^2 analysis commonly used on high-compressibility, low-pressure systems.

Every Redondo Creek pressure buildup test has an early pressure response which is controlled by wellbore storage. This response is initially controlled by the compressibility of the wellbore's two-phase mixture but quickly changes to a rising liquid level storage response (Fallon, 1982). Fracture flow is also evident in many pressure buildup tests, indicated by the one-half slope lines on the log-log plots.

Once the wellbore storage and fracture flow effects have diminished, many Redondo Creek wells exhibit reservoir pressure fluctuations. This instability is probably related to the reservoir equilibration of phases following a period of production. Whatever the physical mechanism, it appears to be aggravated by the withdrawal and rentry of wireline tools. Two of the affected wells - Baca Nos. 4 and 13 - have been analyzed by noting the average pressure trend of several buildups. To calculate the reservoir parameters of the well the slope of this trend has been combined with the shut-in flow rate of the most representative pressure buildup test.

Table 5.3.1-1 presents the results of the most representative pressure buildup tests for eleven of the nineteen Redondo Creek wells. This includes results obtained for Baca Nos. 6, 10 and 11 presented in the Technical and Management proposal to the DOE (Union, 1978). The four commercial wells plus Baca Nos. 19, 20, 21 and 23 have had successful buildup tests conducted between 1978 and 1982 which are shown in the table.

Table 5.3.1-1 shows that many wells with a high value of kh also tend to have a high value of skin and conversely some wells with a low kh value have a low, or negative, skin factor. This phenomenom is probably not a reflection of a real reservoir characteristic but is an indication of where the reservoir flashing is occurring. The wells which have a high kh produce more mass and less steam and probably flash in the vicinity of the wellbore. The small kh wells have less mass flow, a higher steam fraction and flash a substantial distance into the reservoir.

Flashing in a small restricted volumetric region close to the wellbore will require more of a temperature drop and hence more of a pressure drop than flash in a relatively large zone away from the wellbore. This pressure drop contributes to the increased skin observed. The exception to this rule is Baca No. 15 which produces from two zones; one steam-dominated and one liquid.

Table 5.3.1-1
Results of Pressure Buildup Tests

WELL NAME	PRESSURE BUILDUP	PRESSURE MONITORING DEPTH ft M.D.	FINAL PRODUCTION RATE lb/hr	CORRECTED PRODUCTION TIME HOURS	kh md-ft	SKIN
Baca No. 4	4	5000'	161,065	124.65	5200	+10.
	5	5000'	158,800	294.49		
Baca No. 6[1]	6	3830'	175,000	1840.33	6401	+ 9.7
Baca No. 10[1]	1	5950'	126,000	310.02	5151	+43.
Baca No. 11[1]	6	6640'	305,900	1913.87	3457	- 3.9
Baca No. 13	7	5700'	187,000	1393.70		
	8	5700'	205,700	130.11		
	9	5700'	187,200	308.67	6360	+17.
Baca No. 15	3	5000'	282,700	140.0	3900	- 5.4
Baca No. 19	6	5000'	158,600	93.85	3530	+ 1.4
Baca No. 20[2]	4	4500,5000'	150,442	2680.3	1850	- 3.1
Baca No. 20[3]	DST	-	19,000	6.3	540	- 3.8
	7	5000'	46,700	106.8	540	- 6.7
Baca No. 21	5	2750'	35,320	1275	2800	-
Baca No. 23[3]	DST	2987'	21,000	5.67	2040	- 3.8
Baca No. 24	4	3250'	281,300	123.82	9550	+ 2.4

1. From Technical and Management proposal to the D.O.E.

2. Before hydraulic stimulation.

3. After hydraulic stimulation.

Following is a brief discussion of the most representative pressure buildup for the eight Redondo Creek wells successfully tested since 1978. The buildup interpretation and its implications on implied well characteristics are presented.

Baca No. 4 - pressure monitoring following Flow Tests 4 and 5 showed almost identical pressure responses when displayed on a log-log plot (Figure 5.3.1-1). The early data was controlled by wellbore storage which decreased by a factor of 2.3 and the semilog straight line was dominated by pressure fluctuations. The log-log plot indicates that the correct semilog straight line begins at a shut-in time of a 3 hours, resulting in the smoothed line shown on Figure 5.3.1-2. The Horner Analysis of this line results in an apparent permeability thickness of 5200 md-ft and a skin of +10. Baca No. 4 is therefore a permeable producer with a large skin factor due to near wellbore reservoir flashing.

Baca No. 13 pressure monitoring following Flow Tests 7, 8 and 9 show an extremely unique but consistent behavior when displayed on a log-log plot (Figure 5.3.1-3). The early data was controlled by wellbore storage, a decrease in wellbore storage, fracture flow pressure response, and more wellbore phenomenom before reaching the beginning of the apparent semilog straight line at a shut-in time of 30 hours. The slope of the pressure trend of Figure 5.3.1-4 led to a Horner Analysis calculation of permeability thickness and skin of 6360 md-ft and +17.

There are several subtle, but inconclusive, factors which indicate that Baca No. 13 may be controlled by a constant pressure boundary. The inconsistency of the high calculated skin, but a fracture flow pressure response; the consistent bottomhole flowing pressures calculated (not observed) for the buildups following the significantly different length Flow Tests 7, 8 and 9; and the near pressure stabilization during the apparent pseudo-steady state pressure response (particularly during Pressure Buildup 7).

Baca No. 15 pressure monitoring following Flow Tests 3 and 4 displayed classic examples of changing wellbore storage, as shown in Figure 5.3.1-5. The correct semilog straight line was reached within two hours of shut-in. Figure 5.3.1-6 shows the semilog straight line used to calculate a permeability thickness of 3900 md-ft and a skin of -5.4. The leveling off of the pressure trend at Horner Times of less than four is influenced by a constant pressure boundary.

Baca No. 15 production originates in two separate zones - one two-phase top zone and one single phase bottom zone - which could explain two things. The constant pressure boundary effect could be connected to the wellbore influence of the two-phase zone on the liquid zone and the low skin factor indicates that near wellbore reservoir flashing is not occurring i.e. the relatively high steam fraction is originating almost entirely in the top zone.

FIGURE 5.3.1-1

LOG-LOG PLOT OF BACA NO. 4 BUILDUP DATA FOLLOWING FLOW TESTS NO. 4 AND 5
SHUT-IN ON 6/14/82 0809 HRS AND 7/12/82 0932 HRS, PWF = 500 AND 470 PSIG

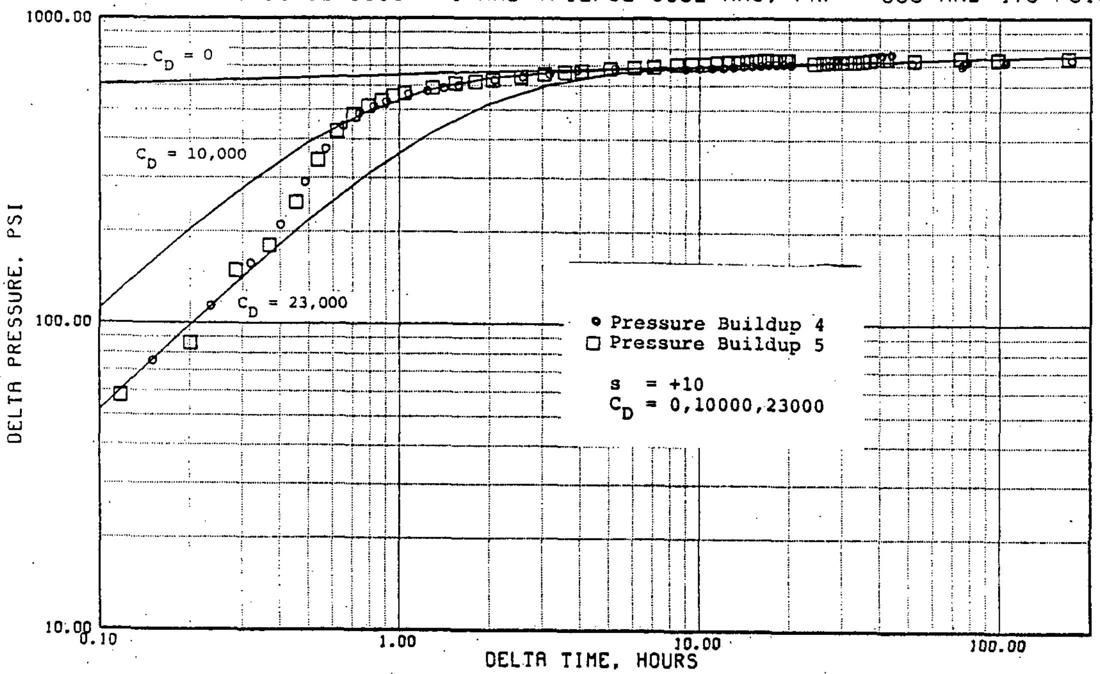


FIGURE 5.3.1-2

BACA NO. 4 PRESSURE BUILDUPS FOLLOWING FLOW TESTS 4 AND 5. HORNER PLOT
SHUT-IN ON 6/14/82 0809 HRS AND 7/12/82 932 HRS

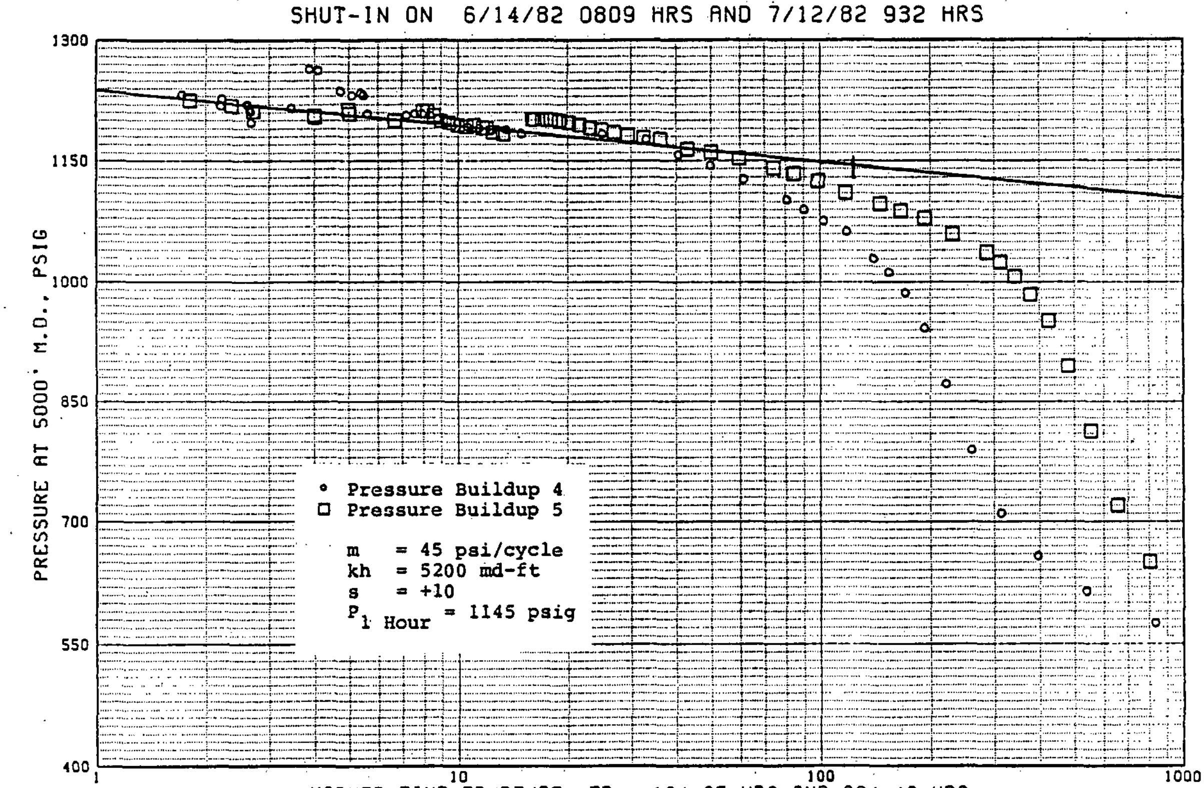


FIGURE 5.3.1-3

LOG-LOG PLOT OF BACA NO. 13 BUILDUP DATA FOLLOWING FLOW TESTS 7,8 AND 9
SHUT-IN ON 4/13/82 6/07/82 AND 7/06/82. PWF= 465 PSIG

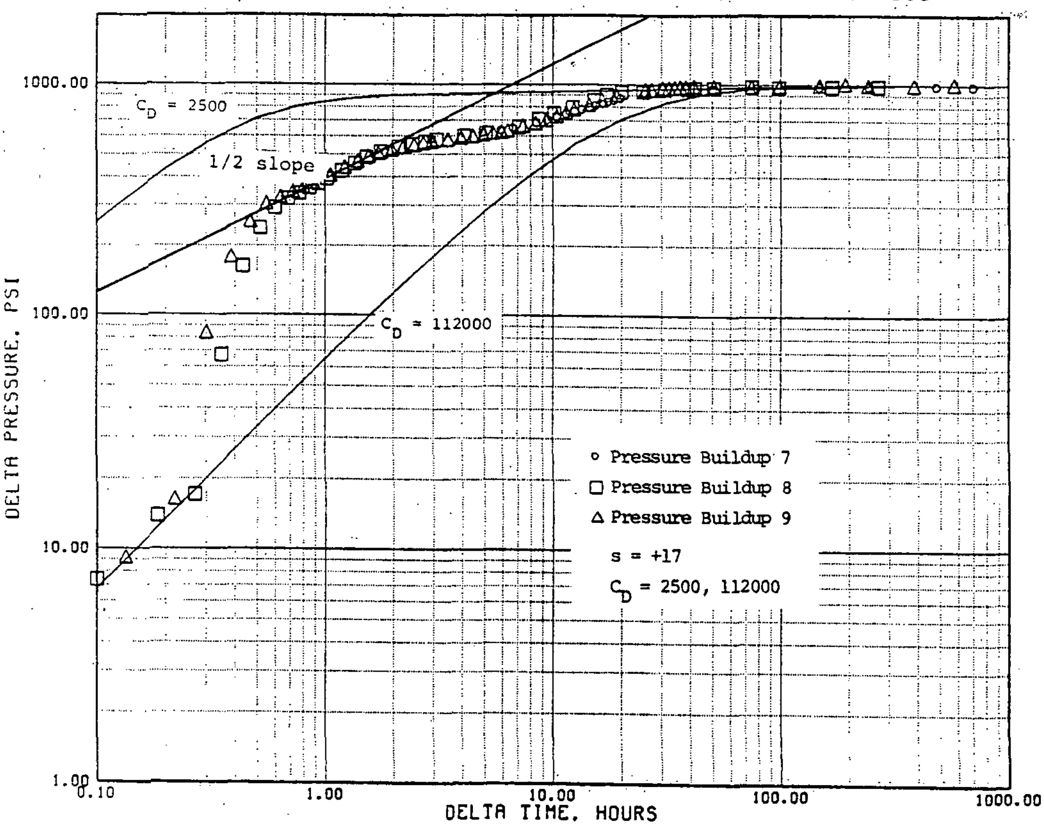


FIGURE 5.3.1-4

BACA NO. 13 PRESSURE BUILDUPS FOLLOWING FLOWTESTS 7, 8 AND 9
HORNER PLOT

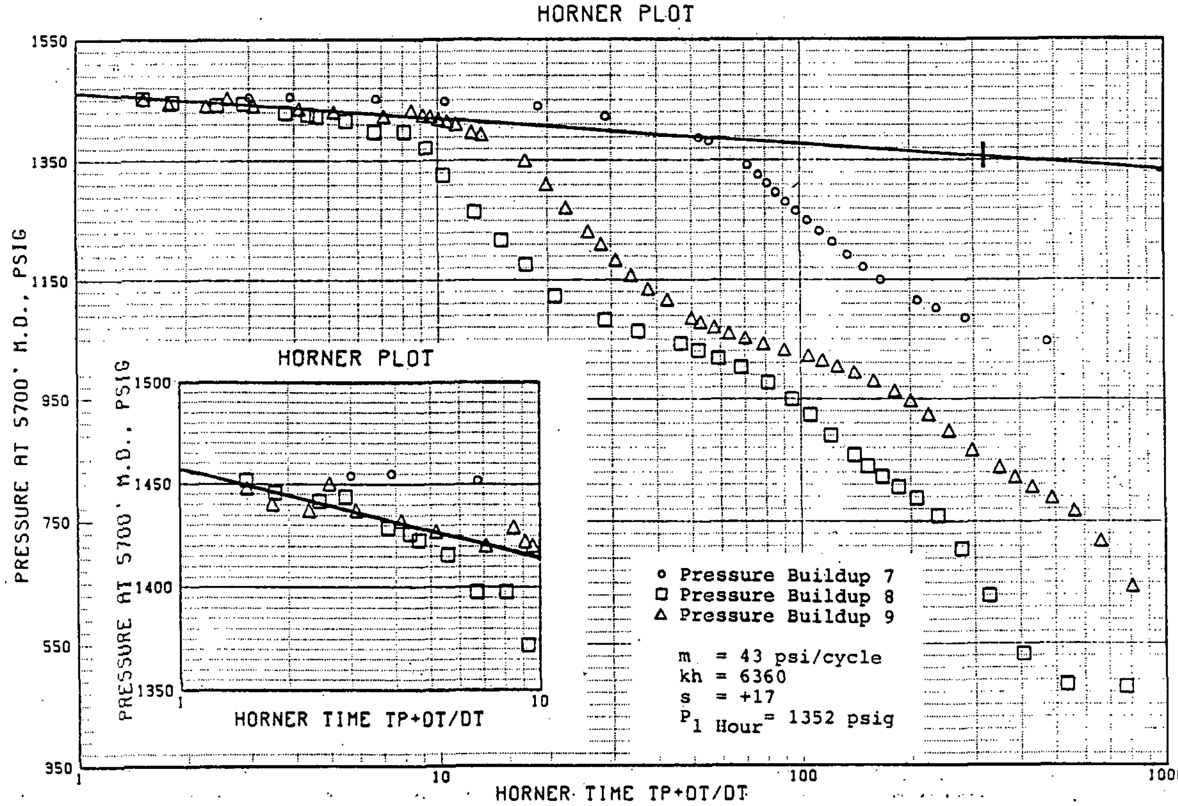


FIGURE 5.3.1-5

LOG-LOG PLOT OF BACA NO.15 BUILDUP DATA FOLLOWING FLOW TEST 3
SHUT-IN ON 7/26/82 AT 0850 HRS, PWF= 516 PSIG

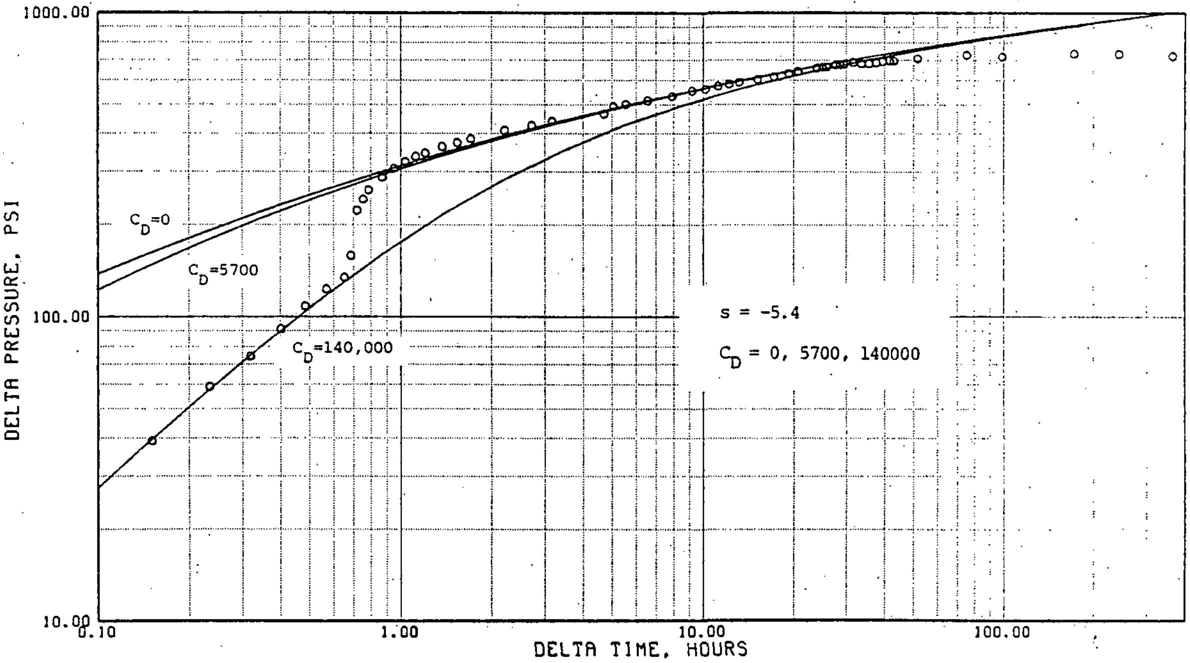
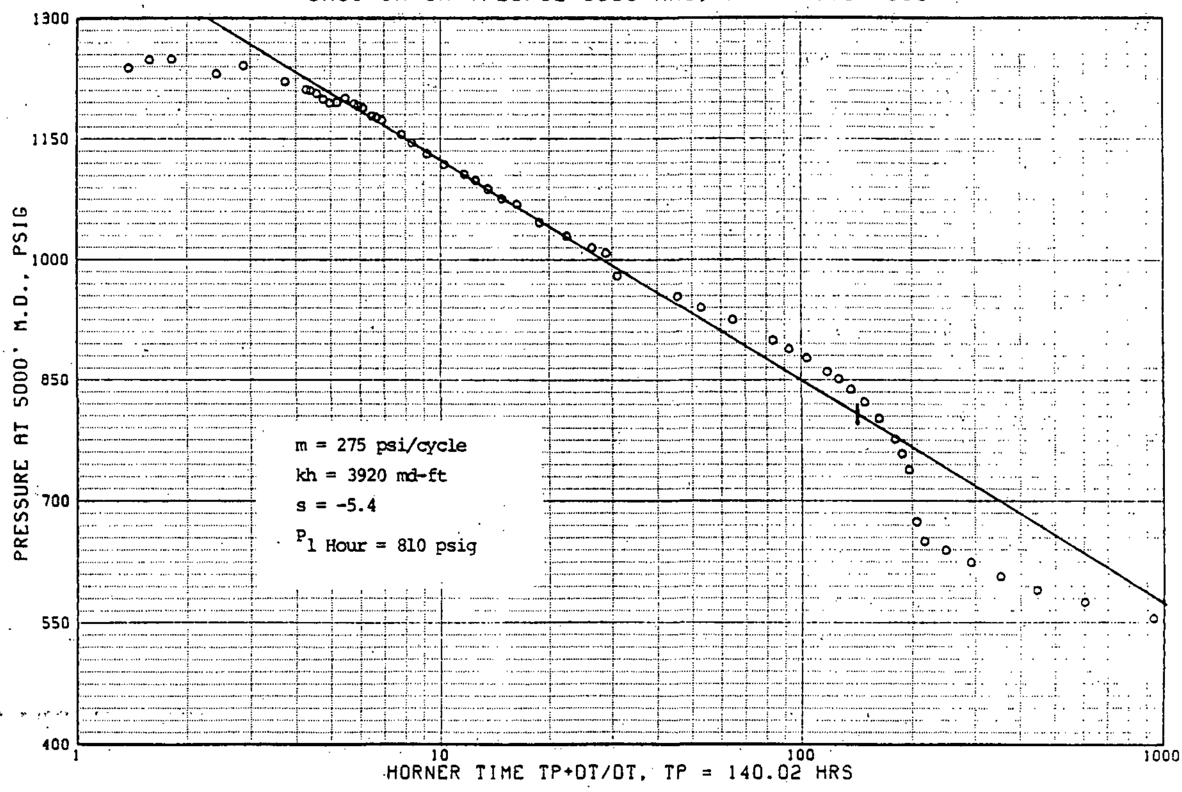


FIGURE 5.3.1-6
BACA NO. 15 PRESSURE BUILDUP FOLLOWING FLOW TEST 3, HORNER PLOT
SHUT-IN ON 7/26/82 0850 HRS, PWF = 516 PSIG



Baca No. 19 Several pressure buildup tests have been conducted on Baca No. 19, most of which followed two-phase flow tests characterized by severe cycling. Figure 5.3.1-7 shows the log-log response of Baca No. 19 following Flow Test 6 - a separator tests with a steady flow rate - with the semilog straight line beginning at a shut-in time of one hour. Figure 5.3.1-8 displays the semilog straight line used to calculate a permeability thickness and skin of 3530 md-ft and +1.4. Baca No. 19 is thus characterized as a well with medium permeability and little if any reservoir flashing. This lack of steam fraction increases the wellbore pressure drop and decreases the flowing wellhead pressure.

Baca No. 20 was hydrualically stimulated during 1981. The prefracture characteristics of the well are best represented by Pressure Buildup 4, while the well's current characteristics are obtained from Pressure Buildup 7. In additional to these tests the drillstem test conducted immediately after the stimulation is presented in Section 4.4.2.

The pressure monitoring following Flow Test 4 was performed at two separate depths; 4500' and 5000' M.D. Figure 5.3.1-9 displays the pressure data and reveals the substantial data scatter when comparing data from 4500' to data from 5000'. The apparent semilog straight line begins at a shut-in time of 50 hours, resulting in analysis of the two dashed lines shown on Figure 5.3.1-10.

The Horner Analysis of these lines led to a calculated kh of 570 md-ft and a skin of -6.7. These values seem to be too poor to be representative of a commercial well. This supports the work of Riney and Garg (1981) who attributed this false semilog straight line to two-phase effects and identified a correct semilog straight line similar to the solid line indicated on Figure 5.3.1-10. Horner Analysis of this line results in an apparent permeability thickness of 1850 md-ft and a skin of -3.1. This indicates that Baca No. 20 had marginal permeability thickness, but was helped by reservoir flashing away from the wellbore.

After recompletion, stimulation, and acid cleanout, Baca No. 20 did not produce commercial quantities of fluid. The high steam quality observed during Flow Test 7 necessitated using the ΔP^2 analysis. Figure 5.3.1-11 is the log-log plot of the pressure buildup following Flow Test 7, indicating effects of a wellbore storage and fracture flow and an observed semilog straight line. The best semilog straight line of the Horner graph (Figure 5.3.1-12) results in calculated parameters of 540 md-ft and -6.7. The close match of this permeability thickness factor with that obtained from the drillstem test suggests that a valid semilog straight line was choosen i.e. that all of the one-half slope line shown on Figure 5.3.1-11 must not be due to fracture flow .

The acid cleanout of Baca No. 20 may be called a success if the change in skin from the drillstem test to Pressure Buildup 7 is considered. The skin improvement had no noticeable effect on production rates; probably a reflection of the poor matrix permeability surrounding Baca No. 20.

FIGURE 5.3.1-7

LOG-LOG PLOT OF BACA NO. 19 BUILDUP DATA FOLLOWING FLOW TEST 6
SHUT-IN ON 9/27/82 AT 1020 HRS, PWF= 707 PSIG

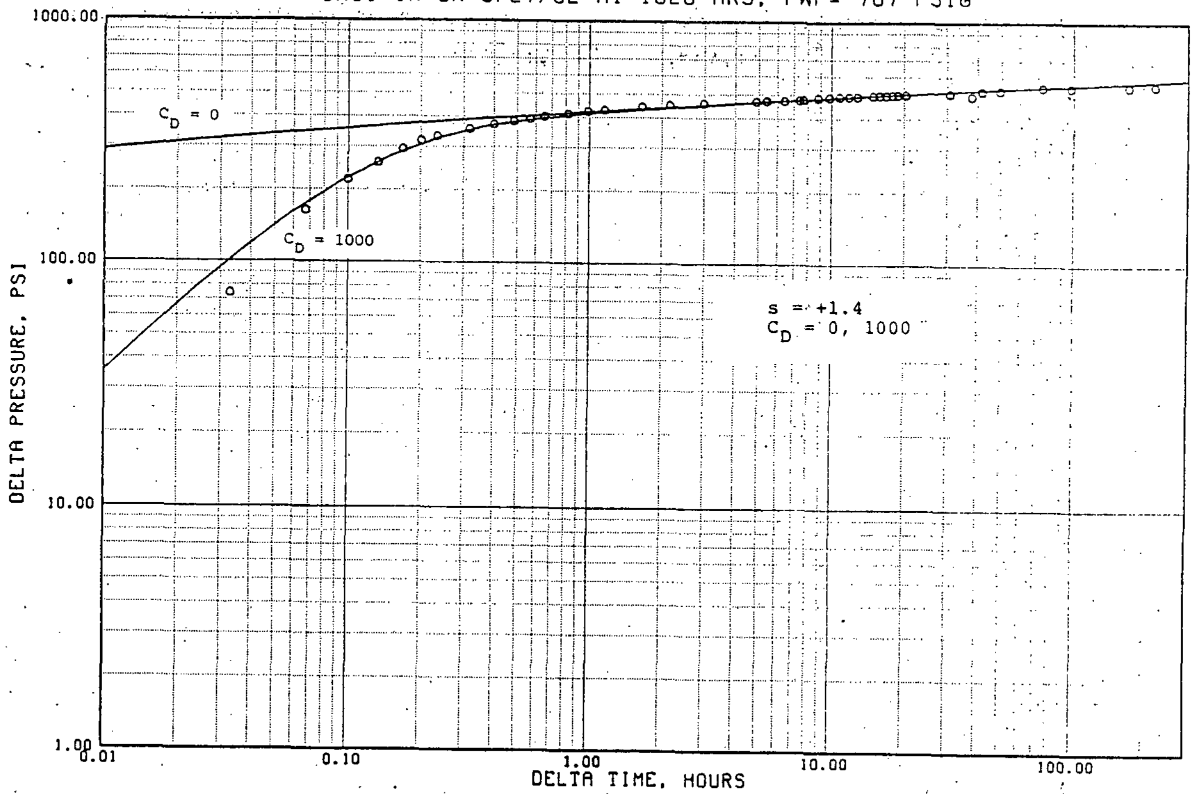


FIGURE 5.3.1-8

BACA NO. 19 PRESSURE BUILDUP FOLLOWING FLOWTEST 6, HORNER PLOT
SHUT-IN ON 9/27/82 AT 1020 HRS

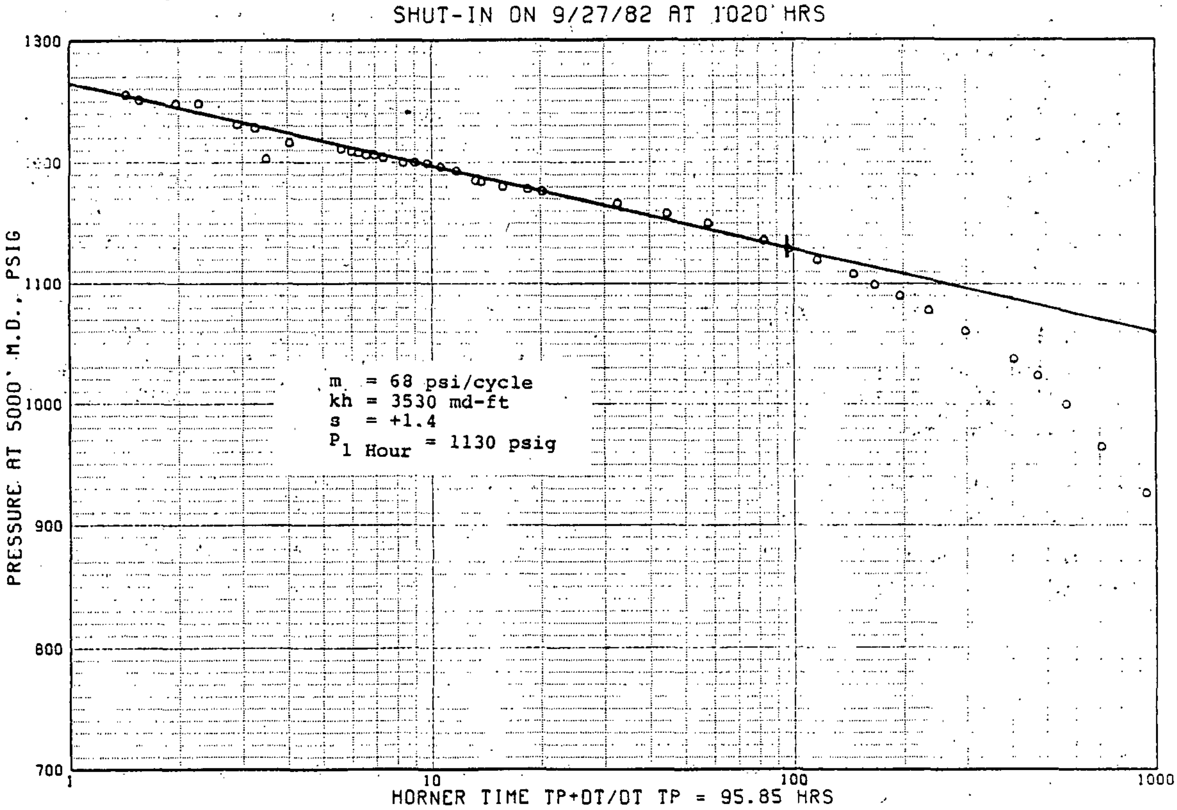


FIGURE 5.3.1-9

LOG-LOG PLOT OF BACA NO. 20 BUILDUP DATA FOLLOWING FLOW TEST 4
SHUT-IN ON 1/06/81 AT 922 HRS. PWF = 200 AND 256 PSIG

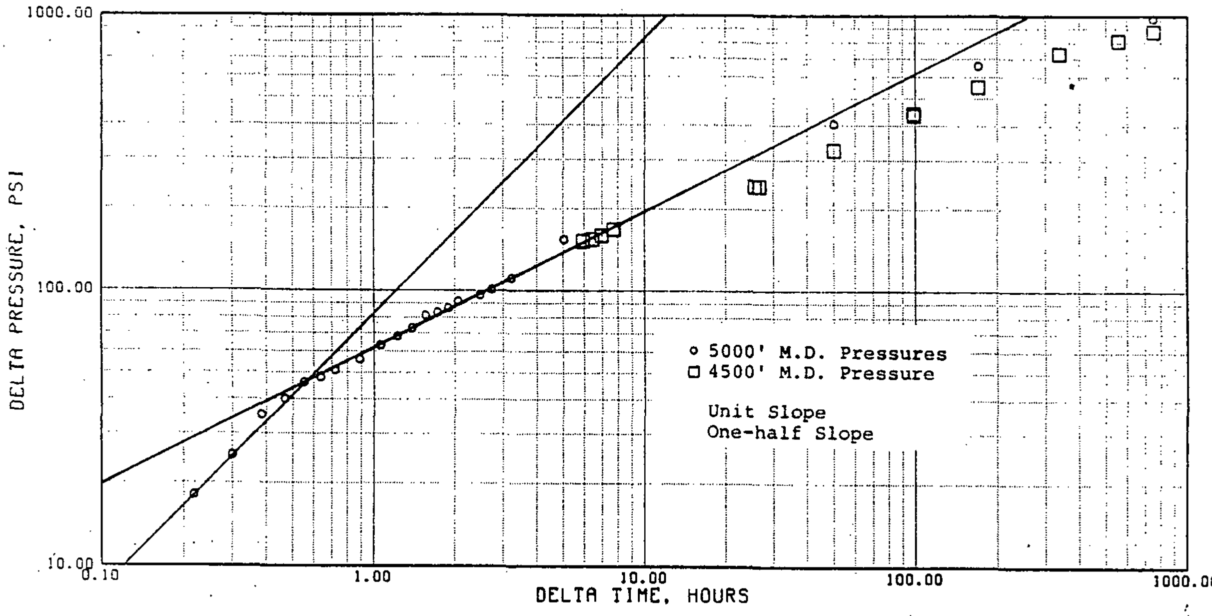


FIGURE 5.3.1-10

BACA NO. 20 PRESSURE BUILDUP FOLLOWING FLOW TEST 4. HORNER PLOT
SHUT-IN ON 1/06/81 AT 0922 HRS

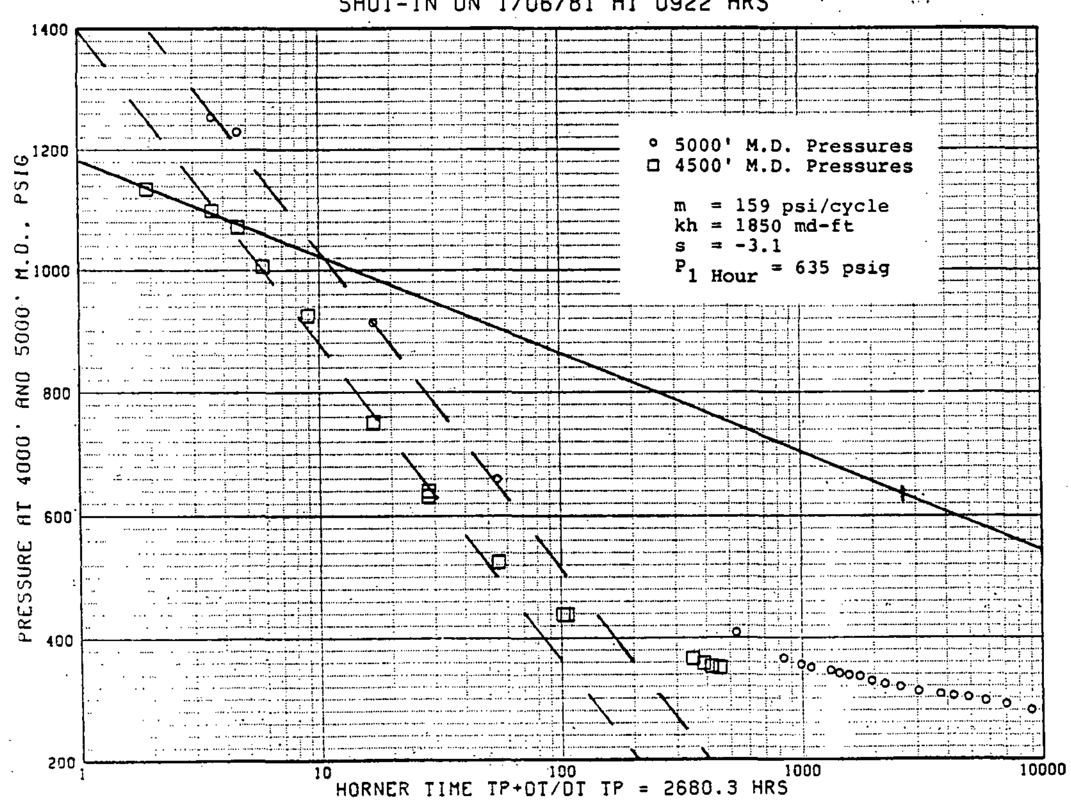


FIGURE 5.3.1-11

LOG-LOG PLOT OF BACA 20 DELTA PRESSURE SQUARED FOLLOWING FLOW TEST 7
PRESSURE BUILDUP 7 PWF= 163.0 PSIA

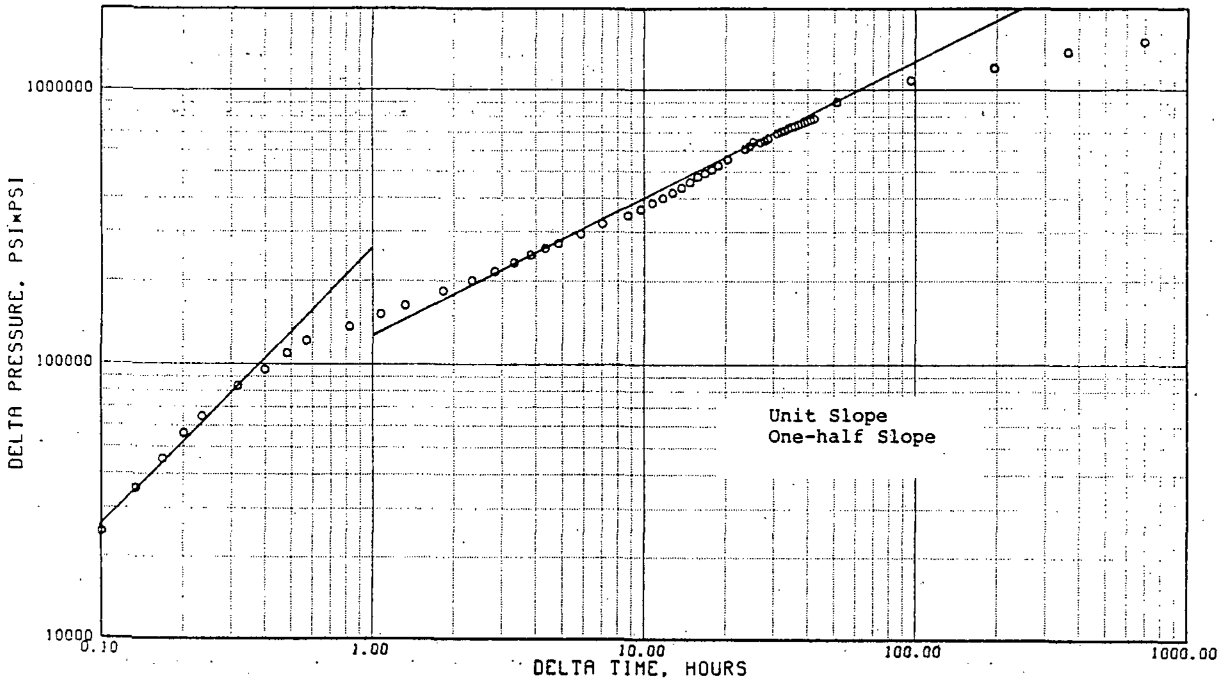
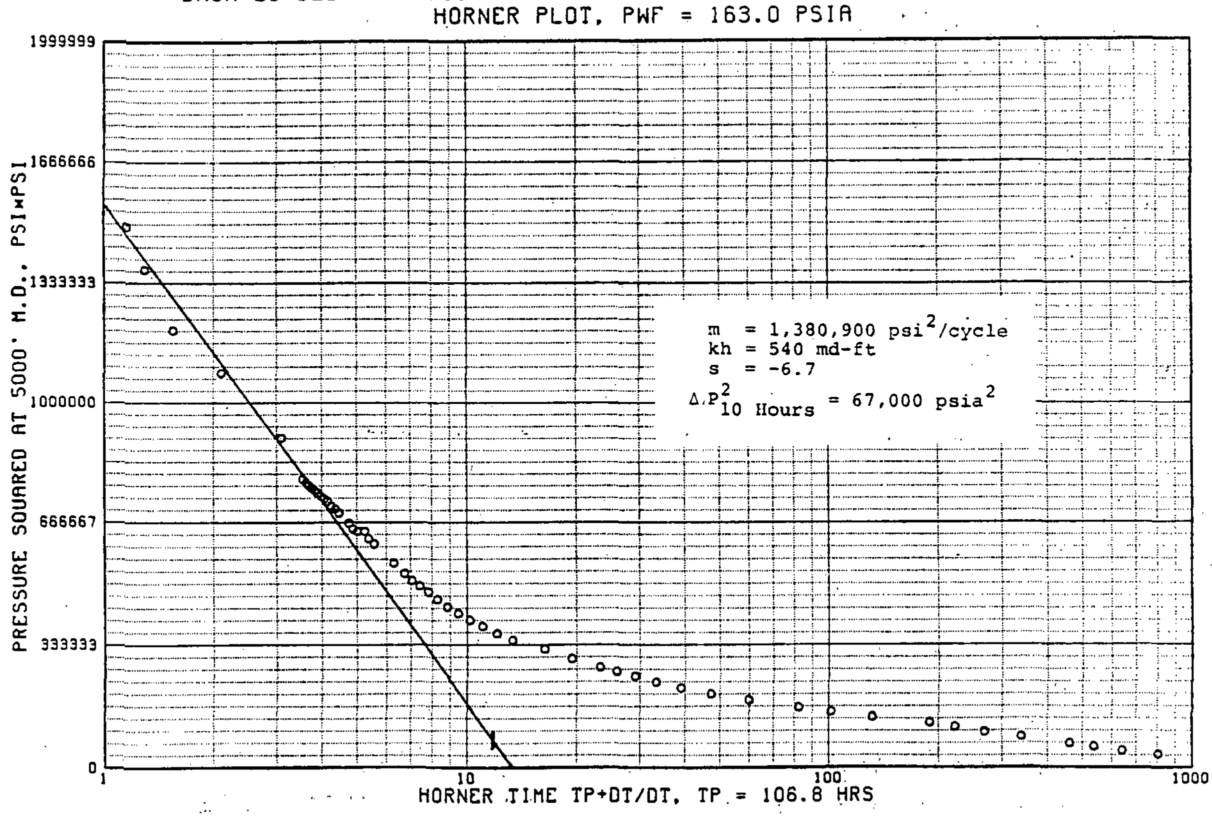


FIGURE 5.3.1-12

BACA 20 DELTA PRESSURE SQUARED BUILDUP TEST FOLLOWING FLOWTEST 7
HORNER PLOT, PWF = 163.0 PSIA



Baca No. 21 is a shallow well which was analyzed by the Δp^2 approach due to the high steam fraction observed during flow tests. Pressure Buildup 5 contained indications of wellbore storage, changing wellbore storage and a fracture flow pressure response. Figure 5.3.1-13 displays the excellent match of the log-log data to a type-curve for a vertically-fractured well with wellbore storage. The first pressure stabilization shown on Figure 5.3.1-13 - from a shut-in time of .3 to 1 hour - is due to an increase in the wellbore storage coefficient. The other stabilizations were probably caused by reservoir equilibration of phases following the two-phase production. The correct semilog straight line was never reached but analysis of the type-curve match indicated on Figure 5.3.1-13 results in a calculated permeability thickness of 2800 md-ft. While a skin parameter was not calculated a negative skin is suggested by the fractured characteristic of the well.

Baca No. 23 has only one valid buildup test; the drillstem test presented in Section 4.4.2. The calculated parameters of permeability thickness and skin of 2040 md-ft and -3.8 characterize Baca No. 23 as a well of marginal permeability producing a high steam fraction.

Baca No. 24 Several pressure buildup tests have been conducted on Baca No. 24 at a pressure monitoring depth significantly removed from the suspected reservoir depth. While each of these buildups - 3, 4 and 5 - have indicated that Baca No. 24 has a large permeability factor, the magnitude of this factor has varied. The log-log plot of the most representative buildup - No. 4 - is displayed on Figure 5.3.1-14, indicating that the start of the semilog straight line is at a shut-in time of 4 hours. Horner Analysis of the semilog straight line indicated on Figure 5.3.1-15 resulted in calculation of an apparent permeability thickness of 9550 md-ft and a skin of +2.4. The dramatic pressure decrease observed between Horner times of 17 and 9 is attributed to two-phase equilibration in the reservoir and wellbore. During Pressure Buildups 3 and 5 these effects were distributed over a longer time period, distorting the pressure buildup behavior of the reservoir.

The low skin factor and the good communication with Baca No. 6 observed during the interference tests suggest that Baca No. 24 is producing single phase fluid into the wellbore from a high permeability reservoir.

FIGURE 5.3.1-13

LOG-LOG PLOT OF BACA 21 DELTA PRESSURE SQUARED FOLLOWING FLOW TEST 5
PRESSURE BUILDUP 5 PWF= 91.0 PSIA

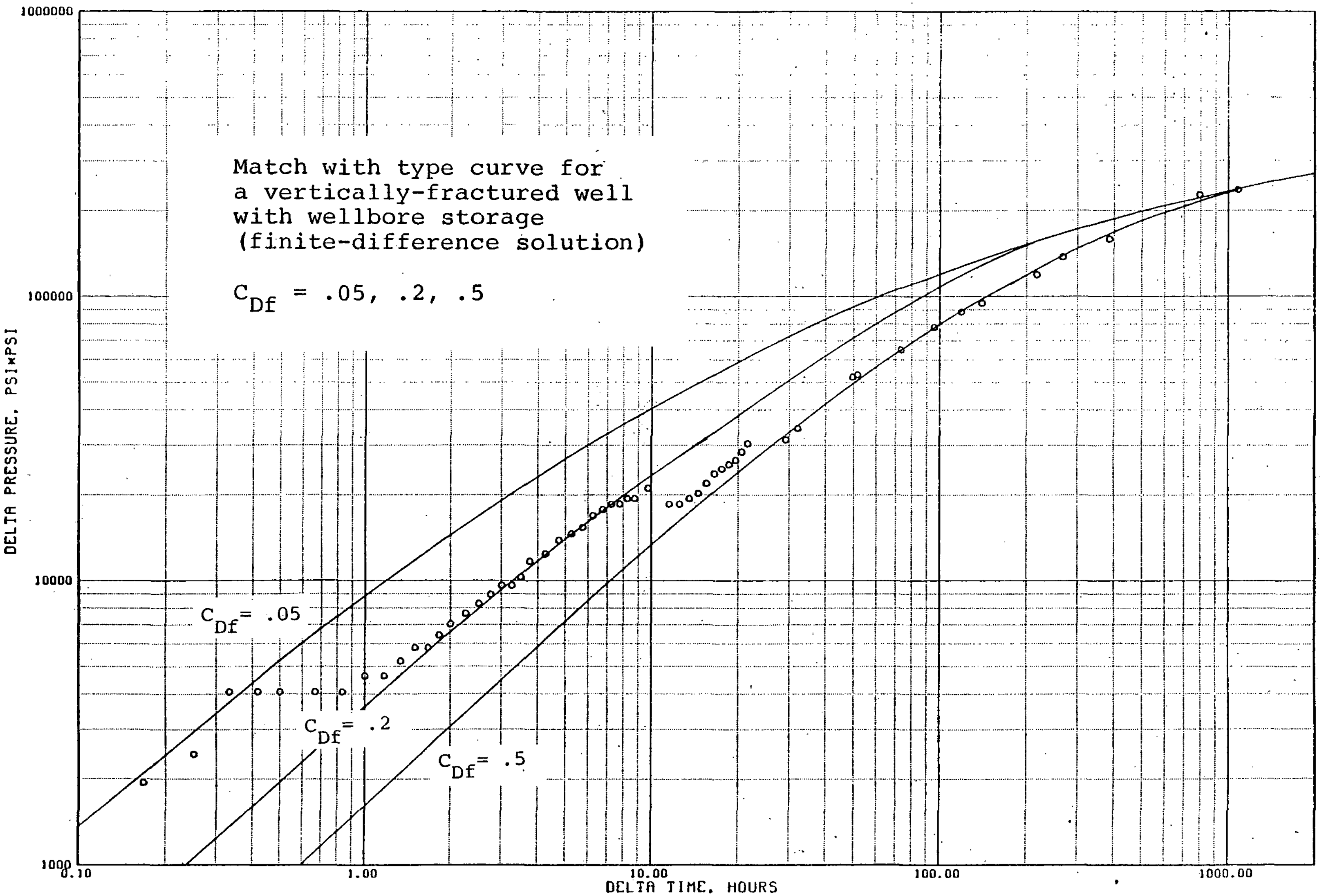


FIGURE 5.3.1-14

LOG-LOG PLOT OF BACA NO. 24 BUILDUP DATA FOLLOWING FLOW TEST 4
SHUT-IN ON 6/21/82 AT 0940 HRS PWF = 412

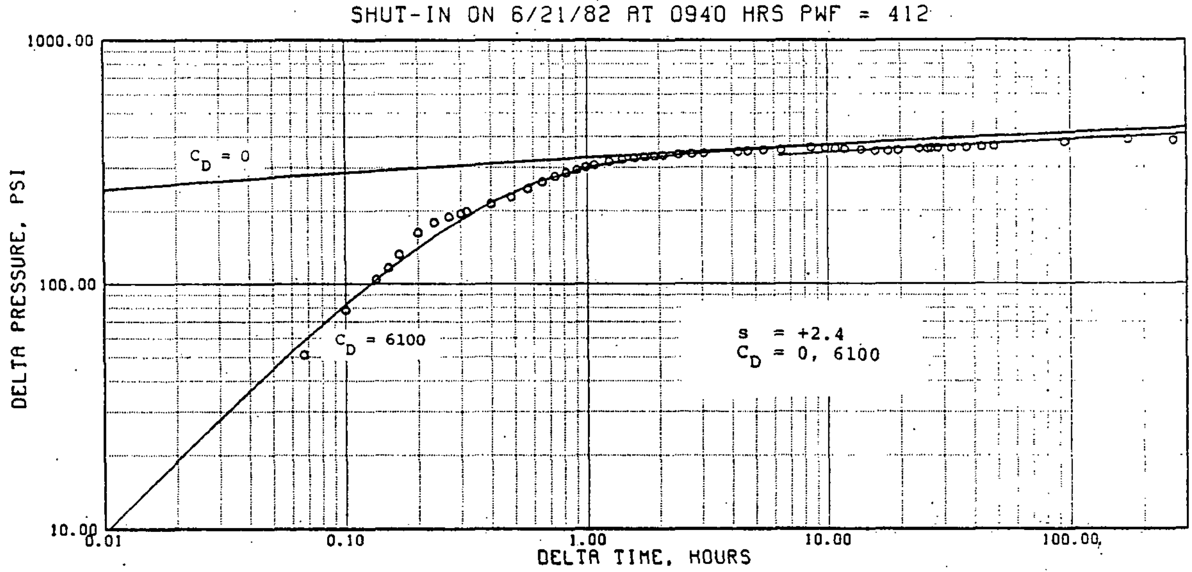
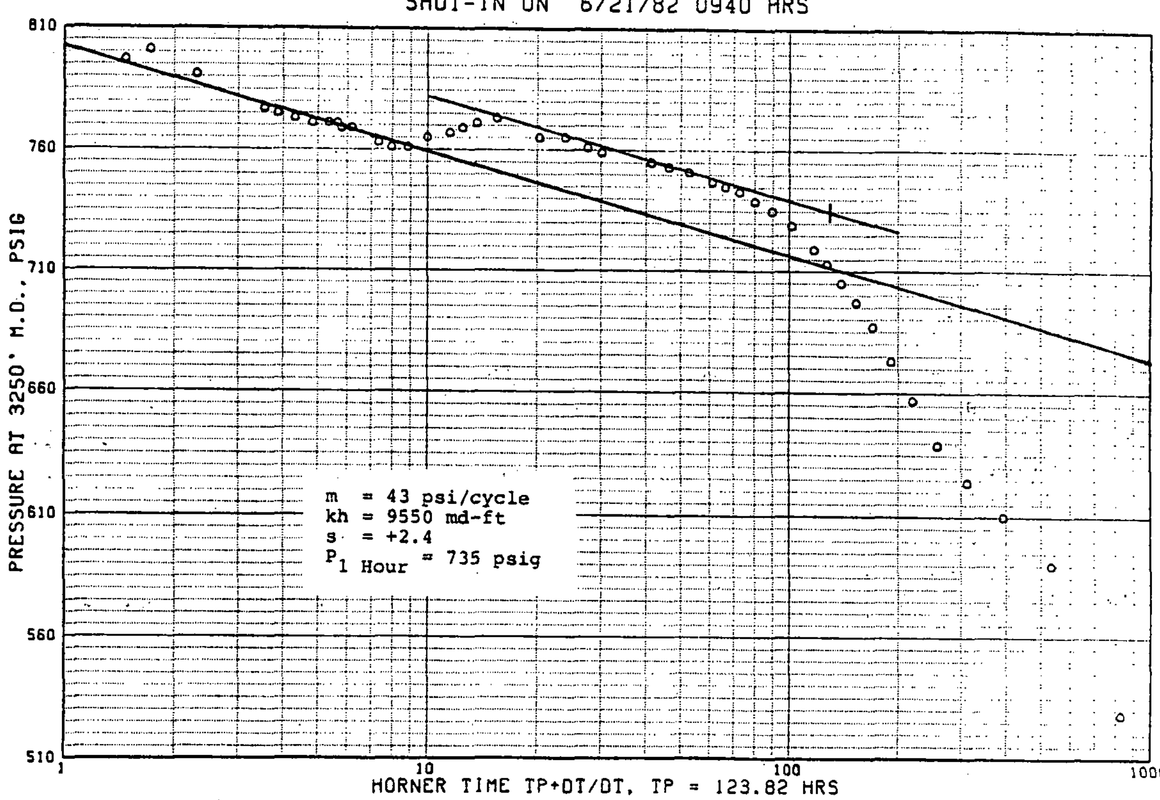


FIGURE 5.3.1-15

BACA NO. 24 PRESSURE BUILDUP FOLLOWING FLOWTEST 4, HORNER PLOT
SHUT-IN ON 6/21/82 0940 HRS



5.3.2 Pressure Falloff Tests

Pressure falloff testing is defined as the monitoring of the reservoir pressure response following the shut-in of an injection test. This pressure response data has been analyzed in a manner completely analagous to the pressure buildup test analysis discussed in Section 5.3.1 with 1) a log-log plot of delta pressure vs. shut-in time used to determine the correct semi-log straight line 2) a typical Horner Analysis of that straight line to determine the reservoir parameters kh and s, and finally 3) these determined parameters are superimposed over the log-log graph to check their validity.

While pressure falloff testing has two advantages over pressure buildup testing in that the two-phases of a recently produced well are not present and the flowing bottomhole pressure is always measured, the falloff analysis is complicated by a temperature difference. The temperature of the injected fluid is typically less than 180°F while the temperature of the formation fluid is roughly 500°F. This temperature contrast is a significant factor which can eliminate any meaningful analysis of a pressure falloff test, particularily if the correct monitoring depth is not selected. The hydrostatic gradients of the two conditions - .421 psi/ft for 180°F and .340 psi/ft for 500°F water - are so dramatically different that as the wellbore fluid temperature increases following shut-in, the change in pressure at any wellbore depth except the major fluid loss zone will be substantial. A 500 foot uncertainty in selection of the correct pressure monitoring depth will result in a 40 psi pressure increase just due to the temperature increase from 180°F to 500°F.

Another complication of a non-isothermal system is the determination of the correct fluid properties to use in the falloff analysis. Computer simulation work at Union Oil Company has indicated that for relatively short injection period (less than 100 days) the pressure response following injection is controlled by the formation fluid i.e. the hot fluid properties. Thus for a given injection mass flow in lb/hr, the specific volume, viscosity and compressibility used in the falloff analysis should correspond to a fluid at reservoir conditions.

Ten of the nineteen Redondo Creek wells have had pressure falloff tests recorded, four of which gave no quantitative results. The analysis of the falloffs from these four wells - Baca Nos. 5A-3, 13-1, 14-3 and 24-1, 2 - were severely affected by the thermal effects mentioned, unrealistic pressure fluctuations, or insufficient injection times and will only be quantitatively discussed. The remaining six falloff tests are presented in Table 5.3.2-1 and discussed in more detail below.

Table 5.3.2-1

Results of the Injection Pressure Falloff Tests

WELL NAME	INJECTION TEST	FLUID TEMPERATURE ORIFICE °F	FLUID TEMPERATURE RESERVOIR °F	INJECTION RATE lb/hr	CORRECTED INJECTION TIME hrs	kh md-ft	s
Baca No. 12	3	60	450	200,000	33.8	1760	-3.9
Baca No. 15	1	180	500	132,000	159	3440	-5.7
Baca No. 18	6	150	490	122,000	186	7670	- .6
Baca No. 19	2	60	480	340,000	–[1]	4000	-2.1
Baca No. 20[2]	1	165	500	115,000	127	2530	-3.6
Baca No. 23[3]	1	160	450	78,200	145	4850	+2.2

1. Used Horner Variable Time Analysis.
2. Pre-Fracture
3. Post-Fracture

Table 5.3.2-1 shows a range of permeability-thickness that is consistent with the range calculated from the buildup tests (Table 5.3.1-1). The values of skin are all significantly lower than the range seen in Table 5.3.1-1. This is due to the additional skin which occurs as the well flashes during production; not present during injection. Almost all pressure falloff tests were dominated by wellbore storage regimes immediately following shut-in. A field-wide average dimensionless wellbore storage factor of C_D = 1000 was used on all of the log-log graph validations.

Baca No. 5A Falloff 3 followed 570,900 gallons of injected water. Examination of the log-log plot of delta pressure vs. shut-in time suggests 1) that the actual skin of Baca No. 5A is greater than zero and 2) the valid semilog radial flow straight line was not reached due to wellbore storage.

Baca No. 12 Falloff 3 was conducted following injection of 811,200 gallons of cold water at 400 gpm. The log-log plot (Figure 5.3.2-1) suggests that Baca No. 12 was a stimulated well. The Horner Analysis resulted in an apparent permeability-thickness and skin of 1760 md-ft and -3.9. Figure 5.3.2-2 shows the semilog straight line and the deviation of the last four pressure observations. The thermal changes which caused this deviation apparently did not significantly effect the earlier data points, as is shown by the good fit of the Horner parameters on the log-log plot.

Baca No. 13 Falloff 1 followed injection of 844,121 gallons of water. The log-log plot indicated that the first 10 hours of shut-in pressure response was dominated by fracture flow phenomenom. The correct semi-log straight line was never reached.

Baca No. 14 Falloff 3 followed injection of 814,900 gallons of cold water. A discrepancy between the apparent reservoir parameters obtained from 1) the Horner Analysis and 2) the log-log type curve match suggests that the non-isothermal injection falloff conditions severely altered the pressure falloff behavior.

Baca No. 15 Falloff 1 was conducted following injection of 2,600,000 gallons of water over a six day period. The steam entry and downflow identified during the water injection (from the spinner surveys) continued during the first part of the pressure falloff. This activity slightly distorted the log-log plot which tentatively indicated that Baca No. 15 is a stimulated well. Figure 5.3.2-3 shows the Horner Graph with the correct straight line identified. The early pressure fluctuations are caused by the steam downflow and the late-time data reveals a leveling off of the pressure falloff. This leveling is characteristic of the Baca No. 15 transient tests. The Horner Analysis resulted in an apparent permeability-thickness of 3440 md-ft and a skin of -5.7.

FIGURE 5.3.2-1

LOG-LOG PLOT OF BACA NO. 12 FALLOFF DATA FOLLOWING INJECTION TEST 3
SHUT-IN ON 5/06/80 AT 1956 HRS. PWF = 1434 PSIG

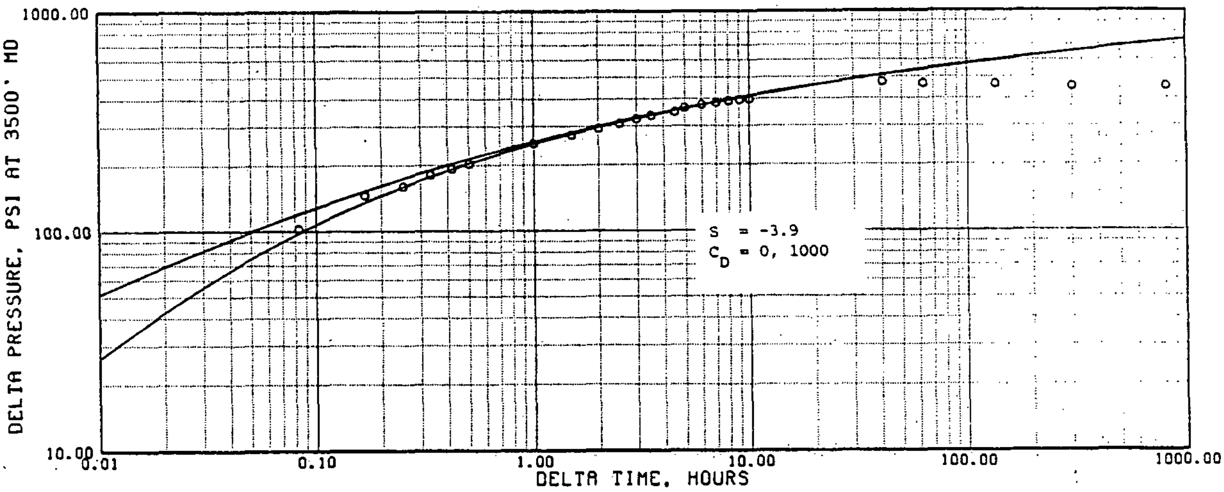


FIGURE 5.3.2-2

BACA NO. 12 PRESSURE FALLOFF FOLLOWING INJECTION TEST 3, HORNER PLOT
SHUT-IN ON 5/06/80 AT 1956 HRS

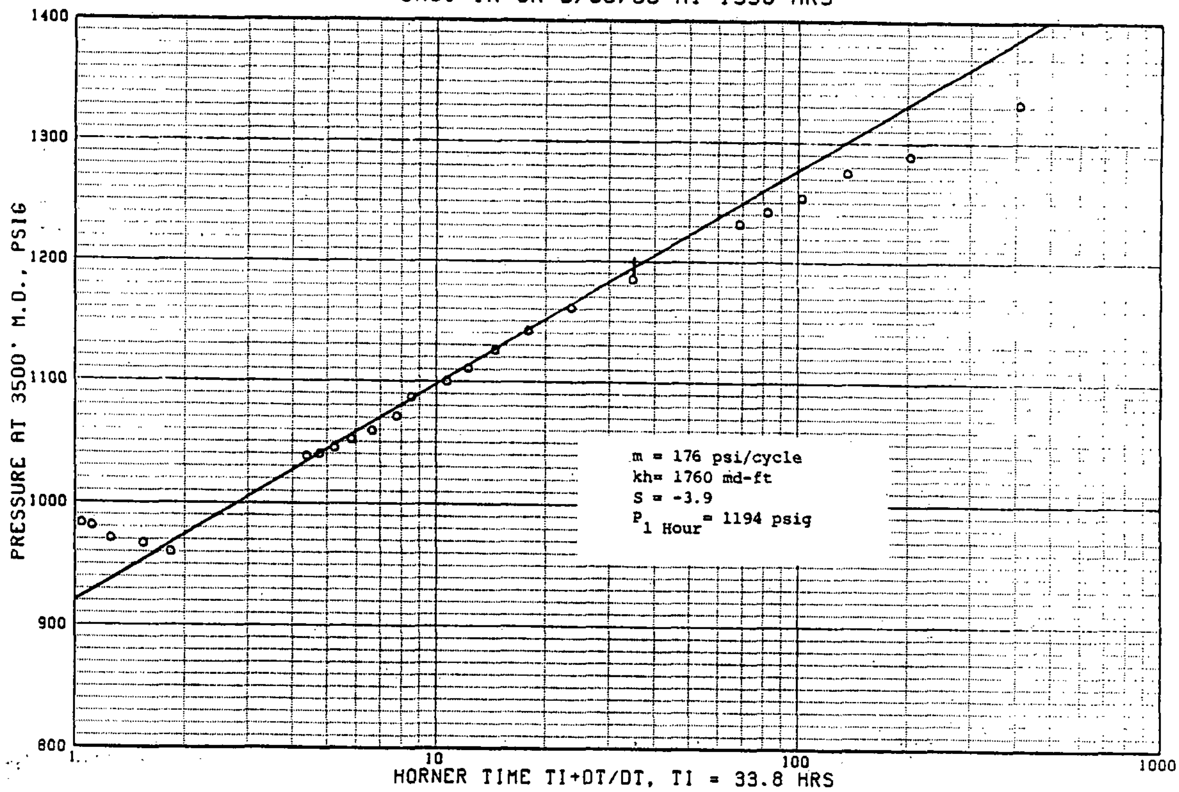


FIGURE 5.3.2-3
BACA NO. 15 PRESSURE FALLOFF FOLLOWING INJECTION TEST 1, HORNER PLOT
SHUT-IN ON 6/30/82 AT 1130 HRS

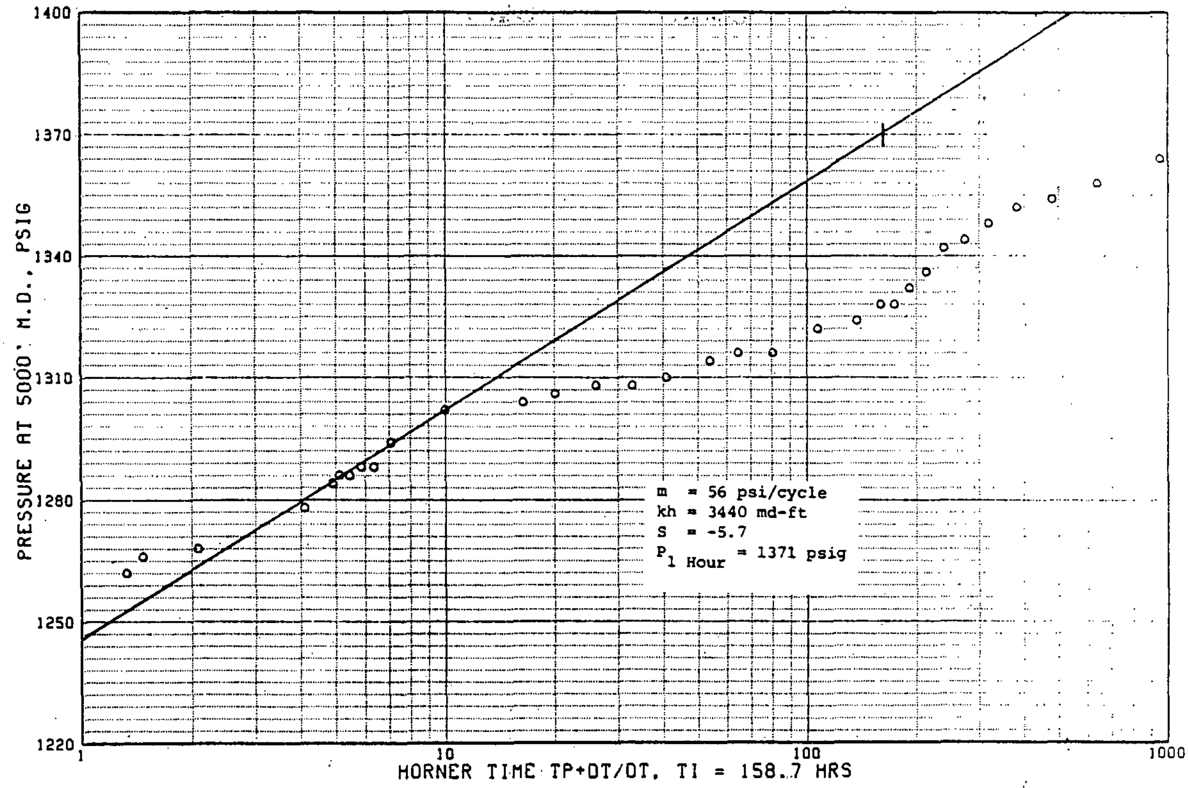
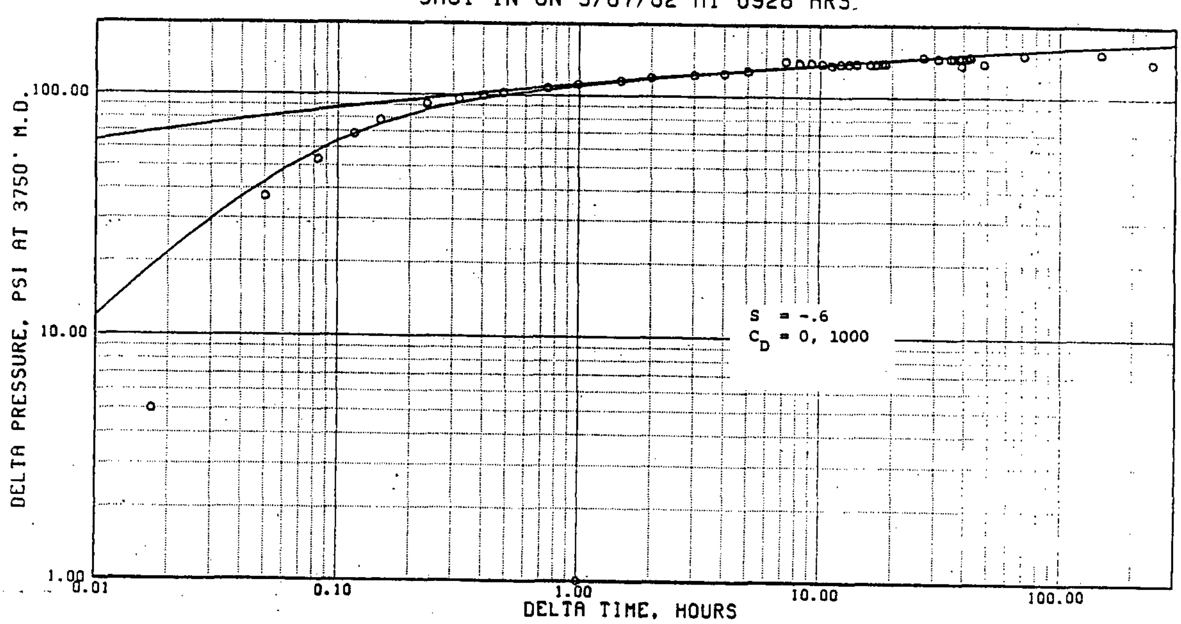


FIGURE 5.3.2-4
LOG-LOG PLOT OF BACA NO. 18 FALLOFF DATA FOLLOWING INJECTION TEST 6
SHUT-IN ON 9/07/82 AT 0926 HRS.



Baca No. 18 Falloff 6 followed injection of 2,773,900 gallons of water over a six-day period. Pressure fluctuations during the semilog straight line regime were caused by the thermal effects of the reservoir/wellbore system. Smoothing this data resulted in an acceptable pressure recovery trend. Examination of the log-log plot (Figure 5.3.2-4) reveals an early wellbore storage regime transitioning to a near zero skin response. The straight line indicated on Figure 5.3.2-5 resulted in Horner Analysis values of 7670 md-ft and -.6. While a permeability of 7670 md-ft is high for a Redondo Creek well, the communication of Baca No. 18 with the high permeability Baca Nos. 6 and 24 reservoir and the good log-log match support its validity.

Baca No. 19 Falloff 2 followed 348,000 gallons of cold water injection at two widely varying rates of 380 gpm and 680 gpm. This difference in rates resulted in an invalid log-log plot and necessitated using of the Horner variable rate analysis. In such an analysis the variable rate Horner Time Group is graphed on a cartesian scale as shown in Figure 5.3.2-6. The well-defined straight line of the figure, and the calculated parameters of permeability of 4000 md-ft and skin of -2.1 support the validity of this analysis, even without the benefit of the log-log plot.

Baca No. 20 Falloff 1 was conducted following injection of 1,793,000 gallons of water. The pressure monitoring at large shut-in times was distorted by an element failure which necessitated using a second element. The second element recorded pressures about 10 psi higher than the first element, but indicated the same pressure trend (Figure 5.3.2-8). The Horner Analysis used the line indicated on Figure 5.3.2-8 to obtain the parameters of permeability-thickness and skin of 2530 md-ft and -3.6. The fit of these values on the log-log plot (Figure 5.3.2-7) is quite good.

Baca No. 23 Falloff 1 was conducted following injection of 1,392,000 gallons of water. The log-log plot seen in Figure 5.3.2-9 suggests that Baca No. 23 has a positive skin. The Horner Analysis derived from Figure 5.3.2-10 supports this observation with calculated parameters of permeability-thickness and skin of 4850 md-ft and +2.2. The leveling off of the pressure at large shut-in times is attributed to the thermal effects of the injection falloff.

Baca No. 24 Falloffs 1 and 2 were both unsuccessful. The large vertical distance - coupled with the temperature buildup of the wellbore fluid - between the pressure monitoring depth and the suspected fluid loss zones completely masked all reservoir pressure response.

FIGURE 5.3.2-5
BACA NO. 18 PRESSURE FALLOFF FOLLOWING INJECTION TEST 6, HORNER PLOT
SHUT-IN ON 9/07/82 AT 0926 HRS

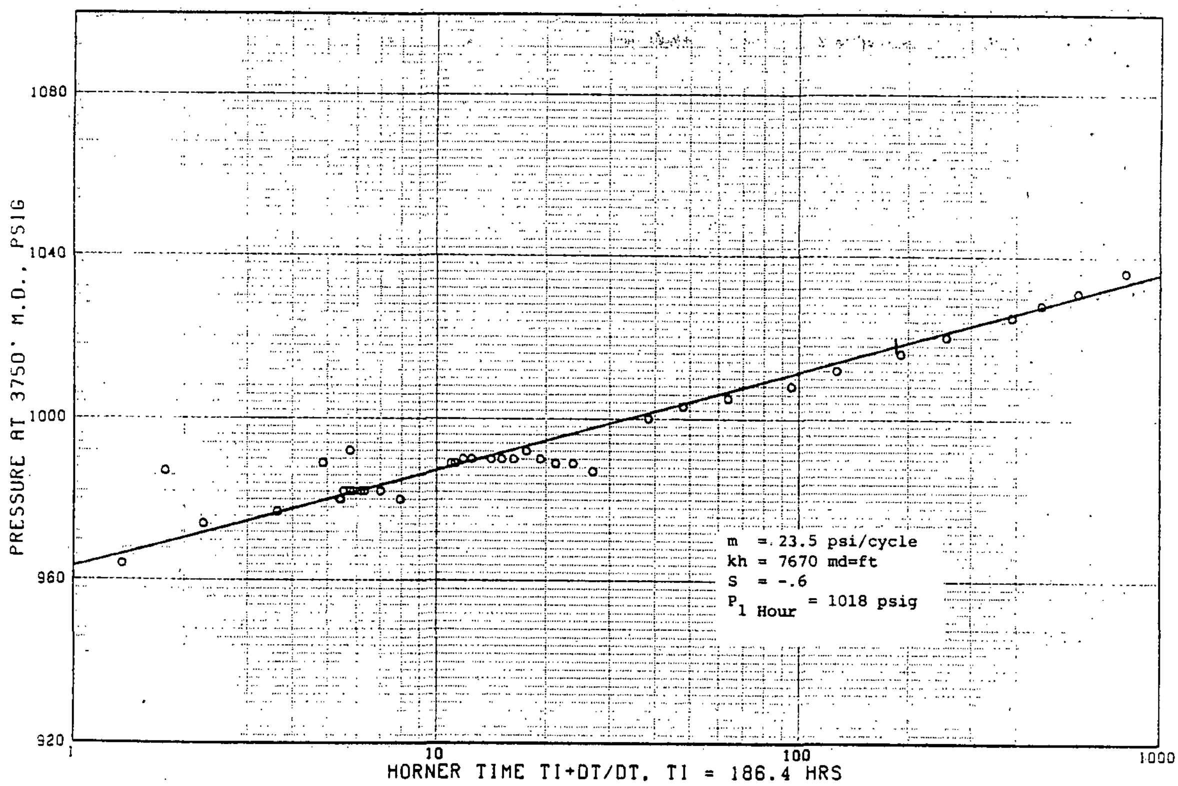


FIGURE 5.3.2-6
BACA NO. 19 PRESSURE FALLOFF FOLLOWING INJECTION TEST 2, HORNER PLOT
SHUT-IN ON 12/09/79 AT 2335 HRS

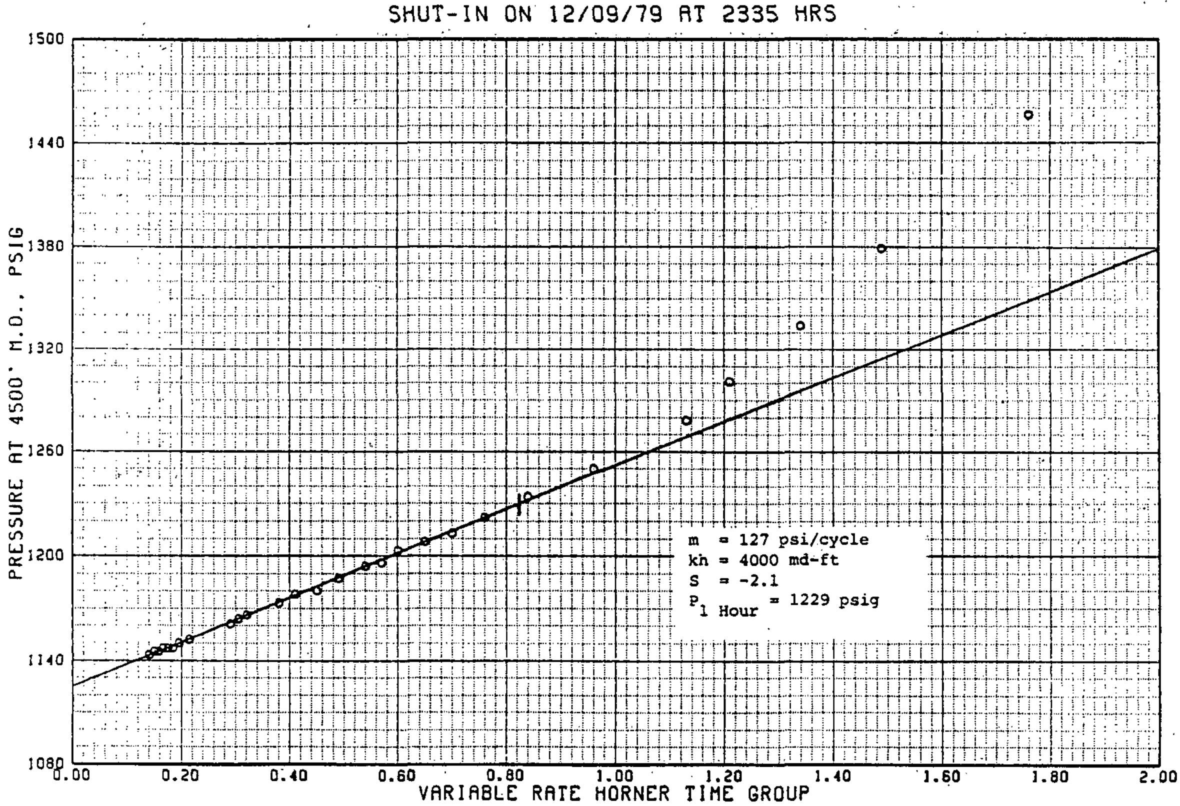


FIGURE 5.3.2-7

LOG-LOG PLOT OF BACA NO. 20 FALLOFF DATA FOLLOWING INJECTION TEST 1
SHUT=IN ON 7/29/81 AT 1928 HRS, PWF = 1783 PSIG

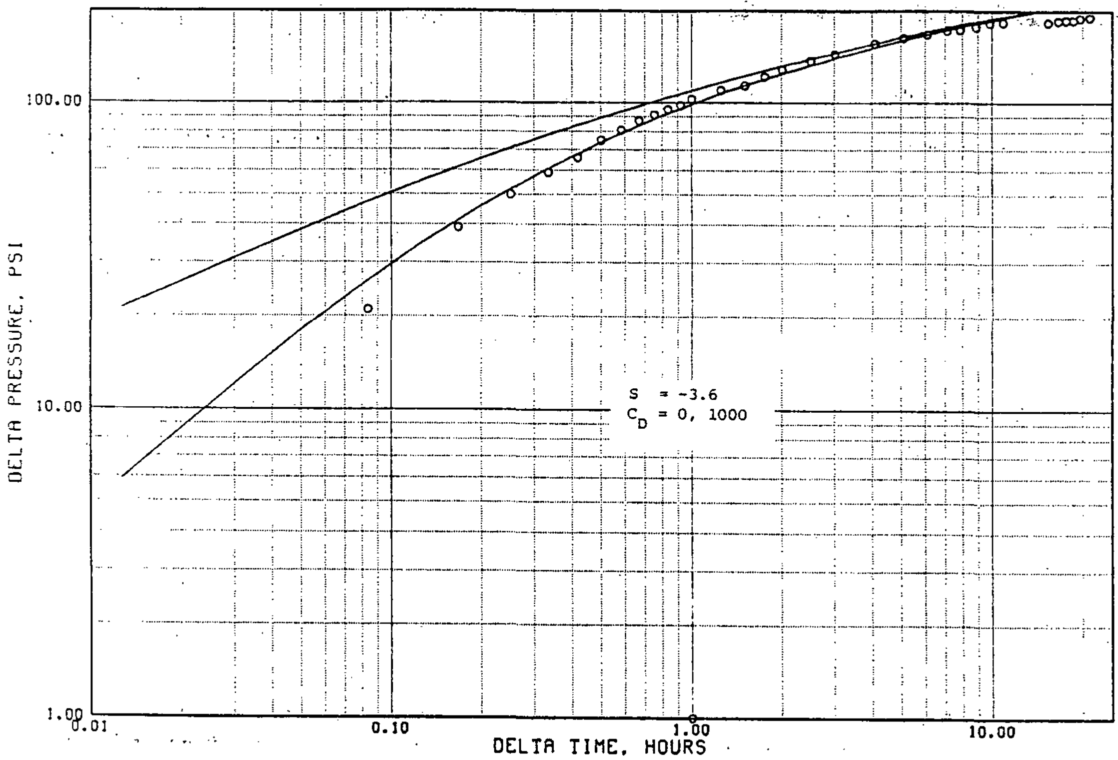


FIGURE 5.3.2-8

BACA NO. 20 PRESSURE FALLOFF FOLLOWING INJECTION TEST 1. HORNER PLOT
SHUT-IN ON 07/29/81 AT 1928 HRS

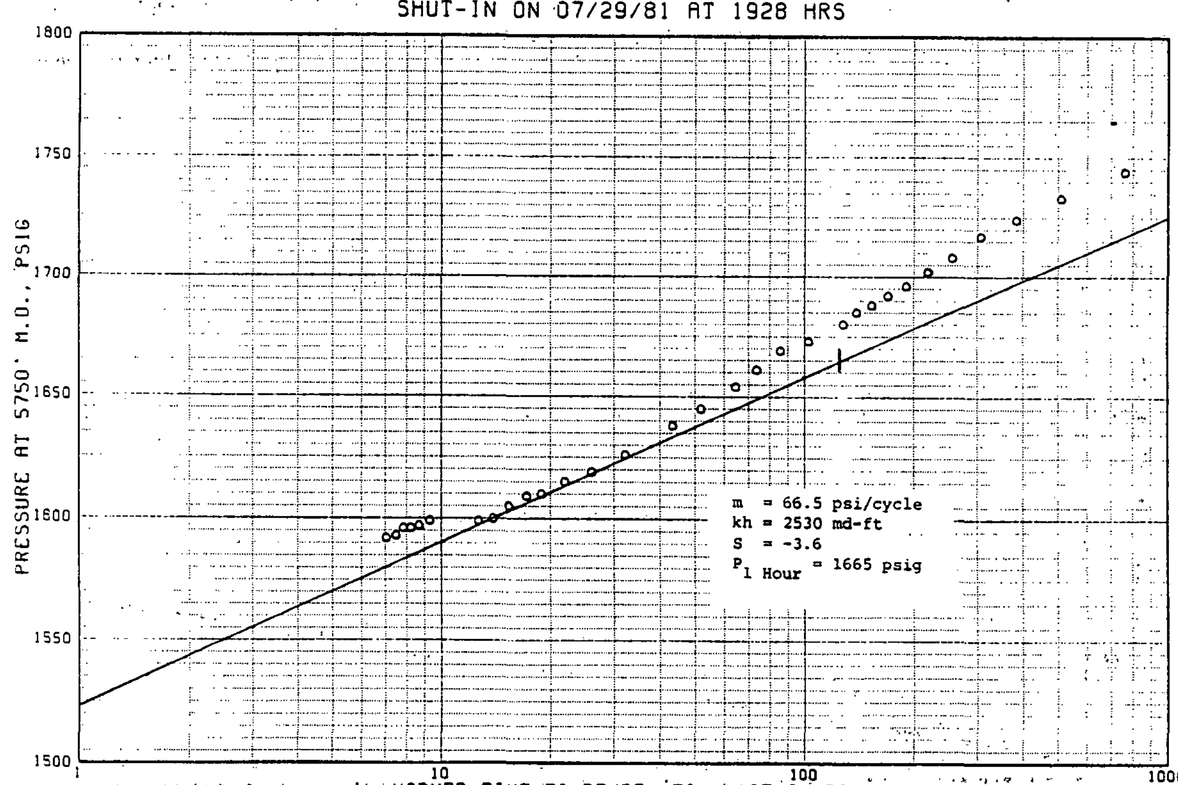


FIGURE 5.3.2-9

LOG-LOG PLOT OF BACA NO. 23 FALLOFF DATA FOLLOWING INJECTION TEST 1
SHUT-IN ON 6/03/81 AT 1839 HRS, PWF = 1102 PSIG

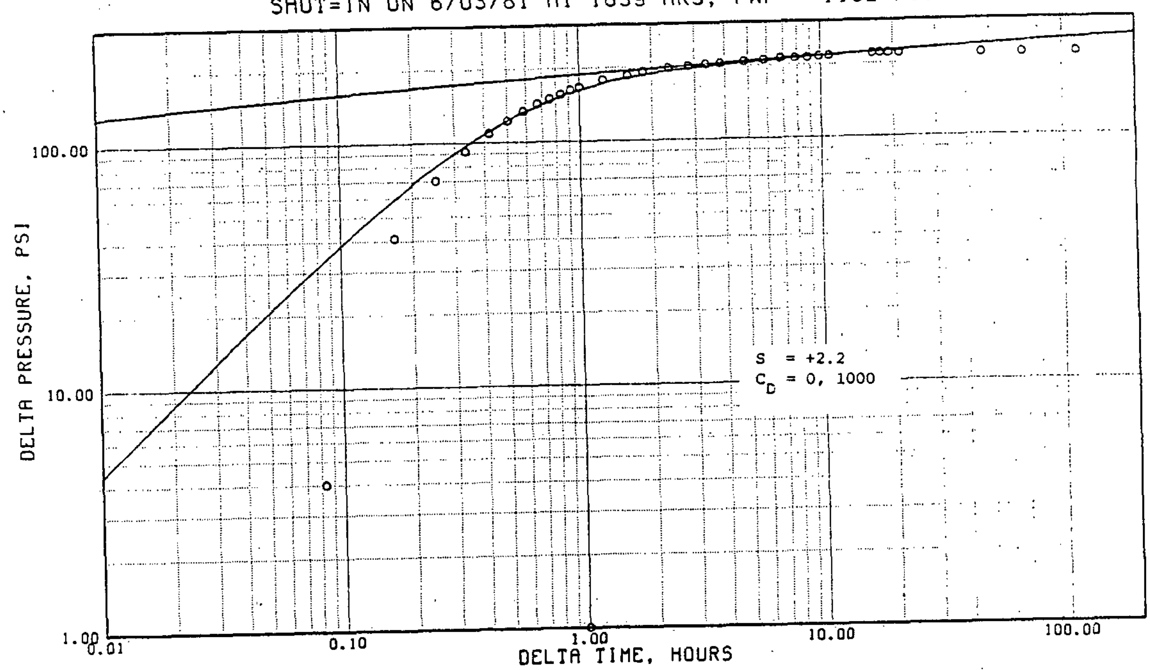
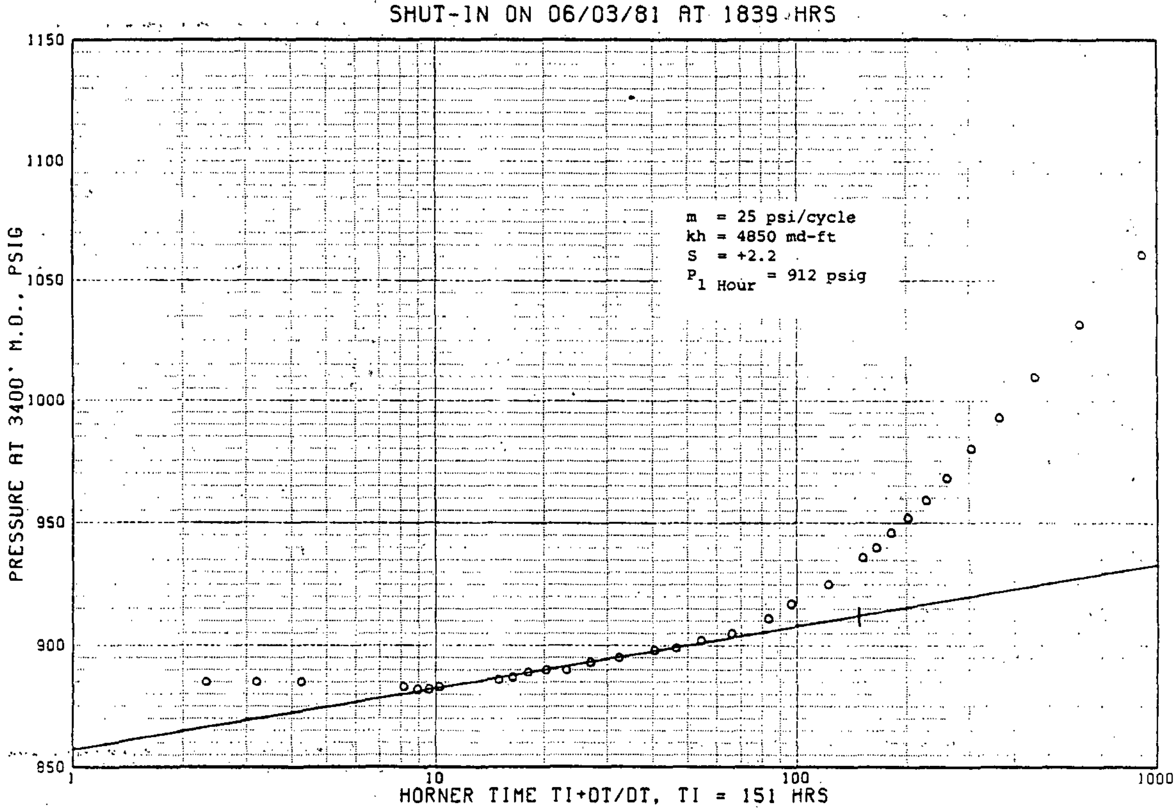


FIGURE 5.3.2-10

BACA NO. 23 PRESSURE FALLOFF FOLLOWING INJECTION TEST 1, HORNER PLOT
SHUT-IN ON 06/03/81 AT 1839 HRS



5.3.3 Injectivity/Productivity

The injectivity/productivity of a well is defined as the ability of a well to accept or produce fluid, normalized to the sandface pressure increase or decrease associated with the activity. This concept when applied to injection typically results in a calculated index of gpm/psi or when applied to flow tests results in what is sometimes referred to a productivity index with units lb/hr/psi. Both factors are a simple measure of how good any given wells is in either a production mode or an injection mode. The sandface pressure of the well is monitored at a known injection or flow rate and compared with the well's "static" pressure. The following discussion emphasizes the injectivity calculations but the main concepts presented also apply to the productivity or productivity index calculations.

An injectivity calculation will be erroneous if the pressure is not being observed at the sandface - major fluid loss zone - and if a steady flow rate is not maintained for a significant time period before and during the pressure monitoring. Failure to maintain a constant rate will 1) create uncertainties as to which flow rate to use in the calculation and 2) introduce additional reservoir pressure transients. While pressure transients are always present during injection tests, the longer the steady rate the smaller their effect on calculated injectivity. For this reason the pressure and injection rate just prior to shut-in are choosen as the most representative values for the calculation of injectivity.

A change in calculated injectivity during an injection test implies that: 1) psudeo-steady state conditions do not exist in the reservoir 2) the pressure is being monitored at an improper depth or 3) there is a possibility of intrawell flow.

Table 5.3.3-1 summarizes the injectivity calculations for eleven of the nineteen Redondo Creek wells. Many of the early injection tests are suspect due to poor pressure measurement and control. The majority of the injectivity values listed lie between .7 gpm/psi and 2.8 gpm/psi with the lone exception being Baca No. 24. The abnormal value of Baca No. 24 is not merely a reflection of that well's reservoir characteristic, but is largely the result of the large vertical distance between pressure monitoring depth and fluid loss zone.

Table 5.3.3-2 summarizes the productivity calculations for ten of the nineteen Redondo Creek wells. The productivity factors identify the good wells and the poor wells much better than the permeability-thickness values presented in Table 5.3.1-1. The exception to this rule is the productivity factor of Baca No. 19 Flow Test 7 which is dramatically high. This is caused by the high bottomhole flowing pressure which is in turn the result of single-phase production from the reservoir rather than a two-phase flow. The values for Baca No. 24 are also slightly high which again mainly reflects an improper monitoring depth.

Table 5.3.3-1

Summary of Injectivity Calculations

WELL NAME	TEST	DATUM DEPTH M.D.	△P psi	INJECTION RATE gpm	INJECTIVITY gpm/psi	INJECTIVITY lb/hr/psi	COMMENTS
Baca 4	1	5500'	86	153	1.78	890	Survey
Baca 5A	1	6400'	66	163	2.46	1234	Not valid
	2	5880'	78	277	3.55	1774	Survey
	3	5500'	152	416	2.78	1370	Pre-falloff
Baca 12	1	6000'	571	157	.27	135	Survey
	2	--	1090	380	.35	175	Not valid
	3	3500'	436	400	.90	450	Pre-falloff
Baca 13	1	5700'	122	129	1.06	530	Pre-falloff
Baca 14	1	4250'	179	450	2.5	1250	Survey
	2	4250'	560	500	.9	450	Not valid
	3	3850'	97	200	2.05	1020	Pre-falloff
Baca 15	1	5000'	136	273	2.0	970	Pre-falloff
Baca 18	1	2100'	105	231	2.2	1080	Survey
	2	3750'	97	232	2.4	1180	Pre-falloff
	6	3750'	158	248	1.57	770	Pre-falloff
Baca 19	1	4500'	64	50	.78	390	Survey
	1	4500'	78	150	1.92	959	Survey
	2	4500'	279	380	1.36	680	Survey
	2	4500'	450	680	1.51	754	Pre-falloff
Baca 20	1	5750'	235	235	1.00	488	Pre-falloff
Baca 23	1	3400'	210	160	.76	371	Pre-falloff
Baca 24	1	3550'	57	244	4.3	2090	Pre-falloff
	2	3250'	38	259	6.8	3300	Pre-falloff

Table 5.3.3-2

Summary of Productivity Calculations

WELL NAME	FLOW TEST	DATUM DEPTH FT M.D.	PWF PSIG	PSTATIC PSIG	FLOW RATE lb/hr	PRODUCTIVITY lb/hr/psi
Baca 4	4	5000'	500	1248	161,065	215.
	5	5000'	470	1248	158,800	204.
Baca 13	7	5700'	465	1464	187,000	187
	8	5700'	465	1464	205,700	206
	9	5700'	465	1464	187,200	187
Baca 15	3	5000'	516	1246	282,724	387
Baca 18	3	5200'	210	1500	50,000	38.8
Baca 19	1	5000'	183	1327	118,000	103
	6	5000'	707	1252	158,600	291
Baca 20	4	4500'	200	1140	56,128	59.7
	7	5000'	153	1242	46,700	42.9
Baca 21	5	2750'	80	484	35,320	87.4
Baca 23	4	3300'	103	860	68,439	90.4
Baca 24	3	3250'	300	797	163,805	330
	5	3250'	412	797	259,800	675

Comparision of the injectivity factors (lb/hr/psi) and productivity factors (lb/hr/psi) shows that the injectivity factors are significantly higher than the productivity factors. This is attributed to (1) the additional pressure drop introduced by the flashing of liquid to vapor in the reservoir and (2) the dilation of reservoir flow conduits during thermal cooling associated with injection. This flashing phenomenon was also noted when comparing the skins calculated from the pressure falloff following injection tests and the pressure buildups following flow tests.

5.4 STEAM DELIVERABILITY AND DECLINE ANALYSIS

Four Redondo Creek wells are capable of flowing geothermal fluid in quantities and pressures sufficient for commercial exploitation. These four wells - Baca Nos. 4, 13, 15 and 24 - have an initial stabilized steam flow rate of 268,000 lb/hr and a projected one year flow rate of between 174,000 lb/hr and 204,000 lb/hr of steam (Table 5.4-1).

The major restriction in projecting an accurate one year deliverability is the lack of long-term production tests. All Redondo Creek wells - as do almost all wells - show an initial period of sharp production decline. After this initial interval, the production decline levels out at a much lower annual decline rate. The true long-term decline is only exhibited after several months of production.

Only one Redondo Creek flow test has lasted for substantially longer than four months: Baca No. 13 Flow Test 4A. Figure 5.4-1 shows the steam flow rates calculated during this flow test and the decline curve which was obtained from a linear regression of the last 107 days of production data. The decline curve calculated corresponds to a 4.6% annual exponential decline.

Two projected declines have been calculated for each of the four commercial Redondo Creek wells. The first assumes that no long-term stabilization will occur and the well will continue to decline at the rate exhibited in the short-term ($<$120 days) flow tests. The second assumes that the well will continue to decline at the short term rate until a producing time of 120 days, and then will stabilize at the decline rate exhibited by Baca No. 13 during Flow Test 4A. The first case is probably pessimistic and the second optimistic, with the actual projected behavior in between.

The calculations and flow tests used in determining the projections are discussed in detail below. All decline rates have been calculated at essentially a constant separator pressure of 125 psig.

The initial Baca No. 4 steam flow rate of 60,000 lb/hr and the projected one year flow rates of 36,400 to 41,400 lb/hr have been obtained from the 113-day Flow Test 3. Figure 5.2.1-1 shows the relatively long period of stabilized separator pressure from 5/19/81 to 7/01/81. A linear regression of the steam flow rates during this interval revealed a 21% annual exponential decline. Figure 5.4-2 shows the data and the match of the decline curve, with the deviation of the stabilized projection evident from 120 to 150 days.

TABLE 5.4-1
REDONDO CREEK FIELD STEAM DELIVERABILITY
AT 125 PSIG SEPARATOR PRESSURE

WELL NAME	FLOW TEST	FLOW TEST DATE	INITIAL RATE lb/hr	CALCULATED ANNUAL DECLINE RATE	PERIOD OF FLOW TEST ANALYZED	PROJECTED ONE YEAR NO STABILIZATION lb/hr	DELIVERABILITY STABILIZATION lb/hr
Baca No. 4	3	3/31/81-7/22/81	60,000	21%	5/19/81-7/01/81	36,400	41,400
Baca No. 13	6	7/21/81-12/18/81	50,000	37.5%	10/01/81-12/18/81	31,800	40,800
Baca No. 15	2	10/07/81-1/06/81	98,000	13%	12/10/76-1/06/77	74,100	78,900
Baca No. 24	3	7/17/81-9/15/81		38%	7/28/81-9/15/81		
Baca No. 24	5	7/08/82-7/19/82	60,000			31,600	43,300
TOTAL FIELD DELIVERABILITY			268,000			173,900	204,400

FIGURE 5.4-1
BACA NO. 13 FLOW TEST 4A STEAM FLOW RATE VS.
PRODUCTION TIME IN DAYS

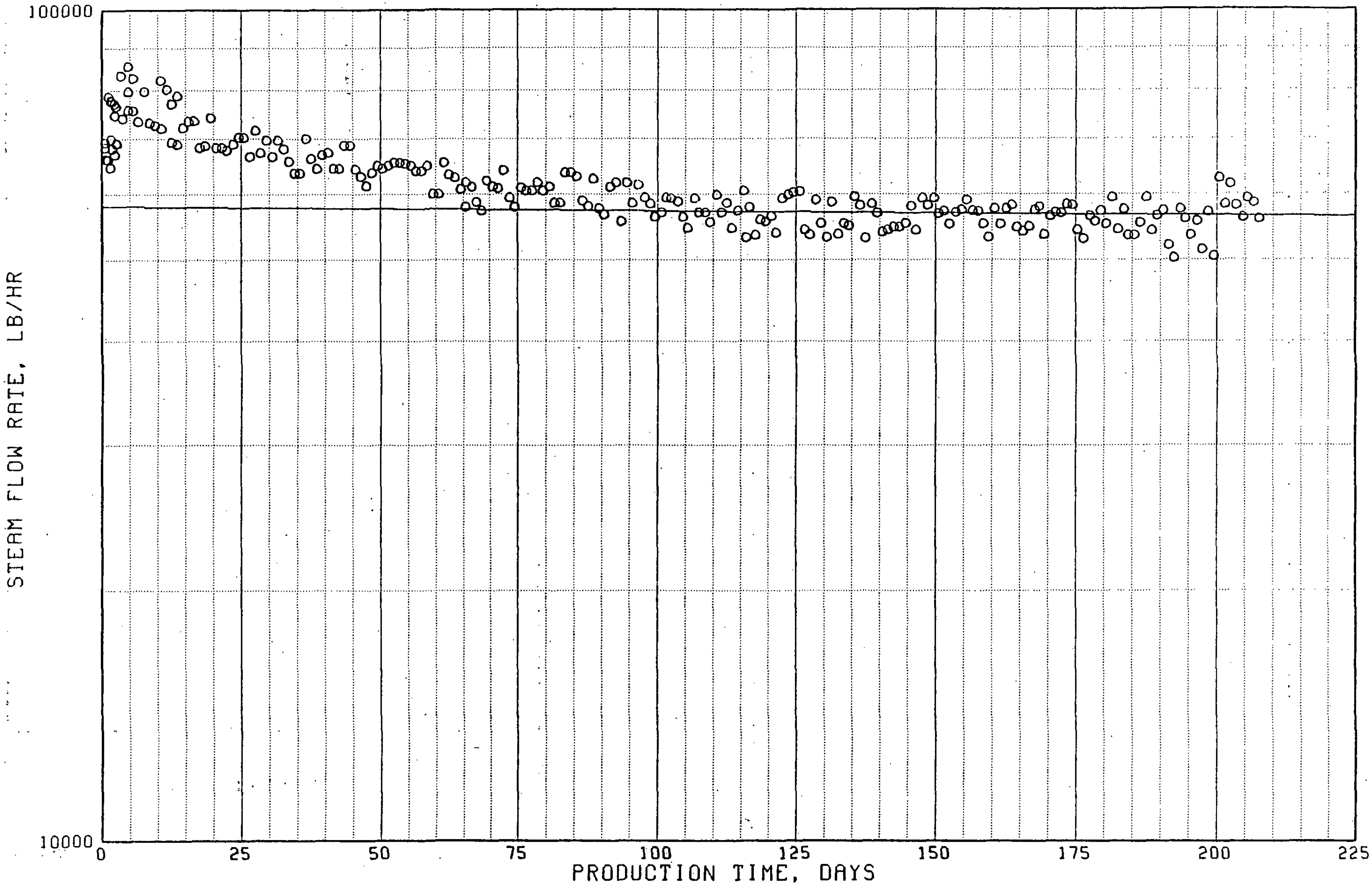


FIGURE 5.4-2
BACA NO. 4 FLOW TESTS 3 STEAM FLOW RATE VS.
PRODUCTION TIME IN DAYS

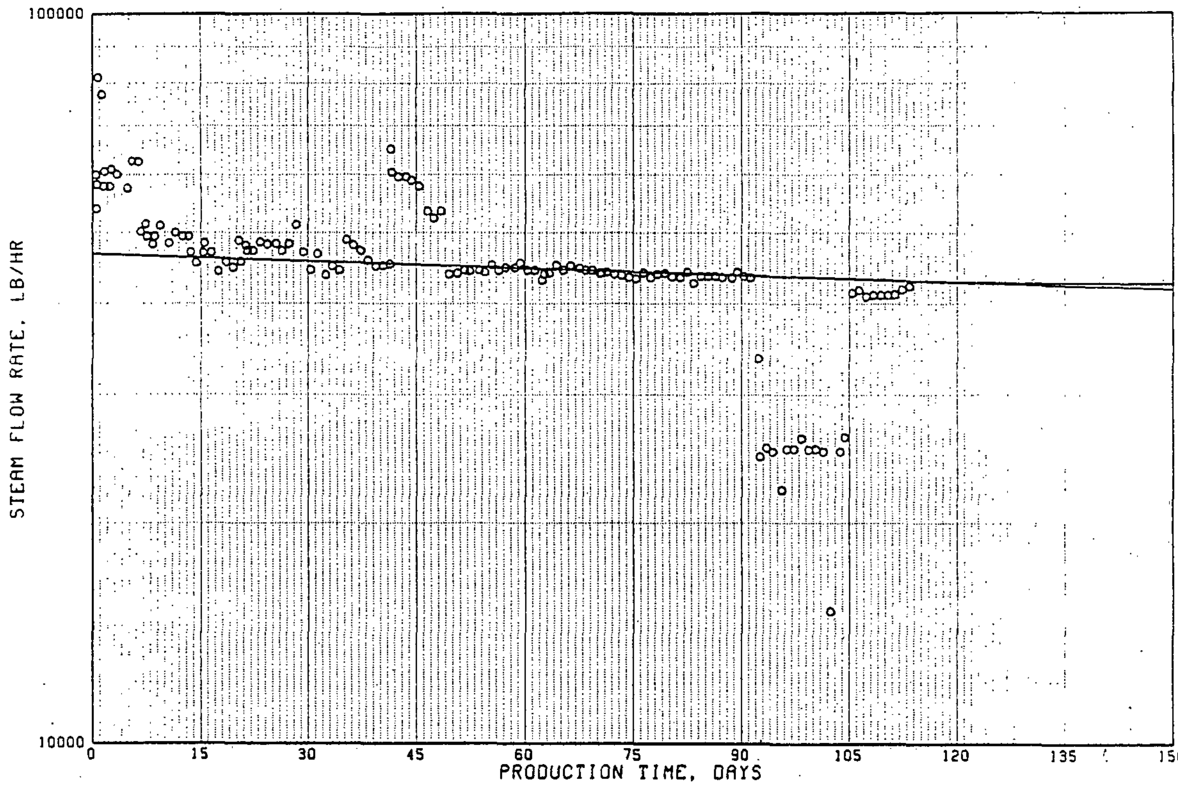
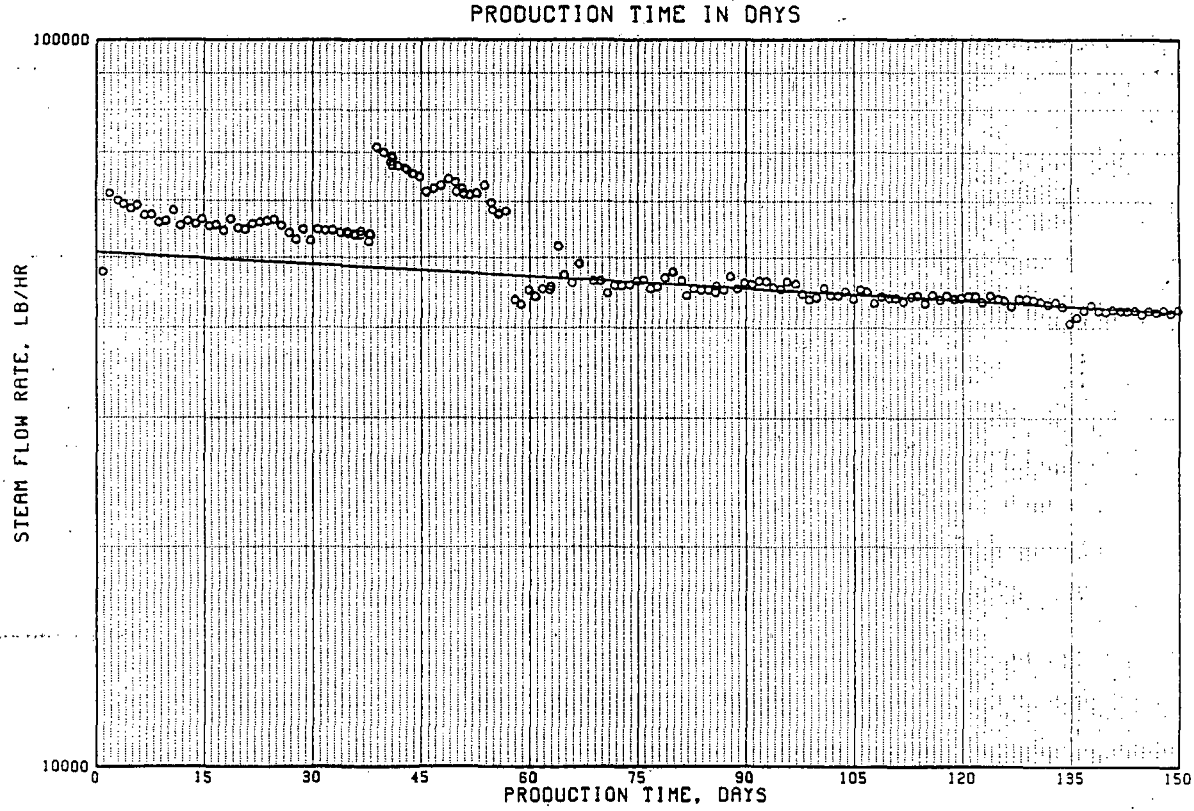


FIGURE 5.4-3
BACA NO. 13 FLOW TEST 6 STEAM FLOW RATE VS.
PRODUCTION TIME IN DAYS



The initial Baca No. 13 steam flow rate of 50,000 lb/hr and the projected one year rates of 31,800 to 40,800 lb/hr have been obtained from the 150-day Flow Test 6. While Flow Test 4A was longer, a wellbore obstruction near 6000' M.D. has since changed the flow characteristics of the well, reducing the steam deliverability by 20%.

Figure 5.2.1-4 shows the effect of a varying separator pressure on steam flow rates, rendering the first 70 days of data useless. A linear regression of the last 80 days of production data determined a 37.5% annual exponential decline rate at essentially a stabilized separator pressure of 125 psig. Figure 5.4-3 shows the steam flow rates and the calculated decline curve. The one year optimistic steam deliverability of Baca No. 13 assumed that long-term stabilization would begin at a producing time of 150 days.

The initial Baca No. 15 steam flow rate of 98,000 lb/hr and the projected one year flow rates of 74,100 to 78,900 lb/hr have been obtained from the 91-day Flow Test 2. While Flow Tests 3 and 4 exhibited total mass flows very different than Flow Test 2, the steam flow rates were almost identical. The current production characteristics are a probably temporary conditions that were caused by extensive water injection into Baca No. 19 (see Section 5.2.2). If Baca No. 15 was flow tested for an extended period of time, it would probably soon revert to its old flow characteristics i.e. similar to Flow Test 2.

Figure 5.2.1-6 shows that Flow Test 2 is characterized by changing wellhead separator pressures. A deliverability curve was used to adjust the flow rates at the various separator pressures to a corrected flow rate at a constant 125 psig separator pressure. A linear regression of the last 27 days of corrected steam rates revealed an 13% annual exponential decline. Figure 5.4-3 shows the corrected steam rates and the decline curve, with the slight deviation of the stabilized projection.

The initial Baca No. 24 steam flow rate of 60,000 lb/hr and the projected one year flow rates of 31,600 to 43,300 lb/hr have been obtained from combination of Flow Test 3 and 5. An injection test in October of 1981 apparently partially cleaned out the fish and rubble left in the wellbore. As a result, the flow rates seen during the only lengthy flow test - Flow Test 3 - are not representative of the current deliverability. Therefore, the decline seen during Flow Test 3 will be applied to the flow rates observed during Flow Test 5 to project the current steam deliverability.

Figure 5.2.1-10 shows the 60-day Flow Test 3 with its various wellhead and separator pressure intervals. Each constant pressure period was analyzed and revealed almost idential annual exponential decline rates of 38%.

FIGURE 5.4-4
BACA NO. 15 FLOW TEST 2, CORRECTED STEAM FLOW RATE VS. PRODUCTION TIME IN DAYS

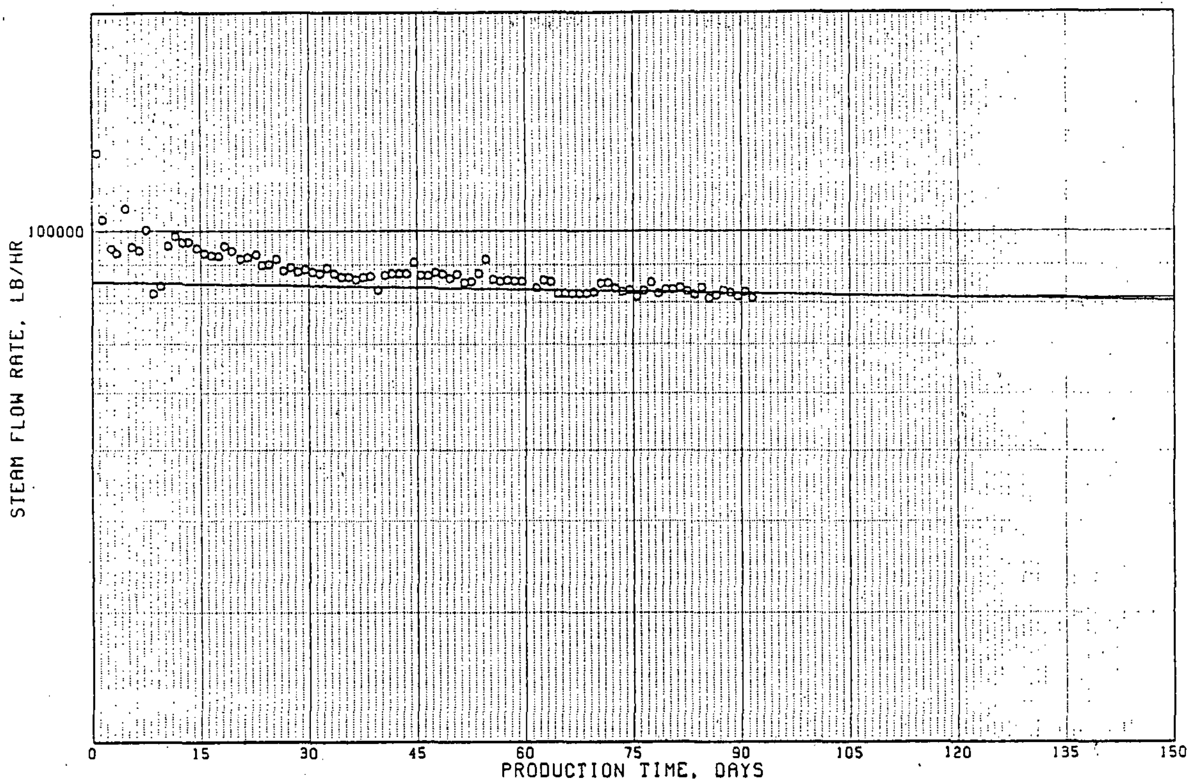
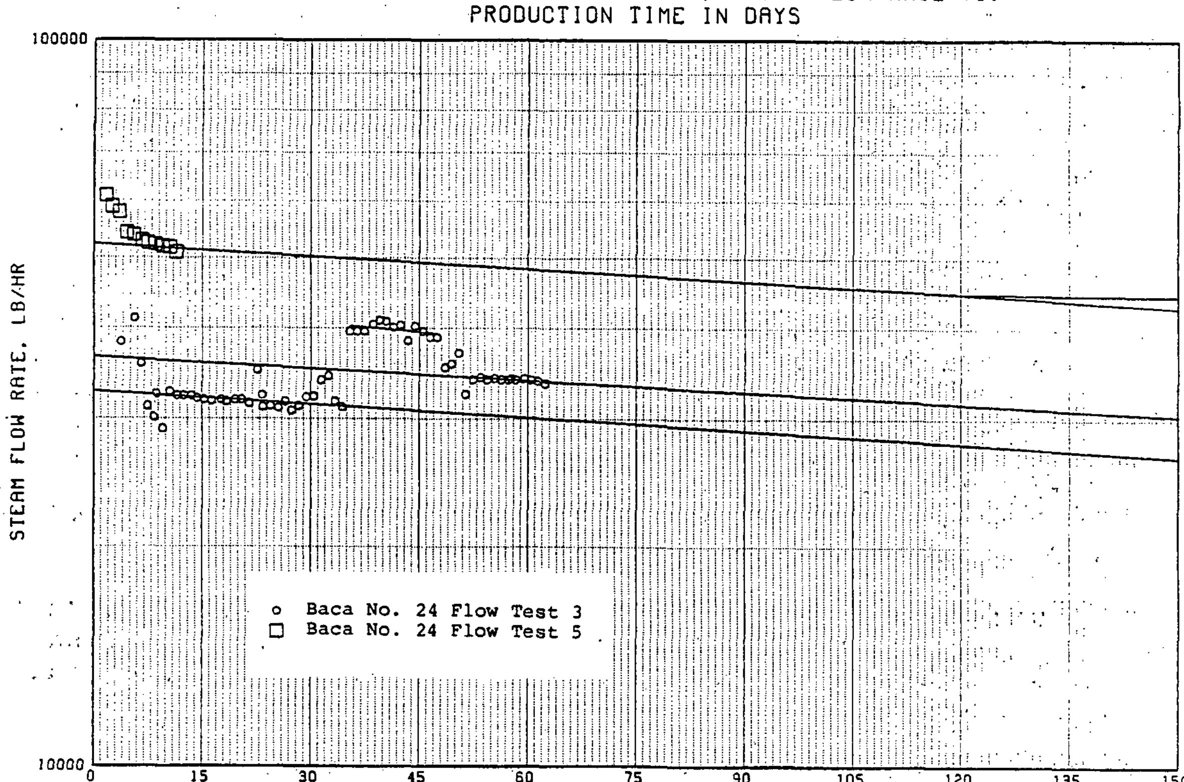


FIGURE 5.4-5
BACA NO. 24 FLOW TESTS 3 AND 5, STEAM FLOW RATE VS. PRODUCTION TIME IN DAYS



The final steam flow rate during the eleven-day Flow Test 5 was assumed to lie on the 38% annual exponential decline curve. Figure 5.4-5 shows the flow tests and the decline curves. It is noted that the stabilization assumption creates a significant change in the projected steam deliverability, as is evident in Figure 5.4-5 and Table 5.4-1.

5.5 INTERFERENCE TESTING AND ANALYSIS

Interference testing is performed to determine the gross characteristics of a reservoir. An interference test is designed to determine three reservoir characters: reservoir and fracture system porosity-thickness product, permeability-thickness product, and continuity of the reservoir. These characteristics are in turn used to determine the amount of reservoir fluids in place and to predict reservoir performance.

In a simplistic case, interference testing is the observation of pressures in Well B while Well A is being produced or injected into (Figure 5.5-1). The magnitude of the pressure response seen at Well B is then used to calculate the reservoir's transmissivity and storage factor (Earlougher, 1977). A flow barrier between the two wells will result in a lack of response.

o__________r__________o

Well A   Well B

Figure 5.5-1

An interference test can be expanded to include several producers, injectors, and observation wells, depending on field and operational conditions. As a rule the more complex the test, the more complex the analysis, the less definitive the final answer. Significant quantities of injection and/or production are required to create a detectable and correlatable pressure response.

Four types of information are necessary to accurately analyze an interference test:

1) The production and injection history of all the wells during the interference test.

2) The pressure history of the observation wells.

3) The bottomhole location of the wells.

4) The fluid properties of the reservoir.

The quality of the above data will influence the reliability of the interference analysis. In the Redondo Creek Field, points one and two are obtained with reasonable accuracy: points three and four involve some approximation.

The production and injection rates have been calculated for each active well at least once a day using orifice meters (Section 5.2.1).

The observation pressures have been taken with a Sperry-Sun "pressure monitoring system." An expansion chamber, 10' x 1.75", was hung at the desired depth and connected to the surface via a .094" O.D. capillary tubing. Both were filled with nitrogen and a surface Paroscientific Digiquartz pressure transducer was used to measure the surface pressure of the nitrogen. This surface pressure was recorded daily and can be converted to downhole pressure through the use of a wellbore temperature gradient.

The surface location and the subsurface well course of most wells are available; however, the exact depth of the intersection with the reservoir is not known for most wells. Table No. 5.5-1 shows the assumed wellbore depth and areal coordinates of the wells used during interference testing in 1981 and 1982.

The fluid properties of the reservoir are dependent upon three things: temperature, chemical composition and fluid phase saturation. The reservoir fluid has been assumed to be pure, liquid water. Any change in phase - as is observed during production - will result in changed fluid properties. The reservoir temperature is assumed constant between 500°F and 600°F, depending upon the interference test being analyzed. The effect of extensive cold water injection has been studied by Union Oil Company. A cold water front will increase the pressure at the injection well in the form of a pseudo skin, but until that cold water front reaches the observation well, the pressure response at the observation well acts as if the reservoir fluid was 100% hot fluid.

Consider the two wells, A and B, r feet apart (Figure 5.5-1). Well A produces at a rate of W lb/hr and Well B is an observation well. After t hours of production, the pressure change seen at B is expressed by an equation dependent upon the conceptual model of the reservoir. The most commonly assumed model is that of a single-phase, radial-cylindical flow within an infinite, homogeneous and isotropic media that has been fully penetrated by a one dimensional well. For this model:

$$\Delta P = \frac{-301.76\, W\mu\bar{v}}{kh} * \left[E_i \left(- \frac{\phi h \mu c_t r^2}{.00105 k h t} \right) \right] \qquad 5.5\text{-}1$$

$$\text{where} \quad E_i(-x) = - \int_x^{\infty} \frac{e^{-u}}{u}\, du$$

W = production rate, lb/hr
μ = viscosity of fluid, cp
v = specific volume of fluid, ft^3/lb
k = permeability, md
h = thickness, ft
ø = porosity, fraction
c_t = total compressibility of fluid and rock, psi^{-1}
r = distance to observation point, ft
t = production time, hours

TABLE 5.5-1

LOCATION OF REDONDO CREEK WELLS

WELL NAME	SURFACE LOCATION EAST	SURFACE LOCATION NORTH	ASSUMED RESERVOIR DEPTH M.D.	RESERVOIR LOCATION EAST	RESERVOIR LOCATION NORTH
Baca No. 4	405,085	1,778,980	5000'	404,942	1,779,250
Baca No. 5A	402,715	1,774,675	5700'	402,532	1,774,868
Baca No. 6	401,580	1,778,490	4200'	401,626	1,778,814
Baca No. 11	403,450	1,781,120	4000'	403,397	1,781,236
Baca No. 12[1]	399,360	1,773,160	8900'	399,294	1,772,964
Baca No. 13	405,725	1,781,685	5700'	405,090	1,781,225
Baca No. 14	400,320	1,776,450	3500'	399,831	1,776,667
Baca No. 15	402,155	1,780,595	5000'	402,421	1,779,989
Baca No. 18	400,705	1,777,810	3750'	401,024	1,778,239
Baca No. 19	402,130	1,780,550	5170'	402,659	1,780,414
Baca No. 20	403,500	1,781,110	4500'	404,101	1,780,781
Baca No. 20[2]	403,500	1,781,110	5000'	404,236	1,781,449
Baca No. 23	400,684	1,777,829	3400'	400,718	1,777,570
Baca No. 24	401,815	1,777,750	5000'	401,587	1,777,787

1 After Recompletion
2 After Stimulation

For many fractured geothermal reservoirs, the permeability in one directon is different from the permeability in the other direction, due to the existence of preferred fracture orientations. If this anisotropic behavior is accounted for, with θ equal to the angle of the preferred axis of permeability, equation 5.5-1 becomes:

$$\Delta P = \frac{-301.76\ W\mu\bar{v}}{\sqrt{(k_x h)(k_y h)}} \left[* E_i \left(- \frac{\phi h\ \mu\ c_t (k_x h Y^2 + k_y h\ X^2)}{.00105\ k_x h\ \ k_y h\ \ t} \right) \right] \qquad 5.5\text{-}2$$

where $X = r \cos \theta$

$Y = r \sin \theta$

Some reservoirs are bounded at their perimeters by sealing faults, decreased permeability due to mineral deposition in fractures, or other natural phenomenom. If such a case is approximated as a sealed cylindural reservoir containing an observation well in the center, the governing equation is given as:

$$\Delta P = \frac{-301.76\ W\mu\bar{v}}{kh} * \left[E_i \left(- \frac{\phi h \mu c_t r^2}{.00105 kht} \right) - E_i \left(- \frac{\phi h \mu c_t r_B^2}{.00105 kht} \right) + \left(\frac{.00105 kht}{\phi h \mu c_t r_B^2} \right) * \operatorname{Exp}\left(- \frac{\phi h \mu c_t r_B^2}{.00105 kht} \right) \right] \qquad 5.5\text{-}3$$

where r_B = cylinder radius.

An alternate reservoir, called a hemispherical model, is described as radial flow of a single-phase fluid within a homogenous, isotropic, hemispherical reservoir. The approximate physical nature of this model is a thick reservoir with an impermeable top containing a well which has penetrated only the uppermost segment. In this model the thickness of the reservoir is not a factor and:

$$\Delta P = \frac{301.76\ W\mu\bar{v}}{kr} * \left[\operatorname{ERFC} \left(\left(\frac{\phi \mu c_t r^2}{.00105 kt} \right)^{1/2} \right) \right]$$

where ERFC = the complimentary error function 5.5-4

$$\operatorname{ERFC}(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-u^2}\, du$$

A computer program (INTER) which utilizes any of the above four reservoir models was written. This program permits analysis of interference tests by superposing transient pressures from a number of injection and production wells. One of the four reservoir models is chosen, the location and production/injection history of each well and the reservoir fluid properties are entered as input parameters. For a given combination of øh and kh, the pressure computed from the appropriate equation is compared against the known observed pressure. This process is repeated for each observed pressure and the normalized sum of the squares of the difference, defined as E, is calculated.

The concept of E is used in the computer analysis in several ways. The E value is used by the program to optimize the match between computed and observed pressures. The E factor is used to compare the fit of one model to the fit of another. The logrithim of E is also plotted in the form of a contour map to identify the sensitivity of E to any particular kh, øh combination as shown in figure 5.5.2-6. The best match on such a plot is located inside the minimum contour, located at kh=22,500 and øh=140.

Four interference tests have been run in the Redondo Creek Field, hereafter referred to as (1) the 1975-1976 Test, (2) the 1980-1981 Test, (3) the 1981 Test and (4) the 1982 Test. The results of these tests are summarized in Table 5.5-2. The 1980-1981 Test was a by-product of several scheduled flow tests and as such did not result in any estimates of reservoir parameters. The field activities during this interference test are presented in Table 5.5-3 and Figure 5.5-2. The remaining three interference tests are presented in Sections 5.5-1, 5.5-2 and 5.5-3.

5.5.1 1975-1976 Interference Test

The 1975-1976 Test was originally analyzed by Union Oil Company and presented in the 1976 Union Oil report and the 1978 Union Oil Company and Public Service Company of New Mexico Technical Proposal to the D.O.E. (Union, 1978). During this test, three wells - Baca Nos. 6, 11, and 13 - were produced and three wells - Baca Nos. 5, 12 and 14 - were used as injectors. The pressure response to this activity was monitored in four wells, three of which observed pressures exclusively with Kuster wire line Tools (see section 5.1). The fourth well, Baca No. 10, utilized a Sperry-Sun "pressure monitoring system" for roughly one-half of its observation period. The production history and observed pressures are shown in Figure 5.5.1-1.

The pressure response at Baca No. 10 was the only response which was large enough to warrant an analysis. This analysis, as originally presented by Union Oil Company, concluded that the reservoir kh was 6000 md-ft ± 500 md-ft and the reservoir øh was 90 ft ± 10 ft. These values seemed to be in the same range as other test results obtained during that time period.

A later analysis of the same test was done by Union Oil Company and will be used in further discussion of the 1975-1976 Test. In this study the Baca No. 10 data was reanalyzed. In addition to using the infinite acting pure radial flow model (the only computer model available to the early Union Oil report), this analysis considered the anisotropic radial flow model and the hemispherical flow model.

TABLE 5.5-2
REDONDO CREEK INTERFERENCE TESTS

OBSERVATION PERIOD	OBSERVATION WELL	METHOD	ACTIVE WELLS	ACTIVE WELLS IN COMMUNICATION	$k_x h$ or kh	$k_y h$	øh	θ	E
10/75 to 8/76	10	Radial	5A 6 11 12 13 14 15	All	6,400		107		6.3
	10	Anisotropic	5A 6 11 12 13 14 15	All	104500	850	15	80	4.5
	10	Anisotropic	5A 6 11 12 13 14 15	All	20000	4750	100	80	5.2
5/81 to 1/82	6	Radial	4 13 14 19 20 23 24	24	22700		139		2.4
	6	Radial	4 13 14 19 20 23 24	14 24	13400		272		1.7
	6	Anisotropic	4 13 14 19 20 23 24	13 14 19 24	3300	37000	526	20	1.4
	23	Radial	4 13 14 19 20 23 24	14	12600		23		3.1
	23	Anisotropic	4 13 14 19 20 23 24	13 14 19 24	27300	800	265	50	3.0
	23	Anisotropic	4 13 14 19 20 23 24	All	22800	660	275	50	3.7
1/82 to 10/82	6	Radial	4 12 13 14 15 18 19 20 24	18 24	31500		468		1.0
	6	Anisotropic	4 12 13 14 15 18 19 20 24	18 24	6400	142000	197	5	.5
	19	Radial	4 12 13 14 15 18 19 20 24	15	13600		1050		2.3
	23	Radial	4 12 13 14 15 18 19 20 24	14	15700		18		6.5
	24	Radial	4 12 13 14 15 18 19 20 24	18	22000		490		.6

TABLE 5.5-3

PRODUCTION AND INJECTION DURING THE 1980-1981 INTERFERENCE TEST

WELL	ACTIVITY	DATE	TOTAL PRODUCTION lb	AVERAGE RATE
Baca No. 13	Flow Test 5	3/05/81 - 3/21/81	108×10^6	306,000 lb/hr
Baca No. 19	Flow Test 5	2/20/81 - 2/27/81	32×10^6	188,000 lb/hr
Baca No. 20	Flow Test 3	9/16/80 - 9/17/80	6×10^6	220,000 lb/hr
Baca No. 20	Flow Test 4	9/24/80 - 1/06/81	149×10^6	59,300 lb/hr
Baca No. 21	Flow Test 4	11/25/80 - 11/29/80	8×10^6	84,200 lb/hr
Baca No. 21	Flow Test 5	2/03/81 - 3/21/81	45×10^6	40,700 lb/hr
Baca No. 22	Flow Test 3	1/30/81 - 1/31/81	2×10^6	60,600 lb/hr
Baca No. 22	Flow Test 4	2/01/81 - 2/24/81	13 x 106	23,500 lb/hr
			TOTAL 363×10^6	
Baca No. 14	Injection 4	11/18/80 - 1/06/81	10.8×10^6	40 gpm
Baca No. 14	Injection 5	3/05/81 - 3/21/81	41.5 x 106	253 gpm
			TOTAL 52.3×10^6	

FIGURE 5.5-2

1980-1981 REDONDO CREEK FIELD SPERRY SUN INTERFERENCE MONITORING

9/01/80 TO 3/31/81

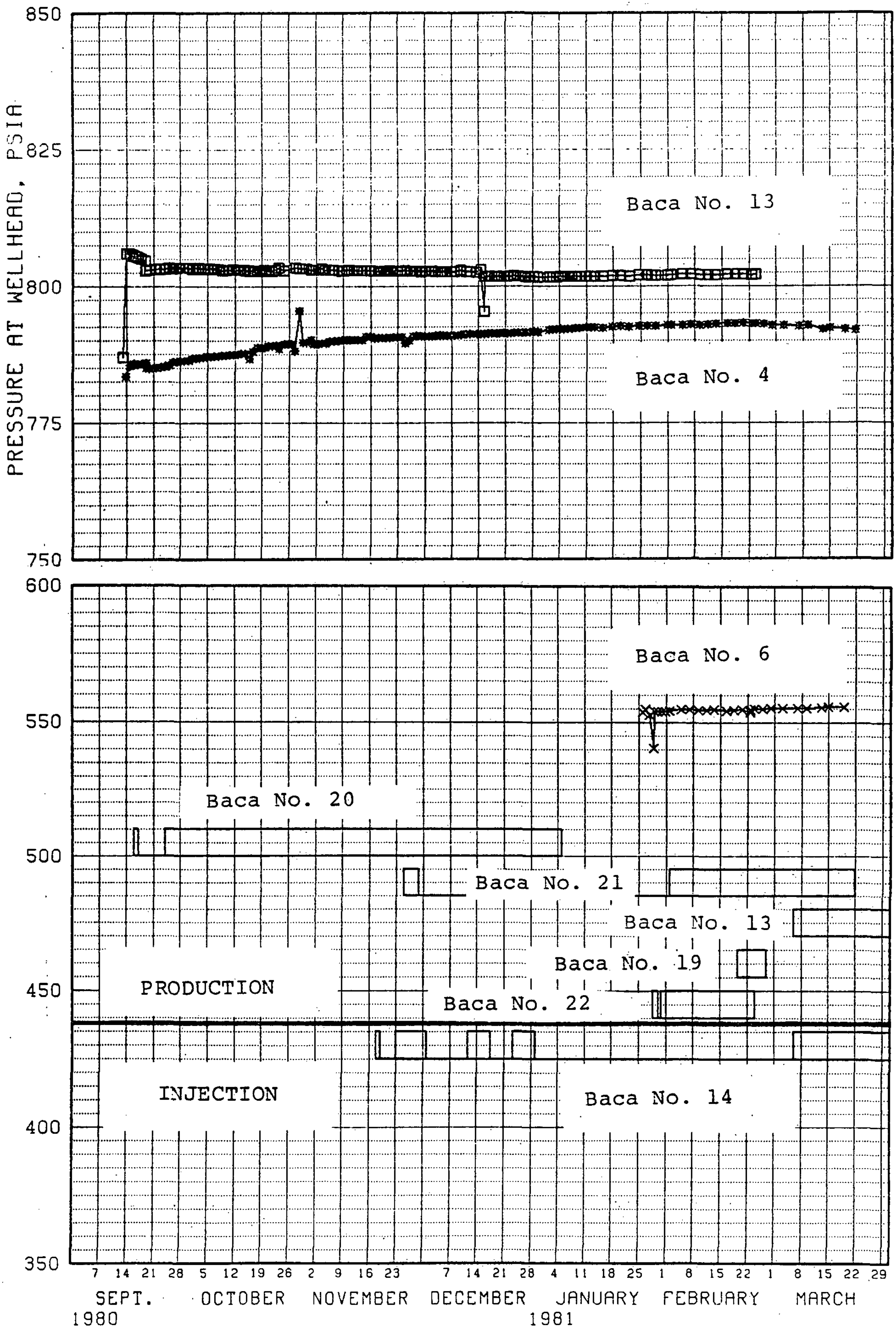
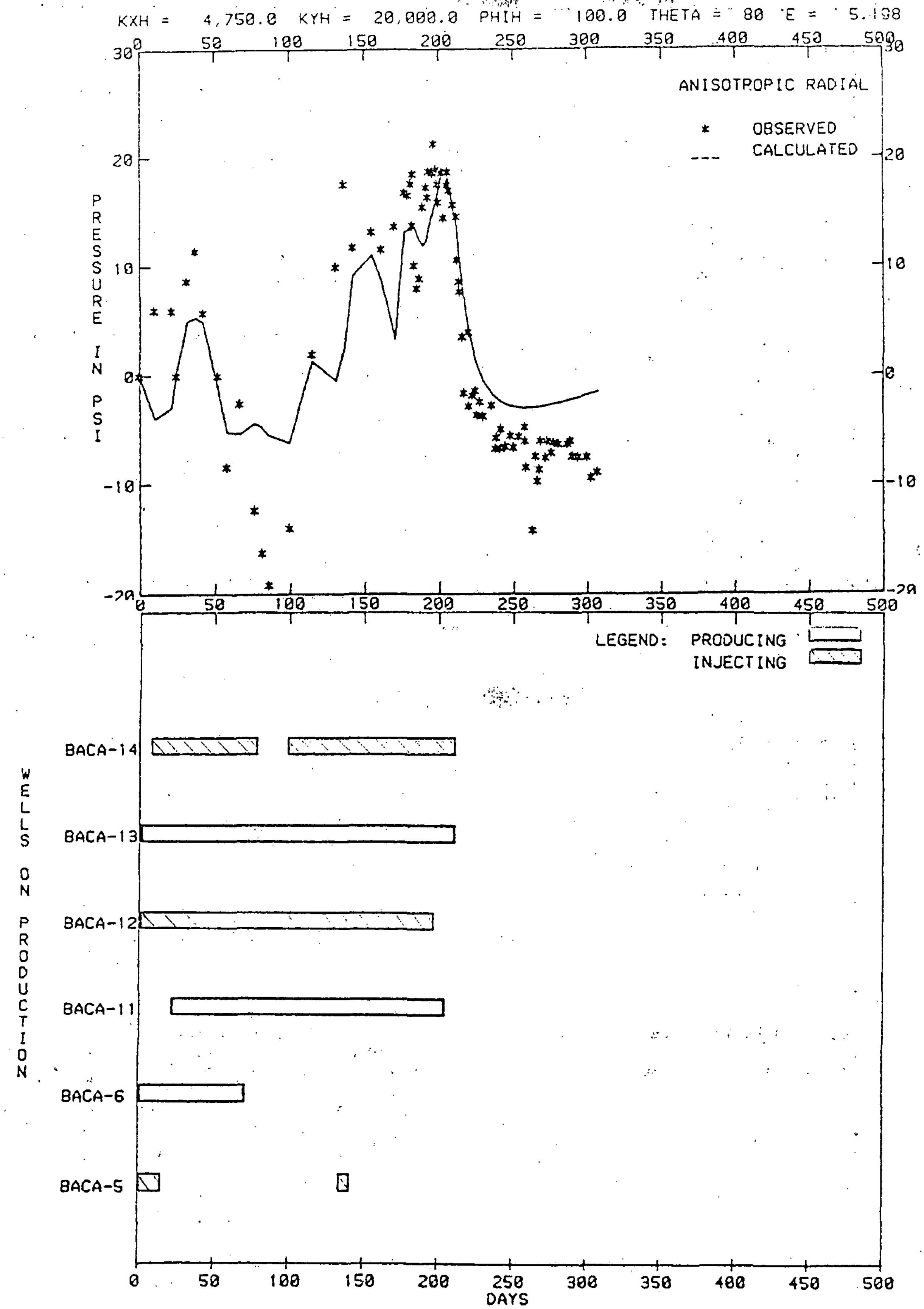


FIGURE 5.5.1-1

Baca 10; 1975-1976 Interference Test

COMMUNICATION WITH ALL WELLS



The results of the second Union Oil report are presented in Table 5.5-2. The unconstrained optimum match for the anisotropic-radial flow showed a moderate improvement over the previously used radial geometry. This optimum match showed severe anisotropy, with the major axis of permeability subperpendicular to Redondo Creek, and a low value of ϕh = 15 feet. From a practical point of view it is impossible to distinguish between this match and slightly worse but still acceptable matches with ϕh = 100 feet and either moderate or no anisotropy. This ambiguity is probably a result of the fact that most wells involved in the test are approximately colinear with Redondo Creek (Figure 5.1-1).

Application of the hemispherical reservoir model to the 1975-1976 Test data produced no improvement in match over the pure radial model, and was not considered further.

The contour maps of the log of the E values are shown in Figure 5.5.1-2 and 5.5.1-3. Figure No. 5.5.1-2 shows the insensitivity of the E value to the Y-direction permeability and strong sensitivity to the X-direction permeability for ϕh = 10 feet. Figure No. 5.5.1-3 shows that for ϕh = 100 feet, the X and Y direction permeability are basically insensitive.

5.5.2 1981 Interference Test

The 1981 Interference Test lasted nine months from the end of the 1980-1981 Interference Test - 3/21/81 - to the beginning of the 1982 Test on 1/10/82. During this 295-day period there were a total of 10 flow tests and 10 water injection periods. From the five production wells - Baca Nos. 4, 13, 20, 23 and 24 - a total mass production of 1700×10^6 lb was produced during the eight of ten flow tests which had a significant amount of production. These flow tests are summarized in Table 5.5.2-1.

The majority of the mass produced during the 1981 Test was reinjected, with Baca No. 14 and Baca No. 19 used as the main disposal wells. In addition, injection tests were run on Baca Nos. 13, 20, 23 and 24 (Table 5.5.2-1) resulting in a total injection of 744.9×10^6 lb or 44% of the total produced mass.

A cross section of Redondo Creek wells - injectors, commercial producers and subcommercial producers - were used to monitor the reservoir pressure. Sperry-Sun instrumentation was installed in Baca Nos. 5A, 6 and 20 in the third week in May, 1981. Additional monitoring was started in the middle of June in Baca Nos. 14 and 23. The instrumentation was removed from Baca No. 20 and switched to Baca No. 18 during the fourth week of July, 1981. The monitoring was continued in Baca Nos. 5A, 6, 14, 18 and 23 until the end of the 1981 Test. Production/injection activity and the observed Sperry-Sun wellhead pressures are shown on Figure 5.5.2-1 which does not display production/injection activity before May 1, 1981 that was included in the analysis. A brief description of the flow tests and injection periods are presented in Sections 5.2.1 and 5.2.2.

FIGURE 5.5.1-2

BACA NO. 10 WITH PHIH=15 FEET

ANISOTROPIC RADIAL MODEL COMMUNICATION WITH ALL WELLS, θ=80°

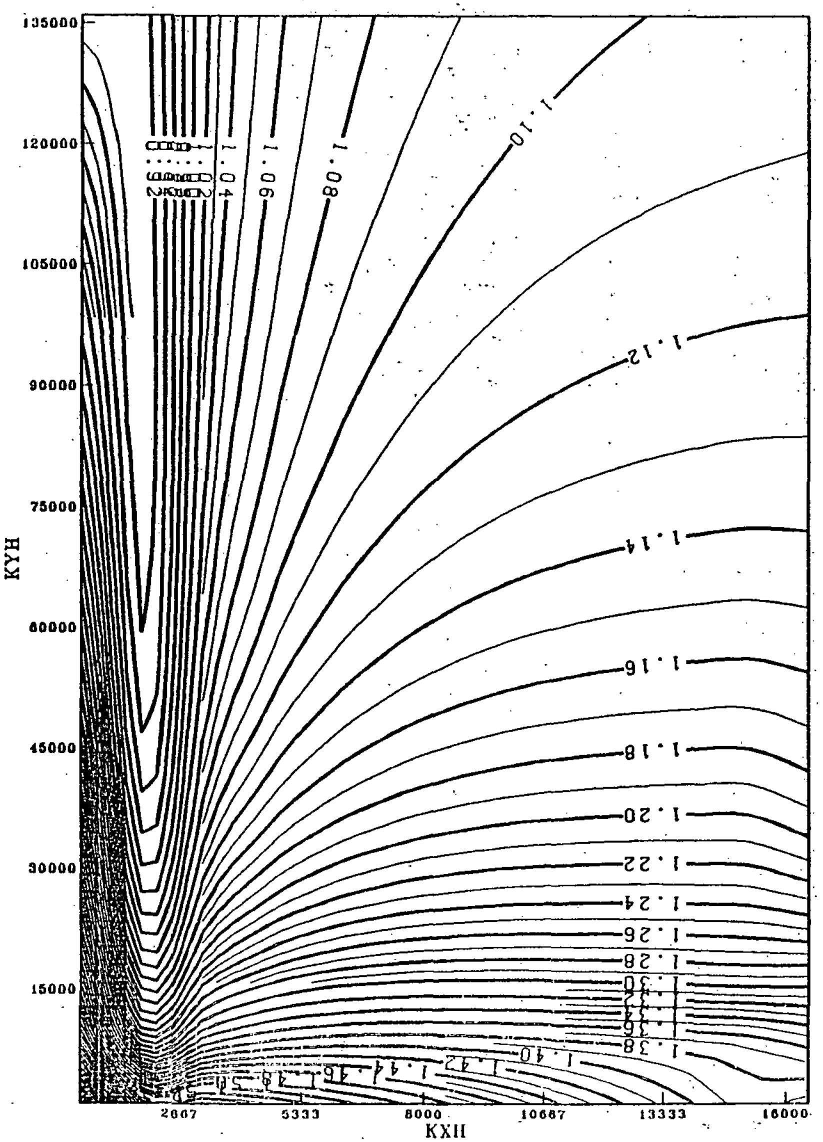


FIGURE 5.5.1-3

BACA NO. 10 DATA WITH PHIH=100 FEET

ANISOTROPIC RADIAL MODEL COMMUNICATION WITH ALL WELLS, θ = 80°

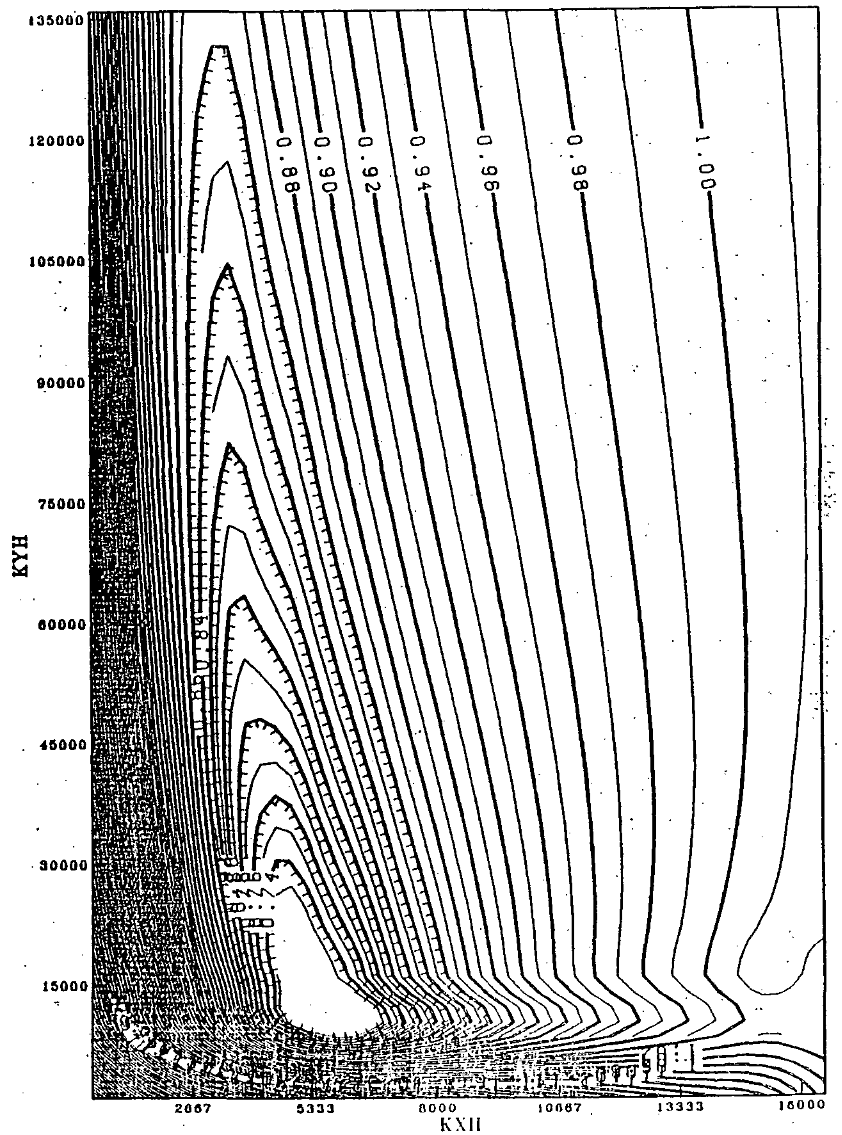
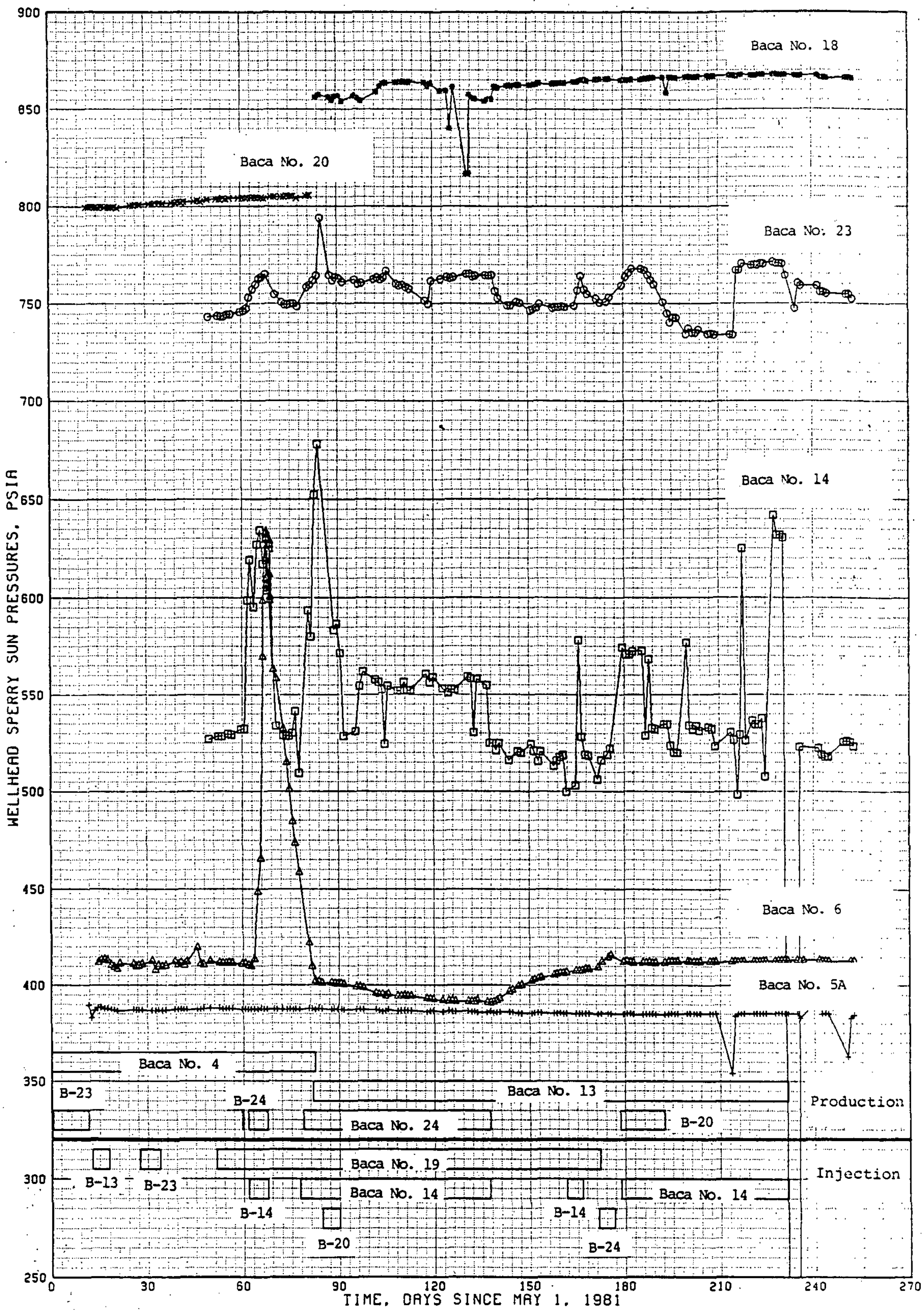


TABLE 5.5.2-1

PRODUCTION AND INJECTION DURING THE 1981 INTERFERENCE TEST

WELL	ACTIVITY	DATE	TOTAL PRODUCTION lb	AVERAGE RATE
Baca No. 4	Flow Test 3	3/31/81 - 7/22/81	394.0 x 10^6	145,100 lb/hr
Baca No. 13	Flow Test 5	3/05/81 - 4/21/81	273.3 x 10^6	242,300 lb/hr
Baca No. 13	Flow Test 6	7/21/81 - 12/18/81	690.8 x 10^6	192,000 lb/hr
Baca No. 20	Flow Test 5	10/26/81 - 11/09/81	26.6 x 10^6	79,200 lb/hr
Baca No. 23	Flow Test 3	4/13/81 - 4/23/81	17.4 x 10^6	71,500 lb/hr
Baca No. 23	Flow Test 4	5/01/81 - 5/21/81	20.4 x 10^6	77,000 lb/hr
Baca No. 24	Flow Test 2	7/01/81 - 7/07/81	48.4 x 10^6	329,000 lb/hr
Baca No. 24	Flow Test 3	7/17/81 - 9/15/81	247.4 x 106	172,300 lb/hr
		TOTAL	1700.8 x 10^6	
Baca No. 13	Injection 1	5/13/81 - 5/18/81	6.9 x 10^6	111 gpm
Baca No. 14	Injection 5	3/05/81 - 4/03/81	82.7 x 10^6	253 gpm
Baca No. 14	Injection 6	7/01/81 - 7/07/81	24.0 x 10^6	338 gpm
Baca No. 14	Injection 7	7/17/81 - 9/15/81	153.7 x 10^6	218 gpm
Baca No. 14	Injection 8	10/09/81 - 10/14/81	13.3 x 10^6	226 gpm
Baca No. 14	Injection 9	10/26/81 - 12/18/81	124.5 x 10^6	201 gpm
Baca No. 19	Injection 3	6/21/81 - 10/19/81	299.3 x 10^6	211 gpm
Baca No. 20	Injection 1	7/24/81 - 7/29/81	14.6 x 10^6	225 gpm
Baca No. 23	Injection 1	5/28/81 - 6/03/81	11.4 x 10^6	149 gpm
Baca No. 24	Injection 1	10/19/81 - 10/24/81	14.5 x 106	241 gpm
		TOTAL	744.9 x 10^6	

FIGURE 5.5.2-1
1981 REDONDO CREEK SPERRY SUN INTERFERENCE MONITORING
5/01/81 TO 1/10/82



The reservoir pressure was monitored in six wells but a positive, correlatable response was only observed in two wells: Baca Nos. 6 and 23. These wells were analyzed with the INTER program. The reservoir fluid parameters used were associated with a 500°F water and the reservoir location of each well included in the 1981 Interference Test are shown in Table 5.5-1.

There are different reasons for the lack of a positive, correlatable response in the remaining wells is varied. Baca No. 14 was extensively used as an injector which effectively masked any pressure response. Baca No. 5A had an extremely stable pressure, not fluctuating more than 3 psi in 8 months. Baca Nos. 18 and 20 showed pressure fluctuations which could not be correlated to any production/injection activity.

The pressure response observed at Baca No. 6 was on the order of 20 psi (Figure 5.5.2-2). The data obtained from July 3 to July 22, 1981 was wrong due to an instrument error. The remaining data points were analyzed for pure radial flow and for anisotropic radial flow. The hemispherical model and the closed boundary model did not give good matches and were not considered further. It was assumed that the reservoir was not a perfect sand box and as such all wells did not necessarily have to be in communication with Baca No. 6.

The observation pressure recorded at Baca No. 6 contains one valley and one peak, both of which appear to be the direct result of injection and production in Baca No. 24. Data scatter in the early portion of the observation period have effectively masked any early period trend. Therefore, Baca Nos. 4 and 23 communication cannot be analyzed during this test.

Figure 5.5.2-3 shows the pressure response, both observed and calculated, for the pure radial flow case considering communication with only Baca No. 24. This match has a reasonable E value and indicates a similar pressure trend. The addition of Baca No. 14 to the pure radial flow analysis gives a slightly better match as shown in Figure 5.5.3-4. This improvement is attributed to the correlation of larger-than-zero delta pressures at late Baca No. 6 data points and Baca No. 14 injection activity during that time. It is quite possible that the starting pressure, P initial, is inaccurate and Baca No. 14 is not in hydraulic communication.

The best E match is obtained using the anisotropic model and assuming communication with Baca Nos. 13, 14, 19 and 24 (Figure 5.5.2-5). The value of E shown in the figure is not sensitive to the angle assumed, but the assumed angle has a large effect on the degree of anisotropy. As an example, for $\theta = 80^\circ$, $k_x h = 10{,}700$ and $k_y h = 4630$ with an E of 1.46.

Figure 5.5.2-6 shows the relative high sensitivity match of Case 1 to the permeability thickness factor, but low sensitivity to a reservoir storage factor. Figure 5.5.2-7 shows high sensitivity of both factors to the match of the anisotropic case. The non-uniqueness of this match to the assumed angle, θ, makes Figure 5.5.2-6 the more meaningful of the two figures.

FIGURE 5.5.2-2

SPERRY SUN PRESSURES IN BACA NO. 6, 1981 INTERFERENCE TEST

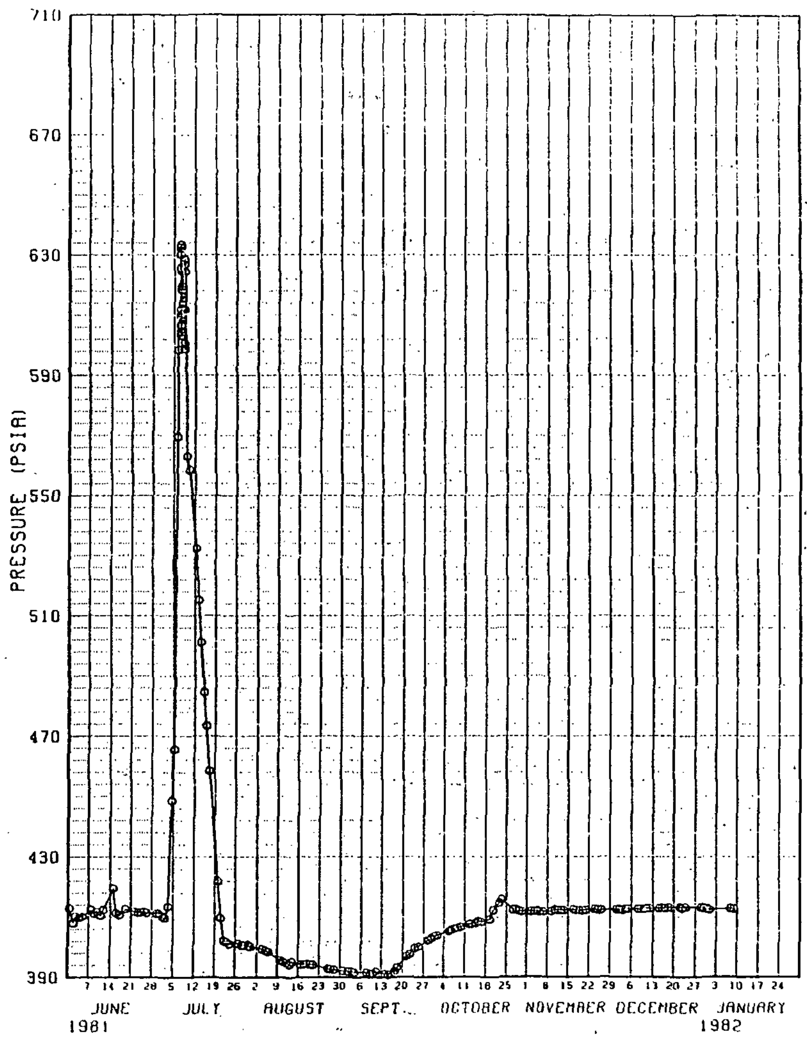


FIGURE 5.5.2-3

OBSERVATION FILE FOR BACA 6 INTERFERENCE TEST 1981

WITH BACA NO. 24

KH = 22,722.8 PHIH = 138.7 E = 2.430

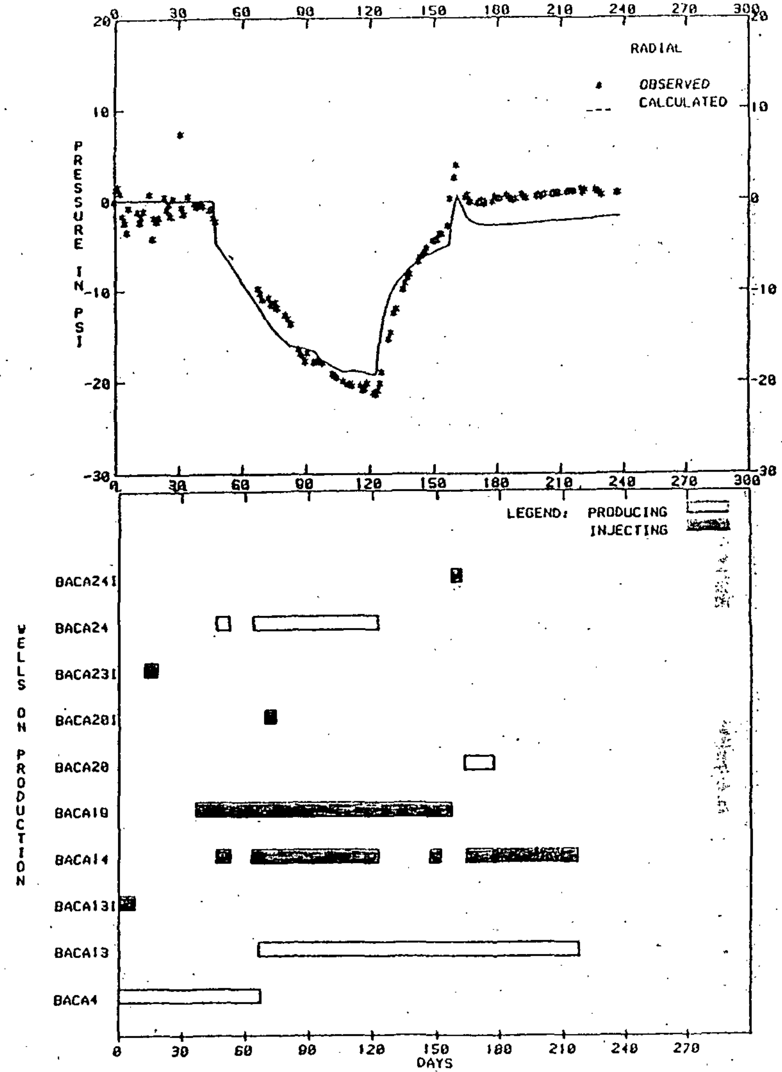


FIGURE 5.5.2-4

OBSERVATION FILE FOR BACA 6 INTERFERENCE TEST 1981

WITH BACA24 AND BACA14

KH = 13,377.8 PHIH = 272.0 E = 1.707

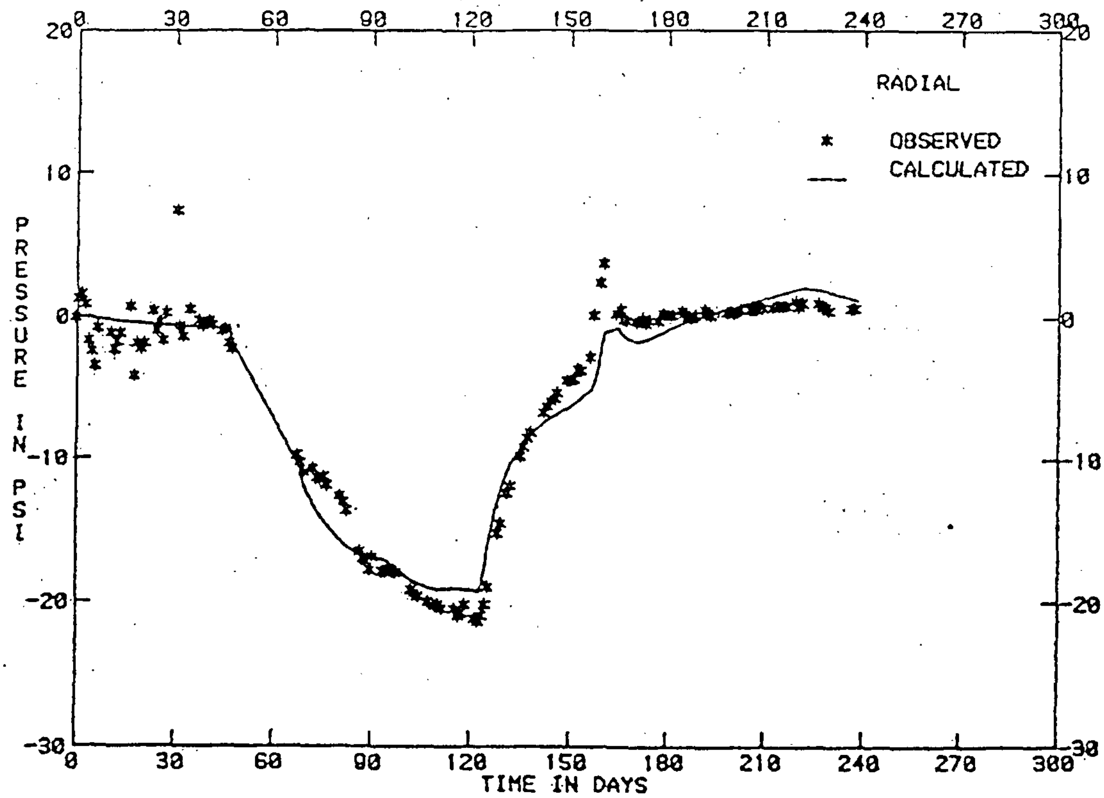


FIGURE 5.5.2-5

OBSERVATION FILE FOR BACA 6 INTERFERENCE TEST 1981

WITH BACA NO. 13,14,19 AND 24

KXH = 3,303.2 KYH = 37,043.6 PHIH = 526.4 THETA = 20 E = 1.356

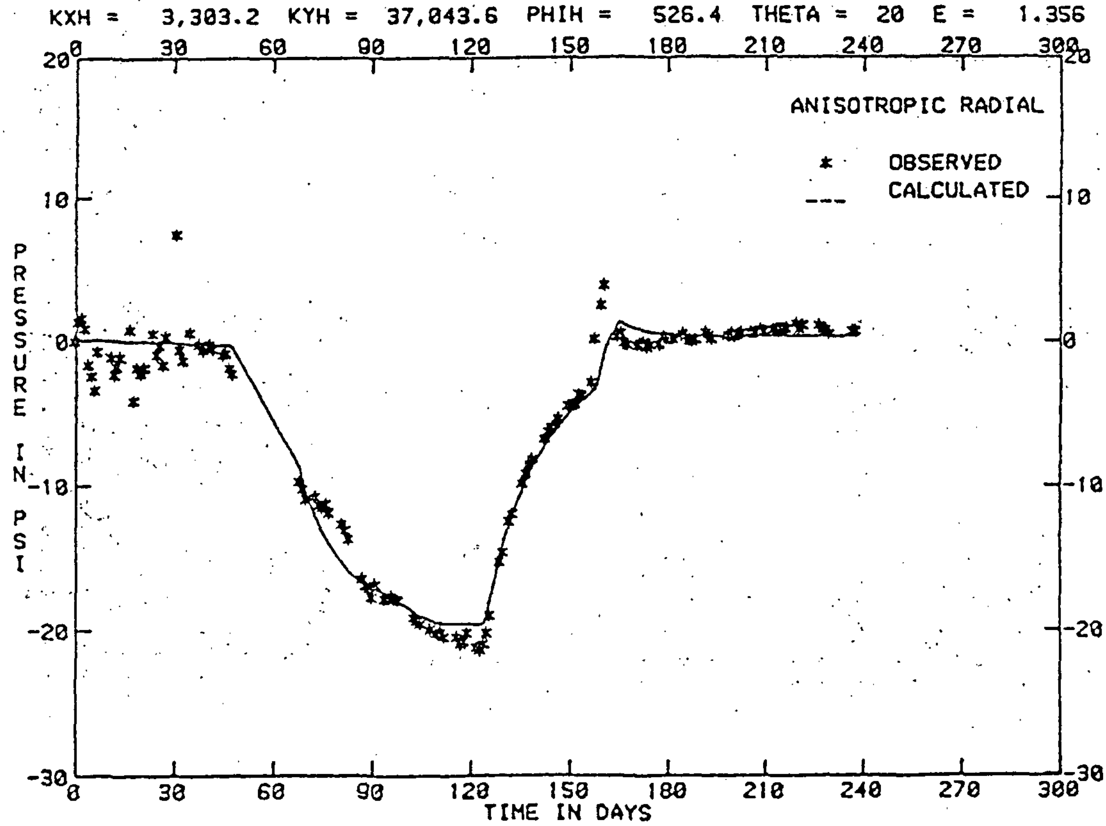


FIGURE 5.5.2-6
BACA NO. 6 DATA
RADIAL MODEL COMMUNICATION WITH BACA NO. 24

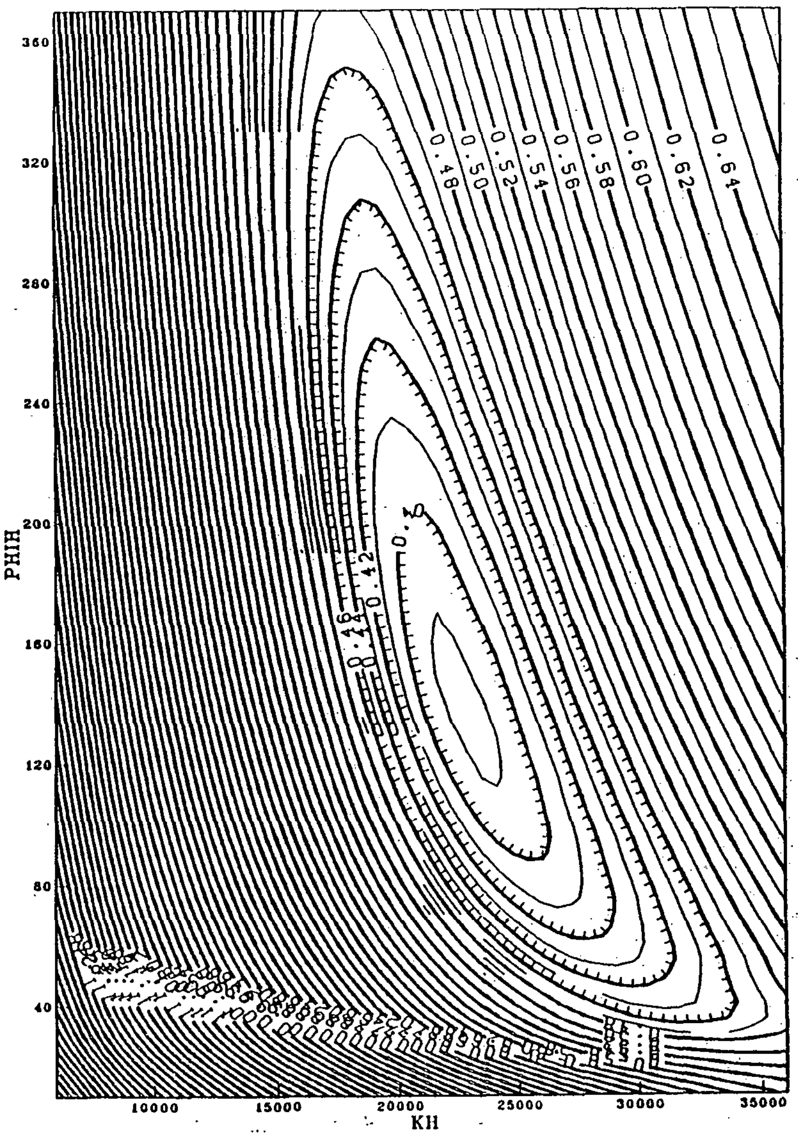
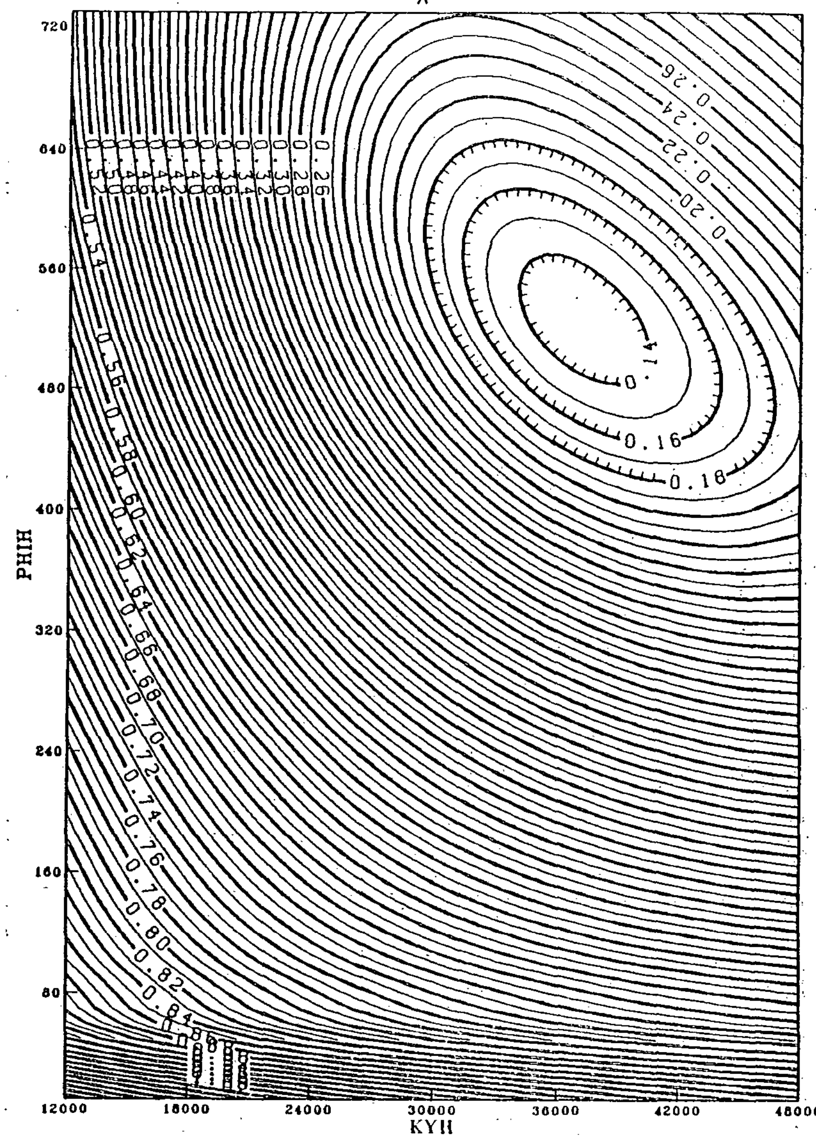


FIGURE 5.5.2-7
BACA NO. 6 DATA
ANISOTROPIC RADIAL MODEL COMMUNICATION WITH BACA NOS. 13, 14, 19, AND 24
$\theta = 20°$ $K_XH = 3300$ MD-FT



The uncertainity of the correct anisotropic theta, and the uncertainity of a correct initial pressure, leave the pure radial case considering hydraulic communication with Baca No. 24 as the best fit. This permeability thickness value of 22,000 md-ft is significantly higher than independent calculations for either Baca Nos. 6 or 24 (see section 5.3.1), but the reservoir storage of 140 ft is in agreement with the 1975-1976 Test.

The pressure response observed at Baca No. 23 was on the order of 25 psi (Figure 5.5.2-8). Several of the peaks and valleys shown on this figure can be attributed to instrument error; the 7/24, the 8/17 to 8/17, and the 11/04 to 12/01 data points. The remaining data points were analyzed for pure radial flow and for anisotropic radial flow. The hemispherical model and the closed boundary model did not give good matches and were not considered further. It was again assumed that the reservoir was not a perfect sand box and as such all wells did not necessarily have to be in communication with Baca No. 23.

The pressure response observed at Baca No. 23 contains many valleys and peaks, all of which can be directly correlated to Baca No. 14 injection. Conversely the production/injection activity of Baca No. 24 either just barely contributed, or did not contribute at all to the pressure response observed. Communication with the remaining Redondo Creek wells can not be positively determined.

Figure 5.5.2-9 shows the pressure response, both observed and calculated, for the pure radial flow case with only Baca No. 14 communicating. This match has a reasonable E value and shows all the main valleys and peaks. Addition of other wells, besides Baca No. 24, made little effect on this match.

Figure 5.5.2-10 shows the pressure response for the anisotropic case, assuming communication with Baca Nos. 13, 14, 19 and 24. The inclusion of Baca Nos. 13 and 19 makes little effect on the match; probably due to the timing of their activity.

Figure 5.5.2-11 shows the anisotropic case assuming communication with all wells with little change in the optimuim calculated parameters. Table 5.5-2 compares the above three cases.

The permeability-thickness ranges from 12,000 to 27,000 md-ft for the major axis of permeability. If anisotropy is assumed, the minor axis of permeability is calculated to be 650 to 800 md-ft at a θ of 50°. This angle implys that the major axis of permeability approximates the trend of Redondo Creek.

The major discrepancy encountered in the analysis is the reservoir storage value, øh. The radial model calculates a value one order of magnitude smaller than the anisotropic model. The EGRID plots shown in Figures 5.5.2-12 and 5.5.2-13 show the sensitivity of this calculated value of øh. The discrepancy is not the result of the different models, since the 1975-1976 test showed the exact opposite conclusions: higher øh with pure radial and lower with severe anistropy.

FIGURE 5.5.2-8

SPERRY SUN PRESSURES IN BACA 23, 1981 INTERFERENCE TEST

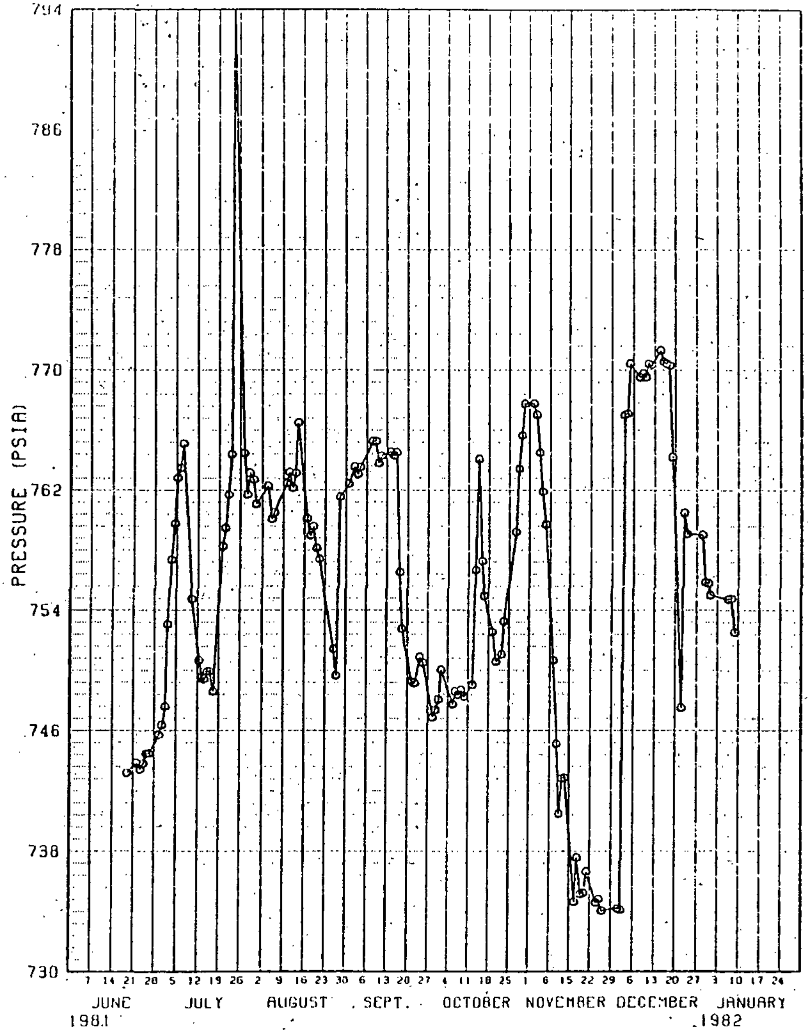


FIGURE 5.5.2-9

OBSERVATION FILE FOR BACA 23 INTERFERENCE TEST 1981

CONSIDERING ONLY INJECTION INTO BACA NO. 14

KH = 12,626.5 PHIH = 22.8 E = 3.086

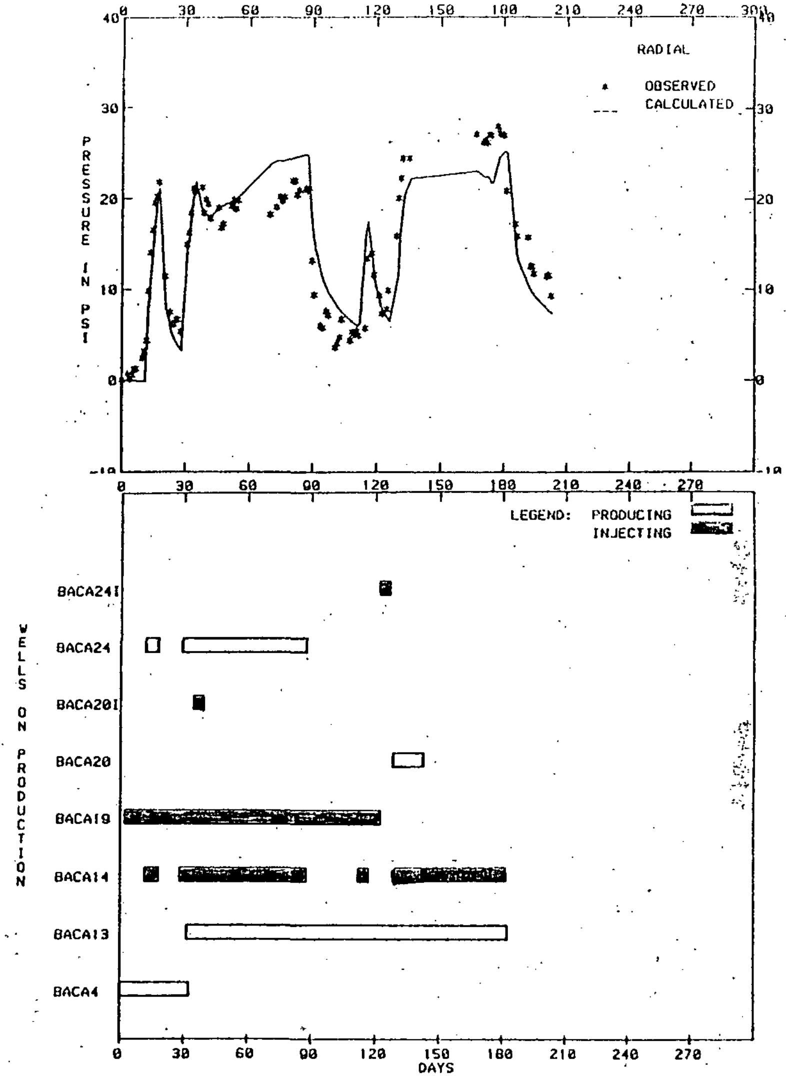


FIGURE 5.5.2-10

OBSERVATION FILE FOR BACA 23 INTERFERENCE TEST 1981

WITH BACA 13,14,19, AND 24

KXH = 27,324.0 KYH = 814.0 PHIH = 265.0 THETA = 50 E = 2.973

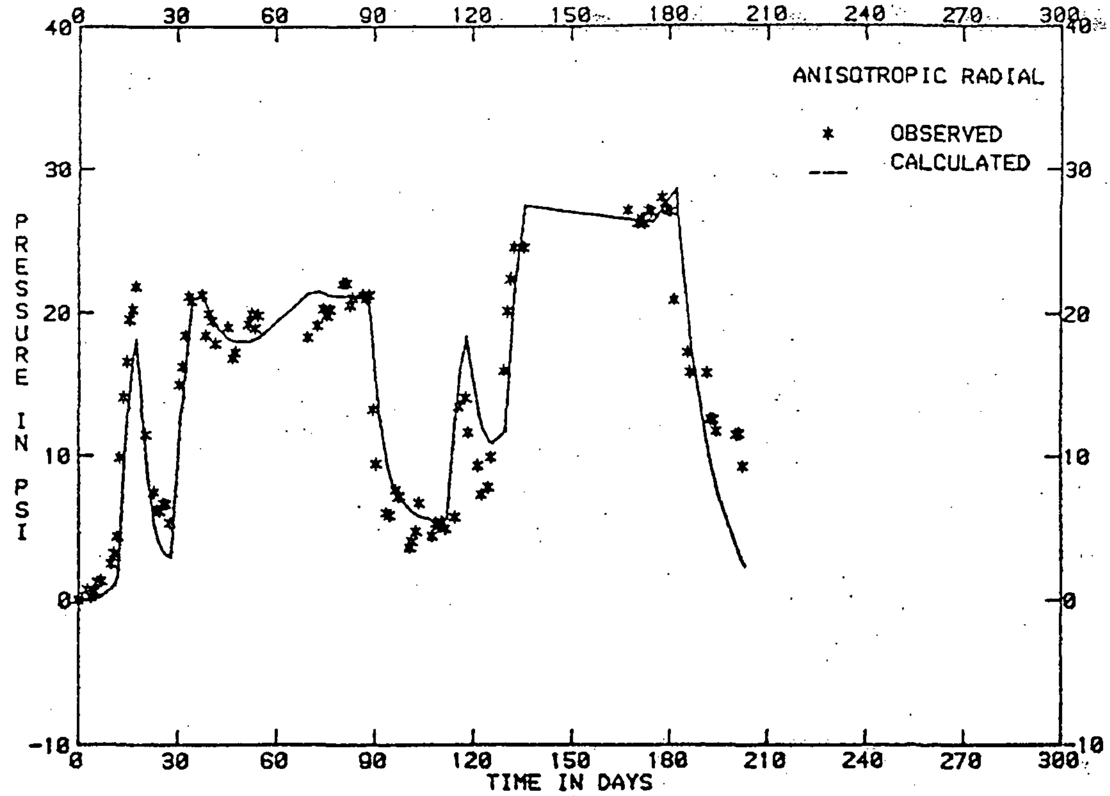


FIGURE 5.5.2-11

OBSERVATION FILE FOR BACA 23 INTERFERENCE TEST 1981

ALL WELLS

KXH = 22,831.2 KYH = 656.7 PHIH = 274.5 THETA = 50 E = 3.731

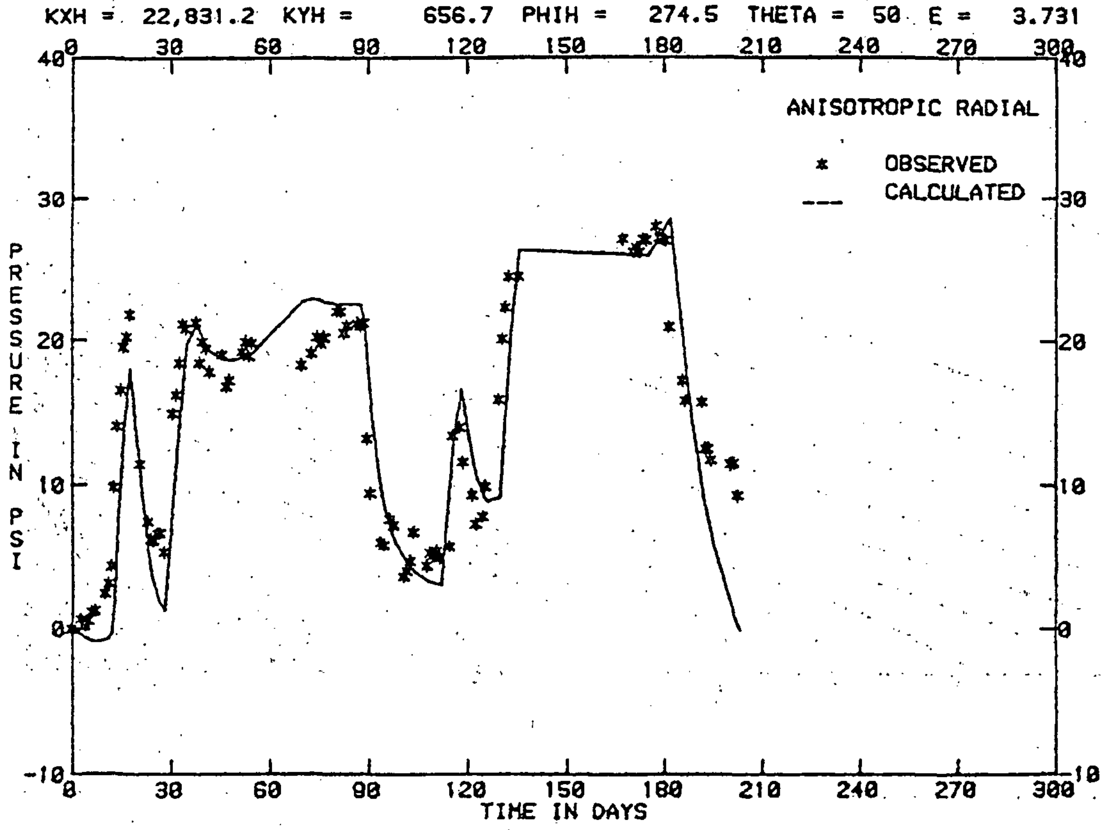
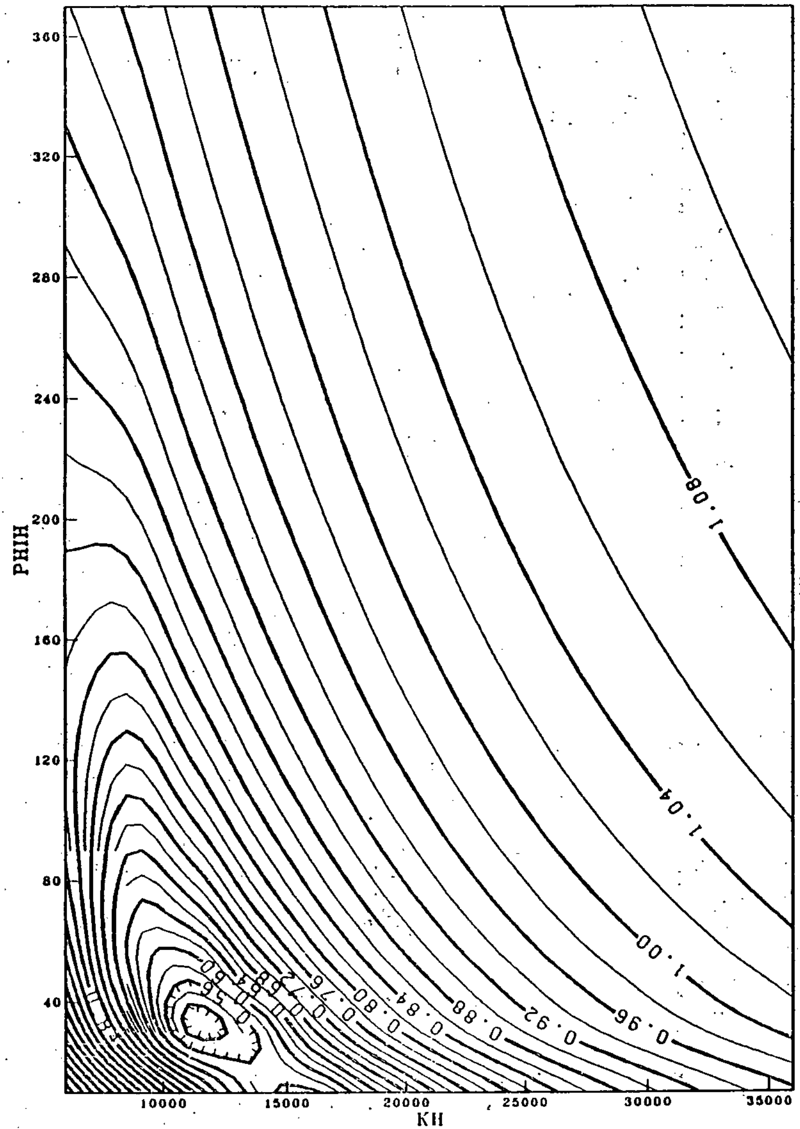
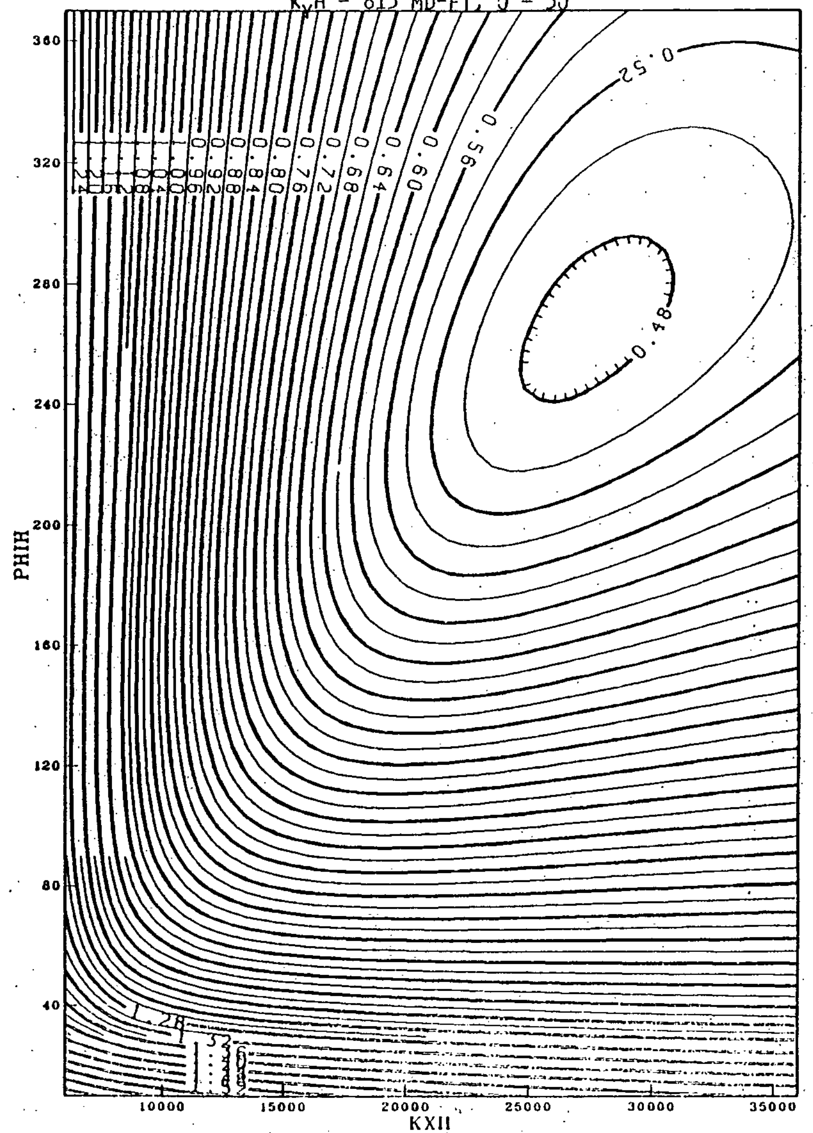


FIGURE 5.5.2-12
1981 BACA 23 RADIAL FLOW
RADIAL MODEL COMMUNICATION WITH BACA NO. 14



1981 BACA 23 ANRAD
FIGURE 5.5.2-13
ANISOTROPIC RADIAL MODEL COMMUNICATION WITH BACA NOS. 13, 14, 19 AND 24
K_yH = 815 MD-FT, θ = 50°



Either value is plausible. Due to the limited completion interval in Baca No. 23 and the limited fluid loss zone in Baca No. 14, a øh value of 23 feet is reasonable. If all wells communicate, and a larger section of the reservoir is tested, a larger value of øh is expected. Therefore, it is impossible to distinquish from a pure radial case with limited communication and reservoir storage, and severe anisotropy with more communication and a large reservoir storage.

5.5.3 1982 Interference Test

The 1982 Interference Test occurred over a nine month period from the end of the 1981 Test - January 10, 1982 - until the end of the Redondo Creek activity on October 22, 1982. During these 285 days a total of 15 flow tests and 20 injection periods were conducted (Tables 5.5.3-1 and 5.5.3-2). The six flow tested wells - Baca Nos. 4, 13, 15, 19, 20 and 24 - were each tested at least twice for a total mass production of 761.1 x 10^6 lb.

The 1982 Test was divided into two stages. The first stage of activity involved pressure observation at four wells while producing Baca No. 13 (Flow Test 7) and injecting into Baca No. 18. The second stage of activity involved flow testing several wells for two short durations - 3 to 12 days - and observing the pressure response elsewhere. The main focus of the first stage activity was to gather interference data, and the main goal of the second stage activity was to conduct pressure buildup and falloff tests, but each stage actually accomplished a little of each.

Nearly 60% or 453 x 10^6 lb of the produced mass was reinjected. Baca Nos. 14 and 18 were used as primary water disposal wells, with injection tests also being completed on Baca Nos. 4, 15, 18 and 24.

Six wells were used to monitor the Redondo Creek reservoir pressure response during the 1982 Test. Sperry-Sun instrumentation was initially installed in January, 1982 (or left in place from the 1981 Test) at Baca Nos. 6, 14, 19, 23 and 24. Before beginning of the second stage of activity the instrumentation was removed from Baca Nos. 14 and 24 and installed in Baca No. 20. The pressure monitoring continued in Baca Nos. 6 and 23 until the end of the 1982 Test, but was terminated in Baca Nos. 19 and 20 in the middle of September and early August respectively. Production/injection activity and observed Sperry-Sun pressures are shown in Figure 5.5.3-1. The production activity and the injection activity are described in Sections 5.2.1 and 5.2.2.

None of the six monitored wells had a positive, correlatable pressure response to all of the active Redondo Creek wells. Baca Nos. 14 and 20 showed a lack of communication with any active well. Baca Nos. 6, 19, 23 and 24 appear to have hydraulic communication with at least one active well each.

TABLE 5.5.3-1

PRODUCTION DURING THE 1982 INTERFERENCE TEST

WELL	ACTIVITY	DATE	TOTAL PRODUCTION lb	AVERAGE RATE lb/hr
Baca No. 4	Flow Test 4	06/09/82-06/14/82	20.1×10^6	169,700
Baca No. 4	Flow Test 5	06/30/82-07/12/82	46.8×10^6	163,100
Baca No. 13	Flow Test 7	02/16/82-04/13/82	260.6×10^6	194,000
Baca No. 13	Flow Test 8	06/02/82-06/07/82	26.8×10^6	223,200
Baca No. 13	Flow Test 9	06/24/82-07/06/82	57.8×10^6	200,600
Baca No. 13	Flow Test 10	08/11/82-08/15/82	28.3×10^6	289,900
Baca No. 13	Flow Test 11	09/14/82-09/20/82	43.4×10^6	298,700
Baca No. 15	Flow Test 3	07/21/82-07/26/82	39.6×10^6	333,100
Baca No. 15	Flow Test 4	08/30/82-09/08/82	61.6×10^6	285,500
Baca No. 19	Flow Test 6	09/23/82-09/27/82	14.9×10^6	160,500
Baca No. 19	Flow Test 7	10/07/82-10/18/82	43.8×10^6	165,900
Baca No. 20	Flow Test 6	08/03/82-08/05/82	3.5×10^6	64,200
Baca No. 20	Flow Test 7	08/26/82-08/30/82	5.0×10^6	51,900
Baca No. 24	Flow Test 4	06/16/82-06/21/82	34.8×10^6	290,700
Baca No. 24	Flow Test 5	07/08/82-07/19/82	74.1×10^6	280,800
		TOTAL	761.1×10^6	

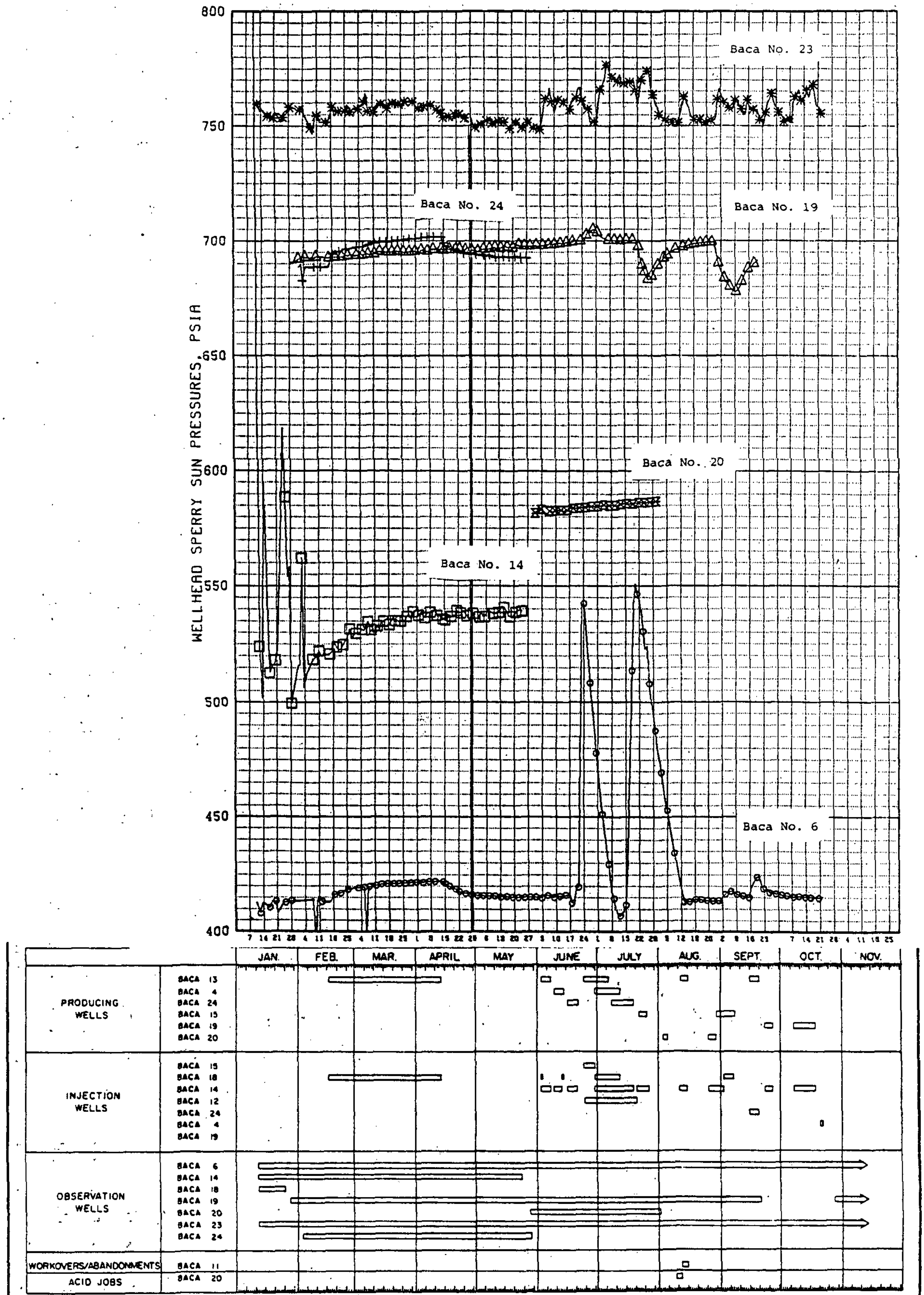
TABLE 5.5.3-2

INJECTION DURING THE 1982 INTERFERENCE TEST

WELL	ACTIVITY	DATE	TOTAL INJECTION lb	AVERAGE RATE gpm
Baca No. 4	Injection 1	10/21/82-10/22/82	2.0×10^6	148
Baca No. 12	Injection 4	06/23/82-07/21/82	10.7×10^6	32
Baca No. 14	Injection 10	01/11/82-02/03/82	7.5×10^6	28
Baca No. 14	Injection 11	06/02/82-06/07/82	13.5×10^6	230
Baca No. 14	Injection 12	06/09/82-06/13/82	8.6×10^6	173
Baca No. 14	Injection 13	06/16/82-06/21/82	15.3×10^6	261
Baca No. 14	Injection 14	06/24/82-07/19/82	66.6×10^6	226
Baca No. 14	Injection 15	07/21/82-07/27/82	21.9×10^6	316
Baca No. 14	Injection 16	08/11/82-08/15/82	12.1×10^6	261
Baca No. 14	Injection 17	08/26/82-09/09/82	10.0×10^6	123
Baca No. 14	Injection 18	09/14/82-09/15/82	4.0×10^6	360
Baca No. 14	Injection 19	09/23/82-09/27/82	10.2×10^6	214
Baca No. 14	Injection 20	10/07/82-10/18/82	24.2×10^6	186
Baca No. 15	Injection 1	06/24/82-06/30/82	21.2×10^6	306
Baca No. 18	Injection 2	02/16/82-04/13/82	164.4×10^6	251
Baca No. 18	Injection 3	06/02/82-06/03/82	4.7×10^6	365
Baca No. 18	Injection 4	06/13/82-06/14/82	3.4×10^6	339
Baca No. 18	Injection 5	06/30/82-07/12/82	14.4×10^6	102
Baca No. 18	Injection 6	09/01/82-09/07/82	22.7×10^6	320
Baca No. 24	Injection 2	09/15/82-09/20/82	15.6×10^6	263
		TOTAL	453.0×10^6	

FIGURE 5.5.3-1

1982 REDONDO CREEK FIELD SPERRY SUN INTERFERENCE MONITORING
1/11/82 TO 10/22/82



UNION 76	UNION OIL COMPANY - GEOTHERMAL DIVISION		
SANTA ROSA DISTRICT	REVISED FIELD ACTIVITY SCHEDULE REDONDO CREEK FIELD BACA LOCATION NEW MEXICO		
DESIGN: JBF			
DRAWN: MRA			
CHECK	SIZE / AFE NO	DWG NO 5266	REV 1
DATE 7/8/82	SCALE N/A		SHEET 1 OF 1

Analysis of the 1982 Test utilized the INTER program. A reservoir fluid of 500°F liquid and reservoir location presented in Table 5.5-1 were used in the analysis of the four wells which demonstrated some response. With the exception of Baca No. 6, each of the analyzed wells indicate a response attributable to only one active well. In this situation the anisotropic model is meaningless and was not considered. The relatively good match of the radial model in each analysis was not improved by the hemispherical or bounded radial flow models. The four analyses are described in brief below with the results shown on Table 5.5-2.

The pressure response of 10 to 12 psi observed at Baca No. 6 (Figure 5.5.3-2) was due to injection activity in Baca Nos. 18 and 24. Erroneous pressure data observed from June 17 to August 15 were disregarded and the remaining data points analyzed with the pure radial flow model and the anistropic radial flow model.

Figure 5.5.3-3 shows the observed and calculated pressure response for the pure radial flow model which considered only Baca Nos. 18 and 24 activity. While the match is good, a slight deviation exists between the observed and calculated pressures at times greater than 210 days. This is the only analyzable data attributable to Baca No. 24 activity and indicates that the permeability-thickness between Baca No. 6 and No. 24 is higher than 31,000 md-ft.

Figure 5.5.3-4 shows the pressure response, both calculated and observed, for the anistropic model considering communication with Baca Nos. 18 and 24. The excellent E value is marred somewhat by the high calculated kyh. The angle, $\theta = 5^{\circ}$, indicates that the major axis of permeability extends from Baca No. 6 to Baca No. 24. This is an indication of some locally enhanced-permeability structure existing between Baca Nos. 6 and 24. The kh value in the Baca No. 18 direction is close to the 31,000 md-ft obtained from the radial model analysis.

Figure 5.5.3-5 shows the relatively insensitivity of kxh and øh to the optimized match. Similar graphs indicated that the kyh parameter was very sensitive to the calculation of the E factor. Thus the Baca No. 6 parameters of kxh = 6400, kyh = 142,000 and øh = 200 feet are the optimized match.

The pressure response observed at Baca No. 19 was on the order of 25 psi (Figure 5.5.3-6). The pressure increase which occurred during the first stage of activity does not appear to be connected to the Baca No. 18 injection, but is rather a natural pressure phenomenom. The pressure response which follows June 24 is entirely the result of Baca No. 15 activity.

FIGURE 5.5.3-2

BACA NO. 6 SPERRY SUN PRESSURES

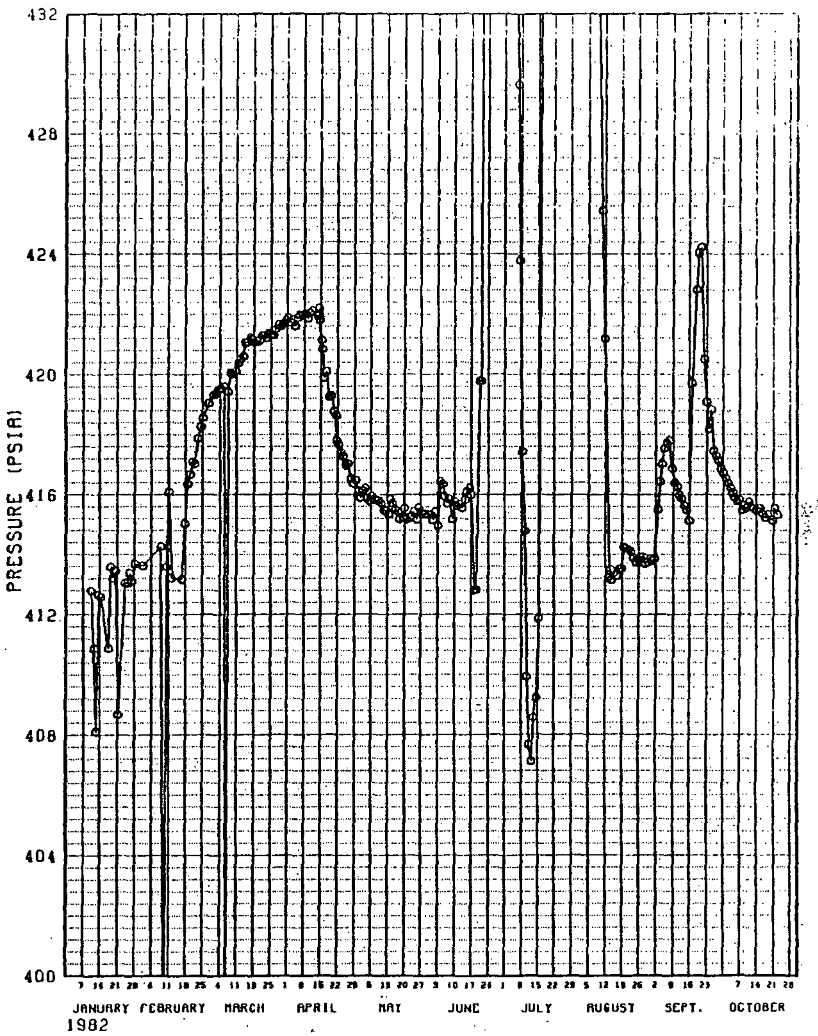


FIGURE 5.5.3-3

OBSERVATION PRESSURES FOR BACA 6 INTERFERENCE TEST 1982

WITH BACA NOS. 18 AND 24

KH = 31,492.1 PHIH = 467.8 E = 0.960

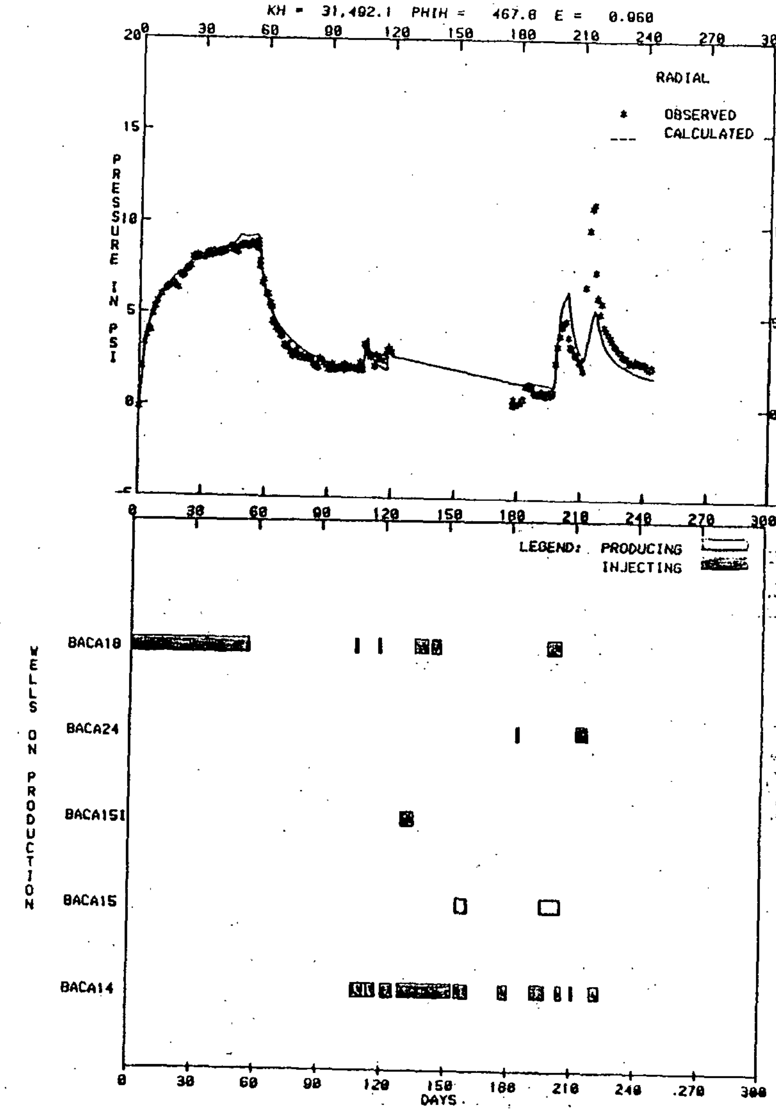


FIGURE 5.5.3-4

OBSERVATION PRESSURES FOR BACA 6 INTERFERENCE TEST 1982
WITH BACA NOS. 18 AND 24

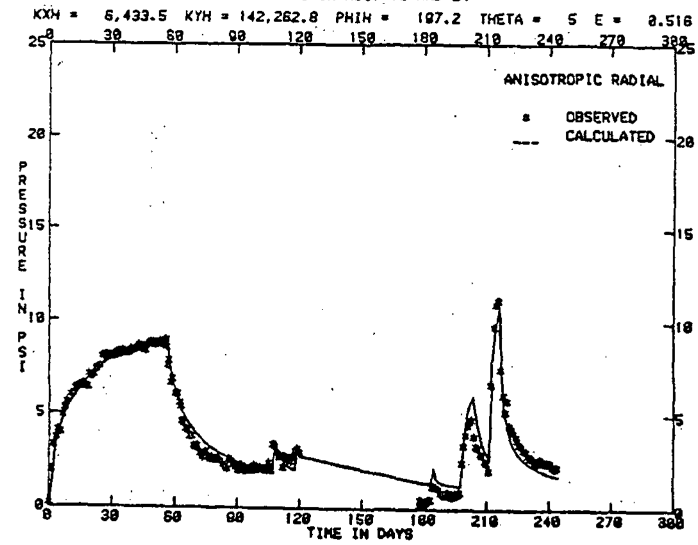


FIGURE 5.5.3-5
BACA NO. 6 DATA
Anisotropic Radial Model Communication With
Baca Nos. 18 and 24 θ=5°, K_XH=142,000 MD-FT

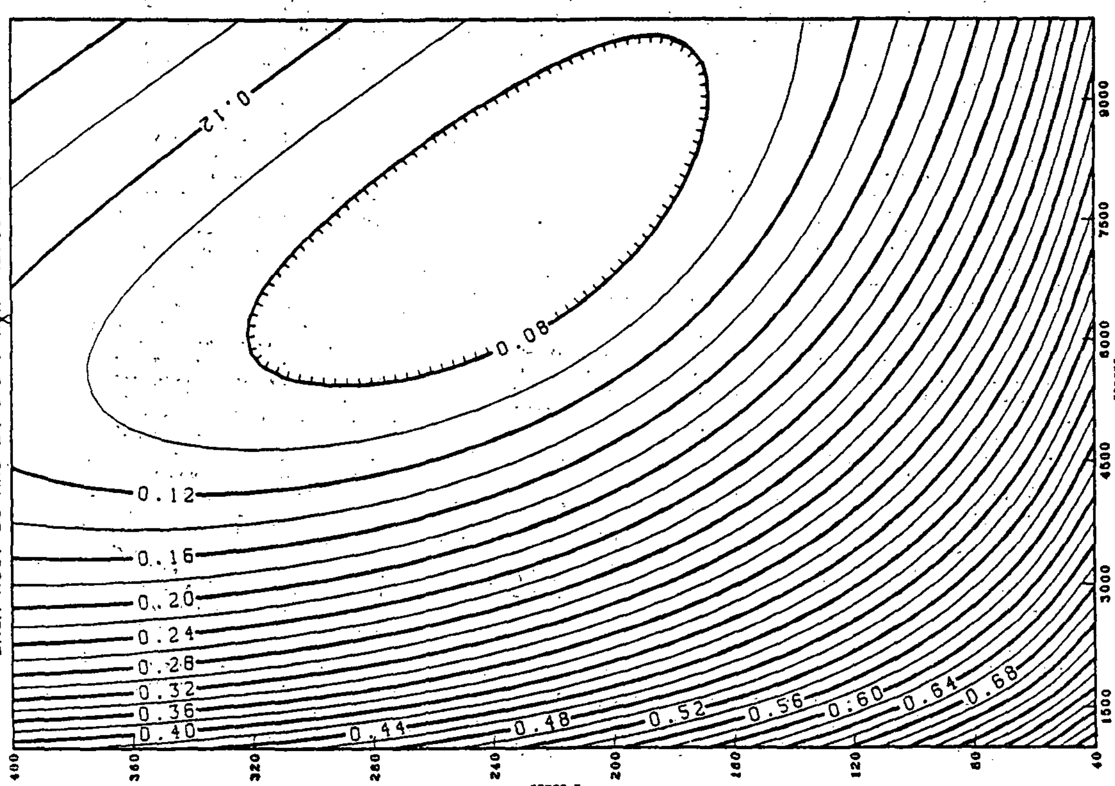


FIGURE 5.5.3-6
BACA NO. 19 SPERRY SUN PRESSURES

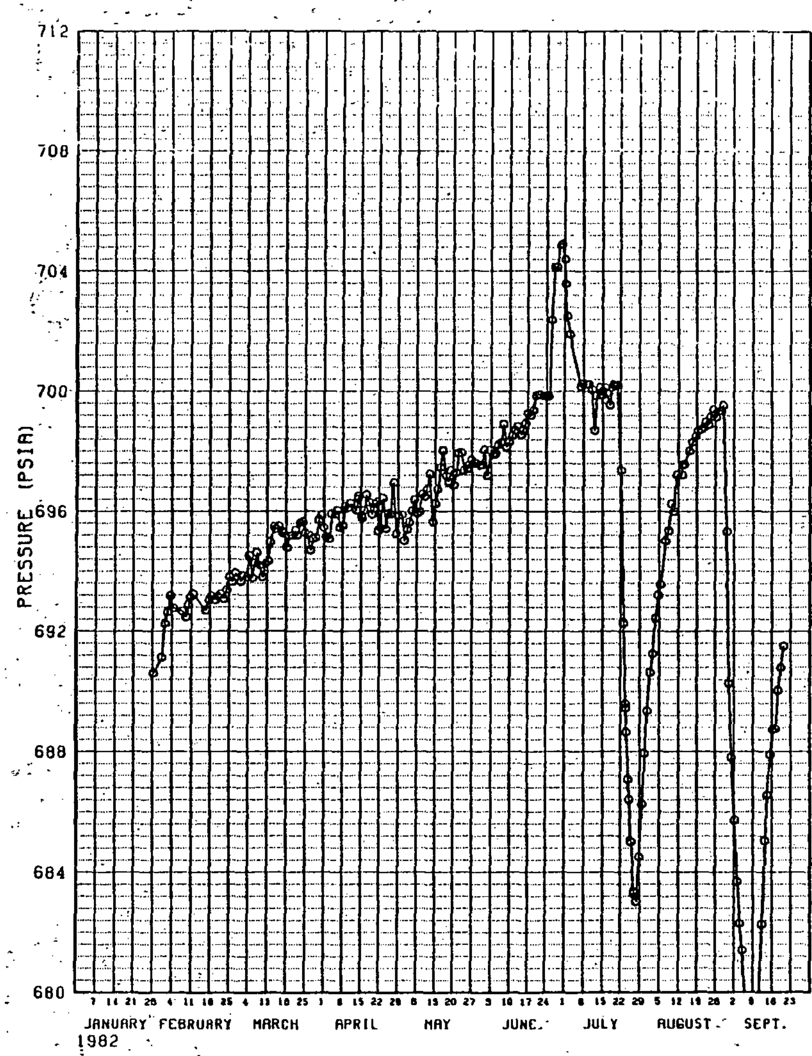


FIGURE 5.5.3-7
OBSERVATION PRESSURES FOR BACA 10 INTERFERENCE TEST 1982
WITH BACA NO. 15
KH = 13,553.3 PHIH = 1,045.2 E = 2.130

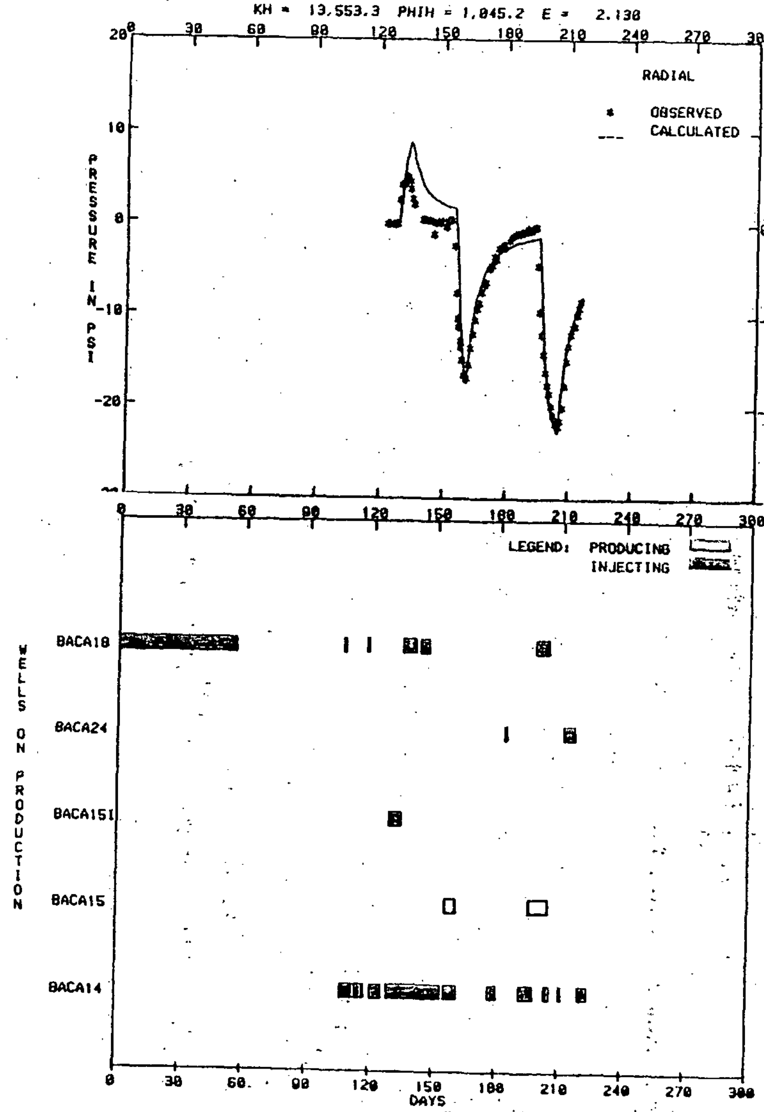


Figure 5.5.3-7 displays the calculated and observed pressure response for the pure radial flow model considering communication with only Baca No. 15. The good match between observed and calculated pressures is slightly distorted by the early-time discrepancy which occurred during the Baca No. 15 injection test. This slight deviation implys that not all of the injected water was entering a reservoir in direct communication with Baca No. 19. The implications of this upon the apparent vertical permeability of the Redondo Creek reservoir are discussed in Section 5.6.

Figure 5.5.3-8 shows the high sensitivity of the optimized kh and øh parameters. This indicates that the Baca Nos. 15-19 data results in optimized reservoir parameters are kh = 13,500 md-ft and øh = 1050 feet.

Figure 5.5.3-9 shows the 30 psi pressure fluctuations of Baca No. 23 observed during the 1982 Test. During periods of Baca No. 14 injection and periods of no activity the pressure communication between Baca Nos. 14 and 23 remained remarkable. While the observed Baca No. 23 pressures during the first stage appear to follow the trend of the Baca No. 18 injection, the timing of the start of the pressure rise and the start of the pressure decline are not consistent with the injection timing.

Figure 5.5.3-10 displays the pressure history of Baca Nos. 14 and 23 during the first stage of activity. The strong communication is apparent in the correlations between the pressure peaks and valleys of each well.

The calculated and observed Baca No. 23 pressure response during the second stage of activity for the pure radial flow model are presented in Figure 5.5.3-11. The natural pressure fluctuations of Baca No. 23 make the E factor poor, but the match shown is acceptable as all of the major peaks and valleys are accounted for. The addition of other active wells did not improve the calculated pressure response.

Figure 5.5.3-12 shows that the optimizaton value is relatively sensitive to kh, but that øh can vary from 10 to 30 feet without significant change. The calculated parameters of kh = 15,700 md-ft and øh = 17.6 feet agree with the parameters obtained from the 1981 Test.

Figure 5.5.3-13 displays the pressure history of Baca No. 24 during the first stage of activity. The observed pressure response of 13 psi indicates strong hydraulic communication between Baca Nos. 18 and 24. Since the Sperry-Sun instrumentation was removed prior to the activity of other wells, other communication cannot be determined.

Figure 5.5.3-14 shows the calculated and observed pressure response for Baca No. 24. The parameters calculated from this pure radial model analysis - kh = 22,200 md-ft and øh = 490 feet - are high when compared to buildup tests but average if considering interference tests. The sensitivity of the optimized match to these parameters are shown in Figure 5.5.3-15. The kh value is sensitive but the øh parameter may be as low as 400 feet without significantly affecting the calculated pressure response.

FIGURE 5.5.3-8

BACA NO. 19 DATA

RADIAL MODEL COMMUNICATION WITH BACA NO. 15

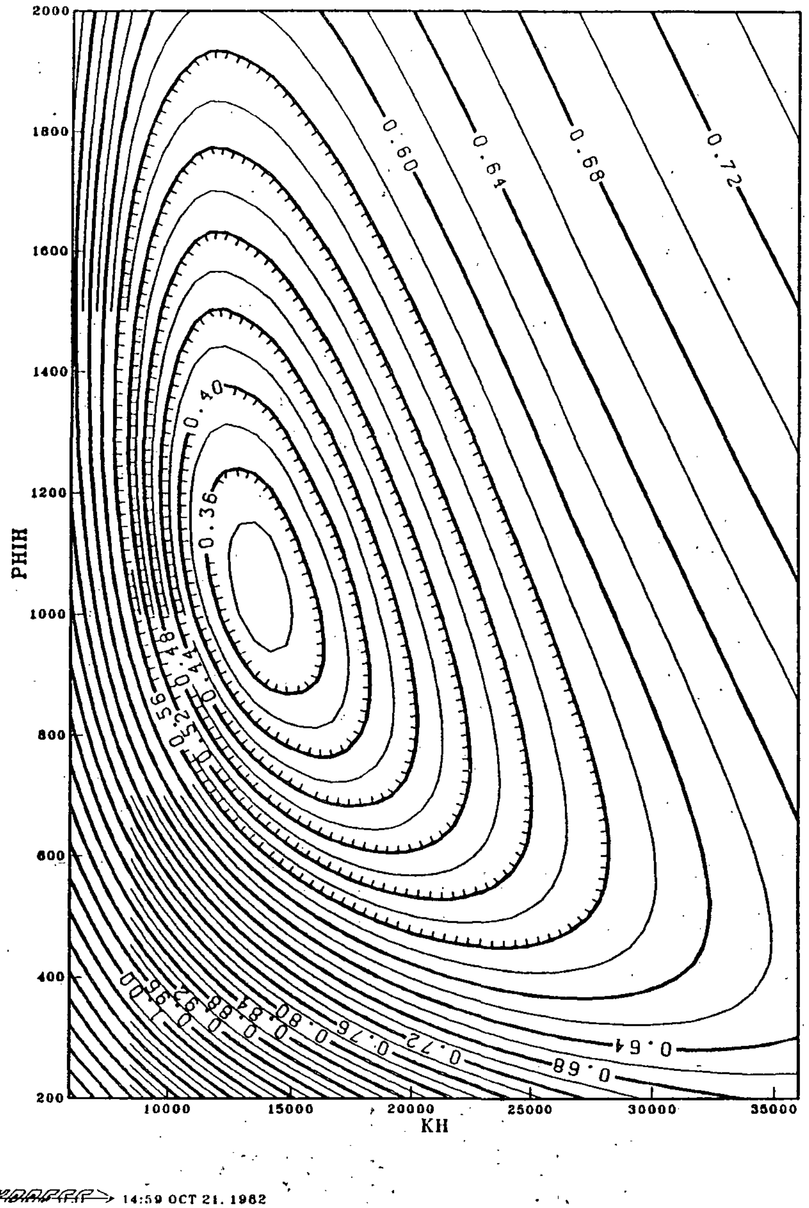


FIGURE 5.5.3-9

BACA NO. 23 SPERRY SUN PRESSURES

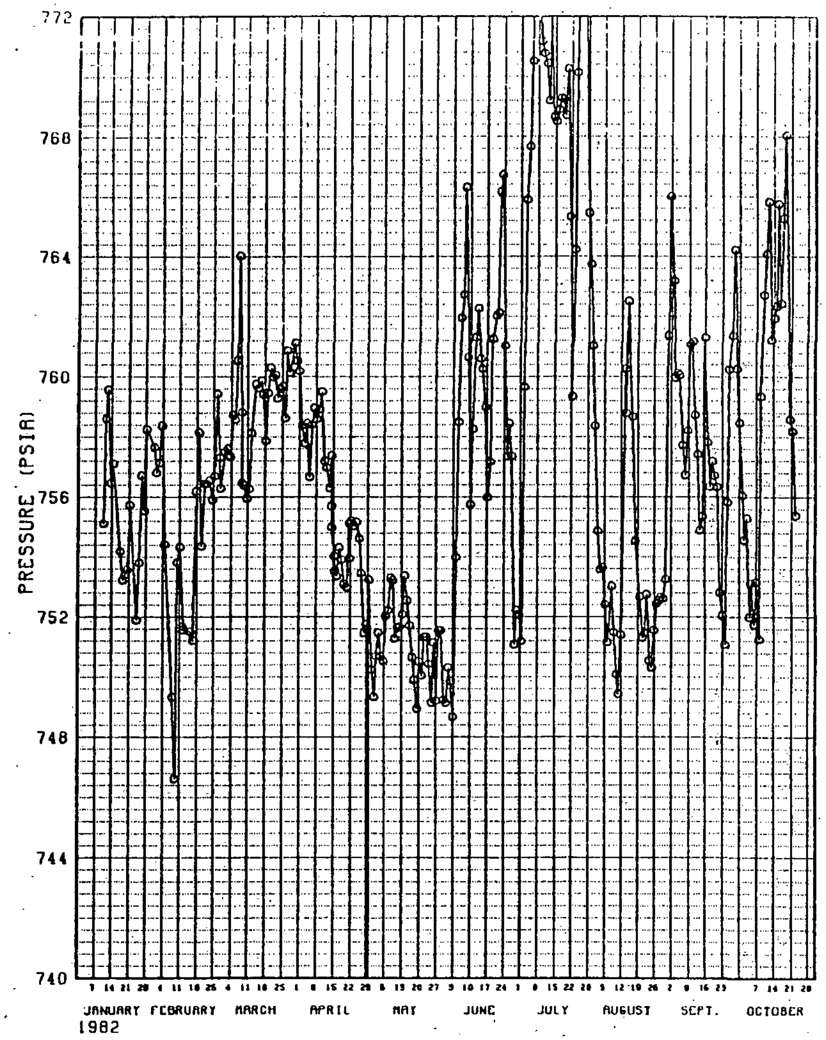


FIGURE 5.5.3-11

OBSERVATION PRESSURES FOR BACA 23 INTERFERENCE TEST 1982
WITH BACA NO. 14
KH = 15,721.6 PHIH = 17.6 E = 6.506

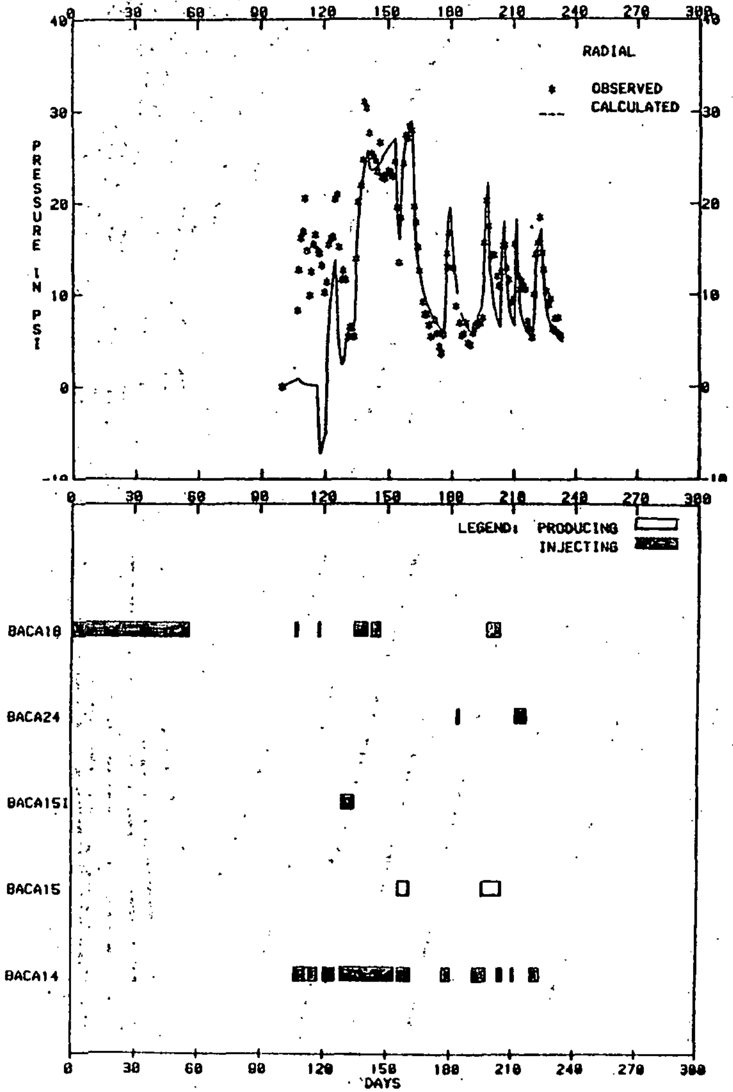


FIGURE 5.5.3-10

COMPARISON OF PRESSURES OBSERVED IN BACA NOS. 14 AND 23 DURING FIRST STAGE ACTIVITY, 1982 INTERFERENCE TEST

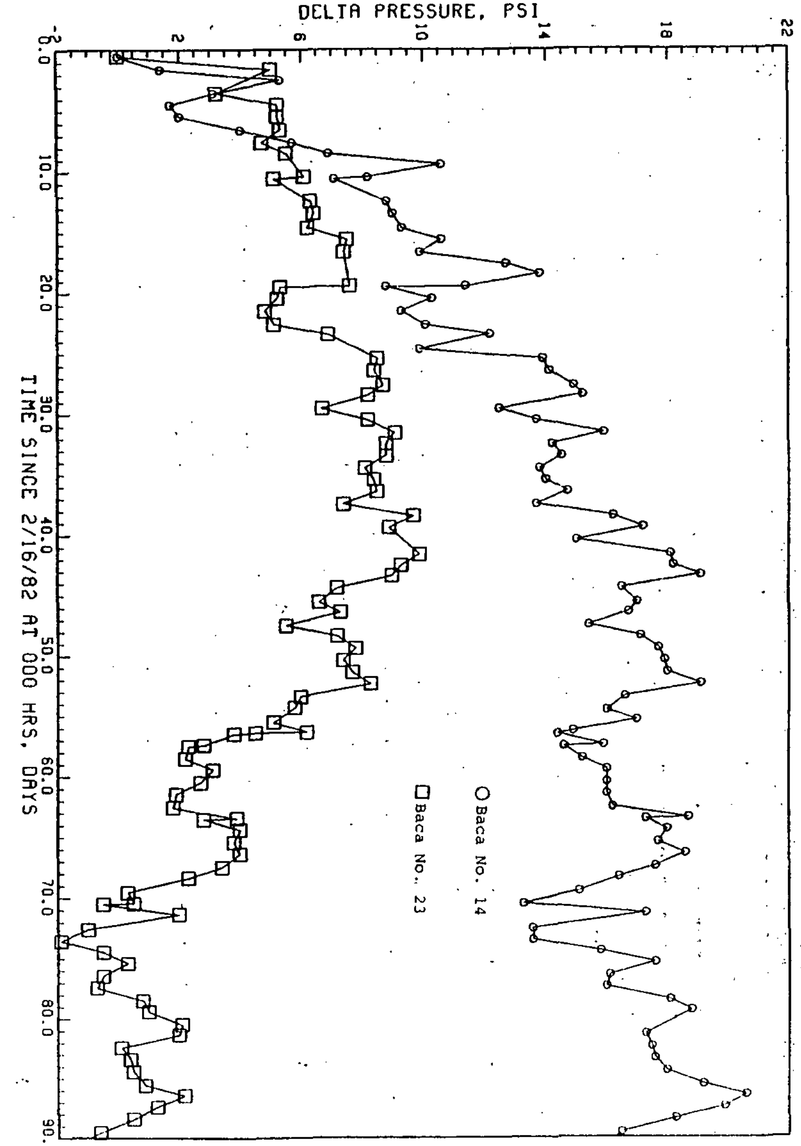


FIGURE 5.5.3-12

BACA NO. 23 DATA

RADIAL MODEL COMMUNICATION WITH BACA NO. 14

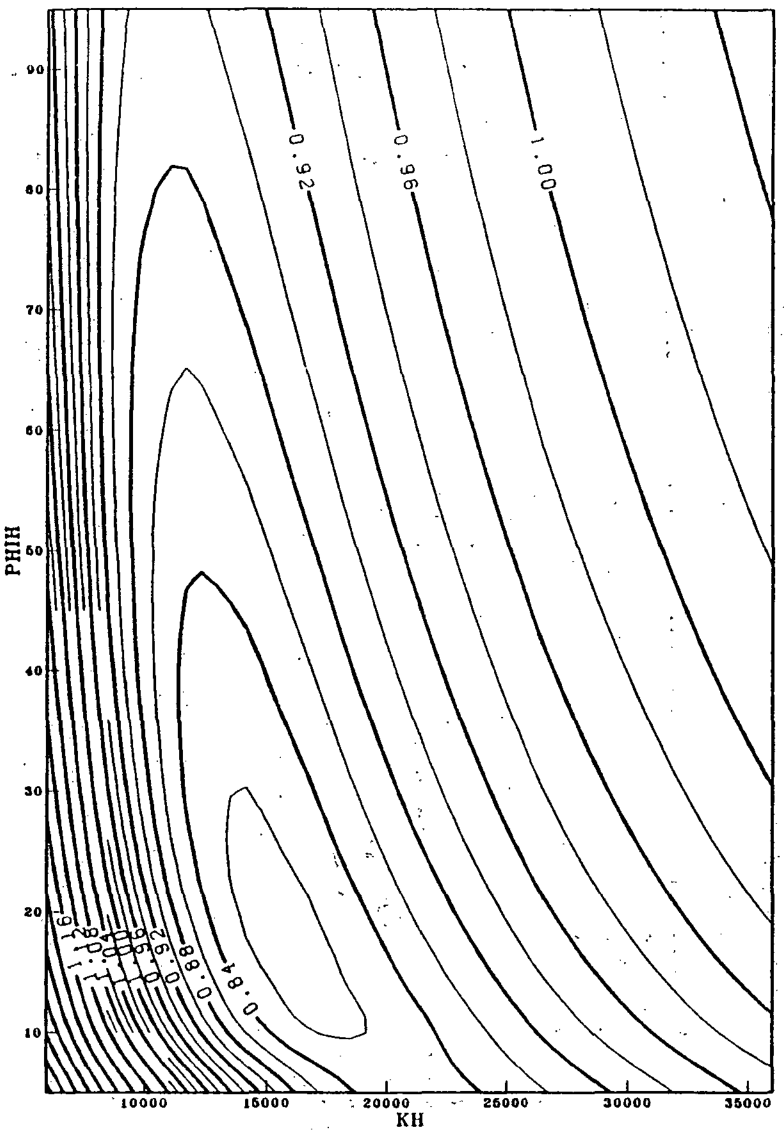


FIGURE 5.5.3-13

BACA NO. 24 SPERRY SUN PRESSURES

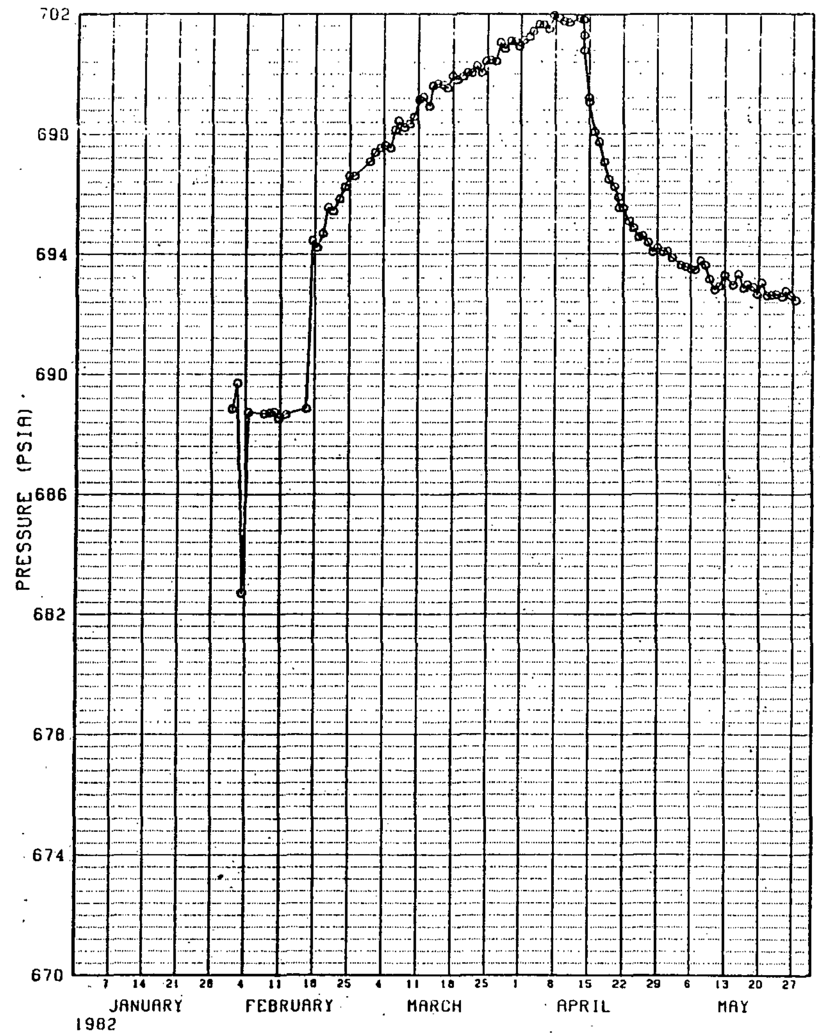


FIGURE 5.5.3-14

OBSERVATION PRESSURES FOR BACA 24 INTERFERENCE TEST 1982
WITH BACA NO. 18

KH = 22,244.6 PHIH = 490.7 E = 0.682

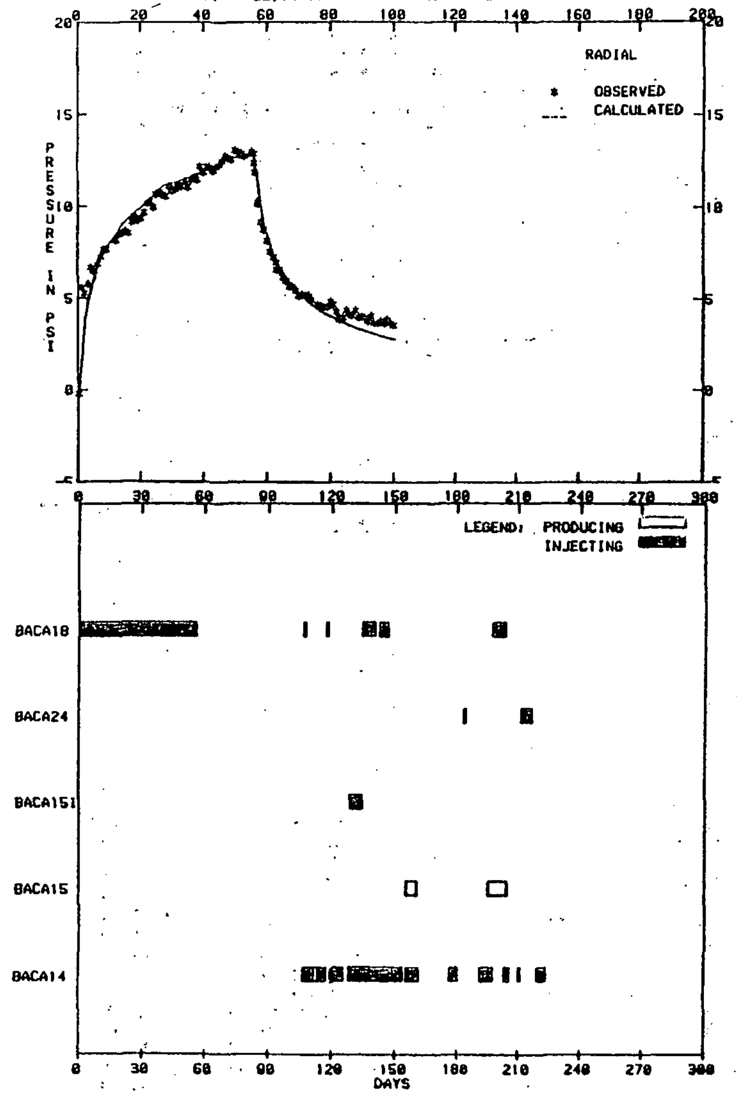
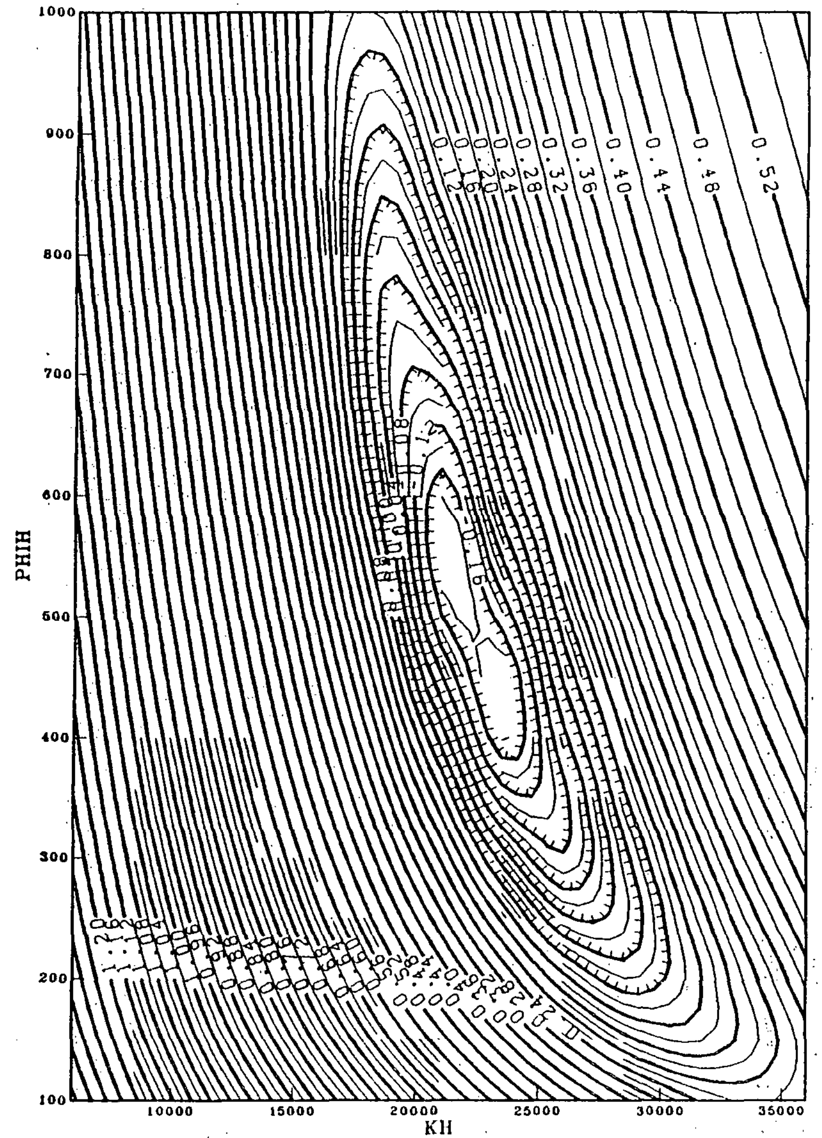


FIGURE 5.5.3-15

BACA NO. 24 DATA

RADIAL CASE COMMUNICATION WITH BACA NO. 18



5.6 Conceptual Model of the Reservoir

Summary

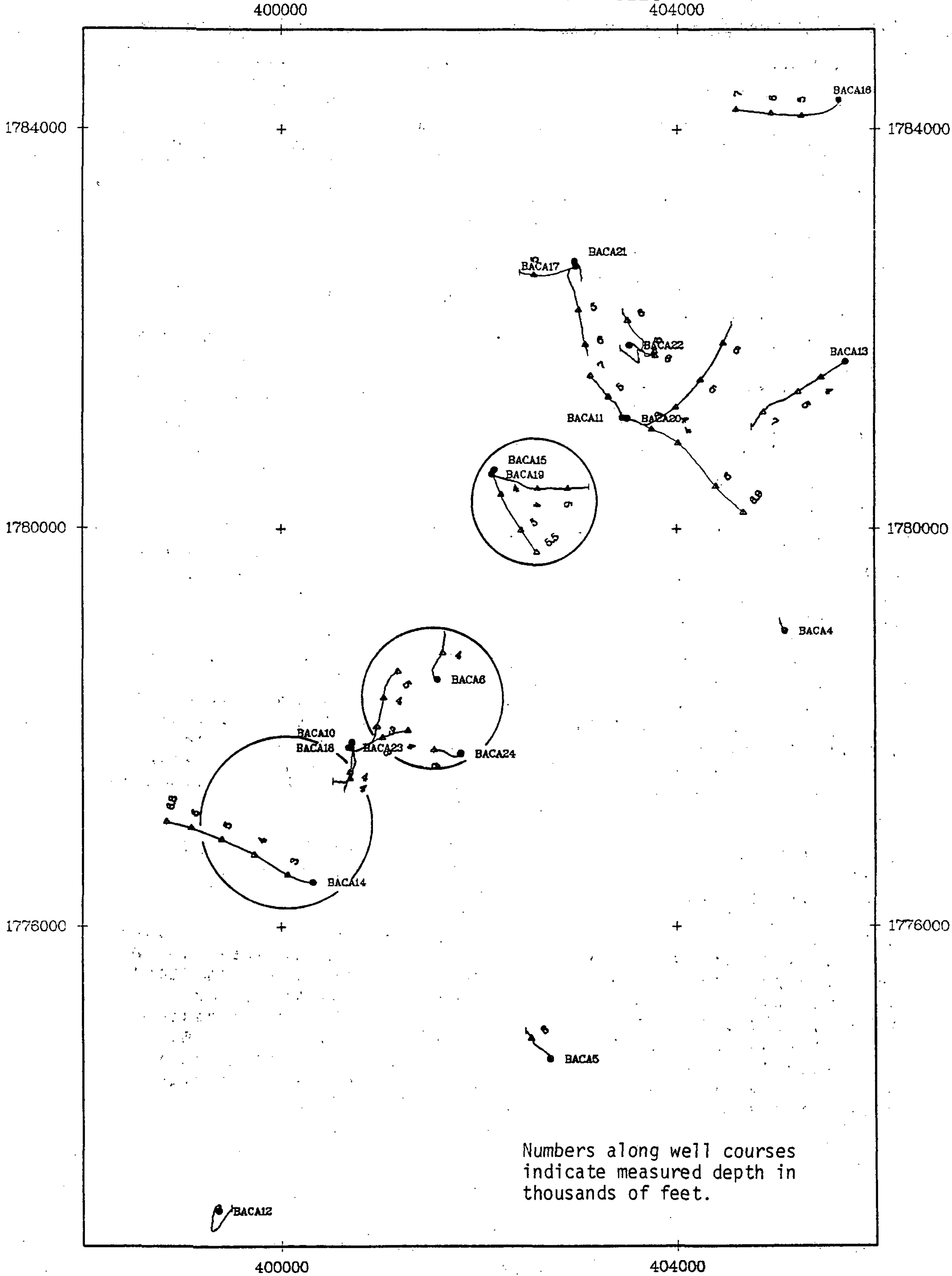
The behavior of the Redondo Creek reservoir is dominated by the characteristics of the Bandelier Tuff Formation: horizontally layered with limited vertical permeability. The primary Redondo Creek reservoir is located within the contact zone consisting of the bottom few hundred feet of the Bandelier Tuff and the top few hundred feet of the Andesite. The high porosity of the Basal Bandelier is attributed to its characteristic as a low-temperature, pumicey, air fall unit that was relatively cool and thus poorly welded. The top of the Andesite was probably a weathered zone, also poorly welded, which along with the Basal Bandelier appears to be the primary production zone controlling the pressure of the Redondo Creek reservoir. For a well to be commercial it must intersect a permeable portion of this contact zone. If the contact zone intersected is not highly permeabler an upper steam-dominated zone must also be tapped for a well to be commercial.

Discussion

The primary Redondo Creek Reservoir is located within the contact zone consisting of the bottom few hundred feet of Bandelier Tuff and the top few hundred feet of Andesite. Other permeable horizons identified in the Redondo Creek Reservoir such as steeply-dipping faults (Behrman and Knapp, 1980) and stratigraphic aquifers (Hulen and Nielson, 1982) are felt to influence but not dominate the reservoir productivity. The static pressures of the Redondo Creek wells are controlled by a deep reservoir zone (Section 5.1.2): presumably the contact zone. Almost every Redondo Creek well intersected a permeable zone when drilling through this contact. Sulphur Creek wells - Baca Nos. 7 and 8 - located outside the buried Toledo Caldera in a thinner section of Bandelier Tuff have a dominant pressure zone much higher in elevation. Since the contact zone is also much higher, the correlation between dominant reservoir zones and the contact zone appears to be consistent throughout the area.

While this contact zone extends throughout the Redondo Creek field and the pressure has equilibrated during geologic time, faulting has apparently created individual cells within this zone. These reservoir cells have been identified on the basis of communication patterns during interference tests. They behave as if no inter-cell communication exists during testing even though communication is observed on a geological time scale. From the four Redondo Creek Interference Tests three reservoir cells have been identified: the Baca Nos. 15 and 19 cell; the Baca Nos. 10, 14 and 23 cell; and the Baca Nos. 6, 18 and 24 cell (Figure 5.6-1).

FIGURE 5.6-1
IDENTIFIED RESERVOIR CELLS



1450 APR 21 1982

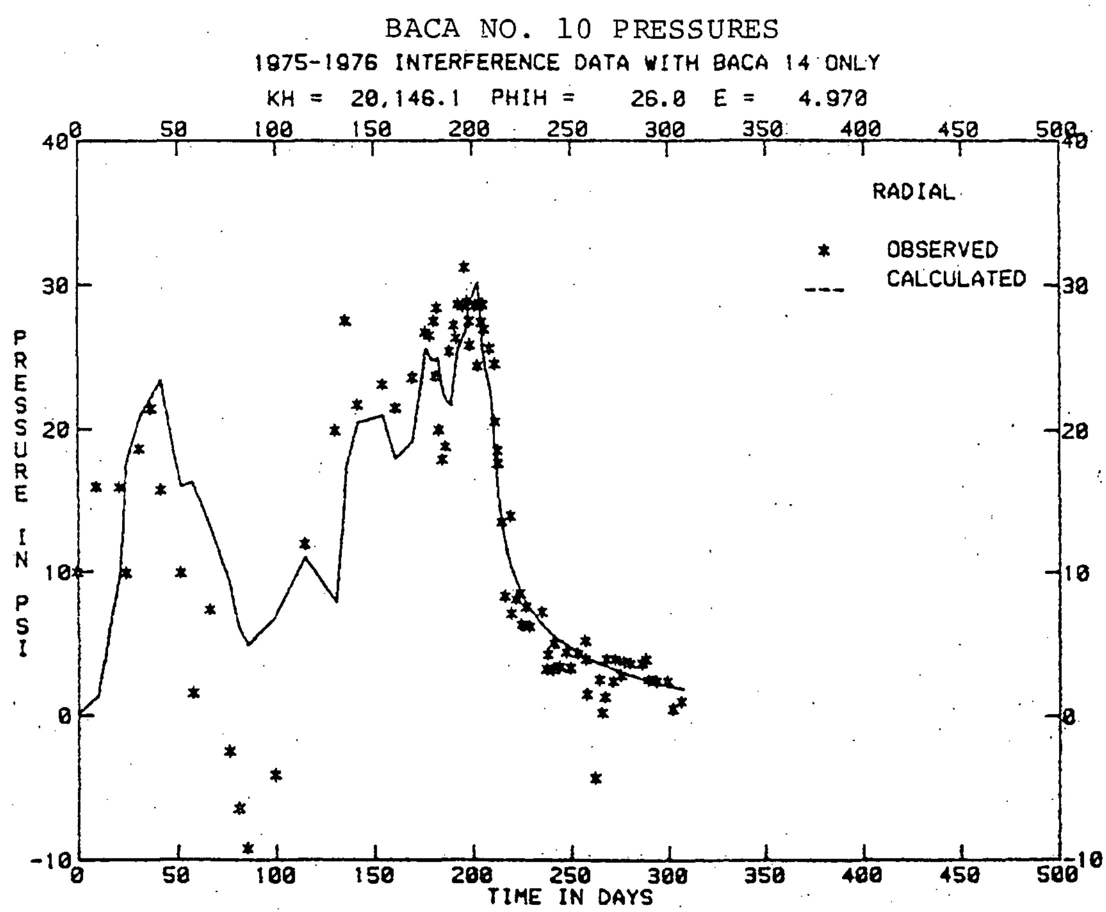
The Baca Nos. 15 and 19 reservoir cell was identified from the 1982 Test when Baca No. 19 responded strongly to Baca No. 15 injection and production activity. The two wells are communicating through a permeable contact zone. Baca No. 15 activity did not create a pressure response at other Redondo Creek wells, and the activity of other wells did not affect the pressures observed at Baca No. 19.

The Baca Nos. 10, 14 and 23 cell has been detected in three interference tests: 1975-1976, 1981, and 1982. The 1975-1976 Test was analyzed in Section 5.5.1 considering communication between Baca No. 10 and all active Redondo Creek wells. The excellent match of Figure 5.6-2 shows that an analysis considering only Baca No. 14 communication is probably a more realistic approach. The values of kh and øh are very similar to the values calculated from Baca No. 23 pressure observation during the 1981 and 1982 Tests which also noted a strong response to Baca No. 14 activity and little if any pressure response to other Redondo Creek wells. The three wells are in communication through an upper liquid zone which is not associated with the contact zone.

The Baca Nos. 6, 18, and 24 cell was initially identified during the 1981 Test when Baca No. 6 showing a strong pressure response to Baca No. 24 injection and production. During the 1982 Test Baca No. 18 injection responded at Baca Nos. 6 and 24. The lack of response observed at Baca No. 18 during Baca No. 24 activity (1981 Test), the preferred anistropic permeability between Baca Nos. 6 and 24 (1982 Test), and the contrast of the subcommercial Baca No. 18 with the commercial Baca Nos. 6 and 24 indicate that Baca Nos. 6 and 24 intersect a highly permeable structure near the contact zone which Baca No. 18 does not tap. The apparent bilinear pressure response to Baca No. 18 injection observed at Baca Nos. 6 and 24 implies that the injected fluid flowed linearly to the highly permeable structure connecting Baca Nos. 6 and 24.

In addition to the horizontal discontinuities, the Redondo Creek Field is affected by localized vertical permeability restrictions. Figure 5.5.3-7 displays the match of the observed and calculated pressure response of Baca No. 19 assuming all of the fluid produced from and injected into Baca No. 15 is entering a reservoir which communicates with Baca No. 19. The relatively high calculated delta pressures associated with the injection interval indicates that not all of the injected fluid is entering a zone in hydraulic communication with Baca No. 19. This suggests that the 4600'-4800' M.D. permeable zone identified from the spinner surveys is not in communication with Baca No. 19 i.e. is not in communication with the contact zone of Baca No. 15.

Figure 5.6-2



BACA NO. 10 PRESSURES
1975-1976 INTERFERENCE DATA WITH BACA 14 ONLY
KH = 20,146.1 PHIH = 26.0 E = 4.970
RADIAL
OBSERVED
CALCULATED
PRESSURE IN PSI
TIME IN DAYS
0
50
100
150
200
250
300
350
400
450
500
40
30
20
10
0
-10

Such localized restricted vertical permeability - even within a 1000' vertical section of the reservoir - appears to be characteristic of the Redondo Creek Reservoir. The structural layering of the Redondo Creek Reservoir within the Bandelier Tuff supports the concept of reservoir fluid segregation into a steam-dominated zone and an underlying liquid-dominated zone with limited inter-zone vertical communication. The steam-dominated zone has been identified in Baca Nos. 4, 11, 15 and 21. Pressure communication through this zone has not been observed so its areal continuity is unknown. However, several Redondo Creek wells have been drilled through where the steam zone should exist and have not intersected it. This suggests that the steam-dominated zone is either one continuous zone containing impermeable holes or a combination of several smaller steam zones. These steam zones have a large impact on the commercial status of a well.

Table 5.6-1 displays 18 Redondo Creek wells and the various parameters needed for a commercial well. The two most basic parameters needed are adequate temperature and a successful completion. Three Redondo Creek wells - Baca Nos. 5A, 12, and 14 - are completed in essentially a lower temperature reservoir which would not produce commercial quantities of geothermal fluid. Eight other wells currently contain unbeneficial completions which include casing problems, plugging and abandonments, limited completions and cased-off intervals. Included in this group are Baca No. 6 which has commercial characteristics but wellbore complications and Baca No. 11 which was commercial until casing problems required it to be plugged and abandoned.

Eight wells have successful completions in the high temperature reservoir. For such a well to be commercial it must intersect a permeable portion of the Bandelier Tuff/Andesite contact zone and it must either 1) intersect an upper steam dominated zone or 2) the permeability of the contact zone needs to be abnormally high. Only one of the eight wells fails to intersect a permeable portion of the contact zone: Baca No. 18.

Baca Nos. 4, 15, and 21 intersect the upper steam zone (as did Baca No. 11). All of the wells except Baca No. 21 - which was not drilled deep enough to intersect the contact zone - are commercial wells. Baca No. 15 has permeability-thickness value similar to some subcommercial wells which intersected a permeable contact zone but not the steam zone (Baca Nos. 16 and 19). During production, the steam zone works as a natural gas lift by mingling with the mass flow from the lower zone(s). While production from the steam zone alone would not generally be commercially sufficient, and production from only a normal permeability contact zone would not result in commercial wellhead pressures, the combination of the two zones creates a commercial well.

Table 5.6-1

WELL CHARACTERISTICS NEEDED FOR COMMERCIAL PRODUCTION

WELL NAME	COMMERCIAL STATUS	POSITIVE POINTS	SUFFICIENT RESERVOIR TEMPERATURE	ACCEPTABLE COMPLETION	INTERSECTION OF PERMEABLE CONTACT ZONE	INTERSECTION OF STEAM ZONE	HIGH PERMEABILITY CONTACT ZONE
Baca No. 4	Commercial	5	Yes	Yes	Yes	Yes	Yes
Baca No. 13	Commercial	4	Yes	Yes	Yes	No	Yes
Baca No. 15	Commercial	4	Yes	Yes	Yes	Yes	No
Baca No. 24	Commercial	4	Yes	Yes	Yes	No	Yes
Baca No. 21	Noncommercial	3	Yes	Yes	No	Yes	No
Baca No. 6	Noncommercial	3	Yes	No	Yes	No	Yes
Baca No. 19	Noncommercial	3	Yes	Yes	Yes	No	No
Baca No. 16	Noncommercial	3	Yes	Yes	Yes	No	No
Baca No. 11	Noncommercial	3	Yes	No	Yes	Yes	No
Baca No. 5A	Noncommercial	2	No	Yes	Yes	No	No
Baca No. 18	Noncommercial	2	Yes	Yes	No	No	No
Baca No. 20	Noncommercial	1	Yes	No	No	No	No
Baca No. 23	Noncommercial	1	Yes	No	No	No	No
Baca No. 14	Noncommercial	2	No	Yes	No	No	No
Baca No. 12	Noncommercial	1	No	No	Yes	No	No
Baca No. 10	Noncommercial	1	Yes	No	No	No	No
Baca No. 22	Noncommercial	1	Yes	No	No	No	No
Baca No. 17	Noncommercial	1	Yes	No	No	No	No

Underlined No indicates the major well characteristic hindering commercial production.

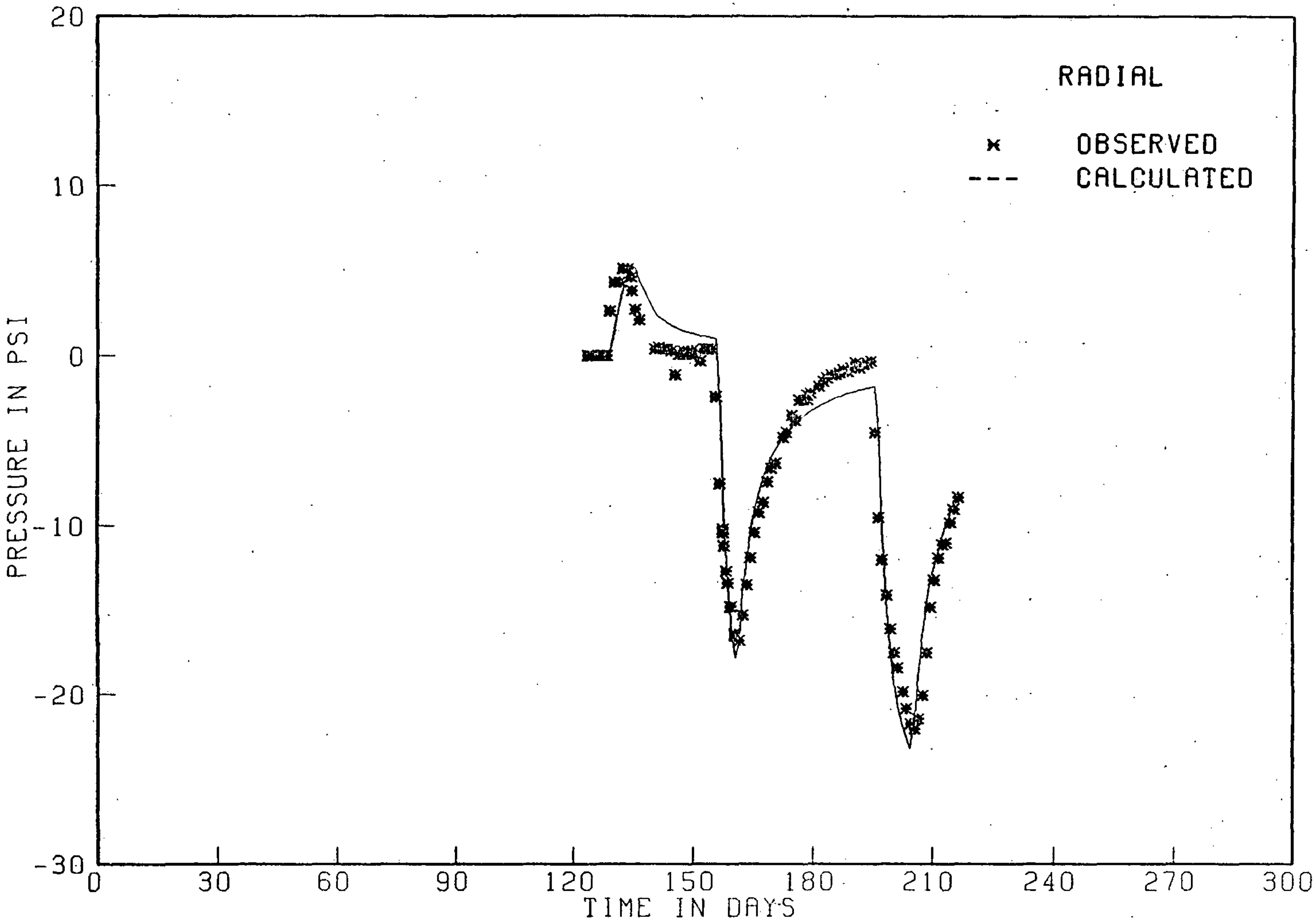
Two commercial Redondo Creek wells - Baca Nos. 13 and 24 - are dependent upon a highly permeable contact zone and produce commercial quantities despite a lack of a steam zone. Baca No. 4 intersects a moderately high permeable zone in addition to a steam zone which ensures its commercial status despite a seven-inch protective liner (restricting flow). Baca No.6 also intersects a high permeability contact zone but has completion complications. These four wells have the four highest permeability-thickness values calculated in the Redondo Creek field: each exceeding 5000 md-ft and three of the four exceeding 6000 md-ft. The frequency of intersecting such a highly permeable contact zone appears to be about the same as of intersecting the upper steam dominated zone.

In summary the four commercial Redondo Creek wells all produce from the contact zone of the Andesite and Bandelier Tuff. Baca Nos. 4 and 15 intersect a steam zone which aids in production by reducing the density of the fluid column in the flowing wellbore. Baca Nos. 13 and 24 intersect a highly permeable section of the contact zone and flow commercially despite a lack of natural gas lift. Baca Nos. 16, 18, 19, and 21 are all successfully completed in the main Redondo Creek Reservoir, but will not flow commercially due to lack of an intersected steam cap or lack of sufficient contact zone permeability.

Comparison of permeability-thickness values obtained from pressure buildup and falloff tests with values obtained from the interference tests shows that the interference values are significantly higher (Tables 5.3.1-1, 5.3.2-1 and 5.5-2). The interference values were based upon 100% of the fluid entering or originating in a zone communicating with observation well. With the identified vertical permeability restrictions it is suspected that these interference values are optimistic. Figure 5.6-4 displays the 1982 Interference Test data for Baca No. 19 assuming that 50% of the Baca No. 15 production data and 30% of the injected fluid affected the Baca Nos. 15 and 19 reservoir cell. The resultant kh and øh values of 6600 md-ft and 530 feet are felt to be more representative of the Baca Nos. 15 and 19 reservoir. The dependency of this method of analysis on assumed flow percentages makes its quantitative results no better than the initial assumptions.

The permeability-thickness values obtained from the pressure buildup and falloff tests range from 1000 to 10,000 md-ft. Their average value of 4000 md-ft is felt to be representative of the average permeability thickness of the Redondo Creek field.

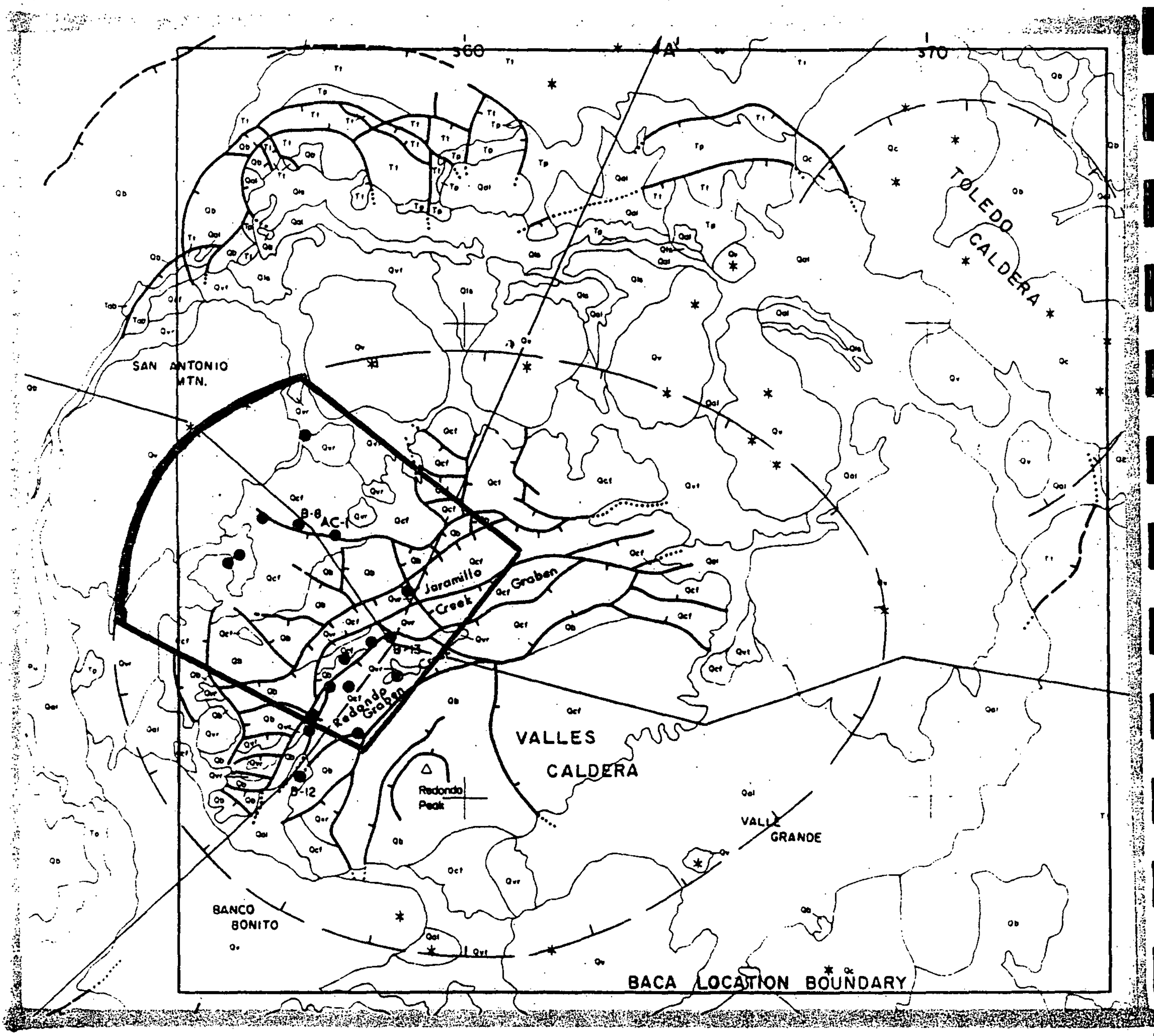
FIGURE 5.6-3
OBSERVATION PRESSURES FOR BACA 19 INTERFERENCE TEST 1982
50% FLOW RATES, 30% INJECTION RATES
KH = 6,635.4 PHIH = 530.9 E = 1.610



The porosity-thickness values obtained from the interference tests will generally be optimistic and unreliable due to the vertical permeability restrictions. The coring data available indicates that the majority of the Bandelier Tuff has a porosity of 5% while the contact zone approaches 15%. This suggests that the reservoir storage factor (ϕh) ranges from 100 to 200 feet, with an effective contact zone storage of about 90 feet; interestingly the value calculated from the 1975-1976 Interference Test analysis.

Since the reservoir limits have not been identified during the Redondo Creek testing the reservoir is best defined by the geologic and geophysical data. This approach has been used by Bodvarsson et. al. (1980) who suggests that the reservoir has an areal extent of 4.3×10^8 ft^2 (40 km^2). Figure 5.6-5 shows the approximate boundaries proposed by Bodvarsson which result in a conservative calculated reservoir storage of 2.1×10^{12} lb of approximately 500°F fluid. These values seem to be reasonable and are close to the values of 4.7×10^{12} lb of in-place fluid presented in the Technical and Management Proposal to the DOE (Union, 1978). Thus while substantial fluid and energy exist in the Redondo Creek reservoir, the frequency of drilling a well which intersects the reservoir zones controlling commercial production is low.

FIGURE 5.6-4
Estimated Boundary of the Hot Reservoir
(From Bodvarsson, 1980)



5.7 Conclusions

1. The primary Redondo Creek reservoir is located within the contact zone consisting of the bottom of the Bandelier Tuff and the top of the Andesite. This relatively high permeability, high porosity zone controls the reservoir pressure of the field and dominates all commercial wells.

2. The four commercial wells have an initial steam flow of 268,000 lb/hr and a one year projected flow rate of between 174,000 lb/hr and 204,000 lb/hr.

3. The commercial wells have a wellbore temperature of at least 500°F at a 5500' MSL datum while the subcommercial wells are below 480°F.

4. Interference testing has identified three reservoir cells which communicate through relatively thin sections of the reservoir. Interference testing response has been observed within the Baca Nos. 10, 14 and 23; the Baca Nos. 6, 18 and 24; and the Baca Nos. 15 and 19 cells.

5. The storage factor (øh) of the contact zone averages 90 feet. The entire reservoir storage factor approaches 200 feet.

6. The average permeability thickness (kh) of the reservoir is 4000 md-ft, with individual wells ranging between 1000 md-ft and 10,000 md-ft.

7. The Redondo Creek Reservoir contains localized vertical permeability restrictions. The magnitude of the fields gross vertical permeability is not known.

8. While substantial fluid and energy exist in the Redondo Creek reservoir, the frequency of drilling a well which intersects the reservoir zones controlling commercial production is low.

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SECTION 6: ENVIRONMENTAL

An extensive environmental monitoring program was established for the Baca Geothermal Demonstration Project by mutual agreement of the three partners: Union, PNM and DOE.

It was agreed that PNM and Union share the responsibility of monitoring the following:

Air Quality of Region Surrounding Redondo Canyon

Water Quality of Jemez River Watershed

Aquatic Ecology of Redondo Creek

Endangered Species in Redondo Canyon

Selected Flora and Fauna of Redondo Canyon

A PNM representative was appointed Administrator/Coordinator of the entire monitoring program. Specific programs were administered by Union and PNM personnel respectively.

6.1 Air Quality

The air monitoring program for the Baca GDPP Project was administered entirely by PNM's Air Quality Division .

The network design was intended to provide meteorologic data to be used in analysis and dispersion modeling of the complex regional terrain and also to provide H_2S concentration data near public access (boundaries of the ranch). The program was operated by Western Scientific Services Inc. (WSSI), a subsidiary of Environmental Research & Technology Inc.

Four units comprised the air monitoring network: Stationary Units 1 and 2 and Mobile Units 3 and 4.

Station 1 is located about 100 yards northeast of the PNM generator plant site, and consists of:

A 200-foot meteorological tower which carried the following:

- Wind speed recorders at 10, 30 and 60 meter elevations
- Temperature recorders at 10, 30 and 60 meter elevations
- Recorders of temperature difference between 10 and 60 meter elevations
- Dew point recorders at 10, 30 and 60 meter elevations
- Solar radiation recorder at 10 meter elevation
- Precipitation recorder at ground level

A station at the base of the tower contained:

- One Meloy H_2S analyzer (285 E)
- Two flow-controlled TSP hi-volume samplers

Support equipment for the station included:

- Heated/air-conditioned shelter
- Air sampling manifold
- Monitor Labs Data Logger (9300)
- Kennedy Model 9800 9-track recorder
- Telemetry, receiver and antenna
- Sola voltage regulator

Station 2 was located at the edge of the old gravel pit site in Redondo Canyon approximately one mile south of the generator plant site. The site consisted of an acoustic sounder furnished by PNM, which included:

Aerovironment Mono-Static Acoustic Sounder with:

- Antenna assembly: fiberglass parabolic reflector, transducer and acoustic enclosure
- Preamplifier
- Transmit/receive and signal-conditioning control unit
- Interconnecting power lines and cables

The sounder was located in a heated/air conditioned shelter.

Mobile Units 3 and 4 are movable heated/air conditioned monitoring stations carrying:

1. Meteorological Equipment

   a. One 30-foot meteorological tower
   b. One wind-direction sensor at 30 feet elevation
   c. One wind-speed sensor at 30 feet elevation

2. Air Chemistry Equipment

   a. One Meloy H_2S analyzer (285 E) 5
   b. One flow-controlled TSP hi-volume sampler
   c. Air sampling manifold
   d. Instrument rack
   e. Telemetry scanner and transmitter
   f. Three single-channel strip chart recorders
   g. Sola voltage regulator

One of the stations is equipped with a propane-operated 15 kW generator (for sites where power was unavailable).

The mobile units were stationed for a period of two to six months at public sites located in the region around Redondo Canyon. Sites were selected to reflect points where unusual meteorologic conditions might result if cooling tower plumes came near to ground level, or where ambient H_2S levels were likely to be elevated above other areas in the region.

A map (Figure 6.1-1) indicates sites where mobile stations were located during the course of the study. Units were located at sites as follows:

Sulphur Springs	Nov. 1, 1979-Jan. 9, 1980
Sulphur Gate	Nov 20, 1979-Jan. 7, 1980
Humming Bird Camp	Jan. 9, 1980-May 7, 1980
Soda Dam	Jan. 14, 1980-June 13, 1980
Old Union Hdqtrs.	May 12, 1980-Oct. 29, 1980
Banco Bonito (Cajete)	June 17, 1980-Oct. 21, 1980
Sulphur Springs	Oct. 29, 1980-May 21, 1980
Sulphur Gate	Oct. 23, 1980-May 21, 1980
Central Sta.	Mar. 1, 1980-May 21, 1980

Data processing and monthly reports were executed according to the WSSI proposal dated August 31, 1978. Data were digitized into 15 minute average values and hourly average values. Summaries of data and wind rose information from each site are available in PNM's Summary Report, Baca Geothermal Air Monitoring Program.

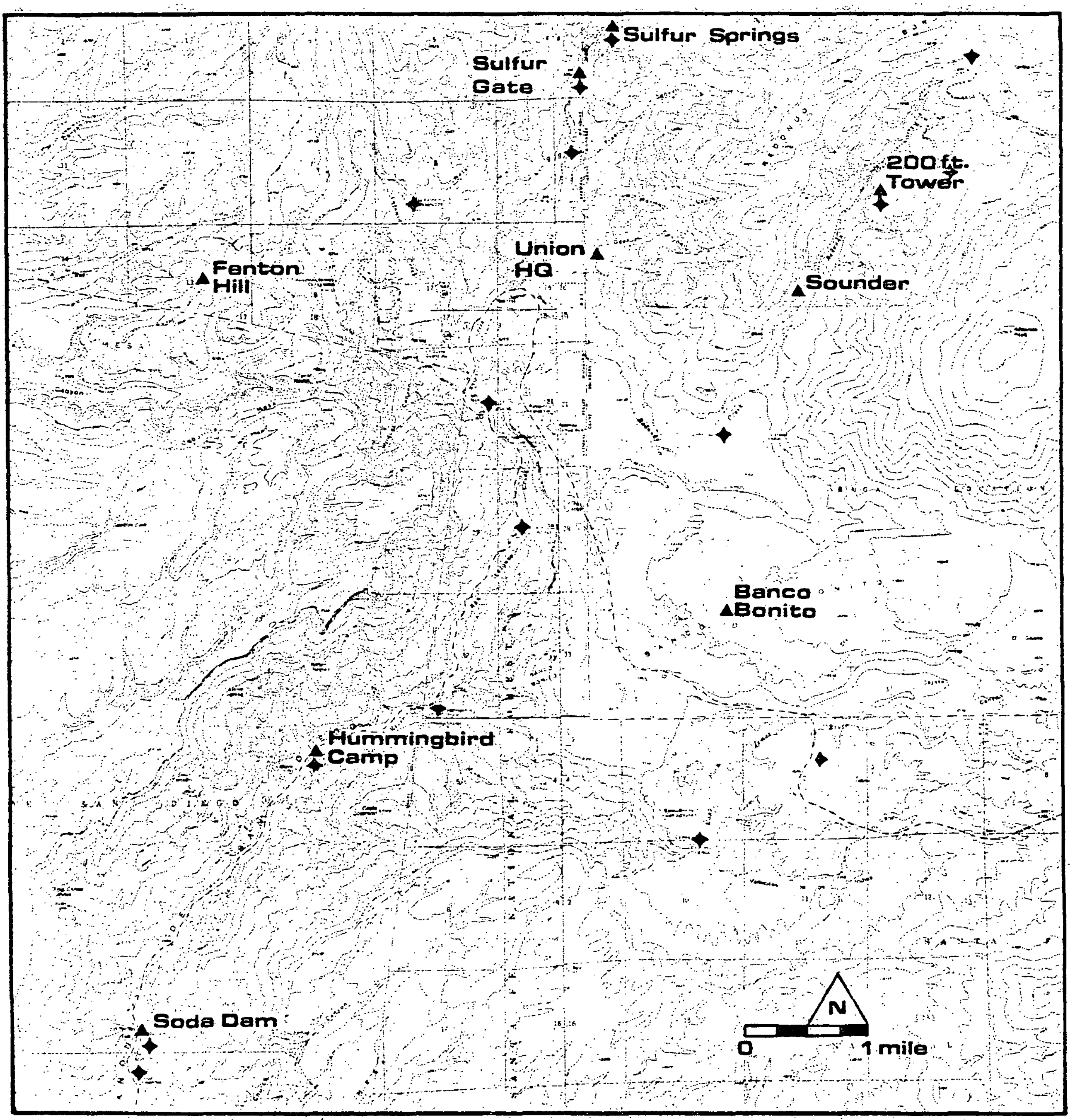


FIGURE 6.1-1

MOBILE AIR/METEOROLOGIC MONITORING SITES

▲ Mobile Station Sites

✦ H_2S Tab Sites

FROM PNM, 1981

TABLE 6.1-1

TYPICAL DATA SHEET AIR/METEOROLOGICAL MONITORING PROGRAM

PNM TOWER DATA--BACA GEOTHERMAL STATION...MARCH 1981

HOURLY SUMMARY

DAY : 2

	WIND DIRECTIONS			WIND SPEED			TEMPERATURES				HYDROMET.				RADIATION
HOUR	60M DIR. DEG.	30M DIR. DEG.	10M DIR. DEG.	60M SPD MPS	30M SPD MPS	10M SPD MPS	60M TEMP. C	30M TEMP. C	10M TEMP. C	50M LAPSE RATE C	60M DEW POINT C	30M DEW POINT C	10M DEW POINT C	PPT INCHES	TOTAL CALS /CM2 /MIN
1	46.	48.	60.	2.1	1.5	.7	-2.6	-3.4	-4.2	1.5	-7.5	-6.9	-7.3	0.00	0.00
2	44.	61.	61.	1.5	1.3	.7	-2.4	-3.5	-4.5	1.8	-7.4	-6.5	-7.2	0.00	0.00
3	44.	73.	59.	.7	.9	.6	-1.5	-2.2	-3.4	1.7	-6.7	-5.8	-6.0	0.00	0.00
4	41.	64.	60.	1.2	1.1	.6	-1.6	-2.3	-3.0	1.4	-6.0	-5.2	-5.6	0.00	0.00
5	241.	3.	53.	.4	.4	.6	-1.4	-1.7	-2.5	1.0	-5.2	-4.6	-5.0	0.00	0.00
6	224.	233.	222.	2.3	1.4	.5	-1.2	-1.2	-1.3	.1	-4.9	-4.2	-4.4	0.00	0.00
7	222.	233.	252.	2.4	1.3	.3	-.8	-.8	-.9	.1	-4.7	-4.0	-4.2	0.00	0.00
8	213.	218.	235.	3.2	2.5	2.1	-.4	-.2	-.0	-.3	-4.7	-3.8	-3.8	0.00	.02
9	220.	223.	237.	3.2	2.4	2.2	-.0	.2	.4	-.4	-5.0	-4.2	-4.0	0.00	.09
10	235.	232.	255.	4.1	3.5	3.7	.5	.8	1.1	-.5	-5.2	-4.5	-4.0	0.00	.36
11	195.	215.	234.	3.2	2.1	2.3	1.1	1.4	1.8	-.6	-4.9	-4.1	-3.7	0.00	.51
12	207.	221.	238.	4.6	3.7	2.8	1.0	1.2	1.6	-.6	-4.5	-3.7	-3.4	0.00	.28
13	205.	211.	252.	3.8	3.6	2.4	1.2	1.5	1.8	-.5	-4.9	-4.1	-3.8	0.00	.15
14	215.	234.	241.	5.3	4.6	3.5	1.9	2.2	2.6	-.6	-4.9	-4.2	-3.7	0.00	.31
15	207.	216.	231.	4.4	3.4	3.6	2.1	2.4	2.7	-.5	-4.4	-3.7	-3.5	0.00	.10
16	225.	233.	227.	3.5	3.5	2.7	.4	.5	.7	-.3	-2.3	-1.4	-1.6	.01	.05
17	221.	232.	233.	4.3	3.9	2.2	.2	.3	.5	-.3	-2.1	-1.1	-1.5	.00	.01
18	219.	228.	242.	5.2	4.0	3.3	-.3	-.2	0.0	-.3	-1.7	-.8	-1.1	.02	0.00
19	224.	231.	241.	6.2	4.3	3.7	-.7	-.6	-.4	-.3	-1.6	-.8	-1.2	.03	0.00
20	224.	226.	242.	5.4	3.6	3.2	-.5	-.4	-.2	-.3	-1.5	-.7	-1.2	.01	0.00
21	215.	215.	233.	4.9	3.3	3.2	-.7	-.6	-.4	-.3	-1.7	-.9	-1.3	.04	0.00
22	217.	230.	235.	6.5	5.0	3.8	-.5	-.4	-.2	-.3	-1.3	-.5	-.9	.02	0.00
23	224.	228.	235.	5.0	4.0	2.7	-.6	-.4	-.3	-.3	-1.5	-.6	-1.0	.02	0.00
24	217.	222.	238.	4.2	3.4	2.3	-.8	-.7	-.5	-.3	-1.6	-.8	-1.0	.02	0.00
AVERAGE	215.	225.	238.	3.2	2.4	2.0	-.3	-.3	-.4	.0	-4.0	-3.2	-3.4	.01	.08
MAXIMUM				6.6	5.0	3.8	2.1	2.4	2.7	1.8	-1.3	-.5	-.9	.04	.51
MINIMUM				.4	.4	.3	-2.6	-3.5	-4.5	-.6	-7.5	-6.9	-7.3	0.00	0.00

Table 6.1-1 is a typical data sheet from one of the monthly reports. The monthly reports are computer printouts of digitized data from the MET tower in Redondo Canyon (Station 1) and the two mobile stations.

Reports dated from November 1979 through May 21,1981 are available in PNM's Albuquerque offices, DOE's San Francisco Area Office, and Union's Rio Rancho and Los Angeles Offices.

The data from the acoustic sounder is in the form of "sonographs" on charts approximately 10" x 30". No attempt has been made to digitize the sounder data. The charts are available for view in the PNM's Air Quality Division Offices in Albuquerque.

WSSI conducted two upper atmosphere studies for Participant in 1981. Upper atmosphere data were collected using minisondes released for two weeks in July and two weeks in October. The minisondes and temperature sensors were released on helium filled balloons from the power plant site and from a meadow at the bottom of Redondo Canyon. Data were digitized and graphed, and are available with other air quality data.

During 1980 H_2S tabs were exposed at 15 sites per month. The tabs represent ambient H_2S concentration as a factor of exposure time and color intensity. The tab exposure locations are shown in Figure 6.1-1.

On May 21, 1981, the air monitoring program was suspended by PNM. The two mobile stations were stored at the base of the 200' MET tower (Station 1). The sounder is stored at its operating site. PNM will remove it from the project in summer of 1982.

The complex air monitoring survey resulted in pinpointing the most probable air pollution effects. Drainage winds predominate at night at nearly every site monitored. The effect on a cooling tower plume in Redondo Canyon would probably hold it in the 100-105' drainage layer down-canyon, and pollutants emitted during the night would build up in the Cajete (Banco Bonito) so that high concentrations might result near Redondo Campground.

Less commonly, neutral air flow conditions that sometimes occur in the Canyon could result in high concentrations of pollutants occuring on high terrain to northeast and southwest of the Canyon including Battleship Rock and Banco Bonito.

6.2 Water Quality

The surface water quality program was administered entirely by Union's Rio Rancho Office.

This program was designed to continuously monitor water quality parameters in Redondo Creek, and to characterize water quality in the Jemez River watershed above and below Redondo Creek's confluence with it.

The Redondo Creek water quality monitoring station is located about 1.5 miles downstream from the wellfield. The station consists of a 23.94 cfs maximum capacity steel Parshall measuring flume set into the creek bed. A shelter covers the flume and its attached stilling well to protect monitoring equipment from temperature extremes and weather. A butane gas heater and a backup electric heater prevent recorders from freezing. Flow rate, pH and water temperature are recorded continuously at the station from the stilling well. Once each week the instruments are checked and charts are collected and transported to Union's Rio Rancho Office.

Flow is recorded on a Stevens Type A meter with a 6 month hand wind clock, 18" float, 4" per day time scale and a 1:2 English gauge scale.

Temperature and pH are recorded by an Analytical Instruments Model 30 AC pH/temperature recording meter with pH range of 2-12 and temperature range of 0-50°C. The instrument carries an automatic temperature compensation gear train set for 1/4" per hour and is run by electric hook-up. A Barton temperature meter with a 7 day hand wind clock and a temperature range of 0-100°F serves as a backup for the Analytical instrument. There is no backup pH recording unit.

Flow, pH and temperature data were digitized into hourly averages for report format. Charts are archived in the Rio Rancho Office.

Table 6.2-1, a one week tabulation for Octoer 1980, shows typical flow, pH and water temperature data for Redondo Creek for the two years.

Samples of water from Redondo Creek are collected automatically by two ISCO Model 2100 Samplers. Samples are collected by a peristaltic pump with a self purging mode between sample collections and a precollection wash mode. One ISCO is set to collect samples during increased flow only and to shut off after flow has decreased. It is capable of collecting up to 28

TABLE 6.2-1

TYPICAL DATA, REDONDO CREEK

FLOW (cfs)/pH/TEMPERATURE ($T^{o}C$)

OCTOBER 1980

DAY	1			2			3			4			5			6			7		
TIME	Flow	pH	T	Flow	pH	T	Flow	pH	T	Flow	pH	T	Flow	pH	T	Flow	pH	T	Flow	pH	T
0000	2.1	ND	ND	2.2	7.0	10.5	2.2	7.0	10.5	2.2	7.0	10.0	2.2	7.0	10.0	2.4	7.0	10.0	2.4	7.0	10.0
0100																					
0200																					
0300						10.0			10.0												
0400																					
0500															9.5						
0600	2.3											9.5									
0700					6.8								2.4								
0800				2.3																	
0900									9.5									9.5			
1000					7.0																
1100						9.5															9.5
1200												9.0									
1230					7.1																
1300									9.0						9.0						
1400												8.5						9.0			
1500															8.5						9.0
1530																					
1600	2.2	START																			
1700		7.0	9.0	2.2																	8.5
1800			9.5												9.0						
1900			10.0		7.0																9.0
2000						10.0						9.0									
2100			10.5						9.5												
2200												9.5			9.5			9.5			
2300									10.0			10.0			10.0						
MEAN	2.2	7.0	10.0	2.2	7.0	10.0	2.2	7.0	9.5	2.2	7.0	9.5	2.3	7.0	9.5	2.4	7.0	9.5	2.4	7.0	9.5
HI	2.3	--	10.5	2.3	7.1	10.5	--	--	10.5	--	--	10.0	2.4	--	10.0	--	--	10.0	--	--	10.0
LO	2.1	--	9.0	2.2	6.8	9.5	--	--	9.0	--	--	8.5	2.2	--	8.5	--	--	9.0	--	--	8.5
RANGE	0.2	--	1.5	0.1	0.3	1.0	--	--	1.5	--	--	1.5	0.2	--	1.5	--	--	1.0	--	--	1.5

sequential samples of predetermined volume at predetermined frequency. The second ISCO sampler, installed July 31, 1981, is set to collect one 100 ml sample every eight (8) hours.

Table 6.1.2-2 shows typical ISCO data from the second sampler. ISCO samples were tested for only parameters that might indicate a geothermal contribution to flow.

Monthly grab samples were collected from the creek at the station and analyzed for specific water quality parameters.

The Jemez River watershed monitoring program was designed to make monthly checks on water from seven sites located either upstream or downstream from Redondo Creek and the Baca Project. Locations of the seven sites (including Redondo Creek) are designated by number on the map in Figure 6.2-1.

Tables 6.2-3 and 6.2-5 show values for water quality parameters at three of the watershed sites.

At each sample site, water temperature and pH are measured using a Beckman Chem-Mate pH Meter with a futura combination field electrode. Temperature is checked with a hand held thermometer. Conductivity is measured using a YSI field conductivity meter. Flow rate is calculated by measuring the time it takes a plastic cup filled with water to pass through a measured volume of stream. A sample of water is collected for transmittal to Core Laboratories or EDA Laboratories of Albuquerque. Raw water is collected in approximately one (1) liter plastic bottles, held at 4°C, and taken to a laboratory for analysis within six hours. All seven sites were visited in one day.

Field data plus pertinent weather and activity information were logged at each site.

In December, 1981 the watershed sampling program was suspended. The continuous monitoring at Redondo Creek Station continues. Data continue to be digitized.

Data have been collected into two reports for water year 1979-1980 and for water year 1980-1981. Both reports are available from Union's Rio Rancho Office, Union Oil Company of California's office in Los Angeles, DOE's Area Office in San Francisco, California and PNM's Albuquerque Office, Water Quality Division.

TABLE 6.2-2

TYPICAL "8 HOUR" ISCO SAMPLES

Sample Identification	TDS (Mg/L)	TSS (Mg/L)	pH	E.C. µmhos cm	SO4 (Mg/L)	Cl (Mg/L)	B (Mg/L)	Br (Mg/L)	As (Mg/L)	Hg (Mg/L)	Si (Mg/L)
ISCO #13 8/26/81	180	86	7.59	151	6	22.0	0.17	<0.1	0.01	<0.001	11.0
ISCO #14 8/26/81	150	64	7.55	151	2	20.0	0.15	<0.1	<0.01	<0.001	12.0
ISCO #15 8/26/81	160	116	7.57	159	7	23.0	0.16	<0.1	0.01	<0.001	10.0
ISCO #16 8/27/81	120	87	7.53	158	2	21.0	0.18	<0.1	0.01	<0.001	10.0
ISCO #17 8/27/81	170	49	7.48	152	<1	21.0	0.17	<0.1	<0.01	<0.001	11.0
ISCO #18 8/27/81	280	2290	7.07	290	3	61.0	0.22	0.1	0.01	<0.001	8.1
ISCO #19 8/28/81	180	323	7.42	172	4	28.0	0.13	<0.1	<0.01	<0.001	11.0
ISCO #20 8/28/81	180	120	7.61	169	7	25.0	0.41	<0.1	<0.01	<0.001	10.0
ISCO #21 8/28/81	160	86	7.55	169	3	22.0	0.25	<0.1	<0.01	<0.001	11.0
ISCO #22 8/29/81	220	2290	7.20	232	12	41.0	0.31	<0.1	0.01	<0.001	8.1
ISCO #23 8/29/81	190	516	7.44	183	2	35.0	0.15	0.2	<0.01	0.012	8.7

FIGURE 6.2-1

BACA SURFACE WATER MONITORING PROGRAM

SAMPLING SITES

JEMEZ WATER SHED

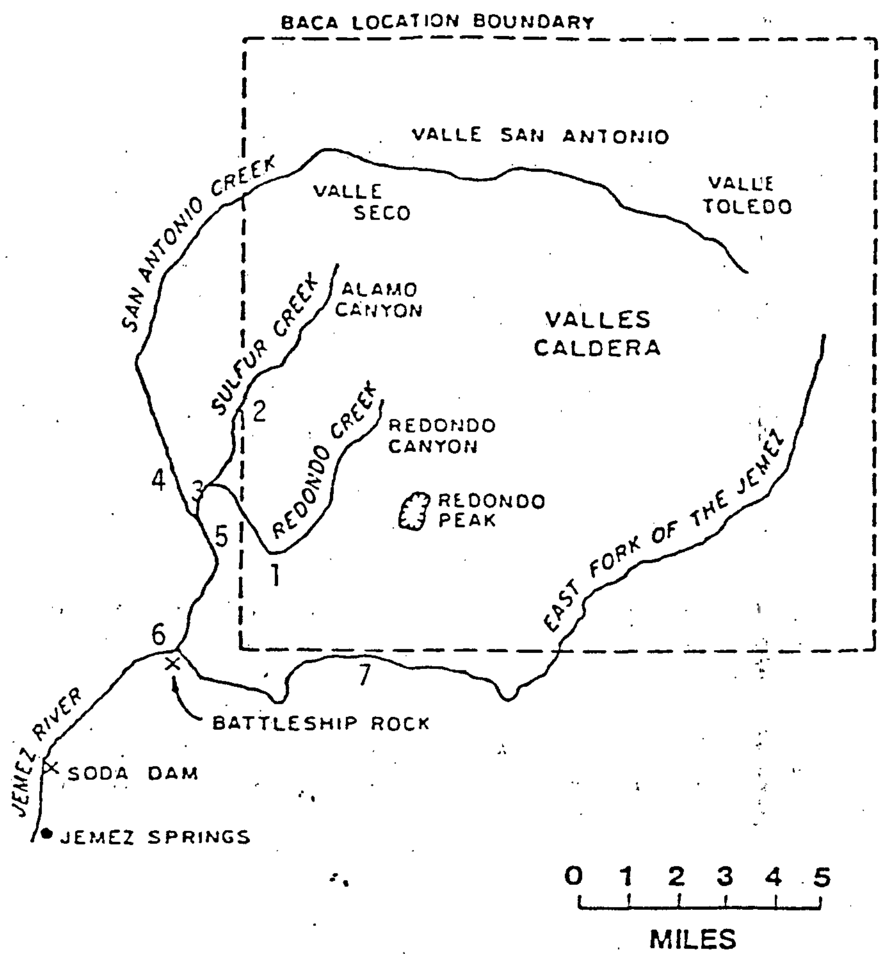


TABLE 6.2-3

WATER YEAR 1980-1981

REDONDO CREEK WATER QUALITY

DATE	AUGUST 1980	SEPT 1980	OCT 1980	OCT 30, 1980 ISCO	NOV 1980	JAN 1981	JAN 1981	FEB 1981	MAR 1981	APR 1981	MAY 1981	JUNE 1981	JULY 1981	AUG 1981
Flow cfs	2.3		0.6		2	1.7	1.5	0.9	2.2	3.0	5.1	2.0	2.9	1.1
TSS mg/1	23	15	8.3	30	15	5.8	13	18	120	53	46	38	140	44
TDS mg/1	228	228	250	230	250	190	190	230	270	203	130	114	170	168
μmhos	245	150	210	370	50	165	175	225	276	190	118	110	199	140
T°C	13		1	3	1	1.5	0	0	2.5	2	11	12	14	14
pH	7.4	7.4	6.9	6.8	6.7	7.4	7.3	7.0	6.9	7.5	7.0	7.2		7.6
SO_4 mg/1	4.0	<0.1	11.0	<1.0	11.0	<1.0	<1.0	6.0	16.0	12.0	6.0	3.0	22.0	10.0
Si mg/1	13.0	15.0	14.0	17.0	15.0	15.0	14.0	14.0	14.0	14.0	14.0	15.0	13.0	22.5
Cl mg/1	76.4	76.4	96.0	95.0	110.0	62.0	70.0	94.0	120.0	68.0	23.0	16.0	40.0	25.2
HCO_3 mg/1	37.3	37.3	42.0		35.0	32.0	33.0	21.0	31.0	27.0	29.0	64.0	38.4	30.2
F mg/1	0.1	0.05	0.19		0.17	0.12	0.13	0.20	0.60	0.20	0.15	0.05	0.25	0.15
B mg/1	0.5	0.16	0.64	0.67	0.67	0.39	0.50	0.50	0.63	0.40	0.18	0.13	0.28	
Ba mg/1	<0.01	<0.01	0.17		0.08	<0.05	<0.06	<0.04	<0.05	<0.05	0.03	0.06	0.10	
As mg/1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.005
Hg mg/1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fe mg/1	.07	0.17	0.39		0.08	0.05	0.01	0.09	0.11	0.11	0.04	0.04	0.01	0.16
PO_4 mg/1	.07	0.6	0.05		0.08	0.03	0.02	0.02	0.03	0.03	0.06	0.10	0.08	0.18
NO_3 mg/1	.03	<0.01	0.01		0.10	0.09	0.18	0.20	0.30	0.15	0.33	0.33	0.16	<0.01
Na mg/1	31.0	31.0	33.0		35.0	21.0	31.0	34.0	39.0	26.0	13.0	11.0	25.0	15.6
K mg/1	4.6	1.9	4.6		5.5	3.4	3.9	5.5	4.8	5.0	2.4	2.0	7.3	2.6
Ca mg/1	18.0	20.6	36.0		27.0	19.0	19.0	28.0	34.0	18.0	12.0	14.0	16.0	26.0
Mg mg/1	2.0	1.2	2.6		2.8	2.2	2.2	2.7	3.7	4.2	1.1	1.1	5.0	2.3
BOD_5 mg/1	2.4	2.5	<0.25		<0.25	1.05	1.05	0.45	0.60	<0.25	0.25	<0.25	4.2	

TABLE 6.2-4

WATER YEAR 1980-1981

WATER QUALITY JEMEZ WATERSHED

San Antonio Above La Cueva

MONTH	Aug	Sept	Oct	Nov	Jan	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
YEAR	1980				1981	1981							1981
Flow cfs	11.3		15.8	19.3	19.6	11.6	15.0	15.1	16.7	9.7	16.6	14.0	
TSS mg/l	2.0	62.0	1.0	7.0	1.6	12.0	3.0	5.0	9.5	7.3	15.0	21.0	16.0
TDS mg/l	164	171	140	130	130	170	110	130	130	140	153	130	204
mhos	155	190	91	95	89	82	78	84	118	130	155	120	147*
T°C	12		7.5	2.0	4.0	0	2.5	1	5	14	17	17	
pH	7.6	6.2*	7.5	7.3	7.2	7.3	7.5	7.2	7.2	7.7	6.3	7.8	7.9*
SO_4 mg/l	5.0	< 0.1	12.0	12.0	< 1	1	6	2	7.0	7.0	8.0	7.0	14.8
Cl mg/l	3.0	4.0	3.0	3.0	0.9	5.0	1.0	4.0	1.0	1.0	0.9	119.0	9.6
HCO_3 mg/l	89.6	120.1	90.0	61.0	68.0	100.0	59.0	95.0	64.0	70.0	90.0	69.2	62.0
PO_4 mg/l	0.05	0.07	0.03	0.06	0.01	0.05	0.01	0.02	0.03	0.03	0.07	0.06	0.27
F mg/l	1.10	0.95	1.70	2.00	1.70	1.20	2.10	1.80	1.30	0.88	0.55	2.00	1.2
B mg/l	0.02	0.17	0.02	0.02	0.02	0.10	< 0.10	0.03	0.03	0.13	0.05	1.30	
NO_3 mg/l	0.06	< 0.01	0.01	0.01	0.01	0.03	0.10	0.10	0.08	0.08	0.06	0.38	< 0.01
Ba mg/l	< 0.01	0.13	0.06	< 0.04	< 0.05	< 0.06	< 0.04	< 0.05	< 0.05	0.03	0.09	0.03	
Na mg/l	15.0	17.0	11.0	13.0	11.0	31.0	11.0	16.0	10.0	12.0	21.0	28.0	50.84
K mg/l	2.9	2.2	1.8	2.9	2.1	2.9	1.4	2.0	3.5	1.8	2.8	3.5	3.13
Ca mg/l	16.0	22.2	15.0	14.0	11.0	11.0	10.0	12.0	11.0	13.0	16.0	12.0	14.6
Mg mg/l	1.9	1.8	1.4	1.5	1.2	1.8	1.0	1.2	2.9	1.5	1.6	1.8	2.04
Fe mg/l	0.33	0.26	0.38	0.21	0.16	0.06	0.23	0.12	0.20	0.05	0.12	0.08	0.22
As mg/l	< 0.01	0.06	0.01	0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.005
Hg mg/l	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.0013
Si mg/l	29.0	32.0	30.0	29.0	26.0	31.0	26.0	28.0	24.0	29.0	36.0	25.0	51.0
BOD_5 mg/l	0.9	0.75	1.20	< 0.25	0.30	0.45	< 0.25	< 0.25	< 0.25	2.10	< 0.25	2.40	

*Laboratory values at 25°C

TABLE 6.2-5

WATER YEAR 1980-1981

WATER QUALITY JEMEZ WATERSHED

San Antonio Below La Cueva

MONTH	Aug	Sept	Oct	Nov	Jan	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
YEAR	1980				1981	1981							1981
Flow cfs	16.7		22.0	17.8	19.3	15.6	9.6	16.5	27.4	15.8	12.3	20.1	
TSS mg/l	3.0	2.4	5.3	49.0	2.8	3.6	6.0	5.0	12.5	7.3	13.0	91	6.0
TDS mg/l	170	149	150	140	140	150	120	140	155	160	153	84	
mhos	148	160	110	100	160	80	98	90	133	82	170	125	200*
T°C	13		8	2	5.5	0	3.5	0	5	11	20	15.5	
pH	7.8	6.5*	6.8	7.3	7.6	7.4	7.5	6.8	6.9	7.8	7.0	7.7	8.1*
SO_4 mg/l	7.0	< 0.1	12.0	12.0	< 1	< 1	17	17	22.0	12	18	12	16.5
Cl mg/l	28.8	4.0	8.0	6.0	41.0	6.0	7.0	6.0	8.0	6.0	1.8	1.0	8.6
HCO_3 mg/l	84.6	89.6	72.0	75.0	51.0	64.0	57.0	67.0	61.0	66.0	87.0	76.9	62.0
PO_4 mg/l	0.05	0.04	0.03	0.07	0.02	0.03	0.03	0.02	0.02	0.04	0.10	0.06	0.35
F mg/l	1.10	0.81	1.70	1.50	1.30	1.10	1.60	1.80	1.20	0.56	0.52	1.90	1.18
B mg/l	0.06	0.13	0.05	0.05	0.04	0.04	0.10	0.04	0.08	0.12	0.10	1.10	
NO_3 mg/l	1.20	< 0.01	0.01	0.01	0.02	0.02	0.04	0.10	0.08	0.07	0.07	0.05	< 0.01
Ba mg/l	< 0.01	0.12	< 0.06	0.08	< 0.05	< 0.06	< 0.04	< 0.05	< 0.05	0.03	0.12	0.05	
Na mg/l	22.0	11.2	14.0	17.0	12.0	17.0	13.0	15.0	12.0	13.0	21.0	22.0	57.6
K mg/l	3.2	2.0	2.3	2.6	2.1	2.5	1.6	2.2	4.2	7.1	3.2	4.5	3.47
Ca mg/l	19.0	21.3	14.0	14.0	12.0	10.0	18.0	13.0	14.0	14.0	17.0	14.0	16.05
Mg mg/l	2.2	1.6	1.7	1.7	1.5	1.4	1.5	1.5	3.9	1.7	1.7	1.9	2.3
Fe mg/l	0.46	0.25	0.26	0.14	0.15	0.06	0.23	0.16	0.16	0.06	0.09	0.06	0.14
As mg/l	< 0.01	0.01	0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.04	0.01	< 0.01	0.01	< 0.005
Hg mg/l	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.0012
Si mg/l	27.0	29.0	27.0	27.0	25.0	29.0	26.0	28.0	22.0	26.0	32.0	24.0	55.0
BOD_5 mg/l	3.0	1.9	1.90	< 0.25	2.70	< 0.25	< 0.25	< 0.25	< 0.25	0.40	3.15	0.75	

*Laboratory values at 25°C

The monitoring station and ISCO pinpointed two geothermal contributions to Redondo Creek each water year. Contributions were typically of short duration and resulted from spills of 20-150 barrels of fluid related to drilling activities. On only one occasion was the contribution discernable below Redondo Creek's confluence with Sulfur Creek.

The water years 1979-1980 and 1980-1981 provide good baseline data on chemical character of surface water of the Jemez River watershed, should a geothermal resource be developed at the Baca Location at some future date.

6.3 Aquatic Ecology

A one-year survey of aquatic ecology of Redondo Creek was conducted by S. Zeiser under contract to PNM.

Three sites were selected in Redondo Creek to reflect varying degrees of construction related disturbance to the creek (see Figure 6.3-1). Each site was sampled eight times at approximate monthly intervals from September, 1979 to August, 1980. Sampling was suspended during periods when snow and ice covered the creek.

Water was collected and sampled for oxygen saturation, free CO_2 and alkalinity using standard techniques.

The pH was recorded with a Mini pH Meter, Model 47. Conductivity was measured as micro mhos per centimeter (mhos/cm) with a Lecto Mho-Meter (Lab-Line Instruments).

Water and air temperatures were measured with a standard mercury thermometer. Monthly miximum-minimum water temperatures were recorded with a Taylor Max-Min Thermometer (VWR), permanently anchored at each station.

A Hach Turbidometer, Model 2100A was used to measure turbidity.

Suspended sediment was determined in triplicate. One-liter aliquots of stream water were poured into an Imhoff cone. Suspended material was allowed to settle for 3 to 5 hours. Settleable matter was recorded as micro liters per liter (1/l) (Standard Methods 1976).

Discharge was estimated from data recorded at permanently established stream transects. Average velocity at each station was computed from triplicate measurements with a Digital Flowmeter, Model 2030 (General Oceanics, Inc., Miami, Florida). Stream width and water depth at 10-cm intervals were plotted on finely divided graph paper. The total number of enclosed grid squares was proportional to the cross-sectional area of each transect. Stream discharge was calculated as velocity x transect area.

6.3.1 Algal Standing Crop

Ten gravel substrates were collected at each station on each collection date. Periphyton was removed by scraping each substrate with a stiff brush into a container of 90 percent acetone (Standard Methods 1976). Acetone extracts were stored in numbered Whirlpak bags, refrigerated in transit and placed in a freezer upon return to the laboratory.

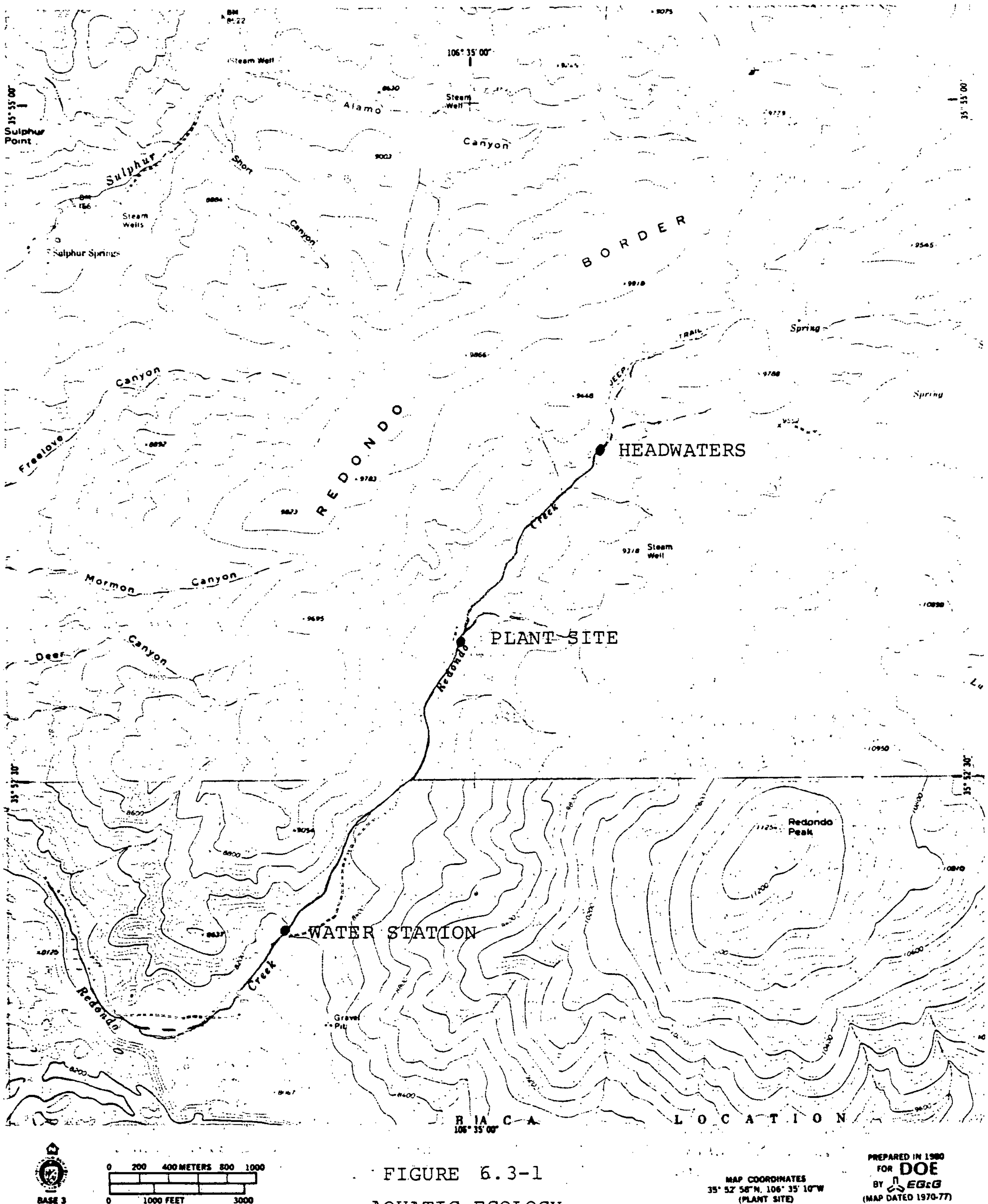


FIGURE 6.3-1

AQUATIC ECOLOGY

MONITORING SITES

Substrate areas visible from directly overhead were assumed to be an approximation of substrate areas exposed to light and, therefore, available for algal growth (after standard techniques). Each substrate was outlined on paper and a planimeter used to determine its area.

Chlorophyll extracts were homogenized in a 50-ml tissue grinder and centrifuged at 15,000 rpm for 12 minutes. The chlorophyll, a content of the supernatant, was determined fluorometrically (Standard Methods 1976) using a Fluoro-Colorimeter, Model J4-7439 (American Instruments Co., Silver Springs, Maryland). Algal standing crop was expressed in milligrams (mg) chlorophyll a/m^2 substrate.

6.3.2 In Situ Organic Detritus

Ten midstream Surber samples (0.22-mm mesh) were collected at each station on each date. The Surber samples were collected at 15-meter intervals along the stream channel, avoiding debris dams and large logs. Specific collection sites were rotated to prevent oversampling. Field samples were preserved in ethyl alcohol and later washed through a series of graded sieves (1.00 mm, 0.50 mm and 0.25 mm). All macroinvertebrates and wood fragments greater than 3 mm were removed from the 1.00-mm fraction. All three fractions were then dried at 65°C, weighed, ashed at 500°C and reweighed. Organic content was recorded as loss on ignition.

6.3.3 Macroinvertebrates

All macroinvertebrates visible under 7x magnification of a compound binocular dissecting scope were removed from the 1.00-mm detrital fraction. Organisms were sorted, identified (usually to genus) and counted. Chrionomids, most of which passed through the 1-mm sieve, were not considered in this study. Specimens were identified according to the following:

a. General: Pennak (1978)

b. Nematodes: Tarjan et al. (1977)

c. Oligochaetes: Brinkhurst and Jamieson (1971); Hiltunen and Klemm (1980)

d. Water mites: Cook (1974)

e. Insects general: Usinger (1956); Merrit and Cummins (1978)

f. Trichoptera: Wiggins (1977)

g. Diptera: Johannsen (1934, 1935, 1937a, 1937b)

6.3.4 Substrate Type

One predominant substrate type was visually determined for the area enclosed by the Surber net frame before collecting each faunal sample. The first three of the following categories were defined by WEC (1979). The last category was added for the present study.

a. rubble: 30 cm 7.5 cm

b. gravel: 7.5 cm 0.25 mm

c. fines: 0.25

d. embedded boulders: rubble fully embedded in the stream channel so that only the upper surface is exposed

6.3.5 Results

Seasonal variations were demonstrated in temperature, discharge, water velocity, O_2% saturation, alkalinity, pH, suspended sediment, turbidity and chlorophyll.

The three sampling stations along Redondo Creek were subjected to varying degrees of construction-related disturbance. The headwaters served as a control for the two downstream stations which were directly influenced by geothermal development. The downstream stations were selected to differentiate between the major potential impacts as identified in the environmental impact statement for surface waters at the Baca Location. The benthic stream community at the construction site was directly affected by localized sedimentation which occurred as a direct result of construction activities. The Redondo water station was affected minimally or not at all. Both the construction site and the water station communities are equally impacted by chemicals, specifically geothermal brine solutions deposited into the stream at the building location.

Neither algal periphyton nor detrital standing crop appeared to be limiting as food sources for benthic macroinvertebrates at Redondo Creek. However, total organic matter was correlated with total numbers and diversity of the benthic fauna. The only other physicochemical parameter significantly correlated to macroinvertebrate abundance was discharge. Total organic matter and discharge may be important factors related to benthic community structure. The head waters site had overall greater organic matter than either of the other sites. The headwaters also carried a steady discharge relative to the more variable flows of the other two sites.

The most important potential and actual perturbations to Redondo Creek were sedimentation and addition of geothermal brines. Measurements of physicochemical variables directly relating to these perturbations -- specifically, suspended sediment, turbidity and conductivity -- could continue to better define normal ranges and to identify deviations from those norms.

The benthic community parameters of total numbers and diversity provide the most valuable criteria for identifying impacts related to geothermal development.

Table 6.3-2 lists the organisms identified in Redondo Creek during the course of the study. The complete study is available from PNM's Environmental Division in Albuquerque or Union's Rio Rancho Office.

TABLE 6.3-1

	water station	construction site	headwaters
TURBELLARIA		+	+
NEMATOMORPHA	+		
NEMATODA			
Alaimus	+		+
Oionchus	+	+	1
others	+		
OLIGOCHAETA			
Lumbriculidae	15	25	
Aeolosoma	3	4	1
Haemonais	+	1	1
Paranais	1	4	1
MOLLUSCA			
Pisidium	+	+	92
Gastropoda	+	+	+
HYDRACARINA			
Atractides	+	5	+
Sperchon	+	+	+
Lebertia	+	+	1
Hygrobates	+		
Testudacarus			+
Sperchonopsis			+
OSTRACODA			+
COLLEMBOLA			1
PLECOPTERA			
Acroneuria	7	6	255
Malenka	7	19	65
Alloperla	11	9	18
Isoperla	20	13	2
Pteronarcella	1	+	
Claassenia			1
EPHEMEROPTERA			
Baetis	608	632	541
Ephemerella	1	1	99
Cinygmula	2	12	16
Epeorus	2	4	2
Paraleptophlebia	2	1	10
Rhithrogena		+	+
Ameletus	+	+	

+ = present, not quantified

TABLE 6.3-1 (Continued)

	water station	construction site	headwaters
TRICHOPTERA			
Amiocentrus			+
Hydroptila	+	+	+
Micrasema	+	+	271
Namamyia	1	3	90
Hydropsyche	12	24	213
Pycnopsyche	1	3	
Hesperophylax	4	17	
Glossosoma	+	1	+
Rhyacophila	+	1	+
Lepidostoma	+	+	18
Anagapetus	+	+	
Brachycentrus	1		
others	2	+	1
COLEOPTERA			
Curculionidae		+	
Dytiscidae	1	4	
Chrysomelidae		+	
Hydrophilidae			+
Elmidae	10	12	287
others	1	+	2
HEMIPTERA			
Limnogonus		+	
Gerris	+		1
Microvelia	+		
DIPTERA			
Simulium	4	149	59
Dixa	1	8	5
Chelifera	6	3	2
Ptychoptera	+		+
Pericoma		1	18
Maruina			4
Aedes			1
Dicronota	31	29	124
Tipula	3	1	11
other Tipulidae	1	+	1
Helodidae	1	1	3
Stratiomyidae		+	

+ = present, not quantified

6.4 Rare and Endangered Species

6.4.1 Plethodon neomexicanus

One species of salamander, Plethodon neomexicanus, that met the criteria of "rare and endangered" in New Mexico was identified in Redondo Canyon.

Areas of occurrence had been outlined by Whitford in early baseline surveys of the Canyon.

Union and PNM cooperated in design of an appropriate survey and the attempt to run it.

Discussions with experts on Plethodon neomexicanus led to the following design.

A grid of squares 100' x 100' was roughly outlined over identified Plethodon neomexicanus habitat. The grids were to be examined by turning logs over until a salamander was found. Turned logs were to be carefully replaced in original position. The number of logs that must be turned to find a salamander was to offer a statistical index of relative densities from year to year with the least disturbance to the population. The design was not in place for the 1979 survey year.

In 1980 and 1981 no salamanders were located. The winter of 1980-81 was exceptionally warm and dry. There was little snow cover.

The survey during 1981 showed many logs to have been ripped up by bears. It is possible some salamanders had been lost during that time.

It is probable that the population(s) of Plethodon neomexicanus in Redondo Canyon are much smaller than original estimates indicated based on two unsuccessful years' attempts to locate even one.

It is possible that the population is very difficult to sample on the surface unless conditions are ideal. No attempt was ever made to find the species subsurface.

6.4.2 Euderma maculata

Euderma maculata, or the spotted bat, is considered potentially rare and endangered in New Mexico. Because its potential range covers most of the Jemez Mountains, including the Baca Ranch, bats were netted by Union once each year to determine if Euderma might actually be on the project.

Bats are netted by setting out fine mesh nets over water sources. Bats drink by skimming the surface of pools or relatively smooth running water. A net at the surface of the water will snag a bat's wings as it tries to veer off from it. The nets must be carefully watched, and caught individuals removed before they drown or freeze. Individuals are identified and released.

At least six species of bats were identified each sampling period, but no Euderma were found.

6.5 Selected Flora & Fauna

6.5.1 Flora

A baseline study was designed to provide data for monitoring future potential cooling tower drift effects in Redondo Canyon. The survey was designed and run by WESTEC Services under contract to Participant. Five (5) transects were established around the BGDPP plant site (see Figure 6.5-1). A total of 17 sample plots was distributed at intervals along the transects. Vegetation and soil samples were collected from plots and tested for boron, arsenic, mercury and flourine levels using standard laboratory techniques. Tree species were selected that were common to all transects. Foliage samples were collected in summer (June-July) and fall (September) 1980. Samples were tested using appropriate standard laboratory techniques. Table 6.5-1 provides typical data for representative species from transects.

In addition to chemical analysis, injury or damage to selected plants was determined by visual inspection. Visual assessment was made of the Canyon as a whole. The most striking observation was heavy insect infestation during the June sampling period. Quaking aspen foliage was particularly affected. This insect activity had declined significantly by September. No foliar pathogens were noted in either survey.

Alder were seen to display some early senescence, although the condition was noted consistently outside as well as within the study area.

Soil corings were taken at eight selected sites on eleven sample plots. These plots were located on AD&E transects as shown in Figure 6.5-2. Soil invertebrates were extracted from the corings and preserved for identification and analysis.

The results of the chemical analysis of foliage samples indicated that concentrations of boron, arsenic, mercury and fluorine seem well within the normal range for natural vegetation and crops. Mercury concentrations were consistently low, at or below the limit of detection (0.1 ppm) in almost every sample. Arsenic levels were also quite low, with most values below 1.0 ppm. In the June-July sampling period, fluorine concentrations were recorded within a narrow range, from below the limit of detection (3 ppm) to 11 ppm. The September sample included some higher values, ranging up to 42

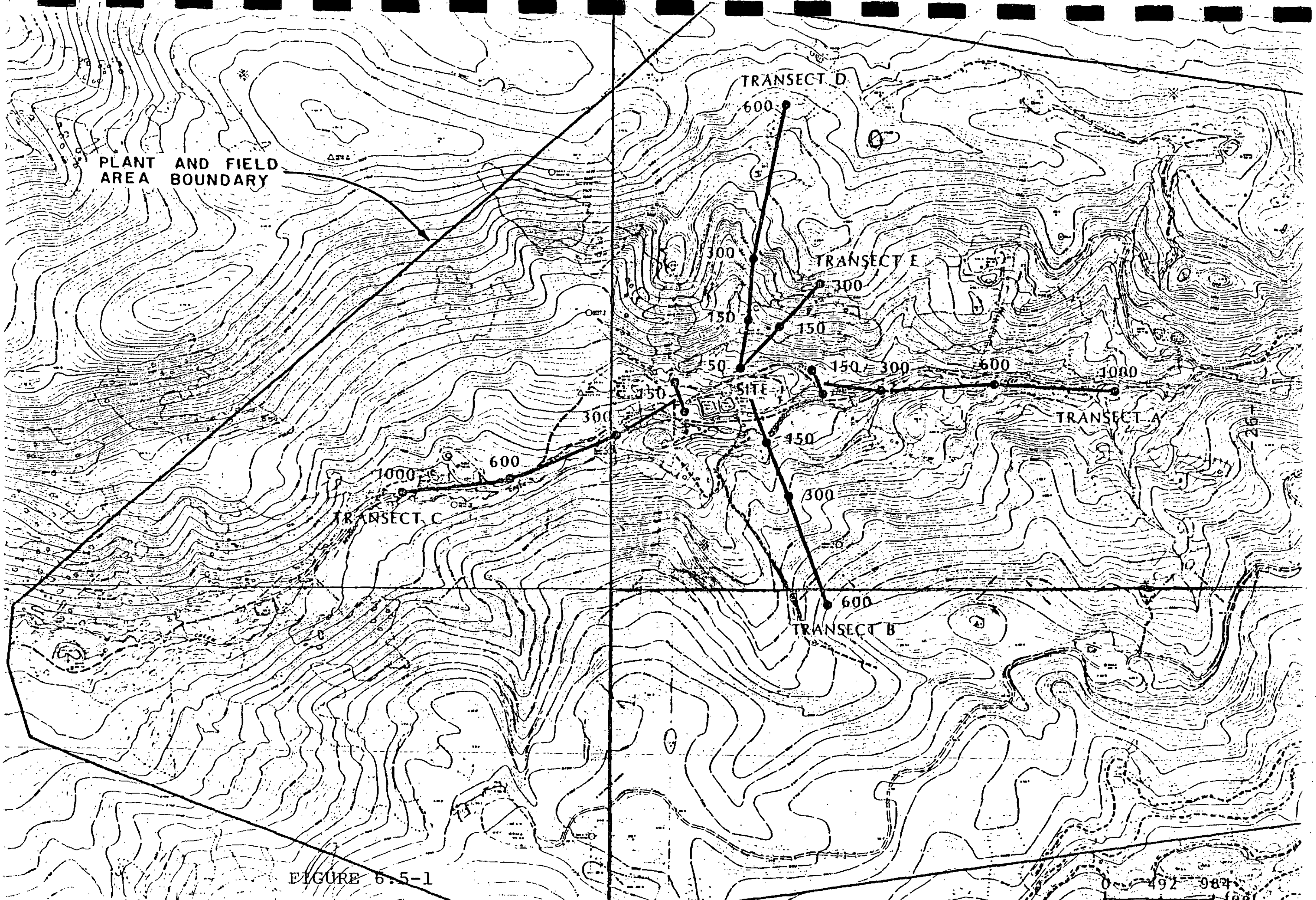


FIGURE 6.5-1

TRANSECTS AND SAMPLING PLOTS FOR VEGETATION AND SOILS

FROM WESTEC INTERIM REPORT - 1981

TABLE 6.5-1

CONCENTRATIONS OF BORON, ARSENIC, MERCURY, AND FLUORINE IN FOLIAGE SAMPLES TAKEN IN THE VICINITY OF THE BACA GEOTHERMAL DEMONSTRATION POWER PLANT (June 24-27 and July 9-11, 1980)

SAMPLE PLOT		BORON ppm	ARSENIC ppm	MERCURY ppm	FLUORINE ppm
A 150	Gambel Oak	10	0.4	< 0.1	< 3
	Quaking Aspen	26	0.4	< 0.1	8
	Alder	66	0.3	< 0.1	6
	Douglas Fir	27	1.1	< 0.1	5
A 300	Quaking Aspen	34	0.3	< 0.1	6
	Alder	25	0.4	< 0.1	9
A 600	Quaking Aspen	37	0.1	< 0.1	10
	Alder	28	0.1	< 0.1	11
	Douglas Fir	19	0.5	< 0.1	4
A 1000	Quaking Aspen	20	0.1	< 0.1	5
	Alder	19	0.3	< 0.1	7
	Douglas Fir	14	1.4	< 0.1	8
B 150	Quaking Aspen	36	0.2	< 0.1	8
	Douglas Fir	19	0.6	< 0.1	9
	White Fir	14	0.1	< 0.1	7
B 300	Quaking Aspen	28	< 0.1	< 0.1	3
	Douglas Fir	22	0.8	< 0.1	5
	White Fir	17	0.1	< 0.1	8
B 600	Quaking Aspen	22	< 0.1	< 0.1	4
	Douglas Fir	20	0.4	< 0.1	4
	White Fir	10	0.1	< 0.1	7

 FROM WESTEC INTERIM REPORT - 1981

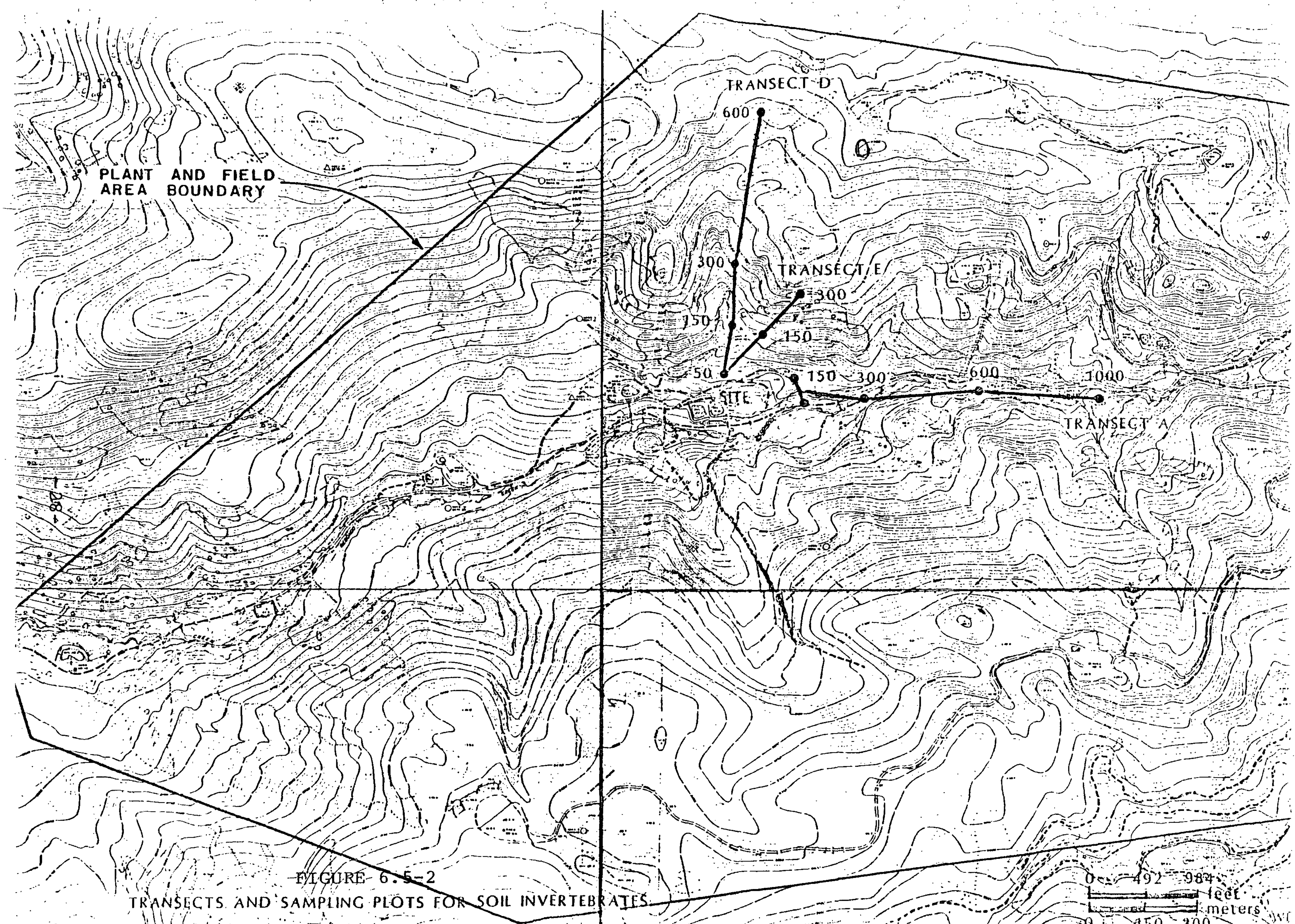


FIGURE 6.5-2

TRANSECTS AND SAMPLING PLOTS FOR SOIL INVERTEBRATES ppm. Boron concentrations were more variable, with most levels between 10 and 30 ppm in the June-July period, while September levels were generally higher including many over 30 ppm and one as high as 180 ppm.

The results of the chemical analysis of soil samples indicate concentrations of arsenic and mercury in soils were quite comparable to those recorded for vegetation samples. Boron, however, was present in soils at much lower levels than in foliage, while fluorine concentrations in soils greatly exceeded those in vegetation. Shallow (0 to 7.5 cm) and deep (7.5 to 15 cm) samples at each plot tended to show very similar chemical analyses. Table 6.5-2 gives typical soil data.

The results of preliminary counting and analyses of soil invertebrate samples extracted from 12 of the 88 corings are presented in Table 6.5-3. The total number of arthropods per replicate coring ranged from 148 in A 300a to 655 in D 300b, with a mean of 363.75. This mean value extrapolated to an overall density of 104,000 arthropods/m^2 of surface area. This figure falls within the normal range encountered in previous studies of forest and meadow soil arthropod populations. A full analysis of all soil invertebrate samples has not yet been provided as an addendum to the WESTEC report.

Copies of the WESTEC Baseline Ecosystem Studies of Cooling Tower Emmission Effects 1980 interim report are located at PNM's Environmental Division of their Albuquerque Office, Union's Rio Rancho Office and DOE's San Francisco Area Office.

Additional flora surveys were made along the large mammal transects in Redondo Canyon by PNM. Their data are not available in this office.

6.5.2 Fauna

Union and PNM jointly surveyed large mammal population densities and bird population densities. Small mammal surveys were run separately.

Four permanent transects were established for bird/large mammal surveys. The transects outlined on Figure 6.5-3 started at the head of Redondo Canyon and ran the length of the Canyon and below the project. Rebar posts were installed at 20' intervals along each transect to provide scat sampling sites for large mammal surveys.

TABLE 6.5-2

CONCENTRATIONS OF BORON, ARSENIC, MERCURY, AND FLUORINE IN SOIL SAMPLES TAKEN IN THE VICINITY OF THE BACA GEOTHERMAL DEMONSTRATION POWER PLANT (September 16-19 1980)

SAMPLE PLOT	BORON ppm Sat'd Extract		ARSENIC ppm Soil		MERCURY ppm Soil		FLUORINE ppm Soil	
	0-7.5cm	7.5-15cm	0-7.5cm	7.5-15cm	0-7.5cm	7.5-15cm	0-7.5cm	7.5-15cm
A 150	0.61	0.38	2.6	5.7	< 0.1	< 0.1	345	390
300	0.25	0.27	3.0	4.9	0.1	0.1	250	275
600	0.33	0.24	1.9	0.4	< 0.1	< 0.1	255	260
1000	0.16	0.13	2.1	2.0	< 0.1	< 0.1	340	345
B 150	0.27	0.20	1.3	1.1	< 0.1	< 0.1	345	325
300	0.32	0.22	1.6	1.6	< 0.1	< 0.1	250	255
600	0.25	0.32	5.3	1.8	< 0.1	< 0.1	170	165
C 150	0.21	0.17	4.2	2.2	< 0.1	< 0.1	340	390
300	0.57	1.6	5.0	3.6	< 0.1	< 0.1	365	395
600	0.16	0.17	3.3	3.8	< 0.1	< 0.1	390	425
1000	0.23	0.18	3.5	4.2	< 0.1	< 0.1	275	305
D 50	0.18	0.15	4.0	7.1	< 0.1	< 0.1	470	375
150	0.29	0.24	3.8	3.7	< 0.1	< 0.1	255	210
300	0.19	019	5.8	8.5	< 0.1	< 0.1	325	315
600	0.23	0.29	4.7	5.5	< 0.1	< 0.1	390	290
E 150	0.20	0.14	10.3	11.1	< 0.1	< 0.1	470	530
300	0.22	0.28	3.3	2.8	< 0.1	< 0.1	160	200

FROM WESTEC INTERIM REPORT - 1981

TABLE 6.5-3

PRELIMINARY COUNTS OF SOIL INVERTEBRATE POPULATIONS FROM 12 SOIL CORINGS TAKEN IN THE VICINITY OF THE BACA GEOTHERMAL DEMONSTRATION POWER PLANT (August 25-26, 1980)

TAXON	SAMPLE PLOT AND REPLICATE												
	A 150a	A 150a	A 300a	A 1000a	D 150a	D 150b	D 300a	D 300b	D 600a	E 150a	E 150b	E 300a	Total
INSECTA													
Diptera larvae	2	8	2		2	1	1		2	6	3		27
Coleoptera larvae	6	3		2				4		1	1		17
Coleoptera adults		2								1	1		4
Lepidoptera larvae		1		1	1					1			4
Pseudococcidae		159	1		1	1		376					538
Aphididae	3	9											12
Psocoptera	2							1			1	1	5
Thysanoptera				1				1					2
Protura		1	1	1	1	2		5		7		3	21
Collembola	31	137	11	435	54	67	76	16	88	83	21	29	1058
Other Insecta	3						1						4
Total Insecta	57	320	15	440	59	71	78	403	90	99	27	33	1692
MYRIAPODA													
Pauropoda	2					11		1			3		17
Symphyla	1										1		2
Chilopoda	1					4	1	1		1			9
Diplopoda							1	1		1	1		9
Total Myriapoda	4					15	1	2		1	5		28
ARACHNICA													
Araneae	1							3					4
Pseudoscorpionida										2			2
Acarina													
Cryptostigmata	243	112	13	7	75	139	131	128	141	48	37	61	1135
Megostigmata													
Gamasina	30	27	12	43	41	32	11	28	25	26	5	18	298

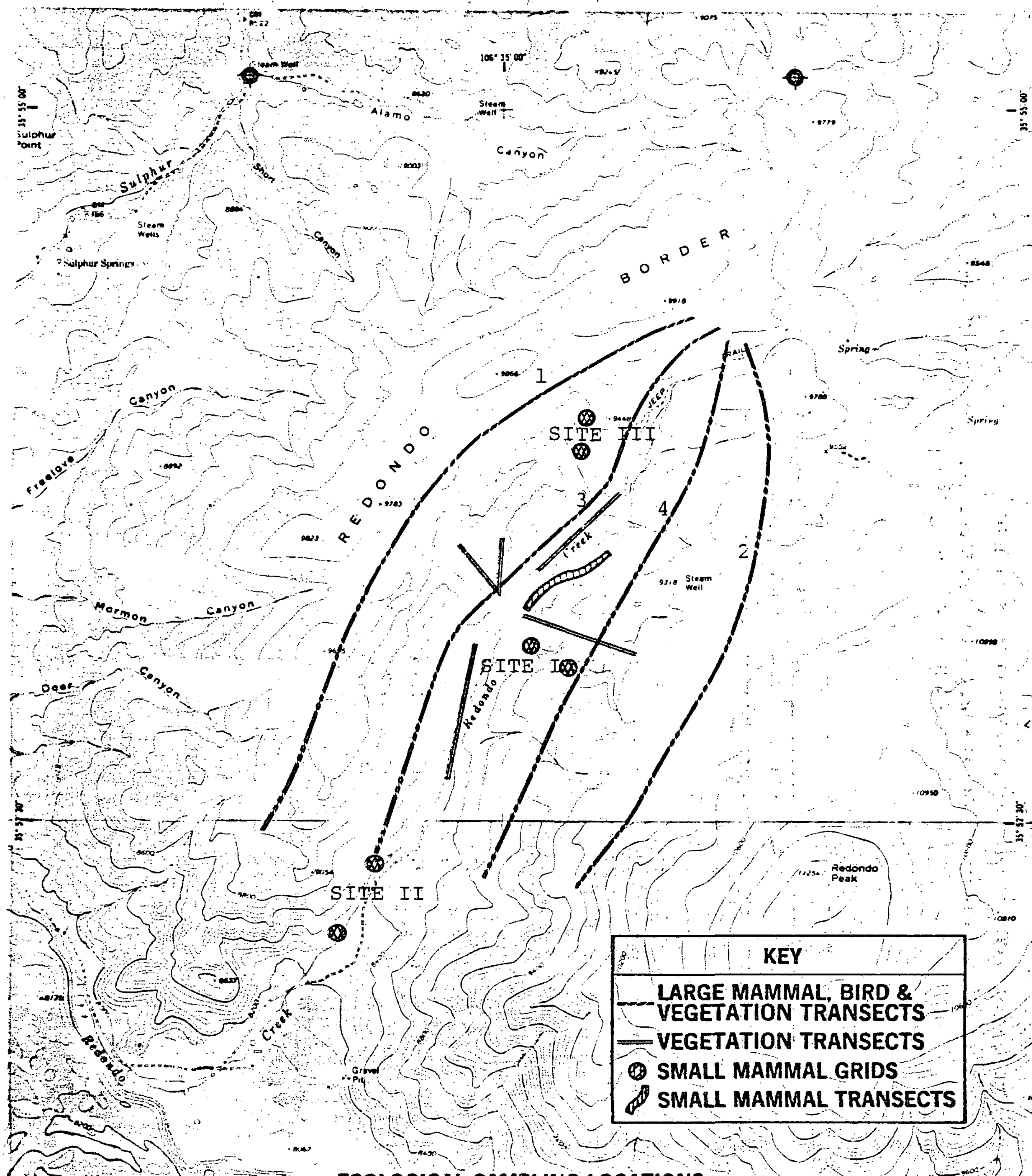
TABLE 6.5-3 (Cont'd)

PRELIMINARY COUNTS OF SOIL INVERTEBRATE POPULATIONS FROM 12 SOIL CORINGS TAKEN IN THE VICINITY OF THE BACA GEOTHERMAL DEMONSTRATION POWER PLANT
(August 25-26, 1980)

TAXON	SAMPLE PLOT AND REPLICATE												
	A 150a	A 150a	A 300a	A 1000a	D 150a	D 150b	D 300a	D 300b	D 600a	E 150a	E 150b	E 300a	Total
ARACHNICA (continued)													
Prostigmata													
Tydeidae	4	5	12	8	23	16	19	49	26	8	13	23	206
Rhagidiidae	14	1		2		3		7			6	3	36
Eupodidae	23	3	6	12	18	13	6	1	8	41	50	19	200
Bdelloidea	4				2	2	2		1	3	4	2	20
Raphignathoidea	2			1						2	8	20	33
Other Prostigmata	11	1	1	4		3	3	19		2	2	5	51
Endeostigmata	14	8		6		22	2	15		210	3	4	284
Heterostigmata	14	2	60	55	60	21	70			31	3	16	332
Astigmata	1		29			1			10	1	2		44
Total Acarina	360	159	133	138	219	252	244	247	211	372	133	171	2639
Total Arachnida	361	159	133	138	219	252	244	250	211	374	133	171	2645
Total Arthropoda	422	479	148	578	278	338	323	655	301	474	165	204	4365

FROM WESTEC INTERIM REPORT - 1981

FIGURE 6.5-3



ECOLOGICAL SAMPLING LOCATIONS

OVERLAY FOR BASE 3 BACA

BASE 3

0 200 400 METERS 800 1000

0 1000 FEET 3000

THE BACA GEOTHERMAL PROJECT LOCATION

MAP COORDINATES 35° 52' 58"N, 106° 35' 10"W (PLANT SITE)

PREPARED IN 1980 FOR DOE BY EG&G (MAP DATED 1970-77)

6.5.2.1 Large Mammals

Elk were the most common large ungulate in Redondo Canyon, and the transects were designed to monitor their relative densities and movements with minimum actual disturbance to the animals. Mule deer are relatively rare, but their density was monitorable.

Bear are the most common large predator in the Canyon and the transects provided information on their activities. Bobcats, cougar and porcupine data were also collected. Three foot radius plots were monitored around each rebar post, scat was counted and cleared from each plot. Plots were read June of 1980 and 1981 after snow melt and October of 1980 and 1981 before the first snow fall. Elk densities were determined from pellet group counts and number of use days available using standard statistical tests.

Table 6.5-4 shows numbers of pellet groups counted during the four surveys taken along the transects. Generally, large mammals do not appear to be impacted by activity in Redondo Canyon. There did not appear to be avoidance of active or disturbed sites. Construction of new wellpads in forested areas may account for some increase in the deer population from 1980-81.

One sow bear and her cubs accounted for the bear pellet counts along the transects. She successfully reproduced every other year and ranged over all of Redondo Canyon.

One cougar was probably responsible for pellet counts in transect #2. Redondo Canyon was apparently on the edge of the cat's range, as it would be present in the Canyon about every six weeks. The fact that the Canyon remained part of the cougar's range for two years tends to indicate very little man-made disturbance to the large mammals in the area.

Statistical analyses of the large mammal pellet counts proved to be inconclusive to date. The raw data provide good base line data for comparison with any future studies that may be done.

PNM plans to remove the posts from the transects to avoid potential for physical damage to wildlife.

TABLE 6.5-4

LARGE MAMMAL CENSUS, REDONDO CANYON

		TRANSECT 1 (Upper Redondo Border)	TRANSECT 2 (Upper Redondo Peak)	TRANSECT 3 (Lower Redondo Border)	TRANSECT 4 (Lower Redondo Peak)
1980	June	73 Elk groups 12 Deer groups *	37 Elk groups 1 Deer group *	95 Elk groups 1 Deer group *	111 Elk groups *
	Oct.	124 Elk groups 13 Deer groups	127 Elk groups 2 Deer groups 2 Cougar groups 1 Bear group	38 Elk groups 1 Deer group 1 Bear group 1 Coyote group	82 Elk groups 1 Deer group 4 Bear groups
1981	June	111 Elk groups 8 Deer groups 1 Bear group	71 Elk groups 7 Deer groups 1 Coyote group	33 Elk groups 4 Porcupine groups	70 Elk groups
	Oct.	128 Elk groups 22 Deer groups	77 Elk groups 18 Deer groups 1 Cougar group 1 Bear group 3 Porcupine groups	53 Elk groups 3 Deer groups 6 Bear groups 4 Porcupine groups	60 Elk groups 2 Deer groups 1 Bear group

Groups are pellet groups, not actual animal counts.

* No data on additional species available

6.5.2.2 Birds

Union and PNM jointly collected bird data once in fall of 1979 and three times a year in 1980 and 1981. The large mammal transect lines were used for data collection. Each transect was walked two successive days per sample period, one day by each person. Transects were walked between dawn and noon each day to minimize variability due to time of day. Species and number of birds sighted were recorded with distance from transect and habitat type the sighting occurred in. Habitat was identified as meadow, mixed conifer, oak or Riparian. Redondo Canyon is very patchy, and nearly half of all sightings occurred near the edge of two habitats. Tables 6.5-5 and 6.5-6 list species typically found during a survey, typical densities and type of habitat they are found in.

Surveys revealed that an average of 16 species of birds are year-long residents of Redondo Canyon. By snow melt each spring (May-June) over 30 species may be found in the Canyon. Of these species over half are known to reproduce in the Canyon. Spring counts average 230-300 individuals. By June 450-550 individuals may be counted.

6.5.2.3 Small Mammals

In 1979 a series of transects was established in appropriate areas of Redondo Canyon to monitor changes in small mammal diversity and density.

PNM established a single line transect bordering the generator plant site and crossing the meadow between the generator site and the 200' MET tower (see 6.1). No data are presently available from PNM's survey.

Union established six grid transects; three bordering wellpads in various phases of construction and three set about 100'+ away from each "disturbed site". Figure 6.5-3 pinpoints the location of the grids in the wellfield.

SITE I: Wet mixed conifer low altitude habitat

- Grid 1: East edge of Baca No. 24 wellpad. The pad was newly constructed when the grid was established and actively used during parts of 1980 and 1981.
- Grid 2: 100' east of Grid 1 and just north of a tributary to Redondo Creek.

SITE II: Low altitude Rocky Ponderosa pine/oak complex.

MC = Mixed Conifer
Asp = Aspen
Med. = Meadow

TABLE 6.5-5

BACA GEOTHERMAL AVIAN CENSUS

Transect Number: # 1 Date: 7/30/80

Distance from Transect Line (Meters)

Species	Habitat	0-5	5-10	11-15	16-20	21-25	26-30	31-40	41-50	51-75	76-100	100
Dendragopus	Mc				2							
" obscurus	Mc/Asp		1									
"	Asp/med.		2									
Columba fasciata	Mc	1										
Selasphorus platycercus	Oak/Asp		1									
Colaptes cafer	"	2			1							
"	Asp/Mc med.						1					
Sphyrapicus varius	Mc	1										
Flycatcher	Mc/Oak									1		
Tachycineta thalassina	Mc							2				
Cyanocitta stelleri	Asp/Mc med.		1				1					
"	Oak/Asp	1		1								
Corvus corax	Asp/Mc med.						1					
Nucifraga columbiana	"						1					
Parus gambeli	"			2								
"	Mc	1		1	1							
"	Asp/Mc			1	1							
Sitta canadensis	Mc	1	3		1							
	Asp/Mc med.				2							
Thryomanes bewickii	Oak/Asp	1	1									
Turdus migratorius	Oak					1						
Hylocichla guttata	Mc		1									
Myadestes townsendii	Mc/med.		1									
(young) "	Mc/Asp	1										
(young) "	Oak/Asp	1										

TABLE 6.5-5 (Cont'd)

BACA GEOTHERMAL AVIAN CENSUS

Transect Number: # 1, Page 2 Date: 7/30/80

Species	Habitat	Distance from Transect Line (Meters) 0-5	5-10	11-15	16-20	21-25	26-30	31-40	41-50	51-75	76-100	100
Regulus calendula	Mc		4	2	1							
"	Mc/Oak		2									
Dendroica audoboni	Mc				2							
Piranga ludoviciana	Mc		1									
Pheucticus melanocephalus	Mc/Asp				2							
Junco oreg.	Asp/Mc	1	2	1								
Spizella passerina	"		2	1								

Notes Also sighted --

1 young of year Redtail hawk

1 bandtail pigeon

Tamiasciurus ~~1111~~ 11

Chipmunk 1

Cottontails (young) 11

Cow Elk on B-17

Elk above 14

Mc = Mixed Conif.
Med = Meadow

TABLE 6.5-6

BACA GEOTHERMAL AVIAN CENSUS

Transect Number: #1 (Upper Redondo Border) Date: November 5, 1980

Distance from Transect Line (Meters)

Species	Habitat	0-5	5-10	11-15	16-20	21-25	26-30	31-40	41-50	51-75	76-100	100
ccipiter gentilis	Scrub Oak									1		
yanocitta telleri	Mc		2		2		2		1	1		
Cyanocitta stelleri	Med.		2									
rvus rax	Mc											6
Nucifraga lumbiana	"											1
arus gambeli	"	1	3		6			10				
Parus ambeli	Med.								1			
itta carolinensis	Mc						2					
yadestes ownsendi	Mc											1
Junco sp.	"	5			6			10				

Grid 1: Southwest edge of Baca No. 12 wellpad. The pad was over five years old at the time the grid was established and revegetated. Major reconstruction of the pad occurred late in 1981.

Grid 2: 100' south of Grid 1. Between the north edge of an old gravel pit and the road.

SITE III: High altitude dry mixed conifer/aspen.

Grid 1: Between Baca No. 17 wellpad and Baca No. 22 wellpad.

Grid 2: North edge of Baca No. 22 wellpad. The grid was located before construction and the original site was partially buried. The grid was relocated vertically onto the boulder edge of the pad after construction was completed.

Figure 6.5-4 is a representative trapping log including number of species and individuals trapped at each site.

Each grid is set out using 100 Sherman live traps. Each grid has 10 lines with 10 traps in each line. Each grid measures 100' x 100'. If four animals are caught, trap success is 4%. The percent of trap success provides an indication of relative density between trap sites.

Each grid is trapped two successive nights in a row. Trapping is done during the dark phase of the moon to minimize variability between trapping periods. Any fatalities were donated to the Museum of Southwestern Biology located on the UNM campus as voucher specimens of the area.

Table 6.5-7 shows relatively little difference in population densities between "disturbed" and "undisturbed" areas in similar habitat types. The increases in percent trap success by summer both years reflects the recruitment of young into the populations. The very large increase in summer of 1981 reflects the very mild 1980-81 winter when there was apparently little die-off. Fall of 1981 indicates the large populations are being impacted by predators and/or desease.

Table 6.5-8 lists small mammal species trapped in Redondo Canyon in order of commonness from most common to least common. Deer mice are the most common species trapped. Over 50% of all animals trapped were deer mice.

FIGURE 6.5-4

October 1980

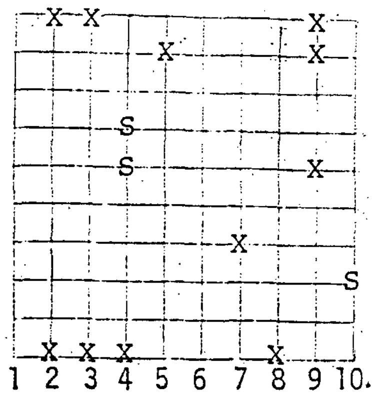
Small Mammal Trapping - Grid Results

October 9, 10, 11, 1980

S - Sprung
O - Not set
X - Animal caught

SITE I

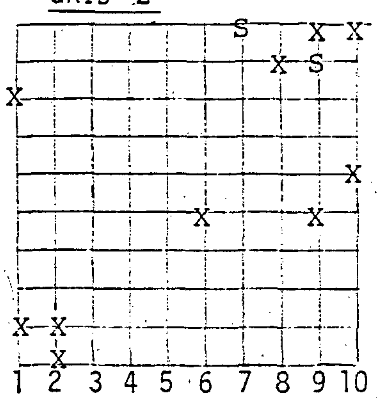
GRID 1



2(10) Peromyscus maniculatus
2(1) P. maniculatus
3(1) Neotoma mexicana
3(10) N. mexicana
4(1) P. maniculatus
5(9) P. maniculatus (bobtail)
7(4) P. maniculatus
8(1) P. maniculatus
9(6) P. maniculatus
9(9) P. maniculatus
9(10) N. mexicana (voucher)

2 spp. 12%

GRID 2

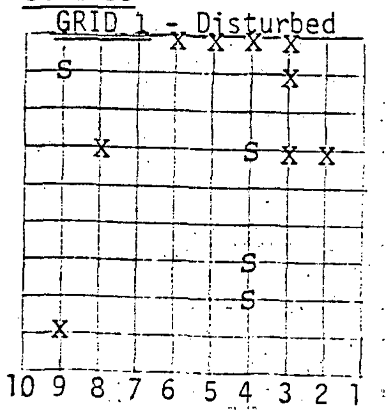


1(2) P. maniculatus
1(8) P. maniculatus
2(2) P. maniculatus
2(1) Microtus longicaudus (voucher)
6(5) Sorex vagrans (voucher)
7(10) P. maniculatus
8(9) P. maniculatus
9(5) N. mexicana
9(10) P. maniculatus
10(6) S. vagrans (voucher)
10(10) N. mexicana

4 spp. 11%

SITE II

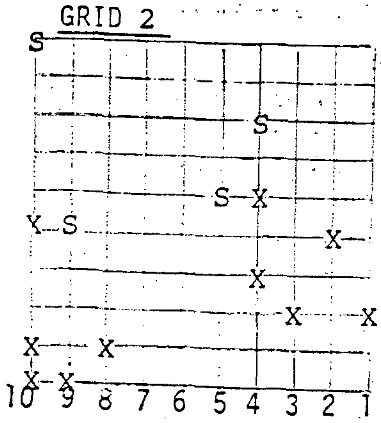
GRID 1 - Disturbed



2(7) S. vagrans (voucher)
3(7) P. maniculatus
3(9) P. maniculatus
3(10) P. maniculatus
4(10) P. maniculatus
5(10) P. maniculatus
6(10) P. maniculatus
8(7) P. boylei
9(2) P. maniculatus

3 spp. 9%

GRID 2



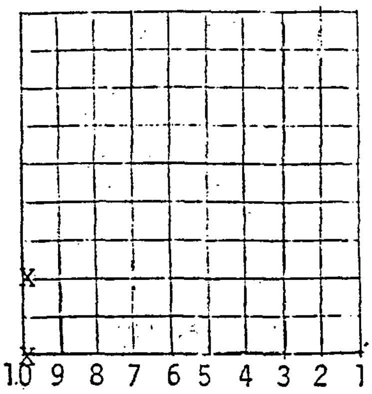
1(3) P. maniculatus
2(5) P. maniculatus
3(3) P. maniculatus
4(4) P. maniculatus
4(6) P. maniculatus (juv.)
5(4) P. maniculatus (juv.)
6(1) S. vagrans (voucher)
8(2) P. maniculatus (juv
9(1) P. maniculatus
10(1) P. maniculatus
10(2) P. maniculatus
10(5) P. maniculatus (juv

2 spp. 12%

October 1980 Small Mammal Trapping - Grid Results

SITE III -

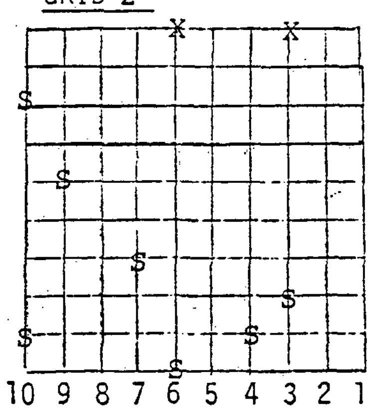
GRID 1



2(3) P. maniculatus
2(6) N. mexicana
2(9) N. mexicana
5(1) N. cinerea
8(8) Eutamius minimus
10(1) P. maniculatus
10(3) P. maniculatus

4 spp. 7%

GRID 2



3(10) P. maniculatus
6(10) N. cinerea

2 spp. 2%

TABLE 6.5-7

SITE I	"Disturbed" Grid 1	"Undisturbed" Grid 2
SPRING 1980	2 spp. 4%	1 sp. 1%
SUMMER 1980	3 spp. 8%	4 spp. 5%
FALL 1980	2 spp. 10%	4 spp. 10%
SPRING 1981	3 spp. 5%	2 spp. 6%
SUMMER 1981	6 spp. 21%	3 spp. 11%
FALL 1981	1 sp. 10%	2 spp. 8%

TABLE 6.5-7 (Cont'd)

SITE II	Grid 1 "Disturbed"	Grid 2 "Undisturbed"
SPRING 1980	3 spp. 5%	4 spp. 6%
SUMMER 1980	5 spp. 9%	1 sp. 4%
FALL 1980	3 spp. 9%	2 spp. 12%
SPRING 1981	2 spp. 8%	2 spp. 9 %
SUMMER 1981	3 spp. 18%	2 spp. 12%
FALL 1981	3 spp. 14%	3 spp. 10%

TABLE 6.5-7 (Cont'd)

		"Disturbed"	"Undisturbed"
SITE III	Grid 1		Grid 2
SPRING 1980		2 spp. 5%	2 spp. 3%
SUMMER 1980		4 spp. 6%	3 spp. 8%
FALL 1980		4 spp. 7%	2 spp. 2%
SPRING 1981		3 spp. 5%	2 spp. 5%
SUMMER 1981		4 spp. 20%	3 spp. 11%
FALL 1981		3 spp. 5%	3 spp. 9%

TABLE 6.5-8

SMALL MAMMAL SPECIES IDENTIFIED
FROM LIVE TRAP CAPTURE

Peromyscus maniculatus	(Deer Mouse)
Dutamias minimus	(Least Chipmunk)
Neotoma mexicana	(Mexican Wood Rat)
Clethrionomys gapperi	(Gapper's Red Backed Vole)
Neotoma cinerea	(Bushy-tailed Wood Rat)
Sorex vagrans	(Vagrant Shrew)
Peromyscus boylii	(Brush Mouse)
Microtus longicaudus	(Long-tailed Vole)
Spermophilus lateralis	(Golden Mantled Ground Squirrel)
Sorex palustris	(Water Shrew)
Mustella erminea	(Ermine)
Neotoma albigula	(White Throated Wood Rat)

Aberts and red squirrels were not monitored by the small mammal grids. Numbers of golden mantled ground squirrels and ermine do not reflect their commonness because of trap bias.
The five most common species in high densities can seriously impact revegetation efforts. Weasel and owl populations in the canyon are important for control.

Some traps were damaged by coyote attacks -- also an important control of rodent populations.

Additional traps were damaged by elk which were drawn into the transects by the oatmeal bait in the traps.

6.6 Archeology

The keeper of the National Register of the Office of Archeology and Historic Preservation decided in 1979 that Redondo Canyon held archeological sites that could yield significant scientific information which could be adversely impacted by irrevocable commitment of land in the Canyon to construction.

Union was solely responsible for monitoring archeology of the BGDPP wellfield. PNM was solely responsible for monitoring archeology impacted by transmission lines. PNM's study is not available for this report.

A survey was designed and operated by the Office of Contract Archeology located at the University of New Mexico Campus, under contract with Union, to identify and excavate significant sites in response to that decision.

Twenty nine (29) sites were located in the Canyon, and of these 21 were excavated. Excavations revealed most to be Archaic/Basketmaker 1 sites of bifacial obsidian tool production. Evidence of plant preparation sites was scanty. No evidence was found of hearths or structures. Excavation crews worked nine months in Redondo Canyon.

In addition to excavating known sites, a series of "random" excavations was made throughout Redondo Canyon in areas identified as likely to be impacted by future wellfield construction. This series of "random" excavations failed to identify any new archeological sites.

An excavation consisted of carefully digging a series of 3'x3'x3' plots within a site and sifting through all the material dug out of the plot. Horizons of soil were noted. Depth at which artifacts were found was recorded with position and type of artifact. Some artifacts were removed to OCA's laboratory in Albuquerque for analysis. After an excavation was completed, the materials taken from the plot were returned so that excavations were difficult to identify one year later. Each site and plot was surveyed to precisely pinpoint where excavations were made.

Sites of major importance are located on saddles and ridges and were not in danger of being impacted by wellfield construction. A map in Figure 6.6-1 shows the major archeological sites in Redondo Canyon.

Figure 6.6-2 shows typical artifact material recovered from excavations.

Pueblo use of the region was examined by ethnographic survey of a local pueblo's oral history. Euro-American use of the valley was documented by ethnographic survey and local record searches. Both Pueblo and Euro-American ethnographic studies indicate a long history of grazing, plant gathering and logging operation in the project area.

The surveys and analysis of artifacts resulted in the publication of a 376 page book, "High Altitude Adaptations Along Redondo Creek, the Baca Geothermal Anthropological Project", edited by Craig Baker & Joseph C. Winter, published by the Office of Contract Archeology, University of New Mexico June 9, 1981. Copies are available from OCA or from Union's New Mexico Office. The report has been submitted to the Office of the New Mexico State Historic Preservation Officer and to the Department of Energy District Office.

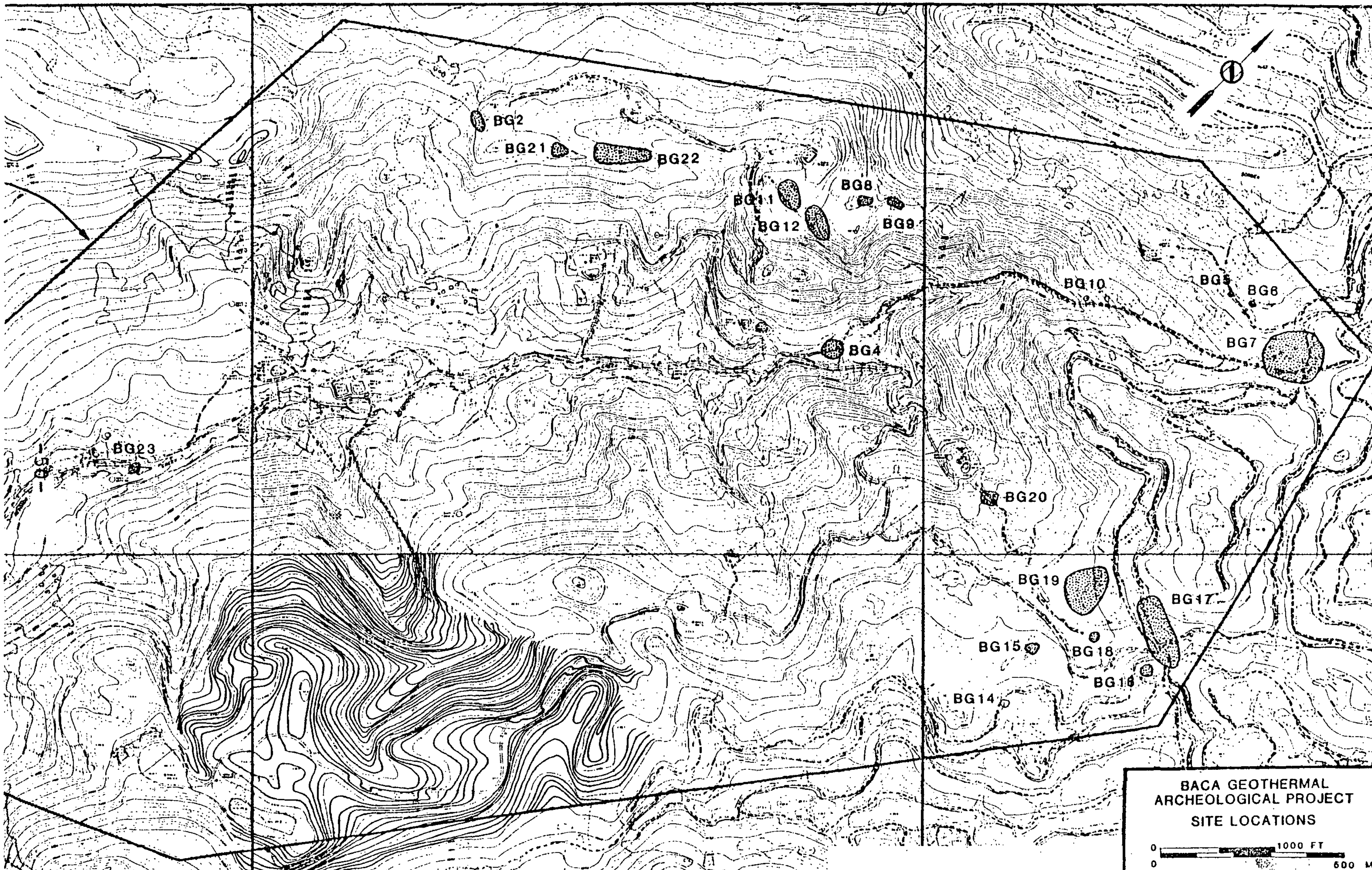

BG2
BG21
BG22
BG8
BG11
BG12
BG9
BG10
BG5
BG6
BG7
BG4
BG23
BG20
BG19
BG17
BG15
BG18
BG16
BG14
BACA GEOTHERMAL
ARCHEOLOGICAL PROJECT
SITE LOCATIONS
0
1000 FT
0
500 M

FIGURE 6.6-1

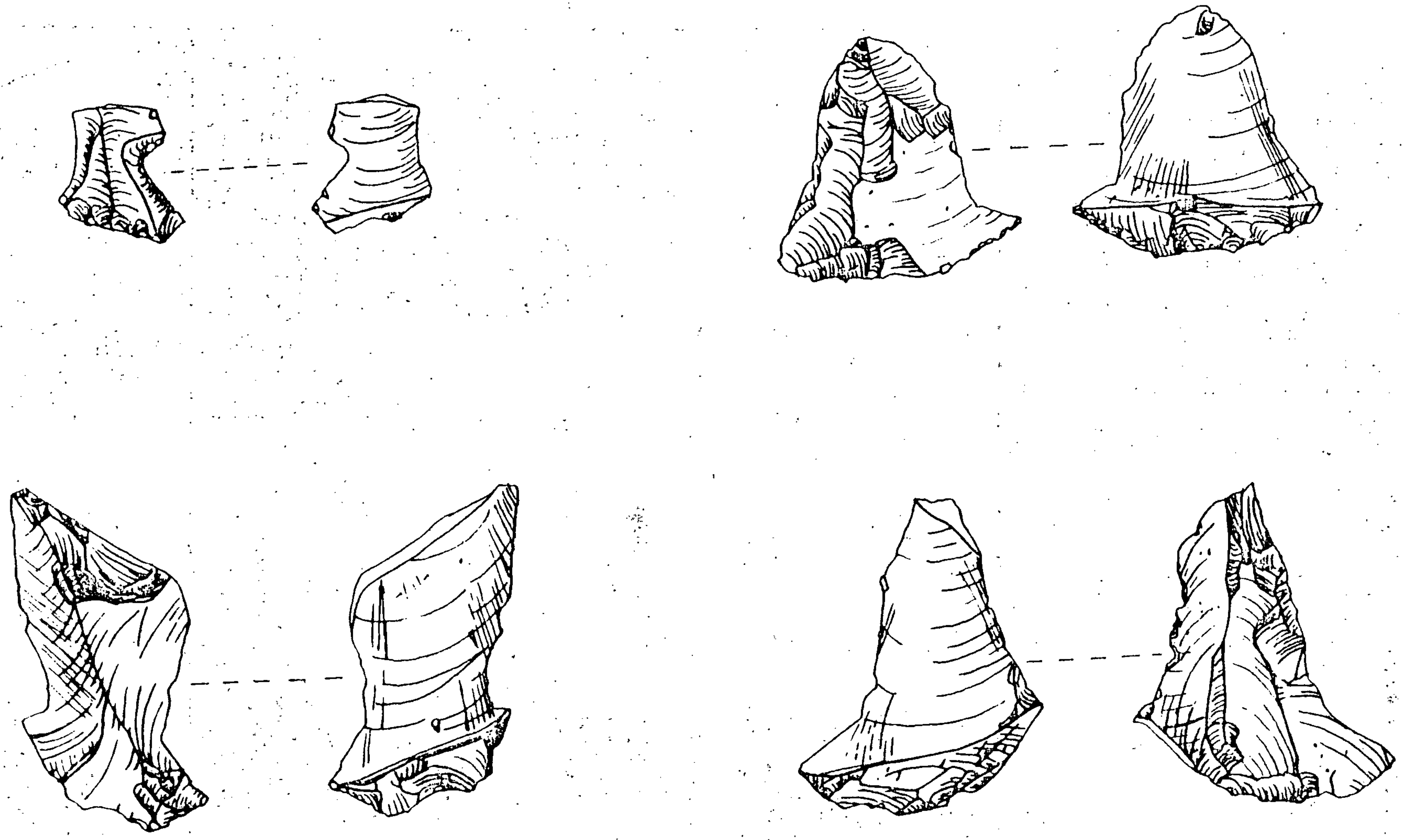


FIGURE 6.6-2

0 3
cm.

Dorsal and ventral view of biface tool production debris from site BG-19

From High Altitude Adaptations, OCA - 1981

6.7 Hydrology

A groundwater quality monitoring program was designed to evaluate the effects of extracting geothermal fluids from the caldera reservoir on regional hot springs and groundwater. Water Resources Associates, a subsidiary of WESTEC Services, designed and operated the study under contract to Union. Union was solely responsible for monitoring regional hydrology.

Sample collection concentrated on springs and wells to the west and south of the Baca Location with additional selected sites on the Ranch.

Table 6.7-1 lists some representative sampling dates, springs sampled, the parameters sampled and values for the parameters.

At each sample site water temperature, conductivity and an estimate of flow were made. Samples of water were collected in one liter bottles and stored to be analyzed by BC Laboratories, Inc., Bakersfield, California.

Samples were collected in the summer after runoff, and in the fall. Only fall samples were included in Table 6.7-1 to delete potential seasonal variability from runoff. Samples were begun summer of 1979 and will continue through summer 1982.

The following wells were monitored for level of head in the casing.

1. LASL - Four geothermal test wells A,B,C and D.
2. USFS - Horseshoe Springs well.
3. Mr. Hoffheins of CJC, Inc. - Three wells.
4. USGS - Two wells at Battleship Rock.

Artesian wells tested for flow and water chemistry are:

1. Baca artesian well in Valle Grande.
2. Baca artesian well in Valle Toledo.

TABLE 6.7-1

FALL WATER QUALITY PARAMETERS

OF THERMAL SPRINGS, JEMEZ MTS.

		McCAULEY HOT SPRINGS			SAN ANTONIO HOT SPRINGS			SODA DAM TOP SPRING			SODA DAM EAST SPRING			SPENCE SPRINGS			SULPHUR SPRINGS			SAN ANTONIO WARM SPRING			JEMEZ SPG. GAZEBO	
		1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981	1980	1981
T°F		89			105			115			112			106			109			100				
Conduct. (μmhos)		140		200	120		125	6100		6700.	6100		6400	250		310	7200		9200	140		184.		4000
pH		7.8	7.7	8.0	6.9	7.7	8.0	7.1	6.3	7.0	7.1	6.5	7.3	6.6	7.7	8.1	2.0	2.0	1.7	7.5	6.3	6.0	7.2	7.4
Calcium	PPM	8.0	7.0	8.2	1.0	2.0	2.8	137	310.0	260.	109	290.	138.	3.0	5.0	6.4	6.9	74.0	65.	3.0	4.0	5.4	58.	132.
Magnesium	"	3.6	4.0	4.8	0.11	0.1	0.22	23.5	23.	22.5	23	23.	24.5	1.0	1.3	1.7	5	8.0	9.0	0.17	0.20	0.30	4.4	5.2
Sodium	"	21	20.0	20	23.	24.0	22.	1200	1010.	1060.	1200	975.	1075.	60	51.0	56.	12	18.0	22.	27	25.	27.	630.	654.
Potassium	"	1.0	1.0	1.2	1.9	1.7	2.2	191	180.	200.	191	180.	210.	1.5	1.4	2.1	24	31.	40.	4.2	4.4	4.8	73.	79.
Carbonate	"	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0.	0.	0.0	0.	0.	0.	0.
Bicarbonate	"	91.8	80.6	88.4	60.6	60.6	58.9	1560.9	1134.8	1399.8	1456.1	1241.3	1030.8	147.3	121.3	152.5	0.0	0.	0.	74.5	65.0	78.8	535.3	679.1
Chloride	"	3.2	2.5	2.8	2.5	<1.8	1.8	1416.	1547.	1508.0	1447.9	1532.8	1554.1	4.3	6.4	6.7	<1.8	<1.8	<1.8	1.8	<1.8	2.5	831.9	916.9
Sulfate	"	<5	6.0	6.	<5	<5.0	6.	37	40.	32.	41.0	44.0	36.	16.	16.	14.	2030	2400.	3800.	10	13.	10.	42.	41.
Iron	"	<0.05	0.08	0.07	<0.05	<0.05	<0.05	0.05	0.05	0.07	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	42.0	78.	390.	<0.05	<0.05	<0.05	0.12	0.20
Manganese	"	<0.01	0.01	<0.01	<0.01	0.01	<0.01	0.08	0.78	0.56	0.06	0.36	<0.01	<0.01	0.01	<0.01	0.52	1.2	3.00	<0.01	<0.01	<0.01	0.01	0.18
Arsenic	"	0.03	0.02	<0.01	<0.01	<0.01	<0.01	1.6	1.50	<0.01	1.5	1.40	<0.01	0.05	0.05	<0.01	0.01	<0.01	0.03	<0.01	<0.01	<0.01	0.58	<0.01
TDS	"	85	131.	131.	60	94.	94.	3824	4510	4509	3773	4317.	4096.	160	208.	239.	2219	2660.	4390.	84	115.	129.	2292.	2592.
Boron	"	0.05	0.02	0.03	0.05	<0.01	0.03	13.5	11.2	11.6	12.8	11.2	12.9	0.13	0.08	0.15	–	0.50	0.09	0.05	<0.01	0.03	6.0	6.4
Lithium	"	0.44	3.4	0.30	0.04	0.03	0.03	14	14.	13.0	14	13.8	13.0	0.70	0.78	0.70	0.03	0.04	0.07	0.05	0.04	0.03	8.0	8.0
Bromide	"	0.6	<0.1	<0.1	0.4	<0.1	<0.1	4	3.8	1.9	4.2	4.0	2.1	<0.1	0.2	<0.1	<0.1	< 0.1	< 0.1	0.4	<0.1	<0.1	4.7	1.4
Hydrogen	"	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	40.0	61.	–	–	–	–	–

NUMBERS SUBMITTED AS RECEIVED FROM BC LABS.

6.8 Revegetation

In 1980, Union and a local firm, Plants of the Southwest, worked out an appropriate revegetation program for the Baca wellfield.

Recommendations for erosion control and increasing revegetation success included:

1. Cut all disturbed slopes at a 2:1 angle.
2. Return top soil to exposed azonal surfaces of cuts or fills.
3. Seed/plant seedlings in September.
4. Apply tackifier, jute netting or mulch when possible.

The basic requirements of the revegetation program were to cover disturbed slopes with vegetation as soon as possible for erosion control, to provide a native base to the biotic community and to provide visual appeal.

A complex seed mix was agreed upon to maximize the success of these three requirements.

The following species complex was planted:

GRASSES

Agropyron riparium	streambank wheatgrass
A. smithii 'Rosanna'	western wheatgrass
A. caninum	slender wheatgrass
Agrostis alba	redtop
Festuca arizonica	Arizona fescue
F. ovina	sheep fescue
F. thurberi	Thurber's fescue
Poa pratensis	Kentucky bluegrass (naturalized in Jemez Mts.)

Blended to be hand-broadcast at a rate of 18 lbs/acre.

LEGUMES

Latnyrus arizonicus	Arizona peavine
Lupinus alpestris	mountain lupine
L. argenteus	silvery lupine
Thermopsis pinetorum	golden banner
Trifolium repens	white clover
Vicia americana	American vetch

Above legumes, treated, inoculated with nitrogen fixing bacteria, and custom blended to be hand-broadcast at a rate of 4 lbs/acre.

SHRUBS

Potentilla fruticosa	shrubby cinquefoil
Ribes aureum	goden currant
Rosa woodsii	wild rose

Blended and hand-broadcast at a rate of 2 lbs/acre.

FORBS

Achillaea millefolium	yarrow
Chrysanthemum leucanthemum	ox-eye daisy
Erigeron superbus	fleabane
Helenium hoopesii	orange sneezeweed
Iris missouriensis	wild iris
Ipomopsis aggregata	skyrocket
Linum lewisii	blue flax
Oenothera hookeri	evening primrose
Penstemon barbatus	scarlet bugler
P. palmeri	Palmer penstemon
P. strictus	Rocky Mountain penstemon
Potentilla hippiana	cinquefoil
Viguiera multiflora	showy goldeneye

Blended and hand-broadcast at a rate of 2 lbs/acre.

The mix was hydroseeded onto slopes at a rate of 26 lb/acre with a mulch and tackifier hydroseeded over it. In places where slopes were 1:1, a jute netting was laid over the top edge of the slope. Hydroseeding was done in September/October. A total of 20 acres was hydroseeded in 1980 and 1981. Seed mixes were hand cast onto additional areas where appropriate.

The very dry winter of 1980-81 resulted in 80% loss of seed planted to steep southeasterly facing slopes. All other slopes show cover. There have been favorable comments regarding the wildflowers.

Seedling trees were planted onto slopes where erosion control was especially critical. Approximately 8,000 two-year old seedling trees were planted from 1979 through 1981.

Ponderosa Pine		(50%)
White Fir	)	
Douglas Fir	)	(50%)
Colorado Blue Spruce	)	

In 1979, trees were received from the State of New Mexico Forestry Department. Better than 50% died. In 1980, trees were again received from the New Mexico Forestry Department and a separate shipment was received from Colo-hydro Nurseries located in southern Colorado. The trees from Colo-hydro had a much higher survival rate than the trees from the State, so 4,000 trees were received from Colo-hydro in 1981.

In 1981, four local young people were hired to plant trees in an effort to provide summer work for local students. Planting went very well, and trees were not held in containers for long periods of time which should have resulted in a decreased death rate among seedlings.

Trees were hand planted into small depressions dug into the slope as catchment basins. On two wellpad cuts, Baca Nos. 15/19 and Baca Nos. 17/20 seedlings were planted in horizontal ridges or terraces. No exclosures or mulch were added to any planting.

In 1980-1981 seeds were collected from native oaks and planted into steep slopes in appropriate habitat. Seedling oaks and roses were collected from B5A pipeline cut and transplanted to exposed surfaces in appropriate habitat. About 50% success in transplanted seedlings was observed. It is presently too early to determine the percent success of oak seed plantings.

Revegetation will continue through September 1982.

6.9 Noise Monitoring

A study of the ambient noise levels in Redondo Canyon and in public areas around the Baca Ranch was initiated in October 1979 by Union to determine if noise was an environmental problem of any significance. The State of New Mexico presently has no ambient noise level regulations except for a general "nuisance" law. Basic public relations with "neighbors", however, makes noise monitoring a reasonable part of an environmental monitoring program.

Four (4) sites were selected in the Villages of La Cueva and Thompson Ridge Estates to determine ambient noise levels in populated areas. One point was located at a white gate along the Sulphur Creek Road at about 8,000' directly west of Baca wellfield and separated from Redondo Canyon by Redondo Border. A second point, labeled Thompson Ridge Overlook, was located along the road to Thompson Ridge Estates where it overlooks Sulphur Canyon just northwest of the Sulphur Canyon study site and located at about 9,000'. A third point was located in the Village of Thompson Ridge Estates on the south edge of a large grassy park. A fourth point was located in the Village of La Cueva just south of San Antonio Creek and west of Highway 4 where the road bordering the creek branches to form a Y.

Sites were selected at La Cueva picnic ground, Battleship Rock picnic ground and Redondo campground because of heavy public use of these areas during summer and some winter months.

Baca Ranch headquarters was selected because it is the nearest concentration of ranch personnel to the Redondo Creek wellfield.

Within the Baca wellfield, sites were selected to the northeast (Baca No. 16 overlook), east (Baca No. 4 wellpad), west (Baca Nos. 15/19 wellpad) and southwest (Redondo Creek Water Station) of the field, and one site (200' MET tower) was located in the center of the field. Study sites are located on the map in Figure 6.9-1.

Noise measurements are taken as weighted dB(A) levels using a Genrad 1981B precision sound level meter with digital readout and capture display calibrated with a Genrad GR1567 sound level calibrator.

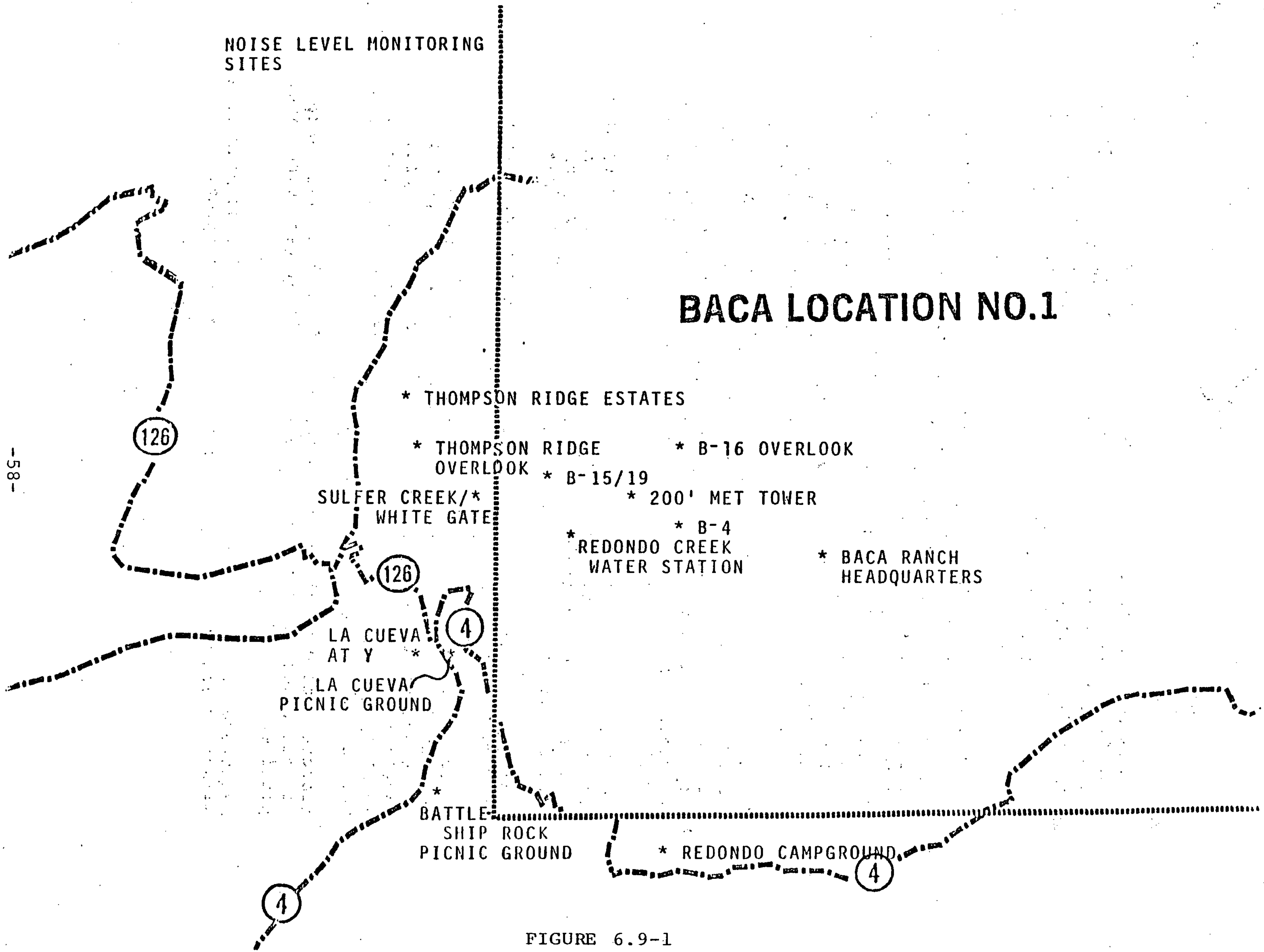

NOISE LEVEL MONITORING
SITES
BACA LOCATION NO.1
* THOMPSON RIDGE ESTATES
* THOMPSON RIDGE
OVERLOOK
* B-16 OVERLOOK
* B-15/19
* 200' MET TOWER
SULFER CREEK/*
WHITE GATE
* B-4
*
REDONDO CREEK
WATER STATION
* BACA RANCH
HEADQUARTERS
126
126
4
LA CUEVA
AT Y *
LA CUEVA
PICNIC GROUND
*
BATTLE
SHIP ROCK
PICNIC GROUND
* REDONDO CAMPGROUND
4
4

FIGURE 6.9-1

Measurements are taken at 15 second intervals and a histogram of sound levels is generated. Measurements continue at each site until 100 readings or until 25 readings of a dB(A) level are taken. Surveys of fewer than 25 readings have been deleted from the study. Notes at each survey identify sources of noise and activities in the area. Samples are run without regard to drilling activities in Baca wellfield.

The most common sounds in the populated areas were generated by traffic, construction, animals and wind. High decible levels were typically generated by airplanes and traffic. At times a humming from a drilling rig could be heard faintly in Sulphur Canyon during 1980-81 but the direction of the sound was indiscernable and could have been from Fenton Hill or Redondo Canyon. The sound was always too faint to contribute to noise levels about L_1. A drilling rig could be heard occasionally at Baca Ranch headquarters but again the sound was faint enough to not contribute significantly to noise levels above L_1.

Noise levels in campgrounds and picnic areas were typically generated by traffic, people, wind and running water. High decible levels were typically generated by traffic and airplanes. A drilling rig was heard once only at Redondo campground and the sound did not contribute significantly to decible levels above L_1.

Baca wellfield noise levels varied greatly with activity in the canyon. At no time, however, did L_{50}'s approach the OSHA workplace standard for ambient noise levels. On only one occasion did an ambient reading exceed the 90 dB(A) level.

Histograms generated at individual sites are available from Union's Rio Rancho or Santa Rosa Offices.

Noise level samples were also taken at specific sites in Redondo Canyon to determine potential exceedences of OSHA workplace noise level standards. OSHA standards for noise levels in the workplace requires ambient levels no higher than 90 dB(A) during an 8 hour work period, and levels no higher than 100 dB(A) for 2 hour periods.

Measurements were taken inside and outside of the field shop without regard to activity to develop an "average" sound level profile.

Measurements taken near wells on test were collected near or at meters or equipment that required personnel attention.

Measurements taken at rigs were collected on the ground near equipment, pipelines or pits where production personnel would work. Measurements were taken without regard to drilling activity to develop an "average" sound level profile.

Measurements were collected at an injection pump and during a wireline test even though personnel would typically not be operating these two pieces of equipment for 1-8 hour periods. The wireline generated highest noise level when it was being reeled in. During normal operation the wireline generator produced noise levels below 85 dB(A).

Figures 6.9-2 through 6.9-6 identify L_{99}'s, L_1's and L_{50}'s of workplace noise levels at the places previously discussed. Graphs were generated from histograms taken at each site. The noise source for each histogram is identified where the noise source varies in a graph. (See Figures 6.9-5 and 6.9-6).

Results of the workplace study indicate that workplace noise levels on the Baca Project met OSHA requirements.

FIGURE 6.9-2

INSIDE BACA OFFICE/SHOP

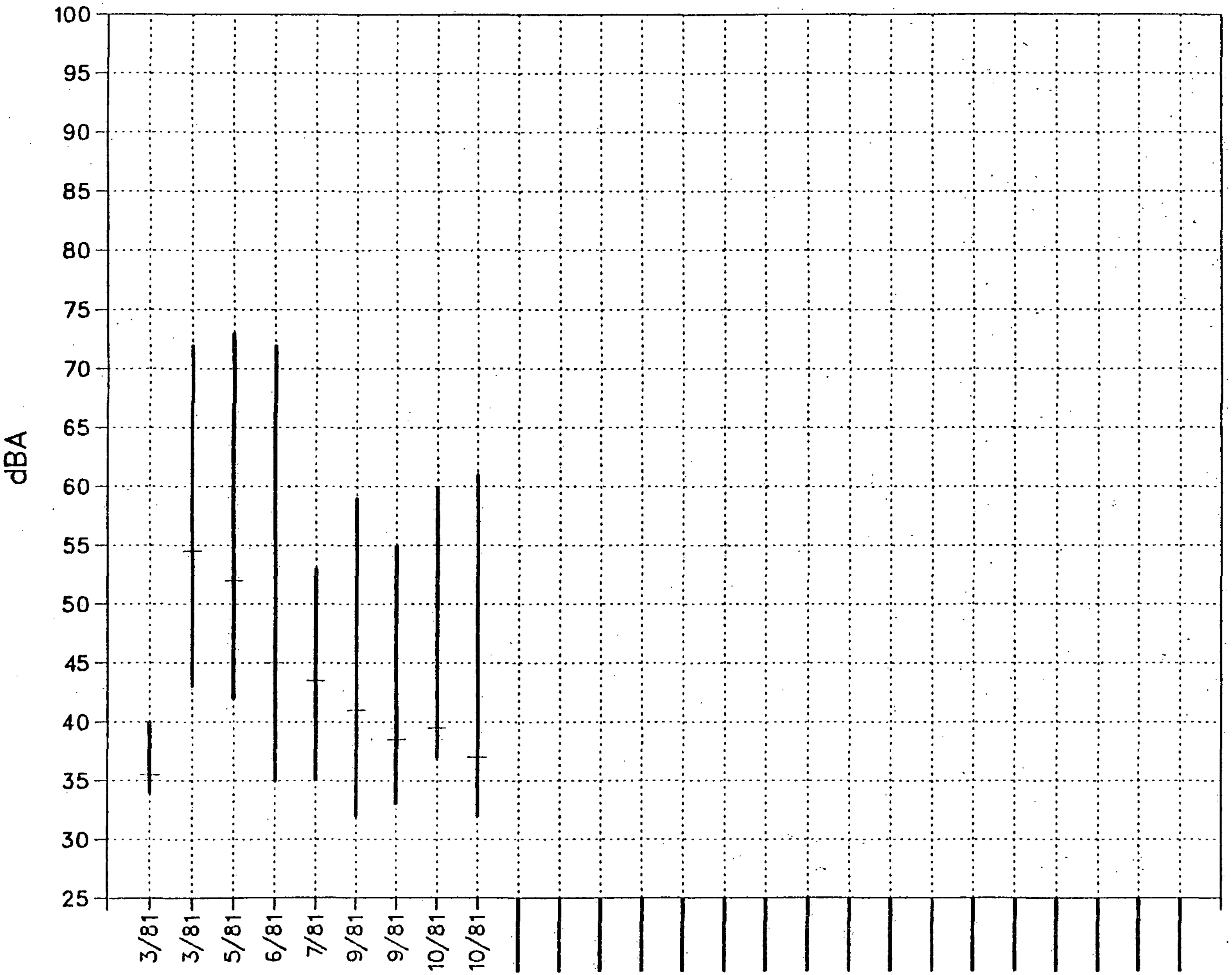
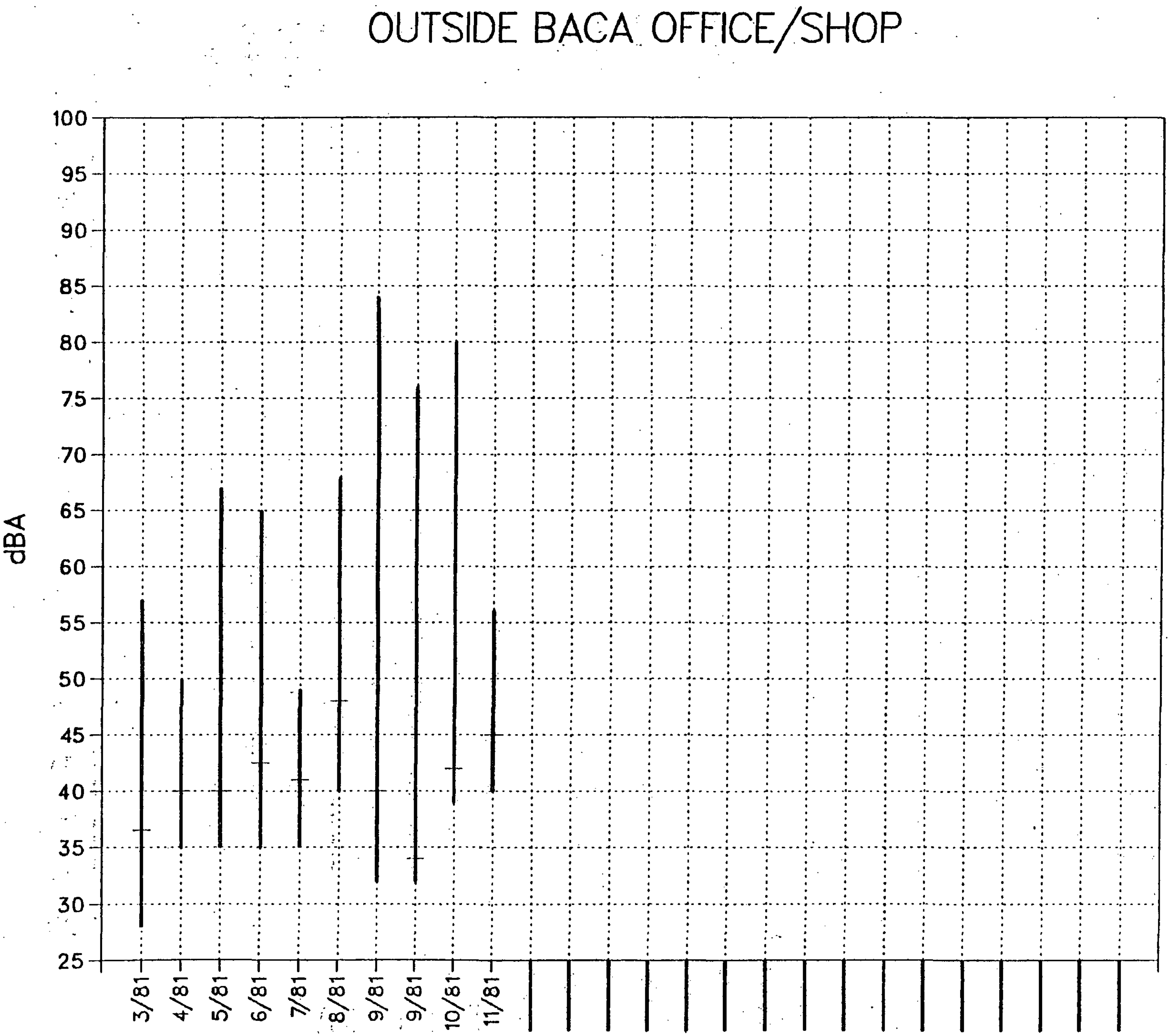


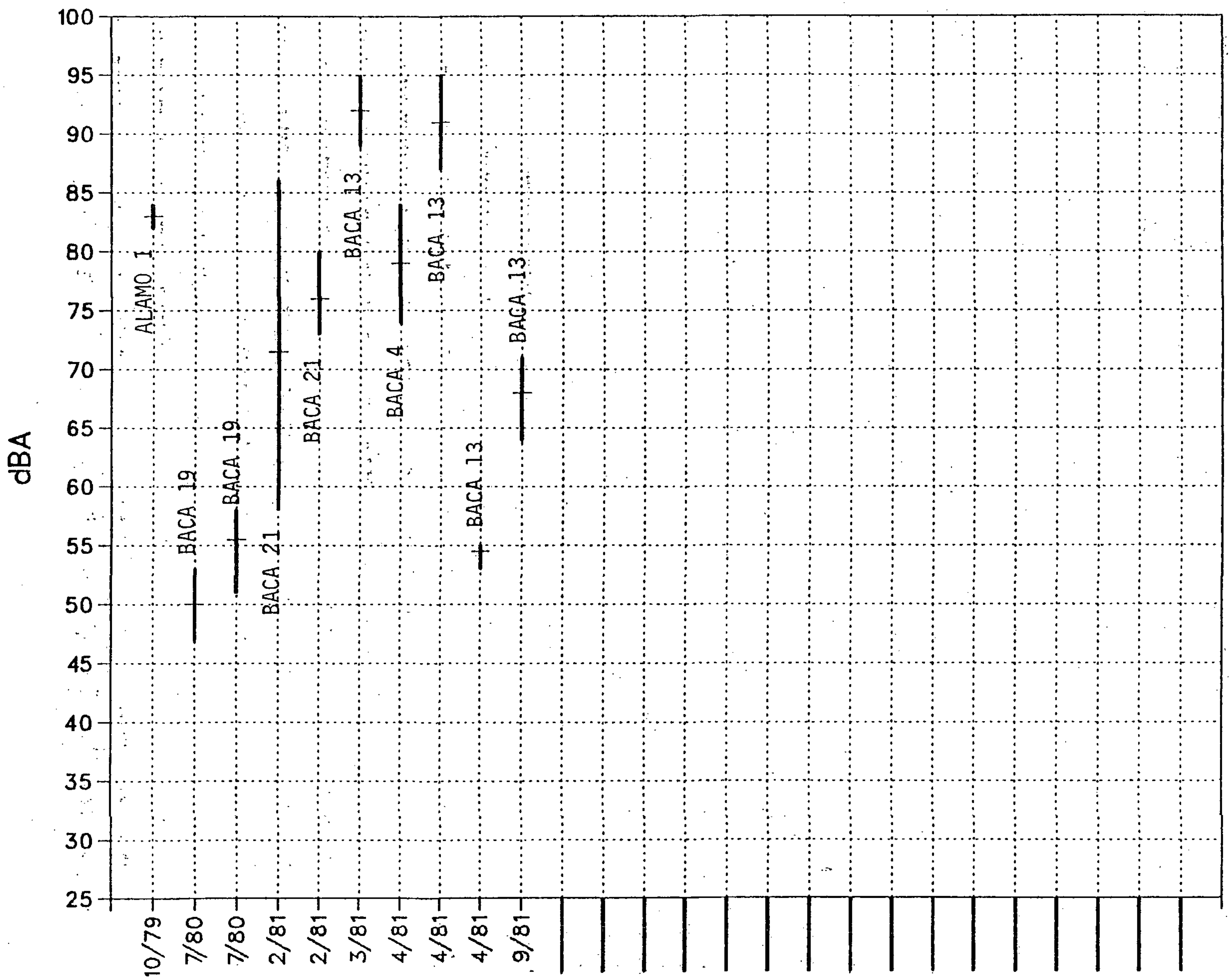
FIGURE 6.9-3



OUTSIDE BACA OFFICE/SHOP
dBA
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
3/81
4/81
5/81
6/81
7/81
8/81
9/81
9/81
10/81
11/81

FIGURE 6.9-4

WITHIN 500 FT OF WELL ON TEST



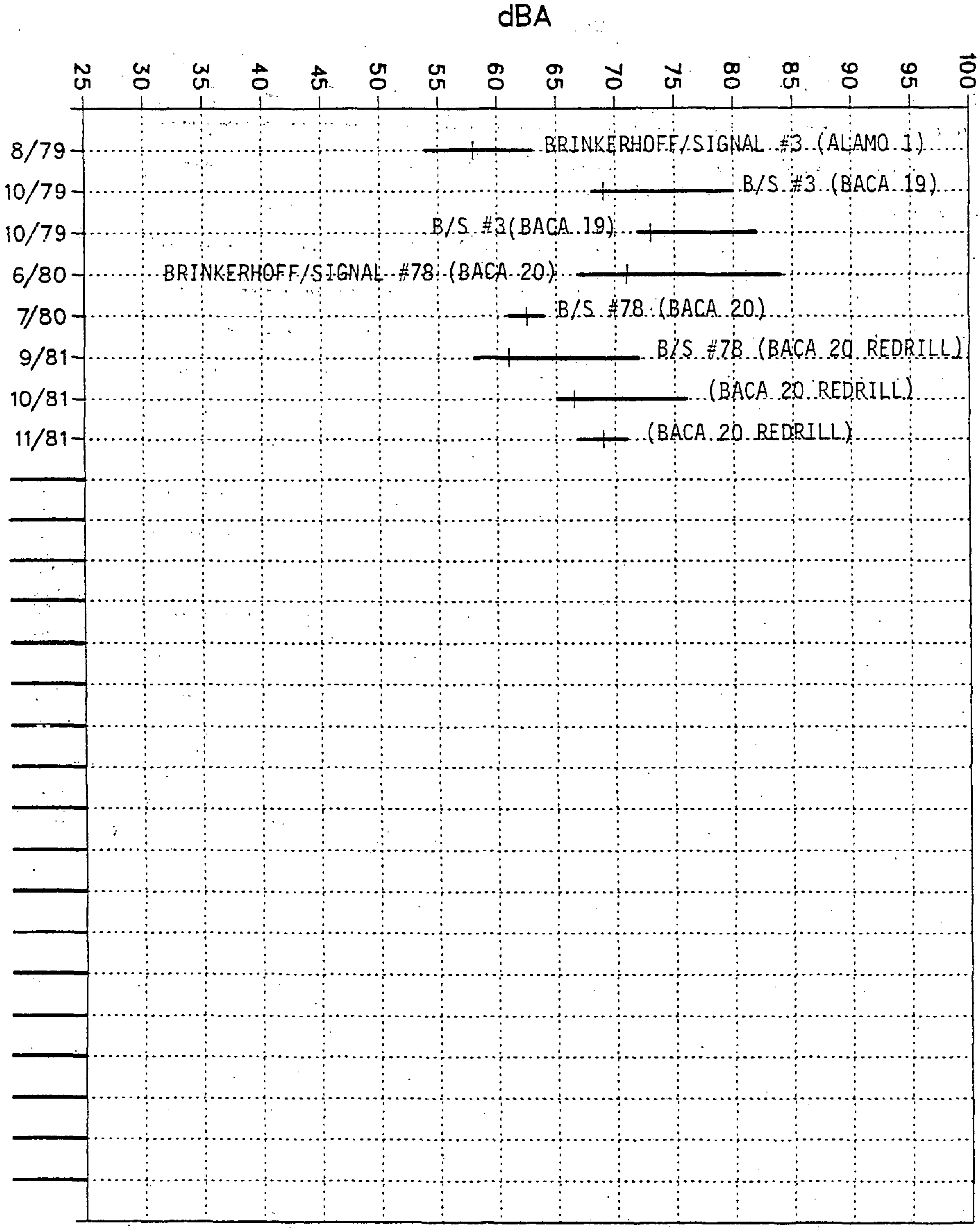
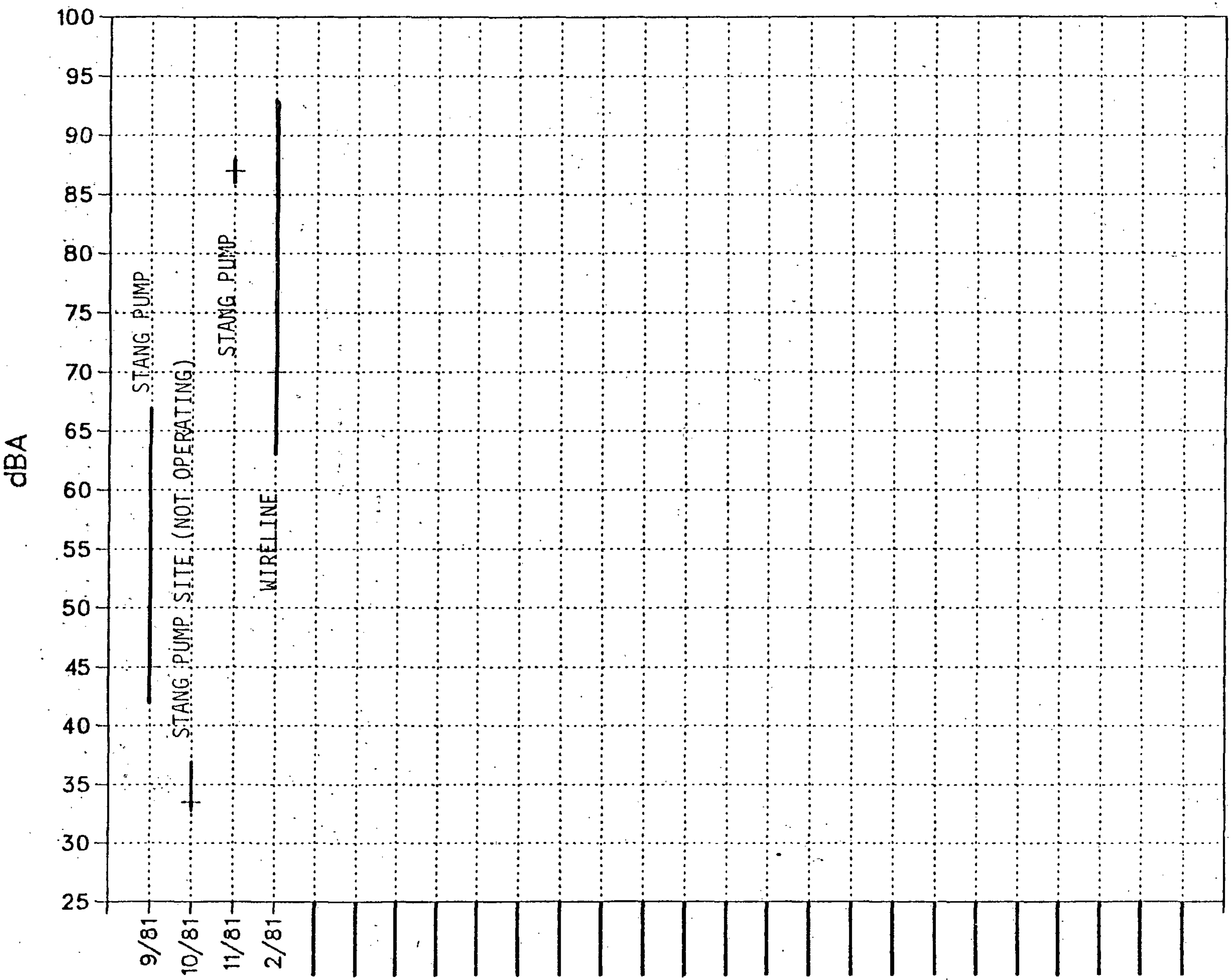


FIGURE 6.9-5

WITHIN 500 FT OF ACTIVE RIG

FIGURE 6.9-6

OPERATING EQUIPMENT



SECTION 7: PRODUCTION-SYSTEM ENGINEERING

Union was responsible for providing production and injection system piping, steam separation facilities, and associated pumps, valves and controls for the Baca GDPP Project.

The design of the steam production system included three satellite separator stations located in the wellfield, each combining the output of several wells. The locations of these stations are indicated in Figure 7-1, Conceptual Fluid Production Pipeline System.

The production system design utilized a single-flash steam separation system. During system operation, two-phase fluid is transported through pipelines from several wells to localized satellite flash separators. Steam flashed in the separators is piped to the power plant and unflashed liquid is transported to an injection facility. Noncondensible gases are removed from the geothermal fluid (steam phase) in the turbine exhaust-steam condenser by steam ejectors and processed by a hydrogen sulfide abatement system.

Design of the Baca system progressed through several stages, borrowing from experience with the Philippine geothermal systems. Following is a description of the design process begun in late 1979 and concluded in mid-1981.

7.1 Overall 50 Mw Preliminary Design

The concept for the Baca 50 Mw Power Plant geothermal system came from the Union Oil/Public Service Company of New Mexico joint PON, which presented a satellite system. This concept, proven in the Philippines, groups production wells to minimize two-phase flow lines into several separation facilities (satellites) from which single-phase fluid is piped to the plant and to injection wells. Drilling results prior to 1980 dictated three satellite stations in the Redondo Creek Canyon with 5 to 6 wells each. Preliminary design began with a flow diagram to delineate the vessels, connections, control valves, pumps and liquid storage area needed for a 50 Mw plant (see Figure 7.1-1). From this, a heat and mass balance was performed (using estimated flow rates for future wells) to determine equipment capacities. In conjunction, a layout on a map of the area was made to position satellite and injection facilities relative to the plant. Satellites were located on larger well pads, generally lower in elevation from the wells feeding into it to minimize two-phase slugging in the well-to-separator piping.

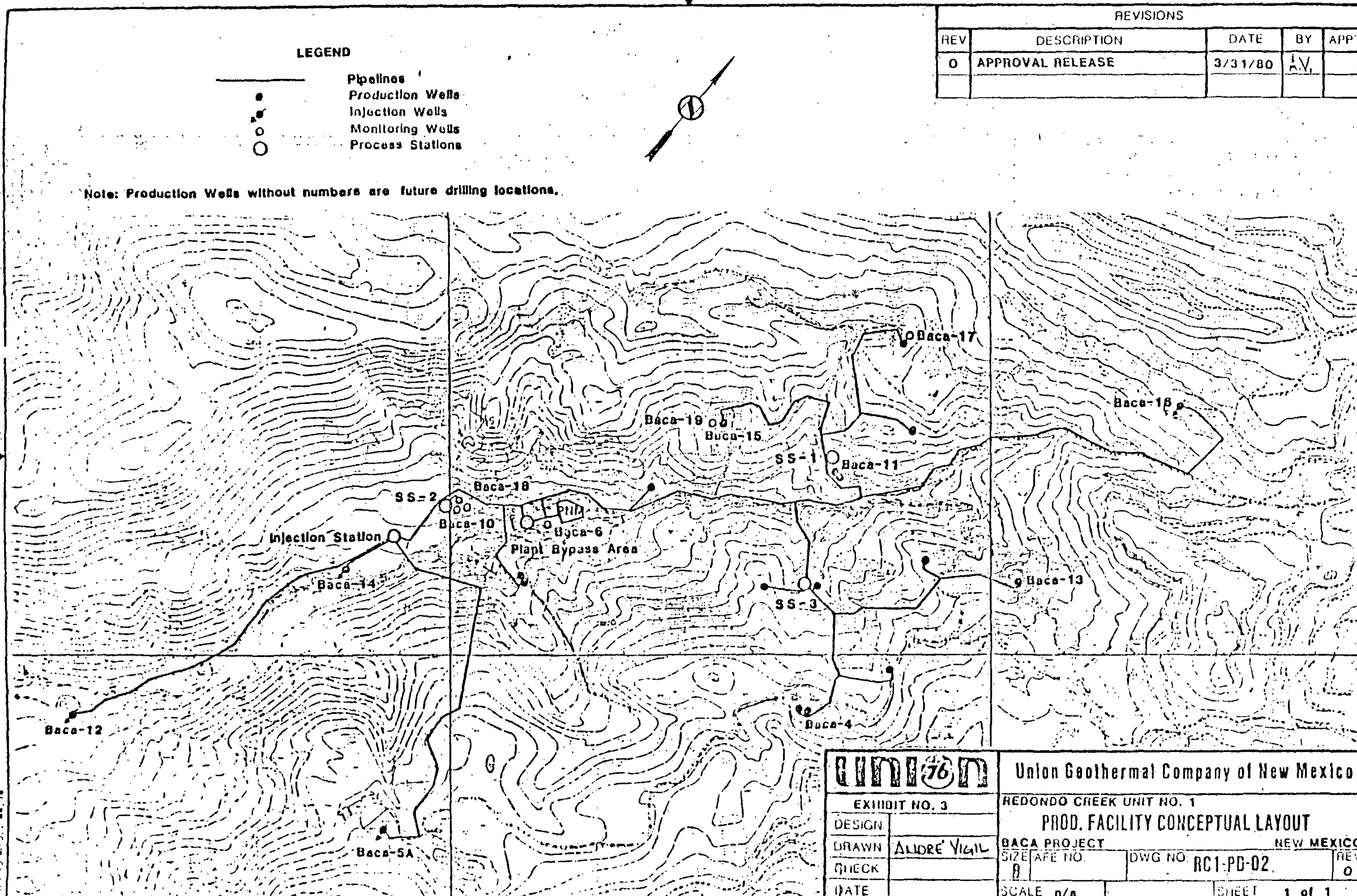
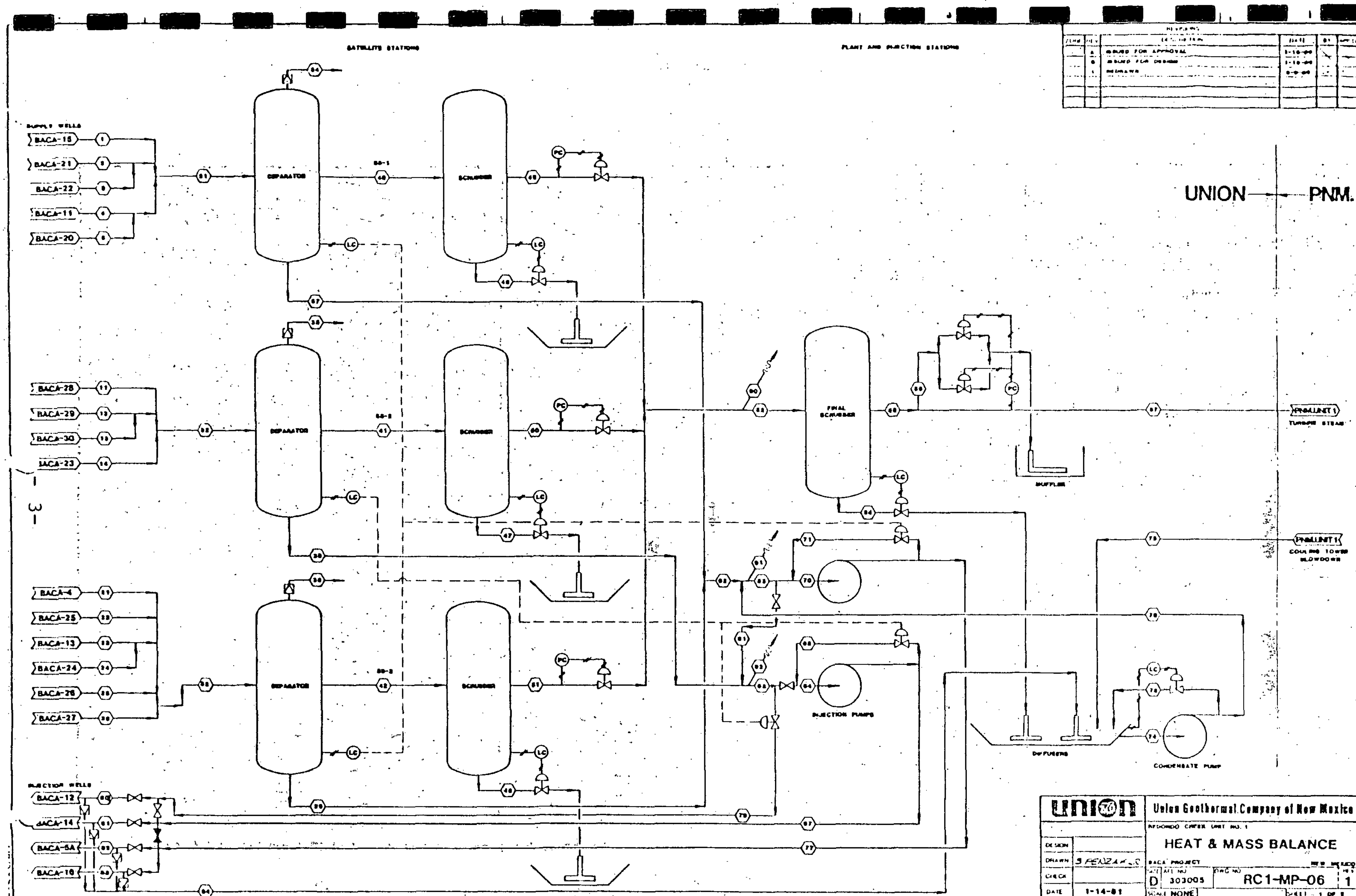

REVISIONS
REV | DESCRIPTION | DATE | BY | APP'D
0 | APPROVAL RELEASE | 3/31/80 | A.V.
LEGEND
Pipelines
Production Wells
Injection Wells
Monitoring Wells
Process Stations
Note: Production Wells without numbers are future drilling locations.
Baca-17
Baca-16
Baca-19
Baca-15
SS-1
Baca-11
Baca-18
SS-2
Baca-10
Baca-6
Injection Station
Plant Bypass Area
Baca-14
Baca-13
SS-3
Baca-4
Baca-12
Baca-5A
EXHIBIT NO. 3
DESIGN
DRAWN Andre' Vigil
CHECK
DATE
Union Geothermal Company of New Mexico
REDONDO CREEK UNIT NO. 1
PROD. FACILITY CONCEPTUAL LAYOUT
BACA PROJECT
NEW MEXICO
SIZE B
AFE NO.
DWG NO. RC1-PD-02
REV 0
SCALE n/a
SHEET 1 of 1

FIGURE 7-1



SATELLITE STATIONS
PLANT AND INJECTION STATIONS
SUPPLY WELLS
BACA-15
BACA-21
BACA-22
BACA-11
BACA-20
BACA-28
BACA-29
BACA-30
BACA-23
BACA-4
BACA-25
BACA-13
BACA-24
BACA-26
BACA-27
INJECTION WELLS
BACA-12
BACA-14
BACA-5A
BACA-10
SEPARATOR
SCRUBBER
FINAL SCRUBBER
MUFFLER
INJECTION PUMPS
DIFFUSERS
CONDENSATE PUMP
UNION
PNM.
PNM UNIT 1
TURBINE STEAM
COOLING TOWER BLOWDOWN
Union Geothermal Company of New Mexico
REDONDO CREEK UNIT NO. 1
HEAT & MASS BALANCE
BACA PROJECT
NEW MEXICO
D
303005
RC1-MP-06
1
1-14-81
NONE

FIGURE 7.1-1

Piping and instrumentation drawings, P&ID's, were developed to detail the 50 Mw gathering system. Five sheets were used, one for each of the three satellites, one for the plant area scrubbing and vent system and one for the injection facilities. The satellite P&ID's were copies of each other for the major part of the drawing. Well names and certain junction points differed. A numbering system was developed for valves, vessels, pipelines and other equipment and instrumentation to identify them and locate them relative to the P&ID, and therefore to the general area of the plant.

7.2 Satellite Station 1 Detailed Design

Satellite Station 1 (SS-1) was so designated because it was to be the first area drilled and the first section of the gathering system to be constructed. Since definite construction seasons existed between the winter snows, SS-1 was to be constructed more than a year before the plant would be operational. By building SS-1 with temporary connections and with most of the injection lines, the satellite could be operated to prove up the design, and to provide operating experience for the field personnel. Therefore, the next step of the design was to develop a complete design for SS-1 and the required injection system.

Two P&ID's were redrawn and revised to reflect the temporary hookups for SS-1 and the Injection Station (see Figures 7.2-1 & 7.2-2) and incorporate the following changes. By using the elevation changes in the field, there would be no need for injection pumps at the lower flow rates of one satellite station. A control valve off the satellite separators would provide back pressure to simulate a turbine inlet. An extra connection into the satellite station diffuser sump would provide for steam blow off.

Several items were identified as long delivery items. A complete specification for SS-1 vessels was prepared. It was felt that two vessels, a separator and a steam scrubber, would be more flexible and produce cleaner steam over a wide range of inlet conditions, since the wells in the Baca field varied considerably in percent flash. The vessels were specified as 500 psig design pressure because a large pressure control valve was to be placed on the steam outlet of the second vessel. This valve would be used to increase pressure in the vessel to reduce the flow rates from the wells during curtailment or shutdown of the plant. The vessel specification was sent to three vendors for bid, and CENatco was chosen early in 1980. The vessels for SS-1 were placed on order for fall delivery.

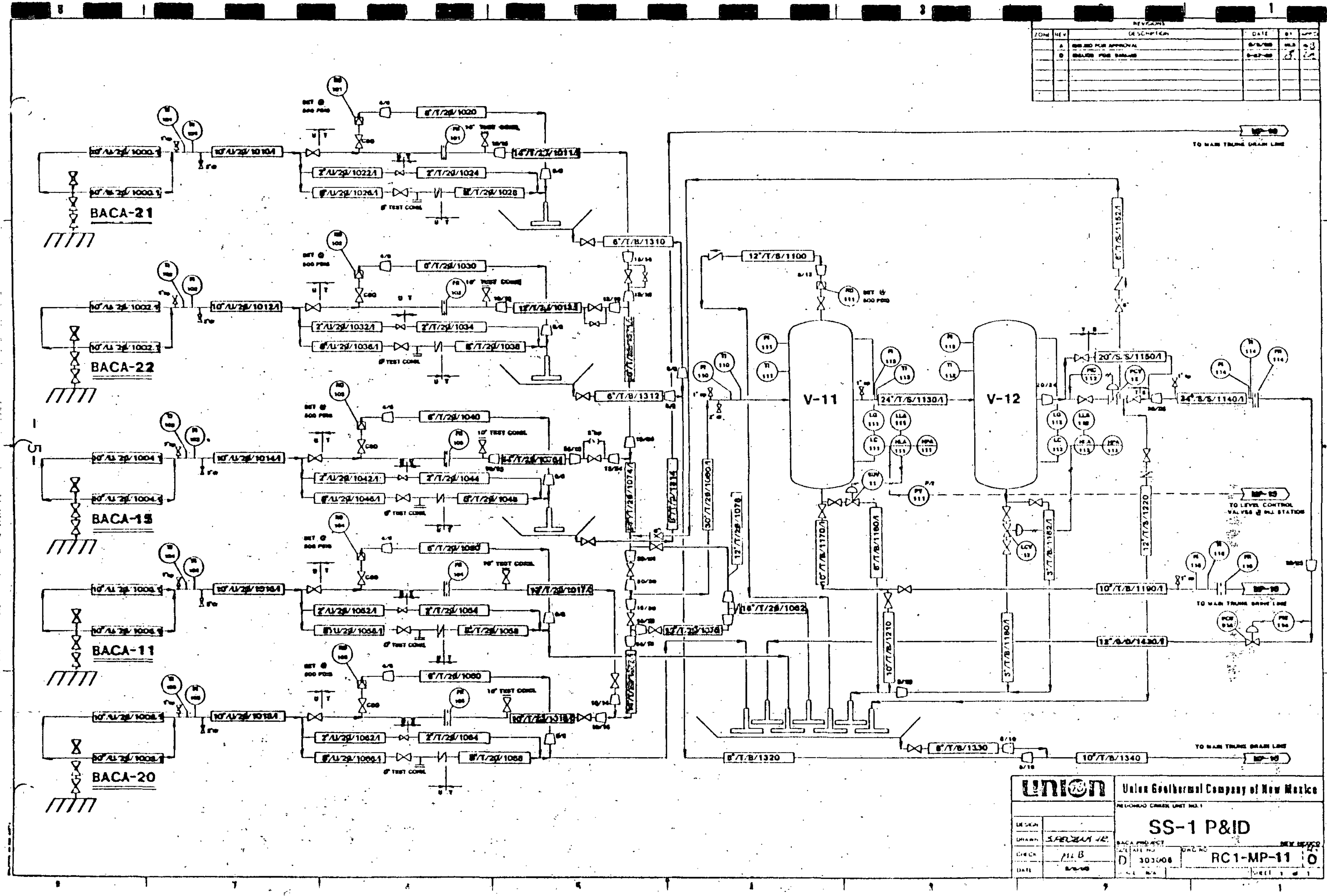
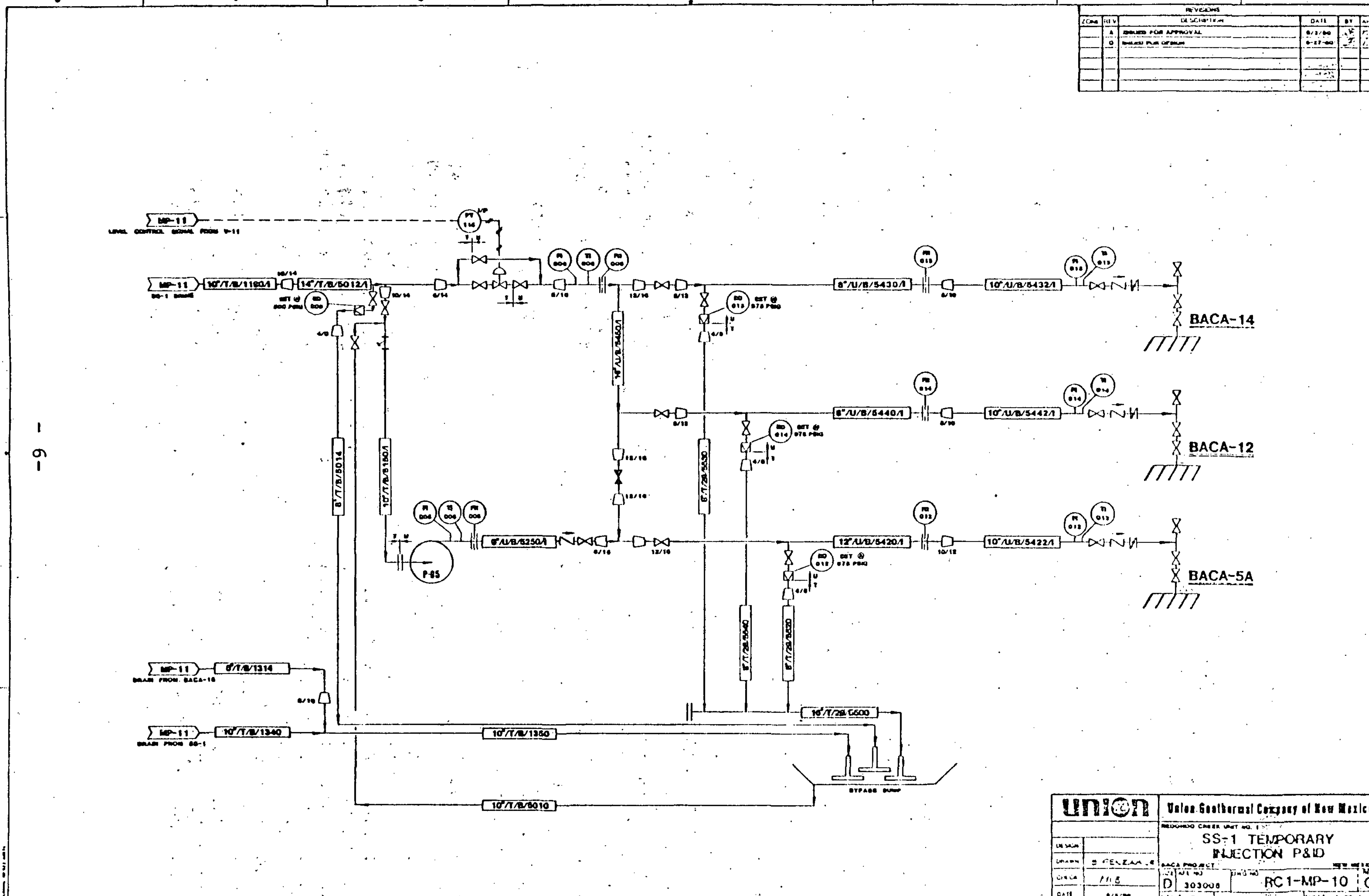

BACA-21
BACA-22
BACA-15
BACA-11
BACA-20
V-11
V-12
TO MAIN TRUNK DRAIN LINE
TO LEVEL CONTROL VALVES @ PLL STATION
Union Geothermal Company of New Mexico
SS-1 P&ID
RC1-MP-11

FIGURE 7.2-1



MP-11
MP-11
MP-11
MP-11
10"/T/B/1160/1
14"/T/B/5012/1
14"/U/B/5450/1
8"/T/B/5014
10"/T/B/5150/1
8"/U/B/5250/1
P-85
8"/U/B/5430/1
10"/U/B/5432/1
8"/U/B/5440/1
10"/U/B/5442/1
12"/U/B/5420/1
10"/U/B/5422/1
BACA-14
BACA-12
BACA-5A
8"/T/B/1314
10"/T/B/1340
10"/T/B/1350
10"/T/B/5010
10"/T/2B/5500
BYPASS SUMP
Union Geothermal Company of New Mexico
SS-1 TEMPORARY
INJECTION P&ID
RC1-MP-10

FIGURE 7.2-2

-9-

The other long-lead items were control valves and large block valves. From experience in the Philippines and Geysers operations, the control valves were to be Fisher vee-ball type, and the block valves were to be WKM SAF-T-SEAL gate valve type. Both were specified with the help of the vendor and Union's research department and placed on order. The block valves were those valves in 500 psig or 975 psig design pressure lines, 8" and larger. The control valves were the steam back pressure valve (a butterfly due to its 20" size), a liquid level control valve for each of the vessels and vent valve to act as turbine inlet.

The next step in design involved layout of actual rights-of-way for flow lines and placement of the lines. The design of SS-1 and injection facilities was intended to use lines which would be final full-scale system lines where possible. Rights-of-way were to use existing roads to mitigate damage to the natural vegetation. Also, any lines which could run in parallel on the same supports were to do so. Since SS-1 was at the opposite end of the field from the injection wells, most of the rights-of-way for the first construction would be used for Satellite Stations 2 and 3 piping to the plant and injection wells. A local civil engineering firm had flown the area and provided the mapping of the gathering system terrain, so the initial rights-of-way were spotted using a stereo scope and photographs. The major road through the field would carry the separator liquid down past the plant and to the injection wells (see Figure 7.1-1). The main steam line and sump drain lines would be added in the second year of construction. Roads to each of the well locations were used for most of the well flow lines, cutting off some of the curves by going cross-country. The civil engineering firm took the right-of-way layout, prepared plan and profile drawings and laid out the route in the field with stakes.

Most roads as they existed were not wide enough to accommodate the new lines, so the civil engineering firm was commissioned to design the earth work necessary to widen and stabilize the roads. They prepared civil drawings sufficient to use to request bids of that work along with pipeline construction. The pipelines were laid out on the plan and profile drawings, putting supports every 40 feet on most lines. Using a rule of thumb of an anchor every 320 feet with an expansion loop between anchors, the line was drafted onto the plans and profiles as a first approximation. Each section between anchors was then coded up into computer input files for the ADLPIPE computer program for stress analysis. ADLPIPE, a stress design program from the Arthur D. Little Company, was used for design of the Brawley steam gathering system on an outside computer system. The program was purchased for the Union Oil computer system for this and future gathering systems because the expenditure in computer time equalled the cost of the program for the Brawley system. Each of the piping sections was stress analyzed for thermal and pressure loads, deadweight and seismic according to ANSI code B31.1 for Power Piping. Most of the sections were predicted to have stresses below the allowable since the rule of thumb was conservative. Those sections which had stress overages were redesigned as necessary and rerun along with the sections on either side if they were modified. This was the first use of ADLPIPE on the Union Oil system, and very valuable experience in computer modeling of pipeline systems was gained during this phase.

As pipeline sections were completed, the marked-up plan and profile drawings were drafted into construction plans and profiles, showing line angles, elevations, slopes, supports, anchors, guides, connections and expansion loops. These were the major part of the mechanical bid package.

A pipeline material take-off was made up and bids acquired by purchasing for pipe and fittings. Deliberate overages were added to ensure that enough material was on hand, with the knowledge that two more satellite stations were to be built.

The mechanical construction bid package was put together including the pipeline drawings (in a preliminary issue), welding specifications, general specifications, safety rules and miscellaneous required forms. A pre-bid letter was sent out to those local contractors who might be interested. From the response to that letter, only three contractors received bids. The winning bid, by a considerable margin, was a California-based contractor who had built several Geysers systems. However, licensing problems in New Mexico prevented them from being awarded the job. A subsequent rebid confirmed their numbers, but continued licensing problems delayed construction until early October 1980. Little reasonable weather was expected to remain for construction at that time, so no contract was awarded and the bids were to be reissued early in 1981 to start construction just after the spring thaw.

7.3 Additional Design Work

In the interim, the construction drawings were completed and instrumentation specifications were made up. Attention was turned to the complete 50 Mw system, since it looked as though SS-3 would be constructed in the same year as SS-1 in order to meet plant startup early in 1982. No right-of-way planning could be accomplished until the SS-3 roads and well locations were installed, so the next design item was the full scale Injection Station. Several schemes for injecting the brine from three Satellite Stations into three wells were considered. The best scheme assigned a well to each Satellite Station, with manifolding to switch wells and station output. Two wells were lower and one higher in elevation from the Injection Station, requiring various pump head and flow conditions. A bid package was made up for the injection pumps including variable speed electric drivers to allow the most flexibility in pump output. Seven pump companies responded with detailed bids, but it was evident that the inquiry required too much of the pumps. The use of three pumps per satellite (one standby) at a 600 psi output meant small multi-stage pumps where single stage pumps were preferred. This led the design to be re-evaluated as to the number of pumps and standby capacity. The variable speed drivers appeared promising in concept, though limited in horsepower and high in cost. Variable speed couplers between driver and pump looked best in terms of maintenance, cost and flexibility.

It was intended that the pump bids and the mechanical bid be reissued in early spring 1981. At that time the project was delayed indefinitely so no further bids were requested. Vessels, block valves and control valves were ordered for SS-3 due to long deliveries, all copies of the SS-1 design. No further design work was performed on SS-3.

In the summer of 1981, the feasibility of tying two wells in the SS-3 area into SS-1 was studied, including a survey of the rights-of-way (using existing roads), stress analysis and layout of the pipelines. Stress analysis was completed, but construction drawings were never made up.

SECTION 8: WBS 1.1 COSTS - WELL AND STEAM PRODUCTION

8.1 Summary of Actual Expenditures

Table 8.1-1 is a summary of actual expenditures for WBS 1.1 incurred as of January 31, 1982. The total amount expended is a tabulation of the DOE monthly billings that were issued by Union Geothermal Company of New Mexico and the amount that Union expended on the Project prior to October 1978.

Please note that the DOE's share of the expenditures made by Union prior to October 1978 was for the transfer of data from Union to the DOE.

The cost data from Table 8.1-1 is summarized below.

Summary of Expenditures ($000)

Description	Total Expenditure	DOE's Share	Union's Share
WBS Element 1.1.1	$ 518	$ 201	$ 317
WBS Element 1.1.2	28,639	16,788	11,851
WBS Element 1.1.3	3,760	1,524	2,236
WBS Element 1.1.4	12,117	4,156	7,961
WBS Element 1.1.5	0	0	0
Total	$ 45,034	$22,669	$22,365
Parties Percentage Contribution*	100%	50.3380%	49.6620%

8.2 Allocation of Costs Between Parties

The allocation of costs between the DOE and Union for the various WBS elements was based upon the DOE's desire to minimize their contributions towards the cost of salvageable material and equipment. The guidelines which were used in establishing DOE's priorities in determining their contribution are listed below in descending order.

1. Consumable items (e.g., cement, fuels and lubricants, paint, drilling mud and chemicals, drill pipe, materials which require periodic replacement, etc.)

* Parties percentage contribution calculated using dollar amounts from Table 8.1-1.

TABLE 8.1-1

BACA GEOTHERMAL
DEMONSTRATION POWER PROJECT
SUMMARY OF ACTUAL EXPENDITURES - WBS 1.1

MONTHLY ACTIVITY

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
1971-77	$	$ 8,779,691	$	$ 6,050,926	$	$ 14,830,617	$ 14,830,617
TOTAL 1971-77		8,779,691		6,050,926		14,830,617	
TOTAL TO DATE		8,779,691		6,050,926		14,830,617	
1978							
OCT.		627,392				627,392	15,458,009
NOV.		334,675				334,675	15,792,684
DEC.	638	377,608				378,246	16,170,930
TOTAL 1978	638	1,339,675				1,340,313	
TOTAL TO DATE	638	10,119,366		6,050,926		16,170,930	
1979							
JAN.		1,465,364				1,465,364	17,636,294
FEB.		367,246				367,246	18,003,540
MARCH		899,187		498,410		1,397,597	19,401,137
APRIL		335,150		54,322		389,472	19,790,609
MAY	954	101,352		51,232		153,538	19,944,147
JUNE	54,488	7,767		66,057		128,312	20,072,459
JULY	37,800	263,588		50,312		351,700	20,424,159
AUG.	6,281	4,162		44,541		54,984	20,479,143
SEPT.	10,874	17,416		43,730		72,020	20,551,163
OCT.	22,168	101,607		77,702		201,477	20,752,640
NOV.	20,536	440,576	1,124	46,390		508,626	21,261,266
DEC.	22,000	457,152	43,456	108,159		630,767	21,892,033
TOTAL 1979	175,101	4,460,567	44,580	1,040,855		5,721,103	
TOTAL TO DATE	175,739	14,579,933	44,580	7,091,781		21,892,033	

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
1980							
JAN.	208	18,135	4,493	76,127		98,963	21,990,996
FEB.	43,867	564		145,796		190,227	21,181,223
MARCH	3,502	8,036		91,265		102,803	22,284,026
APRIL	13,432	11,482		103,016		127,930	22,411,956
MAY	538	(1,829)		95,657		94,366	22,506,322
JUNE	5,632	6,646		109,794		122,072	22,628,394
JULY	17,416	347,097	65,207	144,153		573,873	23,202,267
AUG.	23,004	295,832	66,552	139,238		524,626	23,726,893
SEPT.	3,329	531,208	224,221	201,208		959,966	24,686,859
OCT.	10,735	644,073	917,377	201,931		1,774,116	26,460,975
NOV.	12,001	942,860	937,285	291,084		2,183,230	28,644,205
DEC.	64,564	938,357	231,574	372,886		1,607,381	30,251,586
TOTAL 1980	198,228	3,742,461	2,446,709	1,972,155		8,359,553	
TOTAL TO DATE	373,967	18,322,394	2,491,289	9,063,936		30,251,586	
1981							
JAN.	6,742	881,768	114,572	189,695		1,192,777	31,444,363
FEB.	1,122	407,235	75,280	268,182		751,819	32,196,182
MARCH	23,094	1,182,197	225,832	240,081		1,671,204	33,867,386
APRIL	1,237	293,029	325,694	174,833		794,793	34,662,179
MAY	9,442	572,513	48,257	493,832		1,124,044	35,786,223
JUNE	16,081	736,683	28,264	263,700		1,044,728	36,830,951
JULY	13,059	813,514	9,845	177,746		1,014,164	37,845,115
AUG.	6,770	1,471,648	111,921	214,274		1,804,613	39,649,728
SEPT.	38,952	620,465	158,077	176,479		993,973	40,643,701
OCT.	3,506	647,269		178,886		829,661	41,473,362
NOV.	12,844	757,380	145,500	181,530		1,097,254	42,570,616
DEC.	4,331	1,307,676	25,958	273,181		1,611,146	44,181,762
TOTAL 1981	137,180	9,691,377	1,269,200	2,832,419		13,930,176	
TOTAL TO DATE	511,147	28,013,771	3,760,489	11,896,355		44,181,762	

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
1982							
JAN.	3,530	475,446		134,730		613,706	44,795,468
FEB.	1,136	96,623		68,145		165,904	44,961,372
MARCH	1,731	48,514		11,906		62,151	45,023,523
APRIL		4,770		6,195		10,965	45,034,488
MAY							
JUNE							
JULY							
AUG.							
SEPT.							
OCT.							
NOV.							
DEC.							
TOTAL 1982	6,397	625,353		220,976		852,726	
TOTAL TO DATE	$ 517,544	$28,639,124	$ 3,760,489	$12,117,331	$	$ 45,034,488	

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
MONTHLY ACTIVITY - DOE SHARE							
1971-77	$	$ 4,389,959	$	$ 3,025,541	$	$ 7,415,500	$ 7,415,500
TOTAL 1971-77		4,389,959		3,025,541		7,415,500	
TOTAL TO DATE		4,389,959		3,025,541		7,415,500	
1978							
OCT.		380,311				380,311	7,795,811
NOV.		157,363				157,363	7,953,174
DEC.	319	202,686				203,005	8,156,179
TOTAL 1978	319	740,360				740,679	
TOTAL TO DATE	319	5,130,319		3,025,541		8,156,179	
1979							
JAN.		1,432,225				1,432,225	9,588,404
FEB.		174,941				174,941	9,763,345
MARCH		482,801				482,801	10,246,146
APRIL		153,625				153,625	10,399,771
MAY	477	56,693				57,170	10,456,941
JUNE	27,244	3,707		6,677		37,628	10,494,569
JULY	18,900	80,377		125,156		224,433	10,719,002
AUG.	3,140	1,994		4,995		10,129	10,729,131
SEPT.	5,437	12,361		8,551		26,349	10,755,480
OCT.	11,084	74,134		7,979		93,197	10,848,677
NOV.	10,268	287,759		8,422		306,449	11,155,126
DEC.	11,000	143,306		18,382		172,688	11,327,814
TOTAL 1979	87,550	2,903,923		180,162		3,171,635	
TOTAL TO DATE	87,869	8,034,242		3,205,703		11,327,814	

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
1980							
JAN.	104	16,680		11,555		28,339	11,356,153
FEB.	14,947	564		38,238		53,749	11,409,902
MARCH	5,022	8,036		12,984		26,042	11,435,944
APRIL	6,272	6,462		27,211		39,945	11,475,889
MAY	19	(632)		22,430		21,817	11,497,706
JUNE	2,816	1,526		18,547		22,889	11,520,595
JULY	6,479	174,284	65,207	19,465		265,435	11,786,030
AUG.	10,728	103,653	13,664	24,535		152,580	11,938,610
SEPT.	1,272	424,421	106,758	47,003		579,454	12,518,064
OCT.	4,933	353,868	375,701	42,062		776,564	13,294,628
NOV.	6,000	353,611	376,583	31,634		767,828	14,062,456
DEC.	18,968	414,773	126,123	40,299		600,163	14,662,619
TOTAL 1980	77,560	1,857,246	1,064,036	335,963		3,334,805	
TOTAL TO DATE	165,429	9,891,488	1,064,036	3,541,666		14,662,619	
1981							
JAN.	1,100	582,195	65,985	40,870		690,150	15,352,769
FEB.	561	393,393	41,325	43,945		479,224	15,831,993
MARCH	1,299	766,906	108,633	55,994		932,832	16,764,825
APRIL	618	272,845	98,729	54,521		426,713	17,191,538
MAY	625	323,819	27,438	53,067		404,949	17,596,487
JUNE	3,132	589,537	27,747	27,792		648,208	18,244,695
JULY	5,895	485,201	1,389	31,137		523,622	18,768,317
AUG.	3,385	856,870	4,397	65,562		930,214	19,698,531
SEPT.	5,661	609,021	277	31,580		646,539	20,345,070
OCT.	1,754	341,718		38,836		382,308	20,727,378
NOV.	6,422	467,140	71,282	41,328		586,172	21,313,550
DEC.	2,166	901,849	12,979	47,734		964,728	22,278,278
TOTAL 1981	32,618	6,590,494	460,181	532,366		7,615,659	
TOTAL TO DATE	198,047	16,481,982	1,524,217	4,074,032		22,278,278	

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
1982							
JAN.	1,764	463,375		42,705		507,844	22,786,122
FEB.	568	(167,346)		29,956		(136,822)	22,649,300
MARCH	865	11,550		2,986		15,401	22,664,701
APRIL		(1,781)		6,570		4,789	22,669,490
MAY							
JUNE							
JULY							
AUG.							
SEPT.							
OCT.							
NOV.							
DEC.							
TOTAL 1982	3,197	305,798		82,217		391,212	
TOTAL TO DATE	$ 201,244	$16,787,780	$ 1,524,217	$ 4,156,249	$	$ 22,669,490	

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
MONTHLY ACTIVITY - UNION GEOTHERMAL CO.'s SHARE							
1971-77	$	$ 4,389,732	$	$ 3,025,385	$	$ 7,415,117	$ 7,415,117
TOTAL 1971-77		4,389,732		3,025,385		7,415,117	
TOTAL TO DATE		4,389,732		3,025,385		7,415,117	
1978							
OCT.		247,081				247,081	7,662,198
NOV.		177,312				177,312	7,839,510
DEC.	319	174,922				175,241	8,014,751
TOTAL 1978	319	599,315				599,634	
TOTAL TO DATE	319	4,989,047		3,025,385		8,014,751	
1979							
JAN.		33,139				33,139	8,047,890
FEB.		192,305				192,305	8,240,195
MARCH		416,386		498,410		914,796	9,154,991
APRIL		181,525		54,322		235,847	9,390,838
MAY	477	44,659		51,232		96,368	9,487,206
JUNE	27,244	4,060		59,380		90,684	9,577,890
JULY	18,900	183,211		(74,844)		127,267	9,705,157
AUG.	3,141	2,168		39,546		44,855	9,750,012
SEPT.	5,437	5,055		35,179		45,671	9,795,683
OCT.	11,084	27,473		69,723		108,280	9,903,963
NOV.	10,268	152,817	1,124	37,968		202,177	10,106,140
DEC.	11,000	313,846	43,456	89,777		458,079	10,564,219
TOTAL 1979	87,551	1,556,644	44,580	860,693		2,549,468	
TOTAL TO DATE	87,870	6,545,691	44,580	3,886,078		10,564,219	

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
1980							
JAN.	104	1,455	4,493	64,572		70,624	10,634,843
FEB.	28,920			107,558		136,478	10,771,321
MARCH	(1,520)			78,281		76,761	10,848,082
APRIL	7,160	5,020		75,805		87,985	10,936,067
MAY	519	(1,197)		73,227		72,549	11,008,616
JUNE	2,816	5,120		91,247		99,183	11,107,799
JULY	10,937	172,813		124,688		308,438	11,416,237
AUG.	12,276	192,179	52,888	114,703		372,046	11,788,282
SEPT.	2,057	106,787	117,463	154,205		380,512	12,168,795
OCT.	5,802	290,205	541,676	159,869		997,552	13,166,347
NOV.	6,001	589,249	560,702	259,450		1,415,402	14,581,749
DEC.	45,596	523,584	105,451	332,587		1,007,218	15,588,967
TOTAL 1980	120,668	1,885,215	1,382,673	1,636,192		5,024,748	
TOTAL TO DATE	208,538	8,430,906	1,427,253	5,522,270		15,588,967	
1981							
JAN.	5,642	299,573	48,587	148,825		502,627	16,091,594
FEB.	561	13,842	33,955	224,237		272,595	16,364,189
MARCH	21,795	415,291	117,199	184,087		738,372	17,102,561
APRIL	619	20,184	226,965	120,312		368,080	17,470,641
MAY	8,817	248,694	20,819	440,765		719,095	18,189,736
JUNE	12,949	147,146	517	235,908		396,520	18,586,256
JULY	7,164	328,313	8,456	146,609		490,542	19,076,798
AUG.	3,385	614,778	107,524	148,712		874,399	19,951,197
SEPT.	33,291	11,444	157,800	144,899		347,434	20,298,631
OCT.	1,752	305,551		140,050		447,353	20,745,984
NOV.	6,422	290,240	74,218	140,202		511,082	21,257,066
DEC.	2,165	405,827	12,979	225,447		646,418	21,903,484
TOTAL 1981	104,562	3,100,883	809,019	2,300,053		6,314,517	
TOTAL TO DATE	313,100	11,531,789	2,236,272	7,822,323		21,903,484	

ACCTG YR/MO	WBS 1.1.1	WBS 1.1.2	WBS 1.1.3	WBS 1.1.4	WBS 1.1.5	TOTAL	TOTAL EXP. TO DATE
1982							
JAN.	1,766	12,071		92,025		105,862	22,009,346
FEB.	568	263,969		38,189		302,726	23,312,972
MARCH	866	36,964		8,920		46,750	23,359,722
APRIL		6,551		(375)		6,176	23,365,895
MAY							
JUNE							
JULY							
AUG.							
SEPT.							
OCT.							
NOV.							
DEC.							
TOTAL 1982	3,200	319,555		138,759		461,514	
TOTAL TO DATE	$ 316,300	$11,851,344	$ 2,236,272	$ 7,961,082	$ -	$ 22,364,998	

2. Intangible costs (e.g., labor, transportation, freight, consultants, equipment rentals, etc.)

3. Non-salvageable materials (e.g., casing, road surfacing materials, concrete, etc.)

4. Difficult to salvage material and equipment (e.g., pipe, transmission towers and wire, permanently affixed equipment, etc.)

5. Movable and/or salvageable equipment (e.g., tools, vehicles, valves, vessels, etc.)

8.3 <u>Work to be Accomplished by Union</u>

In the performance of the work which comprises WBS 1.1, Union was responsible for accomplishing the following tasks:

1. Environmental studies (WBS Element 1.1.1)

   Conduct environmental studies in connection with geothermal resource development and production of steam from the geothermal resource, as required, for the preparation of the formal Environmental Impact Statement (EIS) and for obtaining the necessary permits and licenses. At least the following areas are included: meteorology; air quality and dispersion modeling; water quality; ground water hydrology; biota (terrestrial and acquatic); radio activity; land use and esthetics; socioeconomics; cultural and archeological studies; geological, soils and seismicity; and subsidence and emissions.

   In addition to these studies and reports, take the necessary steps to minimize and mitigate impacts on the environment. This shall include, at least, minimizing visual impact of steam lines, disposal of waste and revegetation of disturbed land not in regular use.

   See Tables 8.3-1 and 8.3-2 for cost detail and contribution by Parties.

2. Preproduction Drilling of Geothermal Wells (WBS Element 1.1.2)

   Drill, complete and test the production wells necesary to supply the steam to operate the power plant at rated capacity. Conduct production tests on each well. Test the injection wells through which the produced geothermal fluid will be returned to the underground formations after usage.

TABLE 8.3-1

BACA GEOTHERMAL
DEMONSTRATION POWER PLANT PROJECT
SUMMARY OF ACTUAL EXPENDITURES

WBS ELEMENT 1.1.1 - ENVIRONMENTAL STUDIES

	1978	1979	1980	1981	1982	TOTAL
Other Charges	$ 608	$ 166,762	$ 185,260	$ 128,207	$ 5,979	$ 486,816
General & Administrative	30	8,339	12,968	8,973	418	30,728
TOTAL WBS ELEMENT 1.1.1	$ 638	$ 175,101	$ 198,228	$ 137,180	$ 6,397	$ 517,544

TABLE 8.3-2

BACA GEOTHERMAL
DEMONSTRATION POWER PLANT PROJECT
SUMMARY OF ACTUAL EXPENDITURES

WBS ELEMENT 1.1.1 - ENVIRONMENTAL STUDIES

	TOTAL EXPENDITURES	UNION'S SHARE	DOE'S SHARE
Other Charges	$ 486,816	$297,171	$189,645
General & Administrative	30,728	19,129	11,599
TOTAL WBS ELEMENT 1.1.1	$ 517,544	$316,300	$201,244

See Tables 8.3-3 and 8.3-4 for cost detail and contribution by Parties.

3. Steam Production and Fluid Injection Systems (WBS Element 1.1.3)

Design, construct and test the steam gathering and injection systems. This includes: all pipelines to deliver well output to separators, steam from separators to the power plant, and fluids from separators and power plant to injection system; separators for separating steam from the geothermal fluid; injection system, with filters for the return of geothermal fluid and power plant waste fluid to the underground formation; well site valves and connections; vessel valves, instrumentation and control air system; and any other system facilities necessary to the delivery of steam to the power plant and the injection of geothermal fluid and power plant waste fluid.

See Tables 8.3-5 and 8.3-6 for cost detail and contribution by Parties.

4. Operation and Maintenance (WBS Element 1.1.4)

Operate and maintain the wells and steam gathering and injection systems in a manner that assures the availability of sufficient steam to operate the power plant at rated capacity during the demonstration period.

This includes providing all operating supplies, equipment and tools; maintenance; materials; services; repairs; rentals; instruments; facilities and accommodations. It also includes obtaining operating permits and licenses, and water rights.

See Tables 8.3-7 and 8.3-8 for cost detail and contribution by Parties.

5. Makeup Well Drilling (WBS Element 1.1.5)

Drill, complete and test supplemental wells necessary to offset production decline and maintain steam supply necessary to operate the power plant at rated capacity during the demonstration period. This task includes piping and tie-in to the steam gathering system.

During the life of the Project, no expenditures were made for makeup well drilling.

TABLE 8.3-3

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT
SUMMARY OF ACTUAL EXPENDITURES

WBS ELEMENT 1.1.2 - PREPRODUCTION DRILLING

	1978	1979	1980	1981	1982	TOTAL
Direct Material						
Drilling Bits	$ 72,710	$ 250,361	$ 277,717	$ 912,153	$ 22,650	$ 1,535,591
Drilling Mud & Chemicals	112,290	111,467	145,816	577,812	30,049	977,434
Casing	39,718	256,367	345,919	398,910	3,693	1,044,607
Production Equipment	6,197	111,584	179,317	129,653	18,436	445,187
Fuel	42,581	115,455	140,839	307,402	0	606,277
Total Direct Material	$ 273,496	$ 845,234	$1,089,608	$2,325,930	$ 74,828	$ 4,609,096
Other Direct Costs						
Equipment Rentals	$ 38,170	$ 90,179	$ 96,419	$ 368,267	$ 39,970	$ 633,005
Specialized Drlg. Serv.	362,276	641,150	927,706	3,053,170	177,786	5,162,088
Transportation	32,448	43,694	39,887	62,263	16,261	194,553
Location Preparation	1,328	128,076	236,556	104,338	0	470,298
Well Testing	4,913	10,888	0	0	0	15,801
Drilling Contractor	489,645	1,151,368	1,281,786	2,632,158	255,727	5,810,684
Supervision	52,600	48,800	(101,400)	0	0	0
Miscellaneous	21,005	67,501	173,240	62,473	41,012	365,231
Total Other Direct Costs	$1,002,385	$2,181,656	$2,654,194	$6,282,669	$ 530,756	$12,651,660
General & Administrative	$ 63,794	$ 146,090	$ 262,066	$ 602,600	$ 42,391	$ 1,116,941
Warehouse Stock						
DOE Casing Inventory	$ 0	$1,350,399	$ (253,912)	$ 513,324	$ (4,939)	$ 1,604,872
Pre-Cooperative Agreement Inv.	0	(62,812)	(9,495)	(33,146)	(17,683)	(123,136)
Total Warehouse Stock	$ 0	$1,287,587	$ (263,407)	$ 480,178	$ (22,622)	$ 1,481,736
TOTAL WBS ELEMENT 1.1.2	$1,339,675	$4,460,567	$3,742,461	$9,691,377	$ 625,353	$19,859,433

TABLE 8.3-4

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT
SUMMARY OF ACTUAL EXPENDITURES

WBS ELEMENT 1.1.2 - PREPRODUCTION DRILLING

	TOTAL COST	UNION'S SHARE	DOE'S SHARE
Direct Material			
Drilling Bits	$ 1,535,591	$ 0	$ 1,535,591
Drilling Mud & Chemicals	977,434	0	977,434
Casing	1,044,607	0	1,044,607
Production Equipment	445,187	445,187	0
Fuel	606,277	0	606,277
Total Direct Material	$ 4,609,096	$ 445,187	$ 4,163,909
Other Direct Costs			
Equipment Rentals	$ 633,005	$ 0	$ 633,005
Specialized Drlg. Serv.	5,162,088	0	5,162,088
Transportation	194,553	0	194,553
Location Preparation	470,298	470,298	0
Well Testing	15,801	0	15,801
Drilling Contractor	5,810,684	5,810,684	0
Supervision	0	0	0
Miscellaneous	365,341	365,231	0
Total Other Direct Costs	$12,651,660	$ 6,646,213	$ 6,005,447
General & Administrative	$ 1,116,941	$ 449,882	$ 667,059
Warehouse Stock			
DOE Casing Inventory	$ 1,604,872	$ 0	$ 1,604,872
Pre-Cooperative Agreement Inv.	(123,136)	(79,670)	(43,466)
Total Warehouse Stock	$ 1,481,736	$ (79,670)	$ 1,561,406
TOTAL WBS ELEMENT 1.1.2	$19,859,433	$ 7,461,612	$12,397,821

TABLE 8.3-5

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT
SUMMARY OF ACTUAL EXPENDITURES

WBS ELEMENT 1.1.3 - FIELD PRODUCTION SYSTEM

	1978	1979	1980	1981	1982	TOTAL
Direct Material						
Pipeline - Pipe	$ 0	$ 0	$ 1,539,928	$ 611,299	$ 0	$ 2,151,227
P/L - Insul. & Int. Parts	0	0	0	0	0	0
Vessels, Valves/Instr/Control Air	0	0	0	5,753	0	$ 5,753
Wellsite Valves & Connections	0	0	407,925	226,917	0	634,842
Inject. Plt. & Filt. Sys.	0	42,457	4,279	0	0	46,736
Separation Equip.	0	0	111,092	217,773	0	328,865
Total Direct Material	$ 0	$ 42,457	$ 2,063,224	$ 1,061,742	$ 0	$ 3,167,423
Other Direct Costs - Labor						
P/L ROW/Pipe Supports	$ 0	$ 0	$ 73,009	$ 123,652	$ 0	$ 196,661
Instal.-Pipe Supports	0	0	0	0	0	0
Instal.-Insul.	0	0	0	0	0	0
Vessels, Valves/Instr/Control Air	0	0	0	0	0	0
Wellsite Valves & Conn.	0	0	338	0	0	338
Inject. Plt. & Filt. Sys.	0	0	0	0	0	0
Engr./Draf./Surveying	0	0	150,072	776	0	150,848
Total Other Direct Costs	$ 0	$ 0	223,419	$ 124,428	$ 0	$ 347,847
General & Administrative	$ 0	$ 2,123	$ 160,066	$ 83,030	$ 0	$ 245,219
TOTAL WBS ELEMENT 1.1.3	$ 0	$ 44,580	$ 2,446,709	$ 1,269,200	$ 0	$ 3,760,489

TABLE 8.3-6

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT
SUMMARY OF ACTUAL EXPENDITURES

WBS ELEMENT 1.1.3 - FIELD PRODUCTION SYSTEM

	TOTAL	UNION'S SHARE	DOE'S SHARE
Direct Material			
Pipelines - Pipe	$ 2,151,227	$ 1,075,613	$ 1,075,614
P/L - Insul. & Int. Parts	0	0	0
Vessels, Valves.Instr/Control Air	5,753	5,753	0
Wellsite Valves & Connections	634,842	634,842	0
Inject. Plt. & Filt. Sys.	46,736	46,736	0
Separation Equip.	328,865	327,821	1,1044
Total Direct Material	$ 3,167,423	$ 2,090,765	$ 1,076,648
Other Direct Costs - Labor			
P/L ROW/Pipe Supports	$ 196,661	$ 0	$ 196,661
Instal.-Pipe Supports	0	0	0
Instal.-Insul.	0	0	0
Vessels, Valves/Instr/Control Air	0	0	0
Wellsite Valves & Conn.	338	0	338
Inject. Plt. & Filt. Sys.	0	0	0
Engr./Draft./Surveying	150,848	0	150,848
Total Other Direct Costs	$ 347,847	$ 0	$ 347,847
General & Administrative	$ 245,219	$ 0	$ 347,847
TOTAL WBS ELEMENT 1.1.3	$ 3,760,489	$ 2,236,272	$ 1,524,217

TABLE 8.3-7

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT
SUMMARY OF ACTUAL EXPENDITURES

WBS ELEMENT 1.1.4 - OPERATION & MAINTENANCE

	1978	1979	1980	1981	1982	TOTAL
Direct Material						
Operating Supplies	$ 3,614	$ 7,683	$ 56,845	$ 74,545	$ 7,374	$ 150,061
Repair & Replacement Mat'l	21,400	32,068	72,035	81,118	27,359	233,980
Total Direct Material	$ 25,014	$ 39,751	$ 128,880	$ 155,663	$ 34,733	$ 384,041
Direct Labor						
Salaries & Wages	$ 42,538	$133,715	$ 334,091	$ 480,139	$ 28,186	$1,018,669
Labor Overhead						
Employee Benefits	$ 10,886	$ 37,136	$ 106,666	$ 152,702	$ 8,570	$ 315,960
Travel						
Transportation & Travel	$ 26,731	$ 58,827	$ 127,345	$ 157,660	$ 17,244	$ 387,807
Other Direct Costs						
Rent & Utilities	$ 16,691	$ 66,866	$ 83,511	$ 105,368	$ 16,607	$ 289,043
Oper. Contract Services	56,705	122,719	305,918	497,537	76,838	1,059,717
Maint. Contract Services	24,394	54,018	65,995	94,585	13,828	252,820
Security Guard Facilities	0	0	8,066	0	0	8,066
Other Expense	(470)	1,141	5,192	3,077	(118)	8,822
Special Well Repairs	0	0	0	268,957	0	268,957
Charges from District Office	69,424	121,918	255,343	374,581	16,433	837,699
Field Office Warehouse Complex	0	0	253,488	80,021	0	333,509
Road System Permanent Surfacing	0	0	0	0	0	0

TABLE 8.3-7 (cont'd)

	1978	1979	1980	1981	1982	TOTAL
Other Direct Costs (cont'd)						
Support Equipment & Tools	$ 0	$ 21,872	$ 102,752	$ 201,379	$ (5,872)	$ 320,131
Acquisition of Acreage for Water Rights Allocation	0	0	0	0	0	0
Area Office Furniture	0	7,099	25,659	44,256	71	77,085
Project Management	0	38,178	40,230	31,193	0	109,601
Total Other Direct Costs	$166,744	$433,811	$1,146,154	$1,700,954	$117,787	$3,565,450
Special Testing						
Various Tests	$ 0	$ 16,137	$ 0	$ 0	$ 0	$ 16,137
General & Administrative	$ 13,595	$ 35,970	$ 129,019	$ 185,301	$ 14,456	$ 378,341
TOTAL WBS ELEMENT 1.1.4	$285,508	$755,347	$1,972,155	$2,832,419	$220,976	$6,066,405

TABLE 8.3-8

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT
SUMMARY OF ACTUAL EXPENDITURES

WBS ELEMENT 1.1.4 - OPERATION & MAINTENANCE

	TOTAL COST	UNION'S SHARE	DOE'S SHARE
Direct Material			
Operating Supplies	$ 150,061	$ 150,061	$ 0
Repair & Replacement Mat'l	233,980	233,980	0
Total Direct Material	$ 384,041	$ 384,041	$ 0
Direct Labor			
Salaries & Wages	$1,018,669	$1,018,669	$ 0
Labor Overhead			
Employee Benefits	$ 315,960	$ 315,960	$ 0
Travel			
Transportation & Travel	$ 387,807	$ 387,807	$ 0
Other Direct Costs			
Rent & Utilities	$ 289,043	$ 289,043	$ 0
Oper. Contract Services	1,059,717	12,579	1,047,138
Maint. Contract Services	252,820	252,820	0
Security Guard Facilities	8,066	0	8,066
Other Expense	8,822	8,822	0
Special Well Repairs	268,957	268,957	0
Charges from District Office	837,699	837,699	0
Field Office Warehouse Complex	333,509	333,509	0
Road System Permanent Surfacing	0	0	0

TABLE 8.3-8 (cont'd)

	TOTAL COST	UNION'S SHARE	DOE'S SHARE
Other Direct Costs (cont'd)			
Support Equipment & Tools	$ 320,131	$ 320,131	$ 0
Acquisition of Acreage for Water Rights Allocation	0	0	0
Area Office Furniture	77,085	77,085	0
Project Management	109,601	104,863	4,738
Total Other Direct Costs	$3,565,450	$2,505,508	$1,059,942
Special Testing			
Various Tests	$ 16,137	$ 16,137	$ 0
General & Administrative	$ 378,341	$ 307,575	$ 70,766
TOTAL WBS ELEMENT 1.1.4	$6,066,405	$4,935,697	$1,130,708

8.4 Baca Location Reservoir Test and Evaluation 1982 Program

As part of finalizing the Baca Geothermal Demonstration Power Plant Project, Union conducted an interference test followed by various production and injection tests on some of the Baca wells. The reason for the test was that it was not possible to collect these kind of data because of field operational complications associated with past drilling activity.

The total cost of the test program was estimated to be $749,540. Please refer to Table 8.4-1 for a detail of this amount. DOE's participation in the test program is not to exceed their percentage contribution in the project. DOE's share shall not exceed $377,303.

Table 8.4-2 is a summary of actual expenditures for the Baca testing program incurred during the time period February through December 31, 1982. The total amount expended is a tabulation of the monthly activity as recorded by Union's Geothermal Division Accounting Department.

The cost data from Table 8.4-2 is summarized below:

Description	SUMMARY OF EXPENDITURES ($000) Total Expenditures	DOE's Share	Union's Share
Baca Testing Program	$ 826	$ 377	$ 449
Parties Percentage Contribution	100%	45.6949%	54.3051%

TABLE 8.4-1

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT

SUMMARY TESTING PROGRAM BUDGET

OPERATING & MAINTENANCE:

DESCRIPTION	BACA LOCATION	AREA MANAGER	TOTAL COSTS	UNION'S SHARE	DOE'S SHARE
DIRECT MATERIALS					
OPERATING SUPPLIES	$ 22,000	$ 5,500	$ 27,500	$ 13,657	$ 13,843
REPAIR & REPLACEMENT MATERIAL	24,000	-0-	24,000	11,919	12,081
TOTAL DIRECT MATERIALS	$ 46,000	$ 5,500	$ 51,500	$ 25,576	$ 25,924
DIRECT LABOR					
SALARIES & WAGES	$ 62,100	$176,700	$238,800	$118,593	$120,207
LABOR OVERHEAD					
EMPLOYEE BENEFITS	$ 24,300	$ 52,900	$ 77,200	$ 38,339	$ 38,861
TRAVEL					
TRANSPORTATION & TRAVEL	$ 21,500	$ 21,000	$ 42,500	$ 21,106	$ 21,394

TABLE 8.4-1 (Cont'd)

DESCRIPTION	BACA LOCATION	AREA MANAGER	TOTAL COSTS	UNION'S SHARE	DOE'S SHARE
OTHER DIRECT COSTS					
RENT & UTILITIES	$ 22,000	$ 39,600	$ 61,600	$ 30,592	$ 31,008
OPERATION CONTRACT SERVICES	119,900	16,000	135,900	67,491	68,409
MAINTENANCE CONTRACT SERVICES	22,000	-0-	22,000	10,926	11,074
OTHER EXPENSE	1,100	1,100	2,200	1,093	1,107
SPECIAL WELL REPAIRS	15,000	-0-	15,000	7,449	7,551
CHARGES FROM DISTRICT OFFICE	-0-	41,000	41,000	20,361	20,639
EMPLOYEE ACTIVITIES	-0-	800	800	397	403
ENVIRONMENTAL STUDIES	-0-	12,000	12,000	5,959	6,041
TOTAL OTHER DIRECT COSTS	$180,000	$110,500	$290,500	$144,268	$146,232
GENERAL & ADMINISTRATIVE	$ 23,373	$ 25,667	$ 49,040	$ 24,355	$ 24,685
TOTAL TESTING PROGRAM BUDGET	$357,273	$392,267	$749,540	$372,237	$377,303

TABLE 8.4-2

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT

SUMMARY OF ACTUAL EXPENDITURES

OPERATION & MAINTENANCE - BACA TESTING PROGRAM:

DESCRIPTION	BACA LOCATION	AREA MANAGER	TOTAL COSTS	UNION'S SHARE	DOE'S SHARE
DIRECT MATERIALS					
OPERATING SUPPLIES	$ 6,955	$ 5,500	$12,455	$ 6,764	$ 5,691
REPAIR & REPLACEMENT MATERIAL	13,309	0	13,309	7,227	6,082
TOTAL DIRECT MATERIALS	20,264	5,500	25,764	13,992	$ 11,773
DIRECT LABOR					
SALARIES & WAGES	$ 61,215	$ 196,220	$257,435	$ 139,800	$117,635
LABOR OVERHEAD					
EMPLOYEE BENEFITS	$ 25,216	$ 57,051	$ 82,267	$ 44,675	$ 37,592
TRAVEL					
TRANSPORTATION & TRAVEL	$ 39,520	$ 40,084	$ 79,604	$ 43,229	$ 36,375

TABLE 8.4-2 (Cont'd)

DESCRIPTION	BACA LOCATION	AREA MANAGER	TOTAL COSTS	UNION'S SHARE	DOE'S SHARE
OTHER DIRECT COSTS					
RENT & UTILITIES	$ 13,919	$ 42,350	$ 56,269	$ 30,557	$ 25,712
OPERATING CONTRACT SERVICES	95,410	58,337	153,747	83,492	70,255
MAINTENANCE CONTRACT SERVICES	20,304	0	20,304	11,026	9,278
OTHER EXPENSE	200	1,941	2,141	1,163	978
SPECIAL WELL REPAIRS	14,479	0	14,479	7,863	6,616
CHARGES FROM DISTRICT OFFICE	0	59,910	59,910	32,534	27,376
EMPLOYEE ACTIVITIES	0	3,522	3,522	1,913	1,609
ENVIRONMENTAL STUDIES	0	16,242	16,242	8,820	7,422
TOTAL OTHER DIRECT COSTS	$144,312	$182,302	$326,614	$177,368	$149,246
GENERAL & ADMINISTRATIVE	$ 20,336	$ 33,681	$ 54,017	$ 29,334	$ 24,683
TOTAL TESTING PROGRAM	$310,863	$514,838	$825,701	$448,398	$377,303

Tables 8.4-3 and 8.4-4 are summaries of actual expenditures by quarters for the Baca Location and Area Manager Cost Centers.

8.5 Preparation and Processing of the DOE Billing

Union's Los Angeles, California Office was responsible for the accounting functions for the Baca Geothermal Demonstration Power Plant (GDPP) Project. The Rio Rancho, New Mexico Area Office and the Santa Rosa District Office received, processed and forwarded to the Los Angeles Office various charges which were chargeable to the Project. The Monthly Activity Listing, which was the resulting report, was the document which was used by Rio Rancho Office personnel to prepare the monthly DOE billing.

In accordance with the procedure set forth in the Modified Letter of Credit Procedure of the Cooperative Agreement for the Project, Union issued "Cash Calls" during a month and credited these amounts on the monthly billing. Thus, Union was able to receive funds in a very timely manner. The Letter of Credit Procedure proved very efficient and Union would like to suggest that the DOE consider using this procedure in disbursing funds in any future project(s) that it may enter into with any company or corporation.

TABLE 8.4-3

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT

SUMMARY OF ACTUAL EXPENDITURES

OPERATION & MAINTENANCE - BACA TESTING PROGRAM

BACA LOCATION COST CENTER

DESCRIPTION	FIRST QUARTER	SECOND QUARTER	THIRD QUARTER	FOURTH QUARTER*	TOTAL
DIRECT MATERIALS					
OPERATING SUPPLIES	$ 1,061	$ 1,270	$ 1,360	$ 3,264	$ 6,955
REPAIR & REPLACEMENT MATERIAL	75	2,199	5,261	5,774	13,309
TOTAL DIRECT MATERIALS	$ 1,136	$ 3,469	$ 6,621	$ 9,038	$ 20,264
DIRECT LABOR					
SALARIES & WAGES	$ 9,158	$ 20,356	$ 25,726	$ 5,975	$ 61,215
LABOR OVERHEAD					
EMPLOYEE BENEFITS	$ 3,598	$ 8,513	$ 10,715	$ 2,390	$ 25,216
TRAVEL					
TRANSPORTATION & TRAVEL	$ 15,985	$ 6,143	$ 11,614	$ 5,778	$ 39,520

TABLE 8.4-3 (Cont'd)

DESCRIPTION	FIRST QUARTER	SECOND QUARTER	THIRD QUARTER	FOURTH QUARTER*	TOTAL
OTHER DIRECT COSTS					
RENT & UTILITIES	$ 2,371	$ 4,216	$ 886	$ 6,446	$ 13,919
OPER. CONTRACT SERVICES	3,499	49,465	32,672	9,774	95,410
MAINTENANCE CONTRACT SERVICES	8,329	7,867	1,968	2,140	20,304
OTHER EXPENSE	0	0	0	200	200
SPECIAL WELL REPAIRS	0	0	12,648	1,831	14,479
CHARGES FROM DISTRICT OFFICE	0	0	0	0	0
ENVIRONMENTAL STUDIES	0	0	0	0	0
TOTAL OTHER DIRECT COSTS	$ 14,199	$ 61,548	$ 48,174	$ 20,391	$ 144,312
GENERAL & ADMINISTRATION	$ 3,085	$ 7,002	$ 7,199	$ 3,050	$ 20,336
TOTAL	$ 47,161	$107,031	$110,049	$ 46,622	$ 310,863

* FOURTH QUARTER IS ACTUAL EXPENDITURES FOR OCTOBER AND BUDGET AMOUNTS FOR NOVEMBER AND DECEMBER.

TABLE 8.4-4

BACA GEOTHERMAL DEMONSTRATION POWER PLANT PROJECT

SUMMARY OF ACTUAL EXPENDITURES

OPERATION & MAINTENANCE - BACA TESTING PROGRAM

AREA MANAGER COST CENTER

DESCRIPTION	FIRST QUARTER	SECOND QUARTER	THIRD QUARTER	FOURTH QUARTER*	TOTAL
DIRECT MATERIALS					
OPERATING SUPPLIES	$ 1,769	$ 1,780	$ 670	$ 1,281	$ 5,500
REPAIR & REPLACEMENT MATERIAL	0	0	0	0	0
TOTAL DIRECT MATERIALS	$ 1,769	$ 1,780	$ 670	$ 1,281	$ 5,500
DIRECT LABOR					
SALARIES & WAGES	$ 62,567	$ 68,032	$ 35,731	$ 29,890	$ 196,220
LABOR OVERHEAD					
EMPLOYEE BENEFITS	$ 18,144	$ 19,729	$ 10,362	$ 8,816	$ 57,051
TRAVEL					
TRANSPORTATION & TRAVEL	$ 9,959	$ 18,539	$ 8,035	$ 3,551	$ 40,084

TABLE 8.4-4 (Cont'd)

DESCRIPTION	FIRST QUARTER	SECOND QUARTER	THIRD QUARTER	FOURTH QUARTER*	TOTAL
OTHER DIRECT COSTS					
RENT & UTILITIES	$ 6,665	$ 14,628	$ 7,253	$ 13,804	$ 42,350
OPER. CONTRACT SERVICES	26,442	15,109	9,639	7,147	58,337
MAINTENANCE CONTRACT SERVICES	0	0	0	0	0
OTHER EXPENSE	395	1,576	(230)	200	1,941
EMPLOYEE ACTIVITIES	1,523	1,043	456	500	3,522
CHARGES FROM DISTRICT OFFICE	2,166	13,330	29.355	15,059	59,910
ENVIRONMENTAL STUDIES	2,680	11,200	2,362	0	16,242
TOTAL OTHER DIRECT COSTS	$ 39,871	$ 56,886	$ 48,835	$ 36,710	$ 182,302
GENERAL & ADMINISTRATION	$ 9,262	$ 11,548	$ 7,254	$ 5,617	$ 33,681
TOTAL	$141,572	$176,514	$110,887	$ 85,865	$ 514,838

* FOURTH QUARTER IS ACTUAL EXPENDITURES FOR OCTOBER AND BUDGET AMOUNTS FOR NOVEMBER AND DECEMBER.

Section 9: PUBLIC ISSUES

9.1 Introduction

Two of the Objectives listed in the ERDA Program Opportunity Notice (PON) issued on September 30, 1977 were:

- Act as a "path-finder" for the regulatory process and other legal and institutional aspects of geothermal development; and
- provide a basis for the financial community to estimate the risks and benefits associated with geothermal investments.

Because the Baca Geothermal Demonstration Project was located in an environmentally sensitive area and was in a region containing a population which is generally environmentally attuned, the project was expected to generate some controversies. The uniqueness of the Baca Project (the first geothermal electrical project in New Mexico) made controversy unavoidable, even for what might have been considered to be more "routine" regulatory activities. In this respect it was a "path-finder" for the regulatory process, and partly as a result of these controversies and delays, the financial community could get a more complete understanding of the complexity of risks attending geothermal projects in the western United States.

The high visibility of these public controversies may have misled many observers into believing that the controversies were a principal contributing factor in the eventual termination of the Project. More so since the environmental documents, press releases and public discussions constitute the principal public knowledge of the Project. Even though the controversies did not deter Union from pursuing the Project, these controversies are clearly deserving of discussion in this Report since they are, in a sense, elements of risk, albeit subjective risks.

The following sub-sections discuss the principal public issues affecting Union's activities at the Baca Project. Some public controversies attended the activities of Public Service Company of New Mexico (PNM) but will not be discussed here even though Union may have participated to some extent. Issues addressed by both Union and PNM will be covered here.

Figure 9.1 shows a map of the lands surrounding the Baca Project. Also indicated are principal features of the project. As can be readily seen, the project is virtually surrounded by National Forest, National Monument lands,

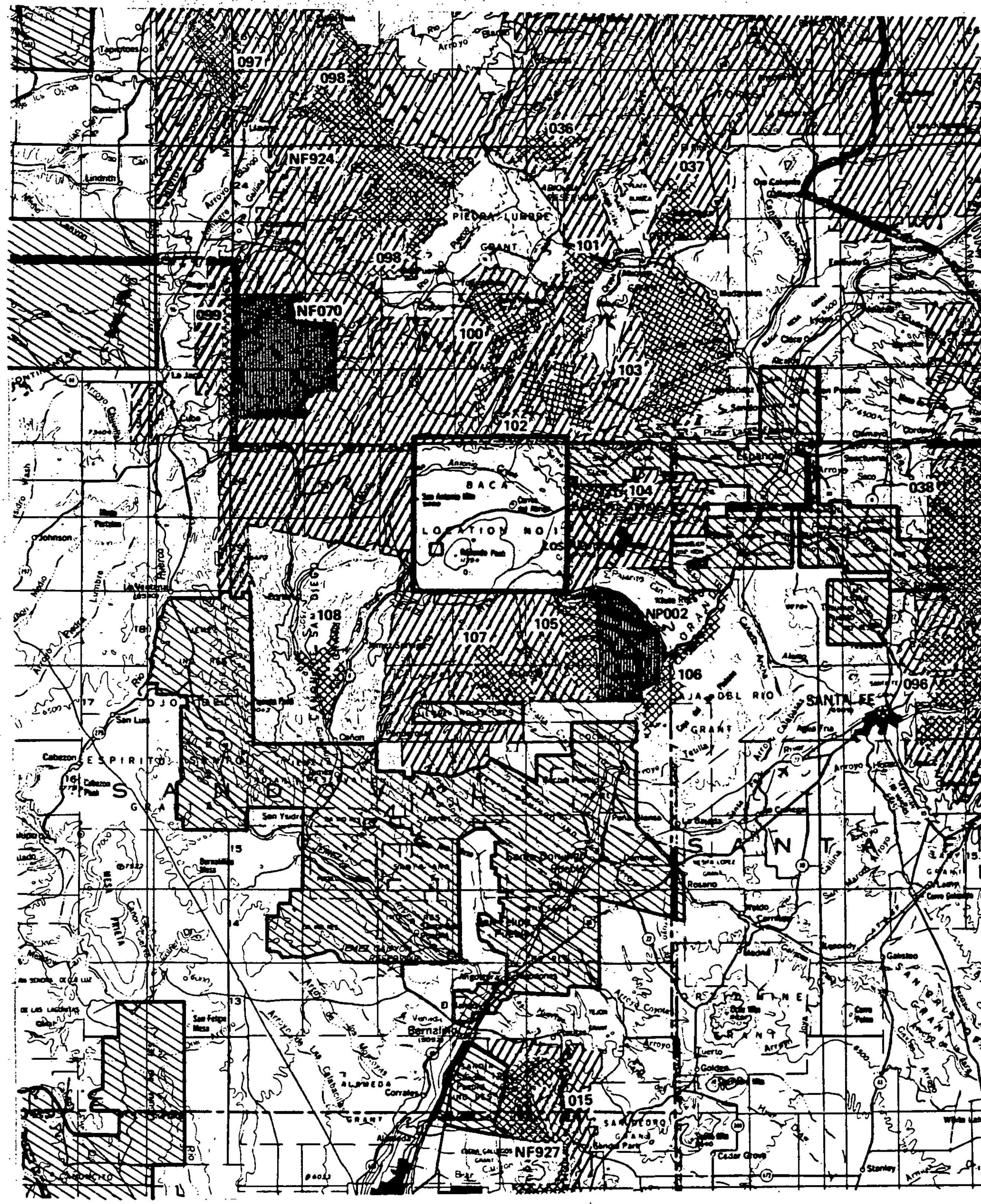


Figure 9.1

BACA LOCATION NO.1 AND SURROUNDING LANDS

- NATIONAL FOREST LANDS
- INDIAN PUEBLO LANDS
- WILDERNESS STUDY AREAS
- EXISTING WILDERNESS AREAS

and Indian lands. In addition, the Baca property is geologically the center of the Jemez Mountains and serves as the headwaters to many of the creeks which flow into these surrounding lands. Therefore it is not surprising that many of the neighboring land-owners or users would nervously watch development on the Baca property, or exploit opportunities to gain access to this island of lightly used land.

It was early felt that a comprehensive environmental baseline survey was essential for evaluating the effects of the project which would eventually be built. Therefore, in the early exploratory stage, Union began environmental baseline surveys, principally located in Redondo Canyon, the expected project site. Some of the studies covered wider areas, including lands on and off the Baca property. These studies included air quality/meteorology, water quality/hydrology, geology/soils, ecology/endangered species, radioactivity, and gravity/subsidence.

These studies provided a principal component to the Department of Energy's (DOE) Environmental Impact Statement (EIS), prepared by the Oak Ridge National Laboratory. DOE encouraged the Participant (Union and PNM) to work closely with Oak Ridge in assuring a complete and accurate EIS.*

During the period that the EIS was being prepared, additional studies were begun by Union and PNM to confirm initial studies and to fill in gaps of information for inclusion in the EIS (such as land use, socio-economic impacts, aesthetics and archeology). Some of the studies which were begun during this period were also the beginnings of anticipated long-term data gathering efforts (such as air quality and meteorology).

Before the EIS was issued most public discussion of the project was based on speculation. Union and PNM organized tours and discussions of the project but little opposition appeared. Indeed, the traditional opponents to electric generating plants generally supported the project as an alternative to fossil and nuclear plants, and primarily were interested that the site-specific impacts were adequately mitigated.

* It was with some pride that Union, PNM and Oak Ridge heard in informal comments that the Baca Project Draft EIS was considered by the DOE Assistant Secretary for the Environment (Dr. Ruth Davis) to be the best she had seen and that it was her office's model EIS. She noted it was also the CEQ's model EIS and that a copy had been sent to the White House where it was well received.

However, when the EIS was finally issued and circulated, intense interest was stirred, principally in the Indian community. Many of the subjects addressed in the EIS were, of necessity, couched in very conditional and subjective evaluations, providing many effects that "may" or "could" occur. Readers unfamiliar with EIS's often take these effects as "likely" and hence become agitated when learning of them. Much of the ensuing discussions were, in Union's opinion, spent correcting misunderstandings or alarm over small or unlikely impacts from the Project.

Once the EIS had sensitized the observers of the Project, opponents moved to exploit any opportunity available to retard or halt the projct. Besides the EIS process itself (which delayed the Project by several months), the EIS revealed numerous other regulatory mechanisms which could be intervened in to disrupt the orderly progress of the Project.

Some of the avenues which could be followed by opponents searching for vehicles for delay were more fruitful than others. These are discussed in the following sections. Also discussed are some subjects that Union and PNM spent considerable time and money on to prevent or minimize delays. Finally, there is a discussion of Union's opinion of the groups actively interested in the Baca Project.

9.2 Permit to Appropriate Underground Waters

In the vicinity of the Baca Project water is in short supply. Figure 9.2 shows the surface streams in the vicinity of the Project, and the locations of the chief downstream landowners. Many of the downstream landowners depend entirely on surface water flows for subsistence and for some religious purposes.

9.2.1 Applicable Regulations

The beneficial use of water in New Mexico is based upon the legal doctrine of prior appropriation and is administered by the State Engineer. Prior appropriation separates the ownership of land from the right to use the water on the land. The water is considered public property and is subject to appropriation for beneficial use. One can acquire the right to use water not previously appropriated by applying the water to a beneficial use. The first person to appropriate a quantity of water for a beneficial use has the prior right to utilize such water. Subsequent users may appropriate water to beneficial use only to the extent that such appropriation will not impair the rights of prior users.

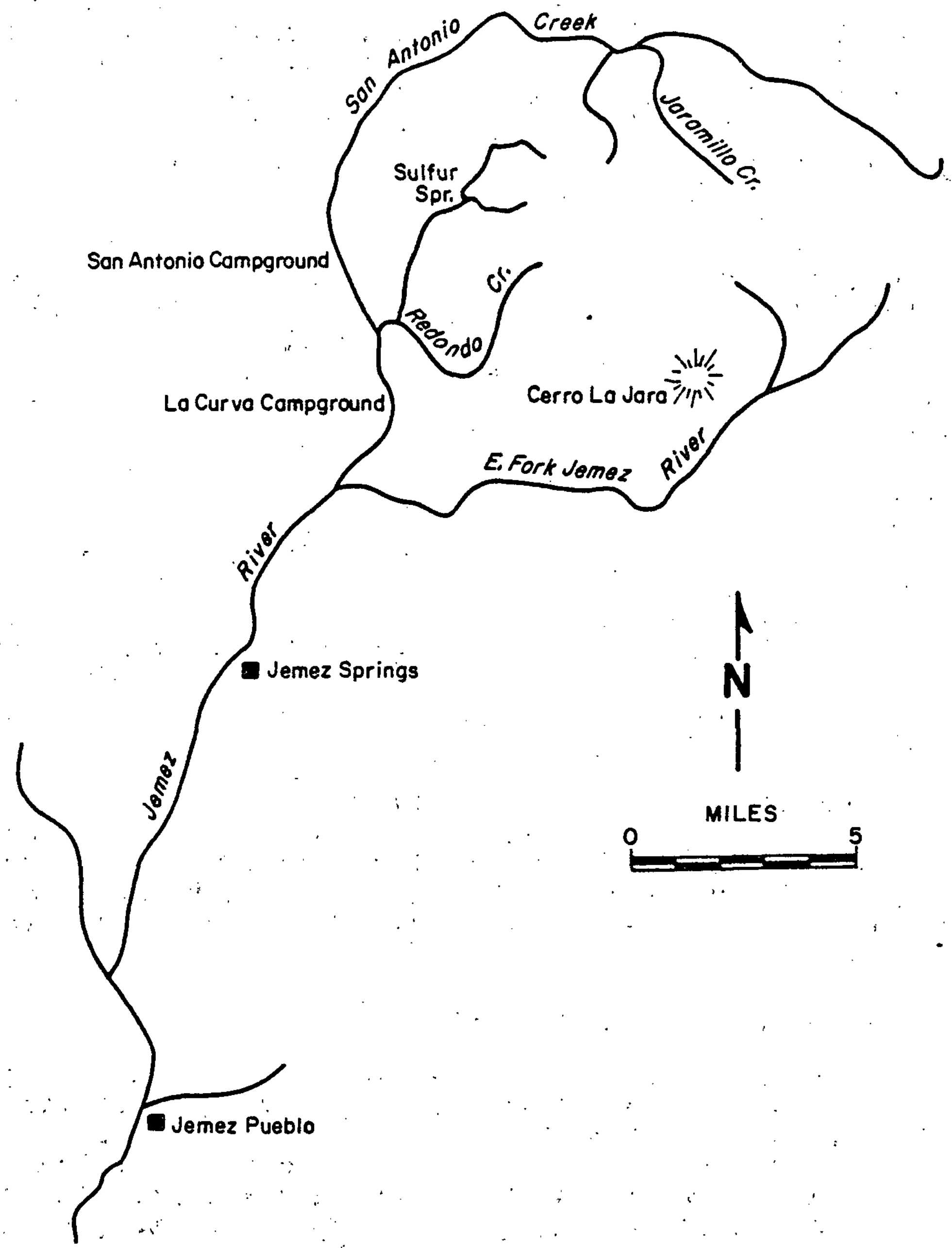


Figure 9.2

SURFACE STREAMS IN BACA PROJECT AREA

In most areas of New Mexico, the water rights have all been previously appropriated. Therefore, for geothermal development, it will be necessary to acquire an existing water right from a present owner and transfer the point of diversion of that water and its purpose of use. Water reinjected into the ground is usually credited against the volume withdrawn and only the net depletion is considered in establishing the effect on existing water rights.

Typically, less than one year is needed to acquire a permit to appropriate underground waters. A hearing is required if protests are filed against an application. The permit is then good for five years after which time it will be converted to a license which will be valid for as long as the water continues to be used.

The State Engineer considers a geothermal well to be a water well and the regulations of the Office require that all water wells be drilled only by state licensed water well drillers. To obtain such a license, a driller must pay a $20 application fee and post a $5000 performance bond, conditioned upon the applicant's compliance with the laws of the state and the rules and regulations of the State Engineer's Office (which also grants the license). The license is valid only so long as the bond is in effect.

9.2.2 <u>Acquisition of Water Rights by Union</u>

A Declaration of Water Rights for 34.59 acres of irrigated land along San Antonio Creek (referred to locally as the Abousleman acreage) was filed with the State Engineer on September 22, 1978. Another Declaration of Water Rights was filed with the State Engineer on October 27, 1978, for a similar fifteen acre parcel.

An Application for Permit to Change the Place of Use of Surface Waters and an Appropriation of Underground Waters, were filed with the State Engineer's Office on June 13, 1979. Union requested in the Application for Permit to Change the Place of Use of Surface Waters and the water rights (55 acre-feet per year) be transferred to the project area for use as geothermal makeup water, to compensate for any diminished surface water flow that might be caused by geothermal extraction. Also requested was permission to appropriate 2,640 acre-feet per year of ground water for steam production and to retire the acquired surface water rights. Both requests are generally recognized as common and acceptable practices, provided the changes would not impair or otherwise detrimentally affect existing water rights.

9.2.3 State Engineer Proceedings

As required by law, a Notice of Publication was placed in a local newspaper on June 27, 1979. The State Engineer's Office subsequently received protests from the Jemez Pueblo, the Santa Ana Pueblo and the U.S. Department of the Interior on behalf of the Jemez, Santa Ana and Zia Pueblos. A meeting held with the protesting Pueblos and their legal representatives did not dissuade their protests. A formal hearing with the State Engineer's Office on this matter was set.

A hearing on applications for the appropriation of water for beneficial use, and transfer of existing water rights from adjoining Union-owned lands, was held on April 10 and 11, 1980 before representatives of the State Engineer's Office. Union filed a "Brief in Support of Applications to Appropriate Underground Waters" with the State Engineer on May 26, 1980.

On August 1, 1980, the New Mexico State Engineer's Office ruled in favor of Union's application for the transfer of water rights acquired with the purchase of land adjoining the Baca Location. The ruling allowed for a water rights transfer to Union of 55 acre-feet per year to support drilling and operating activities. The decision also approved the diversion of geothermal fluids in the amount of 8800 acre-feet per annum, with a maximum consumption for beneficial use of 2640 acre-feet per annum. These amounts represent the total annual mass production and steam production, respectively, required to supply the Baca Project. Union would acquire additional water rights in the Jemez watershed to offset the State Engineer's predicted maximum stream diminution due to geothermal operations, estimated at 199 acre-feet per year.

Subsequent to the State Engineer's decision, an appeal of the ruling was filed by the Santa Ana Pueblo. The case was assigned to District Court. In November 1980, a motion to dismiss this appeal was filed by Union with the District Court. On December 18, 1980, a ruling by the District Court denied Union's motion and allowed the Santa Ana Pueblo to refile the original appeal.

Based on the results of a New Mexico State Supreme Court ruling on a similar water rights case, Union provided oral argument November 5, 1981 for the District Court to reconsider our prior Motion to Dismiss the Appeal. The Court ruled from the bench that it did not have jurisdiction and an Order of Dismissal was issued on November 18, 1981.

The Santa Ana Pueblo then filed an appeal on December 16, 1981 to the State Supreme Court to reconsider the dismissal issued in District Court. In April 1982, after reconsidering its position, the Santa Ana Pueblo filed a Stipulation of Dismissal. The case was dismissed on May 5, 1982 and approved by the State Supreme Court.

Union currently holds 55 acre-feet of senior water rights which are available for use in support of geothermal production operations.

9.3 Indian Religious Claims

9.3.1 AIRFA and Its Relation to The Baca Project

The American Indian Religious Freedom Act (AIRFA) (Publ. L. 95-341, 42USC1996) was signed into law on August 11, 1978. Section 1 reads as follows:

"On or after August 11, 1978, it shall be the policy of the United States to protect and preserve for American Indians their inherent right of freedom to believe, express, and exercise the traditional religions of the American Indian, Eskimo, Aleut, and Native Hawaiians, including but not limited to access to sites, use and possession of sacred objects, and the freedom to worship through ceremonials and traditional rites." (Section 2 directs agencies to take certain steps to comply and directs the President to report to Congress.)

The legislative history of AIRFA identifies three general interferences by government activities. These are 1) denial of access to Indians of certain physical locations, 2) restrictions on use of substances, and 3) actual interference in religious practices which could be affected by this Act.

Space and earth forms figure prominently in Pueblo Indian religion. The high peaks and springs of mountain ranges in New Mexico, southern Colorado and Arizona have been considered sacred by the Pueblos since they settled in the Southwest.

Pueblo religious practices and values are described in detail in the Final Environmental Impact Statement (FEIS) for the Baca Project, the Union-sponsored "High Altitude Adaptations along Redondo Creek" by the Office of Contract Archeology of the University of New Mexico; and the DOE-sponsored report by MITRE Corporation, titled, "Baca Ranch Geothermal Demonstration Program, A Background Study of Pueblo Indian Religious Freedom".

Historically, Pueblos have demonstrated great adaptability in continuing their religious practices in areas outside of their own lands. Figure 9.1 shows the relationship of the Baca Project and the privately-owned Baca Ranch to the Pueblo lands.

Geothermal development on the Ranch became the focus of contention between the northern Pueblos and the Baca Project. During hearings on the Draft EIS for the Baca Project in August 1979, Pueblo representatives alleged that geothermal development in the Redondo Peak area would infringe on the Pueblos' religious freedom, and that DOE's participation in the Project violated AIRFA.

9.3.2 DOE Findings on AIRFA

The Department of Energy responded to Indian allegations made at the EIS hearings by examining all information available regarding Pueblo religion as it related to the Baca Project specifically. Extensive archeological surveys located no Pueblo sites within the Project boundaries. The land has been owned and used by non-Indians for over 100 years. In light of the physical and historical evidences regarding the project's relationship to Pueblo religion, the Secretary of the Department of Energy decided that the American Indian Religious Freedom Act would not be violated by the Baca Project. This finding was published as part of the Record Decision for the Baca Project on May 13, 1980 as follows:

"Infringement of Indian religious practices is the most difficult issue to mitigate satisfactorily. This difficulty is due mainly to the refusal by the Pueblo Indians to furnish specific information on these practices.

"DOE has made an exhaustive effort to determine the potential impacts of the demonstration project on Indian religious practices. Pursuant to the Congressional Joint Resolution on American Indian

Religious Freedom (Pub. L. 95-341), DOE consulted extensively with Indian tribal leaders and outside experts on Pueblo religion in order to ascertain whether the project is located on or near sacred Indian religious sites involving the conduct of specific religous practices. Comments pertaining to the infringement issue were received on the draft environmental impact statement, and comments were made by tribal leaders at a DOE-sponsored hearing conducted by the All Indian Pueblo Council.

"During the preparation of the Final EIS, DOE carried out additional consultations with Pueblo representatives. Despite repeated efforts, however, DOE was unable to obtain detailed information on specific religious practices and, therefore, was unable to evaluate the potential impacts of the project on the practice of religion. Several Pueblos have protested against the project, but they have not provided examples of infringements of specific religious practices on the grounds that secrecy is an important principal of the Pueblo religion.

"As a result of its consultations with the Pueblo Indians, a review of property rights in the project area, and currently available information, DOE has determined that:

(1) The Pueblos do not posses property rights in the Baca sufficient to support a valid claim of infringement on any specific religious activities that occur on the Baca;

(2) There has been no showing by the Pueblos that the project will infringe their religious freedom.

"However, DOE will make every effort to pursue a mitigation plan to minimize those generalized impacts that the Pueblos allege. The All Indian Pueblo Council has proposed to assist DOE in the preparation and execution of such a plan."

9.3.3 Indians' Lawsuit

Eighteen northern Pueblos filed a civil suit in the United States District Court for District of Columbia against the Secretary of Energy of the United States in January 1981. The suit alleged that the Department of Energy, as a participant in the Baca Project, was infringing upon the religious practices of the Pueblos and violating the Pueblos'

First Amendment rights, the American Indian Religious Freedom Act and the trust obligation of the United States to the Pueblos. The Pueblos based this suit on religious values described in the Final EIS and MITRE reports, and the Department of Energy's Record of Decision regarding the Final EIS.

Specifically, the Pueblos alleged that the Project could potentially infringe on their religious freedom by reducing the quantity and quality of water at Soda Dam, changes in flow of both hot and cold springs, blocking or limiting access to sacred sites, reducing or relocating populations of animals and plants gathered or hunted for ceremonial purposes and increasing visibility of secret ceremonies to non-Indians.

The Department of Energy responded to these allegations. Union and PNM supplied pertinent information on regional hydrology, archeological evidence and biological surveys conducted in the Baca Project boundaries. Venue was changed to the United States District Court in New Mexico. Shortly thereafter the Project was terminated for lack of resource. Therefore, on March 4, 1982, the action was dismissed without prejudice.

(During these proceedings, the Pueblos utilized the forum of the U.S. Civil Rights Commission New Mexico Advisory Committee to enlarge their prospective audience. The report of their testimony and a response by Union Oil Company are attached at the end of this Section.)

9.4 Air Quality Rules

9.4.1 Federal H_2S Rules

Hydrogen sulfide (H_2S) has no National Ambient Air Quality Standards and no PSD increments. It would be the principal air pollutant emitted by the Baca Project. However, a court decision in 1980 (Alabama Power case) found that H_2S is regulated by the Clean Air Act.

Union and PNM both requested EPA review to determine if PSD rules were applicable to geothermal development projects. The EPA found that a PSD permit was not required for Union to develop the geothermal well field for the Baca Project. This finding established a small precedent for geothermal production systems.

PNM's power plant design included a Stretford H_2S abatement system and met EPA criteria for PSD.

9.4.2 New Mexico State Standards

The State of New Mexico had an ambient H_2S standard of 3 parts per billion (ppb) for one hour. However, it had provisions for sour oil and gas production areas with levels as high as 100 ppb.

PNM and Union had performed modeling studies to determine the likely magnitude and location of impacts from the project during normal operation with the Stretford system functioning properly and during upset "stacking" conditions. The project could not always achieve 3 ppb, but could achieve levels below 10 ppb outside the Baca property boundary. The New Mexico Environmental Improvement Division (NMEID) also felt the 3 ppb standard should be relaxed to encourage geothermal development without damaging the New Mexico air quality. Therefore, Union/PNM and NMEID separately requested a relaxation of this standard in 1979.

A hearing on both requests was held before the Environmental Improvement Board in September 1979. Both requests were heard during the 2-day hearing which was open to the public.

The Union/PNM proposed H_2S standard change reflected conservative modeling of regional wind patterns, climatic and weather conditions and potential future development, and reflected different levels of concentration in known geothermal resource areas (KGRA's) and in the state at large. Union and PNM conducted a variety of model analyses based on small (50 MW) medium (150 MW) and large (400 MW) development in the Redondo Creek and adjacent areas. A consulting firm was retained to help analyze the complex scenarios and mountain meteorology present at the site. As a result, the Union/PNM rule-change proposal was divided into graduated steps to accommodate growth to larger electrical capacity but never to exceed 10 ppb annual average. EID's proposed change was simply to relax the ambient standard from 3 ppb (one hour) to 10 ppb with no KGRA boundaries.

It was clear that a flat 10 ppb limit would not accommodate a second 50 MW plant with abatement technology available at that time, let alone 400 MW. If a few exceeds of 10 ppb were allowed during the course of a year to accommodate those few meteorologic conditions which cause an ambient H_2S concentration to rise, then larger growth could occur.

However, the New Mexico Environmental Improvement Board, in a public meeting, adopted the NMEID's proposal, and New Mexico H_2S standard is presently a 10 ppb (one hour) ambient concentration statewide. PNM received its construction permit for the Baca Project power plant from EID in January 1980.

Union received an opinion from EID in February 1980 that a construction permit was not required.

It was agreed by NMEID that contributions of H_2S from the project would be considered to be the additional amount <u>above</u> the existing natural background levels. Since there are numerous H_2S-bearing gas seeps and springs near the Baca Ranch boundary, this was an important point.

However, a question not decided was where to enforce the ambient standard. For the Baca Project, relatively shielded by the Ranch lands between Redondo Canyon and the Ranch boundary, public access was distant and achieving the standard on public lands was simpler. But for future projects located on public lands where the public has intimate access to the project area, this issue is crucial.

9.5 Land Use

In preparation of the Draft EIS for the Baca Project, Participant met with representatives of any other federal agencies that could have potential impacts on the Project. The U.S. Forest Service and the National Park Service were involved with transmission line corridor placement from ranch land to Los Alamos. The Heritage Conservation and Recreation Service was involved with landmark status of the ranch.

9.5.1 Private Land Use Practices

Historic and existing land use practices on the Baca Location No. 1 are described in detail in "High Altitude Adaptations Along Redondo Creek" by Office of Contract Archeology and in the Final EIS. The ranch is presently used for seasonal logging and grazing operations, geothermal exploration, and private hunting and fishing. Activities are geared to ensure that the natural status of the land will not be negatively impacted.

9.5.2 National Landmark Status and Significance

The Baca Location No. 1 Land Grant was designated a National Natural Landmark in August, 1975 under the Natural Landmark Program administered at that time by the Heritage Conservation and Recreation Service. The Baca Location received the designation because it contains most of the Valles Caldera (which is one of the largest examples of a collapse subsidence volcanic caldera in the world), and because the caldera exists in a relatively natural state. Parts of the caldera are visible to the public from New Mexico Route 4, although access to the land itself is limited to landowners. Designation of landmark status imparts no legal obligation on the private landowners.

9.5.3 Efforts by Federal Agencies to Purchase

The National Park Service and United States Forest Service have indicated interest in purchasing all or part of the Baca Location No. 1 for at least ten years. The landowner, until his death in 1980, also was interested in public acquisition of the ranch.

The National Park Service did purchase a small portion of the Baca Location in the late 1970's which was incorporated into Bandelier National Monument. This area is shown in Figure 9.3.

The Department of the Interior completed a study of public management alternatives for the remainder of the ranch in 1979. The study found that the Baca Location/Valles Caldera qualifies as nationally significant because it is an outstanding example of a geologic formation which is extremely rare in the nation, it possesses great ecological and geologic diversity, it possesses outstanding scenic values, and federally designated endangered species have been observed in the caldera region. The study made no final recommendations as to which public management alternative should be adopted. There was no indication of when such a decision might be forthcoming.

Because of the present geothermal leasing agreement, any public management plan for the Ranch would have to accommodate geothermal development. Union's development rights could not be diminished merely by a sale of the land to a government agency.

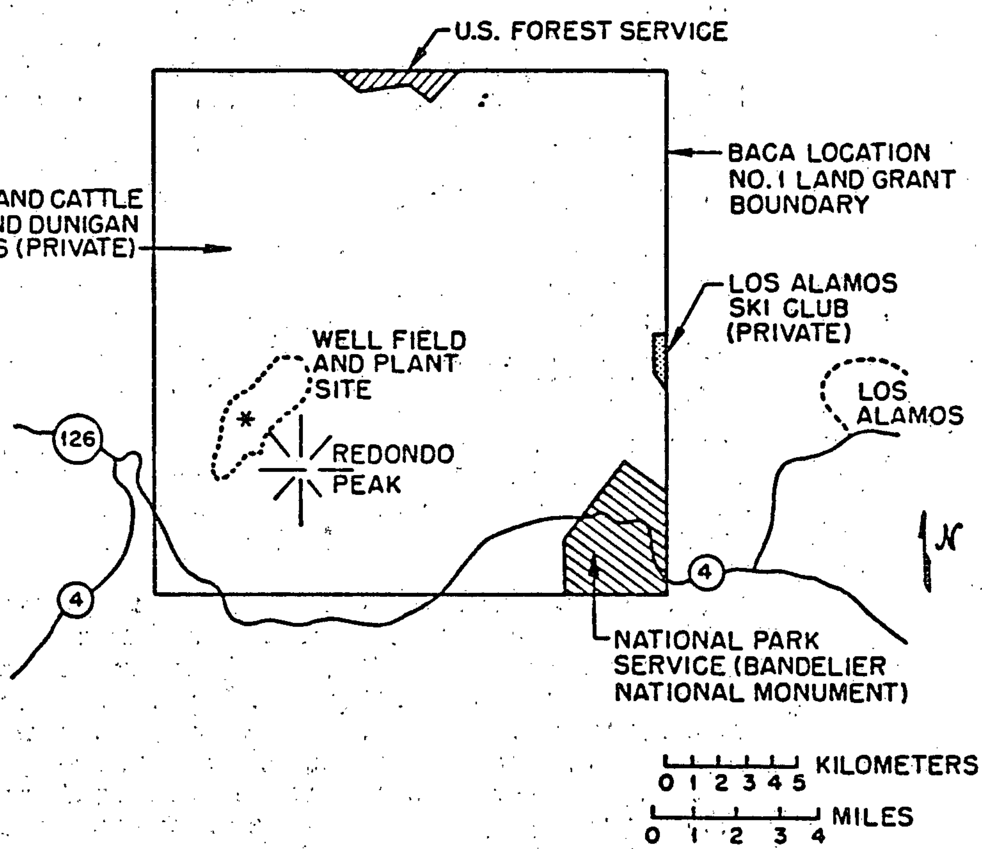


Figure 9.3 Present surface ownership of the Baca Location No. 1 Land Grant and the general location of the well field and plant site.

Source: DOE/EIS-0049

9.6 Community Interest Groups

The Baca Project was a first attempt to develop a project in joint cooperation with a department of the Federal Government, a public utility and a private energy producer as partners. The Project was also the first attempt at a commercial geothermal development in an economically depressed but scenic area of New Mexico.

The uniqueness of the Union/PNM agreement and the involvement of the federal government made the project extremely visible as well as vulnerable, and quickly generated local interest for and against development.

An Environmental Impact Statement (EIS) was prepared (see Introduction, Section 9.1) because of the federal involvement with the Project. (New Mexico has no general environment impact report requirement.) As a result, public hearings and interagency meetings were required to generate a meaningful and legal Final EIS.

Later, the New Mexico Public Service Commission hearing for PNM's Certificate of Convenience and Necessity request for the Project was open to the public. In addition, as mentioned elsewhere in this Report, the Project was exposed to numerous other public proceedings which opponents often exploited to delay or halt the project. These included the Oil Conservation Commission permits, the State Engineer water appropriation process (see Section 9.2), the American Indian Religious Freedom Act (see Section 9.3), the trust obligations of the federal government for Indian lands, and the NMEID ambient air standard hearings (see Section 9.4). The Draft EIS hearing also opened up almost every subject that normally would have little public involvement (such as archeological clearance by the State Historic Preservation Officer, endangered species mitigation plans approval by the New Mexico Department of Game and Fish, and Forest Service transmission line siting activities, to name a few). Without the partnership of the DOE, fewer opportunities for delay would have been available to opponents.

The three members of the Baca Project partnership met frequently about publicizing the Project. Each member by nature of its relationship to the public had publicity approaches divergent from the other members. Melding the needs and wishes of each member into an appropriate community information program was a sensitive and difficult task.

Information was generated through press releases, public meetings, and responding to invitations to speak or show material. Tours were made available to the press and any community group that expressed interest in actually seeing the Project. Interest generally came from three groups--local Pueblo communities, local non-Indian communities and special interest groups.

9.6.1 Local Pueblo Communities

Pueblo communities became strongly opposed to the Project because of apparent (to the Pueblos) threats to religious activities (see Section 9.3) and to water supply (see Section 9.2).

Opposition from the Pueblos became clear at the public hearing for the Draft EIS. Ironically, the Pueblos had never shown much concern over other projects in recent history which could or did have as large or larger impacts, both on water quality and religious practices. Other uncontested projects on both nearby private and federal lands include heavy logging using destructive practices, U.S. Forest Service geothermal leasing, and even proposals for dam construction by the Jemez Pueblo on their own land.

Nevertheless, Union and PNM held an open meeting with the All Indian Pueblo Council (AIPC) in August of 1979 before the Draft EIS hearing in an attempt to address the points of opposition with the Pueblos. Short meetings were held with council members or Pueblo representatives and an "open" line of communication was maintained between Pueblos and the local DOE office from the Draft EIS hearing in September of 1979 until the local DOE office closed in 1981.

A tour of the Baca Project was provided to the Americans for Indian Opportunity in July of 1979.

9.6.2 Local Non-Indian Communities

Questions regarding geothermal development generated in local communities concerned job opportunities, potential pollution problems, potential changes in local life-style with increased traffic and activity and potential threats to local water supplies. The Final EIS addressed these questions. Generally, local non-Indian communities were supportive of the Project. The two principal affected non-Indian communities were Jemez Springs (and nearby residents) and Los Alamos.

A series of public meetings was held by the Jemez Institute located at Hummingbird Camp near the Project during the summer and fall of 1980 to address the questions of local residents. Union and PNM were invited to join and took an active role in several discussions. A tour of the Project site was provided for local residents in September of 1980.

Union and PNM met in public meetings with community representatives of the Village of Jemez Springs in 1980. Since some Union employees reside in Jemez Springs, a close relationship developed with the community, including donations of money and goods and trading of services. Los Alamos, the other nearby non-Indian community, was relatively farther away from the Project location. Through NMCCAW (see Section 9.6.3.2), the Project was relatively well publicized in Los Alamos. Union donated funds to musical, arts and commerce organizations in Los Alamos.

9.6.3 Special Interest Groups

9.6.3.1 "Save the Jemez" was organized by a group of people from Albuquerque and Los Alamos in direct opposition to the Baca Project. The organization opposed any type of development in the Jemez region because of potential impacts to recreational aspects of the area. "Save the Jemez" opposed PNM's application for a Certificate of Convenience and Necessity from the New Mexico Public Service Commission. "Save the Jemez" involved itself in any promising avenue of opposition to the Project, and in Union's opinion, usually exploited public misunderstanding of the Project by elevating extraneous or irrelevant information. The organization published a pamphlet irregularly and sponsored a fund raising mountain run each year. Their publicity is anti-geothermal development.

9.6.3.2 New Mexico Citizens for Clean Air and Water is primarily interested in strict regulation of potential air pollutants. They are generally in favor of geothermal development, but only if the industry is regulated directly. Union and PNM attended several monthly meetings of NMCCAW to discuss the project and geothermal development informally.

The NMCCAW and the League of Women Voters hosted a panel discussion in Los Alamos, N.M. on March 6, 1980. The discussion, titled "Geothermal in Our Backyards", was paneled by Union, PNM, a member of "Save the Jemez" and a representative of the Pueblos. A local radio station carried the discussion live.

9.6.3.3 The Audubon Society hosted a panel discussion in Albuquerque between Participant and "Save the Jemez" in August 1980. The Society had no political position regarding the geothermal development.

9.6.3.4 The Sierra Club toured the Baca Project site in September 1980. Geothermal development is generally considered a favorable energy alternative by the Sierra Club, but locally the Club requested a 10 year moratorium on development in the Jemez Mountains.

Union felt from the beginning of the Project that public understanding was essential to its eventual success. Therefore, a program of continuing contacts was established to enhance that understanding. However, it was felt that not every "public" needed to be contacted directly because of their distance or expected low level of interest. An example of this type of group was Indian Pueblos. Their geographic distance and history of self-isolation as well as the lack of obvious or severe impacts made them unlikely opponents (in initial Union evaluations) to the Project. Somewhat surprisingly, they grew to be a major voice in the review process, and with adroit manipulation by "Save the Jemez", figured heavily in DOE mitigation plans.

Attachment 9A

January 1982

ENERGY DEVELOPMENT IN NORTHWESTERN NEW MEXICO:
A CIVIL RIGHTS PERSPECTIVE

A report prepared by the New Mexico Advisory Committee to the United States Commission on Civil Rights.

Attribution:

The findings and recommendations contained in this report are those of the New Mexico Advisory Committee to the United States Commission on Civil Rights and, as such, are not attributable to the Commission. This report has been prepared by the State Advisory Committee for submission to the Commission, and will be considered by the Commission in formulating its recommendations to the President and the Congress.

Right of Response:

Prior to the publication of a report, the State Advisory Committee offers to all individuals or organizations that may be defamed, degraded, or incriminated by any material contained in the report an opportunity to respond in writing to such material. All responses have been incorporated, appended, or otherwise reflected in the publication. Additional opportunities for review and comment by affected agencies and institutions have also been provided and are included in Appendix D of this report.

E. The Baca Geothermal Project - A Case Study

A major test of the Act is now being pursued by the All Indian Pueblo Council (AIPC) in reference to the Baca Geothermal Demonstration Project located near Redondo Peak, a mountain sacred to the people of the Jemez Pueblo and other pueblo people in the region.[76] In filing this case the plaintiffs stated, in part, that the

> ...Defendant, the Secretary of Energy of the United States, and his subordinates at the Department of Energy have been, and are now, responsible for the approval and substantial Federal funding of a proposed geothermal power plant at a site known as Baca Location No. 1 near Redondo Peak. The Secretary and his subordinates are obligated -- along with all other Federal officials -- to insure that such Federal programs, policies and actions do not denigrate or interfere with the religious practices of American Indian tribes, such as the plaintiff pueblos, pursuant to the First Amendment in the Constitution of the United States, the American Indian Religious Freedom Act (42 U.S.C. 1996), and the strict trust obligation of all Federal officials to all Indian tribes.[77]

To understand the critical nature of this case it is important to recognize that the pueblo way of life is inextricably tied to the environment which the Indians refer to as "Mother Earth". Because of the severe environment and the delicate ecological balance of the region, they have developed a profound appreciation of the land. This appreciation forms the basis of the belief and practices that constitute the pueblo religion.[78]

As is the case with other Native American people, pueblo religious beliefs and practices are an integral part of their lives. Their beliefs prescribe certain relationships with the natural world and even among the pueblos themselves. A key element is the precept that space is sacred. Thus each pueblo sets precise limits to its world. Although boundaries differ from tribe to tribe, all essentially adhere to the same principle for setting boundaries. Their horizontal world is bounded in each of the cardinal directions by sacred mountains. One of these mountains is Redondo Peak.[79]

In 1978, the Union Oil Company of California and the Public Service Company of New Mexico (PNM) entered into an agreement of intent to build a demonstration power plant utilizing geothermal energy resouces on land farmed and grazed by the Baca Land and Cattle Company. That land is located in the Jemez Mountains about 60 miles north of Albuquerque and 19 miles west of Los Alamos in Sandoval County in the Valles Caldera region. Together they applied to the U.S. Department of Energy (DOE) for financial assistance under the DOE Geothermal Demonstration Program. As a result, Union, PNM and DOE formed a partnership to develop and construct a 50 megawatt geothermal plant.[80]

The Jemez Pueblo, however, took the position that all of the Jemez Mountains including the Baca location were sacred and, therefore, the area constitutes a religious site.[81] In January 1980, the Department of Energy issued a Final Environmental Impact Statement on the proposed Baca project. That statement acknowledged the primary importance of the Redondo Peak area to the religions of the pueblos. The report also noted that the proposed project would infringe on their religious rights in a number of ways:

> The [Baca] project is likely to infringe on Indian religious practices in one or more of the following ways: (1) by destroying religious sites; (2) by destroying sacred objects including plants, water, animals, birds, trees and shrubs; (3) by increasing the opportunity for invasions of privacy; (4) by contamination and/or reducing the availability of water for sacred practices; (5) by depleting the flow of sacred springs; and (6) by interferring with access to religious sites.

Despite these findings, the Department of Energy, while acknowledging that there were a number of alternatives to the construction of the proposed plant at the Baca location decided to fund the project.[83] That decision was made in April 1980. However, as part of its decision to fund the project, the Department of Energy also promised to pursue a mitigation plan to minimize the impact on the religious freedom of the pueblos. In its suit the AIPC alleges that the Department of Energy had "not developed or promulgated any such plan or proposal".[84] Because of this it filed its suit in January 1981. Essentially it seeks to restrain and enjoin the Department of Energy from approving, funding or in any other way encouraging the development of the proposed geothermal plant until and unless it formulates a land use plan that will:

> (a) guarantee that all of the religious shrines of the plaintiffs on or near Redondo Peak will be preserved in their present natural state, both during the construction and operation of the plant over its entire life; (b) guarantees that the plaintiffs will have unrestricted access of those shrines at all times for the purpose of practicing their religious beliefs; and (c) assures that the plaintiffs will be able to conduct their religious ceremonies in secrecy and privacy which is required for such observances ... [85]

Lt. Governor Sando, who is also the director of natural resources for the AIPC, explained to the Advisory Committee why the pueblos have taken such a strong and persistent positon on the Baca project:

> You must wonder why the pueblos are so strongly against it. The Department of Energy states, "Why concern yourself? It is not your land to begin with, it's on private land."... Well, little do they..know that the area is vitally important to the pueblo people. For it is where the most precious plants and herbs are gathered, where the tribal religious initiations take place, where animals and birds are hunted for ceremonial purposes, where our sacred springs are located and where our source of water comes from.[86]

He added:

> I do not think the Department of Energy is ignorant of the fact that the area we talk about is important to us. I do believe they are ignoring the gut of the issue and the area that we are concerned with will be impacted from the standpoint of our religious beliefs.[87]

Union Geothermal Division

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Attachment 9B

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P. Robinson
er Environmental
gulatory Compliance

November 29, 1982

U.S. Commission on Civil Rights
1121 Vermont Avenue
Washington, D. C. 20425

Gentlemen:

I would like to comment on Energy Development in Northwestern New Mexico: A Civil Rights Perspective, a report prepared by the New Mexico Advisory Committee to the United States Commission on Civil Rights, dated January 1982. I recognize that my comments are very late, and I apoligize for taking so long to respond. However, the inclusion of the case example of the Baca Geothermal Demonstration Project beginning on page 63 is of considerable importance to our Company, the State of New Mexico and the Nation, and although the project has been terminated for lack of geothermal resources, the lessons regarding American Indian religious freedom transcend individual projects.

With such a controversial case as Baca presented to them by the All Indian Pueblo Council (AIPC) we were disappointed and puzzled that the Advisory Committee did not contact us for comment. Our Company was to be the steam supplier for the project, and we provided the instigation and the principal momentum to the project. We were also intimately involved with and impacted by the AIPC lawsuit against the Secretary of Energy. The Advisory Committee's report discusses only one side of the dilemma. The Department of Energy (DOE) Project Manager apparently felt that his contributions on this subject would be inappropriate until the pending lawsuit was settled. (See his letter on page 213 of the Advisory Committee Report.) Unfortunately the Indians did not feel so constrained.

A crucial point neglected in the AIPC explanation to the Advisory Committee is that the land in question (the Baca

Ranch) is privately owned and has been for well over 100 years.[1] To the best of my knowledge the Indians who claim spiritual ownership over this land have never shown the courtesy to make a perfunctory nod toward the current legal owners by asking permission to use the land. Indeed, the guarantees of unrestricted access demanded by the Indians in their lawsuit against DOE (page 65 of the Advisory Committee Report) are the perogative of the landowner, not the DOE.

Regardless of the fact that they do not own the land (it is not even public land) the Indians appeared to be singularly unhelpful in trying to solve the complex problem of religious infringement. They would regularly invoke a cloak of secrecy to confound DOE's efforts to define and mitigate the problem. And DOE made numerous efforts in this direction. The DOE Record of Decision gives ample evidence of the concern, and frustration, encountered while addressing this issue:

> Infringement on Indian religious practices is the most difficult issue to mitigate satisfactorily. This difficulty is due mainly to the refusal by the Pueblo Indians to furnish specific information on these practices.
>
> DOE has made an exhaustive effort to determine the potential impacts of the demonstration project on Indian religious practices. Pursuant to the Congressional Joint Resolution on American Indian Religious Freedom (Pub. L. 95-341), DOE consulted extensively with Indian tribal leaders and outside experts on Pueblo religion in order to ascertain whether the project is located on or near sacred Indian religious sites involving the conduct of specific religious practices. Comments pertaining to the infringement issue were received on the draft environmental impact statement, and comments were made by tribal leaders at a DOE-sponsored hearing conducted by the All Indian Pueblo Council.
>
> During the preparation of the FEIS, DOE carried out additional consultations with Pueblo representatives. Despite repeated efforts, however, DOE was unable to obtain detailed information on specific religious practices and, therefore, was unable to evaluate the potential impacts of the project on the practice of religion. Several Pueblos have protested against the project, but they have not provided examples of infringements of specific religious practices on the grounds that secrecy is an important principle of the Pueblo religion.[2]

[1] Baker, C. and Winter, J.C., High Altitude Adaptations Along Redondo Creek, The Baca Geothermal Anthropological Project, Univ. New Mexico, Office of Contract Archeology, June 1981.

[2] Federal Register Vol. 45, No. 94, p. 31486, May 13, 1980

It is clear from the above statement that the DOE and the project participants were aware of the religious problem, sought to solve or substantially mitigate it, and were certainly not forging ahead with the project ignorant or blind to this perplexing issue. However, in the face of this lack of cooperation, DOE was forced to conclude:

> As a result of its consultations with the Pueblo Indians, a review of property rights in the project area, and currently available information, DOE has determined that:
>
> (1) The Pueblos do not possess property rights in the Baca sufficient to support a valid claim of infringement on any specific religious activities that occur on the Baca;
>
> (2) There has been no showing by the Pueblos that the project will infringe their religious freedom.[3]

Even though the Indians could not or did not show infringement, DOE still felt it should make continuing efforts to address this problem:

> However, DOE will make every effort to pursue a mitigation plan to minimize those generalized impacts that the Pueblos allege. The All Indian Pueblo Council has proposed to assist DOE in the preparation and execution of such a plan.[4]

Apparently this effort to assist was composed of a lawsuit.

The Advisory Committee Report quotes one portion of the Baca Project Final Environmental Impact Statement pertaining to the likely infringement of religious practices <u>if unmitigated</u>.[5] Unfortunately the Report does not quote other pertinent sections, Section 11.1.1.6 "(Mitigation of) Impacts on Indian Religious and Cultural Activities"[6] in particular. This section provides a framework for a mitigation plan which would be subject to approval by the Pueblo Indians, DOE, and the project operators. Its purpose was to avoid the very impacts enumerated in the quoted section.

The Advisory Committee Report follows the above quote with the statement, "Despite these findings (of likely infringement on Indian religious practices), the Department of Energy, while

[3]Ibid.

[4]Ibid.

[5]U.S. Dept. of Energy, <u>Final Environmental Impact Statement, Geothermal Demonstration Project 50 MW Power Plant, Baca Ranch</u>, January 1980, p. 4-22 et seq.

[6]Ibid., p.11-3, et seq.

acknowledging that there were a number of alternatives to the construction of the proposed plant at the Baca location, decided to fund the project." Yes, DOE identified seven possible alternatives, three of which would have had impacts equal to or greater than the project as proposed. Of the remaining four, one involved alternate plant design (DOE could suggest no feasible improvements over those already in the design), one involved delayed funding (which merely delays the impact), one involved developing another location in the United States (DOE received one other proposal for this funding effort, and it was rejected at the time as having major technical, management and business weaknesses) and the last involved removal of federal funding (ie, no project).[7] These, then, were the "number of alternatives", none of which could have accomplished DOE's objectives.

It may be said that all this is moot. The Indians' lawsuit against the Secretary of Energy has been dismissed and the Baca Geothermal Demonstration Project has been terminated by DOE and the participants because of inability to discover sufficient producible geothermal reserves to justify construction of the project. However, the pertinent issue of religious infringement was not settled with this example, and it is not likely to be so for some time. Certainly it will not be settled if Indians continue to approach the issue with unbending rigidity or if developers or agencies are not sufficiently sensitive to the spiritual needs of their neighbors. Both sides will lose if they cannot achieve a satisfactory compromise, and compromise they must.

Yours very truly,

Joel P Robinson

Joel P. Robinson

JPR:mcm

[7] Federal Register, op. cit., p. 31485.